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San Francisco Bar Pilot Fatigue Study

Alan Hobbs
San Jose State University Research Foundation

Kevin Gregory
San Jose State University Research Foundation

Bonny Parke
San Jose State University Research Foundation

Sean Pradhan
San Jose State University Research Foundation

Zachary Caddick
San Jose State University Research Foundation

Nicholas Bathurst
San Jose State University Research Foundation

Erin Flynn-Evans
NASA Ames Research Center

July 2018

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Erin Flynn-Evans
NASA Ames Research Center

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California

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Glossary

Term	*Description*
Bay move	A ship movement that occurs entirely within the San Francisco Bay. For example, moving from a dock to an anchorage.
Board time	The time at which a pilot boards a vessel.
Bottom of Board (BoB) time	The time at which a pilot's name is placed at the bottom of the name board awaiting the next assignment. Also used to define the end of a work period.
Circadian low	The point in the circadian rhythm associated with lower body temperature, reduced alertness, reduced cognitive performance, and increased drive for sleep. It typically occurs between 0200-0600 in individuals who are entrained to the light-dark cycle of their local environment.
Circadian rhythm	The rhythmic 24-hour variability of certain behavioral and physiological functions (e.g., sleep/wake cycle, body temperature).
Effectiveness score	The primary output metric of the SAFTE-FAST model. A metric to describe predicted "cognitive effectiveness" which refers to measures corresponding to performance speed and errors, vigilance, and probability of lapses.
Fatigue	A biological drive for recuperative rest.
Light trip	A positioning trip in which a pilot travels as a passenger to the offshore pilot station.
Minimum Rest Period (MRP)	The recommended 12-hour minimum rest period between BoB time and ride time.
Off-call	A week or weeks during which a pilot is not available for pilotage ("off watch" or "off the Board").
Off time	Pilot disembarkation at the end of an assignment.
On-call	A week or weeks during which a pilot is "on watch" or "on the Board".
Relief trip	A positioning trip in which a pilot travels as a passenger from the off-shore pilot station to Pier 9 (or the equivalent).
Rest period	The period from BoB time to ride time.
Ride time	The time at which a pilot would need to report to Pier 9 to commence duty, regardless of the route the pilot takes to the start of the job.

SAFTE-FAST	Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) – Fatigue Avoidance Scheduling Tool (FAST). Modeling software used to estimate performance based on recent or predicted sleep history.
Skill fatigue	The degradation in skilled performance that can occur after sustained periods of intense concentration.
Sleep apnea	A medical condition in which the upper airway is obstructed during periods of sleep, resulting in intermittent hypoxia, episodic arousals, and sleep fragmentation.
Sleep debt	The deficit between the amount of sleep needed and the amount of sleep obtained. Sleep debt can accumulate over multiple nights, producing progressively more severe performance impairment.
Sleep inertia	The “grogginess”, “disorientation”, and associated performance impairments experienced upon waking.
Work period	The period from ride time to BoB time.

San Francisco Bar Pilot Fatigue Study

Alan Hobbs[1], Kevin Gregory[1], Bonny Parke[1],
Sean Pradhan[1], Zachary Caddick[1],
Nicholas Bathurst[1], and Erin Flynn-Evans[2]

> *Maritime pilot: "…a mariner with expert knowledge of local waters and special ship handling skills. The pilot directs and controls the movement of a vessel through near-shore and inshore waters (referred to as pilotage waters or pilot grounds) unfamiliar to the master or provides navigation advice to or through the master for this purpose. The pilot is expected to integrate local knowledge with operational information to effect a safe passage."*
>
> *National Academy of Sciences (1994, p. 70)*

Preface

This study examines the effect of work and rest periods on physiological and psychological ability and safety for maritime pilots licensed by the Board of Pilot Commissioners (BOPC) for the Bays of San Francisco, San Pablo, and Suisun. It contains the key deliverables specified in the "Pilot Fatigue Study Request for Proposals (RFP)" issued by the BOPC in 2016. That document stated:

Key deliverables will be recommendations to the Board with respect to:

1. How to prevent pilot fatigue and ensure safety, taking into account operational considerations and the need to facilitate safe but ongoing waterborne commerce on the waters under the Board's jurisdiction.
2. Fatigue mitigation/management systems.
3. Recommendations from which the Board can promulgate regulations intended to prevent pilot fatigue. (BOPC, 2016, p.4)

This study was conducted by staff of the San Jose State University Research Foundation (SJSURF) based at NASA Ames Research Center, in collaboration with Dr. Erin Flynn-Evans of the NASA Ames Fatigue Countermeasures Laboratory. The work was performed under contractual agreement 15M900007 between BOPC and SJSURF.

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[1] San Jose State University Research Foundation; NASA Ames Research Center, Moffett Field, CA.

[2] NASA Ames Research Center, Moffett Field, CA.

Executive Summary

San Francisco Bar Pilots have been guiding ships to and from the San Francisco Bay and within the associated waterways since 1850. These maritime pilots are known as Bar Pilots in reference to the sand bar that lies 8 miles west of the Golden Gate. In this report, San Francisco Bar Pilots will be referred to simply as "Bar Pilots".

The purpose of this study was to evaluate the extent of fatigue among Bar Pilots and its potential impact on safety, and to make recommendations concerning how the risk of fatigue could be managed. Information was gathered via a literature review, observations of Bar Pilots at work, surveys, a task analysis, and an analysis of dispatch records.

The work of Bar Pilots involves an unusual mix of activities and job demands. Their work calls for situational awareness, reasoning, communication, and perceptual abilities comparable to those required by airline pilots and air traffic controllers. Errors can have severe consequences for public safety and the environment, as well as significant financial costs.

Fatigue is increasingly recognized as a hazard that must be managed by the transportation industry. The reduced sleep quality and quantity experienced by personnel who work at night, in conjunction with circadian misalignment can lead to an operationally significant level of cognitive impairment. Fatigue can have a detrimental impact on cognitive functions that are critical to safe maritime piloting, such as vigilance, judgment, reaction time and communication.

The surveys distributed to Bar Pilots did not uncover evidence of widespread fatigue. Bar Pilots had overall low scores on the subjective fatigue measures used in the survey, and generally assessed the safety risk due to fatigue as low. Compared to air traffic controllers, Bar Pilots gave significantly lower ratings on questions concerning the prevalence and impact of fatigue. The application of fatigue modeling software to Bar Pilot dispatch records identified that in most cases, the cognitive effectiveness of Bar Pilots was predicted to be acceptable during their duty periods. However, these results could not be verified with objective data.

The study identified a number of fatigue issues that deserve attention. These include Bar Pilot work periods that frequently infringe on the circadian low, consecutive work periods without a significant break, consecutive periods of night work, unpredictable work schedules, start time variability, the potential for sleep inertia, and the number of pilots on the board at any given time.

Structure of this Document

This document begins with an introduction to the topic of fatigue, its causes, and its impact on human performance. The work of San Francisco Bar Pilots (referred to simply as "Bar Pilots") is then described, based on information gathered from observations of Bar Pilots at work and a cognitive task analysis. We then review the literature on fatigue in transport and industry, including prior studies of maritime pilots in the United States and abroad. This is followed by a summary of work and rest regulations from a variety of transport and industrial settings. We then describe the two main data-gathering and analysis activities conducted as part of this study: (1) surveys of Bar Pilots, (2) an analysis of their dispatch records for a 12-month period. Following a final summary and conclusions section, we list a series of recommendations intended to assist the BOPC as it develops mitigation systems and regulations to manage the risk of Bar Pilot fatigue.

1. Fatigue and Its Impact on Human Performance

Williamson et al. (2011) define fatigue as "a biological drive for recuperative rest." As shown in Figure 1, in the absence of adequate rest, fatigue can impair human performance capabilities, resulting in accidents. In addition to the drive for sleep (or sleepiness), the term "fatigue" is sometimes used to describe other conditions. These include "skill fatigue"—the degradation in skilled performance that can occur after sustained periods of intense concentration (Hockey, 1986), emotional fatigue, and physical fatigue (International Maritime Organization, 2001). This study is focused on fatigue resulting from three sleep-related factors either in isolation or in combination: homeostatic sleep pressure, circadian timing, and sleep inertia.

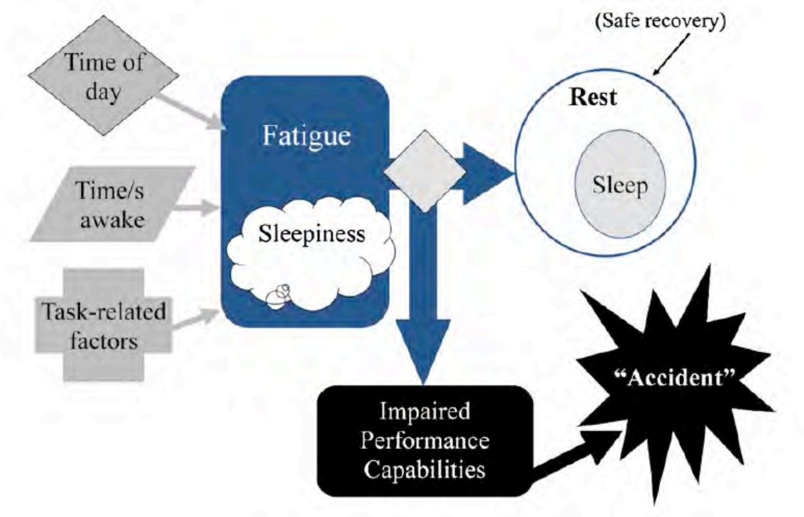

Figure 1. Conceptualization of the relationship between fatigue and safety. From Williamson et al. (2011).

1.1 Homeostatic Sleep Regulation and Sleep Debt

The drive for sleep is partially regulated by a homeostatic process (Borbély & Achermann, 2005). As the duration of wakefulness increases, the need for sleep builds. The system is in balance when the sleep obtained after the period of wakefulness is of sufficient quantity and quality to relieve the pressure for sleep that had built during wakefulness. A period of wakefulness that is not followed by adequate sleep will result in a sleep debt.

The average adult requires around 8 hours of sleep per night (Hirshkowitz et al., 2015; Watson et al., 2015), allowing for approximately 16 hours of wakefulness each day. Wake episodes that extend beyond this threshold can result in an acute sleep debt sufficient to produce measurable decrements in cognitive performance (Anderson et al., 2012). A succession of reduced or poor quality sleep episodes can produce a cumulative, or chronic, sleep debt and significant performance decrements, even when sleep is reduced by only one or two hours each night (Belenky, et al., 2003; Van Dongen, Baynard, Nosker, & Dinges, 2002).

Numerous studies have demonstrated that airline pilots, truck drivers, and heath care providers working non-standard hours regularly obtain two or three hours less sleep than their optimal daily requirement (Rosekind, 2005), and hence are performing safety-critical tasks while suffering from a cumulative sleep debt. Even when sleep opportunities are available during daylight hours, sleep obtained during the day is less restorative than nighttime sleep for a person whose circadian rhythm is entrained to local time.

Chronic sleep loss may also arise from untreated sleep disorders, notably sleep apnea and insomnia. Sleep apnea is a medical condition in which the upper airway is obstructed during periods of sleep, resulting in intermittent hypoxia, episodic arousals, and sleep fragmentation (Young et al., 1993). Up to 18% of the population may be affected by sleep apnea (Kang, Seo, Seo, Park, & Lee, 2014; Young et al., 2002) and the condition is a particular concern in the transport industry. In the maritime sector, attention focused on this issue following a collision at Port Arthur, TX involving a vessel under the control of a maritime pilot who was suffering from untreated sleep apnea (Strauch, 2015). Reid, Turek, & Zee (2016) found that personnel in the tug, towboat and barge industry had a higher level of risk factors for sleep apnea compared to the general population. Reid et al. recommended that the maritime industry develop improved screening and treatment for sleep apnea and other sleep disorders, similar to best practices in other industries. Bar Pilots currently undergo screening for sleep apnea as part of their regular medical checks.

The sleep environment can have a significant impact on the quality and duration of sleep. Noise, lighting, inadequate airflow, and sleeping in environments either too hot or too cold for comfort can result in fragmented sleep and subsequent performance impairment (Caddick, Gregory, Arsintescu, & Flynn-Evans, 2018). Maritime pilots sometimes take the opportunity to sleep on board a ship or a pilot boat. Sleep on a moving vessel can be impacted by ship movement, noise, vibration, inadequate climate control, and motion sickness (Oldenburg, Baur, & Schlaich, 2010). On smaller vessels, "slamming" and other harsh motions can be problematic (Matsangas, Shattuck, & McCauley, 2015). Tamura, Kawada, and Sasazawa (1997) found that the continuous noise of a diesel ship engine had a negative effect on sleep. However, the relationship between ship motion and sleep is not a simple one. Matsangas et al. found that in rough seas, crewmembers of a US Navy vessel reported more seasickness, but slept longer than they did during calmer conditions. The motion of a ship or vehicle has also been found to induce drowsiness in susceptible individuals (Graybiel & Knepton, 1976).

1.2 Circadian Timing

The human body possesses a biological clock that coordinates many aspects of behavioral and physiological functions (Czeisler & Gooley, 2007). The biological clock regulates daily (or circadian) rhythms in physiological functions and behavior that exhibit a natural period of around 24 hours (Czeisler, 1999). In humans and other diurnal mammals, that are awake during the day and asleep at night, the biological clock ensures that the body begins to prepare for the waking day before the sun has risen and begins to prepare for sleep prior to one's habitual bedtime. In order to align the circadian rhythm with the solar light-dark cycle and 24-hour rotation of the earth, the internal biological clock must be reset each day. It was once thought that a range of factors acted on the body clock (Wever, 1975); however, we now know that exposure to light is the single most powerful influence on circadian timing (Czeisler, Weitzman, Moore-Ede, Zimmerman, & Knauer, 1980). When an individual is not exposed to light during the day, the circadian rhythm will revert to its own endogenous period, creating a transient misalignment between the social day and internal timing (Flynn-Evans, Tabandeh, Skene, & Lockley 2014). Light exposure at different times has different effects. For example, light in the biological evening causes later shifts (i.e., the drive to sleep and wake are shifted later), while light in the biological morning causes earlier shifts (i.e., the drive to sleep and wake are shifted earlier). The potency of the light stimulus is dependent on the intensity, wavelength, pattern, and duration of the light exposure. When an individual is exposed to light during the biological night, such as is the case for shift workers and those experiencing jet lag, misalignment between the drive to sleep and wake can occur.

It is possible for individuals to adjust to jet lag or shift schedules with careful control of light exposure; however, it can take many days for an individual to adapt to a new circadian phase. Although such adaptation is possible, it is typically not practical in most shiftwork situations, where individuals revert to being awake during the day and asleep at night on days off (Smith & Eastman, 2012). Under typical circumstances, shiftwork or non-standard working hours may move the body clock by a few hours either side of the local norm (Flynn-Evans et al., 2017); however, the powerful effect of sunlight exposure prevents all but a few shiftworkers from adapting fully to non-standard hours (Hursh, Balkin, & Van Dongen, 2017).

A range of cognitive performance measures (including reaction time and short-term memory) have been shown to exhibit circadian rhythms, with reduced performance during the night hours, and improved performance during the normal hours of daylight and evening. Alertness and cognitive performance typically improve throughout the morning, as a function of the circadian drive to wake, even for a person who is sleep-deprived (Angus & Heslegrave, 1985).

The low point of the circadian rhythm typically occurs between 0200-0600 in individuals who sleep during the night and are awake during the day. The circadian low is characterized by lowered body temperature, diminished alertness, reduced cognitive performance, and an increased drive for sleep. For an individual entrained to the light-dark cycle of their local environment, the circadian low will typically occur in the early hours of the morning. However, for individuals experiencing jet lag, or other forms of circadian misalignment the low may occur at other times, possibly during periods of daylight when performance decrements may not be typically experienced. A second, less pronounced period of increased fatigue and lowered performance typically occurs at around 1500 (Hursh, Balkin, Miller & Eddy, 2004; Minors & Waterhouse, 1985). This period is sometimes referred to as the "post-lunch dip" however, it occurs even when no meal has been eaten.

The preference for wake and sleep times (chronotype) varies across individuals and appears to be a relatively stable personal characteristic. Morning types, commonly referred to as "larks" have a preference for waking early and going to bed early, whereas evening types "night owls", prefer to wake late and go to bed late (Horne & Östberg, 1976). Beyond the preference for wake and sleep times, there is often an associated behavioral preference for when to perform mentally demanding tasks. Night owls tend to perform better later in the day when compared to their lark counterparts (Horne, Brass, & Petitt, 1980).

1.3 Sleep Inertia

Sleep inertia is the "grogginess", disorientation, and associated performance impairment experienced upon waking (Jewett, et al., 1999). Sleep inertia is of concern in workplaces where people must perform a critical function immediately after awakening. The severity and duration of sleep inertia is dependent upon prior sleep debt, the duration of the sleep episode, the timing of awakening, and the sleep stage prior to waking (Tassi & Muzet, 2000; Scheer, Shea, Hilton, & Shea, 2008).

Sudden awakening from deep sleep can lead to more severe sleep inertia than sudden awakening from lighter sleep (Tassi and Muzet, 2000). Sleep inertia is most problematic for people carrying a sleep debt, due to the higher probability of an individual going into deep sleep when sleeping under a higher sleep pressure (McHill, Hull, Czeisler, & Klerman, 2017; Signal, Gander, van den Berg, &

Graeber, 2013; Hilditch, Centofanti, Dorrian, & Banks, 2016). Sleep inertia is also most likely to be problematic when the person is awakened during the circadian low, or has been asleep longer than 30 minutes (Caldwell et al., 2009). Although there are factors that can exacerbate or mitigate sleep inertia severity and duration, sleep inertia can still occur following habitual sleep, brief naps, awakening from any sleep stage, and at any time of day (Achermann, Werth, Dijk, & Borbely, 1995; Hilditch, Dorrian, & Banks, 2017).

The performance impairment associated with sleep inertia can outweigh the recuperative effect of a nap (Ruggiero & Redeker, 2014). It has been estimated that immediately after awakening, a person experiencing sleep inertia may perform worse on complex cognitive tasks than a person who has been continuously awake for 48 hours. (Wickens, Hutchins, Laux, & Sebok, 2015). Wertz, Ronda, Czeisler, and Wright (2006) found the most severe cognitive impairment in the first 3 minutes after awakening; however, the effects of sleep inertia can take several hours to completely dissipate (Jewett et al., 1999). The impact of sleep inertia also appears to be dependent on the type of task that is being completed during the sleep inertia episode. Selective attention appears to be particularly sensitive to sleep inertia (Burke, Scheer, Ronda, Czeisler, & Wright, 2015).

1.4. Performance Effects of Fatigue

Fatigue produces well-documented impairments in cognitive performance, yet people are often poor judges of their own level of fatigue (Van Dongen, Maislin, Mullington, & Dinges, 2003). The detrimental effects of fatigue on human performance include slowed reaction time, impaired decision making, reduced attention, and increased incidence of human error (Van Dongen et al.; Wickens, et al., 2015). The International Maritime Organization (2001) lists the following possible effects of fatigue on the job performance of maritime pilots (Table 1).

Table 1. Signs and Symptoms of Fatigue-Related Performance Impairment

Sign	*Symptoms*
Inability to concentrate	• Unable to organize a series of activities • Preoccupation with a single task • Focuses on a trivial problem, neglecting more important ones • Less vigilant than usual
Diminished decision-making ability	• Misjudges distance, speed, time, etc. • Fails to appreciate the gravity of the situation • Fails to anticipate danger • Fails to observe and obey warning signs • Overlooks items that should be included • Chooses risky options • Has difficulty with simple arithmetic, geometry, etc
Poor memory	• Fails to remember the sequence of task or task elements • Has difficulty remembering events or procedures *Forgets to complete a task or part of a task
Slow response	• Responds slowly (if at all) to normal, abnormal or emergency situations
Mood change	• Quieter, less talkative than usual • Unusually irritable
Attitude change	• Unaware of own poor performance • Too willing to take risks • Ignores normal checks and procedures • Displays a "don't care" attitude

Source: International Maritime Organization, 2001.

2. The Work of San Francisco Bar Pilots

The legal framework for maritime piloting in the United States was established in one of the first acts of the US Congress, the Lighthouse Act of 1789 (Kirchner and Diamond, 2010). As a consequence, the regulation of maritime pilots, including their hours of work, remains a responsibility of the states. The San Francisco Bar Pilots (so named because of the sand bar that lies 8 miles west of the Golden Gate) have been guiding ships in and out of San Francisco Bay since 1850. The pilotage grounds cover approximately 200 miles of shipping routes and include seven ports within the San Francisco Bay, and the ports of Sacramento, Stockton, and Monterey.

San Francisco Bar Pilots are licensed and regulated by a California state agency, the Board of Pilot Commissioners for the Bays of San Francisco, San Pablo and Suisun (BOPC). In addition to the license issued by the BOPC, Bar Pilots possess a Coastguard license. Bar Pilots are not State employees but operate as members of the San Francisco Bar Pilots Association, a private unincorporated association of individuals.

In order to understand the impact of fatigue upon job performance, it is necessary to understand the nature of the job, including its physical and mental demands. Whereas the physical performance of tasks can be observed directly, the underlying cognitive demands may be less obvious to an observer, and even to the performer of the task.

The research team began with a series of familiarization ride-alongs, observing Bar Pilots at work on ten vessels. Six of the trips occurred during the hours of daylight or dusk, and three were during night or pre-dawn hours. The ride-alongs occurred on tankers, bulk carriers, and container ships. The trips included ship moves within the San Francisco Bay, ships inbound from sea, a river transit to Stockton, and a ship turn in the Oakland Inner Harbor turning basin. On each occasion, team members were escorted by an off-duty Bar Pilot. Each ride-along provided an opportunity for the team to observe Bar Pilot activities, and to discuss the activities with the escorting Bar Pilot. The results of these observations, combined with findings from the research literature, are presented in the following section.

2.1 General Observations of Bar Pilots at Work

Most Bar Pilots work a pattern in which they are on watch for a one-week period followed by one week off, although some choose to work a two-week on/two-week off pattern. While on watch, pilots are on-call 24 hours a day and are listed sequentially on a list referred to as the “board” in recognition of its origins as a wooden board with pilot names displayed in slots. In most cases, a ship requiring a pilot will be assigned to the pilot whose name is listed at the top of the board. The list of names then moves up as each job is assigned. At busy periods, names will move up the board rapidly. This system, known as a “continually rotating roster” (Rhodes & Gil, 2002) or “simple turn roster” (Shipley & Cook, 1980) is in use by other pilotage associations worldwide. When a pilot completes their assigned duties, their name returns to the bottom of the board. Pilots can therefore monitor the board over the internet to anticipate the time at which their next job assignment will occur. They can then use this information to plan their sleep, including setting an alarm. However, anticipated ship assignments and sailing times are frequently updated, meaning that the time the pilot must report for the next job may change, impacting their ability to plan sleep periods. If the assignment is brought earlier than anticipated, the pilot may be woken by a phone call from a dispatcher. Calls from dispatchers are the exception rather than the normal practice; however, this was not always the case. In the mid-1980s, over 1000 telephone calls were made each month between dispatchers and pilots (Manalytics, 1986). If the assignment is moved to a later time while the pilot is asleep, they may be awakened by their alarm, only to find that they could have slept longer.

It appears that ship arrivals are often timed to coincide with the start of the workday at the port where the ship will be offloaded. As a result, maritime pilots are frequently required to meet incoming ships in the early hours of the morning, during the circadian low.

For scheduling purposes, the Bar Pilot Association considers that the pilot work assignment starts at “ride time”, which is the time at which the pilot would need to report to Pier 9 to join the pilot boat or motor vehicle to be transported to the vessel in question. The sequence of events associated with the pilot work period is shown in Figure 2. If the pilot is to meet a vessel close to Pier 9, the ride time could be relatively short (perhaps 30 minutes) whereas for a job starting in more distant locations, the ride time could allow for a significantly longer journey to the vessel.

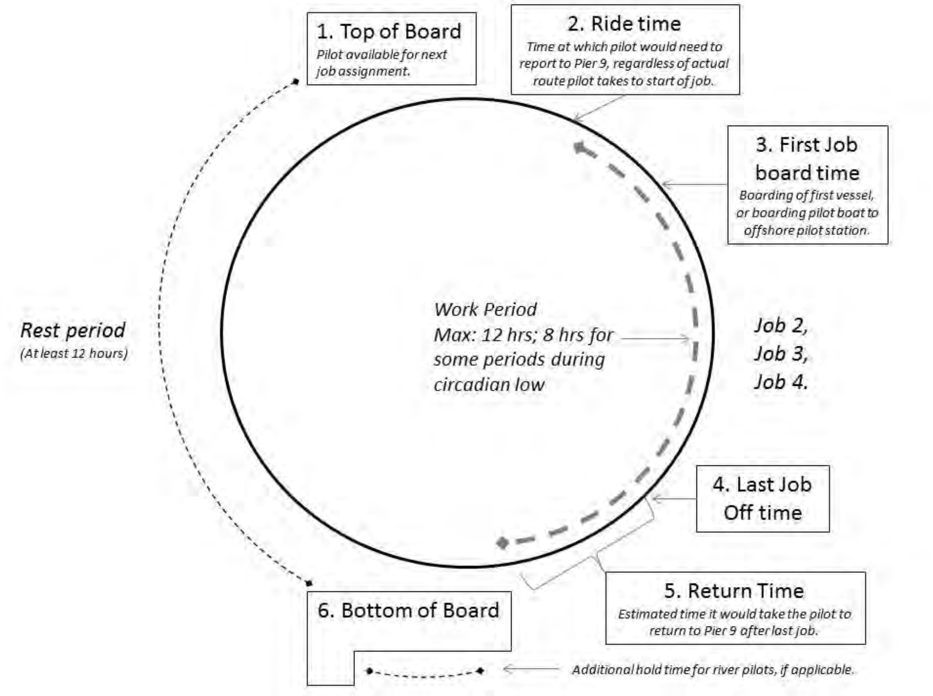

Figure 2. The work cycle of Bar Pilots when on-call.

A typical work period may start with an assignment to guide a ship from a location within San Francisco Bay to sea. Depending on the location of the ship, the pilot may board at a dock, or may ride to the ship on a pilot boat. The time at which the pilot comes aboard the ship is recorded as the "board time". In planning the move, the pilot will take into account factors such as the draft of the ship, the location of hazards and channels, the movements of other vessels, the expected performance of the ship and its crew and tugs, as well as dynamic aspects of the environment, such as tides, winds, light conditions, and the air draft between the ship and bridges. When the pilot reaches the bridge of the ship, the pilot will conduct the Master/Pilot conference. This is an exchange of information with the ship's captain that includes a briefing on the planned move and a discussion of the condition of the ship, including any unserviceable equipment. Unlike the ship's crew, the pilot will not necessarily be familiar with the ship and its unique handling characteristics (Grassi, 2000), and so must rapidly assess the situation and must possess the ship handling skills necessary to manage a wide variety of vessels.

The pilot must pay special attention to the clarity of communication. On the bridge, the pilot gives direct verbal instructions to the ship's crew to control the ship, and communicates with tug operators and Vessel Traffic Services (VTS) via two-way radio. In most cases, English will not be the first language of the crew, therefore the pilot must be attuned to language and cultural issues that could impact communication. In a review of piloting in Finland, Lappalainen, Kunnaala, Nygren, and Tapanainen (2013) noted that effective communication between the pilot, the master and other members of the bridge team is a basic prerequisite for effective piloting. A Canadian study found that miscommunication or misunderstandings between pilots and master was a leading contributing factor in maritime accidents that occurred in pilotage waters (Transportation Safety Board, 1995). Darbra, Crawford, Haleya, and Morrison (2007) asked maritime pilots in Australia and New Zealand to name the most hazardous events in pilotage. Equipment failures and coordination/communication failures with crew were the first and second most commonly identified hazards.

It is critical that the pilot maintains an awareness of the vessel's location and surroundings. Macrae (2009) found that 57% of errors referred to in Australian maritime accident reports involved a pilot misjudging the location of the vessel. On foggy days or at night, navigating in the San Francisco Bay can involve a heavy reliance on radar. On clear days the pilot can rely more on the view from the bridge, but must contend with recreational watercraft that may exhibit unpredictable behavior.

The pilot of a departing ship will return control of the ship to the master at a point approximately 11 miles west of the Golden Gate. The pilot will then disembark the moving ship via a rope ladder to the Offshore Station boat. This boat is a 108 foot vessel that remains offshore to transfer pilots to and from arriving and departing ships. In heavy seas, the transfer can be treacherous as there can be significant relative movement between the ship and the Offshore Station boat. Once onboard the Offshore Station boat, the pilot will typically wait for an incoming ship to guide back to San Francisco.

Depending on ship traffic, the pilot may have the opportunity to take a meal or nap in the bunk facilities provided on board the Offshore Station boat. However, during busy periods the pilot's stay on the Offshore Station boat may be brief. If there is an opportunity to rest, sleep may be impaired by the sea state, or by noise and movement as the boat maneuvers alongside ships to transfer other pilots. For some pilots, sleep on the Offshore Station boat comes easily, whereas others have difficulty falling asleep under these conditions.

Whenever possible, dispatchers attempt to assign arriving ships to pilots who have taken outbound ships to the Offshore Station boat. In such cases, the Offshore Station boat will come alongside the arriving ship and match its speed, enabling the pilot to climb aboard using the rope ladder. The pilot will then go to the ship's bridge, conduct the Master/Pilot conference and take control of the ship.

If the job concludes with the docking of the ship, the pilot will coordinate precise, slow movements as the ship is brought into the dock. This will be done via direct verbal commands to the bridge crew, coordination with the master, and radio commands to the crew of the assisting tugs. Not only is the ship in motion in relation to the water, but in many cases, the water will be in motion relative to the dock due to tidal flow and/or river currents.

In addition to bar crossings, Bar Pilots handle ship movements entirely within the waterways of San Francisco Bay. Pilots with specific experience handle specialized tasks, such as river transits to Stockton and Sacramento, cruise ship movements, and acting as a second pilot (called an "e-pilot" since they bring electronic equipment on board) to assist with the turning of ships in the Oakland Inner Harbor turning basin. As ships become ever larger, the margin for error during turning and maneuvering in confined spaces becomes smaller, requiring accurate perception and precise control by the pilot.

Eight Bar Pilots are designated as "operations pilots." Days or weeks before a vessel move, these pilots work with nautical charts, tide data, information on the ship characteristics, and other material necessary to coordinate and plan the move. Operations pilots can expect to work one week out of four at the Bar Pilot offices. Although they are on-call 24 hours a day, most of their work is carried out during business hours on each of their seven-day workweek. During their remaining work periods, operations pilots follow the normal pattern of a pilot “on the board.”

Regardless of the nature of the type of ship movement, the work of the pilot guiding the ship is considered to be finished after they have disembarked the vessel (or the pilot boat if returning from sea) and time has elapsed that would permit the pilot to return to Pier 9. At this time, the pilot is returned to the “Bottom of the Board”. After the pilot has been returned to the Board, their name moves up the list until they are once more at the top. At this point, they are assigned another ship move.

2.2 Cognitive Task Analysis

Cognitive Task Analysis can provide a description of the processes and skills needed to perform a task at the expert level (Seamster, Redding, & Kaempf, 1997). A cognitive task analysis questionnaire was used to describe the work of fully qualified Bar Pilots in order to identify aspects of the job that could be impacted by fatigue, and to identify jobs with similar cognitive demands. It should be noted that the current task analysis differed from a job analysis previously carried out for the BOPC (Carrion, & Le, 2016). The earlier analysis was focused on the knowledge, skills, abilities, and personal characteristics that must be possessed by applicants for the Bar Pilot Trainee program.

A task analysis questionnaire was compiled using standard items taken from the O*Net occupational database (O*Net OnLine, 2016). O*Net is an on-line resource, sponsored by the US Department of Labor, containing information on hundreds of occupations in the US workforce. An O*Net analysis of the occupation “Pilots, Ship” was conducted in 2016. Some of the respondents who participated in that analysis had job titles of “Relief Docking Master”, and “Towboat Pilot”, implying that their duties may not be directly comparable to those of Bar Pilots. For this reason, there was a need to gather data specifically from Bar Pilots, rather than rely on the national sample.

In order to focus on the cognitive aspects likely to be relevant to the work of Bar Pilots, 63 items that had received high scores from the occupational group “Pilots, Ship” in a 2016 O*Net analysis were included[3]. The questionnaire covered four areas:

- Work context: Physical and social factors of the work.
- Activities: Behaviors that typically occur on the job.
- Work-related abilities: Personal traits relevant to the job.
- Skills: Capabilities that are learned or developed over time.

Ten Bar Pilots volunteered to complete the questionnaire. The results enabled the job of San Francisco Bar Pilots to be compared with the national data for “Pilots, Ship” and with other occupations in the US labor force. The fatigue management approaches applied to comparable occupations could then be examined for insights that could be applied to Bar Pilots.

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[3] Items from the scales of “work-related abilities,” “skills,” and “activities” were selected if they had received a score of 60 or greater (on a scale of 0–100) from the national sample. “Work context” items were selected for relevance from among items that had been rated highly by more than 50% of the national sample (e.g. ratings of “Extremely important,” or “Every day”).

2.2.1 Task Analysis Questionnaire Results

The work context descriptions that received the highest ratings from Bar Pilots related to working outdoors, the need for protective or safety equipment, the potential for serious mistakes, and the freedom to make decisions without supervision. Figure 3 shows a comparison between the Bar Pilot responses on work context items and the O*Net national data for “Pilots, Ship.” It is apparent that there were significant differences between the two groups. Unlike the national sample, Bar Pilots were much less likely to see their work as involving repetitive activities and responsibility for others. Bar Pilots also considered that although they were not able to determine the tasks to be performed, they were free to determine how the task should be performed. Most notably, Bar Pilots were less likely to see themselves as part of a team. This finding is consistent with a Canadian survey that found that whereas more than 50% of ship’s masters considered that the pilot and master always worked as a team, less than 38% of pilots agreed with this statement (Transportation Safety Board, 1995).

The work activities that received the highest importance ratings by Bar Pilots related to Operating vehicles, devices and equipment; Making Decisions and Solving Problems; Monitoring Processes, Materials, or Surroundings; and Getting Information. The O*Net database identified that occupations with similar work activities in each case were airline pilots, physicians, nuclear equipment operators and judge/magistrate. A significant responsibility for many Bar Pilots is on-the-job training and supervision of apprentice pilots as they learn to coordinate complex movements involving crew, tug operators and other personnel. It is therefore notable that O*Net identified that the work of Bar Pilots bears some similarity to that of a choreographer.

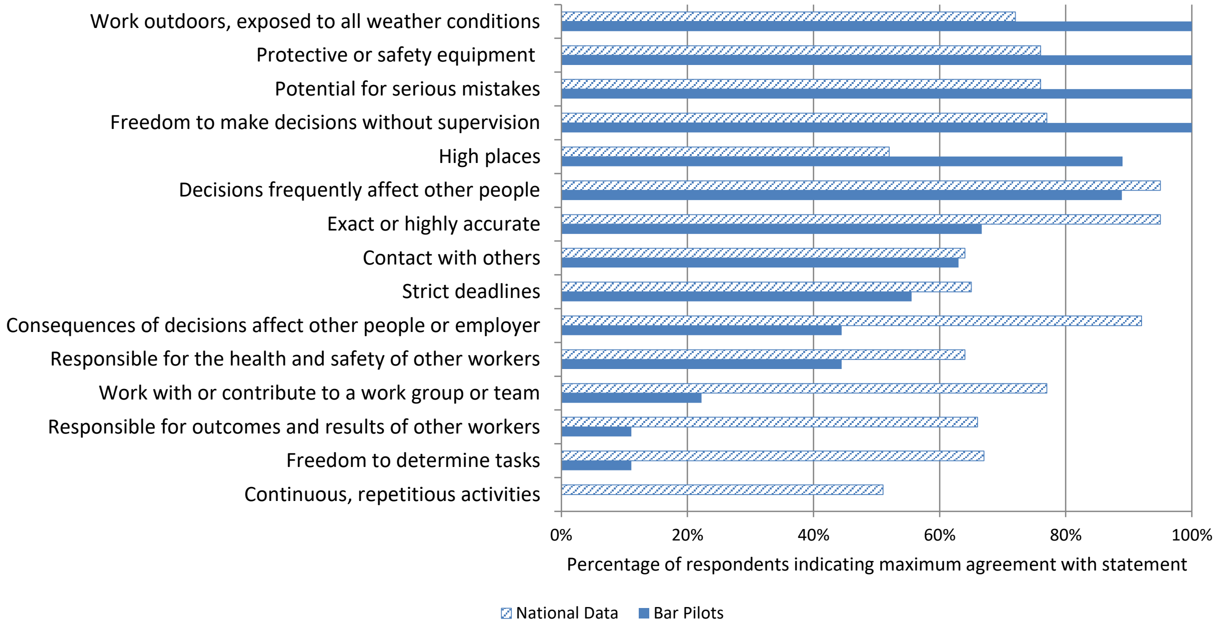

*Figure 3. Bar pilots compared on work context items with national data (O*Net) on ship pilots.*

The work activities that received the highest ratings from Bar Pilots were also common to the national sample for “Pilots, Ship”. However, the two groups diverged in other respects, suggesting that the national sample contained personnel who performed work not directly comparable to that of Bar Pilots (see Appendix 1).

The abilities rated as most important to Bar Pilots indicate a job that requires a high level of situational awareness combined with communication, perceptual, and reasoning abilities. According to O*Net, this is also true for physicians, airline pilots and air traffic controllers. As shown in Figure 4, it is notable that the national sample of ship pilots gave lower ratings on several of the cognitive abilities scales, including night vision, suggesting that the national sample included personnel who were not working during the night.

The skill ratings by Bar Pilots emphasized the importance of working with others, whether involving coordination, communication, judgement and decision making, or monitoring performance. The O*Net analysis identified that chief executives, post-secondary teachers, and airline pilots required a similar set of skills. Bar Pilots placed more emphasis on the social aspects of their work compared to the national sample of ship pilots. This finding is somewhat surprising given that in the work context ratings, Bar Pilots did not consider that they worked as part of the bridge team. Further detail, including comparison of results with the national sample and definitions of terms used in the task analysis, can be found in Appendix 1.

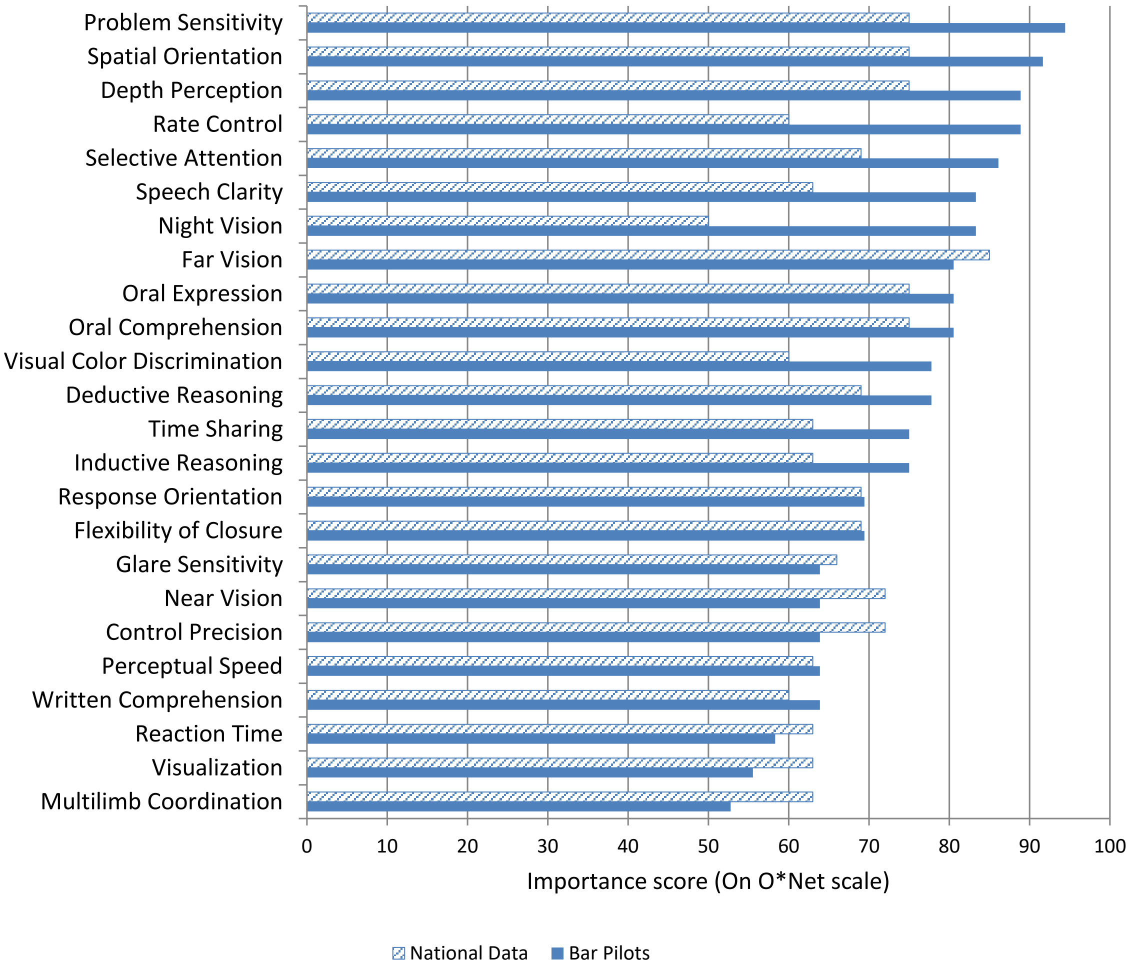

Figure 4. Comparison of needed cognitive abilities from Bar Pilots and national data on ship pilots.

2.2.2 Summary of Cognitive Task Analysis

It was apparent that the job of Bar Pilots involves an unusual mix of attributes and requirements. The preliminary observations of Bar Pilots at work underscored the importance of maintaining vigilance for long periods, clear verbal communication, decisiveness, and a readiness to anticipate and adapt to changing conditions.

The cognitive task analysis emphasized that the job calls for a blend of accuracy and judgment, with a narrow margin for error while working in an outdoor environment involving heights. In terms of work activities and required abilities, there were similarities to airline pilots, physicians, air traffic controllers, and nuclear equipment operators. While the intent was not to recommend the direct adoption of fatigue management practices from any of these occupations, the results suggest that appropriate fatigue management principles for Bar Pilots need not necessarily be limited to existing practices in the wider maritime industry.

3. Fatigue in Industry and Transport

Fatigue is a significant contributing factor to accidents in settings as diverse as road transport, health care, shipping and aviation (Lauber & Kayten, 1988; Mitler, et al., 1988; Smith, Folkard, & Poole, 1994; Walsh, Dement & Dinges, 2005; Williamson, et al., 2011). The National Transportation Safety Board (NTSB) has estimated that fatigue is a contributing factor in approximately 20% of major transport accidents (Marcus & Rosekind, 2017), and the reduction of fatigue-related accidents in all transport modalities is included on that agency's list of ten "most wanted" safety priorities.

Fatigue is a long-recognized hazard that must be managed in the maritime industry (International Maritime Organization, 2001; Sanquist, Raby, Maloney & Carvalhais, 1996). It is not necessary here to summarize the extensive literature on maritime fatigue, however, the following examples serve to illustrate the extent of the problem. Folkard (1999) and Filor (1998) report that groundings are more common at night than during the day, although of course this may also reflect the relative availability of visual cues. Figure 4 presents data drawn from 123 insurance claims showing a distinct peak in ship collisions in the morning hours (Folkard, 1997). McCallum, Raby, and Rothblum (1996) examined 279 maritime accidents and judged that 16% were related to fatigue. They considered that major factors contributing to fatigue were the number of consecutive days worked, days worked in the prior month, and hours on duty prior to the accident. On the basis of an analysis of 93 groundings, Akhtar and Utne (2014) concluded that a fatigued operator on the ship's bridge increased the probability of groundings by 23%. Starren et al. (2008) claimed that between 11–25% of groundings and collisions are at least partly due to fatigue.

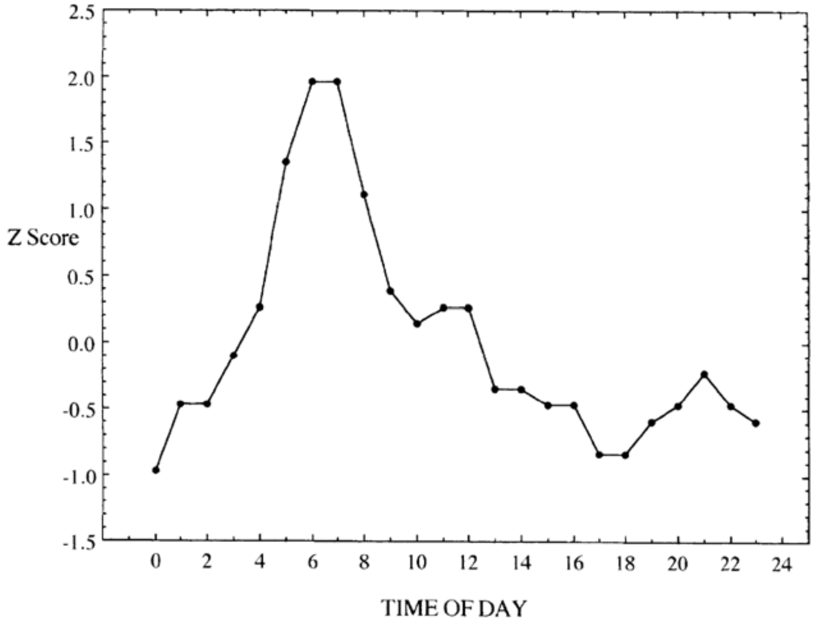

Figure 5. The trend in ship collisions over the 24 hours of the day with reference to the hourly mean (represented by a standardized Z score relative to the overall mean). From Folkard (1997).

In the United States, mariner fatigue has been identified as a contributing factor in several high-profile maritime accidents, including those involving the Exxon Valdez (1989), the Star Princess (1995), and the Eagle Otome (2010), (Strauch, 2015). The grounding of the Exxon Valdez led to rest requirements for the crew of tanker vessels.

3.1 Fatigue and Maritime Pilots

There have been no accidents involving San Francisco Bar Pilots in which fatigue has been identified as a causal factor. However, the potential hazards of maritime pilot fatigue have received attention as a result of a 2010 collision involving the Eagle Otome in Port Arthur, Texas, involving a vessel under the control of a pilot. The NTSB Investigation identified pilot oversight and mariner fatigue as contributors to the accident (NTSB, 2011). The pilot was deemed to be functioning on insufficient sleep as a result of untreated obstructive sleep apnea, extended wakefulness, and disrupted circadian rhythm. Furthermore, the NTSB noted that the cognitive skills needed to successfully navigate the narrow canal were those typically affected by fatigued states, including: vigilance, perception, judgment, and reaction time.

Nicol and Botterill (2004) note that maritime pilots, in common with locomotive engineers and medical residents, generally work according to an "on-call" schedule, meaning that their job assignments are driven by operational demands rather than a set schedule. Nicol and Botterill found that on-call work can negatively affect sleep, wellbeing, and personal life. Shipley and Cook (1980) found that British pilots averaged 6.1 hours of sleep when on-call. More than two-thirds reported that they woke up too early "often" or "quite often" when on-call. Shipley and Cook noted that older pilots appeared to have more difficulty with the working hours of the job, reporting more sleep-related difficulties than the younger cohort, and a greater use of medications to induce sleep. In a related study, Cook and Shipley (1980) found that the average duty day of maritime pilots in the vicinity of London was 15 hours (from leaving home until return), although only 5.5 of these hours were spent piloting ships. A major conclusion of that study was that pilots found it particularly challenging to maintain alertness during long pilotage jobs at night.

Berger (1983) studied the working arrangement of Port Phillip Sea Pilots in Melbourne, Australia. Berger noted the pride that maritime pilots express for their work, and the satisfaction they derive from ship handling, close quarter work, and precise ship berths or unberths. Nevertheless, when asked about the negative aspects of their work, the most frequent complaints related to nightwork, scheduling uncertainty, disruptions to sleep and rest, and disrupted social lives. In a submission to an Australian Parliamentary Inquiry into fatigue in transport, the Australian Marine Pilots' Association (2000) noted that marine pilots work at all hours of the day and night, every day of the year. They are particularly susceptible to fatigue due to the unpredictable nature of ship movements and schedules that follow no particular pattern. The submission referred to anecdotal reports of pilots on the bridge struggling to stay awake.

In 1986, the consulting firm Manalytics examined the work practices of San Francisco Bar Pilots and the human factors relevant to their work. At that time, most Bar Pilots worked a "two-week on, two-week off" work pattern. The policy of the Bar Pilot Association was to recommend a minimum rest period of 8 hours, although a longer period was required following river moves. Pilots worked shifts of approximately 12 hours, and had an average rest period between shifts of almost 21 hours. However, Manalytics noted that ship movements were not evenly distributed and that during peaks, pilots sometimes were called back to work before they had obtained 8 hours of rest.

Rhodes and Gil (2002) studied fatigue management in marine pilotage in Canada. They noted that pilots work irregular hours, have significant night work, and need to try to sleep during the day about half the time, when sleep quality is known to be poorer. Following a day assignment, pilots reported that they slept an average of 7 hours. However, they slept an average of less than 5 hours during the day following a night assignment. When pilots operating within the Great Lakes were asked to name the aspects of piloting most affected by fatigue, they listed: decision making, attention, keeping awake, and reaction time. Napping was a common strategy to manage fatigue, and most respondents indicated that when possible, they napped before reporting to work. Rhodes and Gil noted that most pilots in the Great Lakes were covered by a "0600 no call" rule, meaning that after working two night transits, they would receive a rest period until at least 0600 the next day. Rhodes and Gil identified scheduling practices that could compromise safety, including more than three consecutive periods of night pilotage, and consecutive long-duration assignments (those lasting more than 12 hours).

In recognition of the sensitive marine environment of the Great Barrier Reef on the east coast of Australia, there have been several studies of the work patterns of marine pilots operating in the vicinity of the reef. Piloting in this area is somewhat unusual as pilots remain on board for long coastal transits that can last up to two days. The nature of pilotage on the reef also changed in 1993 when a single pilotage provider that had operated for 100 years was replaced with three competing companies (Australian Transport Safety Bureau, 2012).

Parker and Hubinger (1998) examined the work of 58 pilots conducting Great Barrier Reef transits. These voyages lasted up to 55 hours. Parker and Hubinger noted that the work of pilots involved irregular hours, frequent early morning starts, reduced opportunities for sleep on board ships, and a need to obtain sleep on land at times other than during optimal sleeping hours. They found that 30-

40% of the pilots' sleep ashore was obtained outside the optimal sleep hours of 2200 – 0800, and thus could not be expected to be as restorative as night-time sleep. When on board the ship, the pilot would have access to a cabin; however, their sleep on board usually consisted of irregular fragmented nap periods, and on average, pilots incurred a sleep debt of approximately 2.5 hours for each 24-hour period they were at sea. Pilots were asked to report their level of fatigue while on duty. It was found that the strongest predictors of self-reported fatigue were the length of the break immediately preceding the assignment and the duration of the assignment. At the time, the guidelines for Great Barrier Reef pilots called for at least 12 hours of rest (excluding travel time) before most piloting assignments (where the pilot would be on board for between 14-16 hours) and 24 hours of rest before the longest assignments (Inner Route Passage with an average duty time of 54 hours). In most cases, pilots obtained rest well in excess of guidelines before an assignment; however, up to 10% of breaks were less than the minimum rest period.

Brown (1999) conducted a fatigue risk assessment of pilotage on the Great Barrier Reef. Brown examined 24 reports of groundings and collisions that had occurred near the reef over a 13-year period. In just over half of cases, a pilot was on board at the time of the occurrence. Unfortunately, the occurrence reports contained no information about the possible role of fatigue. Brown examined international statistics on maritime accidents and made a "ball park estimate" that 10–25% of incidents involving pilots involve fatigue; however, she cautioned that these figures were based on incomplete data.

A team from the Centre for Sleep Research at the University of South Australia conducted an extensive study of Great Barrier Reef Maritime Pilots for the Australian Maritime Safety Authority (Ferguson, Lamond, & Dawson, 2005; Ferguson, Lamond, Kandelaars, Jay, & Dawson, 2008). They used sleep diary information in conjunction with the Psychomotor Vigilance Task (PVT) and actiwatch monitoring to examine the sleep patterns and alertness of pilots operating near the reef. Ferguson et al. (2008) found that although the pilots' work periods sometimes extended well beyond 24 hours, they were able to maintain a relatively constant level of performance on the PVT over long periods of duty. Nevertheless, pilots recorded an average of only 5 hours of sleep per 24-hour period while on duty and reported higher levels of subjective fatigue at the end of pilotage than at the start. It appeared that the strategy of taking regular brief naps while on board ship enabled the pilots to maintain a remarkably constant level of objectively monitored performance over their duty periods.

Reid, Turek, and Zee (2016) studied the work and rest patterns of crew on tugs, towboats, and barges operating on the inland waterways of the United States. The study population included river pilots. Most of the crews worked a 6:6:6:6 pattern, with each six-hour duty followed by six hours of rest. Ninety percent of crew were found to be using a split sleep approach, in which they obtained sleep in two periods; a main (or anchor) period during one rest period, followed by a nap during another rest period. This strategy provided captains and pilots with an average of 6.5 hours of sleep each 24-hour period, significantly less than the optimum 8 hours.

Boudreau, Lafrance, and Boivin (2018) studied St. Lawrence River pilots using a methodology similar to that used by Ferguson et al. (2008) (i.e., actigraphy, PVT, diary, and subjective sleepiness scales). In contrast to the long transits studied by Ferguson et al., the St. Lawrence River transits lasted an average of just under 6 hours. Such shorter transits may be more comparable to the work of the San Francisco Bar Pilots. Boudreau et al. found that objective reaction time and subjective alertness varied with time of day and deteriorated with increased work duration. Fatigue was most pronounced at the end of long transits that ended in the early hours of the morning. Despite irregular work schedules and frequent night work, the circadian rhythms of St. Lawrence River pilots appeared to remain adapted to a diurnal pattern. Boudreau and colleagues raised the possibility that work scheduling that aligned with an individual's chronotype (preference for night or day work) could reduce the risk of performance decrements. However, they acknowledged that such a scheduling system may be difficult to introduce in practice.

4. Current Work/Rest Regulations

4.1 Fatigue Management in Industrial and Transport Settings

The traditional approach to the management of fatigue risk in industry and transport are Hours of Service (HOS) standards. These standards typically specify the maximum allowable hours of work in a period (frequently a period of 24 hours or 7 days) and may also refer to minimum rest requirements. Rosekind (2005) has cautioned that managing fatigue involves more than just limiting the length of shifts. Additional considerations include whether sleep opportunities occur during the day or night, night versus day work, the number of consecutive work days, the length of recovery periods between work cycles, schedule predictability, and whether the person is required to be on-call.

Appendix 2 summarizes HOS standards for the crew of seagoing vessels. Unlike maritime pilots, these crew members work on the same vessel for a period of weeks or months, remain on board during their off-duty time, and of course, have no commute time. The harmonized International Labour Organization (ILO) and International Maritime Organization (IMO) requirements are widely applied internationally, are largely repeated in Canadian and European Union regulations, and partially reflected in US regulations. Title 46 §15.1111 of the US Code of Federal Regulations (re-stated in a US Coast Guard Policy Letter) requires that the crew of seagoing vessels obtain a minimum of 10 hours rest per 24 hours, and a minimum of 77 hours rest in a 7-day period. Title 46 § 81.04(n) of the US Code of Federal Regulations specifies that licensed individuals on tankers must not work more than 15 hours in each 24-hour period, and 36 hours in each 72-hour period. This requirement was added in response to the grounding of the Exxon Valdez. It appears that Title 46 § 81.04(n) was not intended to apply to pilots.

Appendix 3 summarizes HOS standards for maritime pilots. Much of this information was reported to the NTSB in response to a letter sent to 24 states and 2 territories following the accident involving the Eagle Otome. In that letter, the NTSB recommended that pilot oversight organizations specify HOS rules to prevent fatigue among maritime pilots. Not all recipients responded to the letter. In most cases, it appeared that piloting customs and rules had evolved to meet local conditions, sometimes tying limitations to specific locations, or requiring two pilots on some transits. In two cases (both in Oregon) piloting organizations had engaged the services of fatigue experts to develop HOS rules. All three piloting associations in Oregon placed limits on successive periods of night work. Minimum rest periods are a common feature of piloting rules and range from 6 hours for Puget Sound Pilots to 12 hours (Maryland and Oregon in certain cases).

Appendix 4 summarizes HOS standards for a range of safety-critical work environments including aviation, rail, road transport, medicine, and the nuclear industry. It should be noted that these are current practices, but not necessarily "best practices". The allowable work hours for Air Force pilots, nuclear power plant operators, and medical residents are particularly concerning. With the exception of medical residents, the maximum duty period averages around 13 hours, and the minimum rest period (where specified) averages 9.5 hours.

The task analysis identified that, in terms of cognitive abilities, the work of Bar Pilots was similar to that of airline pilots and air traffic controllers. However, as an on-call occupation, Bar Pilots do not have the predictable schedules enjoyed by these other occupations. FAA regulations for airline pilots place different limits on flight duty periods according to the start time and the number of segments to be flown. The flight duty period starts when the pilot reports for duty and ends when the pilot has parked the aircraft at the end of their last flight. The maximum limit (14 hours) applies when work starts in the morning after 0700 and only one flight segment is flown. However, the limit is reduced for start times outside these hours and when more than one segment is flown. For example, if the start time is between midnight and 0359, the limit is 9 hours, regardless of the number of segments to be flown. The FAA limits the shift length of air traffic controllers to 10 hours. Additionally, a controller who has worked a night shift (defined as a shift in which the majority of hours are between 2230 and 0630) must then have an off–duty period of at least 12 hours.

Some aviation regulatory authorities permit airline pilots to take controlled naps in the cockpit. NASA research has indicated that brief planned naps are associated with increased alertness and improved performance, without compromising safety (Graeber, Rosekind, Connell & Dinges, 1990). Naps, however, increase the potential for sleep inertia. The International Civil Aviation Organization (2015) recommends that if airline pilots plan to take cockpit naps, the naps should only occur in cruise flight, and the pilot should wake at least 30 minutes before the start of descent. Further, ICAO recommends that pilots wait at least 10-15 minutes after waking before recommencing safety-related duties. Caldwell et al. (2009) recommend that naps by airline pilots should be limited to 30 minutes duration to avoid sleep inertia. For naps lasting longer than 30 minutes, the person should be awakened 30 minutes before performing safety-critical activities, to enable sleep inertia to dissipate. If the nap is taken during the circadian low, the person should be awakened an hour prior to their work period.

4.2 Fatigue Risk Management Systems

In recent years, comprehensive Fatigue Risk Management Systems (FRMS) have been adopted in aviation and road transport, to supplement more traditional Hours of Service (HOS) approaches. The FAA defines FRMS as "…a data driven and scientifically based process that allows for continuous monitoring and management of safety risks associated with fatigue-related error. It is part of a repeating performance improvement process. This process leads to continuous safety enhancements by identifying and addressing fatigue factors…" (FAA, 2010, p. 3).

Figure 6 shows an example of an FRMS from aircraft maintenance (FAA, 2016). This FRMS has a range of possible fatigue management and mitigation interventions arranged around a core set of HOS limits. Some of these interventions assist the individual; educational material, medical screening, treatment of sleep disorders, self-assessment techniques, and strategies for caffeine use. Other interventions are aimed at tasks; modifying procedures to reduce a task's susceptibility to fatigue-related errors, altering the scheduling of critical tasks to avoid times of heightened fatigue risk, and keeping the most critical tasks out of the hands of the most fatigued people (progressive restriction of responsibilities). The FRMS includes organizational-level activities; a statement of policy and management commitment, risk assessment, incident reporting and analysis, and a plan for continuous improvement of the FRMS. For more detail concerning these interventions, refer to Hobbs et al. (2011).

The International Maritime Organization (IMO) is currently integrating FRMS concepts into the Maritime Fatigue Circular 1014 (Grech, 2016). Reid, Turek, and Zee (2016) recommended that the tug, towboat, and barge industry develop FRMS concepts, noting that prescriptive HOS rules are not the best way to manage fatigue. An FRMS approach does not necessarily replace a traditional HOS approach to fatigue management. However, FRMS can provide greater scheduling flexibility if it can be demonstrated that a deviation from a strict HOS rule can be achieved with minimal risk.

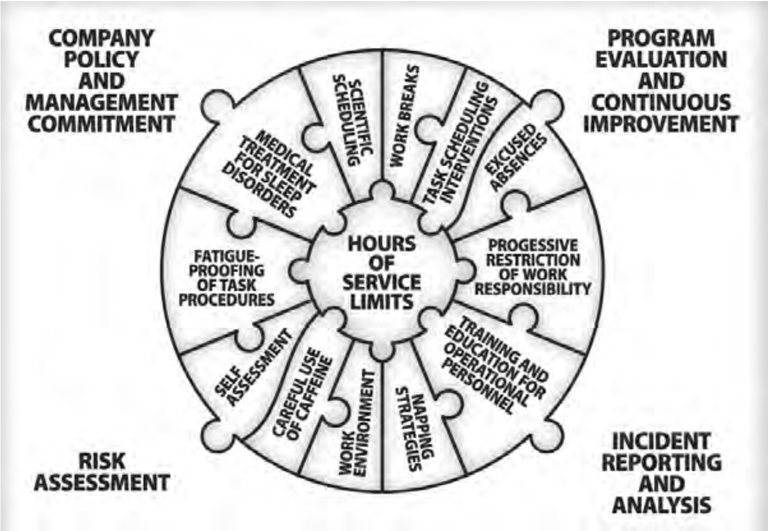

Figure 6. Example of a Fatigue Risk Management System (FRMS).

4.3 Australian and Canadian Maritime Pilot Recommendations

Baker, Fletcher, and Dawson (2000), and Rhodes and Gil (2002) examined the work practices of maritime pilots in Australia and Canada respectively. They each identified the need to limit consecutive nights of work, ensure adequate sleep opportunities, and address the risk of long duration assignments.

Baker et al. recommended the following principles for the design of maritime pilot work schedules:

- Minimize the occasions on which personnel are required to work more than 10 hours in a period.
- Ensure that minimum breaks between shifts enable personnel to have a minimum of 6 hours continuous sleep before resuming work.
- Ensure that any period of extended working hours is compensated with a longer break before resuming a shift.
- Ensure personnel have regular times (a minimum of 36 consecutive hours) free of work in a 14-day period.
- Minimize consecutive night shifts in order to limit reductions in performance levels caused by circadian disruption, fatigue and reduced alertness.
- Account for ‘covering’ contingencies caused by sickness or absences.
- Optimize the opportunity to take breaks within shifts.

Rhodes and Gil recommended the following “Fatigue Management Program” for Canadian maritime pilots:

- Reduce waiting time and scheduling uncertainty.
- Reduce the number of long duration assignments and/or their impact on fatigue.
- Decrease fatigue during night work by reducing assignment length, limiting number of consecutive nights, allowing planned napping and increasing the rest periods between.
- Reduce the impact of short calls on fatigue by assigning them immediately after days off and prohibiting the occurrence of consecutive short calls.
- Improve rest between and during assignments by helping pilots develop effective strategies for sleep at home and during planned nap periods—and by installing improved facilities for sleeping at locks and pilot houses.

4.4 Bar Pilot Fatigue Management Practices

The San Francisco Bar Pilots operate under a set of internal fatigue management policies that appear to have evolved over many years. The Manalytics study of 1986 identified the following Bar Pilot practices related to fatigue:

- “A pilot shall have an inward boarding time of no later than 12 hours after his outward assigned time.”
- “A pilot assigned to an inbound vessel that is destined north of San Pablo, or to Redwood City shall be relieved off the front [near Alcatraz] if on boarding he has been on assignment for 8 hours or more.”
- Additionally, Manalytics noted that the practice at that time was to allow a rest period of at least 8 hours between pilotage assignments. Their report went on to state “Even an MRP [minimum rest period] as long as ten hours would barely provide the necessary rest, depending on personal and family demands.” (Manalytics, 1986, p. 26–7.)

The current fatigue management policies of the San Francisco Bar Pilot Association were developed in collaboration with fatigue researchers affiliated with the Harvard Medical School Division of Sleep Medicine. These policies were outlined in a letter to the BOPC dated January 22, 2016. The policies are guidelines rather than rules and may be exceeded due to unavoidable operational demands. Pilots are limited to 15 consecutive days on-call, although most pilots work a pattern of 7 days on and 7 days off. The maximum duty period is set to 12 consecutive hours. The duty period commences at “ride time,” defined as the time that the pilot would be required to report to Pier 9. The duty period ends when the pilot is returned to the bottom of the board “BoB time.” In the case of an inbound vessel destined for an anchorage in the Central Bay, if the ship arrives at Alcatraz within the pilot’s 12-hour duty period, the pilot is allowed to continue bringing the ship to the anchorage. This avoids the need to hand over to a new pilot at a stage when the job is almost complete.

If a period of duty includes the hours between 0000 and 0600 and the pilot is assigned a departure followed by an arrival, the maximum duty period is set at 12 hours. This is because it is assumed that if the pilot needs to wait for the inbound ship at the pilot station, he will have an opportunity to rest. On the other hand, if a period of duty that includes the hours between 0000 and 0600 is planned to involve multiple bay moves, or other combinations of work that do not provide a natural opportunity for rest between jobs, then the duty period is limited to 8 hours.

If a pilot is required by a vessel departing between the hours of 1800 to 0600, the pilot order must be placed at least 8 hours in advance. In all other cases, orders for pilots must be placed at least 4 hours in advance. The 8 hours advance notice for night duty is intended to provide certainty, enabling pilots to better plan their work and rest periods.

Current policy calls for a minimum rest period (MRP) of 12 hours between work periods, defined as the time from BoB to the next ride time. During the rest period, the pilot is still on-call, with his name moving up the board. Exceptions to the 12-hour policy are reported each month to the BOPC. The rest period can be reduced to 11 hours if at least six consecutive hours of the rest occurs between 2200 and 0800. On rare occasions, a single pilot handles an entire river piloting job without relief at New York Point. In such cases, the affected pilot will be held off the board for 10 hours at the conclusion of the job. In recognition of the intense concentration involved and the small margin for error, turning basin maneuvers for certain Ultra Large Container Vessels (ULCVs) are not conducted during the hours of 0000–0600.

5. Fatigue Factors Surveys

5.1 Introduction to the Surveys

In October 2017 a Bar Pilot Fatigue Factors Survey was made available to the San Francisco Bar Pilots via an online link in an email and via a paper hardcopy mailed to their home[4]. The survey was preceded by an email from the Board of Pilot Commissioners (BOPC) informing the Bar Pilots that this would be occurring. A few weeks after the survey was made available, the BOPC sent an email to the Bar Pilots reminding them to complete the survey. The survey can be found in Appendix 5.

The survey had been approved by the Human Subject Institutional Review Boards of both NASA Ames Research Center and San Jose State University. Taking the survey was voluntary, and the responses were anonymous. The online version did not collect IP addresses. The Bar Pilots were told that the survey would gather their views on factors that contribute to workplace fatigue, such as schedules, sleep patterns, and workplace experiences, and would take about 25 minutes to complete.

The survey consisted of Likert-type rating scales (usually from 1 to 5), categorical choice options, and free text questions. The survey concluded with demographic questions including age and years of experience.

Results are presented in tables when appropriate and graphically when possible. When error bars are used in graphs, they are the 95% Confidence Intervals (CIs) as recommended by the American Psychological Association (APA, 2001, p. 22). These error bars can be used to gauge whether the means are significantly different from each other. If the confidence intervals around two means do not overlap or overlap only slightly, then generally the means are significantly different from each other.

5.2 Response Rates

The response rate to the survey was excellent at 93% (55/59). About two thirds (69%, 38/55) of the responses were on paper and about one third (31% or 17/55) were online.

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[4] Bar Pilot surveys received ethics approval # F17065 from the Human Subjects Institutional Review Board of San Jose State University.

5.3 Background Information

5.3.1 Age

As can be seen in Figure 7, over half (63%; 34/54) of the Bar Pilots were over 50 years of age.

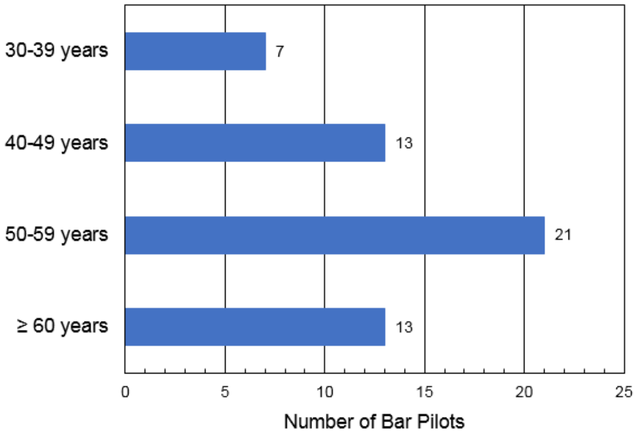

Figure 7. Number of Bar Pilots by age. N = 54/55[5].

5.3.2 Experience

Over half (55%; 29/53) of the Bar Pilots had worked as a Bar Pilot for 10 years or more, as shown in Figure 8.

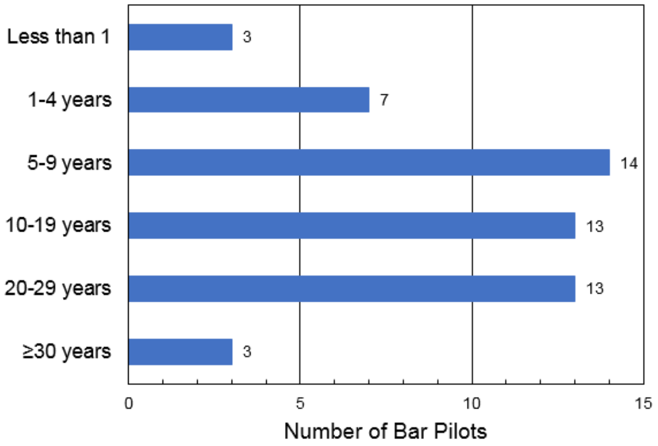

Figure 8. Years respondents worked as Bar Pilots. N = 53/55.

Almost all (87%; 47/54) of the Bar Pilots had been affiliated professionally with ship navigation for 20 years or more, as shown in Figure 9.

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[5] 54 out of a total of 55 respondents answered this question.

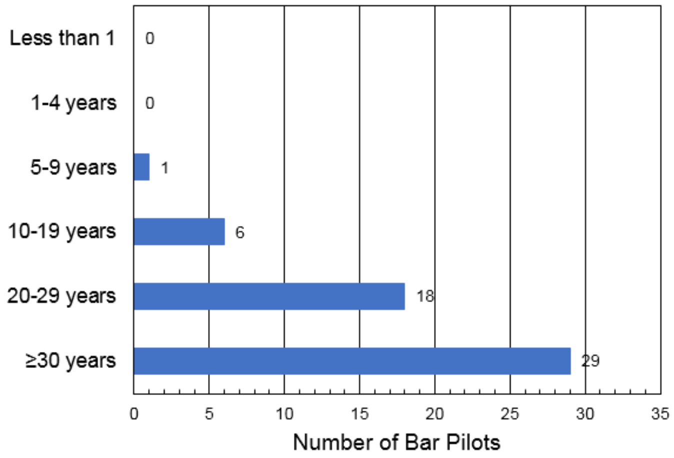

Figure 9. Years Bar Pilots professionally affiliated with ship navigation. N = 54/55.

5.3.3 Off-Call/On-Call Schedule

Of the 50 Bar Pilots who responded, 78% (39/50) worked one week on and one week off in alternating weeks (Group 1 and Group 2). The other 12% (11/50) worked two weeks on and two weeks off in a third group, as shown in Figure 10.

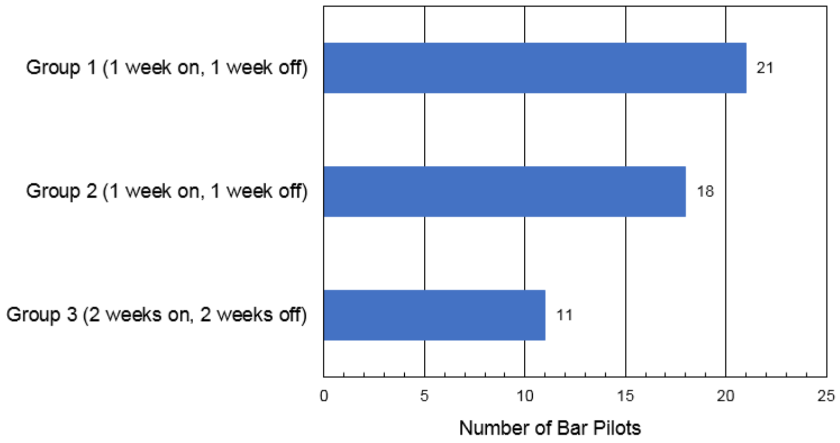

Figure 10. Number of Bar Pilots in three work groups. N = 50/55 (5 pilots did not respond).

5.3.4 Types of Piloting Duties

Respondents were asked what types of Bar Pilot lists they were on. As can be seen in Figure 11, the lists they most frequently checked were “E-pilot” and “Flat Tow” (unpowered vessel).

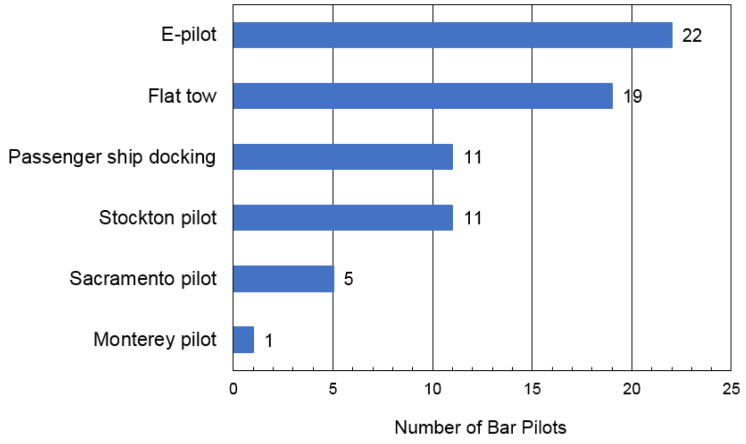

Figure 11. Number of Bar Pilots on lists of those qualified for different duties. Pilots could be on more than one list so the total is greater than 55. N = 40/55 (15 pilots did not respond).

5.3.5 Hours of Sleep Needed

Bar Pilots were asked: “About how many hours of sleep do you feel you need in a 24-hour period, irrespective of whether you are on-call or not?”. As can be seen in Figure 12, most Bar Pilots reported needing about 7–8 hours of sleep.

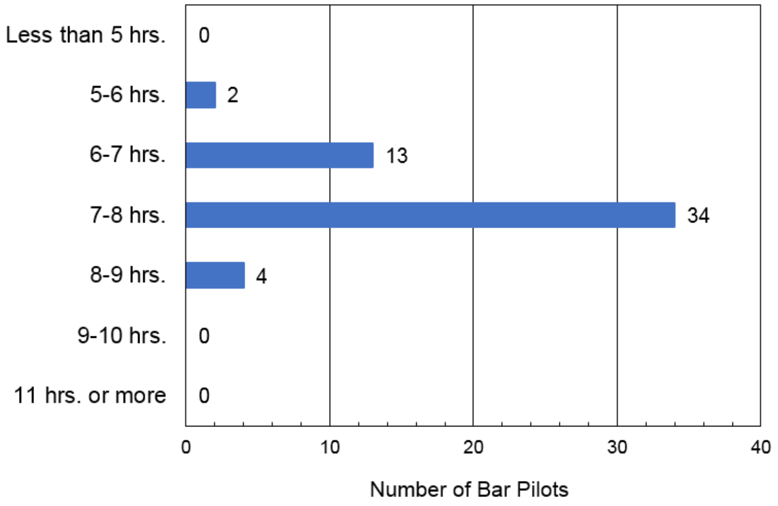

Figure 12. Reported hours of sleep needed in a 24-hour period, on and Off-call. N = 53/55.

5.3.6 Minimum Rest Periods

Minimum Rest Periods (MRPs) are the12-hour recommended minimum rest periods between work periods. Exceptions to these MRPs occur and are reported on a monthly basis to the BOPC. The Bar Pilots were asked on the survey: “During the past year, about how many times have you had an MRP exception (less than 12 hours MRP)?”. Their responses in Figure 13, along with their comments, indicate that many are uncertain as to the number. Of the 55 survey respondents, 11 did not answer this question and 13 said they didn’t know, together comprising 44% (24/55) of those who took the survey. The comments also indicate that Bar Pilots are not informed when they have experienced an MRP exception, nor is there follow-up as to whether they have been fatigued by the exception. It appears that MRP exceptions for individuals are not tracked over the one or two-week work periods, which means that an individual could receive several during their work period.

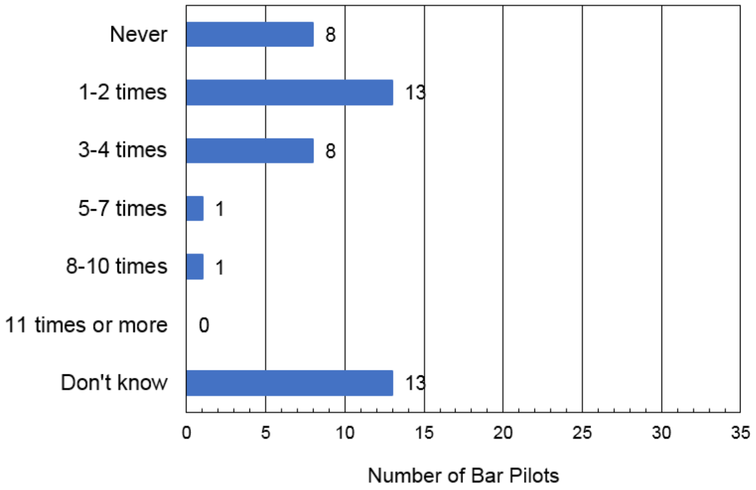

Figure 13. MRP exceptions Bar Pilots were aware of in the previous year. N = 44/55.

5.3.7 Commute Time

The Bar Pilots were asked what their average one-way commute time was from where they slept to their job assignment. Figure 14 shows that most of the Bar Pilots had one-way commutes between 30 and 45 minutes. The average one-way commute time was 40.1 minutes[6]. However, it was noted in the comments that in the Bay area, commute times vary dramatically depending on the time of day.

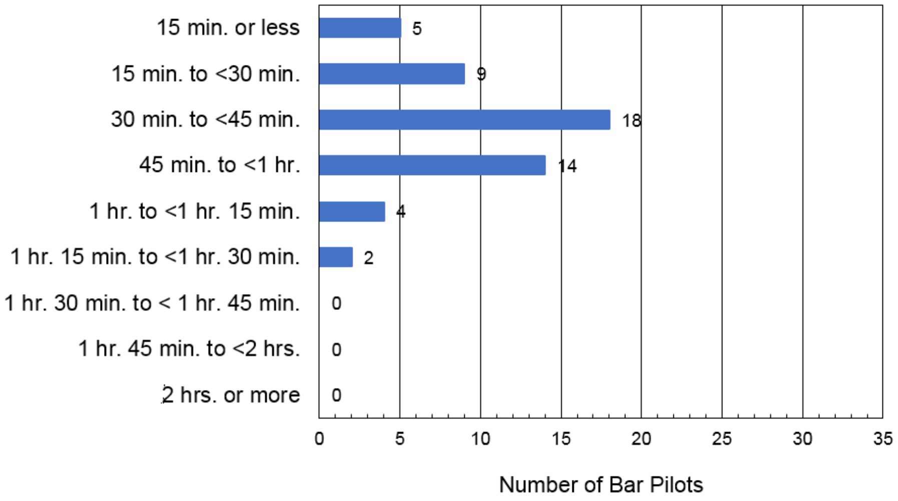

Figure 14. Average one-way commute time. N = 52/55.

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[6] The average can be calculated by taking the mid-point of the 15-minute time intervals and multiplying them by the number of respondents who chose them. Thus, the mean derived is 40.1 minutes, Standard Deviation 17.0 minutes.

5.4 Schedules

5.4.1 Consistency

The Bar Pilots were asked: "How consistent are your work and rest period schedules when you are on-call, i.e., start times are approximately the same each day?". Work and rest period start times were not seen as consistent as shown in Figure 15.

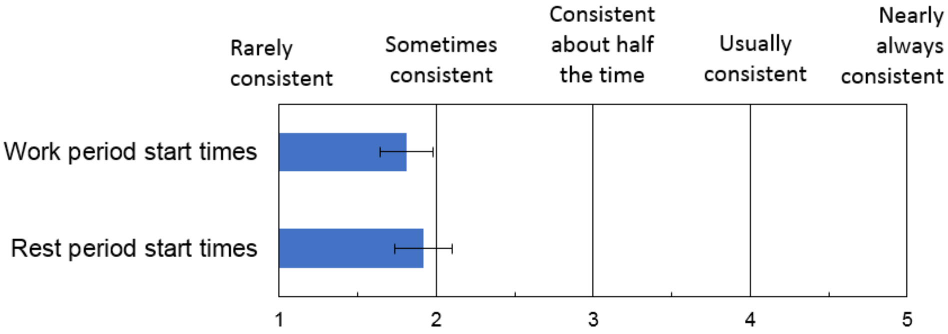

Figure 15. Lack of consistency seen in work and rest period start times. Ns = 53/55 for work; 50/55 for rest periods. Error bars = 95% CIs.

5.4.2 Accuracy/Predictability of Schedules

Bar Pilots were asked: "How accurate are the schedules that appear 10 hours ahead of time?" and "How accurate are the schedules that appear 4 hours ahead of time?". Schedules are not seen as very accurate 10 hours ahead of time and more accurate 4 hours ahead of time, as shown in Figure 16. The large error bars on accuracy of assignments 4 hours ahead of time indicate a lack of consensus among respondents.

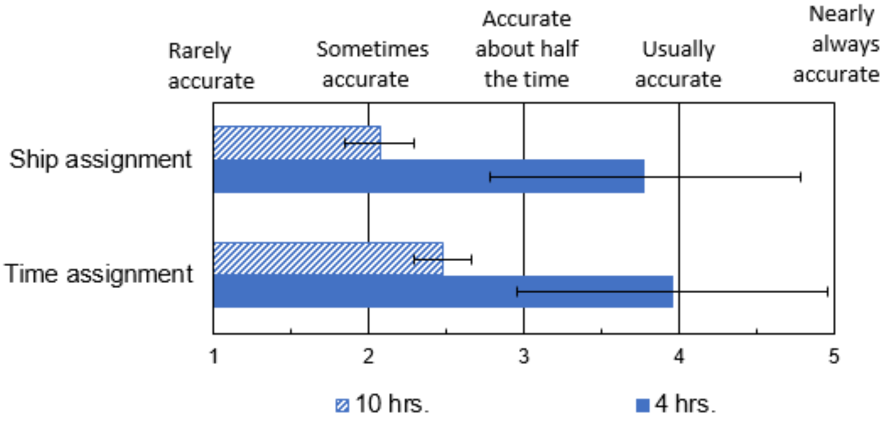

Figure 16. Schedule accuracy 10 hrs. vs. 4 hrs. ahead of time. Ns = 54/55 for 10 hours; 55/55 for 4 hours. Error bars are 95% CIs.

In the comment section that followed, Bar Pilots noted that the lack of predictability in work schedules made it very difficult to schedule rest. Other comments indicated that schedules were somewhat more predictable at night than in the day.

5.4.3 Change in Nighttime Policy Seen as Improving Sleep

Bar Pilots were asked: “Has the recent policy of requiring ships to order a pilot 8 hours ahead of time (instead of 4) when departing between 1800 and 0600, improved your ability to sleep?”. This question refers to one of the new rules introduced in 2016 designed to allow Bar Pilots to schedule their sleep periods in advance for night time work. As can be seen in Figure 17, respondents reported improvement in the ability to sleep with the new ship scheduling policy.

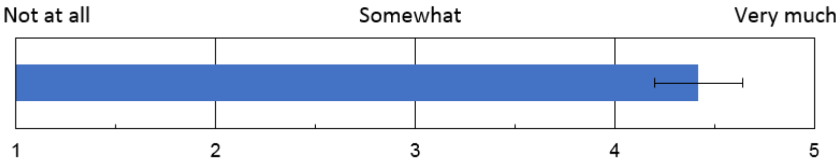

Figure 17. New ship scheduling policy improves ability to sleep. N = 43/55 (10 checked don’t know; 2 did not answer). Error bars = 95% CIs.

5.4.4 Feeling Rested After Main Sleep Period: On-Call vs. Off-call

Bar Pilots were asked: “On average, how rested do you feel after your main sleep period when you are on-call vs. Off-call?”. Not surprisingly, Bar Pilots reported being more rested after their main sleep period when off-call than when on-call. When on-call, they still felt they were significantly more than “Moderately rested,” as shown in Figure 18.

Figure 18. Feeling rested after main sleep period on and off-call. N = 55/55; error bars 95% CIs.

5.4.5 Work Period Start Times and How Rested Bar Pilots Feel

Bar Pilots were asked: “When you are on-call, how rested do you typically feel if you start your work period at these times?”. The results in Figure 19 show that the Bar Pilots felt least rested when their work period started at 0200 and 2400.

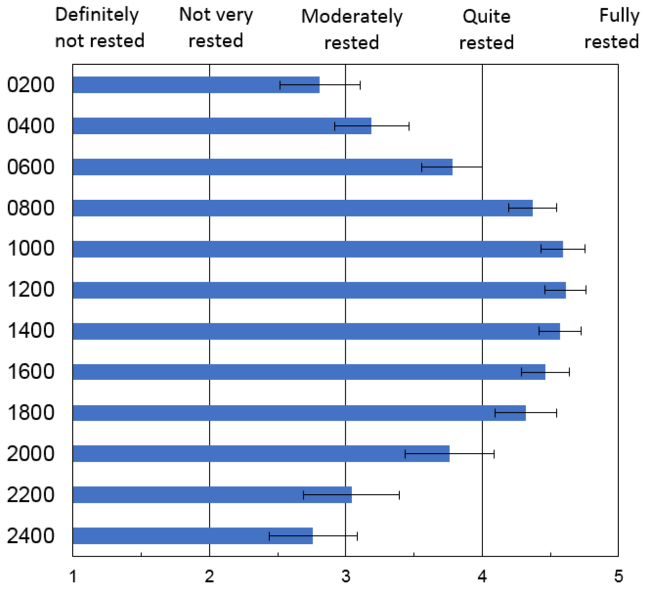

Figure 19. *How rested Bar Pilots describe themselves at various work start times.* *Ns = 53/55 to 54/55; error bars = 95% CIs.*

5.4.6 Quality of Sleep

As shown in Figure 20, Bar Pilots' sleep is more frequently disrupted by awakening when on-call than off-call but this disruption occurs less than half the time on-call. The Bar Pilots were asked: "When you are on-call and off-call, how often does the following occur?".

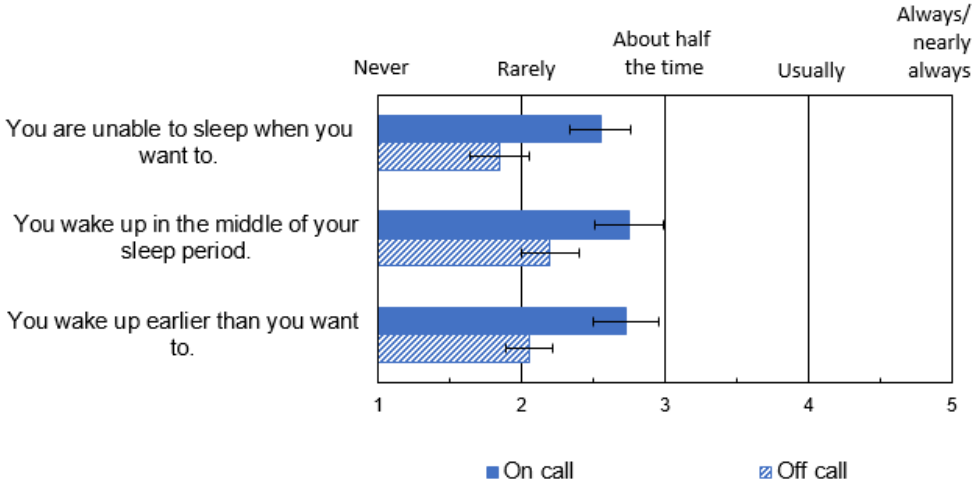

Figure 20. *Frequency of sleep disruption when on and off-call. N = 55/55. Error bars are 95% CIs.*

Over half (30/55) of the Bar Pilots indicated that they had trouble sleeping when on-call due to inconsistent schedules. Figure 21 shows the responses to the question "Do you have trouble sleeping for any of the following reasons both when on-call or off-call?". The Bar Pilots could check more than one of the options below.

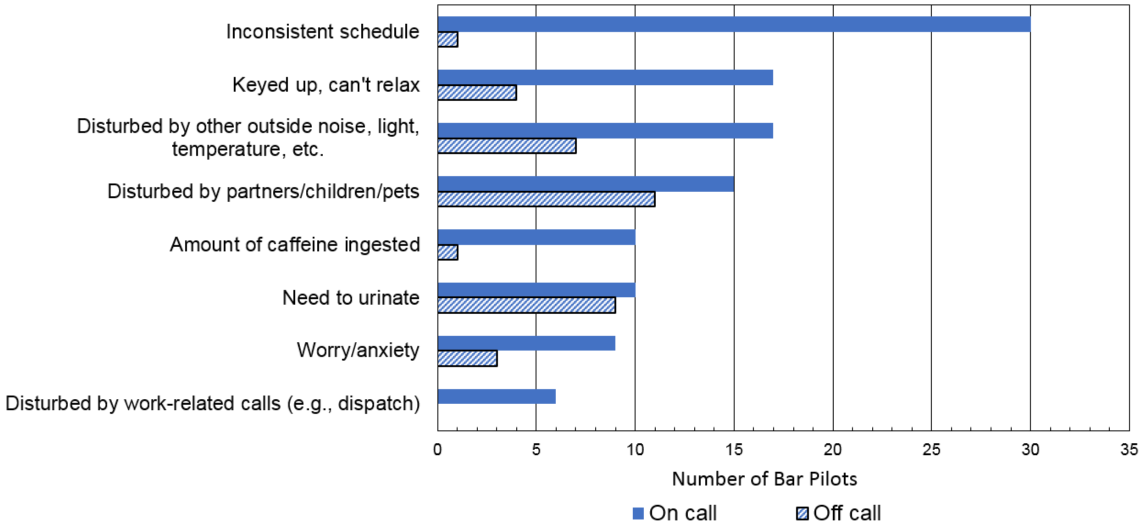

Figure 21. Reasons for having trouble sleeping when on- and off-call. N = 55. Bar Pilots could pick all the reasons that applied; hence the total number of responses add to more than 55.

5.4.7 Caffeine Ingestion

Almost 20% of the Bar Pilots (10/55) indicated that they have trouble sleeping due to the amount of caffeine they ingested on-call, as shown above in Figure 21. The Bar Pilots were also asked a more specific question on this topic: "About how many servings of caffeine (e.g., coffee, tea, soda, energy drinks, NoDoz, etc.) do you typically have in a 24-hour period when you are on-call and when you are off-call?". Their responses are shown in Figure 22.

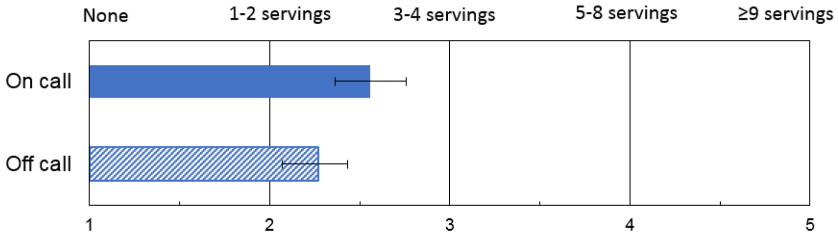

Figure 22. Average number of servings of caffeine ingested on- and off-call in 24 hours. N = 55/55.

Figure 23 shows the average number of servings of caffeine for those who did and did not indicate earlier that caffeine affected their sleep when on-call (Figure 21). As can be seen, those who stated that caffeine affected their sleep reported having significantly more caffeine (3–4 servings) in 24 hours than those who did not state that caffeine affected their sleep.

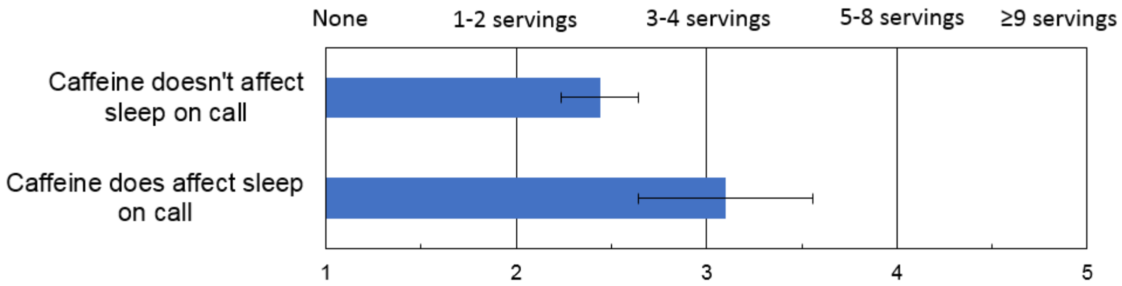

Figure 23. Average number of caffeine servings in 24 hours by those who did and did not state that caffeine affected their sleep. Ns = 45 caffeine does not affect sleep; 10 caffeine does affect sleep. Error bars = 95% CIs.

5.4.8 Napping

As described in the survey, “Naps are brief sleeps in addition to your main sleep. Naps can range from a brief sleep in bed to a brief sleep while sitting as a passenger in a boat or a car.” Bar Pilots were asked: “When you have the opportunity to take a nap during breaks in your work period, about how often do you do so if you are in the following places?”. As can be seen in Figure 24, when the opportunity arises Bar Pilots most frequently take naps in the Offshore Pilot Station and at their normal on-call sleeping places. These locations are more likely to allow uninterrupted naps than the taxi van and pilot boat options.

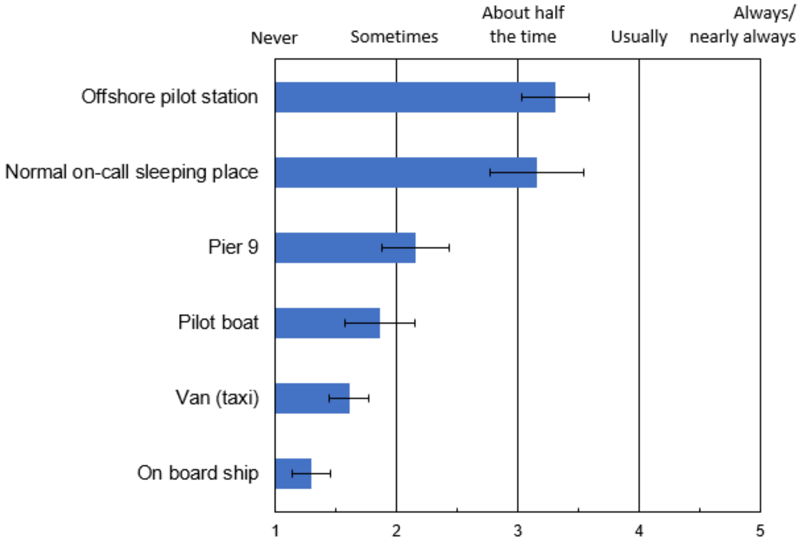

Figure 24. Bar Pilot napping locations. Ns = 52-54/55. Error bars = 95% CIs.

Bar Pilots were asked: “How rested do you feel after napping in the following locations?”. As shown in Figure 25, they indicated they were most rested when they slept at their normal on-call sleeping place, followed by Pier 9 and the Offshore Pilot Station. These latter two locations were purposefully designed to accommodate napping and seem to have been successful in doing so.

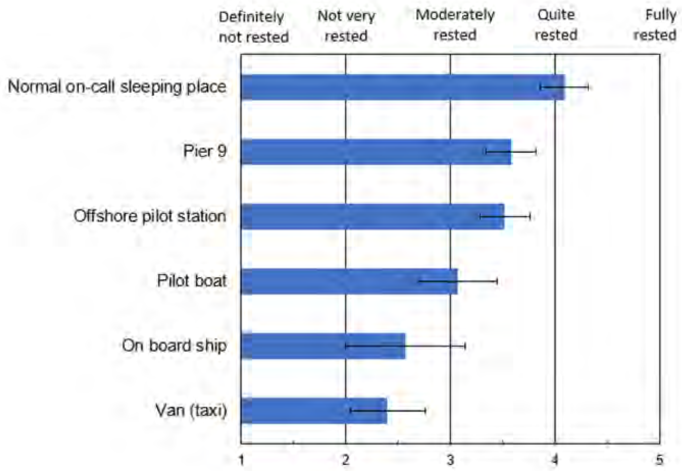

Figure 25. How rested Bar Pilots feel after napping in various locations. Ns = 52-54/55. Error bars = 95% CIs.

5.4.9 Sleep Inertia

The Sleep Inertia Questionnaire (SIQ) (Kanady & Harvey, 2015) consists of 23 questions. A total of four items were selected which loaded heavily on the physiological and cognitive factors of the total questionnaire. These items are shown in Figure 26. As can be seen, the Bar Pilots reported very little sleep inertia as measured by these four items. Sleep inertia questions were prefaced by the statement “Sleep inertia is the period of fogginess or confusion that can be present immediately after one wakes up from sleep or from a nap”. The Bar Pilots were then asked: “When you are on-call, just after you wake up from sleep or from a nap, to what extent do you...”.

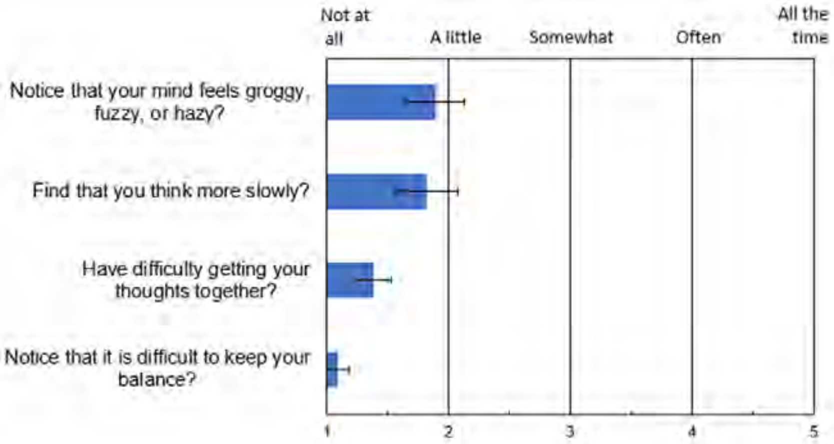

Figure 26. Bar Pilot ratings on a modified Sleep Inertia Questionnaire (SIQ). N = 55/55. Error bars are 95% CIs.

Three Bar Pilots indicated that it was “a little” difficult to keep their balance during a sleep inertia period and one indicated that it was “somewhat” difficult to keep their balance during such a period.

The Bar Pilots were asked: "If you experience sleep inertia, about how much time do you typically need after awakening from sleep or a nap until the symptoms disappear? _____ minutes.". Of the 29/55 Bar Pilots who reported a period of sleep inertia, the average time was 15.8 minutes, as shown in Figure 27.

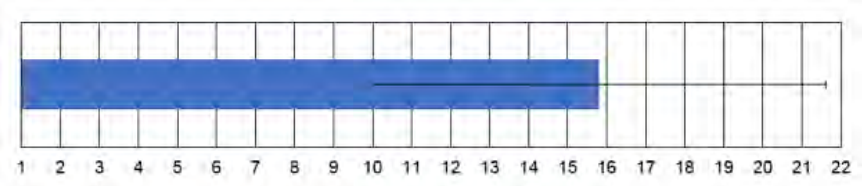

Figure 27. Average minutes of sleep inertia of those who reported sleep inertia. N = 29/55. Error bar = 95% CI.

The histogram in Figure 28 shows that 26 pilots did not report any sleep inertia and most of those who did report it experienced under 20 minutes of sleep inertia. However, 7 pilots reported 30 minutes or over, with a few experiencing periods as long as 55 and 60 minutes.

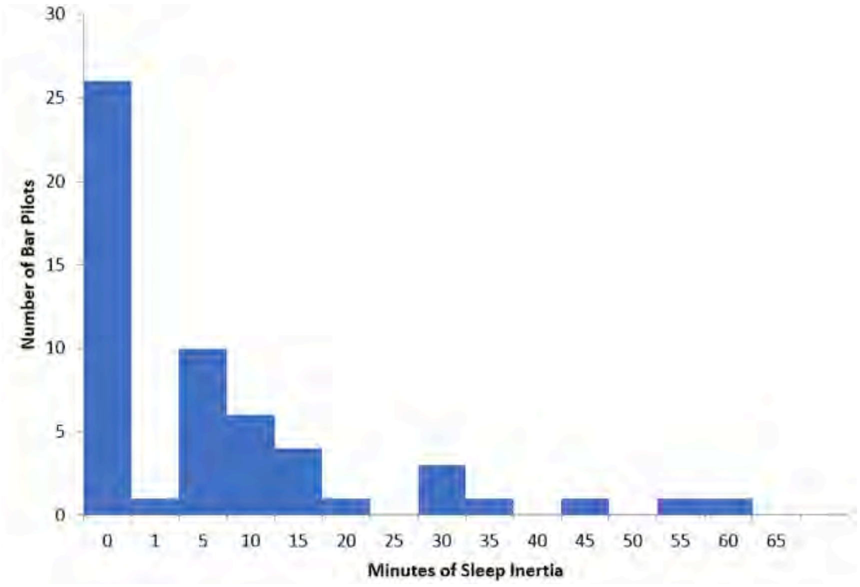

Figure 28. Reported length of sleep inertia by number of Bar Pilots. N = 55/55.

A further analysis (Figure 29) shows that the 7 Bar Pilots who reported sleep inertia periods ≥30 minutes had significantly higher results on the modified Sleep Inertia Questionnaire compared to those who had no sleep inertia or sleep inertia under 30 minutes. There was no difference in sleep inertia by age on any of the measures.

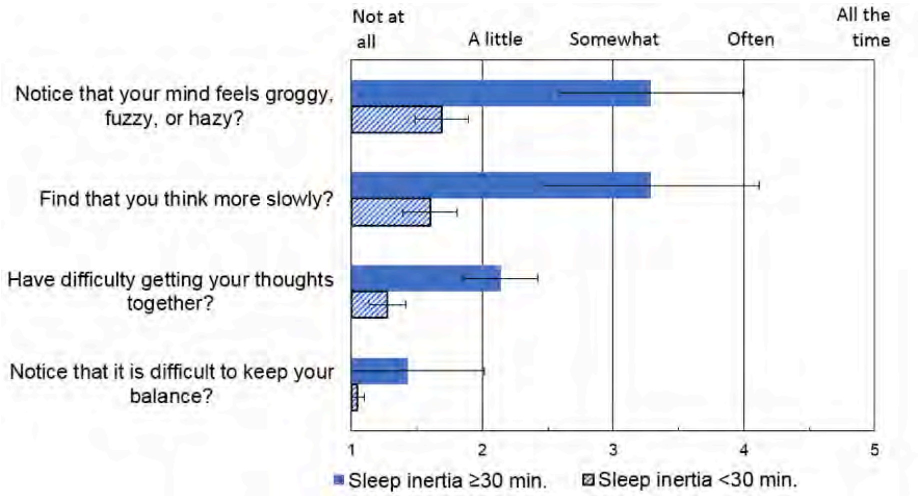

Figure 29. Higher ratings on sleep inertia items for 7 pilots reporting ≥30 minutes duration of sleep inertia. N = 7 ≥30 min.; 48 <30 min.

Judging from the comments, many Bar Pilots recognize the problem of sleep inertia and appear to have good strategies for mitigating the effects of sleep inertia, such as giving themselves adequate time to recover before piloting. However, given the somewhat unpredictable nature of the schedule, there may be times when mitigation efforts are not possible. It has been demonstrated that sleep inertia affects accuracy of performance, worsens when individuals are sleep deprived, and varies in duration and severity with circadian phase (Scheer, Shea, Hilton, & Shea, 2008; Tassi et al., 2006).

5.5 Stress-related Fatigue

Bar Pilots were asked: “If you feel stressed when you are on-call, to what extent do the following contribute to your stress?”. As shown in Figure 30, the factors contributing most to stress were piloting a 1200ft vessel in variable wind, piloting during reduced visibility conditions and unpredictable work schedules. It is noteworthy that all of these areas received ratings on the lower side of the scale and were therefore not seen as very stressful. There was agreement on this as indicated by the small error bars[7].

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[7] Figure 29. Higher ratings on sleep inertia items for 7 pilots reporting ≥30 minutes duration of sleep inertia. N = 7 ≥30 min.; 48 <30 min.

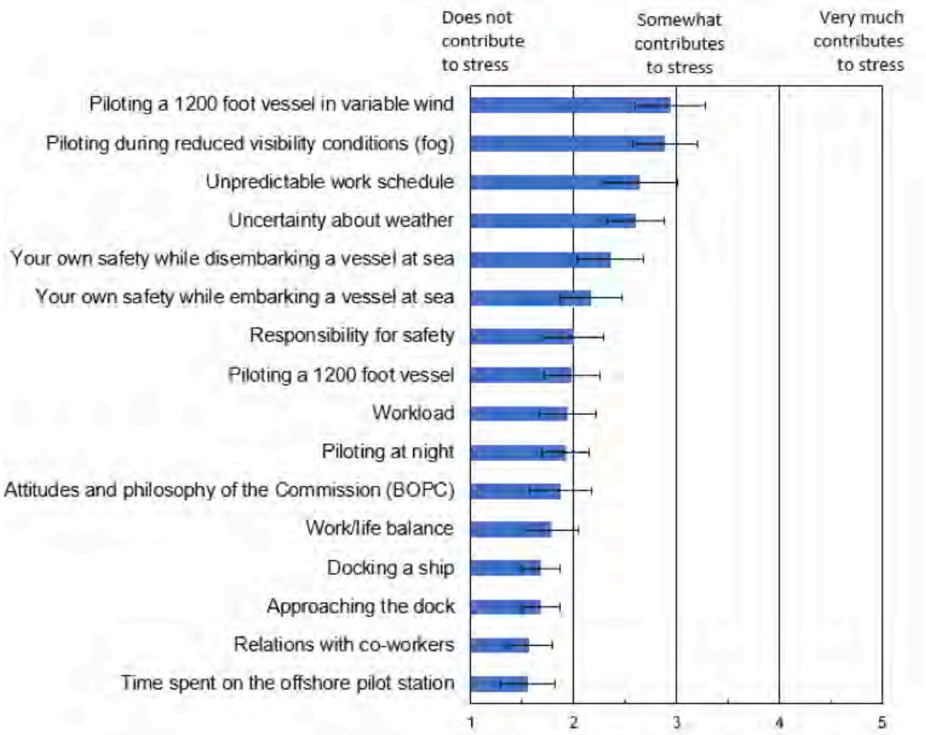

Figure 30. Factors contributing to Bar Pilot stress. Ns = 51-53/55. Error bars = 95% CIs.

The Bar Pilots had an option to add "Other" stressors to their work. Among other stressors reported were the pressure on Bar Pilots due to civil and criminal liability for accidents, the fear of not getting enough sleep to function well on the job, and the fear of not waking up on time. In response to a follow-up question, Bar Pilots indicated that wind was a greater stressor than working at night when piloting a large vessel during a Bay Move.

5.6 Fatigue Scales

5.6.1 Epworth Sleepiness Scale

The Epworth Sleepiness Scale asks the respondents to rate the likelihood of their dozing during eight activities and provides four categories of responses: No chance of dozing, slight chance of dozing, moderate chance of dozing, and high chance of dozing. The scores on each item are added together to give a final score. Figure 31 shows the average ratings on each of the 8 items. The Bar Pilots were asked: "When you are on-call, how likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?" As can be seen, the ratings are low, except on the first item, when it would be advantageous to take a nap.

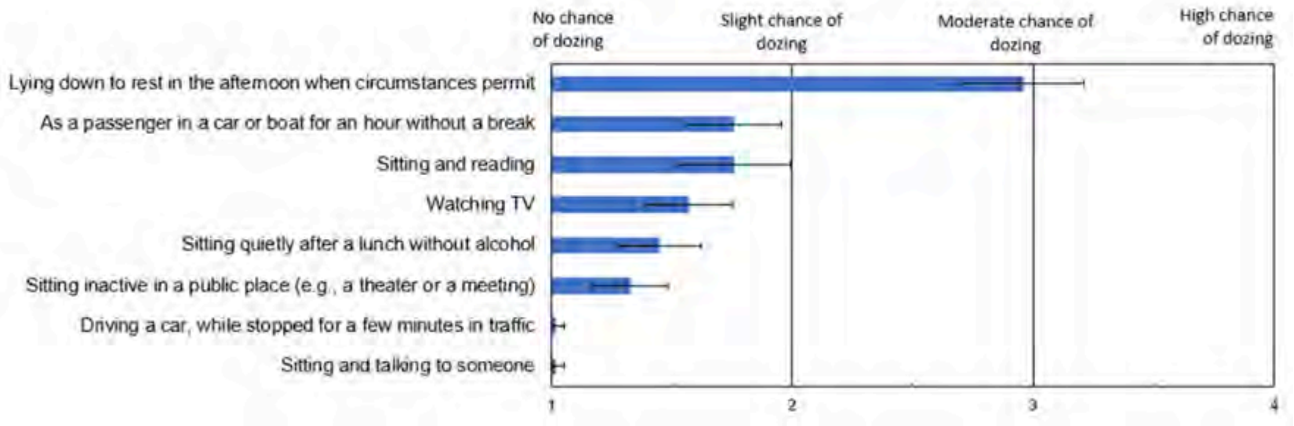

Figure 31. Bar Pilots' ratings on the Epworth Sleepiness Scale items. Ns = 53-4/55. Error bars = 95% CIs.

Figure 32 shows the average final score of the Bar Pilots compared with the average final score of workers on normal daytime shifts (Johns & Hocking, 1997). As can be seen, when on-call the average Bar Pilot Epworth Sleepiness Scale Score was in the "lower normal" daytime sleepiness range, based on a large number of studies.

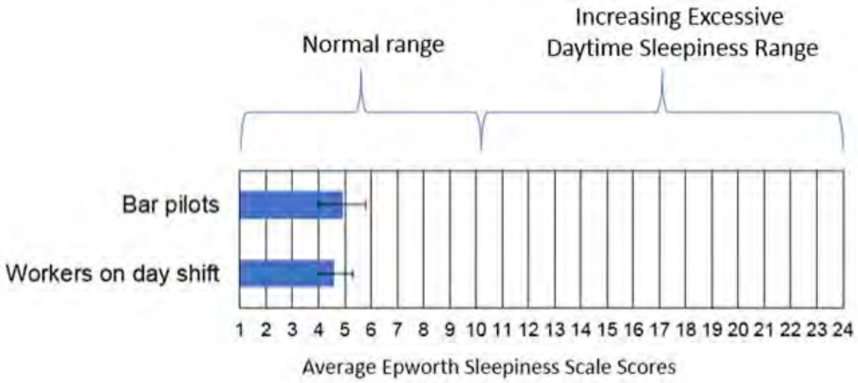

Figure 32. Bar Pilots' final scores on Epworth Sleepiness Scale compared to workers on regular day shifts. N Bar Pilots = 52/55; N normative sample = 507. Error bars = 95% CIs.

Bar Pilots were asked: "In general, are you more likely to doze off when you are on-call than when you are off-call?". Figure 33 indicates that they reported that they were about equally likely to doze off in either case.

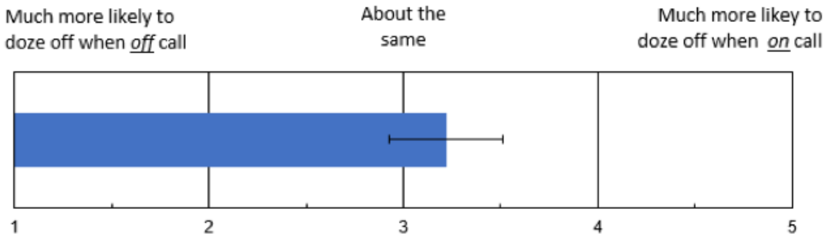

Figure 33. Reported likelihood of Bar Pilots dozing off when on or off-call. N = 46/55. Error bar = 95% CI.

5.6.2 Modified Brief Fatigue Inventory

The Modified Brief Fatigue Inventory shown in Figure 34 indicates the extent to which fatigue interferes in daily activities. It was originally designed to assess the level of fatigue in cancer patients (Mendoza, et al., 1999). It has been shortened and modified to apply to fatigue "recently" rather than to fatigue occurring currently while taking the test and within the previous 24 hours. The Bar Pilots were asked: "When you have recently been on-call, to what extent has fatigue interfered with your...".

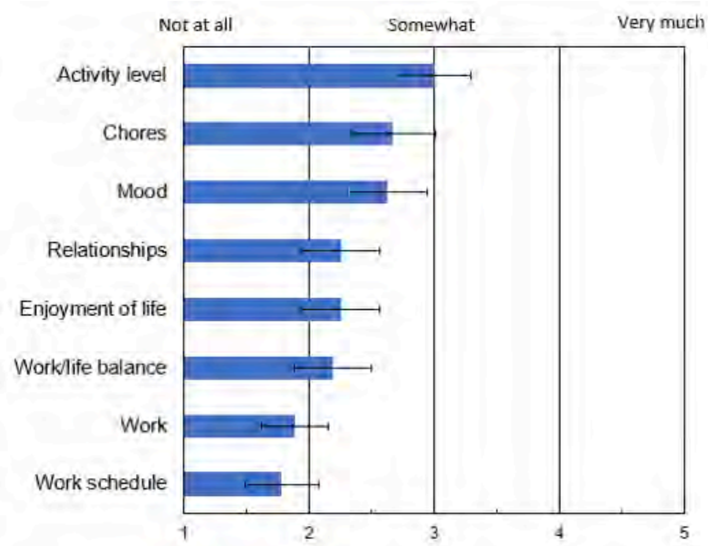

Figure 34. Results on 8 items of the Modified Brief Fatigue Inventory. Ns = 46-53/55. Error bars = 95% CIs.

As can be seen, the responses are all on or near the left side of the scale, indicating that the Bar Pilots considered that fatigue was not a major cause of interference with their daily activities.

To compare levels of fatigue, Bar Pilots were asked: "In general, do you feel more fatigued when you are on-call or off-call?". As shown in Figure 30, Bar Pilots feel significantly more fatigued when on-call than off-call.

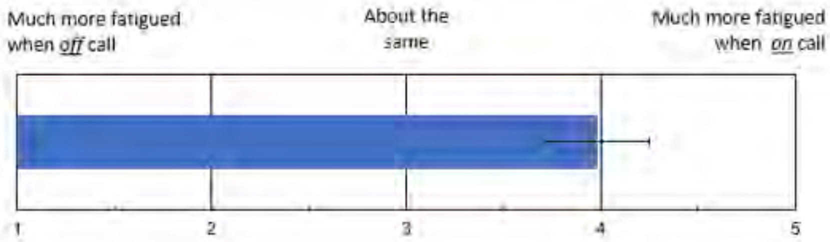

Figure 35. Bar Pilots' fatigue when on- and off-call. N = 51/55. Error bar = 95% CI.

5.6.3 Shiftwork Disorder Scale

The Shiftwork Disorder Scale is a 4-item scale that assesses the likelihood of a primary circadian rhythm sleep disorder indicated by excessive daytime sleepiness and/or insomnia (Barger et al., 2012). As can be seen in Figure 36, the responses are all on the normal, low side. The final average Bar Pilot scores are considered "Low risk" for Shiftwork Disorder according to the scoring system developed by Barger et al.

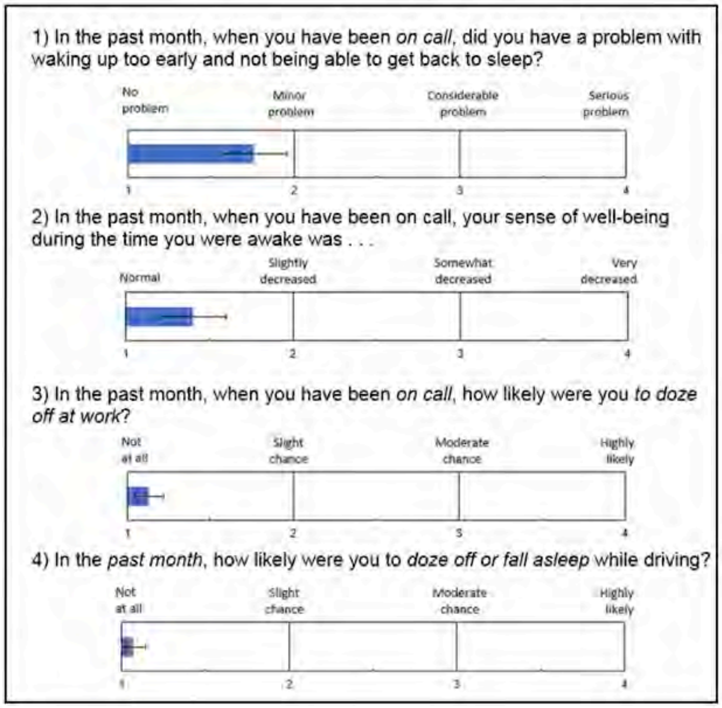

Figure 36. Bar Pilots' ratings on the Shiftwork Disorder Scale. N = 55/55. Error bars are 95% CIs.

5.7 Current Scheduling Practices and Staffing

Bar Pilots were asked: "Please indicate the extent to which you feel the following aspects of current Bar Pilot scheduling practices are at about the right level to support your optimal alertness. If not at the right level, please write a better, though still realistic, length in the far right column.". Very few Bar Pilots wrote a better length. Indeed, most Bar Pilots considered current scheduling practices to be at about the right level to support optimal alertness, as can be seen from the ratings in Figure 37.

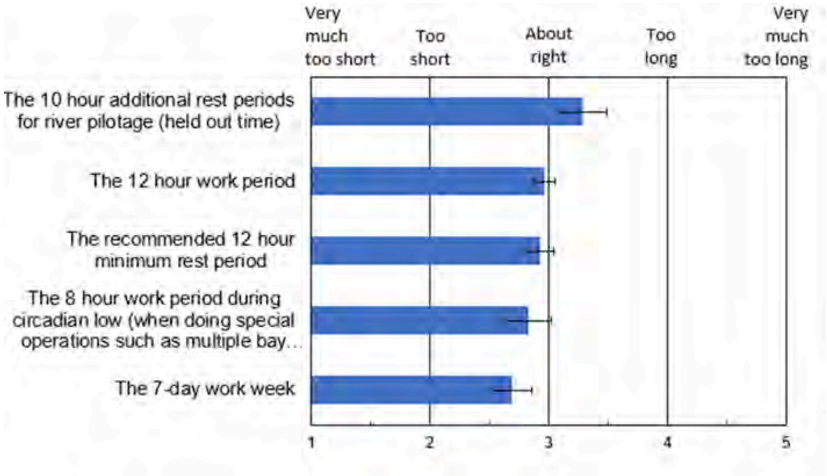

Figure 37. Bar Pilots' assessment of schedule factors in terms of supporting their optimal alertness. Ns = 51-54/55 except for river pilotage, where N = 34. Error bars are 95% CIs.

The first item concerned the additional 10-hour rest period (hold time) applied after certain river transits performed by pilots licensed by the ports of Sacramento or Stockton (river pilots). The 10-hour period is somewhat on the long side when rated by all pilots. One river pilot clarified that it is not "10 hours' additional rest" it is "Bobbing [going to the bottom of the Board] 10 hours later". The nine river pilots who rated this item had an average of 3.1, very close to "just about right." The non-river pilots who responded (n=25) assigned an average rating of 3.4. This difference was not significant. Many river pilots thought this 10-hour period should be optional since it may force them into night work.

The 8-hour work period rule was put into place in 2016 to mitigate the impact of working long hours through the circadian low. Before then, there were no limits on the hours that pilots could work at night. According to interviews, it was not uncommon for them to work up to 15 hours at night. Currently, Bar Pilots can work up to 12 hours at night but only when there is an opportunity to rest. A typical scenario involving an opportunity to rest is when a "departure covers an arrival," i.e., when a Bar Pilot takes a ship to sea in the afternoon, eats dinner, rests on the Offshore Pilot Station, and then boards an incoming ship typically between 0200 and 0300. The 8-hour night rule covers all other combinations of assignments when there is no opportunity to rest, including combination trips of Bay Moves and crossing the bar, if any part of the work takes place between 0000 and 0600.

Most Bar Pilots feel that the 8-hour limitation on night work with no opportunity to rest is "about right" as shown in Figure 37. However, this rule is frustrating to some Bar Pilots since they like to complete jobs and sometimes can't but have to be replaced by another Bar Pilot. Also, since the pilots are not working at night as long as they used to, the rotation is faster and the time between work periods is shorter.

The last item in Figure 37, the 7-day work week, was rated as being on the short side overall. This appeared to be due to the ratings of 11 respondents who worked a two-week on-call schedule. Their average rating was 2.1 (near "Too short;" n = 11, SD = .70). This was significantly different from the average 2.9 rating (n = 37, SD = .48) of those who worked a one-week on-call schedule, t(46) = 4.20, p<.001, two-tailed.

The Bar Pilots were also asked: “Please indicate the extent to which you feel the current staffing level is about right (60 Bar Pilots) to support your optimal alertness”. Their average response (2.7) is shown in Figure 38. As can be seen, the average is significantly below “About right”. Older pilots were more likely to feel that there were not enough pilots compared to younger pilots[8].

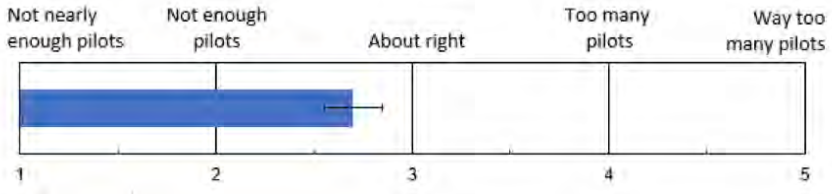

Figure 38. Sufficiency of current staffing levels. N = 47/55. Four respondents marked “NA/Don’t know” and four did not answer. Error bar is 95% CI.

Figure 39 shows the distribution of responses on staffing levels. It can be seen that there were no respondents who felt there were too many Bar Pilots. Thirteen Bar Pilots (24%; 13/55) felt there were not enough.

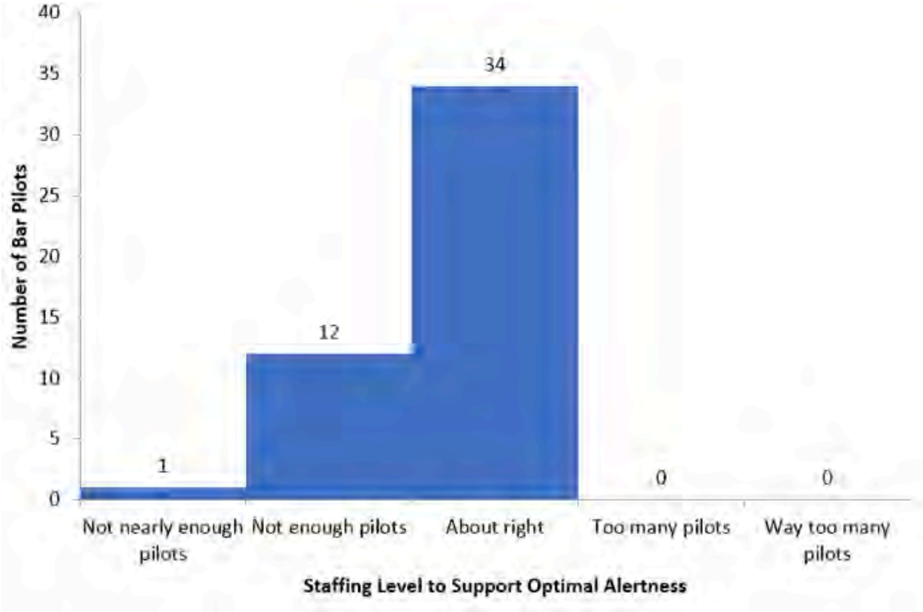

Figure 39. Distribution of responses on staffing level to support optimal alertness. N = 47/55, four respondents marked “NA/Don’t know” and four did not answer.

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[8] The response to this question differed significantly between those who were over 50 years in age (mean 2.6; SD = .24) and those who were under 50 years in age (mean 2.9; SD = .57), t(41.2) = 2.9, p<.01, equal variances not assumed).

The next question on the survey was "If not 'About right', how many Bar Pilots would you like to see? _____". Of the 6 Bar Pilots who responded to this question, the average number was 63.3. Nearly all of the comments that followed indicated that there were rarely 30 pilots per week working due to factors including new Not-Fit-For-Duty (NFFD) medical regulations, committee meetings, and the frequent need for two pilots on Ultra Large Container Vessels (ULCVs). This results in increased pulling from the pool of off-call pilots to reduce on-call MRP exceptions. Pilots who work during their off-call week are paid back with "comp" time, which would reduce the number of pilots in the future. Some comments indicated that the number of pilots on-call was not always balanced and consistent between groups working different weeks. It would be valuable to document the number of pilots available for piloting duties on a daily basis as this number directly relates to Bar Pilot fatigue and alertness.

The Bar Pilots were asked: "What is the maximum number of consecutive days that you feel that you could be on-call and still maintain the required alertness for your job?". As can be seen in Figure 40, the average was well over 14 days[9].

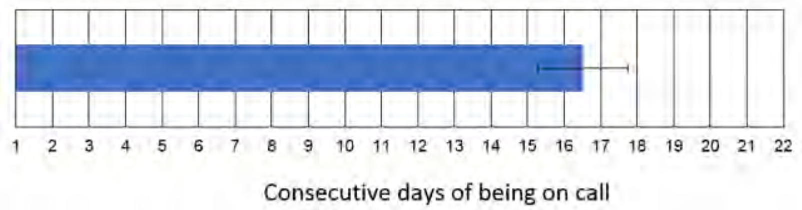

Figure 40. Average number of consecutive days of being on-call while maintaining required alertness. N = 54/55. Error bar = 95% CI.

Figure 41 shows that over one third of the respondents (39%; 21/54) felt they could work 3 weeks in a row while maintaining the alertness required for their job. Comments indicated that how long they could work depended on the weather and how busy the board was.

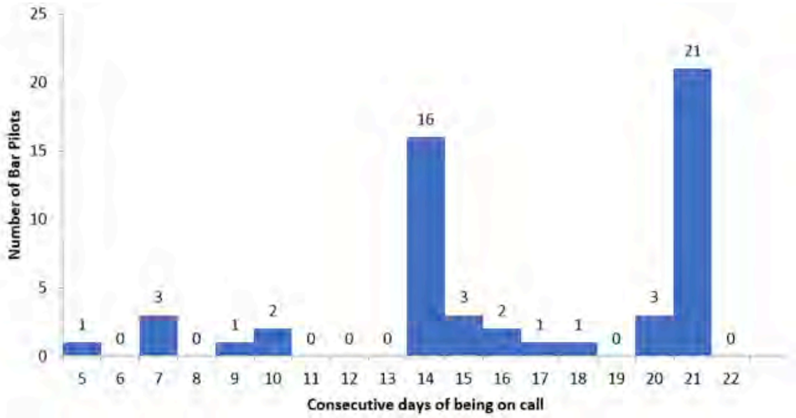

Figure 41. Distribution of responses on number of consecutive days worked while maintaining required alertness. N = 54/55.

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[9] This did not differ significantly by whether pilots worked a two-week or one-week on-call schedule. Although it was not significantly correlated with age, which was broken into only 4 categories, it was negatively correlated with the number of years the respondent had been a Bar Pilot, which was broken into 6 categories, r(51) = -.42, p <.01. In other words, those who had been a Bar Pilot longer, indicated fewer days they could work and maintain alertness.

5.8 Alertness

As would be expected, Bar Pilots on average described themselves as less sharp at the end of a 0200 to 1400 work period than at the beginning of a 1000 to 2200 work period, although there was wide variation (large error bars) as shown in Figure 42. The Bar Pilots were asked: "Please rate how mentally sharp (e.g., alertness, memory) you would typically be at the BEGINNING and END of the two work periods shown below, Work Period #1 and Work Period #2".

Figure 42. Alertness at the beginning and end of two different work periods. N = 52/56. Error bars = 95% CIs.

Bar Pilots were asked: "In your experience, which piloting tasks are most sensitive to the effects of fatigue?". A comment box was beneath this question, allowing the Bar Pilots to describe their answers in free text. These comments were then categorized and the frequency of Bar Pilots mentioning each category was noted. The categories with more than one respondent are shown in Figure 43, which is a histogram with the categories on the *y* axis and the number of Bar Pilots who mentioned the category on the *x* axis. As can be seen, the piloting tasks most frequently cited as sensitive to fatigue were docking, congested vessel traffic, long transits, and low visibility (fog). Docking often occurs at the end of a job when fatigue is likely to be greater (see Figure 41) and hence may be a critical period in terms of fatigue.

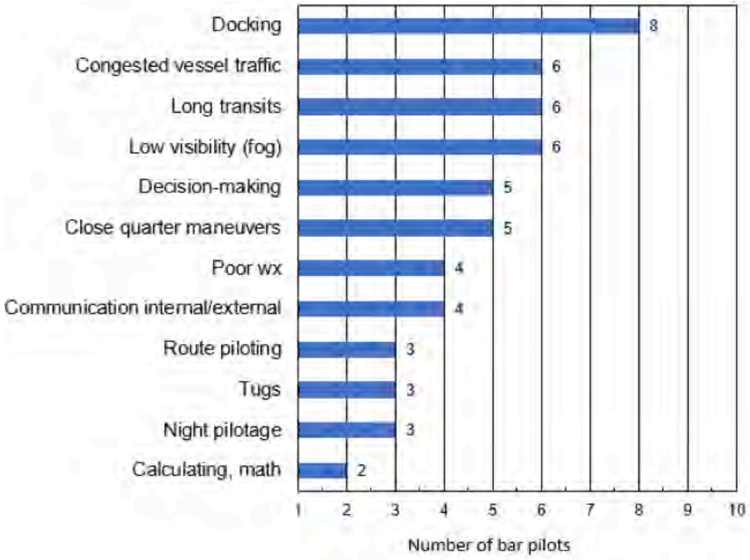

Figure 43. Piloting tasks most sensitive to fatigue by number of Bar Pilots who described them in free text. (Pilots sometimes described more than one category. Categories with two or more responses are shown.)

5.8.1 Fatigue and Incidents

Bar Pilots were asked: "Have you had any close calls or incidents in the last year?". Eight pilots (15%; 8/55) reported yes, 45 reported no, and 2 did not answer. The next question was "If yes, do you believe that your own fatigue contributed?". Of the 8 reporting yes, only 1 reported that he believed that his own fatigue contributed.

5.8.2 Overseas Travel

The request for proposals distributed by the BOPC specified that this study should consider the potential impact of trans-meridian travel on Bar Pilot fatigue. Bar Pilots were asked: "How disruptive to your sleep is the overseas travel required for the manned model training?". The overseas travel required for manned model training was considered moderately disruptive to Bar Pilots' sleep on average, as shown in Figure 44.

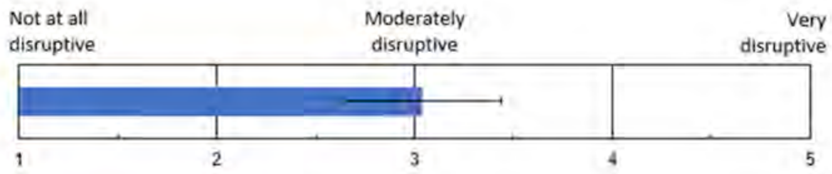

Figure 44. Disruptiveness of overseas travel to sleep. N = 53/55. Error bar = 95% CI.

Bar Pilots were asked: "To what extent is this disruption lessened by being able to sleep comfortably on the plane?". As shown in Figure 45, Bar Pilots considered that the disruption to sleep is lessened by being able to sleep comfortably on the plane.

Figure 45. Extent to which sleeping comfortably on overseas travel lessens disruption to sleep. N = 51/55. Error bar = 95% CI.

Airline seats in economy class generally recline around 5 degrees from vertical. In a laboratory study conducted for the Royal Air Force Institute of Aviation Medicine, Nicholson and Stone (1987) found a clear connection between seat recline angle and the quality and duration of sleep. A seat recline angle of around 40 degrees was necessary before restful sleep could be obtained. (See also Roach, Matthews, Naweed, Kontou, & Sargent, 2018.)

5.9 Job Satisfaction

On average, Bar Pilots are very satisfied with their jobs and rarely think of quitting, as shown in Figure 46. These questions were included because if respondents are strongly dissatisfied with their job, it tends to affect all aspects of their job and it becomes more difficult to distinguish problem areas.

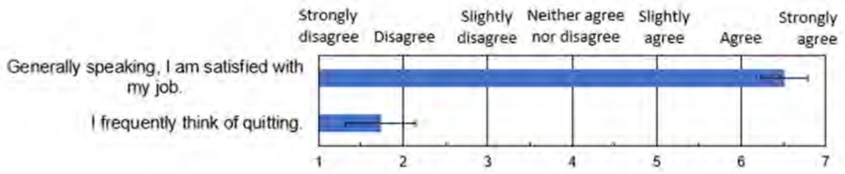

Figure 46. Bar Pilot ratings of job satisfaction. Ns = 55/55 and 53/55. Error bars = 95% CIs.

Although Bar Pilots are very satisfied with the type of work, they are less so with certain aspects of their schedules, as shown in Figure 47.

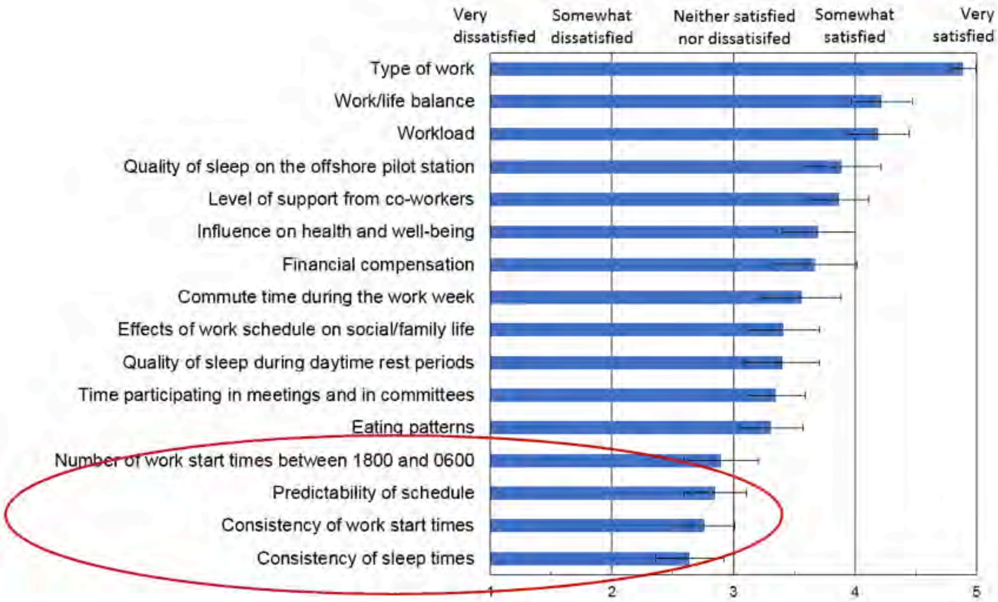

Figure 47. Satisfaction with different aspects of job. Ns = 51 to 55/55. Error bars = 95% CIs.

5.10 Time Off when Fatigued

Bar Pilots were asked: "How often, in the last year, have you tried to find a substitute because you were fatigued?". As Figure 48 shows, there were almost no times in the last year when Bar Pilots tried to find a substitute due to fatigue.

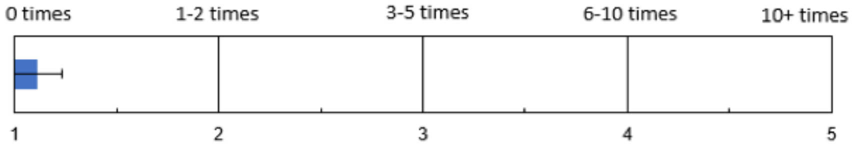

Figure 48. Average number of times Bar Pilots tried to find a substitute in the previous year due to fatigue. N = 55/55. Error bar is 95% CI.

The distribution of times Bar Pilots looked for a substitute is shown in Figure 49. The comments indicate that some pilots believe that there is a financial penalty if one can't find a substitute and one's name is removed from the board due to fatigue—even though there is no penalty for doing so. There may also be a norm that if one takes off work due to fatigue, one is "not doing their share."

This is understandable based on the need to work harder when there is a shortage of Bar Pilots. However, it is an unhelpful norm in the long run if it causes Bar Pilots to work when severely fatigued, as has been seen among maritime pilots in the UK (Shipley & Cook, 1980).

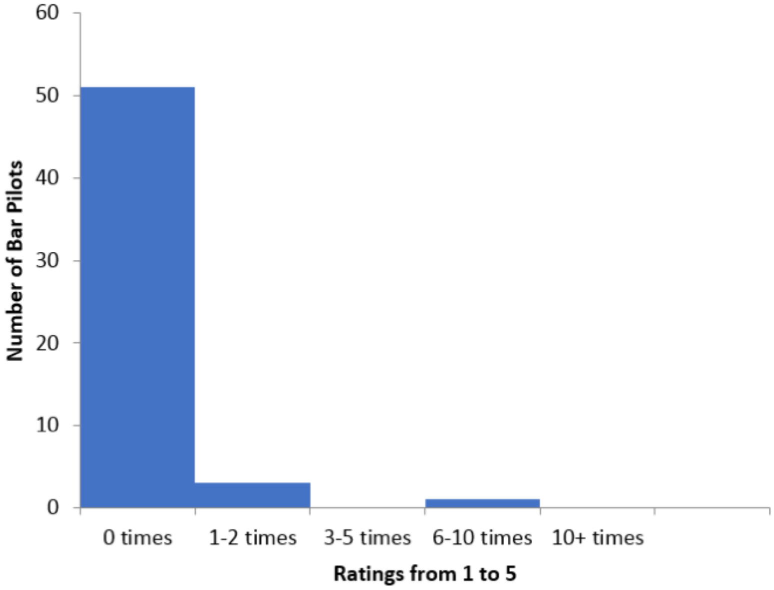

Figure 49. Distribution of times Bar Pilots tried to find a substitute in the previous year due to fatigue. N = 55/55.

5.11 Bar Pilots' Assessment of Fatigue Risk

In their survey responses, Bar Pilots indicated that fatigue occurs infrequently and rarely affects job performance, as shown in Figure 50. Bar Pilots were asked: "How often does the following occur?".

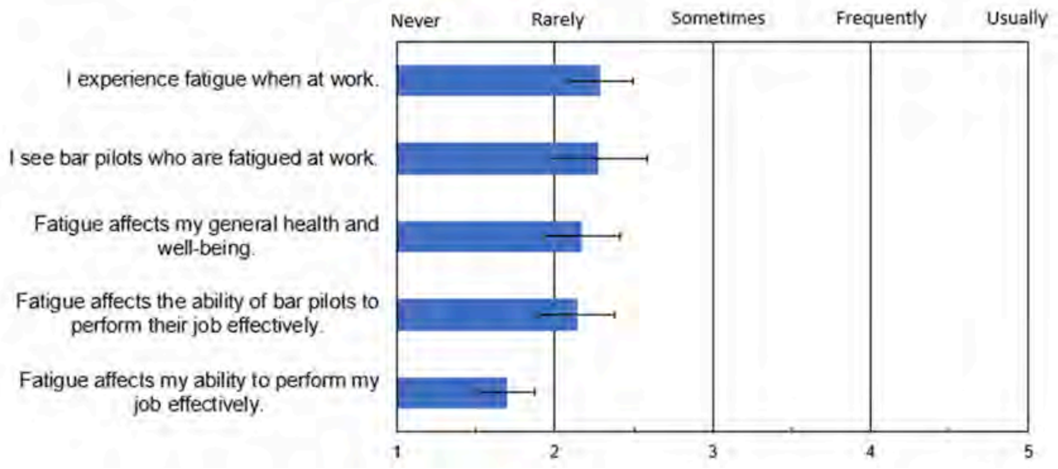

Figure 50. Ratings on fatigue and performance at work. Ns = 44-55/55. Error bars = 95% CIs.

These ratings can be compared to air traffic controllers' responses to the same questions, with "air traffic controllers" replacing "Bar Pilots" in the questions. As can be seen in Figure 51, Bar Pilot ratings are significantly lower than air traffic controller ratings (Orasanu et al., 2012, p. 101).

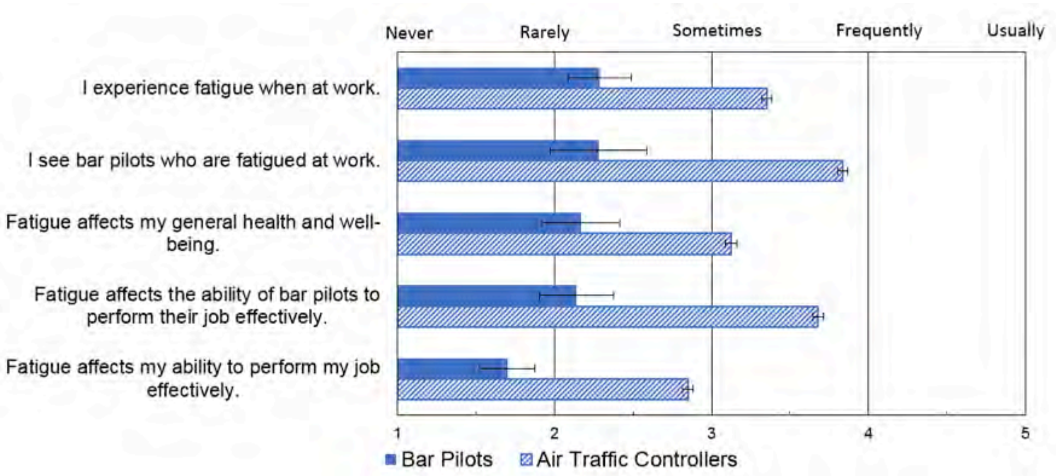

Figure 51. Bar Pilots' ratings on fatigue effects compared to ATC ratings. Ns = Bar Pilots, 44-55/55; Air Traffic Controllers 3168-3228/3268. Error bars = 95% CIs.

Bar Pilots were asked: "To what extent do you believe that the current level of fatigue experienced by Bar Pilots as a whole, represents a safety risk?". On average, Bar Pilots believe their current level of fatigue represents only a slight risk. Figure 52 shows their responses compared to air traffic controllers' responses to the same question, with "air traffic controllers" substituted for "Bar Pilots."

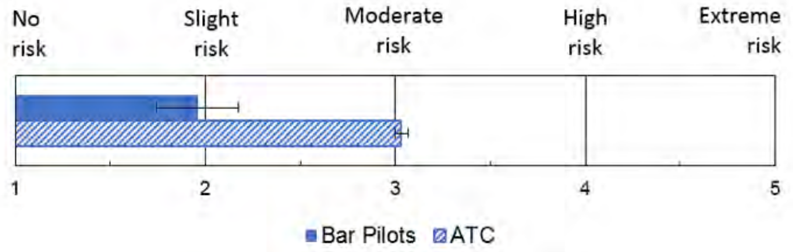

Figure 52. Bar Pilots' assessment of fatigue safety risk compared to Air Traffic Controllers'. N = Bar Pilots 49/55; ATC 2974/3218. Error bar = 95% CIs.

However, seven Bar Pilots thought the risk was moderate and two thought it was high, as shown in the histogram in Figure 53.

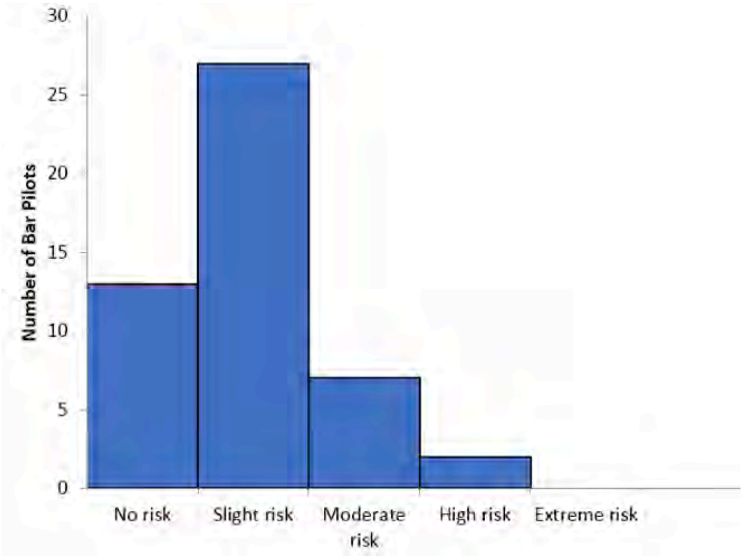

Figure 53. Distribution of ratings on safety risk of fatigue. N = 49/55

Most Bar Pilots' comments on fatigue safety risk referred to the fact that there have been no documented fatigue-related incidents or accidents in over 150 years. Others indicated that having fewer than 30 Bar Pilots on-call increased the safety risk.

5.12 Reducing Fatigue: What Could Help?

5.12.1 Suggestions for the Commission

Bar Pilots were asked: "What suggestions do you have on ways that the Bar Pilot Commission could reduce fatigue?". About half (26) of the Bar Pilots wrote responses to this question, the most frequent of which are described below.

One of the two most common suggestions (made by 10 pilots) was to reduce night pilotage. Five of these pilots suggested controlling the ships' arrival times, which currently peak between 0300 and 0400 for the Bar Pilots apparently for economic reasons associated with the operating hours of port labor (see Section 8.3). Bar Pilots recommended a variety of ways to control ships' early morning arrival times, either by charging higher fees at night (as is done in other ports) or by simply setting rules for when Bar Pilots would engage in piloting. Other rules could be, for example, limiting Bay Moves to one per night.

Another common theme (10 pilots) was increased schedule stability and predictability. Four pilots recommended mandatory 12-hour MRPs, describing the current MRPs as guidelines only.

Eight Bar Pilots felt that they could handle the scheduling to reduce fatigue—rather than having the Commission get involved—and four called for the Commission's support of the ongoing Fatigue Risk Management Program.

Other suggestions by two or more Bar Pilots were as follows:

- Increase stability by longer work hours.
- Schedule ships 12 hours ahead of time.
- Use current technology to enable more precise and consistent scheduling of ships.
- Implement 12-hour off times and 12-hour on times for consistent and predictable schedules. Day/night time blocks could be divided between those preferring to work during the day and those preferring to work at night.
- Give relief to pilots who have had several consecutive night shifts by giving them several days of "Bay Moves" as a "reset".

5.12.2 Suggestions to New Bar Pilots on How to Manage Fatigue

Bar Pilots were asked: "What advice would you give a new pilot on managing their fatigue?". Seventy percent (39/55) of the pilots wrote responses, the most frequent of which are described here[10].

- Thirty pilots suggested an attitude of making sleep a priority when on-call—two of these pilots suggested keeping a log of sleep and naps.
- Ten pilots suggested controlling the environment in such a way as to reduce sound and light to enable sleep. Specific measures included black-out curtains, ear plugs, white noise, "circadian rhythm friendly" (red) lights for hallways, family meetings to communicate the need for quiet during sleep periods, and audits (sound and light) for designated pilot rest areas. Comments indicated that it was more difficult to get sleep when children were around.
- Ten pilots recommended reducing all other activities when on-call except sleep and work.
- Six pilots recommended daily exercise to keep in shape and to induce sleep.
- Three pilots recommended eating well.
- Three pilots recommended eliminating caffeine.
- Two pilots recommended against taking any sleep medications.

Another suggestion was to live as close to work as affordable to reduce the commute time. However, it was noted that increasing housing costs meant that younger families needed to live further away. Not only was this seen as increasing commute time but also magnifying the negative effects of unpredictable schedule changes because if a pilot is already en route to work when a job is cancelled, they cannot easily return home to sleep.

5.12.3 Additional Training

Bar Pilots were asked: "Would you like more training or information on ways to reduce or manage fatigue?". Three answer options were given: "Yes," "Possibly," and "No."

Of the 52 who responded, 13% (7/52) checked "Yes," 44% (23/52) checked "Possibly," and 43% (23/52) checked "No." Therefore a total of 58% (30/52) of Bar Pilots expressed interest in additional training. Some Bar Pilots suggested that well-designed training materials could help them communicate the importance of their need to sleep to their families.

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[10] Bar Pilots could make multiple suggestions, so the total number of suggestions is greater than the number of respondents who answered the question.

5.13 March Follow-up Survey to Assess Seasonal Variation

A second brief follow-up survey was made available to Bar Pilots in March, 2018. It was designed to identify potential fatigue issues due to seasonal or weather variations. In San Francisco, when the first survey was administered in October 2017, the monthly precipitation was 0.31 inches and the average temperature 64°. In March 2018, the monthly precipitation was 4.75 inches and the average temperature was 55° (AccuWeather & US Weather, 2018).

Thirty-six (36/60 or 60%) of the Bar Pilots completed the follow-up survey in March (see Appendix 5 for survey)[11].

5.13.1 March Survey Fatigue Scales

As shown in Figure 54, there was no significant difference between the average Epworth Sleepiness scores in October 2017 and in March 2018. Both scores were in the low normal range.

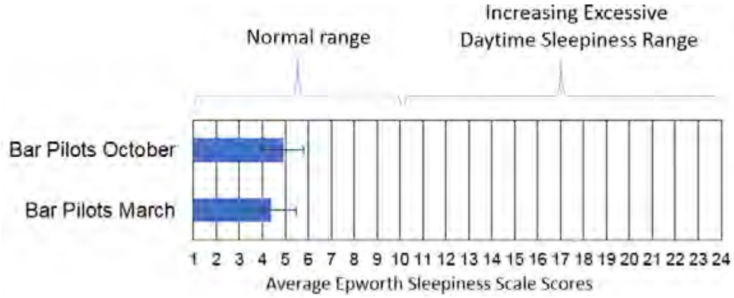

Figure 54. Average Epworth Sleepiness Scale scores in October 2017 and March 2018. Ns = 53-54/55 in October; 36/36 in March. Error bars are 95% CIs.

As shown in Figure 55, there were no significant differences on the average Modified Brief Fatigue Inventory in surveys taken in October 2017 and in March 2018. Both sets of scores were in the low range. Respondents were asked: "When you have recently been on-call, to what extent has fatigue interfered with your...".

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[11] Eleven respondents entered a code that matched a code they gave in the earlier survey. The purpose of this was to enable a comparison on the fatigue scale items within individual respondents (repeated measures analysis). However, given the small n, a more adequate representation of the Bar Pilot population is achieved by comparing group means which includes all respondents to both surveys.

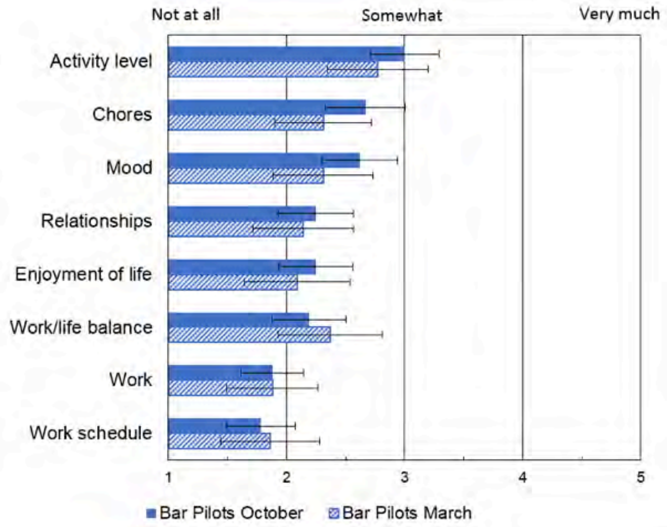

Figure 55. Average ratings on the Modified Brief Fatigue Inventory in October 2017 and March 2018. Ns = 46-53/55 in October; 34-5/36 in March. Error bars are 95% CIs.

As shown in Figure 56, there were no significant differences on the Shiftwork Disorder Scale in October 2017 and March 2018 and the scores were very low on each component of the scale. The final average Bar Pilot scores are both considered "Low Risk" for Shiftwork Disorder (see footnote 4).

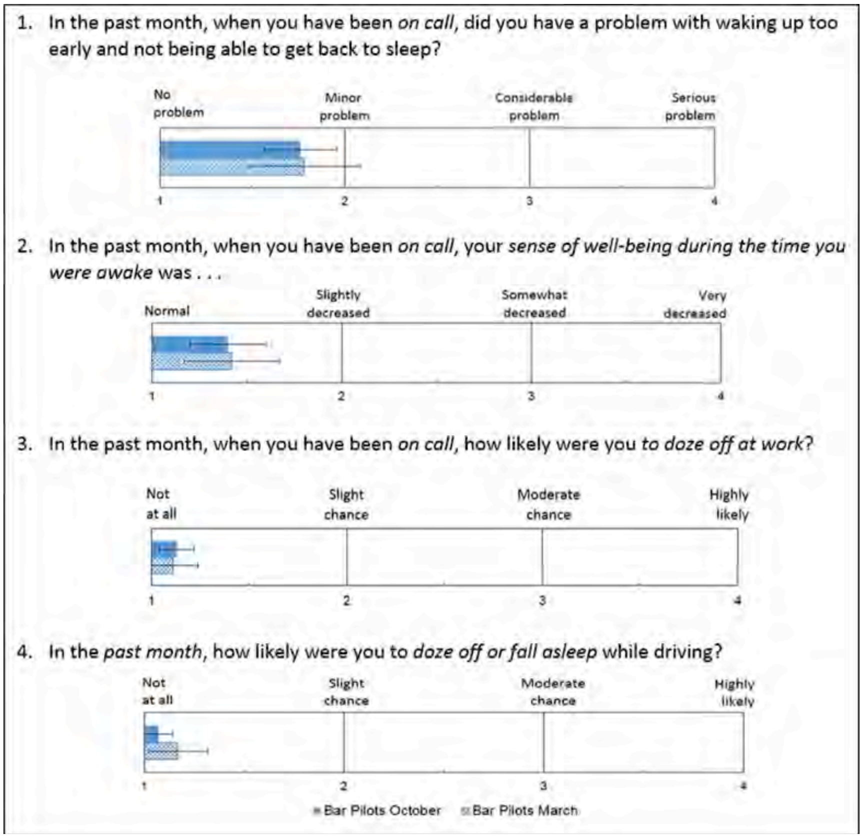

Figure 56. Mean Scores on the Shiftwork Disorder Scale in October 2017 and March 2018. Ns = 54-5/55 in October; 36/36 in March. Error bars are 95% CIs.

5.13.2 March Survey Free Text Questions

5.13.2.1 Seasonal Variation in Alertness

Bar Pilots were asked: “Please describe any seasonal variation in your work that affects your level of alertness when on-call”. Of the 36 pilots who responded to the March survey, 75% (27/36) responded to this question. Over half (55%; 15/27) of those who responded reported that there was no difference between seasons in terms of level of alertness. About a quarter of those who responded (26%; 7/27) noted that the bad weather in the winter (storms and fogs) was stressful and hence decreased alertness; one pilot said that the winter storms sometimes made it hard to sleep on the Offshore Pilot Station. Three pilots (11%; 3/27) noted that in the summer, due to the longer light, it was easier to work ships both earlier and later than in the winter. However, three pilots (11%; 3/27) reported that it was easier to sleep during the day in the winter than in the summer, which increased their alertness in the winter.

5.13.2.2 Sleep inertia

Sleep inertia had been identified as an issue in the first survey, therefore an open response question on sleep inertia was included in the follow-up survey. The Bar Pilots were asked: “If you experience any sleep inertia on-call, where and when is it most noticeable? e.g., after a nap or your main rest period, time of day, location, etc.?”. This question was prefaced by the statement “Sleep inertia is the period of fogginess or confusion that can be present immediately after one wakes up from sleep or from a nap”.

Of the 16 Bar Pilots who answered this question and described episodes of sleep inertia, 69% (11/16) stated that they experienced it after a nap. Five of these 11 specified a daytime nap. The rest of the Bar Pilots (5/16) stated that they experienced sleep inertia after a main sleep period. Two of these specified that the sleep inertia occurred after a main sleep period during the day. Therefore, seven of the 11 who experienced sleep inertia experienced it during the day, either after a nap or a main sleep.

5.14 Summary of Survey Results

- The response rate to the survey was excellent at 93%.
- More than half of the Bar Pilots are over 50 years of age.
- There was uncertainty about the Minimum Rest Periods (MRPs). Almost half of the respondents did not answer the question inquiring about how many MRPs they had in the previous year or replied that they did not know.
- It is possible that an individual may have more than one MRP exception during an on-call week.
- Comments indicate that the peak arrival times for ships beyond the bar at sea are between 0300 and 0400 apparently due to economic reasons associated with the operating hours of port labor.
- Bar Pilots report that they are the least rested when they start their work period between 2200 and 0400.
- Start times of both work and rest periods are seen as inconsistent.
- More than half of the Bar Pilots indicated that they have trouble sleeping when on-call due to inconsistent schedules.
- Schedules are also seen as having unpredictable start times 10 hours ahead of time. At that time, piloting schedules are seen as accurate less than half the time. Four hours ahead of time they are

"usually" accurate. According to comments, the lack of predictability 10 hours ahead of time makes it difficult to schedule sleep.

- The Bar Pilots report that the new rule requiring 8 hours advance notice of ship scheduling times (instead of 4 hours) between the hours of 1800 and 0600 has improved their ability to sleep.
- Bar Pilots describe themselves as more fatigued when on-call than off-call—but their reported fatigue on-call is only in the "moderate" range.
- The subjective fatigue scales are in the low-normal fatigue range and appear not to vary by season as indicated by the results of a second survey administered at a different season.
- Bar Pilots indicate that they take naps more than half the time when the opportunity arises, either at their normal on-call sleeping place or at the Offshore Pilot Station. They report that these naps leave them feeling "quite rested" at their normal on-call sleeping place and more than moderately rested at the Offshore Pilot Station.
- Sleep inertia ratings were low but seven Bar Pilots report duration of sleep inertia over 30 minutes.
- Overall, current scheduling practices are thought to be about right, although a few comments indicate differences of opinion on some aspects of the new rules introduced in 2016. These rules include an 8-hour limit on time worked without an opportunity to rest between the hours of 0000 and 0600. The described downside to this new rule is that it increases the speed of rotation of the board and hence decreases the time off between work periods.
- About 24% (13/55) of the Bar Pilots feel that the current staffing level could be increased to support their optimal alertness. Those who were over 50 years of age were more likely to think this. No Bar Pilot thought that there were too many Bar Pilots.
- Comments indicate that not enough pilots are always available due to other duties, such as committee meetings, training, faster rotation of the board, or pilots not fit for duty (NFFD).
- More than one third of the respondents feel they could work 3 weeks in a row while maintaining the alertness required for their job. Bar Pilots who have been a Bar Pilot longer indicated they could work fewer consecutive days while maintaining required alertness.
- Among the most stressful activities cited was piloting a 1200-foot vessel in winds.
- Docking was thought by the highest number of pilots to be most affected by fatigue.
- Bar Pilots are very satisfied with their job and rarely think of quitting, though they are less satisfied with certain aspects of their schedules, such as the number of work start times between 1800 and 0600, the predictability of their schedule, and the consistency of their sleep times.
- Bar Pilots rarely make an attempt to find a substitute when they are fatigued. Comments indicate that doing so may go against a norm of "doing their share." Comments also indicate that some Bar Pilots may incorrectly believe that there is a financial penalty if they cannot find a substitute and are removed from the Board.
- Bar Pilots report that they do not frequently experience fatigue when at work and that it rarely affects job performance. Bar Pilot fatigue is seen as only a slight safety risk, although seven Bar Pilots thought the risk was moderate and two thought it was high.
- When asked what the Bar Pilot Commission could do to reduce fatigue, the two most common themes that emerged were: (1) reduce night pilotage through rules or higher fees; and (2) increase schedule stability and predictability through a variety of measures.

- When asked what advice they would give a new Bar Pilot to manage fatigue, about half suggested an attitude of making sleep a priority. The next highest was to control the environment in ways to enable sleep.
- More than half the Bar Pilots expressed some interest in additional training on ways to reduce or manage fatigue.

6. Analysis of Dispatch Records

6.1 Introduction to the Analysis of Dispatch Records

The goal of this phase of the study was to identify characteristics of the irregular 24/7 schedules worked by the Bar Pilots that could increase the likelihood of fatigue[12]. The scheduling factors considered were based on those identified by Rosekind (2005) as shown in Table 2. There were two analysis activities undertaken to better understand the characteristics of the Bar Pilot work scheduling practices: (1) analyzing scheduling patterns for both work and off-duty period durations with time of day considerations; and (2) utilizing a commercially available fatigue modeling software package to determine predicted levels of performance relative to input work schedules.

Table 2. Scheduling Factors Considered in the Present Phase of the Study

Work Scheduling	*Fatigue Risks*	*Fatigue Management*
1. Length of work period	Long hours awake and time on task lead to increased risks	Limits hours awake and time on task
2. Length/timing of time off between work periods	Inadequate or poor sleep leading to acute sleep loss	Provide adequate sleep opportunity
3. Night work/time of day	Window of circadian low and early morning starts related to increased sleepiness and reduced performance	Limitations on time working when physiological alertness reduced
4. Consecutive days/nights working	Accumulated effects of operational demands and short-term chronic sleep loss	Limit cumulative effects of work and sleep loss
5. Work period start time variability	Disruption of circadian rhythms	Stability in daytime work timing allows circadian clock to stay in sync
6. Recovery periods between work cycles	Long-term chronic sleep restriction	Provide adequate nighttime recovery sleep opportunities

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[12] The analysis of Bar Pilot dispatch records received ethics approval #F16119 from the Human Subjects Institutional Review Board of San Jose State University. To provide additional legal protection of the data, Certificate of Confidentiality # CC-HL-17-033 was issued by the National Heart, Lung, and Blood Institute.

6.2 Data

Scheduling data were obtained from Bar Pilot dispatch records. A total of 7005 work periods (i.e., shifts) of 61 Bar Pilots from July 2016 to June 2017 were included in the current analysis. Each work period involved a pilot boarding at least one vessel. Work that occurred entirely on shore, such as that of operations pilots or the Port Agent, were excluded from the analysis. Information provided included “ride” and “bottom of the board (BoB)” times for every work period (used to define start and end of work periods), “board” and “off time” for every job within each work period, along with the to and from locations for each job.

6.3 General Findings

All sampled work periods were inspected to identify patterns in the pilots’ schedules. It was apparent that some individual pilots became available for piloting assignments part way through the year or ceased working as a pilot before the year was over. Those pilots who were available for assignments regularly throughout the 12 months in question worked an average of 128 work periods, with a range of between 78 and 162 work periods. As can be seen in Figure 57, there was some variation across the year in the number of total monthly work periods (average of 584) with the most in January, May, August, and December and the fewest in February. Overall, there were about 20 work periods on an average day.

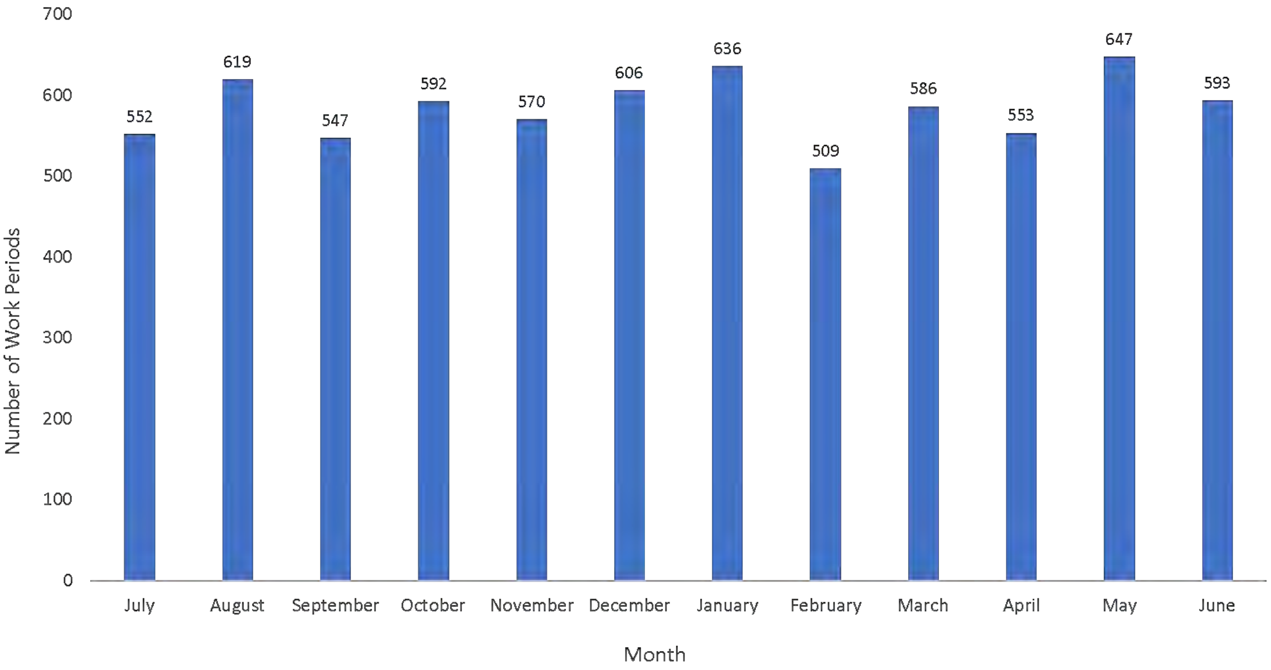

Figure 57. Total pilot work periods by month.

6.3.1 Description of Work Periods

Figure 58 illustrates the timing of work period start (ride) and end (BoB) times. We found that 0200 was the most common hour pilots started work, followed by 0300 and 0400. The most common hour for the end of work periods was 0700.

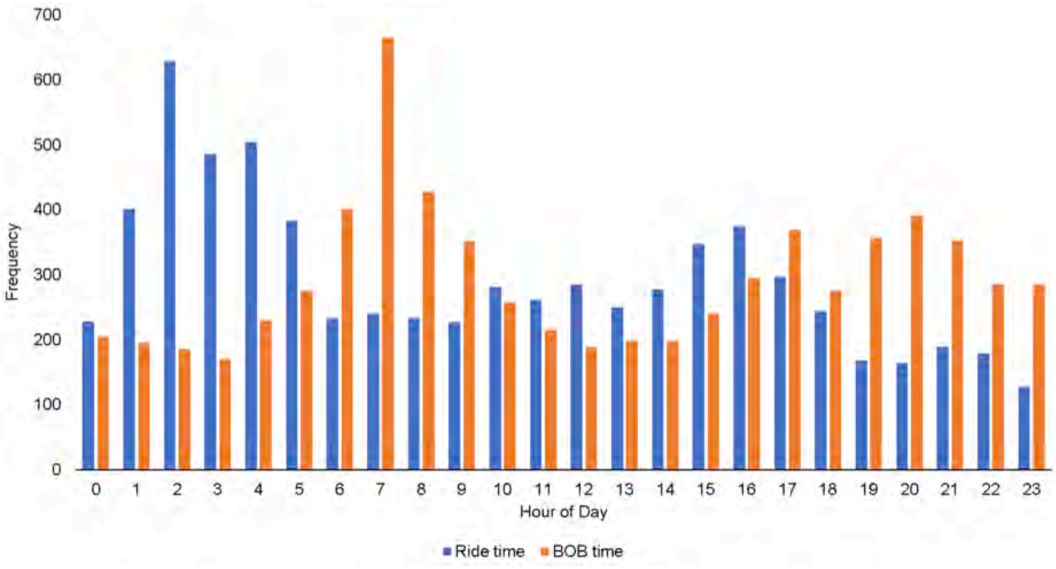

Figure 58 Work period start/end timing by hour of day.

Overall, the average work period from ride time to BoB time (see Figure 59) was 7.6 hours in duration. About 5% of the work periods were longer than 12 hours. Note that 10-hour held time periods related to certain river operations were not included in these calculations.

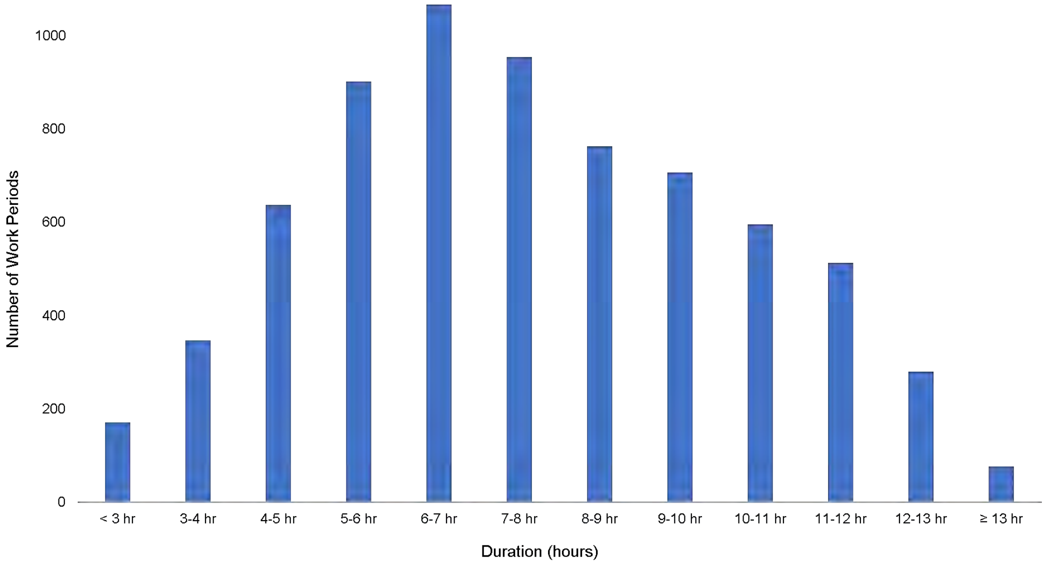

Figure 59. Duration of work periods. Shifts were defined here as ride time to BoB time. 10-hour 'held time' periods were not included in calculations[13]*.*

Figure 60 illustrates the average work period duration based on start time (hour of day). Work period duration was found to be shortest during night hours (i.e., between 2100 and 0400). Work periods starting between 0100 and 0500 had an average work duration of approximately 6.5 hours, while work periods starting between 0600 and 1000 had an average work duration of approximately 9 hours. Pilots typically had 2 piloting job assignments during a given work period (i.e., 61% of all work periods examined involved 2 jobs). The first job averaged 3.3 hours and the second job

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[13] For plots with time bins, the count for each bin includes the lower bound and not the upper.

averaged 2.5 hours in duration. Work periods with 3 or 4 jobs accounted for only about 4% of the total work periods.

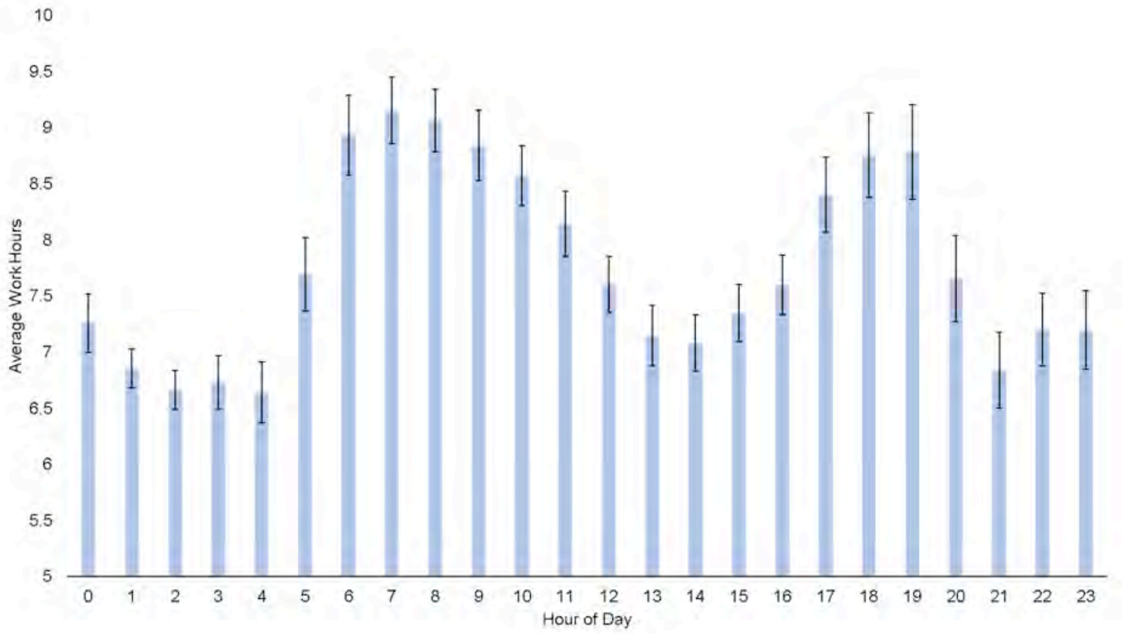

Figure 60. Duration of work periods by start hour. The error bars depict 95% confidence intervals.

Pilots were found to work on average approximately 35 hours per week with a maximum recorded work week of 75.1 hours. Pilots worked 50 hours or more in a week about 8% of the time. We also examined night shift hours (defined as a work period with 1 or more hours during 0000–0600) and found that pilots worked an average of approximately 19 hours at night per week with a maximum of 67.4 hours.

Pilots most commonly worked 2–4 days in a row before receiving a break of 24 hours or longer. The maximum number of consecutive days worked without such a break was 10 days. An example of work period timing during a 7-day work week is shown in Figure 61.

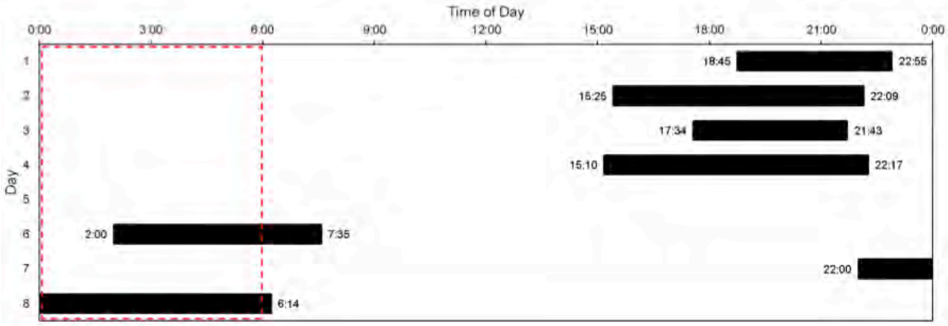

Figure 61. Example of work periods during 7-day work week. Black bars indicate work periods with ride times shown to the left of each bar and BoB times shown to the right. This pilot worked 6 times during this period, the first on Wednesday evening from 1845–2255. The final shift started at 2200 Tuesday night and ended at 0614 Wednesday morning. The pilot then was off the board at noon. The 0000–0600 period is highlighted by the dashed line.

6.3.2 Description of Off-Duty Rest Periods

We looked into the number of hours off duty between consecutive work days (see Figure 62). Predominantly, pilots had between 18–20 hours off duty between consecutive working days (based on start time). Pilots received less than 12 hours off only 3% of the time and 24 hours or more off duty 21% of the time.

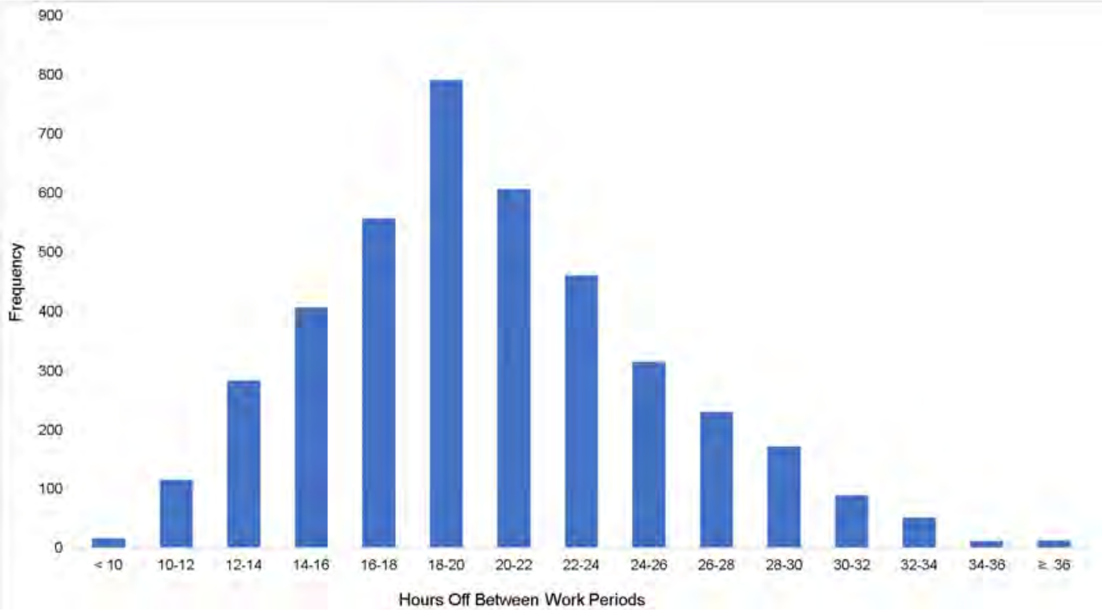

Figure 62. Hours off-duty between consecutive work days.

We also conducted a closer examination of minimum rest period (MRP) exceptions consistent with those reported to the BOPC under Title 7, Division 2, Section 237(d) of the California Code of Regulations. From the dispatch records, we identified 132 instances where there was less than 12 hours between work periods (M = 10.9 hours). Most pilots had at least one MRP exception during the period we studied. These results are summarized in Figure 63. Our findings are consistent with those reported by the survey respondents (albeit for a different time period).

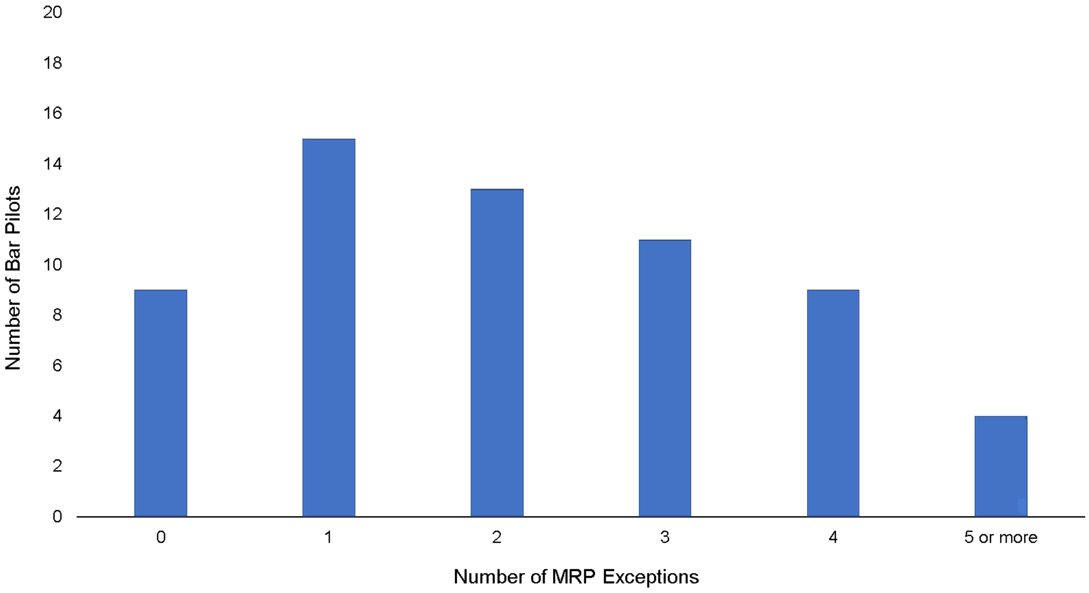

Figure 63. Frequency of MRP exceptions for individual pilots.

Not surprisingly, the board was turning faster than the 20-pilot average on days with MRP exceptions, averaging 23 pilot assignments on those days, with a maximum of 33. A further analysis of these exceptions determined that about 13% were less than 10 hours. About a quarter (24%) of the MRP exceptions spanned the hours 0000-0600 in which a nighttime sleep opportunity could be realized with most (77%) including some time in that timeframe (average of 3.3 night hours overall). More than half (57%) of the work periods following an MRP exception were classified as night work (at least an hour between 0000 and 0600), with about 8% including a full night of work. Some of the MRP exceptions occurred prior to the final work period of a week (22%) but for those cases in which a subsequent work period occurred, the following rest period averaged 25.6 hours in duration with about 11% of those being less than 16 hours.

Data from the Section 237(d) reports were further analyzed to estimate the average number of pilots on the board each day throughout the last ten years. The reports contained data on the number of pilots available for work on days on which an MRP exception occurred. With a potential total of 60 Bar Pilots, it was assumed that no more than 30 could be on watch on a given day. For each day that data were available, we estimated the number of pilots on the board by subtracting from 30 the operations pilot and the number of pilots pulled from the roster that day due to Not-Fit-For-Duty (NFFD), training, vacation, etc. On most days all 60 licensed pilot positions were not filled, so we also subtracted half of the number by which the roster fell short of 60, assuming that the shortfall was equally shared across alternate weeks. Finally, we subtracted 0.5 to account for the Port Agent. The formula was as follows:

$$\textit{Estimated N of pilots on the board} = 30 - 1 - P - \left({}^{R}/_{2}\right) - 0.5$$

Where: P = Number of pilots pulled on that day due to NFFD, training, vacation, etc.
R = Roster short, the number of licensed pilot positions not filled on that day.

By applying this method, we estimated that on a typical day on which an MRP exception occurred, there were around 23 pilots on the board (Figure 64). This does not include pilots who may have been called in from their off-watch period to assist. As the data were for days on which an MRP exception occurred (an average of 60 days/year over the period analyzed), this result may reflect an above average number of pilots pulled from the roster on those days (P in the formula above). Repeating the calculation above, but assuming that no pilots are ever pulled from the roster, produces an average of 26 pilots on the board at any one time. In conclusion, although up to 60 pilots can be licensed by the BOPC, the full complement of Bar Pilots will not necessarily be available on a given day.

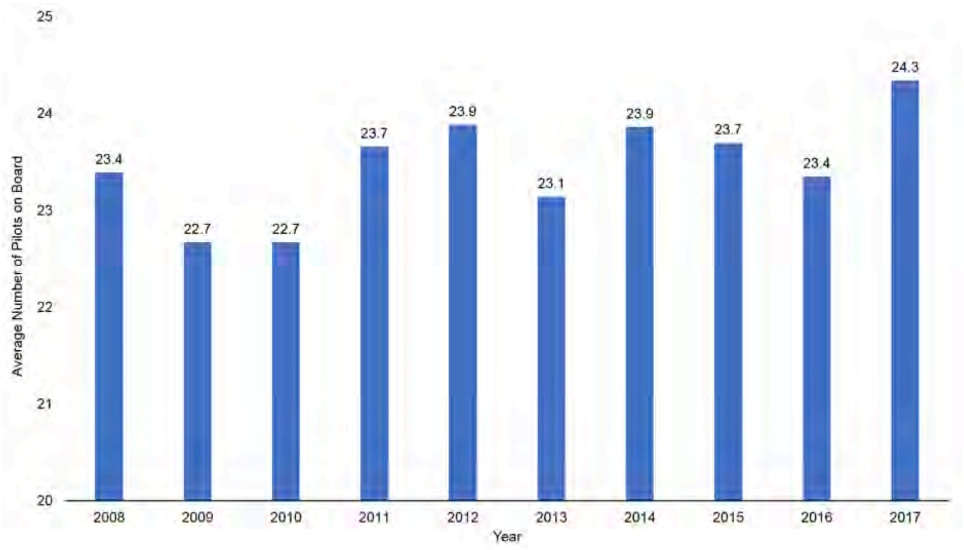

Figure 64. Estimated number of pilots on the board on days when an MRP occurred. (Data from 237(d) reports).

6.3.3 Board Operations

While we lacked information on which work group each pilot was in (i.e., Group 1, 2, or 3), based on our analysis of the dispatch records and on/off week scheduling information in a provided *2016 Tides & Currents* booklet, we were able to determine that a few pilots consistently worked during a given schedule week. Work data were sampled over 10-week periods for two of those pilots ("Pilot A" and "Pilot B") from different weekly work groups to provide an insight into how the board operated during a week. We counted the number of pilots who were called to work in the time it took Pilot A or B to complete a full cycle of the board, from ride time to ride time. These results are presented in Figure 65. It can be seen, for example, that during his first week on-call, Pilot A completed three full cycles of the board from ride to ride. The three data points shown for week 1 indicate that Pilot A's work period was the 22nd, 24th, and 28th period worked by a pilot during those turns of the board. We consider that these numbers provide a rough approximation of the number of pilots who were available for work during each week.

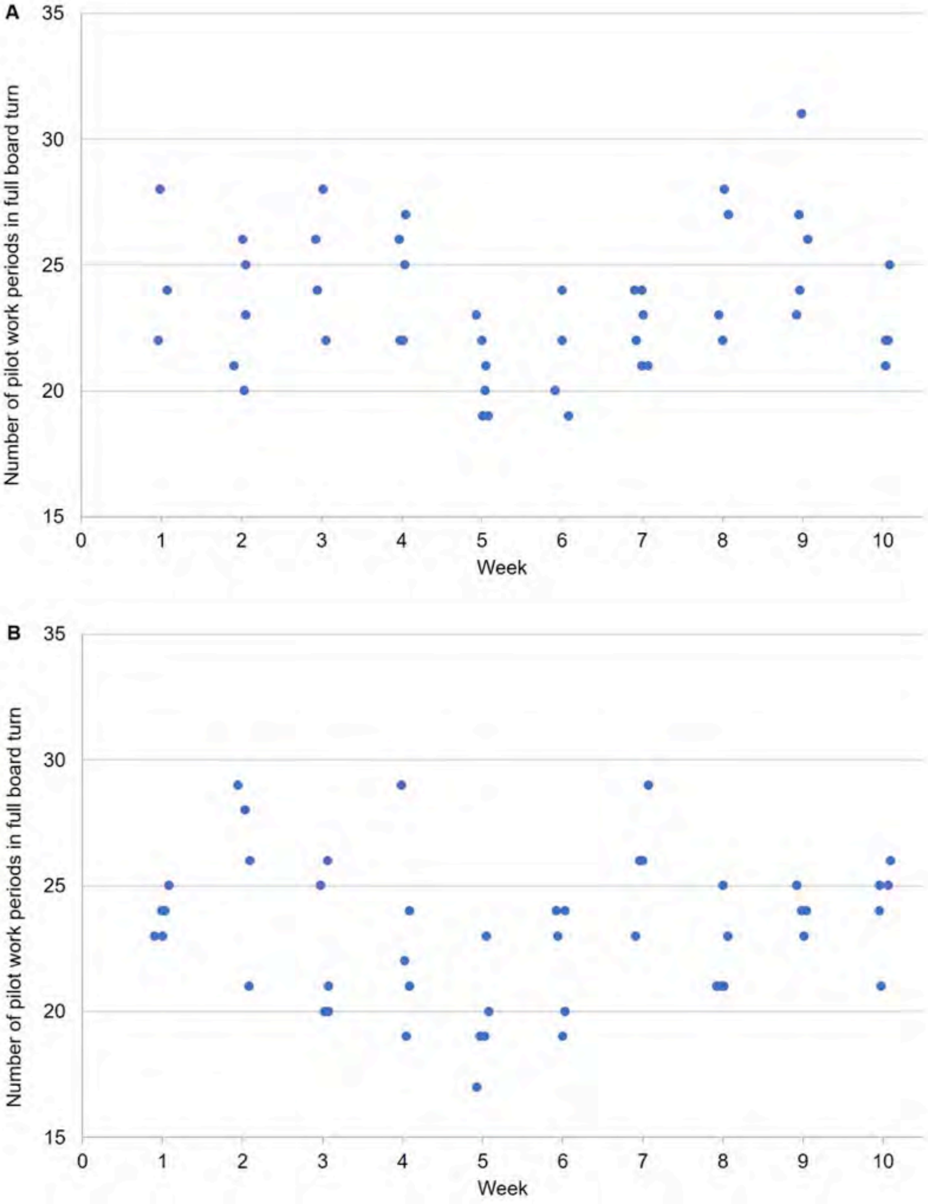

Figure 65. *Example board operations over 10 sampled weeks for two pilots (A and B) who belonged to different work groups. The values represent the number of pilot assignments that occurred during a full turn of the board in the given week.*

The number of individual pilot work periods within a full turn of the board was similar in both sampled cases. On average, when Pilot A's name returned to the top of the board he was pilot number 23.4 in that turn of the board. For Pilot B the average was 23.2. If we assume that this is an approximation of the average number of names on the board, then this is in line with our prior estimate of pilots on the board during MRP exceptions. There was notable variation in the number of work periods it took the two sample pilots to achieve a full turn of the board. This variation occurred even within a work week.

These variations in the turning of the board are further reflected by changes in start times for consecutive work periods (Figure 66). We found that most consecutive duties (72%) started at the same or at a later hour from the previous work start time. Additionally, we found that about a third of consecutive duties (34%) started within a 3-hour period (+/-) of the previous work start time. For the period studied, a start time that ‘flipped’ the clock (i.e., work start time was more than +/-10 hours than the previous start time) occurred about 8% of the time.

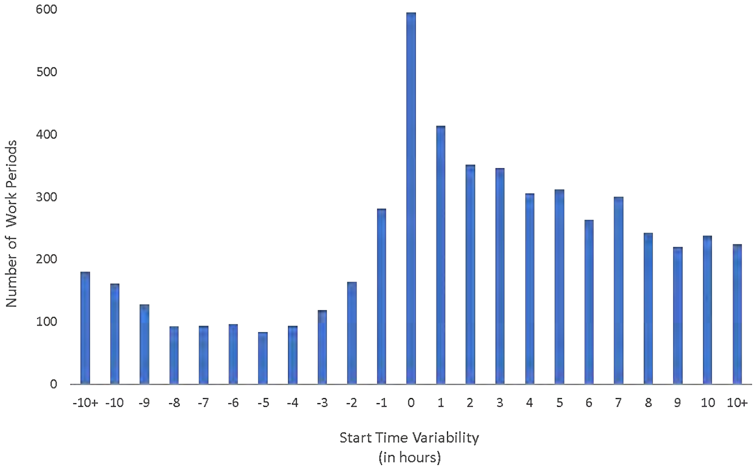

Figure 66. Changes in start hour for consecutive work periods.

Conscious that ship arrivals and departures largely dictate the timing of piloting activity and the rate at which the board turns, we looked into the timing of arrival (from sea) and departure assignments (to sea). Figure 67 displays the ride times and boarding times for ships arriving from sea. We found that the most frequent ride times and boarding times were at 0300 and 0400 hours, while the least frequent ride times and boarding times were at 0000 hours.

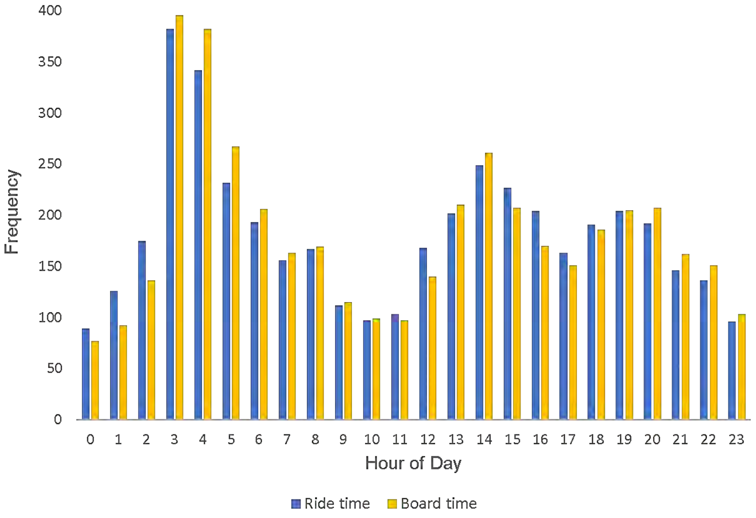

Figure 67. Arrivals from sea by time of day.

Figure 68 illustrates the ride times and boarding times for ships departing to sea[14]. We found that the most frequent ride times and boarding times were between 1500–1700 and 0200–0300. The least frequent rides times and boarding times were between 0600–1300 and 2000–2300. As can be seen, ride and board times show a similar pattern, reflecting the relatively short travel time to reach a ship in the bay.

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[14] Note: “Light” assignments were not included in these calculations.

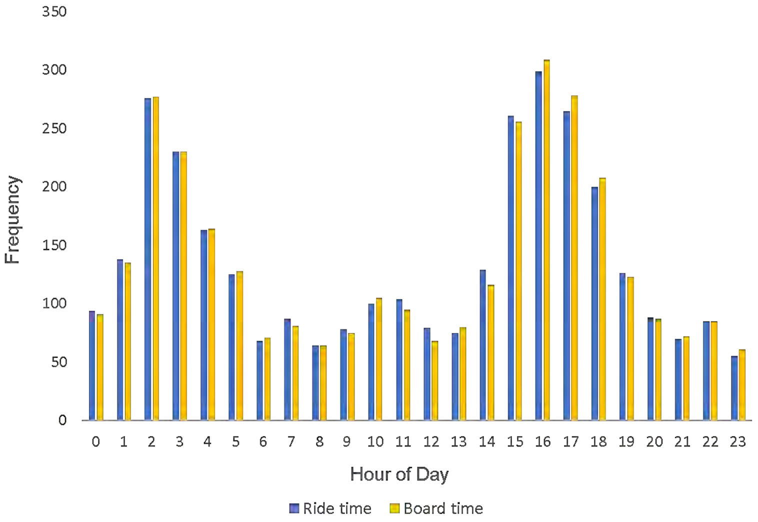

Figure 68. Departures to sea by time of day.

6.4 Application of Fatigue Modeling Software

In order to further assess fatigue risk, the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model was utilized through the Fatigue Avoidance Scheduling Tool (FAST) software package (Hursh, Balkin, Miller, & Eddy, 2004). Originally developed for the Department of Defense, the SAFTE-FAST model provides estimates of performance based on recent work and sleep history. The model generates a primary output metric of "cognitive effectiveness" (referred to as an effectiveness score), which is described as a measure corresponding to performance speed and errors, vigilance, and the probability of lapses (Institutes of Behavior Resources, 2009). A general interpretation of effectiveness scores, according to the program's documentation, is presented in Table 3.

Table 3. Description of SAFTE-FAST Effectiveness Scores

Effectiveness Score	*Interpretation*
Above 90	Range of performance during normal daytime duty following 8-hours of excellent nighttime sleep
65–90	Range of performance during 24-hour period after missing 1 night of sleep
Below 65	Performance following sleep deprivation of two full days and a night; performance that is below level acceptable for operations

Source: Institutes of Behavior Resources (2009).

The SAFTE-FAST model allows for both work and sleep schedules to be entered into the simulation and is widely used by the Federal Aviation Administration (FAA) to assess airline pilots' work schedules (Hursh, 2011). The goal of this modeling activity was to identify characteristics of the irregular 24/7 work schedules of the Bar Pilots that could lead to predicted periods of increased fatigue.

6.4.1 SAFTE-FAST Model Specifications

The SAFTE-FAST model was run using a Dell desktop computer operating on Windows 7. As actual sleep data were not available for the pilots during the analyzed period, the model generated estimated sleep patterns utilizing its AutoSleep feature. This function allows for sleep periods to be simulated based on the model's programmed algorithms. These algorithms take into account expected bedtimes, commute time, allowable minimum and maximum daily sleep durations, and a "forbidden zone," which is a daily period when an individual would not be able to sleep based on the established literature related to human sleep/wake physiology (Lavie, 1986).

For modeling purposes, work periods were determined using the "board time" of the first job (i.e., boarding a ship) as the start time and the "off time" of the last job (i.e., end of ship assignment) as the end of work. Ride time and bottom of the board (BoB) time were not used to define work periods for this analysis, because SAFTE-FAST already includes an estimated commute time at the start and finish of the work day.

6.4.2 Data Analysis

For the purposes of our SAFTE-FAST analysis, we set normal bedtime to 2300 with daily minimum and maximum sleep durations of 1 hour and 9 hours, respectively. Based on results from the fatigue factors survey completed by the Bar Pilots (i.e., the average transit time to and from work was reported as approximately 41 minutes), we set the commute time at 1.5 hours to allow time for wake up and getting ready for work, in addition to transit time to the work period start location. This setting also applied to commute time at the end of the work period. We set the daily "forbidden zone," or "no sleep," setting from 1800 to 2100 to reflect a time when pilots would prioritize waking activities such as meals and family activities. All summary statistics and other analyses were produced using Microsoft Excel and R Studio (version 1.0.136) for Windows.

All 7005 work periods from the 61 Bar Pilots listed in the dispatch records were inputted into SAFTE-FAST. Using the abovementioned model settings, the predicted effectiveness levels, as well as the estimated sleep periods, were generated on a continuous timeline for each individual pilot from the start to the end of the provided dispatch records (i.e., July 2016 to June 2017). Figure 69 provides an example of the output from the model with effectiveness predictions and estimated sleep periods for an individual pilot on a given 7-day on-call period and Figure 70 presents a case for an individual pilot on a given 14-day on-call period.

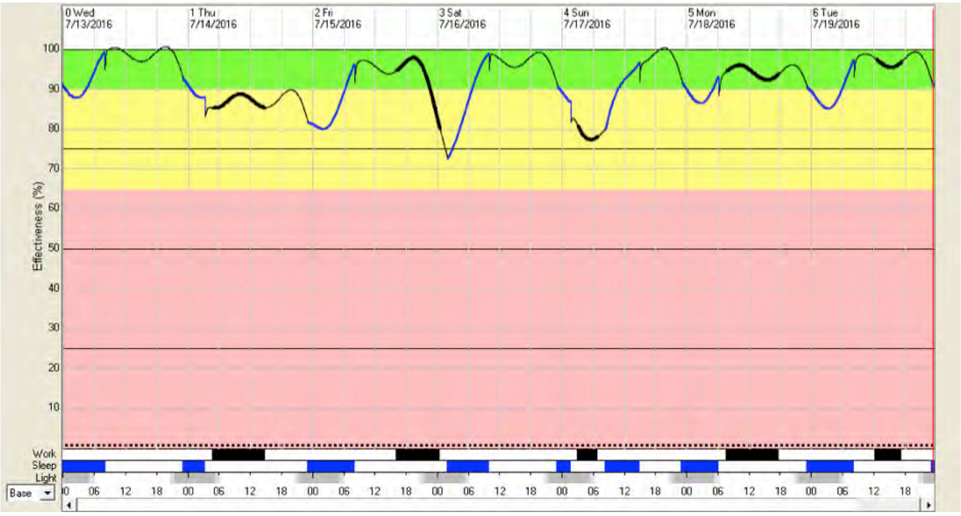

Figure 69. Example SAFTE-FAST output for 7-day on-call work period. For this figure, time goes from left to right, with the dates for the period presented at the top. The predicted effectiveness level is shown by the continuous line (scale on left). At the bottom of the figure, can be seen three lines of bars representing work periods, sleep periods, and daylight periods, which accounts for location and date.

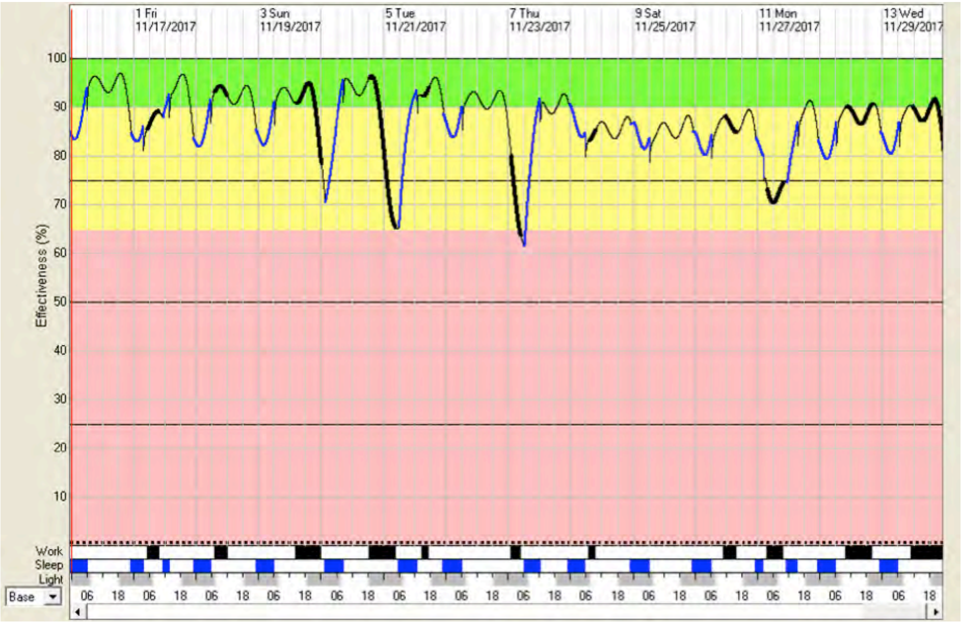

Figure 70. Example SAFTE-FAST output of 14-day work schedule. For this figure, time goes from left to right, with the dates for each work period presented at the top. The predicted effectiveness level is shown by the continuous line (scale on left). At the bottom of the figure can be seen three lines of bars representing work periods, sleep periods, and daylight periods, which accounts for location and date.

6.4.3 Overall SAFTE-FAST Results

The average effectiveness score was generated by the model for every work period. About half of the work periods had an average effectiveness score of 90 or higher, while approximately a quarter of the shifts had effectiveness score of 80 or less. These results are summarized in Table 4.

Table 4. Binned Effectiveness Scores

Effectiveness Score Bin	*Frequency*	*%*
Above 90	3608	52
80–90	1794	26
70–80	1578	23
Below 70	25	<1

Note: n = 7005.

Based on work period start time (time of boarding the first vessel), the predicted effectiveness scores were lowest during the night hours between 0000 and 0400. Daytime shifts starting between 0800 and 1800 consistently showed average effectiveness scores above 90. Figure 71 provides an illustration of these results across the hours of the day. These results are quite similar to self-report ratings of feeling rested by work period start hour from survey respondents.

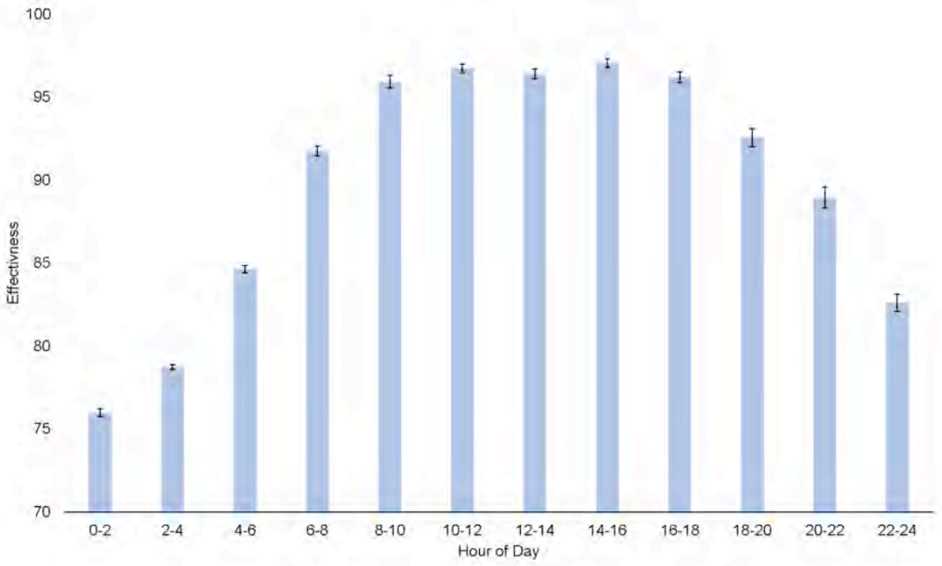

Figure 71. Predicted effectiveness score based on start hours by time of day. The error bars display 95% confidence intervals.

We also examined the effect of the end hours of the work periods on predicted effectiveness scores. Predicted effectiveness was lowest for shifts that ended during the early morning hours (i.e., between 0500 and 0900) with shifts ending at 0700 producing the lowest effectiveness scores. This is consistent with the findings of Boudreau, Lafrance, and Boivin (2018) in their study of St. Lawrence River pilots. These findings also appear to coincide with the results related to start time. In regards to the effects of start time variability, we found that predicted effectiveness scores were higher when pilots experienced a phase delay compared to when pilots experienced a phase advance[15] (M = 91.5 vs. 85.7).

6.4.4 Consecutive Night Shifts and Opportunities for Night Sleep

For further descriptive analysis we also inspected the effectiveness scores over the course of each pilot's on-call work weeks. Specifically, we examined how the types of consecutive duties influenced a pilot's predicted effectiveness. In the manner of previous research, consecutive duties were classified using an off-duty time of up to 36 hours between shifts (i.e., if pilots had less than 36 hours off then the subsequent shift was considered a consecutive one).

In general, pilots who worked consecutive night shifts tended to have lower effectiveness scores than those who had consecutive work periods that allowed for night sleep opportunities (M = 82.0 vs 95.2 respectively). The lowest overall predicted effectiveness scores were associated with working eight consecutive night shifts (M = 78.4). Figure 72 illustrates the predicted effectiveness scores for consecutive night shifts, as well as shifts that allowed pilots to obtain predicted sleep during the night.

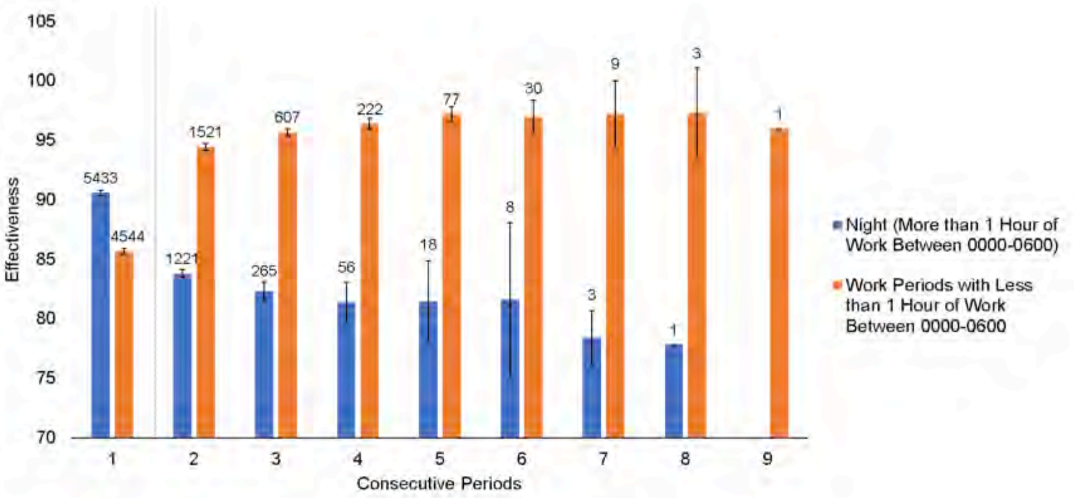

Figure 72. Predicted effectiveness score during consecutive night shifts and consecutive work periods allowing for night sleep opportunities. The error bars illustrate 95% confidence intervals. Note that a consecutive work period value of "1" on the horizontal axis indicates that this was the first work period in a series and a value of "2" indicates the second of two consecutive work periods, etc.. The data labels above the error bars display group sample sizes.

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[15] Phase delay refers to work periods starting at a later time than the previous work period, while phase advance refers to work periods starting at an earlier time than the previous work period.

Figure 73 shows the number of consecutive night shifts worked by Bar Pilots during the period July 2016–June 2017 (horizontal axis) and the number of times each pattern of consecutive shifts occurred during the year (vertical axis). The graph illustrates that whereas most night shifts were followed by a break of 36 hours or more (3772 occasions), on 870 occasions pilots worked two night-shifts before receiving a break of 36 hours or more. However, as a result of chance and the rotation of the board, a small number of pilots were assigned more than three consecutive night shifts without a break. On two occasions, a pilot was assigned seven night-shifts in a row. One pilot received eight night-shifts in a row without a break. The distribution of consecutive night shifts is similar to a Poisson distribution.

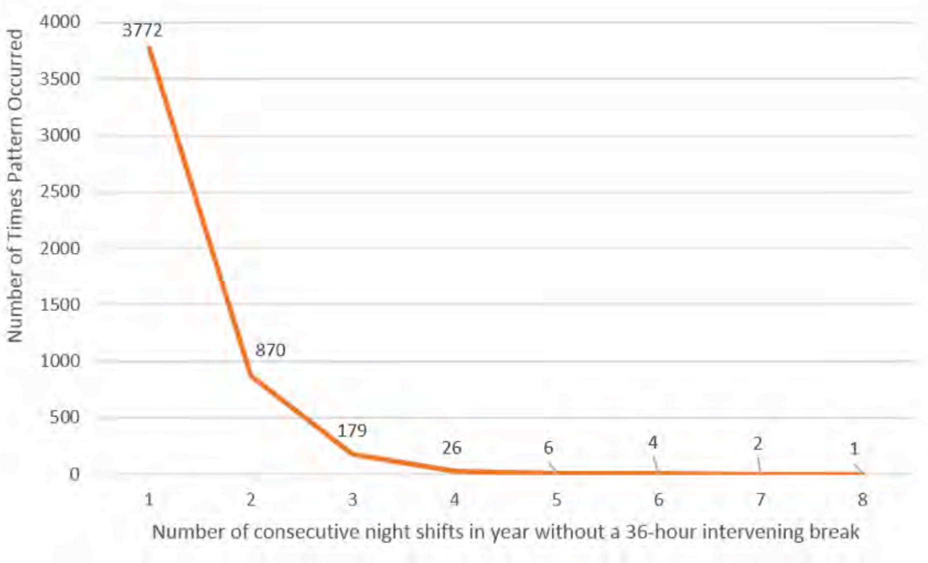

Figure 73. The distribution of consecutive night shifts without an intervening break of at least 36 hours.

6.4.5 Fatigue Factors Regression

To investigate the impact of cumulative sleep loss on predicted effectiveness, we performed a multiple linear regression. This type of analysis can be used to examine how various predictors (i.e., in this case, the selected fatigue factors) can affect an outcome variable (i.e., effectiveness scores). Specifically, we entered the various fatigue factors (i.e., shift duration, time off duty, start time variability, night work hours, number of consecutive night shifts, consecutive work periods that allowed for opportunities for night sleep) into a statistical model to determine their influence on predicted effectiveness scores. For a full summary of these results, refer to Table 5.

The regression produces a series of coefficients that describe the strength of the relationship between each predictor and outcome. The output generates unstandardized and standardized coefficients, along with the intercept. The intercept describes the baseline of the outcome variable (e.g., on average, pilots' effectiveness score will start around 90 and change due to the fatigue factors at a rate described by the unstandardized coefficients, or b values). For example, regressions can be written in slope-intercept form ($y = mx_1 + mx_2 + \ldots + b$) with the slope of each predictor (m) equal to the unstandardized coefficient and the intercept (b). Standardized coefficients, also termed β values, are transformations of each unstandardized coefficient that allow each predictor to be placed on the same numeric scale. They can be positive or negative, with higher absolute values indicating stronger relationships between the predictor and outcome.

Table 5. Fatigue Factors Impact on Effectiveness Score

Fatigue Factors	*Unstandardized Coefficient (b)*	*Standardized Coefficients (β)*	*p-value*
(Intercept)	89.11	.00	***
Shift Duration	0.01	.15	***
Time Off Duty‡	< 0.01	< –.01	.62
Start Time Variability	0.38	.21	***
Night Work Hours	–2.73	–.63	***
Number of Consecutive Night Shifts	– 0.72	–.06	***
Consecutive Opportunities for Night Sleep	1.13	.13	***

*Note: ***p< .001.   ‡Off duty periods greater than 48 hours were excluded.*

Overall, night work hours and start time variability had the strongest relationships with effectiveness score (all β values > .20, all p values < .001). Specifically, the results indicated that as pilots worked more night hours (i.e., between 0000 and 0600), the predicted effectiveness decreased. Thus, based on this analysis, an increase of 1-night work hour would mean a reduction in predicted effectiveness of 2.7 for a given work period (such as, from the intercept of 89.1 to 86.4).

In addition, we observed that positive increases in start time variability were associated with higher predicted effectiveness scores. To note, the remaining fatigue factors we examined had relatively weak relationships with effectiveness score (β values < .20).

6.4.6 Evaluation of Selected Work Periods

Based on the SAFTE-FAST modeling results, work periods with an average effectiveness score below or equal to 70[16] were identified for closer examination of the associated fatigue factors. This followed from an approach used by Hursh, Raslear, Kaye, & Fanzone (2006) in a study of rail operations, in which human factors-related accident risks were found to increase when effectiveness was predicted below 70. This screening procedure yielded a total of 25 potentially problematic work periods. However, given that actual sleep data for each pilot were not available, we assessed the estimated sleep patterns generated by the model on a case-by-case basis. Through this process, six cases from the 25 were excluded from the analysis. These were cases in which the model produced estimated sleep periods that did not fit with the input schedule of work periods, leading to extreme estimates of hours awake prior to the start of a work period (ranging up to more than 40 hours). In these cases, the research team did not consider the predicted effectiveness levels for the excluded work periods to be meaningful for analysis.

Among the 19 remaining cases examined in our analysis, we found that the average predicted effectiveness score for each work period was 67.6 and that 14 different pilots were represented (one pilot had 3 of these cases). The characteristics of these selected work periods are summarized in Table 6 and Table 7 separately for one week on-one week off and two week on-two week off

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[16] Effectiveness scores that were at the lower end of the middle 65–90 "yellow" range.

schedules. On average, both schedule types had nearly identical effectiveness scores among the highlighted work periods.

Table 6. Selected Work Periods Summary Statistics for One Week On–One Week Off Schedules

Date	*Start Time*	*End Time*	*Work Hours*	*Night Hours*	*Duty of Schedule*	*Day of Schedule*	*Eff*	*Time*	*STV*	*Off Duty*	*Board Turn*
Jun 2017	0030	0714	6.73	5.50	4	5	65.2	0420	xx	27.8	
Mar 2017	0130	0859	7.48	4.50	4	5	66.5	0522	xx	19.8	x
Feb 2017	0100	0749	6.82	5.00	5	5	66.7	0406	x	33.8	
Aug 2016	0125	0714	5.82	4.58	6	6	67.2	0543		17.4	
Oct 2016	0130	0809	6.65	4.50	3	4	67.3	0453		36.1	x
May 2017	0224	0649	4.42	3.60	6	6	68.0	0607		13.2	x
Nov 2016	0135	0644	5.15	4.42	4	5	68.1	0548	x	18.3	
Jan 2017	0329	0834	5.08	2.52	6	7	68.3	0526		11.5*	x
Apr 2017	0101	0709	6.13	4.98	3	3	68.4	0450	x	16.8	x
Nov 2016	0101	0800	6.98	4.98	3	4	69.7	0449		21.8	x
Dec 2016	0300	0755	3.82	3.00	5	6	69.8	0600		14.4	

Note. *n* = 11. Eff = mean effectiveness score. Duty of schedule is a count of work periods during the on-call week. Day of schedule refers to the count of calendar days within the on-call week. Time = time during work period when effectiveness score was lowest. STV = start time variability (compared to previous shift; x = value greater than 3 hours, xx = value greater than 6 hours). Off duty = hours off prior to work period, *indicates MRP exception. Board turn (x) refers to more than 20 working pilots per day (i.e., board turning faster than average).

Table 7. Highlighted Work Periods Summary Statistics for Two Week On-Two Week Off Schedules

Date	*Start time*	*End Time*	*Work Hours*	*Night Hours*	*Duty of Schedule*	*Day of Schedule*	*Eff*	*Time*	*STV*	*Off Duty*	*Board Turn*
May 2017	0430	1524	10.90	1.50	12	13	64.0	0809	x	9.4*	
Jun 2017	0100	0633	5.55	5.00	8	10	65.2	0429	xx	31.7	x
Aug 2016	0101	0559	4.97	4.96	7	9	65.8	0615	xx	29.8	x
Jan 2017	0325	1259	9.57	2.58	9	9	66.4	0352	x	13.9	x
Sep 2016	0430	1139	7.15	1.50	11	13	68.4	0655		15.5	x
Mar 2017	0030	0731	7.02	5.50	8	9	69.3	0359	xx	28.1	
Aug 2016	0101	0703	6.03	4.98	6	7	69.7	0447	xx	31.3	x
Jul 2016	0130	0641	5.18	4.50	9	11	69.9	0428	x	36.6	

Note: *n* = 8. Eff = mean effectiveness score. Duty of schedule is a count of work periods during the on-call weeks. Day of schedule refers to the count of calendar days within the on-call weeks. Time = time during work period when effectiveness score was lowest. STV = start time variability (compared to previous shift; x = value greater than 3 hours, xx = value greater than 6 hours). Off duty = hours off prior to work period, * indicates MRP exception. Board turn (x) refers to more than 20 working pilots per day (i.e., board turning faster than average).

In examining potential fatigue factors associated with these work periods, several things stand out. The selected work periods were all classified as night work and while on average were 6.4 hours in duration, the majority of those hours was at night. The majority of these work periods occurred in the latter part of the on-call work week(s) when the pilot had worked an average of 4.5 (one week) or 8.8 (two weeks) prior work periods. Variability in start times between successive work periods was found to be common and differences greater than 3 hours from the previous shift were identified in most of these work periods. Rest periods prior to these work periods averaged about 22 hours with two instances of less than 12 hours (MRP exceptions). For more than half of these work periods, the board on that day was turning faster than the average of approximately 20 assigned pilots.

To further illustrate findings of our highlighted work periods, example 7- and 14-day schedules are respectively presented in Figure 74 and Figure 75. For the 7-day schedule, this pilot would have gone on the board on Wednesday at noon (day 1) and started his first work period in the afternoon at 1630 and was off at 0030 the next morning. His next work period was on Friday morning from 0100 until 0807 and so on. The selected work period (average effectiveness of 69.8) was the 5th work period of the week and was the second successive night, followed a 14 hr 25 min rest period, and started at the same time as the previous work period. In total, the pilot worked a total of 6 times during this week. For the 14-day schedule, the selected work period (average effectiveness of 66.4) was the 9th work period of his on-call period. It followed a 13 hr 56 min rest period and started about 4 hours earlier than the previous work period. In all, the pilot worked a total of 13 times during this 14-day period.

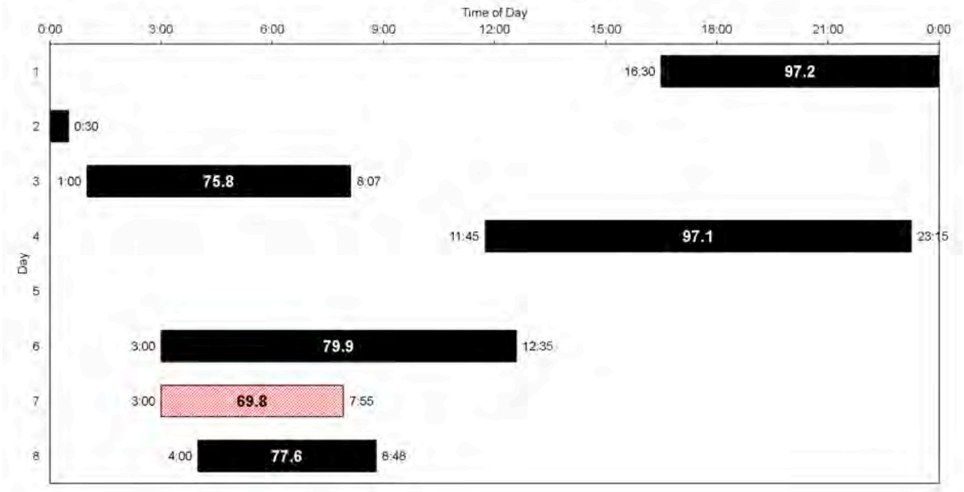

Figure 74. *Sample 7-day pilot work schedule. Black bars indicate work periods with ride times shown to the left of each bar and BoB times shown to the right. The selected work period (average effectiveness of 69.8) is noted in red with patterned lines. The average effectiveness score for each work period is included within each bar.*

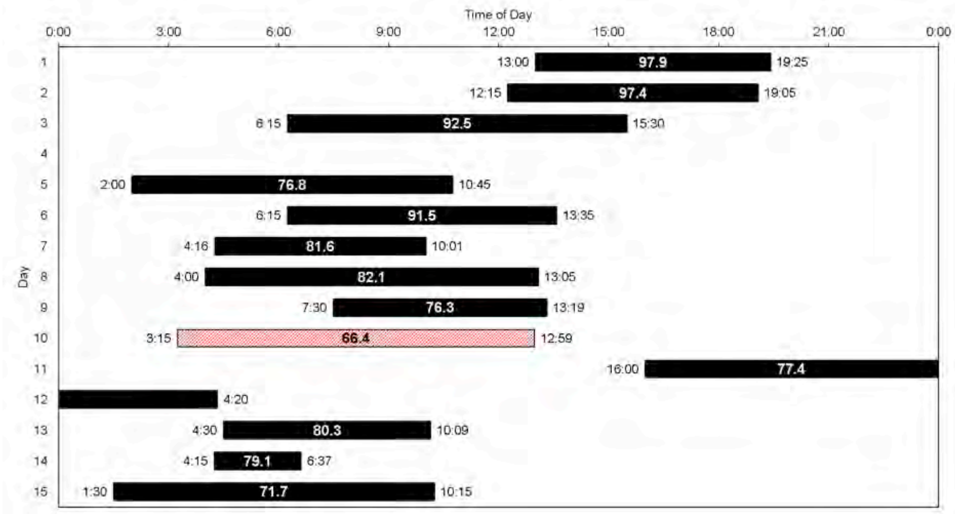

Figure 75. *Sample 14-day pilot work schedule. Black bars indicate work periods with ride times shown to the left of each bar and BoB times shown to the right. The selected work period (average effectiveness of 66.4) is noted in red with patterned lines. The average effectiveness score for each work period is included within each bar.*

This selected set of schedules also allowed us to examine a snapshot of work periods over one- and two-week schedules. For this we plotted the average effectiveness score by work period over the duration of the schedule (Figure 76). For two-week on-call schedules, there was a trend towards lower effectiveness during the midpoint of the schedule (days 9–10). There was a nearly identical trend of the data for one-week schedules. Note that we did not account for the type of shift (day vs. night) in this exercise which may have influenced the effectiveness scores.

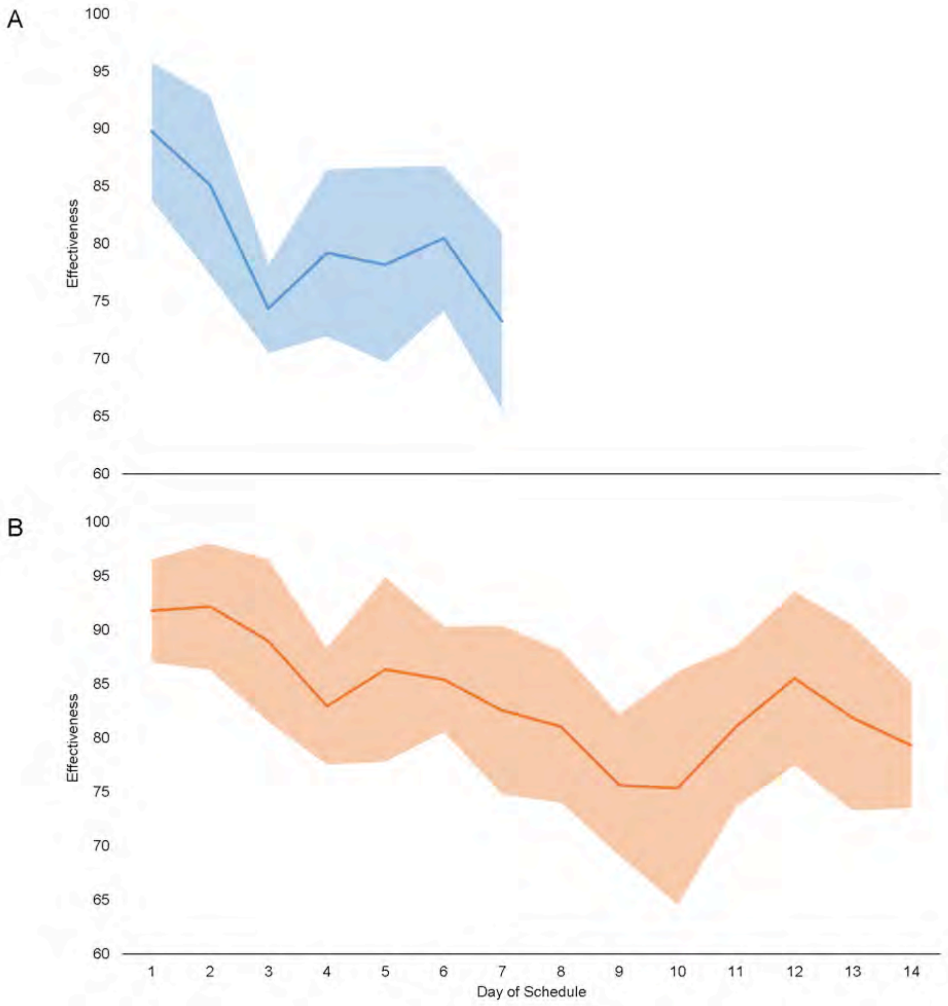

Figure 76. Average effectiveness score for work periods over 7- (Panel A) and 14-day (Panel B) on-call periods. Days that included less than five data points were excluded from this analysis. The error bands depict 95% confidence intervals.

6.4.7 Work Week Irregularity

Following from the earlier examination of board operations, we further observed that at some time most pilots worked during their expected time (week) off, most likely filling in or shift swapping for another ‘on the board’ pilot. Such irregular work periods may interfere with the opportunity to get recovery sleep during periods of scheduled days off. To illustrate this, we selected one pilot as a case study (Figure 77).

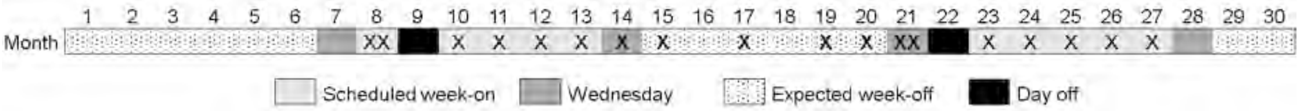

Figure 77. Example month-long work schedule for selected pilot. The X denotes a single work period. Multiple Xs refer to multiple work periods started on the same calendar day.

Over the course of 22 days during the sampled month, this pilot worked 18 duties. Four of these duties between the 15th and 20th of this month were completed during an expected week off. As a result, this pilot worked an additional 25.3 hours, which included 17.3 hours of night work. These supplementary duties also added two consecutive nights of work. In all, the pilot worked a total of 36.6 hours at night. During this span, the pilot may have only had seven predicted opportunities to receive a full night’s sleep. In addition, the pilot had an average of 21.6 hours off duty after each shift, with a maximum off duty period of 35.7 hours and minimum of 15 hours.

Over this 22-day span, the pilot’s average predicted effectiveness dropped from an expected score of 90.1 to 87.5 due to the additional work periods. Within the four additional duties, SAFTE-FAST predicted an average effectiveness score of 79.8. Considering this, if the pilot had received those four days off, the model predicted that his average effectiveness score would have been 98.5 during that time frame. This may have allowed the pilot to obtain adequate recovery time for the subsequent work periods completed during the latter portion of this schedule.

6.4.8 Limitations of Fatigue Modeling Software

When considering the results provided by the modeling software it is important to keep in mind that all such biomathematical models have limitations in their applicability. Foremost, the predicted levels of effectiveness are representative for an “average” person and do not reflect individual differences in sleep need, morning/evening tendencies, and the use of countermeasures such as caffeine. The program is also based on laboratory and other studies of workers that do not fully account for the specific tasks and work conditions experienced by Bar Pilots. The sleep periods estimated by the program were primarily based on the program’s default settings and may not well represent the rest practices of the current group of pilots.

6.5 Summary of Dispatch Records Analysis

Our analysis of dispatch records examined 7005 work periods over a one-year period. Results associated with the fatigue factors identified previously are as follows:

- Work periods averaged less than 8 hours in duration, although about 5% of all work periods were more than 12 hours.
- Time off between work periods was generally between 18-20 hours, though there were some exceptions to the 12-hour MRP.
- The most common work period start times are between 0200 and 0500 and more than half of weekly work hours are at night; a subset of work periods identified by the SAFTE-FAST model with low effectiveness scores were all at night.
- Consecutive days/nights of work occur on a regular basis though these are generally limited to one-week work periods for most pilots; results from the model showed lower effectiveness scores over the course of consecutive nights.
- The work period start time often changes significantly from one work period to the next. The difference between consecutive start times is commonly more than 3 hours.
- Scheduling practices generally allow for a recovery period of one or two weeks between work cycles. In some cases, extra work periods are undertaken during planned time off that may interfere with opportunities for recovery sleep during this time.

7. Summary and Conclusions

The purpose of this study was to evaluate the extent of fatigue among San Francisco Bar Pilots and its potential impact on safety, and to make recommendations concerning how the risk of fatigue could be managed. Information was gathered via a literature review, observations of Bar Pilots at work, a task analysis, surveys, and an analysis of dispatch records.

The work of San Francisco Bar Pilots involves an unusual mix of activities and job demands. Their work calls for situational awareness, reasoning, communication, and perceptual abilities comparable to those required by airline pilots and air traffic controllers. Errors can have severe consequences for public safety and the environment, as well as significant financial costs. As vessels become larger, the margin for error reduces, while the potential consequences increase. The environment in which they work requires fitness and physical coordination and presents significant personal injury risks.

The work hours of maritime pilots in many countries are determined by the timing of ship movements, rather than set work schedules (Nicol & Botterill, 2004; Shipley & Cook, 1980). In these countries, each Bar Pilot is typically on watch for a 7- or 14-day period, during which time he or she is on-call 24 hours a day to respond to requests for pilots by ship operators. These Bar Pilots receive work assignments under a rotating roster system. This system can result in a haphazard pattern of work hours over the course of the work week, disrupting the normal sleep/wake cycle.

Fatigue is increasingly recognized as a hazard that must be managed by the transportation industry. The reduced sleep quality and quantity experienced by personnel who work at night, together with circadian misalignment, can lead to an operationally significant level of cognitive impairment. Fatigue can detrimentally effect cognitive functions that are critical to safe maritime piloting, such as vigilance, judgment, reaction time and communication. Unlike many other workplace hazards, fatigue-induced impairment can be invisible, insidious, and may not be recognized by the affected individual.

Although there have been no fatigue-related accidents involving San Francisco Bar Pilots, the risk must be carefully managed considering the potential consequences of fatigue-induced errors. A comprehensive approach to fatigue management should consider not only the length of shifts, but also the rest periods between shifts, night work, the number of days in a "work week" and the rest period that follows it, and the variability and predictability of work hours.

The "on-call" work assignment system used by some maritime pilots, and the resulting non-standard work hours, mean that it is difficult to identify comparable occupations on which to model a fatigue management approach. Some piloting organizations in the U.S. have adopted the Hours of Service regulations published by the International Maritime Organization and International Labour Organization. However, these regulations were developed for personnel on seagoing vessels, who work fixed watch rotations, work and sleep on board, and have no commute at either end of their work periods. The task analysis identified that the cognitive tasks performed by Bar Pilots are somewhat similar to those performed by airline pilots and air traffic controllers. The regulations for these occupations contain some practices that could be applied to Bar Pilots.

The surveys distributed to Bar Pilots and the analysis of their dispatch records did not uncover evidence of widespread fatigue. The survey results suggested that fatigue was not a major concern of Bar Pilots, and they considered that their current scheduling practices were set at the right level to support their optimal alertness. They had overall low scores on the subjective fatigue measures used in the survey, and generally assessed the safety risk due to fatigue as low. Compared to air traffic controllers, Bar Pilots gave significantly lower ratings on questions concerning the prevalence and impact of fatigue. The application of SAFTE-FAST to the dispatch records identified that in most cases, pilot's cognitive effectiveness was predicted to be acceptable during their duty periods. It should be borne in mind however, that modeling software such as SAFTE-FAST produce predictions, not actual assessments of fatigue. Objective monitoring techniques such as actigraphy and the Psychomotor Vigilance Task (PVT) could have produced more accurate measures of sleep patterns and cognitive performance; however, we were unable to obtain sufficient volunteers to enable an objective monitoring phase of the study to proceed.

Bar Pilots do not currently operate under a formal Fatigue Risk Management System (FRMS), however, several elements of such a system are already in place. Bar Pilots receive periodic training covering fatigue and fatigue mitigation, they undergo regular screening for sleep disorders, incidents are reported to the BOPC, and the Bar Pilot Association applies work and rest policies to limit fatigue. This study found that the duration of work periods is generally less than 12 hours, rest periods are usually adequate, and shifts at night are generally briefer than day shifts. However, this study found some fatigue-related issues that deserve further attention, as described in the following sections.

7.1 Night Work

Bar Pilots are commonly required to work at night. The five most common work period start times were all between 0100 and 0500, with the most common start time being 0200. Transport safety research indicates that the early hours of the morning are a period of heightened risk for human error and accidents (Folkard, 1997). In survey responses, Bar Pilots reported that they felt least rested when they started their work between 0200 and 0400. The fatigue model applied to dispatch records predicted that the lowest effectiveness scores would occur between 0000–0400 and that predicted effectiveness would be lowest for shifts that ended during the early morning hours. This is strikingly similar to a recent finding for St Lawrence River pilots (Boudreau, Lafrance & Boivin, 2018).

We note that San Francisco Bar Pilots currently impose stricter limits on the duration of night work than work during the day. Consistent with the recommendation of Rhodes and Gil (2002) for maritime pilots, and with the practice of the Columbia River Bar Pilots, night work is limited to eight hours in most cases, compared to 12 hours at other times. Aviation regulations for airline pilots (FAA, 2012) also impose special limits on night duty. A nine-hour limit on flight duty applies when the duty starts between midnight and 0400, but duty periods of up to 14 hours are allowed during daylight hours.

A major factor leading to the requirement for night work is the timing of ship arrivals from sea. A disproportionate number of ships arrive at the offshore pilot station at 0300 and 0400, apparently for economic reasons associated with the operating hours of port labor. One survey respondent referred to this as an early morning traffic jam. This sudden peak in demand requires pilots to report for work during the circadian low, with a resultant (and unnecessary) increase in the risk of human error or accidents. Furthermore, sudden peaks in workload, as seen in air traffic control and other transport settings, can make it difficult to match staffing levels to dynamic demands. Some Bar Pilots made survey comments suggesting that rules or an increased charge for piloting services at night could encourage the shipping industry to reduce arrivals during the early morning hours.

7.2 Schedule Predictability

The on-call nature of their occupation makes it difficult for Bar Pilots to predict the timing of their work hours, and therefore arrange their sleep and personal time.

Bar Pilots considered that the work schedules that appeared 10 hours ahead of time were accurate less than half the time, and this uncertainty reduced their ability to plan for sleep. A policy change introduced in 2016 required that for ship departures between the hours of 1800 and 0600, the order for a pilot must be placed eight hours ahead of time, instead of the previous four hours. Bar Pilots felt that their ability to sleep had improved as a result of this change. As long ago as 1980, Shipley and Cook suggested that a better ship forecasting system could help to reduce pilot fatigue. Technological developments of recent years may enable a software application to be developed that would enable the start time for a piloting job to be predicted with greater accuracy.

7.3 Shift Duration

The policy of the Bar Pilot Association is to limit most work periods to 12 hours. This is the same as that specified for locomotive engineers (Federal Railroad Administration, 2008), is less than the maximum 14-hour shift length specified for seafarers by the International Labour Organization (1996) and the International Maritime Organization (2001 and is longer than the 10-hour limit for air traffic controllers. As noted previously, night work is generally limited to eight hours. Analysis of the dispatch records indicated that approximately 5% of work periods exceeded the 12-hour limit.

7.4 Consecutive Shifts Without a Break

Bar Pilots commonly work for multiple consecutive days or nights without a day off. The SAFTE-FAST analysis of dispatch records showed that predicted effectiveness scores decreased with each successive work period. The adverse impact of night duty is exacerbated when consecutive night shifts occur (Folkard, Minors, & Waterhouse, 1985). A feature of the rotating roster system is that a pilot will sometimes be assigned an unfortunate series of consecutive night shifts, purely through the chance operation of the board. The dispatch records contained numerous cases in which Bar Pilots worked successive nights without a break, and the modeling of these data indicated that predicted effectiveness scores were reduced as more night shifts were worked without a break. We note that the Columbia River Bar Pilots, Columbia River Pilots, and Coos Bay Pilots Association (see Appendix 3) each limit pilots to no more than three successive nights of work. A similar provision is contained in the FAA regulation for airline pilots (FAA, 2012). Kecklund, Sallinen, and Axelsson (2017) reviewed the literature on shiftwork and concluded that research results suggest that the maximum number of consecutive night shifts should be limited to three. In the case of 12-hour night shifts, research suggests that night shifts should be limited to two consecutive nights (Folkard, 2003).

In their survey responses, most Bar Pilots considered that they could be on-call for over two weeks, and still maintain the required level of alertness. We note that Columbia River Pilots and Coos Bay Pilots Association limit work periods to 14 days without a break of 24 hours (see Appendix 3). The Columbia River Bar Pilots apply a limit of seven days. Locomotive engineers are limited to a maximum of six consecutive days, which may be extended to seven consecutive days in some circumstances (Federal Railroad Administration, 2008). Airline pilots must obtain 30 consecutive hours of rest each seven-day period (14 C.F.R. § 117). Air traffic controllers must have at least 24 consecutive hours off work in a seven-day period (FAA, 2015).

The dispatch records indicated that most pilots working a 14-day pattern had a break of 24 hours at some stage during their work period. However, the break appears to have been an unplanned result of schedule variability, rather than a scheduled rest period. A two-week work period has the potential to be fatiguing if it involves successive night work and/or no opportunities for an extended period of rest.

7.5 Start Time Variability and Advancing Rotation

For the studied period, the timing of work periods was highly variable with about 2/3 of consecutive work periods starting at a time 3 hours or more different than the previous work period (i.e., equivalent to traveling from one coast of US to the other), potentially leading to a state of perpetual "jet lag" during a work week. In their survey responses, Bar Pilots stated work and rest periods were not consistent while on-call and that schedule inconsistency was the major cause of sleep difficulties while on-call.

Variability in the timing of work periods can lead to circadian disruption and interfere with the ability to obtain restful sleep during off-duty hours (Pilcher & Coplen, 2000; Härmä, Sallinen, Ranta, Mutanen, & Müller, 2002). Changes in work period timing though that are later in the clock (for example, 0200 for one shift, 0600 for the next) may have some benefits in that delays are preferable to advances in circadian timing and more time for sleep opportunities may be available (Bambra, Whitehead, Sowden, Akers, & Petticrew, 2008).

7.6 Time-Off Between Work Periods

Current Bar Pilot policy is to allow a minimum of 12 hours of rest between work periods. The value of a rest period is related to its ability to allow adequate sleep, and a rest period during night hours will clearly be of more value than one that falls during daylight hours. Watson et al. (2015)

recommend that the time off between work periods should allow for a sleep opportunity lasting between 7- to 9-hours.

A surprising finding was that Bar Pilots did not appear to be aware of occasions on which they had received less than 12 hours of rest. Although regular reports of minimum rest period exceptions are made to the BOPC, it appears that no follow-up occurs with the individuals involved.

7.7 Recovery Periods before Commencing a Work Cycle

Recovery periods between work cycles are an important consideration. Baker, Fletcher and Dawson (2000) recommend that maritime pilots obtain a minimum of 36 consecutive hours free of work in a 14-day period. Airline pilots are required to obtain at least 30 consecutive hours of rest in a seven-day period (14 C.F.R. § 117) and commercial truck drivers need 34 hours of rest before their work week can begin anew (49 C.F.R § 395). The current Bar Pilot policy would appear to provide an adequate recovery opportunity between work cycles.

The dispatch records indicated that pilots commonly performed piloting assignments during their scheduled off weeks (i.e., shift swaps). An uninterrupted period of rest is necessary to recover following a work schedule that may have produced chronic sleep loss and a resulting sleep debt (Belenky et al., 2003; Dinges, et al., 1997). The performance of work tasks during periods scheduled for rest can potentially disrupt or limit recovery sleep opportunities that would otherwise enable pilots to be fully rested for the start of their next scheduled work week.

Fatigue resulting from trans-meridian travel has been an area of concern (Board of Pilot Commissioners, 2014). Upon returning from manned model training, a Bar Pilot who has been seated in a standard airline seat may experience sleep debt as a result of poor sleep on the flight (Nicholson & Stone, 1987; Roach, Mathews, Naweed, Kontou, & Sargent, 2018) and circadian desynchronization as a result of the time zone change. The ability to sleep in a horizontal position on the plane would undoubtedly enable more sleep to be obtained but would have no impact on circadian desynchronization. A recovery period before starting work following the journey would also help to mitigate travel-related fatigue.

7.8 Sleep Inertia

Sleep inertia affects accuracy of performance, worsens when individuals are sleep deprived, and varies in duration and severity with circadian phase (Ferrara, De Gennaro, Casagrande, & Bertini, 2000; Milner & Cote, 2009).

Approximately half of the pilots who responded to the survey reported experiencing sleep inertia. The most common symptoms experienced were noticing that the mind felt “groggy, fuzzy or hazy” and slowed thinking. When pilots experienced sleep inertia, its average duration was 15.8 minutes, although seven respondents reported experiencing sleep inertia over 30 minutes. In the follow-up survey of March 2018, the majority of respondents who stated that they experienced sleep inertia stated that it occurred after a nap. In survey comments, pilots indicated that they took precautions to minimize the impact of sleep inertia. Nevertheless, it appears that the riskiest time for sleep inertia would be after a nap on the Offshore Pilot Station inasmuch as the time between waking up and ascending the ladder might be less than 30 minutes.

7.9 Staffing

The BOPC licenses up to 60 Bar Pilots, however, this does not mean that 30 pilots are available for work each week. The number of pilots on the board at any one time is not reported to the BOPC, however, dispatch records and 237(d) reports suggest that at a given moment there are typically around 23 pilots on the board. About a quarter of the Bar Pilots responding to the survey felt that there were not enough Bar Pilots to support their optimum alertness. None felt there were too many. 237(d) reports do not appear to indicate a consistent upward trend in total ship movements, suggesting that factors other than increased ship movements may be involved. Survey comments indicated that the perceived shortfall may be related to pilots performing other duties, such as committee meetings, training, pilots not fit for duty (NFFD), faster rotation of the board due to new rules limiting night duty to 8 hours or less (without an opportunity to rest), and the increased need for two pilots on ultra-large container vessels.

Given that the board appears to turn at a rate of around 19 pilots per 24-hour period, at times of high demand, the board may undergo a full rotation in a 24-hour period, possibly requiring relief pilots to be brought in from the off-watch group.

7.10 Substitutes When Fatigued

Fatigue management policies in the transport industry frequently contain statements to the effect that personnel can request relief of duty when fatigued. Bar Pilots describe themselves as rarely making an attempt to find a substitute when they are fatigued and indicate that doing so may go against a norm of "doing their share." Shipley and Cook (1980) noted that this attitude was part of the worldwide culture of maritime piloting, stating, “Self-control and suppression of weakness (like fatigue) are characteristic values of the male dominated world of seafarers and pilots.” (p. 158). Comments on the survey indicated that some Bar Pilots may wrongly believe that there is a financial penalty if they cannot find a substitute and are removed from the Board.

A fatigue management policy that allows pilots to request to be removed from the board when fatigued may not be fully effective in practice due to the culture of the industry. We note that some piloting organizations have attempted to deal with this concern. For example, the Virginia Pilots Association enables pilots to take a sick day without explanation if the pilot considers that they are not sufficiently rested (NTSB, 2017).

7.11 Sleeping Conditions at Home

There was a widespread recognition among Bar Pilots that obtaining sufficient sleep is a priority when on-call. Around a quarter of pilots responding to the survey had difficulty sleeping while on-call due to stress, noise, light, temperature, or normal household interruptions. Some pilots recognized that their use of caffeine while on-call was interfering with their sleep.

Over half of the Bar Pilots expressed some interest in additional training on ways to reduce or manage fatigue. Such training should address the sleeping environment of Bar Pilots when on-call, and the proper use of caffeine as a fatigue mitigation strategy. It would also be valuable if material could be developed to educate Bar Pilot families concerning the sleep environment.

8. Recommendations

The following recommendations are addressed to the Board of Pilot Commissioners (BOPC). Some of these recommendations may require regulatory action, while others could be addressed in other ways.

Before considering these recommendations, it should be recognized that interventions intended to manage fatigue will sometimes have unintended adverse consequences. For example, a reduction in the length of work periods would cause the board to "turn faster", resulting in reduced rest periods for pilots. Providing relief to one pilot may only transfer the burden to another. For this reason, interventions should be introduced cautiously, with a trial period to enable effectiveness and potential side-effects to be evaluated. Individuals typically find it difficult to adjust to changes in work requirements, and it can be hard to judge the effectiveness of a change based on subjective feedback alone. As a result, work rule changes should ideally be evaluated using objective measures of fatigue before and after implementation to adequately assess the impact of changes.

1. Interventions intended to prevent or manage fatigue should be introduced as part of an overall Fatigue Risk Management System (FRMS), some elements of which are already in place.

2. A limit on the duration of work periods is advisable. The current Bar Pilot Association policy (a limit of 12-hours) appears to be appropriate.

3. The maximum duration of a night work period without a rest opportunity should be less than the allowable duration of a daytime work period.

4. A limit to the number of consecutive night shifts is advisable. A limit of two consecutive night shifts would be most desirable; however, a limit of three consecutive night shifts may be more practical.

5. The BOPC should explore the reasons for the early morning peak in arrivals and consider options to distribute arrivals more evenly throughout the 24-hour day.

6. The BOPC should consider whether a change to the minimum advance notice required when ordering a pilot would help to increase the predictability of pilot schedules.

7. The BOPC should consider whether technological solutions (such as software applications) could enable the timing of piloting assignments to be predicted with greater accuracy.

8. The BOPC should consider whether pilots who are on-call for 14 days should be provided with a rest break at or around the mid-point of the 14-day period. A midpoint break of at least 24 hours may be appropriate. If such a break does not occur naturally due to the movement of the board, it may be feasible to delay the pilot's BoB time to achieve this.

9. The BOPC should consider ways to minimize advancing shift rotation. An advancing shift rotation occurs when each work period in a series has a start time earlier than that of the preceding work period.

10. There should be a Minimum Rest Period (MRP) between work periods. The current Bar Pilot Association policy (12-hour MRP) appears to be appropriate.

11. Minimum Rest Period (MRP) exceptions should be monitored to ensure that no individual pilot is disproportionally burdened with MRP exceptions.
12. The BOPC should consider whether an extended rest period is needed following an MRP exception.
13. Recalls of pilots from an off-call period should be managed so as to minimize disruption of their recovery rest prior to the start of their next on-call period.
14. Pilots should receive an appropriate recovery period after awakening, before boarding a ship. A longer recovery period will be needed when the awakening occurs during the circadian low, or when the pilot has been asleep for more than 30 minutes.
15. The BOPC should receive information on the number of Bar Pilots available on the board.
16. Implement solutions to increase the number of Bar Pilots available on the board at any given time. Approaches could include reducing the amount of "other duties" performed by Bar Pilots, or increasing the number of Bar Pilot Licenses.
17. Implement a system to enable pilots to report fatigue and remove themselves from the roster without consequences when they are significantly fatigued. It will be necessary to address the cultural barriers that could prevent such a system from working.
18. Provide pilots with educational material on the effective use of caffeine, and other aspects of good sleep hygiene.
19. Provide advice to pilots on how to improve their home sleeping environments. This could include educational material for families on how they can contribute to Bar Pilot rest and alertness.

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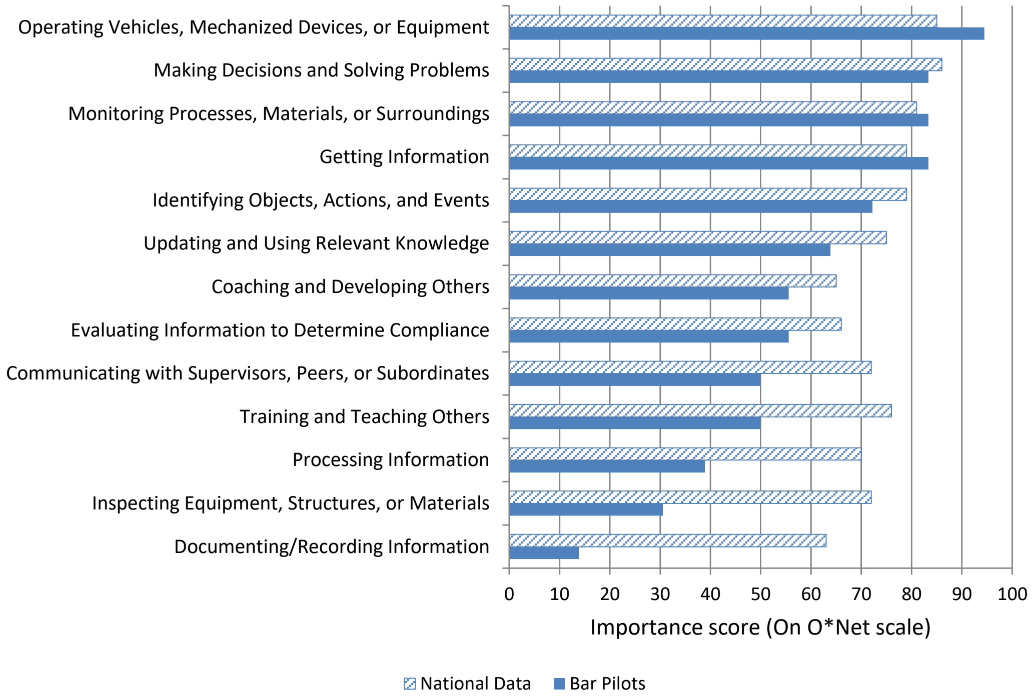
Appendix 1. Task Analysis Definitions and Results Tables

Appendix 1: Table 1. Work Context Descriptions Rates as Most Important by Bar Pilots

Work context	*Occupation with Similar Work Context*
How often does your job require you to work outdoors, exposed to all weather conditions?	Oil derrick workers
How often do you wear common protective or safety equipment such as safety shoes, glasses, gloves, hearing protection, hard hats, or life jackets?	Oil derrick workers
How serious a mistake can you make on your current job (one you can't easily correct)?	Midwives
How much freedom do you have to make decisions without supervision?	Judges, magistrates
How often does your job require that you be exposed to high places?	Roofers
How often do your decisions affect other people or the image or reputation or financial resources of your employer?	Judges, magistrates
How important to your job is being very exact or highly accurate?	Airline pilot

Appendix 1: Table 2. Work Activities Rated as Most Important by Bar Pilots and Other Occupations with Similar Work Activities

Highly-rated Work Activities by Bar Pilots	*O*Net Definition*	*Occupation with Similar Work Activities*
Operating Vehicles, Mechanized Devices, or Equipment	Running, maneuvering, navigating, or driving vehicles or mechanized equipment, such as forklifts, passenger vehicles, aircraft, or water craft.	Airline pilot
Making Decisions and Solving Problems	Analyzing information and evaluating results to choose the best solution and solve problems.	Physician
Monitoring Processes, Materials, or Surroundings	Monitoring and reviewing information from materials, events, or the environment to detect or assess problems.	Nuclear equipment operator
Getting Information	Observing, receiving, and otherwise obtaining information from all relevant sources.	Judge/magistrate
Identifying Objects, Actions, and Events	Identifying information by categorizing, estimating, recognizing differences or similarities, and detecting changes in circumstances or events.	Forensic science technician
Updating and Using Relevant Knowledge	Keeping up-to-date technically and applying new knowledge to your job.	Physician
Coaching and developing others	Identifying the developmental needs of others and coaching, mentoring, or otherwise helping others to improve their knowledge or skills.	Choreographer



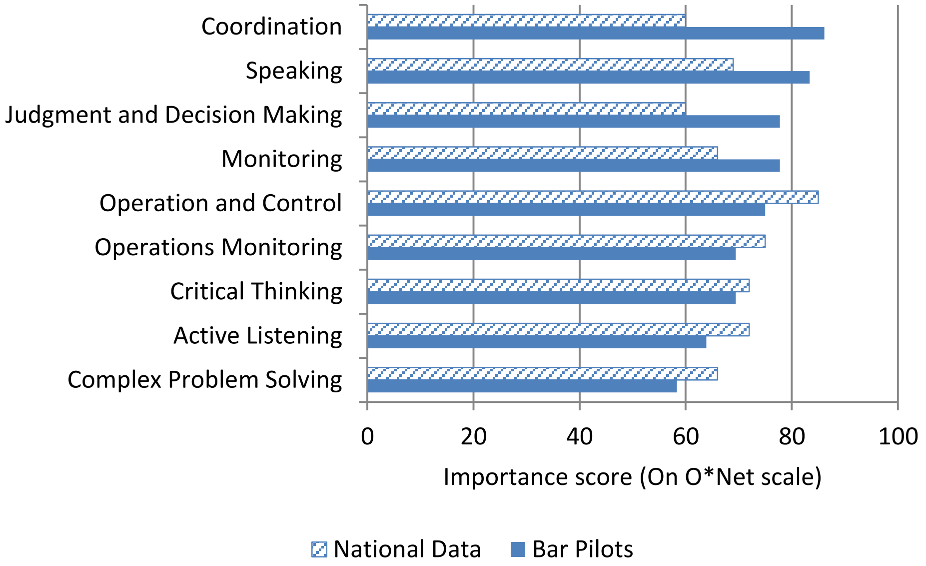
*Appendix 1: Figure 1. Comparison between Bar Pilot ratings of work activities and the corresponding O*Net national data for "Pilots, Ship".*

Appendix 1: Table 3. Cognitive Abilities Rated as Most Important to Bar Pilots and Other Occupations Requiring a Similar Ability

Highly-rated Abilities	*O*Net Definition*	*Occupation Requiring Similar Ability*
Problem sensitivity	The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing that there is a problem.	Physician
Spatial orientation	The ability to know your location in relation to the environment or to know where other objects are in relation to you.	Airline pilot
Depth perception	The ability to judge which of several objects is closer or farther away from you, or to judge the distance between you and an object.	Airline Pilot
Rate control	The ability to time your movements or the movement of a piece of equipment in anticipation of changes in the speed and/or direction of a moving object or scene.	Airline pilot
Selective attention	The ability to concentrate on a task over a period of time without being distracted.	Air traffic controller

Appendix 1: Table 4. Skills Rated Highly as Needed by Bar Pilots and Other Occupations with Similar Skills Required

Highly-rated Skills	*O*Net Definition*	*Occupation with Similar Skill Demand*
Coordination	Adjusting actions in relation to others' actions.	Chief executive
Speaking	Talking to others to convey information effectively.	Post-secondary teacher
Judgement and decision making	Considering the relative costs and benefits of potential actions to choose the most appropriate one.	Chief executive
Monitoring	Monitoring/assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.	Airline pilot
Operation and control	Controlling operations of equipment or systems.	Airline pilot



Appendix 1: Figure 2. Comparison of Bar Pilots and a national sample of ship pilots on skills needed for their occupation.

Appendix 2. Hours of Service Standards for Crew of Seagoing Vessels

International Maritime Organization (IMO)	
Maximum work for 24 hour period: 14	Maximum work for 7 day period: 72
Minimum rest for 24 hour period: 10 hours	Minimum rest for 7 day period: 77* hours
Population: Crew members of seagoing vessels	
Additional Details: *May be reduced to 70 hr; for no more than 2 weeks. Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours.	
Source: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). International Maritime Organization. (International Maritime Organization 2010)	

International Labour Organization (ILO)	
Maximum work for 24 hour period: 14 hours	Maximum work for 7 day period: 72 hours
Minimum rest for 24 hour period: 10 hours	Minimum rest for 7 day period: 77 hours
Population: Crew members of seagoing vessels	
Additional details: Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours.	
Source: International Labour Organization (1996).	

United States Regulation for Seagoing Vessels	
Maximum work for 24 hour period: N/A	Maximum work for 7 day period: N/A
Minimum rest for 24 hour period: 10 hours	Minimum rest for 7 day period: 77 hours
Population: “Every person assigned duty as officer in charge of a navigational or engineering watch, or duty as ratings forming part of a navigational or engineering watch, or designated safety, prevention of pollution, and security duties onboard any vessel that operates beyond the boundary line.”	
Additional details: The hours of rest required … may be divided into no more than two periods in any 24-hour period, one of which must be at least 6 hours in length, and the interval between consecutive periods of rest must not exceed 14 hours. Does not apply to fishing vessels, barges, pilot boats, or small vessels.	
Source: 46 U.S.C. § 15.1111 (2018) (Work hours and rest periods for crew of seagoing vessels)	

United States Coast Guard

Maximum work for 24 hour period: N/A

Maximum work for 7 day period: N/A

Minimum rest for 24 hour period: 10 hours

Minimum rest for 7 day period: 77 hours

Population: Crew members of seagoing vessels

Additional Details: Consistent with STCW guidance; some variations based on type of maritime operation.; expansion to all safety personnel aboard vessel; reporting requirements; exceptions for emergencies or 'overriding operational conditions'

Source: United States Coast Guard. (2012).

Licensed Individuals on Tankers

Maximum work for 24 hour period: 15 hours

Maximum work for 72 hour period: 36 hours

Source: 46 U.S.C. § 8104 (2018) (Licensed individuals on tankers).

Canadian Law

Maximum work for 24 hour period: 14 hours

Maximum work for 7 day period: 72 hours

Minimum rest for 24 hour period: 10 hours

Minimum rest for 7 day period: 77 hours

Population: Marine personnel

Additional Details: Consistent with IMO standards; rules vary for different types of operations (e.g., near coastal)

Source: Marine Personnel Regulations (2009).

European Union

Maximum work for 24 hour period: 14 hours

Maximum work for 7 day period: 72 hours

Minimum rest for 24 hour period: 10 hours

Minimum rest for 7 day period: 72 hours

Population: Seafarers on board every seagoing ship which is registered in the territory of an EU Member State and is ordinarily engaged in commercial maritime operations

Source: European Union Council Directive 1999/63/EC (1999, June). Working time of seafarers.

Appendix 3. Hours of Service Standards for Maritime Pilots

Alaska

Maximum work for 24-hour period: 15 hours

Maximum work for 72-hour period: 36 hours

Additional Details: A passenger vessel in transit of compulsory pilotage waters [where a pilot is mandated] must carry two pilots on board except during an entry transit between a pilot station and a harbor or anchorage within compulsory pilotage waters or an exit from compulsory pilotage waters where the entry or exit transit is normally less than eight hours.

A non-passenger vessel in a continuous transit of compulsory pilotage waters of Southeast Alaska that is expected to exceed eight hours must employ two pilots.

Source: Statutes and Regulations for Marine Pilots, (2017).

Connecticut

After working more than 10 hours with no more than 2 hours rest between assignments, pilots are prohibited from performing pilotage services for at least 10 hours

Source: Connecticut response letter to NTSB, 02/11/16

Hawaii

Minimum rest for 24 hour period: 10 hours

Additional details: The period of rest may be divided into no more than two periods, of which one must be at least six hours in length.

Source: Hawaii response letter to NTSB, 05/29/15.

Louisiana

Minimum rest for 24 hour period: 10 hours

7 day on 7 day off work period for "River Port Pilots"

Source: Response letter to NTSB 08/07/15

Maine

Minimum rest for 24 hour period: 10 hours

At Least 70 hours of rest per 7-day week

Source: State response letter to NTSB, 08/19/13.

Maryland
A pilot is required to take either a “6- or 8-hour” interval between assignments, except when the assignment was of extremely short duration in which case the pilot can elect to take no assignment interval. After three assignments, pilot must take 12 hours off.
Source: Response letter to NTSB, 05/20/13.

New Hampshire
Minimum rest for 24 hour period: 10 hours
Additional details: Complies with 46 Code of Federal Regulations Part 15 section 1111; Title 46 United States Code 8104(d); & STCW
Source: Letter to NTSB, 06/26/15

New York
Sandy Hook Pilots Association: "four weeks on, two weeks off. During the four week rotation period, a pilot averages two jobs within a 24 hour period, and then has approximately 24 hours off before the next assignment.”
The Hudson River Pilots Association by statute must have two pilots for continuous pilotage of more than eight hours assigned at the beginning of the transit. The Association's work rules state no pilot shall sail in and out of Albany on the same day, and that deputy pilots are required to have 36 hours off between the completion of one job and the commencement of another.
"Block Island Pilots Association procedures require that all Long Island Sound Block Island Sound transits in excess of 12 hours have two pilots. No pilot shall work more than 16 hours in a 24 hour period and no pilot shall pilot more than four vessels in a 16 hour period. A pilot who works four vessels in a 16 hour period must take a mandatory eight hour rest period."
Source: Letter to NTSB, 02/21/12.

Oregon

Columbia River Bar Pilots (CRBP)

CRBP fatigue mitigation program guidance limits pilots to <12 hours work, < 8 hours at night. Target of > 11 hours of rest between assignments. Max of 3 successive nights of work. No more than 7 work days without a 24 hour break.

Columbia River pilots (COLRIP)

Limits pilots continuous duty to 12 hours. Requires ≥ 9.5 hours of rest if the Pilot is between ships in Astoria. Requires ≥ 12.0 hours of rest if the Pilot is between ships in Portland. Requires that a pilot work no more than three successive circadian low periods. No more than 14 consecutive days.

Coos Bay Pilots Association

Pilots should have a minimum of 12.0 hours off duty following a duty period to permit an 8-hour sleep opportunity. Duty periods should be limited to 12 consecutive hours. No more than three consecutive calendar nights of duty time that infringe in any amount on the circadian low period. Schedules should not exceed 14 consecutive days during which duty time is incurred.

Source: Email from Oregon Board of Maritime Pilots, 11/9/2017

Port of Long Beach

Maximum work for 24 hour period: 15 hours

Maximum work for 72 hour period: 36 hours

Additional details: Uses Coastguard Tanker rules. In letter to NTSB, indicated that they intended to comply with STCW rules: 14 hours max per day and 72 hrs max work in 7 day period.

Source: Port of Long Beach letter to NTSB, 08/30/12.

Port of Los Angeles

"As a pilot organization with an average number of two jobs per day, an average job duration of two hours, and a 12 hour watch rotation, we do not foresee any possibility of fatigue issues."

Source: Port of Los Angeles response to NTSB letter, 03/05/13.

Puerto Rico

8 hours continuous rest, excluding travel time in each 24 hour period while on watch.

Additional details: "Pilot schedules are to be set in such a manner as to minimize disruption to circadian rhythm. As far as is practicable, pilot watches are to follow a consistent pattern in order to avoid changing sleep schedules."

Source: Puerto Rico Pilot Commission letter to NTSB, 05/29/15.

Rhode Island
Rhode Island State Pilotage Commission: Max 16 hours work in 24 hour period. No more than 4 vessels in 16 hour period. 9 hours rest in a 24 hour period.
Source: Rhode Island State Pilotage. (2016, April 7).

San Diego
Minimum rest for 24 hour period: 10 hours
Port pilots’ hours-of-service comply with the 2010 amendment of STCW Convention and US Coast Guard Policy Letter No. 12-05.
Source: Port of San Diego letter to NTSB, 05/23/13.

Virginia
Maximum work for 24-hour period: 12 hours
Additional details: Pilots work two weeks on, two weeks off. Cannot take more than 2 ships as part of a rotation.
Source: NTSB summary of Virginia pilot working rules 09/16/15.

Washington
State requirement: Piloting job of 7 hours or more must be followed by a rest period of at least 7 hours. Puget Sound Pilots: 6 hours of mandatory rest at home after a transit that ends at port (travel and preparation time does not count as rest), or 8 hours rest after transits ending at the pilot station. Assignments lasting over 8 hours require two pilots, either changeover mid-voyage or 2 pilots on board who work in sequence.
Additional details: Puget Sound Pilots work a two watch system of rotation in which pilots work a shift and then have an off-duty shift of approximately the same length.
Source: State letter to NTSB 01/31/12.

United States Coast Guard, Great Lakes Pilotage

Population: Pilots operating on the Great Lakes

Pilot rest periods. (a) Except as provided in paragraph (b) of this section: (1) Each Registered Pilot upon completing an assignment at a change point designated in §401.450, and (2) Each Registered Pilot upon completing a series of assignments totaling more than 10 hours with no more than 2 hours rest between assignments, shall not perform pilotage services for at least 10 hours. (b) In the event of an emergency or other compelling circumstances a pilotage pool may assign a Registered Pilot for service before his 10-hour rest period required under paragraph (a) of this section is completed.

Source: 46 C.F.R. § 401.451 (2018) (Great Lakes Pilotage)

Australia

No specific hours of service limits are specified.

Minimum rest period after voyages: 12 hours or 24 hours, depending on the route.

Fatigue risk management plan specifies maximum number of days of service without a break, and minimum rest days that must be taken. During a roster period, pilots accrue points according to voyages. Pilot must receive a break when points accrue to a threshold level. Full details can be found in the document referenced below.

Population: Maritime pilots and all pilotage providers that hold a license issued by the Australian Maritime Safety Authority (AMSA).

Additional details: Australian Maritime Safety Authority (AMSA) is an Australian federal agency, and only regulates pilots operating near the Great Barrier Reef. Other pilots work under rules of individual Australian states.

Source: Australian Maritime Safety Authority (AMSA), Fatigue Risk Management Plan. In support of Marine Order 54 (Coastal pilotage) 2014 (MO54).

Appendix 4. Hours of Service Standards for a Range of Safety-critical Work Environments

<table>
<tr><th colspan="2">Airline Pilots</th></tr>
<tr><td>Maximum flight duty period: 14 hours*</td><td>Maximum work for 7 day period: 60 hours</td></tr>
<tr><td>Minimum rest for 24 hour period: 10 hours**</td><td>Minimum rest for 7 day period: 30 consecutive hours</td></tr>
<tr><td colspan="2">Population: Airline pilots</td></tr>
<tr><td colspan="2">* 14 hour limit applies only to duty periods commencing between 7:00 and 11:59 and involving only one flight segment. Lower limits (as low as 9 hours) apply to duty periods commencing outside these times, and those involving multiple flight segments. Longer limits apply when a pilot can be replaced by another qualified flightcrew member for in-flight rest.</td></tr>
<tr><td colspan="2">** Including 8 hours of uninterrupted sleep opportunity (117.25 e)</td></tr>
<tr><td colspan="2">Additional Details: The regulation applies scientific principles to the management of fatigue. As well as specifying flight and duty times in various circumstances, the regulation deals with consecutive night time operations, split duty, the timing of rest opportunities and circadian influences.</td></tr>
<tr><td colspan="2">Source: 14 C.F.R. § 117 (2018) (Flight and Duty Time limitations for Flightcrew).</td></tr>
</table>

<table>
<tr><th colspan="2">Aviation Maintenance (recommendations)</th></tr>
<tr><td>Maximum work for 24 hour period: 12 hours</td><td>Maximum work for 7 day period: 72 hours</td></tr>
<tr><td>Minimum rest for 24 hour period: 9 hours</td><td>Minimum rest for 7 day period: 48 hours</td></tr>
<tr><td colspan="2">Population: Maintenance organizations and individuals involved in maintenance and certification.</td></tr>
<tr><td colspan="2">Additional Details: Recommendations, not requirements</td></tr>
<tr><td colspan="2">Source: Jauregui & Hosey (2007).</td></tr>
</table>

<table>
<tr><th colspan="2">Air Traffic Controllers</th></tr>
<tr><td>Maximum work for 24 hour period: 10 hours</td><td>Maximum work for 7 day period: N/A</td></tr>
<tr><td>Minimum rest for 24 hour period: 8* hours</td><td>Minimum rest for 7 day period: 24 consecutive hours</td></tr>
<tr><td colspan="2">Population: Air traffic control specialists whose primary duties are those directly related to the control and separation of aircraft.</td></tr>
<tr><td colspan="2">Additional Details: *9 hours required preceding day shift; 12 hours off minimum following a midnight shift; Changes implemented in 2015</td></tr>
<tr><td colspan="2">Source: 14 C.F.R. § 65.47 (2018) (Air Traffic Control Duty Periods) & Air Traffic Organization Policy, Joint Order 7210.3Z, December 10, 2015. US Department of Transportation/Federal Aviation Administration (Federal Aviation Administration 2015)</td></tr>
</table>

United States Air Force

Maximum work for 24 hour period: 16* hours

Maximum work for 7 day period: 56** hours

Minimum rest for 24 hour period: N/A

Minimum rest for 7 day period: N/A

Population: USAF pilots, and other pilots involved in the operation of USAF aircraft (manned and unmanned).

Additional Details: Limits Flight hours, specifically. *Maximum work for 24 hour period varies based on aircraft type, with 16 hours being the extreme. **FDP may be waived by MAJCOM/A3 when an ORM assessment determines that mission requirements justify the increased risk. When authorized by the waiver authority, the PIC may extend FDP a maximum of 2 hours to compensate for mission delays. Cockpit rest shall be limited to 45 minutes, taken by only one crewmember at a time, and must be restricted to non-critical phases of flight between cruise and one hour prior to planned descent. Maximum flying time: 125 flight hours per 30 consecutive days, and 330 flight hours per 90 consecutive days.

Source: United States Air Force (2016).

Nuclear Power Plant Operators

Maximum work for 24 hour period: 16 hours

Maximum work for 7 day period: 72 hours

Maximum work for 48 hour period: 26 hours

Minimum rest for 7 day period: 24 hours**

Minimum break between work periods: 10 hours*

* Break can be 8 hours when a break of less than 10 hours is necessary to accommodate a crew's scheduled transition between work schedules or shifts.

** For individuals working 8 hour shift schedules. Individuals working longer shift schedules receive more minimum time off per week.

Additional Details: Text above is a summary. The text of 10 CFR § 26.205 contains significantly more detailed provisions.

Source: 10 C.F.R. § 26.205 (2008). Work Hours. (Nuclear power plant operators).

Medical Residents

Accreditation Council for Graduate Medical Education (2017)

Maximum work for 24 hour period: 24* hours

Maximum work for 7 day period: 80† hours

Minimum rest after a 24 hour work period: 14 hours

Minimum rest for 7 day period: 24† hours

Population: Medical Residents (United States)

Additional Details: Up to 4 hr of additional time may be used for activities related to patient safety, such as transitions of care, and/or resident education.

† May be averaged over a four week period.

Source: ACGME Common Program Requirements (2017)

Commercial Drivers	
Maximum work for 24 hour period: 14* hours	Maximum work for 7 day period: 60** hours
Minimum rest for 24 hour period: 10 hours	Minimum rest for 7 day period: 34 hours
Population: property-carrying commercial motor vehicle drivers	
Additional Details: *11 hour limit for driving. **70 hour limit over 8 days.	
Source: 49 C.F.R § 395 (2018) (Hours of service for commercial motor vehicle drivers).	

Railroad Personnel	
Maximum work for 24 hour period: 12* hours	Maximum work for 7 day period: N/A
Minimum rest for 24 hour period: 10 hours	Minimum rest for 7 day period:
Population: Officers and agents of railroad carrier	
Additional Details:*Maximum of 276 duty hours per calendar month. In most cases, maximum of 6 consecutive days, but may be 7 consecutive days in some circumstances.	
Source: 49 U.S.C. § 21103 (2018). (Rail Safety Improvement Act).	

Appendix 5. Bar Pilot Fatigue Surveys

Fatigue Factors Survey for San Francisco Bar Pilots

This voluntary, anonymous survey will gather your views on factors that contribute to workplace fatigue, such as schedules, sleep patterns, and workplace experiences.

The survey should take about 25 minutes to complete.

Your input will be analyzed by researchers at San Jose State University Research Foundation and NASA/Ames Research Center.

You may skip questions you don't want to answer and you can stop taking the survey at any time. All results will be reported in the aggregate and there is only a remote risk that personal data could become identifiable.

Your input in this research effort is extremely valuable, and your participation is very much appreciated.

If you have any questions or issues related to completing the survey please feel free to contact Alan Hobbs at the NASA Ames Research Center.

Alan Hobbs, Ph.D.
alan.hobbs@nasa.gov
(650) 604-1336

Definitions

In this survey, the following definitions are used:

On call	A week or weeks during which you are available for pilotage ("on watch" or "on the Board")
Off call	A week or weeks during which you are not available for pilotage ("off watch" or "off the Board")
Work period	The time from when you arrive at Pier 9 (or equivalent) to start your assignment, to Bottom of Board (BOB) time when you return to Pier 9 (or equivalent) before your rest period
Minimum rest period (MRP)	The recommended 12 hour minimum rest period starting after BOB between work periods
Rest period	The time from the BOB to when you are next requested for pilotage (the rest period includes the MRP but can extend beyond the MRP)

Background Information

1. Which of the following groups do you belong to?
   - ☐ Group 1 (work every other week)
   - ☐ Group 2 (work every other week)
   - ☐ Group 3 (2 weeks on, 2 weeks off)

2. What types of San Francisco Bar Pilot lists are you on?
   - ☐ Flat tow
   - ☐ E-pilot
   - ☐ Passenger ship docking
   - ☐ SAC pilot
   - ☐ SCK pilot
   - ☐ State mandated Continuing Professional Development

Sleep Schedules

3. About how many hours of sleep do you feel you need in a 24-hour period, irrespective of whether you are on call or not?

☐ less than 5
☐ 5-6 hrs.
☐ 6-7 hrs.
☐ 7-8 hrs.
☐ 8-9 hrs.
☐ 9-10 hrs.
☐ 11 hrs. or more

4. During the past year, about how many times have you had an MRP exception (less than 12 hours MRP)?

☐ never
☐ 1-2 times
☐ 3-4 times
☐ 5-7 times
☐ 8-10 times
☐ 11 times or more
☐ Don't know

Comments?

5. When on call, what is the *average* one-way commute time from where you sleep to your job assignment?

☐ 15 min. or less
☐ 15 min. to <30 min.
☐ 30 min. to <45 min.
☐ 45 min. to <1 hr.
☐ 1 hr. to <1 hr. 15 min.
☐ 1 hr. 15 min. to <1 hr. 30 min.
☐ 1 hr. 30 min. to < 1 hr. 45 min.
☐ 1 hr. 45 min. to <2 hrs.
☐ 2 hrs. or more

Comments?

Stability of Schedules When On Call

6. How *consistent* are your work and rest period schedules when you are on call, i.e., start times are approximately the same each day?

	Rarely consistent *1*	*Sometime s consistent* *2*	*Consistent about half the time* *3*	*Usually consistent* *4*	*Nearly always consistent* *5*
Work period start times	○	○	○	○	○
Rest period start times	○	○	○	○	○

Comments?

7. How accurate are the schedules that appear <u>10 hours ahead of time</u>?

	Rarely accurate *1*	*Sometime s accurate* *2*	*Accurate about half the time* *3*	*Usually accurate* *4*	*Nearly always accurate* *5*
Ship assignment	○	○	○	○	○
Time assignment	○	○	○	○	○

Comments?

8. How accurate are the schedules that appear <u>4 hours ahead of time</u>?

	Rarely accurate *1*	*Sometime s accurate* *2*	*Accurate about half the time* *3*	*Usually accurate* *4*	*Nearly always accurate* *5*
Ship assignment	○	○	○	○	○
Time assignment	○	○	○	○	○

Comments?

9. Has the recent policy of requiring ships to order a pilot 8 hours ahead of time (instead of 4) when departing between 1800 and 0600, improved your ability to sleep?

Not at all *1*	*2*	*Somewhat* *3*	*4*	*Very much* *5*	*Don't know*
○	○	○	○	○	○

Quality of Sleep

10. When you are *on call*, how often does the following occur?

	Never *1*	*Rarely* *2*	*About half the time* *3*	*Usually* *4*	*Always/ nearly always* *5*
You are unable to sleep when you want to.	○	○	○	○	○
You wake up in the middle of your sleep period.	○	○	○	○	○
You wake up earlier than you want to.	○	○	○	○	○

11. When you are *off call*, how often does the following occur?

	Never *1*	*Rarely* *2*	*About half the time* *3*	*Usually* *4*	*Always/ nearly always* *5*
You are unable to sleep when you want to.	○	○	○	○	○
You wake up in the middle of your sleep period.	○	○	○	○	○
You wake up earlier than you want to.	○	○	○	○	○

12. On *average*, how rested do you feel after your main sleep period when you are _on call_ vs. _off call_?

	Definitely not rested 1	*Not very rested 2*	*Moderately rested 3*	*Quite rested 4*	*Fully rested 5*
On call	○	○	○	○	○
Off call	○	○	○	○	○

13. When you are *on call*, how rested do you typically feel if you start your work period at these times?

Start work period at	*Definitely not rested 1*	*Not very rested 2*	*Moderately rested 3*	*Quite rested 4*	*Fully rested 5*
0200	○	○	○	○	○
0400	○	○	○	○	○
0600	○	○	○	○	○
0800	○	○	○	○	○
1000	○	○	○	○	○
1200	○	○	○	○	○
1400	○	○	○	○	○
1600	○	○	○	○	○
1800	○	○	○	○	○
2000	○	○	○	○	○
2200	○	○	○	○	○
2400	○	○	○	○	○

14. Do you have trouble sleeping for any of the following reasons both when *on call* or *off call*? {Choose all that apply}

Trouble sleeping due to	*When on call*	*When off call*
Keyed up, can't relax	○	○
Desire to smoke	○	○
Cannot breathe comfortably	○	○
Hunger	○	○
Amount of caffeine ingested	○	○
Worry/anxiety	○	○
Sleep disorders	○	○
Need to urinate	○	○
Gastrointestinal problems	○	○
Allergies	○	○
Other health issues	○	○
Inconsistent schedule	○	○
Disturbed by partners/children/pets	○	○
Disturbed by work-related calls (e.g., dispatch)	○	○
Disturbed by outside noise, light, temperature, etc.	○	○
Other (please describe below)	○	○

Other_______________________________

15. About how many servings of caffeine (e.g., coffee, tea, soda, energy drinks, NoDoz, etc.) do you typically have in a 24-hour period when you are *on call* and when you are *off call*?

	None	*1-2 servings*	*3-4 servings*	*5-8 servings*	*≥9 servings*
On call	○	○	○	○	○
Off call	○	○	○	○	○

Comments?

Naps

Naps are brief sleeps in addition to your main sleep. Naps can range from a brief sleep in bed, to a brief sleep while sitting as a passenger in a boat or a car.

16. When you have the *opportunity* to take a nap during breaks in your work period, about how often do you do so if you are in the following places?

Taking naps	*Never* *1*	*Sometimes* *2*	*About half the time* *3*	*Usually* *4*	*Always/nearly always* *5*
Pier 9	○	○	○	○	○
Pilot boat	○	○	○	○	○
Van (taxi)	○	○	○	○	○
Offshore pilot station	○	○	○	○	○
On board ship	○	○	○	○	○
Normal on-call sleeping place	○	○	○	○	○
Other (please describe below)	○	○	○	○	○

Other ___________________________________

17. How rested do you feel after napping in the following locations?

Rested after naps	*Definitely not rested* *1*	*Not very rested* *2*	*Moderatel y rested* *3*	*Quite rested* *4*	*Fully rested* *5*	*NA*
Pier 9	○	○	○	○	○	○
Pilot boat	○	○	○	○	○	○
Van (taxi)	○	○	○	○	○	○
Offshore pilot station	○	○	○	○	○	○
On board ship	○	○	○	○	○	○
Normal on-call sleeping place	○	○	○	○	○	○
Other (please describe below)	○	○	○	○	○	○

Other ___________________________________

Comments?

Sleep Inertia

Sleep inertia is the period of fogginess or confusion that can be present immediately after one wakes up from sleep or from a nap.

18. When you are *on call*, just after *you wake up from sleep or from a nap*, to what extent do you . . .

	Not at all 1	*A little 2*	*Somewhat 3*	*Often 4*	*All the time 5*
Notice that your mind feels groggy, fuzzy or hazy?	○	○	○	○	○
Find that you think more slowly?	○	○	○	○	○
Notice that it is difficult to keep your balance?	○	○	○	○	○
Have difficulty getting your thoughts together?	○	○	○	○	○

19. If you experience sleep inertia, about how much time do you typically need after awakening from sleep or a nap until the symptoms disappear? _____ minutes.

Comments?

20. If you feel stressed when you are *on call*, to what extent do the following contribute to your stress?

Possible contributors to stress	*Does not contribute to stress 1*	*2*	*Somewhat contributes to stress 3*	*4*	*Very much contributes to stress 5*
Unpredictable work schedule	○	○	○	○	○
Uncertainty about weather	○	○	○	○	○
Time spent on the offshore pilot station	○	○	○	○	○
Responsibility for safety	○	○	○	○	○
Your own safety while embarking a vessel at sea	○	○	○	○	○
Your own safety while disembarking a vessel at sea	○	○	○	○	○
Piloting during reduced visibility conditions (fog)	○	○	○	○	○
Piloting at night	○	○	○	○	○
Approaching the dock	○	○	○	○	○
Docking a ship	○	○	○	○	○
Piloting a 1200 foot vessel	○	○	○	○	○
Piloting a 1200 foot vessel in variable wind	○	○	○	○	○
Relations with co-workers	○	○	○	○	○
Workload	○	○	○	○	○
Work/life balance	○	○	○	○	○
Attitudes and philosophy of the Commission (BOPC)	○	○	○	○	○
Other (please describe below)	○	○	○	○	○

Other____

21. What is the level of stress involved when piloting a 1200 foot vessel during a Bay Move in each of the following conditions?

Conditions	*Almost no stress 1*	*2*	*Moderate stress 3*	*4*	*Substantial stress 5*	*NA/Don't know*
The day in clear weather	○	○	○	○	○	○
The night in clear weather	○	○	○	○	○	○
The day when moderate to high winds may be encountered	○	○	○	○	○	○
The night when moderate to high winds may be encountered	○	○	○	○	○	○

Sleep Scales

Epworth Scale

22. When you are on call, how likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?

	No chance of dozing 1	*Slight chance of dozing 2*	*Moderate chance of dozing 3*	*High chance of dozing 4*
Sitting and reading	○	○	○	○
Watching TV	○	○	○	○
Sitting inactive in a public place (e.g., a theater or a meeting)	○	○	○	○
As a passenger in a car or boat for an hour without a break	○	○	○	○
Lying down to rest in the afternoon when circumstances permit	○	○	○	○

(continued)	*No chance of dozing* *1*	*Slight chance of dozing* *2*	*Moderate chance of dozing* *3*	*High chance of dozing* *4*
Sitting and talking to someone	○	○	○	○
Sitting quietly after a lunch without alcohol	○	○	○	○
Driving a car, while stopped for a few minutes in traffic	○	○	○	○

23. In general, are you more likely to doze off when you are *on call* than when you are *off call*?

Much more likely to doze off when off call *1*	*2*	*About the same* *3*	*4*	*Much more likely to doze off when on call* *5*
○	○	○	○	○

Modified Brief Fatigue Inventory

24. When you have recently been *on call*, to what extent has fatigue interfered with your . . .

	Not at all *1*	*2*	*Somewhat* *3*	*4*	*Very much* *5*	*NA/Don't know*
Activity level	○	○	○	○	○	○
Mood	○	○	○	○	○	○
Work	○	○	○	○	○	○
Chores	○	○	○	○	○	○
Relationships	○	○	○	○	○	○
Work schedule	○	○	○	○	○	○
Work/life balance	○	○	○	○	○	○
Enjoyment of life	○	○	○	○	○	○

25. In general, do you feel more fatigued when you are on call or off call?

Much more fatigued when off call 1	*2*	*About the same 3*	*4*	*Much more fatigued when on call 5*
○	○	○	○	○

Shiftwork Scale

26. In the past month, when you have been *on call*, did you have a problem with waking up too early and not being able to get back to sleep?

No problem 1	*Minor problem 2*	*Considerable problem 3*	*Serious problem 4*
○	○	○	○

27. In the past month, when you have been *on call*, your *sense of well-being during the time you were awake* was . . .

Normal 1	*Slightly decreased 2*	*Somewhat decreased 3*	*Very decreased 4*
○	○	○	○

28. In the past month, when you have been *on call*, how likely were you *to doze off at work*?

Not at all 1	*Slight chance 2*	*Moderate chance 3*	*Highly likely 4*
○	○	○	○

29. In the *past month*, how likely were you to *doze off or fall asleep* while driving?

Not at all 1	*Slight chance 2*	*Moderate chance 3*	*Highly likely 4*	*Not applicable 5*
○	○	○	○	○

Current Scheduling Practices and Staffing

30. Please indicate the extent to which you feel the following aspects of current bar pilot scheduling practices are at about the right level to support your <u>optimal</u> alertness. If not at the right level, please write a better, *though still realistic*, length in the far right column.

Optimum alertness	*Very much too short 1*	*Too short 2*	*About right 3*	*Too long 4*	*Very much too long 5*	*Ideal length*
The 12 hour work period	○	○	○	○	○	
The 8 hour work period during circadian low (when doing special operations such as multiple bay moves)	○	○	○	○	○	
The recommended 12 hour minimum rest period	○	○	○	○	○	
The 10 hour additional rest periods for river pilotage (held out time)	○	○	○	○	○	
The 7-day work week	○	○	○	○	○	
Other (please describe below)	○	○	○	○	○	

Other__________________________________

Comments?

31. To what extent do work period start times between 1800 and 0600 decrease your optimum alertness?

1 Not at all	*2*	*3 Somewhat*	*4*	*5 Very much*	*NA/Don't know*
○	○	○	○	○	○

Comments?

32. Please indicate the extent to which you feel the current staffing level is about right (60 bar pilots) to support your *optimal* alertness.

	1 Not nearly enough pilots	*2 Not enough pilots*	*3 About right*	*4 Too many pilots*	*5 Way too many pilots*	*Don't know*
Staffing levels	○	○	○	○	○	○

If *not* "About right," how many bar pilots would you like to see?____________

Comments?

33. What is the maximum number of consecutive days that you feel that you could be on call and still maintain the required alertness for your job?

☐ 5 days
☐ 6 days
☐ 7 days
☐ 8 days
☐ 9 days
☐ 10 days
☐ 11 days
☐ 12 days
☐ 13 days
☐ 14 days
☐ 15 days
☐ 16 days
☐ 17 days
☐ 18 days
☐ 19 days
☐ 20 days
☐ 21 days or more

Alertness

34. Please rate how mentally sharp (e.g., alertness, memory) you would typically be at the BEGINNING and END of the two work periods shown below, Work Period #1 and Work Period #2.

Work Period #1 (from 1000 to 2200)	*Not at all sharp 1*	*2*	*Moderately sharp 3*	*4*	*Very sharp 5*
At the beginning (1000)	○	○	○	○	○
At the end (2200)	○	○	○	○	○

Work Period #2 (from 0200 to 1400)	*Not at all sharp 1*	*2*	*Moderately sharp 3*	*4*	*Very sharp 5*
At the beginning (0200)	○	○	○	○	○
At the end (1400)	○	○	○	○	○

Fatigue and Incidents

35. In your experience, which piloting tasks are most sensitive to the effects of fatigue?

36. Have you had any close calls or incidents in the last year?

☐ Yes
☐ No

If yes, do you believe that your own fatigue contributed?

☐ Yes
☐ No
☐ N/A

If you believe fatigue contributed to any close calls or incidents, please indicate what you believe *caused* your fatigue. (Check all that apply.)

☐ Workload
☐ Family
☐ Work schedule
☐ Health
☐ Commute
☐ Personal problems
☐ N/A
☐ Other ___________________________________

Additional Activities

37. Do you have a second paid job in addition to your bar pilot job?

☐ Yes
☐ No

If yes, for about how many hours a week when you are off call do you work this second job?

☐ N/A
☐ less than 5 hrs.
☐ 5-9 hrs.
☐ 10-14 hrs.
☐ 15-19 hrs.
☐ 20-24 hrs.
☐ 25-29 hrs.
☐ ≥30 hrs.

38. How disruptive to your sleep is the overseas travel required for the manned model training?

Not at all disruptive 1	*2*	*Moderately disruptive 3*	*4*	*Very disruptive 5*
○	○	○	○	○

39. To what extent is this disruption lessened by being able to sleep comfortably on the plane?

Not at all lessened 1	*2*	*Moderately lessened 3*	*4*	*Very much lessened 5*
○	○	○	○	○

Job Satisfaction

40. Please indicate the extent to which you agree or disagree with the following statements.

	Strongly disagree *1*	*Disagree* *2*	*Slightly disagree* *3*	*Neither agree nor disagree* *4*	*Slightly agree* *5*	*Agree* *6*	*Strongly agree* *7*
Generally speaking, I am satisfied with my job.	○	○	○	○	○	○	○
I frequently think of quitting.	○	○	○	○	○	○	○

41. Please indicate your level of satisfaction or dissatisfaction with the following aspects of your job.

Aspects of job	*Very dissatisfied* *1*	*Somewhat dissatisfied* *2*	*Neither satisfied nor dissatisfied* *3*	*Somewhat satisfied* *4*	*Very satisfied* *5*
Type of work	○	○	○	○	○
Workload	○	○	○	○	○
Work/life balance	○	○	○	○	○
Influence on health & well-being	○	○	○	○	○
Consistency of work start times	○	○	○	○	○
Consistency of sleep times	○	○	○	○	○
Predictability of schedule	○	○	○	○	○
Eating patterns	○	○	○	○	○
Effects of work schedule on social/family life	○	○	○	○	○
Financial compensation	○	○	○	○	○
Time participating in meetings and committees	○	○	○	○	○
Level of support from co-workers	○	○	○	○	○

Aspects of job (continued)	*Very dissatisfied 1*	*Somewhat dissatisfied 2*	*Neither satisfied nor dissatisfied 3*	*Somewhat satisfied 4*	*Very satisfied 5*
Quality of sleep on the offshore pilot station	○	○	○	○	○
Quality of sleep during daytime rest periods	○	○	○	○	○
Number of work start times between 1800 and 0600	○	○	○	○	○
Commute time during the work week	○	○	○	○	○
Other (please describe below)	○	○	○	○	○

Other____________________________

Time Off when Fatigued?

42. How often, in the last year, have you tried to find a substitute because you were fatigued?

0 times	*1-2 times*	*3-5 times*	*6-10 times*	*10+ times*	*NA/Don't know*
○	○	○	○	○	○

Summing Up

43. How often does the following occur?

	Never *1*	*Rarely* *2*	*Sometimes* *3*	*Frequently* *4*	*Usually* *5*	*NA/Don't know*
Fatigue affects my general health and well-being.	○	○	○	○	○	○
I experience fatigue when at work.	○	○	○	○	○	○
Fatigue affects my ability to perform my job effectively.	○	○	○	○	○	○
I see bar pilots who are fatigued at work.	○	○	○	○	○	○
Fatigue affects the ability of bar pilots to perform their job effectively.	○	○	○	○	○	○

44. To what extent do you believe that the current level of fatigue experienced by bar pilots as a whole, represents a safety risk?

No risk *1*	*Slight risk* *2*	*Moderate risk* *3*	*High risk* *4*	*Extreme risk* *5*	*NA/Don't know*
○	○	○	○	○	○

Comments?

Reducing Fatigue: What could Help?

45. What suggestions do you have on ways that the Bar Pilot Commission could reduce fatigue?

46. What advice would you give a new pilot on managing their fatigue?

47. Would you like more training or information on ways to reduce or manage fatigue?
- ☐ Yes
- ☐ Possibly
- ☐ No

Additional Background Information

48. What is your approximate age?
- ☐ 30-39
- ☐ 40-49
- ☐ 50-59
- ☐ ≥60

49. How many years have you been a bar pilot?
- ☐ Less than 1
- ☐ 1-4
- ☐ 5-9
- ☐ 10-19
- ☐ 20-29
- ☐ ≥30

50. How many years have you been affiliated professionally with ship navigation (includes military)?
- ☐ less than 1
- ☐ 1-4
- ☐ 5-9
- ☐ 10-19
- ☐ 20-29
- ☐ ≥30

General Comments

51. Is there anything else you think we should know? If so, please describe here.

One last thing: We will be distributing a two page follow-up survey this winter with a few questions on seasonal factors. To enable us to anonymously link the current survey to the follow-up survey, we ask that you enter a code below, which you can also put on the follow-up survey. For a code that only you will know, we suggest the first two letters of the month your mother was born followed by the first two letters of her first name, e.g., 03GL.

Code: ____________

Thank you for contributing your valuable time to complete this survey!

Final Fatigue Factors Survey for San Francisco Bar Pilots

This brief survey is a follow-up to the fatigue survey that you received last year. To detect seasonal variation, it repeats several questions from the earlier survey. This survey is voluntary and anonymous. It should take under 10 minutes to complete.

We would appreciate responses by April 6, 2018.

There are two ways you can complete this survey:

- Fill out this paper version and return it in the pre-addressed envelope, or

- Complete the survey on-line at http://tinyurl.com/BarPilotFinalSurvey

Identifying information such as IP or email addresses will not be recorded.
You may skip questions you don't want to answer and you can stop taking the survey at any time. All results will be reported in the aggregate and there is only a remote risk that personal data could become identifiable.

Your input in this research effort is extremely valuable, and your participation is very much appreciated.

If you have any questions or issues related to this study please feel free to contact Alan Hobbs at the NASA Ames Research Center, alan.hobbs@nasa.gov, Ph: (650) 604-1336.

Definitions

In this survey, the following definitions are used:

On call	A week or weeks during which you are available for pilotage ("on watch" or "on the Board")
Off call	A week or weeks during which you are not available for pilotage ("off watch" or "off the Board")

1. When you are on call, how likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?

	No chance of dozing *1*	*Slight chance of dozing* *2*	*Moderate chance of dozing* *3*	*High chance of dozing* *4*
Sitting and reading	○	○	○	○
Watching TV	○	○	○	○
Sitting inactive in a public place (e.g., a theater or a meeting)	○	○	○	○
As a passenger in a car or boat for an hour without a break	○	○	○	○
Lying down to rest in the afternoon when circumstances permit	○	○	○	○
Sitting and talking to someone	○	○	○	○
Sitting quietly after a lunch without alcohol	○	○	○	○
Driving a car, while stopped for a few minutes in traffic	○	○	○	○

2. When you have recently been *on call*, to what extent has fatigue interfered with your . . .

	Not at all *1*	*2*	*Somewhat* *3*	*4*	*Very much* *5*	*NA/Don't know*
Activity level	○	○	○	○	○	○
Mood	○	○	○	○	○	○
Work	○	○	○	○	○	○
Chores	○	○	○	○	○	○
Relationships	○	○	○	○	○	○
Work schedule	○	○	○	○	○	○
Work/life balance	○	○	○	○	○	○
Enjoyment of life	○	○	○	○	○	○

3. In the past month, when you have been *on call*, did you have a problem with waking up too early and not being able to get back to sleep?

No problem *1*	*Minor problem* *2*	*Considerable problem* *3*	*Serious problem* *4*
○	○	○	○

4. In the past month, when you have been *on call*, your *sense of well-being during the time you were awake* was . . .

Normal *1*	*Slightly decreased* *2*	*Somewhat decreased* *3*	*Very decreased* *4*
○	○	○	○

5. In the past month, when you have been *on call*, how likely were you *to doze off at work*?

Not at all *1*	*Slight chance* *2*	*Moderate chance* *3*	*Highly likely* *4*
○	○	○	○

6. In the *past month*, how likely were you to *doze off or fall asleep* while driving?

Not at all *1*	*Slight chance* *2*	*Moderate chance* *3*	*Highly likely* *4*	*Not applicable* *5*
○	○	○	○	○

Sleep Inertia

Sleep inertia is the period of fogginess or confusion that can be present immediately after one wakes up from sleep or from a nap.

7. If you experience any sleep inertia on call, where and when is it most noticeable? *e.g., after a nap or your main rest period, time of day, location etc.?*

Continued next page …

8. Please describe any seasonal variation in your work that affects your level of alertness when on call.

9. Is there anything else you think we should know?

One last thing: Almost all of you gave us a code on the first survey, which we would like to link anonymously with this survey. Can you re-enter this code now? The hint for a possible code on the first survey was "the first two letters of the month your mother was born followed by the first two letters of her first name, e.g., 03GL."

Code: _____________

Thank you for contributing your valuable time to complete this survey!