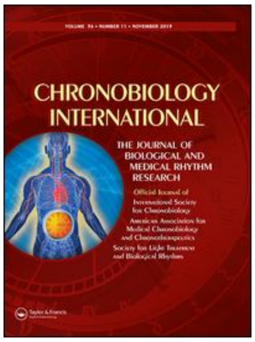

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SELECTED PROCEEDINGS: SHIFTWORK 2019

An evaluation of fatigue factors in maritime pilot work scheduling

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ABSTRACT
Maritime piloting operations involve on-call work schedules that may lead to sleep loss and circadian misalignment. Our study documented pilot work scheduling practices (n = 61) over a one-year period. Most pilots worked a week-on/week-off schedule. Work periods averaged 7.6 hours in duration and pilots worked up to four ship assignments during a given work period. Work weeks averaged a total of 35.0 hours with pilots working on average three consecutive days. Night work was common (19.0 hours/week) with 02:00 h the most common starting hour for a work period. On-call work periods occurred at irregular times with a high degree of start time variability between consecutive work periods. While typical individual and weekly work total hours were not high, there were instances with long work periods, minimal rest opportunities, and extended total weekly work hours. Fatigue-model predictions based on work schedules were similar to objective outcomes collected among other groups of maritime pilots and may prove useful in identifying potential fatigue risks within on-call work schedules. Future studies should be conducted using objective measures to provide further insight on how on-call maritime operations influence sleep timing, alertness, and performance.

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Marine pilots; shift work; on-call work; fatigue

Introduction

Fatigue and its impact on worker performance and safety have been documented in many shiftwork and transportation settings (Lombardi et al. 2010; Marcus and Rosekind 2017; Uehli et al. 2014; Williamson et al. 2011). Fatigue is recognized as a significant safety issue in the transportation industry, acknowledged by Australian, Canadian, and the United States (US) transport safety agencies as a safety priority for all modes of transportation (Crosby 2000; National Transportation Safety Board 2019; Transportation Safety Board of Canada 2019). Maritime piloting operations involve on-demand work schedules that can lead to sleep loss and circadian misalignment, which may affect pilot performance and operational safety. A study of St. Lawrence River pilots found them working at varying times around the clock and averaging less than 6 h of sleep during their on-call periods. Performance measures varied by time of day and were degraded during longer work periods, especially for those that included night work and ended during early morning hours (Boudreau et al. 2018). In maritime settings, analyses have concluded that fatigue is a significant contributor to ship collisions and groundings (Akhtar and Utne 2014; Folkard 1997; McCallum et al. 1996; Starren et al. 2008). In the US, fatigue has been identified as a contributing factor in a number of prominent maritime accidents (Strauch 2015). In 2019, the International Maritime Organization issued updated guidelines for fatigue management to assist all stakeholders in the marine environment to better mitigate the safety and health risks associated with fatigue (International Maritime Organization 2019).

The San Francisco Bar Pilots have been guiding ships in and out of San Francisco Bay since 1850. Their area of operations, which involves delivering oil tankers, container ships, and cruise ships to and from seven ports, covers approximately 200 miles of shipping routes within the San Francisco, San Pablo, and Suisun Bays, as well as ports further into the interior of California, and to Monterey down the California coast to the south. Operational challenges include environmental (wind, currents, fog), physical (bridges, other marine traffic), and cognitive demands on the pilots (situational awareness, decision making, communications, and coordination, workload). The workload of the pilots varies depending on the experience of the pilot and the type of vessel that needs to transit through the Bays. All pilots perform ship movements within the San Francisco Bay. Some pilots with specific experience handle specialized tasks, such as cruise ships, river transits to the inland ports of Sacramento and

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Stockton, and, at times, act as a second "e-pilot" (relying on expertise with specialized technology) to assist with the turning of ships within the narrow confines of the Oakland Inner Harbor. A small number of pilots also perform "operations" duties, assisting with the planning and coordination of ship movements using nautical charts, tide data, and other information. Operations pilots alternate these responsibilities and may work one week a month in this capacity. One pilot acts as a Port Agent and is unavailable for ship movement assignments during the time serving in this role.

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 h/d and are listed sequentially on a moving list referred to as the "board". 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. During busy periods, names will move up the board rapidly. This system, known as a "continually rotating roster" (Rhodes and Gil 2003) or "simple turn roster" (Shipley and 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 monitor the board to anticipate the time when their next job assignment will occur. However, the timing of ship movements is frequently updated, making it difficult for pilots to plan rest periods before their work periods. The purpose of our study was to evaluate the impact of the on-call schedule on the timing and distribution of work shifts and on predicted levels of fatigue.

Methods

The research entailed the analysis of two existing databases: Bar Pilot dispatch records, and pilot responses to a survey. The research followed international ethical standards (Portaluppi et al. 2010) and was approved by the Human Subjects Institutional Review Board of San José State University (#F17065, #F16119). The research proposal was also submitted to the Human Research Institutional Review Board of NASA Ames Research Center. That review board determined that the research was exempt from the requirement for a NASA IRB approval (HR-EX-17-04). All active Bar Pilots were invited to participate in a background survey that included demographic, piloting experience, qualified piloting duties, and duty scheduling information.

Pilot work scheduling data for a 12-month period were obtained from dispatch records. These records included all work periods related to ship movements during this timeframe, with each work period involving a pilot boarding and piloting at least one vessel. The goal of this activity was to identify aspects of the pilots' 24/7 work/rest patterns that could increase the likelihood of fatigue. Information provided in the dispatch record file included pilot identifiers, work period start, and end times, "boarding" and "off time" for every job (each ship movement assignment), vessel information, and to/from locations. The clock time a pilot left the pilot station to board a vessel until the clock time the pilot returned to the station were used to define the start and end times of each work period. Up to four different jobs were possible during a given work period. Work scheduling factors that were considered for analysis were based on those identified by Rosekind (2005) and included: length and timing of work periods; length and timing of off-duty periods; consecutive days and nights of work; variability in work period start times; and recovery periods between on watch periods. Scheduling patterns were evaluated with an emphasis on time-of-day issues and working during the biological night.

Fatigue modeling

The commercially available SAFTE-FAST (Sleep, Activity, Fatigue, and Task Effectiveness-Fatigue Avoidance Scheduling Tool) modeling software package was utilized to determine predicted levels of performance relative to the dispatch work schedules (Hursh et al. 2004a). Widely used in commercial aviation, the model has been applied in an analysis of human factors-related accidents within railroad operations, another industry with an on-call board-based scheduling system (Hursh et al. 2006). A relationship was found between model estimates and accident risks, particularly related to variable and regular night work schedules. The model provides an estimate of performance based on recent work and sleep history. The model generates a primary "cognitive effectiveness" output metric that ranges from 0 to 100, where scores >90 are considered normal, and scores <65 are considered unacceptable. Given that actual sleep data for the pilots were not available, individual pilot work periods were entered into SAFTE-FAST to generate estimated sleep periods based on the model's programmed algorithms. Those algorithms account for expected bedtimes, commute time, allowable levels of minimum and maximum daily sleep, and a "forbidden zone," the daily period when an individual is not able to sleep due to the programming of human sleep/wake physiology (Lavie 1986).

For our purposes, normal bedtime was set to 23:00 h with daily minimum and maximum sleep durations of 1 and 9 h, respectively, allowing for nap and primary sleep periods. Commute time was set at 1.5 h to allow time for wake up and getting ready for work, in addition to transit time to the assignment start location. This setting was also applied to commute time following the work period. We set the daily "forbidden zone", or "no sleep", setting from 18:00 to 21:00 h to additionally reflect a time when pilots would prioritize waking activities, such as meals and family activities given their work scheduling.

All summary statistics and other reported analyses were produced using Microsoft Excel and R Studio (version 1.0.136) for Windows. The range rule was used to estimate standard deviations since access to the original complete data set was no longer possible.

Results

General information

Fifty-five pilots completed the background survey (55/59 active pilots at the time of the survey, a 93% response rate; Table 1). Sixty-three percent reported their age as ≥50 y, with over half (55%) reporting that they had worked as a Bar Pilot for ≥10 y. Three respondents reported that they had worked as a Bar Pilot for ≥30 y.

Most Bar Pilots reported working a "week on/week off" schedule in which they were on-call during their week on watch, followed by a week off. Pilots also reported on their one-way commute time to their work assignments. Most reported a commute time between 30 and 60 min, with an overall average estimated commute of 40 min (this value was used to help determine the commute time setting for the SAFTE-FAST program).

Table 1. General information from pilot respondents.

Variable	*f* (%)
Age (*n* = 54)	
30–39 y	7 (13)
40–49 y	13 (24)
50–59 y	21 (39)
≥ 60 y	13 (24)
Years worked as bar pilot (*n* = 53)	
≤4	10 (19)
5–9	14 (26)
10–19	13 (25)
≥20	16 (30)
On/Off Call Schedule (*n* = 50)	
Group 1 (1 week on/1 week off)	21 (42)
Group 2 (1 week on/1 week off)	18 (36)
Group 3 (2 weeks on/2 weeks off)	11 (22)
Types of pilot duty lists on (*n* = 40)	
E-pilot	22 (55)
Flat tow	19 (48)
Passenger ship docking	11 (28)
Stockton pilot	11 (28)
Sacramento pilot	5 (13)
Monterey pilot	1 (3)

Number of total responses (*n*) for each item are indicated. Number of respondents (percentage of responses). Group 1 and Group 2 work alternating weeks. Pilots could be on more than one type of duty list so the total responses for that item are greater than the total responses listed.

Pilot work schedules: general findings

A total of 7005 work periods from 61 Bar Pilots during the period July 2016 to June 2017 was provided for analysis, although not all those pilots worked actively for the full 12-month period due to retirements and new hires. Work that was conducted on shore, such as for meetings and other support activities performed by the operations pilots and Port Agent, was not included for this analysis.

The most total monthly work periods occurred in May, with the fewest in February. Overall, there was an average of 19.2 work periods per day.

Many work periods (38%) started during the nighttime hours, 00:00–05:59 h, with 02:00 h the most common start time (Figure 1). The most common hour when work periods ended was 07:00 h.

Pilot work schedules: work periods

The average (± standard deviation) duration of a work period was 7.6 (± 2.6) h, with 5% of work periods being >12 h. Pilots averaged 20.1 (± 8.0) h off duty between consecutive work periods (based on start time). Pilots had <12 h off 3% of the time, while 21% of off-duty periods were ≥24 h.

Pilots completed two piloting job assignments during 61% of the work periods and had one assignment during about a third (35%) of their work periods. Work periods

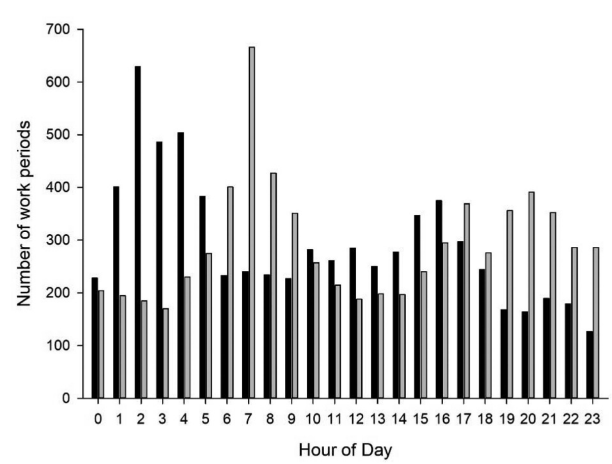

Figure 1. Work period start and end timing by hour of day. Work start times are represented by black bars; end times are represented by gray bars.

with three or four jobs accounted for 4% of all work periods. Some work periods included positioning movements in which a pilot was transported to or from the Offshore Station boat[1] prior to or following a piloting job.

Pilots averaged 3.0 (± 1.2) work days consecutively before having an off-duty period of ≥24 h. The longest consecutive period worked without such a break was 10 d. The average total work time per week was 35.0 (±13.5) h. Pilots worked ≥50 h/week 8% of the time, with a maximum of 75.1 h worked/week during the 12-month period studied. An example of the timing of work periods during a 7 d work week is presented in Figure 2.

Night shifts were defined as a work period with ≥1 h between 00:00 and 06:00 h. Overall, pilots worked about 25% of their total work hours during those night hours over the course of the 12-month period (Figure 3). On average, pilots worked 19 (± 12.0) h/week of night shift work with a maximum of 67.4 h/week.

As depicted in Figure 2, considerable variability in work period timing is common in maritime piloting

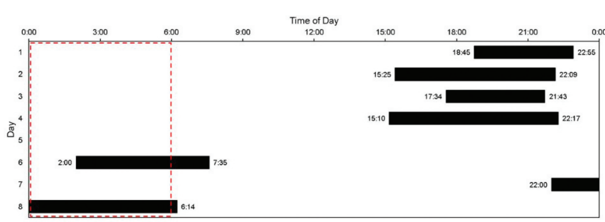

Figure 2. An example of a pilot's work schedule during a 7 d on-call period. Black bars represent work periods with the start and end times labeled to each side of the bar. This pilot worked 6 times during this period with the final two being night work periods. The first work period started at 18:45 h on d 1 and ended at 22:55 h. The final work period started at 22:00 h on d 7 and ended at 06:14 on d 8. The pilot's on-call work week started at 12:00 h on d 1 and ended at 12:00 h on d 8. The 00:00–06:00 h defined night period is highlighted by the dashed line.

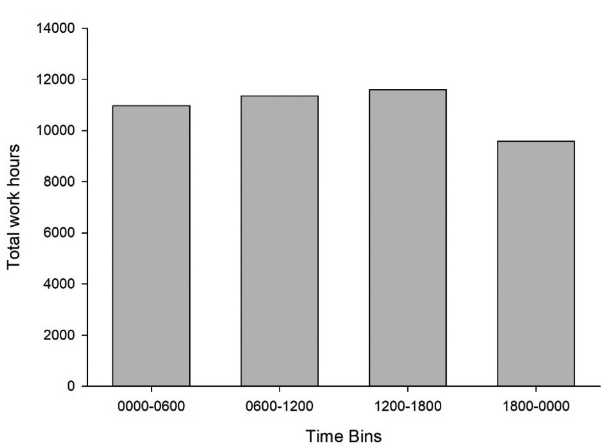

Figure 3. Total work hours per 6 h time-of-day bins.

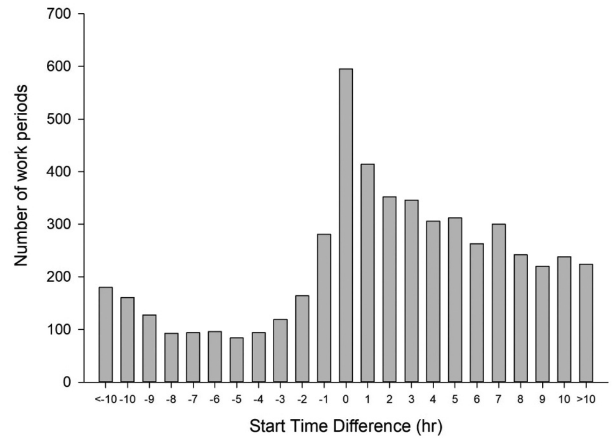

Figure 4. Differences in the start hour across consecutive work periods. A value less than 0 indicates earlier start time, whereas values greater than 0 indicate later start time.

operations. Most work periods (72%) started at the same or at a later hour than the work start time of the previous day (Figure 4). Furthermore, about a third of the consecutive work periods (34%) started within a 3 h period (±) of the previous work start time, and 8% of the start times 'flipped' the clock. i.e., work start time that varied by more than ± 10 h from the previous start time, during the studied 12-month period.

Pilot work schedules: fatigue modeling

An average effectiveness score was generated by SAFTE-FAST for every work period. About half of the work periods (52%) had an average effectiveness score of ≥90, while almost a quarter of the shifts (24%) had effectiveness scores of ≤80. Less than 1% (0.4%) of the work periods had an average effectiveness score < 70. The lowest predicted effectiveness scores were for work periods that commenced between 00:00 and 04:00 h, while daytime shifts beginning between 08:00 and 18:00 h consistently showed average effectiveness scores >90. In addition to working at night, characteristics of work periods with low effectiveness scores (<70) were variability in start time from the prior work period, a work period in the latter part of the on-call work week, days that were busy with a high number of ship assignments, and shorter prior rest periods.

Discussion

We found that the on-call scheduling procedures utilized by the San Francisco Bar Pilots resulted in pilots averaging about 35 h of work/work week, with an average work period that was about 7.6 h in duration. In some circumstances, pilots worked ≥50 h/week. A high number of work periods started during the night and most pilots rotated between day and night shifts during their on-call weeks. In some cases, the rotation of the on-call schedule led to an individual working multiple nights or led to the pilot rotating to an earlier work start time each day. The SAFTE model predicted that approximately <1% of work periods would be associated with concerning levels of fatigue.

On-call work schedules pose unique challenges to pilots in the maritime environment. The majority of work shifts that we studied were not excessive, with only 5% of shifts exceeding 12 h. However, the on-call nature of such work is a common aspect of marine pilot work, with more than half of pilot working time spent on-call (Nicol and Botterill 2004). On-call scheduling can make it difficult for individuals to plan when to sleep in order to be maximally rested before being called to work (Hall et al. 2017). Such schedules can also require mariners to sleep in environments and at times that are not conducive to sleep, which further reduces sleep quality and quantity (Torsvall and Åkerstedt 1988; Torsvall et al. 1987). These factors can also interact with personal characteristics. For example, Shipley and Cook (1980) reported that on-call periods reduced reported sleep quantity and quality, and that older marine pilots had more sleep-related difficulties than younger pilots. Given that almost two-thirds of the pilots that we studied were ≥50 y of age, this finding suggests that the Bar Pilots may experience worse sleep than has been previously reported.

Night work and irregular work start times were prevalent in the Bar Pilot schedules. Although we did not collect objective data on sleep outcomes, other studies suggest that sleep following night work would occur during the daytime and at varied and unpredictable times. Rhodes and Gil (2003) studied Canadian marine pilots and found that they slept <5 h during the daytime following a night work period. However, Bar Pilot daytime work periods may not engender improved rest opportunities either. Irregular work start times lead to changes in circadian phase and irregular sleep patterns that likely further contribute to reduced total sleep (Flynn-Evans et al. 2018; Murray et al. 2019). A study evaluating sleep in shift workers on rotating shifts (a practice that resembles the board assignment system worked by the Bar Pilots), reported <6 h of sleep following night work, which was further reduced when shift times rotated rapidly (Pilcher and Coplen 2000).

While we lacked objective performance measures from the pilots, the SAFTE model provided us with an estimated level of operational effectiveness based on individual pilot work schedules. A small number of work periods were identified with predicted performance at a level which has been associated with increased human factors-related accident risks (Hursh et al. 2006). These work periods tended to include night work and were commonly preceded by a series of work periods with variable start times and short rest periods, consistent with findings from marine operations and other work settings. A recent study examining the impact of work schedules on objective performance demonstrated that all of the factors flagged by the SAFTE model in our study were associated with reduced alertness and performance in a maritime operation similar to the operation we studied (Boudreau et al. 2018). These findings suggest that this model may be able to serve as a fatigue management tool that could identify Bar Pilot work periods with increased safety-related risks; however, additional objective measures of sleep and performance would be necessary to confirm this possibility.

Although we had access to a full year of data from a maritime pilot operation, our study is not without limitation. We were not able to collect objective sleep or performance data from the pilots in our study group. While the dispatch records dataset provided a rich insight into Bar Pilot operations, our analysis of scheduling factors was limited to a general application of principles. The SAFTE model is designed to evaluate work scheduling records such as those we used, but all such models have known limitations, including not being able to account for individual differences in resilience or vulnerability to sleep loss and circadian desynchrony (Hursh et al. 2004b). While we were able to estimate an average commute time for setting the model, Bay Area commute times can significantly vary by time of day and location. In addition, the estimated sleep periods, which provide the model's effectiveness prediction in conjunction with the known work schedule, may not properly reflect the sleep strategies utilized by this pilot group. Such strategies could include napping either on the Offshore Station boat or at the shore-based facility prior to or following ship assignments.

Our study documented Bar Pilot work scheduling practices over a one-year period. The on-call work periods of the maritime pilots occurred at irregular times, often at night. Some work periods included multiple ship assignments. While individual and weekly work total hours were not high on average, there were instances with long work periods, minimal rest opportunities, and extended weekly work hours. Fatigue-model predictions based on work schedules were similar to objective outcomes collected among other groups of pilots and may be useful to identify potential fatigue risks within on-call operations. Future studies should be conducted using objective measures to provide further insight on how on-call maritime operations influence sleep timing, alertness, and performance.

Note

1. An Offshore Station boat remains positioned about 11 miles outside of the Golden Gate to transfer pilots to and from arriving and departing ships. Pilots board ships here for movements through the Golden Gate and into the bay waterways, while pilots assigned to outbound ships disembark here and await an incoming ship.

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Declaration of interest

All authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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