Factors Contributing to Mariner Fatigue: Sleep, Environmental Conditions, Social Support and Recovery

By
Alexandra R. Duval

A Thesis Submitted to
Saint Mary's University, Halifax, Nova Scotia
in Partial Fulfillment of the Requirements for
the Degree of Masters of Science in Applied Psychology

June, 2019, Halifax, Nova Scotia

Approved: Dr. Kevin Kelloway
Supervisor

Approved: Dr. Loris Francis
Examiner

Approved: Dr. Debra Gilin
Examiner

Approved: Dr. Jane Mullen
External Examiner

Date: June 27th 2019

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Mariner fatigue is a serious issue that threatens the safety of seafarers, marine infrastructure and our environment. The aim of this study was to develop a greater understanding of the factors that contribute to mariner fatigue. Eighteen crew members (Officer and Unlicensed) on a marine replenishment vessel (i.e. tanker ship) participated in an eight-day diary study. Objective sleep measures and self-report data on fatigue, environmental conditions, social support and need for recovery were collected while at sea. Need for recovery, sea state (i.e. the size, height and power of waves as perceived by participants) and work stress were all found to significantly contribute to fatigue. None of the social support measures were found to buffer against fatigue. Sleep will remain a key contributor to fatigue, however, research on mariner fatigue needs to look beyond sleep to other factors influencing fatigue in order to develop effective fatigue countermeasures.

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Table of Contents

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Factors contributing to Mariner Fatigue: Sleep, Environmental Conditions, Social Support and Recovery

On the 13th of October 2016, the articulated tug-barge the *Nathan E. Stewart* and tanker *BBL 55* ran aground eventually sinking 10 nautical miles north west of Bella Bella, British Colombia. The investigation revealed that the second mate, who was on watch at the time of the incident, fell asleep missing a critical course change and woke when the tug struck the reef at 1:06 am. Within eight and a half hours the *Nathan E. Stewart* sank having discharged 110,000 liters of oil that were never recovered into the environment (TSBC, 2016).

Fatigue is an undeniable issue facing the marine industry today (Oldenburg, Hogan & Jensen, 2013). A review of insurance reports reveals that human error causes approximately 60% of all marine accidents with this figure surging between 80 and 90% for collisions and groundings (Project Horizon, 2012). Increasingly, fatigue is being recognized as a key contributor in marine accidents (IMO, 2019). Two marine investigation reports drafted by the Transportation Safety Board of Canada (TSBC) a decade apart highlight the shifting attitudes towards fatigue in the marine industry. The first report drafted in 2006 dedicated less than 9 full lines consideration to fatigue. The 2016 report in comparison dedicated approximately 9 pages to fatigue considerations (TSBC, 2006; TSBC, 2016). This increased awareness, however, has not led to resolution or eradication of fatigue in the marine industry. Allen, Wadsworth and Smith, (2007) highlight that International Maritime Organization (IMO) guidelines and working time directives have failed to prevent mariner fatigue. Fatigue continues to pose a threat to ships' safety, the health and well-being of seafarers, and our environment (Dohrmann & Leppin, 2017). Thus, the purpose of my research was to examine the predictors of fatigue among mariners.

Substantial research has already focused on fatigue as a risk factor in multiple transport industries including aviation, land and rail transport (Smith, Allen, & Wadsworth, 2006). While there are indisputably similarities between transport industries, unique characteristics present in the marine environment may contribute significantly and in unexpected ways to mariner fatigue. The IMO (2002) has identified three elements that both define and differentiate the seafaring environment from other work environments.

First, the average seafarer spends a substantial portion of their time every year at sea in what can be called a captive work environment. Seafarers frequently spend up to six months working and living away from home. In addition to being physically separated from their home and loved ones they are on a moving vessel, which exposes them to irregular/erratic work factors (e.g. heat, sea states, etc.; IMO, 2002). A rough sea state (i.e. the size, height and power of waves), for example, can be extremely physically taxing and requires heightened vigilance in the performance of one's duties. Due to the captive nature of this work environment these factors will impact the mariner both during work hours, and during their rest/recuperation periods, making environmental conditions important fatigue considerations.

Second, while at sea there is no tangible distinction between work and recreation (IMO, 2002). For example, while eating lunch during a “rest period” it is likely that mariners will continue to discuss their work and not actually get a respite period. Similarly, while at the gym one might be approached with “one quick question,” which results in a ten-minute work conversation. This recovery disruption could diminish the recuperative benefits of that activity and inhibit psychological detachment from work (Von Thiele Schwarz, 2011), making recovery an important fatigue consideration.

Finally, the IMO (2002) highlights that many of today's crews are composed of seafarers from various nationalities and backgrounds who are expected to work and live together for long periods of time, which make social dynamics relevant when considering mariner fatigue. Given that these environmental conditions, recovery, and the social environment have explicitly been identified by the IMO in their *Guidelines on Fatigue* (2002) as elements unique to the marine environment, it is surprising that no empirical research could be found attempting to understand how they jointly contribute to mariner fatigue.

Fatigue Defined

A review of the work-related fatigue literature uncovers a near rote element of each article or report's opening paragraph; with authors invariably pointing out that there is currently no widely-accepted definition of what constitutes fatigue (followed by the definition used for the purposes of that research). For example, von Thiele Schwarz (2011) defines fatigue as, "part of a continuum stretching from tiredness to exhaustion, with fatigue being placed in the middle of these two." This definition typifies one view of fatigue in literature that avoids defining fatigue by comparing it to other constructs. This is problematic, however, as neither tiredness nor exhaustion are defined in this article. The lack of definition is likely based on the assumption that the differences between tiredness and exhaustion are clear, which some may feel is true. However, whether or not these individuals would agree on the respective definitions for these constructs remains uncertain. Additionally, the relative placement of fatigue between these two constructs leaves the reader to make several inferences regarding what fatigue actually is and what causes/contributes to it. Perhaps, resulting in a simplification of the concept of fatigue to an issue caused by prolonged sleep reduction (more than just one night of reduced sleep). Sleep is certainly an important component of fatigue. Both sleep duration - on average young adults and adults require seven to nine hours of sleep (Hirshkowitz, 2015) - and poor sleep quality have been found to contribute to fatigue (Strauch, 2015). While important, sleep is not the only relevant cause/contributor to fatigue as seen in definitions discussed below.

Other definitions highlight the multi-dimensional nature of fatigue. Wadsworth, Allen McNamara and Smith (2008), for example, defined fatigue as a, “subjective sensation on a continuum with behavioural, emotional and cognitive components” (p. 198). Similarly, Tang, Li, and Huang (2016) acknowledge that fatigue is made up of physical, emotional, behavioural and cognitive components. The IMO has recently updated its definition of fatigue from “the reduction in physical and/or mental capacity as the result of physical, mental or emotional exertion which may impair nearly all physical abilities *including: strength; speed; reaction time; coordination; decision making; or balance*” (2002, p. 4), to “A state of physical and/or mental impairment resulting from factors such as inadequate sleep, extended wakefulness, work/rest requirements out of sync with circadian rhythms and physical, mental or emotional exertion that can impair alertness and the ability to safely operate a ship or perform safety-related duties” (2019, p. 1). This updated definition explicitly addresses the importance of sleep, which is important in a profession that views working despite fatigue as professional behaviour (Grech, 2016). The extreme focus on sleep related factors, however, may lead mariners to believe that sleep is the only solution when experiencing fatigue.

Although there is no clear or consistent distinction between sleepiness and fatigue, Barnett and colleagues (2017) provide a series of elements differentiating the two. In the Project Martha Report they identify sleepiness as an issue that can be experienced by healthy individuals, has a rapid onset, short duration, a single cause and only short-term effects on daily activities. In contrast, fatigue has been related to both physical and mental health disorders, its onset is subtle and persists over time, there are multiple causes and it significantly affects behaviour and well-being (Barnett et al., 2017).

The distinction between sleepiness and fatigue is not, however, universally accepted and others have opted to define different types of fatigue. For example, Von Thiele Schwarz (2011) defined acute fatigue as a condition resulting from high demands that is easily resolved through rest or a change in task, whereas, chronic fatigue was defined as the result of long-term demands. To further complicate the issue, chronic fatigue and chronic fatigue syndrome are medicalized terms referring to fatigue linked to post-viral complications (Devanur & Kerr, 2006). Additionally, fatigue is often subcategorized by the type of strain or stressor that has resulted in fatigue such as physical, emotional and/or mental fatigue (Barofsky & Largo, 1991). There may be circumstances in which these specific conceptualizations of fatigue are beneficial. For example, if previous research with a specific population has identified a specific type of strain as being particularly relevant to the fatigue risk for that employee group a nuanced understanding of how that strain is being experienced by workers may provide the information needed to develop an appropriate intervention. The risk in this approach, however, is that researchers or practitioners could focus on the wrong factors when investigating fatigue or miss additional factor that are significantly contributing to fatigue risk.

There are also, however a surprising number of articles about fatigue that simply avoid the cumbersome task of defining the concept by glossing over their lack of definition focusing instead on casual or predictive factors contributing to fatigue (e.g. Williamson & Friswell, 2013; Grech, 2016). Dohrmann and Leppin (2017) found that approximately 50% of articles addressing fatigue provided a definition or rationale for the measures used to assess fatigue. The use of this term across disciplines to represent varying though similar issues underscores a need for both clarity and specificity in both defining and understanding fatigue. This study aims to clarify the factors contributing to mariner fatigue specifically, with mariner fatigue applying to individuals employed in seafaring work.

The most recent systematic review of seafarer fatigue used Soames-Job and Dalziel's (2008) definition of fatigue (Dohrmann & Leppin, 2017). They defined fatigue as "a state of an organism's muscles, viscera or central nervous system, in which prior physical activity and/or mental processing, in the absence of sufficient rest, results in insufficient cellular capacity or system wide energy to maintain the original level of activity and/or processing by using normal resources; it is caused by sleep – and work-related factors and can be restored by the right interventions like sufficient rest or sleep" (2017, p. 13). The strength of this definition is that it addresses the multiple contributors to and outcomes of fatigue often lacking in other definitions. However, this definition does not address social/emotional factors that may contribute to fatigue, nor does it directly address the importance of recovery beyond actual sleep/rest. Furthermore, the wording of this definition is difficult to understand rendering it essentially inaccessible to the Marine Community and Industry, which could hamper future interventions or educational initiatives. Accessibility in this context is of paramount importance given the extremely applied nature of this research. Therefore, Soames-Job and Dalziel's (2008) definition of fatigue was used to enhance the IMO's current definition of fatigue to create a definition that is both comprehensive and accessible to those not steeped in the literature. For the purposes of this research the following definition is proposed, *the reduction in physical, mental and emotional capacity resulting from physical, mental and/or emotional exertion without sufficient recuperative rest and recovery.*

Conservation of Resources Theory

There is currently no empirical evidence linking sleep, environmental conditions, social support and lack of recovery to mariner fatigue, however, a theoretical link can be inferred through the application of Hobfoll's Conservation of Resources (COR) Theory (1989). The basic premise of COR theory is that individuals will strive to keep, preserve, and increase their valued resources. Applying Hobfoll's (1989) COR theory to the issue of mariner fatigue, one could say that personal well-being (feeling rested) is a valued resource. In this context a failure to safeguard your rested state will result in fatigue. One's rested state can be viewed as total capacity or total resources. Each individual has their own level of capacity. Each of the fatiguing factors discussed here have the potential to add or subtract to an individual's resources.

From this perspective we can understand the assertions that seafarers often report only working and sleeping as an attempt to conserve personal well-being (Thai & Latta, 2010; Paukszat, 2017). It is possible that this approach is motivated by a limited understanding of the factors that contribute to and buffer against fatigue. A seafarer may note their feelings of sleepiness and infer a need for more sleep, without considering other factors that may be contributing to their experience of fatigue. The extreme protection of one resource, in this case sleep, leads to the neglect of recovery activities, like physical activity, and social investments, like card tournaments, which could mitigate fatigue (Fritz & Sonnentag, 2005).

When considering the COR theory from the perspective of a mariner, however, a significant issue quickly emerges. The mariner has limited control over many of the factors that have the potential to deplete their capacity. The IMO (2019) guidelines on fatigue specifically address factors outside of the mariner's control. For example, the sea state (i.e. the size, height and power of waves), the amount of work that needs to be accomplished and the support they receive from their supervisors, are all beyond their control. Recognizing this limitation, the added benefit of this theoretical perspective is that when these factors are considered from an organizational perspective it identifies potential fatigue interventions at the organizational level. For example, an educational program that highlights the importance of a positive work environment and engagement in recovery activities could help mariners make informed decisions about what will help them best preserve or gain in personal well-being, which may not always mean the prioritization of sleep over social/recovery activities (Garrick et. al., 2014; Gross et. al., 2011). Additionally, an understanding from an organizational perspective of the important role social factors play in fatigue could be the impetus needed to improve connectivity with family and friends by investing more heavily in bandwidth and onboard communication capabilities to increase social resources or could identify the need for leadership training to improve perceived supervisor support (Kelloway & Barling, 2010; Van Yperen & Hagedoorn, 2003). From the perspective of COR theory four factors contributing to mariner fatigue were explored, sleep, environmental conditions, social support, and need for recovery.

Factors contributing to Fatigue

Despite the definitional issues surrounding fatigue, some consistent findings regarding the etiology of fatigue have emerged in literature, however, there is a dearth of research in the marine environment that looks at factors beyond sleep (Wadsworth, Allen, McNamara and Smith, 2008). Recognizing this gap, Dohrman and Leppin (2017) called for an exploration of additional factors influencing fatigue in conjunction with an exploration of sleep so that additive and interaction effects can be uncovered.

Sleep. The need for sleep is driven by homeostatic sleep pressure and circadian rhythm.

Homeostatic sleep pressure builds the longer an individual is awake and circadian rhythm is the body's metabolic tendency towards sleep during night and alertness during the day (Borbély, Daan, Wirz-Justice, & Deboer, 2016). As a result, fatigue is likely to increase on longer shifts as well as during shifts that take place during the night (Åkerstedt, Connor, Gray, & Kecklund, 2008). Longer shifts and increased weekly hours have been associated with increased acute and chronic fatigue and increased risk of errors at work (Barker & Nussbaum, 2010; Josten et al., 2003).

Diminished sleep has been linked to reduced problem solving, reduced reasoning and impaired spatial processing abilities (Linde & Bergström, 1992; Neri, Shappell & DeJohn, 1992), as well as increased willingness to engage in risky behaviour (Neri et al., 1992; Killgore, Balkin & Wesensten, 2006). An important finding regarding the relationship between sleep and fatigue is that a sleep debt can be accumulated over time and even a minor sleep restriction over successive shifts can result in significant fatigue effects (Williamson & Friswell, 2013). Though the link between sleep quality/quantity and fatigue is well established H_1 aims to confirm that these established relationships are operating as expected in our sample of seafarers.

H_1: Less sleep quality and quantity will result in increased fatigue.

A study exploring the sleep patterns of leaders found that a dysfunctional sleep myth persisted among many leaders that successful executives sleep less than their less successful counterparts (Svetieva et al., 2017). This type of generally accepted cultural norm or belief is particularly problematic as social pressures can override the biological sleep drive (Walch, Cochran & Forger 2016). These findings point to the importance of the organizational attitudes communicated both implicitly and explicitly regarding sleep.

Analogous to the dysfunctional sleep myth affecting leaders, mariners may also unwittingly subscribe to a dysfunctional sleep myth regarding what constitutes an acceptable amount of sleep and what constitutes professional behaviour. Informal conversations with several mariners seem to indicate a pervasive bravado regarding what constitutes sufficient sleep. Based on these conversations and previous literature indicating a belief that it is professional to work in spite of fatigue (Grech, 2016), however, it seems equally if not more probable that previous experiences of sleep deprivation while working in the marine environment were so extreme that the benchmark for acceptable has been skewed. For example, when talking about sleep deprivation with a former mariner about an incident in which fatigue was a contributing factor, the individual vehemently disagreed with this finding stating “Well I don’t agree six hours sleep in a day is plenty of sleep, I’ve worked with much less.” From the COR perspective a generalized belief that it is professional to work despite fatigue could also be viewed as an attempt to preserve/enhance one’s credibility/ professionalism as a seafarer (Grech, 2016).

Two recent systematic reviews of seafarer stressors/fatigue found that both sleep quality and quantity were associated with fatigue (Oldenburg et al, 2013; Dohrman & Leppin, 2017). One of the most frequently examined elements of fatigue in marine research is the impact of the watch system on quantity and quality of sleep (Lützhöft, Dahlgren, Kircher, Thorslund & Gillberg, 2010; Härmä et al., 2008). The watch system refers to how shifts are structured. Someone who is “on watch” is currently on shift. A seafarer will fly to meet the ship wherever she is currently operating and will stay onboard that ship for a predefined period of time, this can range from two to six weeks up to six or more months at a time. While onboard the ship seafarers typically work every day. Though there are likely exceptions to this rule, the majority of merchant marine organizations operate under one of three watch systems: the 6 on, 6 off (6/6), 4 on, 8 off (4/8) or the 12 on, 12 off (12/12). These watch systems are used because the marine industry operates 24 hours per day. For example, a seafarer working a 6 on 6 off watch could work from 6:00 am to 12:00pm, have a period of rest from 12:00pm to 6:00pm, then work 6:00pm to midnight and have a second rest period from midnight to 6:00am. This would be repeated for the duration of their stay onboard the vessel (e.g. six weeks). Following this companies typically offer their employees an equivalent period or half time (e.g. four weeks worked, two weeks ashore) ashore during which they are not expected to work. However, some shore time will be used in the mandatory maintenance of certifications and academic/professional upgrading for seafarers wishing to progress in their careers.

Research on mariner fatigue has primarily focused on the 6/6 and 4/8 watch systems. The 6/6 watch system has typically been found to result in higher levels of sleepiness compared to the 4/8 system (Lützhöft et al, 2010; Dohrmann & Leppin, 2017). Therefore, this study will add to the literature of seafarer fatigue through the exploration and comparison of factors contributing to fatigue with crew members using the 12/12 and 4/8 watch systems, which is currently lacking. Based on the potential for 8 hours of uninterrupted sleep under the 12/12 watch system, it is possible that levels of fatigue will be comparatively low among this sample. However, Haerma et al. (2008) found that fatigue was associated with quality of sleep, which may still be a factor despite the potential for 8 hours of sleep. Moreover, shifts lasting between 10 and 14 hours have been found to contribute to fatigue and increase the risk of momentarily falling asleep (Perttula, Ojala, & Kuosma, 2011). These issues are compounded by a persistent culture that views perseverance regardless of fatigue as professional behaviour amongst seafarers (Grech, 2016). Sanquist, Raby, Forsythe, and Carvalhais (1997) found that mariners generally sleep substantially less each day (1.3 hours) while on board ship compared to the amount they sleep while at home, which they largely attributed to sleep fragmentation due to work scheduling. This study was conducted with mariners largely working 4/8 schedules thus it is unclear if the 12/12 system results in a similar sleep debt. Nevertheless, even if there is no difference between sleep obtained at home and while on board ship a sleep debt may still accrue due to the higher demands experienced in the marine environment. Diminished quantity and quality of sleep itself, however, is not the only contributor to employee fatigue.

H_2: 4/8 watch system will result in significantly higher levels fatigue compared to the 12/12 watch system.

Environmental Conditions. The work environment itself can contribute to fatigue, for example, we likely do not expect nurses and construction workers to experience the same levels of fatigue, but unique factors within each context may differentially contribute to similar levels of fatigue risk. For example, in the construction industry physical demands and working in inclement weather may serve as risk factors while shift duration, standing for long periods, and patient aggression may be key risk factors for nurses. The amount of sleep obtained in isolation does not provide a comprehensive view of fatigue risk as increased working hours and decreased sleep have independently been found to serve as risk factors in occupational injury (Arlinghaus, Lombardi, Willetts, Folkard & Christiani, 2012). This indirectly supports the notion that fatigue is a multidimensional construct that results from factors beyond sleep. A broadened view of fatigue necessitates a more comprehensive view of the potential impact environmental conditions may have on an individual’s fatigue risk in conjunction with sleep quality/ quantity when exploring fatigue.

Whole body vibrations such as those typically experienced in the road transport industry (from regular driving and pothole impacts) were found to be likely contributors to fatigue

(Troxel, Helmus, Tsang, & Price, 2016). A meta analytic review exploring the impact of whole-body vibrations found decreased perceptual, cognitive, as well as continuous and discrete fine motor ability (Conway, Szalma, & Hancock, 2007). In the marine environment, ships' motion and noise have also been associated with self-reported fatigue measures (Smith, Allen, Wadsworth, 2006). Interestingly, Tamura and colleagues (2002) found that while subjective measures of noise disturbance seemed to indicate habituation to the noise, objective sleep measures indicated that the sleep disturbance persisted. This study used the recorded sound of an actual ship's diesel engine played for participants in a lab setting. As this was an actual recording it likely captured fluctuations in engine sounds as the ship increased and decreased speed and the ship was maneuvered. This would not, however, have captured sounds related to crew movements (i.e. opening/closing cabin and bathroom doors, showers running, etc.) during shift changes and non-synchronized off shift periods used for sleep. Additionally, it would not have captured the impact of noise throughout the work day on fatigue, which has been found to contribute to fatigue (Witterseh, Wyon, & Clausen, 2004). Although no equivalent assessment relating to ship's motion was found, it is possible that seafarers similarly believe they have grown accustomed to the ship's motion though it may actually continue to disturb their sleep. Though no specific research was found demonstrating a relationship between working in extreme temperature (hot/cold) and fatigue in the marine environment specifically, it has been cited as a workplace stressor in multiple studies, as such, it should be considered as a potential environmental factor (Oldenburg, 2009). This is reinforced by a study conducted in a non-marine environment that found heat contributed to fatigue in the work place (Witterseh, Wyon, & Clausen, 2004). Additionally, work stressors more generally (e.g. work load, demands, etc.) have also been found to contribute to fatigue (Rose et al., 2017), and are conceptualized in this research as being part of the mariners work environment.

H_3: Negative environmental conditions will predict increased fatigue.

Social Support. Just as environmental conditions have the potential to impact fatigue, social dynamics have the potential to positively or negatively impact fatigue. For example, emotional regulation has been demonstrated to require and drain cognitive resources (Schmeichel, 2007). The inverse relationship has also been found with cognitive load decreasing an individual's capacity to engage in emotional regulation (Grillion, Quispe-Escudero, Mathur, & Ernst, 2015). Together these findings suggest a reciprocal relationship indicating that a cognitively demanding work environment could contribute to diminished emotional regulation, but also that the need to maintain constant emotional regulation in a 24/7 work environment may deplete cognitive resources. This reciprocal relationship underscores the importance of a positive social environment in the workplace to reduce effortful emotional regulation and depletion of cognitive resources mitigating this fatigue risk factor (Chiaburu & Harrison, 2008). Additionally, lower levels of sleep quality and quantity have been associated with lower peer and subordinate ratings of emotionally intelligent behaviour (Nowack, 2017). This decreased social and interpersonal competence could contribute to a negative work climate and increase an individual's fatigue risk through the reduction of emotional and cognitive resources.

The social context, however, can also represent a buffering factor against fatigue. Social support, in a wide variety of settings, has been found to diminish fatigue. Social support from supervisors and peers has been shown to increase well-being and reduce strain in the workplace (López-Araújo & Segovia, 2011). Social support also positively impacts medically-related fatigue in patients suffering from Multiple Sclerosis and other ailments (Aghaei, Karbandi, Gorji, Golkhatmi, & Alizadeh, 2016; Karakoç & Yurtsever, 2010). A study utilizing a sample of professional drivers found that social support significantly decreased self-reported fatigue, further indicating the potential for social support to function as a mitigating factor in fatigue (Useche, Ortiz, & Cendales, 2017).

The captive nature of the marine environment may make the social atmosphere a more important contributor to fatigue relative to more typical work environments. One of the major stressors reported by mariners is separation from their family and friends for extended periods of time (Oldenburg, 2009). In her theoretical discussion of fatigue risk factors in the marine environment Grech (2016) identified social isolation as a risk factor contributing to fatigue. During a qualitative examination of the marine environment Pauksztat (2017) found that participants reported fatigue impacted the work climate with work climate degrading as fatigue increased. Much like the reciprocal relationship previously discussed between cognitive load and emotional regulation (Grillion, Quispe-Escudero, Mathur, & Ernst, 2015; Schmeichel, 2007) it is possible that a positive social environment can both mitigate fatigue risk and decline as a result of fatigue. This may in part explain the finding that ships' Captains, crew members who typically obtain the most sleep, are the crew members reporting the highest levels of fatigue (Barnett et al, 2017). The hierarchical nature of the marine environment and isolation associated with leadership may mean that Captains do not have access to the mitigating benefits of a positive social climate. Despite the isolation experienced by seafarers, social support onboard ship has been associated with self-reported quality of life (Xiao et al., 2017). This supports the notion that social support may be able to buffer the stress associated with separation from family and friends contributing to lower levels of fatigue. Though work/social interventions will not eradicate fatigue, as sleep remains a biological imperative, effective recovery may also buffer against fatigue.

H_4: Social support will buffer against fatigue.

Recovery. Effective recovery can be defined as the return to baseline following a physical and/or psychological exertion. Von Thiele Schwarz (2011) demonstrated that the interruption of effective recovery contributes to fatigue. Psychological detachment from work is an important component of both sleep *and* recovery experiences. Unfortunately, smartphones now invade rest and recovery periods giving employers access to their employees 24/7 (Deal, 2013). This invasion obstructs psychological detachment from work. Tele-pressure impacts both an individual's ability to recover and has been found to reduce quality of sleep (Sonnentang et al., 2016).

Unlike the typical employee that may have a smart phone creating a barrier to rest and recovery, seafarers literally do not leave their place of work for extended periods of time. The lack of separation between work and rest/recovery periods may negatively contribute to fatigue by inhibiting proper recovery. Rest/recovery disruptions have been associated with increased sleepiness on the following shift (van Leeuwen et al., 2013). These effects, however, have largely been demonstrated to exist through the disruption of sleep. It is possible that the inability to leave the workplace itself contributes to fatigue through ineffective recovery above and beyond the effects of sleep quality/quantity. This possibility is supported by Thai and Latta's (2010) assertion that time onboard ship is spent either working or resting (in this case referring to sleep). This depiction of life onboard ship was supported by the responses provided during interviews on the perception of job demands where seafarers indicated there is typically no "free time", time is either allocated to work or sleep (Pauksztat, 2017).

H_5: Need for recovery will predict increased fatigue.

The Current Study

This study explored the predictors of mariner fatigue with a merchant marine organization on their replenishment vessel. Although most research on mariner fatigue has focused on officers and watch-keeping personnel (Dohrmann & Leppin, 2017), collaboration with this organization enabled the researcher to include all employees in this study. The study was conducted during an eight-day voyage from Pearl Harbour to Victoria. Using a daily diary methodology (participants filled out daily logbooks) and objective sleep measures this research tested the hypotheses that:

H_1: Less sleep quality and quantity will result in increased fatigue.

H_2: 4/8 watch system will result in significantly higher levels of fatigue than the 12/12 watch system.

H_3: Negative environmental conditions will predict increased fatigue.

H_4: Social support will buffer against fatigue.

H_5: Need for recovery will predict increased fatigue.

Method

Participants

The ship is typically staffed by approximately 26 personnel. At the time of the study 27 personnel were on board the ship. Of the 27 crew members onboard, 18 (67% response rate) chose to participate, 16 (91%) identified as male (the remaining participants identified as female) with a $M_{\text{age}} = 40.53$ $SD = 10.80$ (age ranged 25 – 57). The rank of personnel onboard is primarily distinguished as Officer or Unlicensed (Officer = 12 (66.7%), Unlicensed = 4 (22.2%), Other = 2 (11.2%)). The majority of personnel are assigned to the deck or engine department

(Deck = 8 (44.4%), Engine = 7 (38.9%), Other = 3 (16.7%)). Crew typically work on either the 12/12 or 4/8 watch system (12/12 = 12 (66.7%), 4/8 = 5 (27.8%), Other = 1 (5.6%)). Participants identifying their rank, department, or watch type as, "other" were not included in the preliminary analysis of control variables. Participants were entered into a $500 prize draw for their participation. Ballots were earned for each day of participation, a three-ballot bonus was awarded for participation in the entire study. At the conclusion of the study a random number generator was used to select the prize winner. The study started on the 10th of December 2018 with all personnel receiving an invitation to complete the baseline mariner fatigue survey.

Measures

The following measures were used to assess fatigue and factors contributing to fatigue. All scales and instructions for each scale can be found in Appendices A through D.

Sleep. The quantity and quality of sleep for onboard personnel were tracked using the Readiband a sleep tracker developed by Fatigue Science. This tracker assesses six factors related to sleep including circadian rhythm, time of day, sleep quantity, sleep and waking consistency, cumulative sleep debt and wake episode during sleep (Fatigue Science, 2018). This tool was recommended by staff from Memorial University's Marine Institute given the potential for ship's vibrations and movements to effect other sleep tracking devices. This concern has anecdotally been supported by colleagues in the aviation industry who have indicated that their trackers have recorded physical activity inflight while they have in fact been seated. Additionally, it is believed that many seafarers underreport their hours of work (overreporting their sleep) to ensure their reported hours of work/rest conform with regulations (Allen, Wadsworth, & Smith, 2008). Two objective sleeps measures were used in the analysis: total sleep and sleep quality. Total sleep was the total number of hours slept in a 24 hour cycle. Quality sleep was a sleep score derived from the amount of sleep obtained, number of awakenings and duration of awakenings. A subjective measure of sleep was also included in the baseline survey asking participants to rate their typical sleep experiences onboard the ship and at home. These self-report questions were developed for this study, “how many hours do you typically sleep while onboard the ship per 24-hour period” and, “how would you rate the quality of your typical sleep while on ship”. The same questions were then asked regarding the quantity and quality of sleep typically obtained while at home.

Fatigue. Fatigue was measured using the Karolinska Sleepiness Scale (KSS). The KSS is a single item scale of fatigue that assesses sleepiness on a 9-point Likert type scale ranging from 1 = very alert to 9 = very sleepy (fighting off sleep) (Kaida et al, 2006). Fatigue was measured within five minutes of waking up, mid shift, end of shift and just before the end of the 24 hour cycle. The four measures of fatigue were used to create a daily composite fatigue score for each participant. This measure can be found at Appendix A.

Environmental Conditions. Based on a review of the literature on fatigue in the marine environment five environmental factors were identified as fatigue risk factors. A series of single item scales exploring the impact of temperature (heat/cold), vibration, noise, sea state (i.e. the size of, height and power of waves) and stress were developed (e.g. Over the last 24 hours how have these factors contributed to you fatigue? … I was exposed to noise today that) responses to each item were scored on a 5-point Likert type scale 1 = N/A to 5 = significantly contributed to my fatigue that can be found at Appendix C. Environmental factors were assessed at the end of the 24 hour cycle as this is when their full effect was known and still fresh in the participant’s memory.

Social Support. Social support was assessed using Caplan’s (1975) scale of social support. Caplan’s scale of social support has three subscales supervisor, co-worker and significant other support, with each subscale containing four items which were scored on a 5-point Likert type scale 0 = very much, to 4 = don't have any such person (e.g. How did each of these people go out of their way to do things to make your work life easier?) items are listed in Appendix D and alpha's are found in Table 1. Social Support was assessed at the end of the 24-hour cycle as this is when the day's events were over and still fresh in the participant's memory.

Table 1

Alphas for daily measures of supervisor, coworker and significant other support.

Source of Support	Day							
	1	2	3	4	5	6	7	8
Supervisor ±	.85	.84	.84	.89	.92	.88	.88	.98
Coworker ±	.65	.72	.72	.81	.85	.79	.83	.97
Significant Other ±	.91	.94	.95	.96	.94	.96	.96	.99

Notes. Each subscale contained the same 4 items with the source varying by subscale (supervisor, coworker and significant other)

Recovery. Winwood's (2006) recovery subscale from the Occupational Fatigue Exhaustion Recovery Scale (OFER15) was used to assess inter-shift need for recovery. This scale has 5 items scored on a 7-point Likert type scale 0 = strongly disagree, to 6 = strongly agree, items listed in Appendix B, items were slightly modified for daily use (e.g. I did not have enough time between work shifts to recover my energy completely). Alpha reliabilities can be found at Table 2. Recovery was measured prior to the commencement of the first shift before the day's events could begin contributing to the participants need for recovery.

Table 2

Alphas for daily measures inter-shift need for recovery

Recovery	Day							
	1	2	3	4	5	6	7	8
±	.91	.90	.87	.75	.79	.52	.89	.86

Note. Day 6 was the first full day of calm seas which may resulted in recovery questions being answered somewhat differently.

Control Variables. A number of control variables were included in the demographic questionnaire. Control variables included average amount of sleep obtained while at home, BMI (calculated from participants reported height and weight), age, gender, rank (Officer vs Unlicensed), department, and shift type (12/12 or 4/8). Personality was also assessed using the Agreeableness (± = .75) and Neuroticism (± = .73) subscales of the OCEAN 20 which contained 4 items each measured on a 7-point Likert type scale (1 = extremely characteristic to 7 = extremely uncharacteristic).

Procedure

The organization's Chief of Staff was provided an e-mail summarizing this project, which was used when introducing the project to the ship's Captain. Captain buy-in was viewed as important as the Captain announced the research project to members of the crew. Additionally, Captain support was credited with the high participation rates in previous studies with seafaring populations (Barnett et al., 2017). The Captain announced the research opportunity to the crew via an introductory e-mail on the 7th of December 2018, which was prior to any contact with the primary researcher. The Captain's e-mail emphasized the voluntary nature of this study and can be found in Appendix E.

At 0800hrs on the 10th of December (Day 0), I made first contact with the crew in a brief e-mail that invited them to participate in research on mariner fatigue. The e-mail included a link that if clicked brought them to the informed consent form on the Qualtrics platform. By selecting, "I agree" they were then directed to the demographic questionnaire, followed by personality measures and finally the mariner fatigue survey itself. Once participants completed the fatigue survey they were thanked for their involvement and informed that the researcher would provide them the materials and direction needed for the next phase of participation.

I boarded the ship at 1000hrs (Day 0), in Pearl Harbor, Hawaii. A coordination meeting for all participants was scheduled for 1930hrs on Day 0. Unexpectedly, supplies were delivered to the ship at this time which meant that some participants were unable to attend this coordination meeting, three participants came later that evening and an additional two participants collected their materials on the morning of the 11th (Day 1 of the study). During the coordination briefings participants were directed to wear their Readibands at all times (except when showering). The log books were reviewed so that participants understood the correct time to complete each measure. In the log book participants rated their inter-shift need for recovery prior to their first shift of the day. They also assessed their level of sleepiness five minutes after waking up, mid shift, end of shift and prior to lights out (whenever they went to bed) using the KSS. At the end of the day they were also asked to reflect on the previous 24 hours and rate the impact of environmental conditions on their fatigue as well as their perceived social support from supervisors, colleagues and family/friends.

The ship departed from Pearl Harbor, Hawaii at 0800hrs on Day 1 of the study. WIFI while in port at Pearl Harbor is affected by government regulations that limit connectivity on various social media and telecommunications platforms. As a result, crew had reduced ability to contact family or friends who were not aboard ship (WIFI enabled communication often failed, or had substantial delays that impacted quality of communication). Once the ship had sailed for approximately one day (away from Hawaii) these limitations were no longer a factor and WIFI connectivity improved substantially (i.e. Facetime/ Skype calls functioned). On Days 1 and 2 of the study the crew adjusted their clocks (1 hour ahead each day) to reach Pacific Time, local time at their next port. During the study the ship encountered some rough seas (sustained periods of high winds and approximately 6 meter waves), but overall the temperature remained comfortable. On Day 1 of the study, once the ship had reached open waters, the ship encountered 5-meter waves, but the sea state calmed that evening and remained calm throughout the night. On Day 2 the sea state was calm with approximately 1-meter waves. Day 3 starting at approximately 9:30 am sea state increased substantially with waves remaining between 5 and 6-meters throughout the day and night. The sea state remained rough on Days 4 and 5, however, the winds were more favourably positioned on the stern of the ship which minimized the impact of the sea state. In the evening on Day 6 the ship entered the Juan de Fuca Strait and remained in calm waters for the remainder of the sail. The ship arrived in Victoria, British Columbia on Day 8 of the study, this was the ship's debut on the West Coast.

Though the initial plan was to distribute and collect log books daily it quickly became apparent that this was not a feasible plan given the significant variety in crew scheduling and work spaces. On Day 2 participants were provided all remaining log books (i.e. Day 2 – 8) and asked to drop off completed log books to me at their convenience. In order to facilitate this task, I stayed in the mess hall (cafeteria) during meals hours so that participants could easily locate me.

Data Analysis

The analyses used in this study were conducted based on Shek and Ma's (2011) article, which calls for the systematic introduction of fixed and random effects in a multi-level analyses. Analyses were performed using the mixed model procedure in SPSS 24.0. A maximum likelihood (ML) estimator, and unstructured covariance type were used. Unfortunately, for these data, analysis of random effects failed to converge. Several strategies were used in an attempt to resolve this issue including; alternate covariance types (i.e. VC, AR1, and ARH1), an alternate estimation technique was tried (i.e. REML), and an increased number of iterations (i.e. up to 10,000) - none of these resolved the convergence issue. This issue likely represented an attempt to fit a model too complex for the data set, an issue discussed by Bates, Kliegl, Vasishth and Baayen (2015).

As in Shek and Ma (2011) several models were tested including the unconditional model (Model 1), a conditional model with time (Model 2 & 2b) which explored the impact of linear and curvilinear time, Models 3 included all hypothesized predictors (i.e. objective sleep measures, environmental conditions, social support and need for recovery). Model fit was assessed using the – 2 log likelihood, and chi square difference tests were used to determine the significance of changes in model fit. The outcome variable for all analyses was fatigue assessed by the KSS with higher scores representing higher levels of fatigue.

Results

A sample of 18 participants took part in a repeated measures diary study. Observations were collected daily for a period of eight days resulting in 141 observations (fatigue was assessed four times per day to create a composite daily fatigue score). All variables were standardized for the analyses. Observations were nested within days and days were nested within individuals. Analysis was conducted in two phases: phase one was the preliminary analysis exploring control variables; phase two was the main mixed models analysis.

Preliminary Analysis

Initially, all means, standard deviations and bivariate correlations of the independent and dependent variables were explored, they can be found at Tables 3 & 4.

Table 3

Means and Standard Deviations for independent and dependent variables

Variable	M	SD
1. Fatigue	5.66	1.84
2. BMI	30.40	5.07
3. Agreeableness	5.83	0.82
4. Neuroticism	3.15	1.46
5. Recovery	3.98	1.27
6. Temperature	1.87	0.65
7. Vibration	2.52	0.74
8. Noise	2.63	0.75
9. Sea State	3.14	1.09
10. Stress	2.81	0.81

Notes. Notes. Listwise N = 104. M = Mean. SD = Standard Deviation.

Table 3 (continued)

Means and Standard Deviations for independent and dependent variables

Variable	M	SD
11. Supervisor Support	2.52	0.98
12. Colleague Support	2.85	0.76
13. Significant Other Support	2.38	1.48
14. Total Sleep	6.34	1.94
15. Quality Sleep	5.50	2.57
16. Time	4.5	2.30

Notes. Notes. Listwise N = 104. M = Mean. SD = Standard Deviation.

Table 4

Bivariate Correlations for all independent and dependent variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Fatigue																
2. BMI	.21*															
3. Agree.	.04	.01														
4. Neur.	.34**	.40**	-.42**													
5. Recovery	.64**	-.01	-.15	.46**												
6. Temp.	-.06	-.07	.02	-.10	-.15											
7. Vib.	.22**	-.16	-.07	.35**	.32**	.23**	.20									
8. Noise	.23*	-.21*	-.04	.37**	.34**	.01	.60**									
9. Sea	.40**	-.07	-.14	.19*	.39**	.07	.55**	.47**								
10. Stress	.34**	.05	-.11	.39**	.24**	.21*	.35**	.22*	.39**							
11. Sup.	-.28**	.12	.05	-.61**	-.41**	.05	-.38**	-.32**	.18	-.24**	-.33**					

Notes. Listwise *N* = 104. Agree = Agreeableness. Neuro = Neuroticism. Sup. = Supervisor Support. Col. = Colleague Support. Sig. = Significant Other Support.

T. Sleep = Total Sleep. Q. Sleep = Quality Sleep.

$^{*}p < .05$. $^{**}p < .01$.

Table 4 (continued)

Bivariate Correlations for all independent and dependent variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12. Col.	-.15	.35**	.03	-.23**	-.31**	.01	-.46**	-.43**	.21*	-.18*	-.62**					
13. Sig.	.03	-.34**	-.15	-.06	-.09	-.04	-.07	.16	.03	-.03	.11	-.01				
14. T.Sleep	.04	-.00	.01	.12	.07	.12	.01	.02	-.16	-.14	.00	-.14	-.01			
15. Q.Sleep	-.21*	.25**	.04	-.16	-.28**	-.04	-.27**	-.30**	-.37**	-.21*	.08	.16	-.29**	.19*		
16. Time	-.11	.00	.00	.00	-.08	.05	-.13	-.09	-.26**	.00	-.08	-.01	.08	.26**	.24*	

Notes. Listwise N = 104. Agree = Agreeableness. Neuro = Neuroticism. Sup. = Supervisor Support. Col. = Colleague Support. Sig. = Significant Other Support. T. Sleep = Total Sleep. Q. Sleep = Quality Sleep.

$^{*}p < .05$. $^{**}p < .01$.

A preliminary mixed models analysis (Model 0) was conducted with six control variables including; department, rank, watch type, BMI, agreeableness, and neuroticism. The variance estimate of the individual 0.98 was statistically significant (Wald Z = 2.18, *p* = .030). The fixed effect of department specifically being part of the deck crew, *t*(13.00) = -2.90, *p* = .010, significantly predicted fatigue with deck crew reporting less fatigue (*M* = 4.88 *SD* = 1.88) compared to the engine crew (*M* = 5.95 *SD* = 1.64). No other control variables significantly contributed to the prediction of fatigue as seen in Table 5.

Table 5

Summary of Fixed Effects Estimates for All Control Variables

Model 0	Estimate	Std. Error	*df*	*t*	*p*
Intercept	8.09	1.25	13.00	6.47	.000
Department	-2.89	0.97	13.00	-2.99	.010
Rank	-0.26	0.68	13.03	-0.38	.712
Watch	-1.53	0.93	13.02	-1.65	.123
BMI	0.15	0.34	13.01	0.43	.672
Agreeableness	0.38	0.43	13.00	0.89	.392
Neuroticism	0.80	0.46	13.05	1.74	.105

Note. *df* = degrees of freedom.

Additionally, the difference between self-reported average sleep obtained while onboard was compared with the average total sleep participants obtained during this study. Each individual's objective total sleep was averaged over the eight day study and a paired sample t-test was conducted, which demonstrated that self-reported average sleep (*M* = 6.89 *SD* = 0.70) did not differ significantly from objective sleep measures (*M* = 6.35 *SD* = 1.08), t(17) = 1.88, ns, however the raw score difference of 0.54, 95% CIs [-.07, 1.15] was large (Cohen's *d* = 0.59).

Main Analysis

The main analysis tested four models including: the unconditional model (Model 1); the conditional model with time (Model 2); conditional model with time and curvilinear time (Model 2b); the next model included all predictors with time and curvilinear time (Model 3). Finally, Model 3 was rerun with significant control variables (i.e. department) from the preliminary analyses to see if this improved model fit (Model 3b). The results detailed below aim to guide the reader through the most relevant aspects of the analysis. A summary of the fit indices can be found at Table 6.

Table 6

Fit Indices for Nested Sequence of Mariner Fatigue Models

Phase	Model	*df*	-2 Log Likelihood	AIC	BIC	$Ç^2_{diff}$
Main Analysis	1 Unconditional	3	477.34	483.335	492.18	
	2 Time	4	473.95	481.945	493.74	3.39
	2b Time & curvilinear time	5	469.90	479.90	494.64	7.44^{*}
	3 All Predictors	38	274.82	350.82	455.46	195.08^{***}
	3b All Predictors + department	39	272.33	352.33	462.47	2.49

Notes. Model 3 includes time and curvilinear time. Model 3b builds on Model 3 by including department as a control variable.

$^{*}p < .05$. $^{**}p < .01$ $^{***}p < .001$.

The unconditional model yielded a statistically significant estimated between subject variance of 2.12 (Wald $Z = 2.80$, $p = .005$). The intraclass correlation coefficient (ICC) was calculated to be .64 indicating that approximately 64% of the variance in fatigue is attributed to the individual and that independence assumptions are violated confirming the requirement to use a mixed model approach (see Table 7).

Table 7

Summary of Fixed Effects Estimates for the Unconditional and Conditional Models with Time

Model	Intercept	Estimate	Std. Error	*df*	*t*	*p*
1. Unconditional		5.68	.36	18.02	15.94	.000
2. Conditional Time	5.67	-0.17	0.09	123.11	-1.85	.066
2b. Conditional Time & Curv. Time	5.88					
Time		-0.18	0.09	123.11	-1.96	.052
Curv. Time		-.21	0.11	123.10	-2.03	.045

Note. df = degrees of freedom. Curv. Time = Curvilinear Time.

The conditional model (Model 2) which included linear time as a fixed effect (- 2 log likelihood = 473.95, *df* = 4) did not have significantly better fit to the data than the unconditional model as determined by a chi square difference test $\chi^2_{diff}(1) = 3.35$, p = .066. The substantial sea states during the sail, however, introduced the possibility of a curvilinear relationship. Therefore, Model 2b the conditional model with both linear and curvilinear time (- 2 log likelihood = 469.90, *df* = 5) was assessed. Model 2b had significantly better fit to the data than the unconditional Model as determined by a chi square difference test χ^2_{diff} (2) = 7.44, p = .024, explained variance increased from 64% to 65%. In Model 2b the variance estimate of the individual was 2.12; this was a statistically significant (Wald Z = 2.80, *p* = .005). The fixed effect of curvilinear time was significant, *t*(123.10) = -2.03, *p* = .045 (see Table 9). Significant curvilinear time indicated that over time participants became increasingly fatigued, but by day five fatigue began to decrease as can be seen in Figure 1.

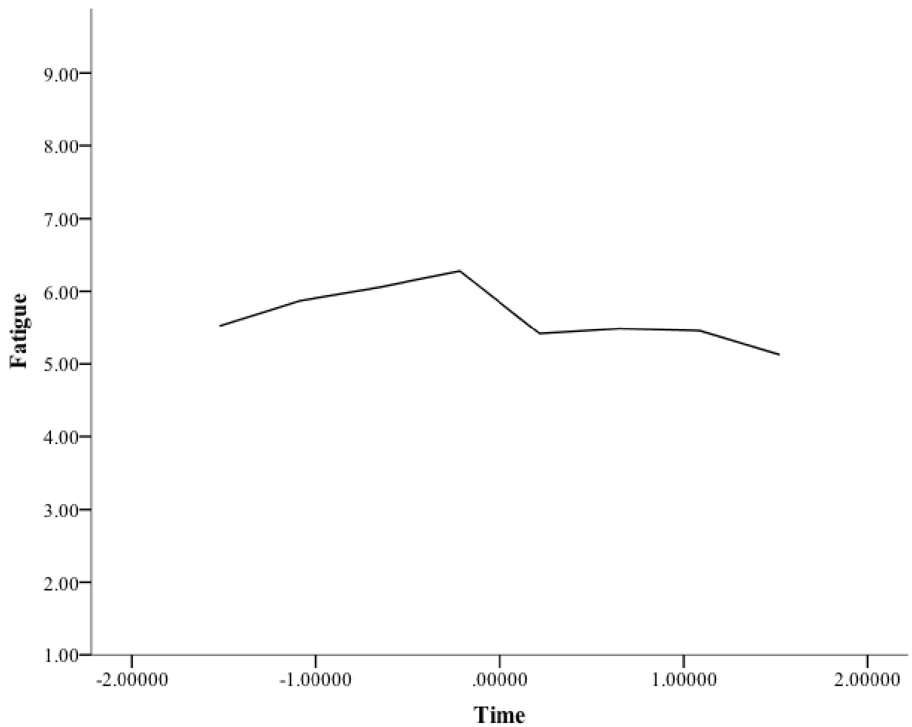

Figure 1. Shows self-reported sleepiness over time.

Model 3 assessed the effect of time and all predictors on fatigue. Model 3 (- 2 log likelihood = 274.82, *df* = 38) fit the data significantly better than Model 2b as determined by a chi square difference test χ^2_{diff} (33) =195.08, *p* < .001. The estimate of individual variance 1.18 was significant (Wald *Z* = 2.67, *p* = .008) with this model capturing 75% of explained variance, which represents a 10% increase from Model 2b. All fixed effects are noted in Table 8, the fixed effects of total sleep $t(105.05) = 2.36$, $p = .020$, recovery $t(101.94) = 5.55$, $p < .001$, sea state interacting with linear time $t(102.13) = - 2.64$, $p = .010$, stress interacting with linear time $t(106.69) = 2.92$, $p = .004$, and sleep quality interacting with curvilinear time $t(102.04) = -2.57$, $p = .012$ were significant. Figure 2 depicts the interaction between sea state and time. Early in the sail those experiencing higher sea state were more fatigued then participants experiencing lower sea states. Later in the sail, however, those reporting high sea states were less fatigued than those reporting low sea states.

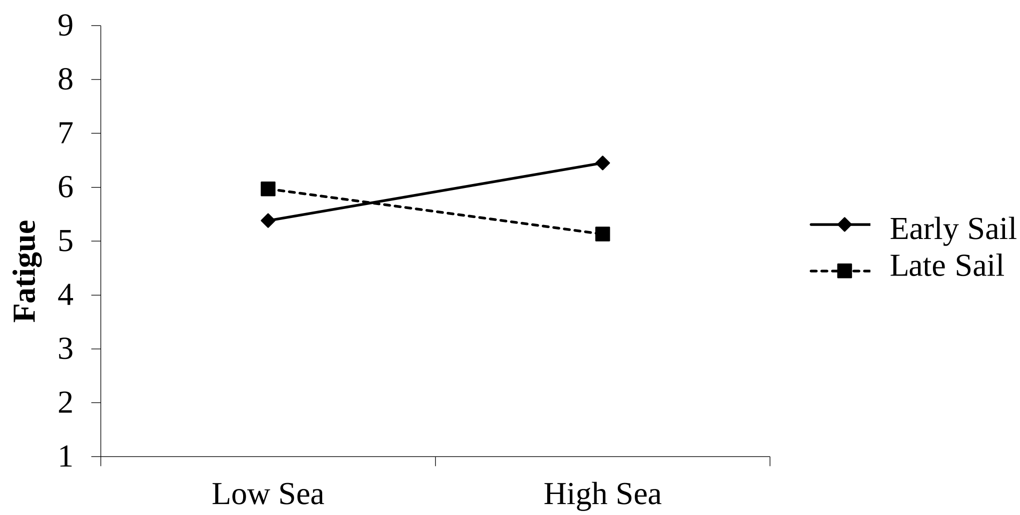

Figure 2. Interaction between low and high sea states on fatigue early in the sail and late in the sail.

Figure 3 represents the interaction between time and stress. Early in the sail low stress is associated with nearly equivalent levels of fatigue compared to individuals reporting higher stress. Later in the sail, however, those reporting low stress are significantly less fatigued than those reporting high stress.

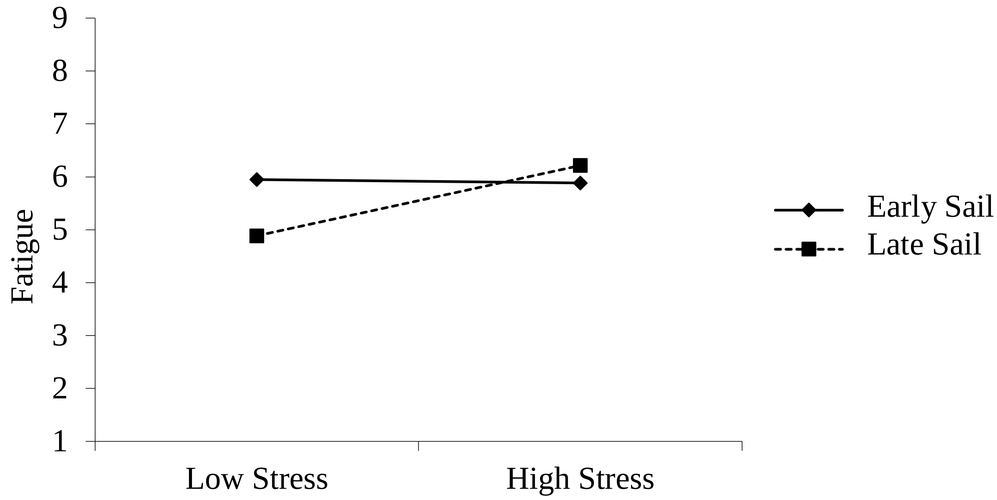

Figure 3. Interaction between low and high stress on fatigue early and late in the sail.

Table 8

Summary of Fixed Effects Estimates for all individual predictors with Time

Model 3	Estimate	Std. Error	*df*	*t*	*p*
Intercept	5.73	0.28	20.66	20.24	.000
Time	-0.18	0.12	107.44	-1.48	.143
Curv.	-0.13	0.16	112.40	0.57-0.79	.431
Total Sleep	0.35	0.15	105.05	2.36	.020
Quality Sleep	0.21	0.13	103.55	0.21	.104
Temperature	0.24	0.152	114.52	1.56	.122
Vibration	-0.00	0.17	104.74	-0.1	.990
Noise	-0.21	0.15	105.70	-1.34	.183
Sea	0.06	0.18	105.17	0,32	.749
Stress	0.32	0.16	110.45	1.96	.053

Notes. Total Sleep = is the cumulative amount of sleep achieved in a 24-hour cycle. Stress = generalized work stress described as relating to work load/pace etc. *df* = degrees of freedom. Curv. = Curvilinear Time.

Table 8 (continued)

Summary of Fixed Effects Estimates for all individual predictors with Time

Model 3	Estimate	Std. Error	*df*	*t*	*p*
Supervisor Support	-0.11	0.29	90.34	-0.37	.713
Colleague Support	-0.04	0.26	103.34	-0.15	.885
Sign. Other Support	0.36	0.21	85.36	1.73	.088
Recovery	0.87	0.16	101.94	5.55	.000
Total Sleep X Time	0.05	0.11	105.32	0.42	.677
Quality Sleep X Time	0.07	0.13	106.63	0.55	.581
Temperature X Time	0.05	0.14	104.26	0.36	.723
Vibration X Time	0.33	0.22	99.64	1.49	.140
Noise X Time	-0.13	0.18	102.71	-0.84	.405
Sea X Time	-0.48	0.18	102.13	-2.64	.010
Stress X Time	0.34	0.12	106.69	2.92	.004

Notes. Total Sleep = is the cumulative amount of sleep achieved in a 24-hour cycle. Stress = generalized work stress described as relating to work load/pace etc. *df* = degrees of freedom. Curv. = Curvilinear Time.

Table 8 (continued)

Summary of Fixed Effects Estimates for all individual predictors with Time

Model 3	Estimate	Std. Error	*df*	*t*	*p*
Supervisor Support X Time	-0.10	0.16	99.90	-0.67	.503
Colleague Support X Time	0.11	0.16	101.53	0.69	.494
Sig. Other Support X Time	-0.18	0.11	103.13	-1.65	.101
Recovery X Time	0.03	0.12	98.06	0.26	.798
Total Sleep X Curv.	-0.14	0.16	108.92	-0.87	.389
Quality Sleep X Curv.	-0.40	0.15	102.04	-2.57	.012
Temperature X Curv.	-0.16	0.13	100.08	-1.18	.240
Vibration X Curv.	0.39	0.23	105.081	1.65	.103
Noise X Curv.	0.23	0.18	101.64	1.32	.190
Sea X Curv.	-0.06	0.17	97.87	-0.34	.733
Stress X Curv.	-0.26	0.15	105.02	-1.75	.084

Notes. Total Sleep = is the cumulative amount of sleep achieved in a 24-hour cycle. Stress = generalized work stress described as relating to work load/pace etc. *df* = degrees of freedom. Curv. = Curvilinear Time.

Table 8 (continued)

Summary of Fixed Effects Estimates for all individual predictors with Time

Model 3	Estimate	Std. Error	*df*	*t*	*p*
Supervisor Support X Curv.	0.02	0.20	104.50	0.11	.916
Colleague Support X Curv.	0.20	0.19	106.12	1.02	.310
Sig. Other Support X Curv.	-0.18	0.15	100.13	-1.19	.237
Recovery X Curv.	-0.24	0.15	107.27	-1.59	.116

Notes. Total Sleep = is the cumulative amount of sleep achieved in a 24-hour cycle. Stress = generalized work stress described as relating to work load/pace etc. *df* = degrees of freedom. Curv. = Curvilinear Time.

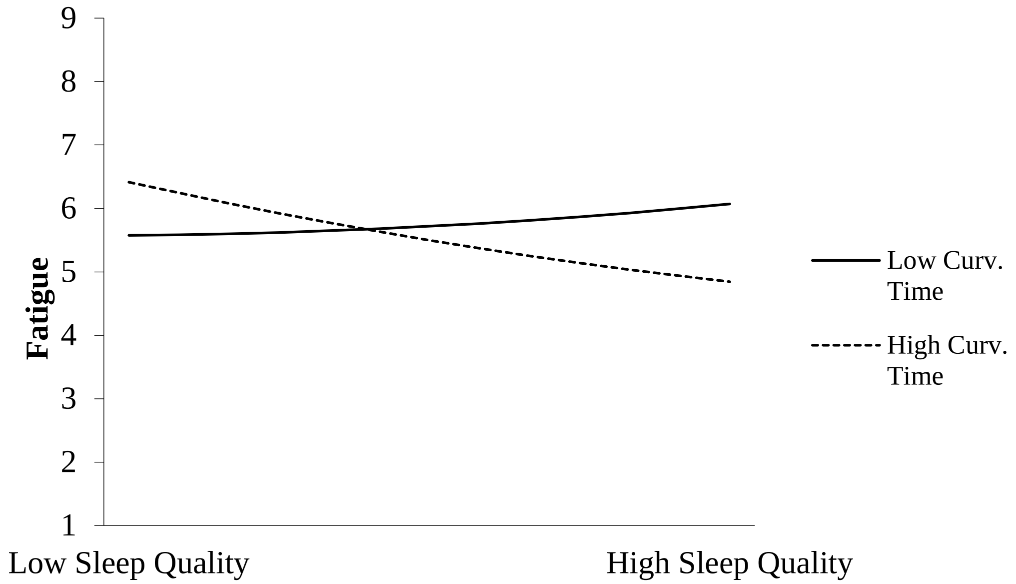

Figure 4. Illustrates the interaction between low and high sleep quality and low and high curvilinear time.

Figure 4 represents the interaction between sleep quality and curvilinear time. Early in the sail participants getting lower quality sleep reported less fatigue than participants reporting higher sleep. Later in the sail, however, participants getting lower quality sleep reported higher levels of fatigue than participants getting high quality sleep.

Overall, total sleep need for recovery, sea state over time, stress over time and quality of sleep over curvilinear time were all significant factors contributing to reported fatigue. When the significant control variable from the preliminary analyses (i.e. department) was introduced into the analyses the factors contributing to fatigue were unchanged.

Discussion

The threat fatigue poses to the lives of marine crew, marine infrastructure and the environment is increasingly being recognized, as observed by IMO Fatigue Guidelines (2019), the importance placed on sleep in marine incident investigations (TSBC, 2016), and major research initiatives like Project MARTHA (2017). Despite this increased awareness the issue of mariner fatigue has yet to be resolved. While the ideal outcome would be to eradicate fatigue, this is not a realistic goal for a myriad of reasons. The ultimate goal thus becomes minimizing the number of factors mariner are exposed to that increase their fatigue risk while maximizing the potential benefits of factors that buffer against fatigue. To this end this research project aimed to explore factors that both contribute to and buffer against fatigue with the primary aim of finding practical ways to minimize fatigue risk while also advancing our knowledge in this area to further theory as it relates to fatigue. This exploration looked at objective sleep measures, environmental conditions, social support and need for recovery as the main contributors/protective factors related to fatigue.

Conservation of Resources Theory

Mariner fatigue was explored through the Hofboll's (1989) COR theory. From this perspective individuals will strive to preserve or gain resources and will take action to prevent the loss of or threat to resources that are valued. Through this lens mariners will attempt to preserve or improve their rested state (i.e. their well-being). Model 3 explored the ability of all predictors (i.e. time, curvilinear time, total sleep, quality sleep, noise, temperature, vibration, sea state (i.e. the size, height and power of waves as perceived by participants), general stress, supervisor support, co-worker support, family/friends support and need for recovery) to predict fatigue. Each of the predictors are discussed below.

Sleep

Substantial research has explored the relationships between sleep quantity, quality and well-being (Litwiller, Snyder, Taylor, & Steele, 2017). Despite the well-established relationships between sleep quantity and quality it was imperative that these factors be included in the model to understand how other predictors contribute to fatigue when factors like quantity and quality of sleep are considered. It was predicted that this sample would conform to the well-established finding that decreased quantity and quality of sleep would predict increased levels of fatigue (Pilcher, Schoeling, & Prosansky, 2000). This hypothesis was partially supported in that total sleep (representing quantity of sleep) obtained in a 24-hour cycle was a significant predictor of fatigue. Sleep quality, however, did not directly predict fatigue. This finding contrasts with Pilcher, Schoeling & Prosansky (2000) findings that sleep quality was the best predictor of fatigue. This is potentially attributable to the observation that average sleep in the current study was lower than average sleep in Pilcher and colleagues' (2000) study. Though sleep quality interacting with curvilinear time was a significant predictor of fatigue the relationship itself was unexpected. Early in the sail participants reporting low quality sleep were also reporting lower levels of fatigue than individuals reporting high quality. Later in the sail, however, low quality sleep was associated with higher levels of fatigue when compared with individuals reporting higher quality sleep as would be expected. This may indicate a cumulative effect whereby low quality sleep may only contribute to fatigue over time as a sleep debt accumulates. Using this objective sleep capturing data software was seen as critical to this research as previous research has indicated that seafarers may overreport sleep and underreport hours worked in their logs (Allen, Wadsworth, & Smith, 2008).

Interestingly, a comparison of self-reported and objective average sleep while onboard the ship, which resulted in a 30-minute overestimation of sleep obtained, was not statistically significant – possibly because of the lack of statistical power resulting from a small sample. Despite the non-significance of this finding, this difference represents a large effect size suggesting practical implications. The inference that this 30-minute difference is of practical importance is reinforced by the body of research which indicates that even a 30-minute sleep deficit can result in significant cognitive impairments (Williamson & Friswell, 2013). The practical difference between reported sleep and objective sleep measures underscores the importance of objective sleep measures.

A review of the studies included in Dohrmann and Leppin’s (2017) systematic review highlights the gap in literature regarding the impact of 12/12 versus the 4/8 watch systems on fatigue. It has largely been established that the 4/8 system results in lower levels of fatigue compared to the 6/6 watch system. Developing a hypothesis regarding the potential differences between the 12/12 and 4/8 was challenging as each watch system posed different fatigue risks. Previous findings linking extended shift length to both acute and chronic fatigue (Barker & Nussbaum, 2010; Josten et al., 2003), would imply that the 12/12 watch system could result in higher levels of fatigue. In contrast to this finding, however, individuals working the 12/12 have the possibility of getting eight hours uninterrupted sleep versus the broken sleep that is possible on the 4/8 watch system, which would indicate that the 4/8 watch system would result in higher levels of fatigue. Sanquist and colleagues (1997) attributed daily sleep deficits of 1.3 hours (per 24-hour cycle) to sleep fragmentation due to work scheduling. The hypothesis that the 4/8 watch system would result in greater fatigue than the 12/12 was not supported as neither the 12/12 nor the 4/8 watch systems significantly predicted higher levels of fatigue. This may indicate that these two watch systems represent similar levels of fatigue risk, but that the risks posed by each watch type are simply different. This is possible as the differing risks inherent in each watch type made the development of this hypothesis quite difficult.

Environmental Conditions

Workplace stressors have repeatedly been shown to be related to strain, fatigue and wellbeing (Sonnentag & Fritz, 2015). Therefore, it is vital to understand how environmental conditions contribute to mariner fatigue, especially given this population typically works at least 12 hours per day for extended periods of time, which in and of itself elevates their risk of fatigue (Williamson & Friswell, 2013). The hypothesis that negative environmental conditions will predict increased fatigue, was only partially supported. None of the predictors directly predicted fatigue and only sea state and general work stress predicted fatigue over time. It was not surprising that sea state was a significant predictor of fatigue; as previously discussed, the ship encountered some very rough seas during days 1 to 5 of the study, which was very taxing on the body during waking as well as sleeping hours. As can be seen in Figure 2, sea state early in the voyage significantly predicted fatigue in that low sea state was associated with lower fatigue whereas high sea state was associated with higher levels of fatigue. This finding mirrors Ellis, Allen and Burke's (2003) study which found that crew alertness could be predicted by employment on high or low motion vessels. In contrast later in the voyage low sea state was associated with higher levels of fatigue than high sea state. This is a somewhat puzzling finding as it runs counter to previous literature. This relationship may be related to differing work routines during high and low sea states (i.e. certain work cannot be done during rough seas). Furthermore, it should be noted that even when crew members are on a ship objectively experiencing the same sea state their personal experiences may differ, due to personal sensitivity or location on the ship (i.e. crew positioned higher on the ship experience more motion than those located lower on the ship). Additional research is needed to understand this relationship.

Crew members advised me that placing equipment under one side of the mattress was a common measure taken to prevent being thrown from one's bed while sleeping (see Figure 5). The intention behind this countermeasure is to create a barrier that keeps the individual in the bed during rough seas. While this countermeasure does increase safety and minimize the risk of injury it is not a comfortable arrangement its necessity highlights the impact the marine environment has on seafarers both on and off the clock.

Figure 5. Typical precaution to prevent being thrown from one's bed during rough seas.

Stress over time also emerged as significant predictor. Figure 3 depicts a cumulative effect whereby high levels of stress early in the sail do not seem to have a large impact on fatigue with participants reporting high and low levels of stress having similar reported levels of fatigue.

As time progressed, however, higher stress predicted higher levels of fatigue. The significant motion of the ship meant that even very simple actions like walking up a flight of stairs or eating one's meals required extra vigilance. It is possible that the rough seas themselves reduced overall resources available aggravating the impact of general stressors on fatigue. It is also possible, however, that the push experienced by the crew to prepare the ship for her first port visit to Victoria British Columbia contributed to work load and pace increasing experiences of stress (i.e. freshly washing/painting the deck, painting railings etc.).

The lack of significant findings regarding the impact of temperature and noise should be interpreted with caution as this does not necessarily mean they are not relevant contributors to mariner fatigue. This study took place from 10 – 18 December 2018 with the ship docked in Pearl Harbour, Hawaii and continuing on the Victoria British Columbia. The temperature from Hawaii (in winter) to the West Coast of Canada was quite temperate. When sailing in different parts of the world or at different times of the year temperature may be more relevant. Anecdotally, some of the deck crew explained that while the bridge was very comfortable during this sail (kept quite warm in colder conditions) the wrap around windows meant that in hotter climates and sunny conditions it became quite warm (with one person describing it as a sauna) as the cooling system was not as efficient in regulating temperature. The relatively ideal conditions regarding temperature during this sail likely extended to the crew working out on the ship's deck as the temperate environment did not capture the spectrum of heat and cold that crew must at times contend with depending on the time of year and location of the sail.

The lack of significant findings regarding noise must also be interpreted conservatively due to an issue that was retrospectively uncovered with the stressor items. Specifically, the question asks the participant to rate how much on a scale of 1 – 5 noise has contributed to their fatigue. The phrasing is problematic in light of Tamura and colleagues (2002) findings that seafarers continue to have disturbed sleep when exposed to noises in their environment, but fail to recognize these disturbances. Additionally, Sunde, Bråtveit, Pallesen, and Moen, (2016) demonstrated with objective sleep measures that noise reduces seafarers sleep efficiency. This ship, however, was recently refit so it is also possible that the layout, or perhaps modern equipment, are protective factors against sleep disturbances.

Social Support

Social support has long been viewed as a buffering resource that can mitigate negative outcomes (Baruch-Feldman, Brondolo, Ben-Dayan, & Schwartz, 2002). Previous research has shown that the source of social support can differentially impact work outcomes (Halbesleben, 2006). However, a great deal of this research has focused on outcomes like job satisfaction, and burnout. In contrast to expectations, however, none of the sources of social support buffered against fatigue, thus the hypothesis that social support would buffer against fatigue was not supported. There are a few potential explanations for the lack of findings in this study. This may be because social support perceptions are fairly stable over time and do not dramatically fluctuate day to day. A second explanation is that, the measure used failed to capture day to day changes in perceived support. The third is that social support does not buffer against fatigue in the marine context.

Halbesleben and Wheeler (2015) note a dearth of research that explores daily fluctuations in social support with the majority of literature focusing on the source of support. Their study, however, supported the notion that support fluctuates daily (Halbesleben & Wheeler, 2015). Therefore, it appears that the measure used in this study may not have captured daily fluctuations effectively. The non-significant findings regarding social support as a buffer may also have reflected the very limited number of social activities seafarers participate in while on board. As was previously mentioned it did not appear that there were any extra-curricular social activities taking place beyond communal meal times. The minimal fluctuation may have been a result of very few opportunities to meaningfully perceive support from these sources throughout the study. While it is possible that a lack of variability, or inability to capture variability may explain the insignificant relationship between social support and fatigue it is also possible that a significant relationship simply does not exist. Conditions experienced in the marine environment (i.e. environmental conditions, lack of recovery) may be so extreme that the draw on personal resources cannot be offset by gains achieved through social support. In a review of literature on the strength of bad versus good experiences Baumeister, Bratslavsky, Finkenauer, and Vohs, (2001) found that negative events/factors had a greater impact across a host of experiences in comparison to positive events. From this perspective resources drawn by environmental condition (or need for recovery) may outpace the refill experienced by social support.

Recovery

The potential for recovery to mitigate strain is a generally accepted concept within psychological literature (Bennet, Bakker & Field, 2018). Thus it was hypothesized that recovery need would predict fatigue, which was confirmed in Model 3. There is a substantial body of literature that identifies effective recovery as a protective factor against fatigue (Sonnentag & Bayer, 2005; Von Thiele Schwarz, 2011). The issue is that pervasive throughout this research is an assumption that individuals have the opportunity following a shift to return home and recover. As previously discussed, mariners operate in a captive work environment and need to recover while still at work, which is a concept that has not been thoroughly explored. Variance over time during this study in need for recovery indicates that one can recover from work even if they are never able to completely remove themselves from the work environment. This finding extends recovery literature by demonstrating the capacity to recover without leaving the work environment over an extended period of time. Additionally, these findings demonstrate the incremental predictive capacity of need for recovery despite the fact that objective sleep measures (i.e. total sleep and sleep quality) were included in the model. This identifies recovery as potential resources that can be used to mitigate fatigue risk.

As previously mentioned, however, during the period of this sail the researcher observed no crew members participating in extracurricular activities that could provide recovery experiences; in addition to potential recovery benefits these types of activities could also bolster access to social support (Fritz & Sonnentag, 2005). This observation reinforces the qualitative finding by Thai and Latta (2010) that seafarers spend their time onboard working and sleeping, which may represent an attempt to protect one's rested state. If seafarers believe that only a lack of sleep results in feelings of sleepiness they may feel they have no way to improve their well-being beyond getting more sleep.

Limitations

The most significant limitations of this study were sample size and study duration. Hox (2010) recommends a minimum of 30 groups with at least 30 observations each to ensure sufficient statistical power to conduct multilevel modelling analysis. This study had 18 participants (representing a 67% response rate) that participated over a period of eight days. Overall, this means that findings must be interpreted with caution especially with regards to group comparisons. This also means that it is possible some analysis failed to reject the null hypothesis when it was in fact false, Type II error, due to a lack of power. This was, however, the only window of opportunity for the researcher to meet the ship while in port and sail, as any other sail would have required a prolonged absence from classes or would have incurred additional international travel expenses which was not possible.

In retrospect the wording of the stressor questions was problematic. Contrary to Hinkin's (1998) recommendation to avoid double barrelled items the environmental conditions items asked participants about exposure to stressors and asked them to ascribe the degree to which that stressor impacted their fatigue. This is particularly problematic in the face of research that identifies individuals are at times unaware of the impact various stressors have on their fatigue level (Tamura et. al., 2002). The wording of items necessitated that participants associate exposure to a stressor with their level of fatigue. Double barrelled items may have masked effects if participants did not believe exposure to certain stressors were relevant to their level of fatigue (though they may have been relevant).

A substantial portion of the studies examining the determinants of mariner fatigue operationalize fatigue using the KSS, as was done in this study (Dohrmann & Leppin, 2017). This operationalization of fatigue, however, in and of itself represents a limitation as it distills the more complex experience of fatigue to an experience of sleepiness. A multifaceted measure of fatigue which considers the many components of fatigue would better clarify how different factors protect or drain individual resources. For example, Frone and Tidwell's (2015) Three-Dimensional Work Fatigue Inventory explores the emotional, mental and physical aspects of work fatigue, a similar type of scale developed for daily use would be ideal.

As with many studies conducted in an applied setting, it is possible that these results do not generalize to all seafarers. Participants may represent a subset of seafarers that prioritize sleep and rest making them more likely to participate in this study. If rest priorities are different fatigue mitigation behaviours/ choices may also be different. Non-participants may be suffering higher levels of fatigue and self-selected out to mask their fatigue (Allen, Wadsworth, & Smith, 2008). If non-participants are more fatigue the relationships may have presented differently with them as participants. For example, social interactions can be more volatile for individuals who get less sleep as decreased sleep has been shown to decrease emotional regulation and negatively impact relationships between supervisors and subordinates (Barnes, 2017; Nowack, 2017; Schmeichel, 2007).

Finally, it is unclear if the lack of significant findings regarding social support was due to, the relationship truly not being significant, related to a true lack of variability in perceived social support or a failure in the measure used to explore these relationships. Perhaps, an event-based predictor which explored incidence of negative and positive interactions (i.e. arguments, bullying, task related conflict, being helped, being thanked, being complimented etc.) would have greater variability and provide a clearer picture of the relationship between the social environment and fatigue. However, to comprehensively cover potential events this scale would need to be much longer, which would not be conducive to a diary study over longer periods of time. A different support scale, perhaps the one used by Halbesleben and Wheeler (2015) (modified perceived organizational support measure of Eisenberger, Huntington, Hutchison, and Sowa (1986)), which did find daily variation may be a better tool. The example item provided in their article, however, does not seem sufficiently different to have resulted in greater variability, “My coworker was willing to extend him/herself in order to help me perform my job to the best of my ability.” Nonetheless, the lack of clarity surrounding the outcomes regarding social support represent a limitation in interpreting the findings and avenues for future research.

Practical Implications

Despite the limitations of this study there are several practical implications. First and foremost, these findings highlight the incremental predictive ability of recovery above and beyond objective sleep measures to predict fatigue. In an environment where it is not always possible to change the amount or quality of sleep obtained interventions beyond simply recommending that seafarers get more sleep are crucial. This does not imply that quantity and quality of sleep are not extremely important it simply recognizes the limitations inherent in this environment when looking to minimize fatigue risk as much as possible. Ships operates 24/7 meaning someone has to be awake for their shift at 3:00am. While we cannot change that someone will be working the 3:00 am shift, we can endeavour to maximize recovery while off shift to minimize fatigue.

Potential recovery interventions may be as simple as the purposeful introduction of social activities (i.e. movie night, card tournament, BBQ, etc.) into the ship's routine on a regular and ongoing basis, social activities have been found to improve recovery (Fritz & Sonnentag, 2005). Additionally, recovery training could not only enhance recovery, but also provide mariners with an understanding of the factors that contribute to their recovery (Hahn, Binnewies, Sonnentag, & Mojza, 2011). Beyond enhancing recovery ability this training could underscore seemingly innocuous behaviours that may be inhibiting proper recovery. Specifically, policies surrounding recovery interruptions for work related matters should be considered, work interruptions may inhibit the psychological detachment needed for recovery (Sonnetag & Fritz, 2015). For example, a no "shop talk" policy while in the cafeteria, gym or lounges may enhance recovery.

Both sleep quantity and quality emerged as significant predictors of fatigue. Thus, despite the limitation inherent in this environment ensuring seafarers understand good sleep hygiene remains imperative as this could improve both quantity and quality of sleep by providing the seafarers the informational tools needed to maximise sleep opportunities. Good sleep hygiene has been found to improve both quality of sleep and reduce sleep latency enabling individual to get more sleep in the same period of time (Murawski, Wade, Plotnikoff, Lubans, & Duncan, 2018; Yang, Lin, Hsu, & Cheng, 2010).

In addition to quantity/ quality of sleep and recovery, sea state and stress over time emerged as incremental predictors of fatigue. These findings also have practical implications for management and crew. Establishing standard operating procedures following challenging sea states regarding crew rest could be a way to offset the fatiguing effects of rough seas. For example, reduced staffing resulting from certain sea states to allow crew additional rest time could minimize the impact of this fatigue risk.

Stress over time also emerged as a significant predictor of fatigue. An in-depth review of work place stressors specific to the organization could identify friction points in processes or other challenges crew face that could be corrected or minimized to reduce the impact of environmental conditions on seafarers’ fatigue. Follow up research could clarify if stress typical builds from one port to the next or if the specific stressors associated with entering the west coast port for the first time created atypical levels of stress.

Future Research

While this research is indicative of the importance sleep, environmental conditions, and recovery play in contributing to fatigue there remain many avenues requiring additional research. In particular, it is recommended that further research focus on the impact of social support (and other elements of social dynamics more generally), specific environmental conditions and recovery as they contribute to fatigue. Additional research comparing the 12/12 and 4/8 watch system is also essential.

Additional research exploring the impact of social support as it relates to fatigue is needed. There was very little variability in perceptions of social support across the study period, additional opportunities to perceive social support may introduce variability and enhance perceptions of support. At the time that this study was conducted there were no formal or informal social activities taking place onboard (excluding meal hours). It would be interesting to see what impact social events, like BBQs (with reduced staffing) or social activities like card tournaments have on perceptions of social support, recovery and ultimately fatigue. Social activities during the weekend have been shown to promote recovery, improve general well-being and increase engagement at work (Fritz & Sonnentag, 2005). Social activities during off shift time may provide seafarers with similar benefits. Organizing social activities onboard the ship may enhance perceptions of social support and promote effective recovery.

Though this study only indicated that sea state and general work stress (of the five environmental conditions examined) significantly contributed to fatigue it is premature to rule out other stressors as potential contributors to fatigue. Additional research over different periods of time would clarify the relevance of each stressor as it relates to stress in the marine environment. Moreover, the attribution portion of environmental condition items should be removed. The finding that sea state contributed to fatigue was not surprising given the significant physical and cognitive drain this imposes. Based on this finding, however, various policies and procedures should be explored with the aim of maximising recovery while minimizing the impact on ships operations. Perhaps the “best solution” would be to sail into port and have everyone sleep, however, this solution would be extremely unpalatable to industry making it unlikely to be implemented. Therefore, a solution that maintains 24/7 operations is most likely the only achievable solution. Research which explores a reduced work posture during rough seas versus a reduced work posture following rough seas is an excellent place to start. It is possible that reducing the number of individuals working during very rough seas would reduce the overall fatigue experienced by the crew, however, during rough seas it can be difficult to rest as previously discussed (you are still exposed to the constant motion). A reduced work posture once in calmer waters may enhance recovery by providing greater opportunity to recover when recovery would be most effective. In addition to recovery from specific stressors recovery more generally also requires additional research.

There are several elements related to recovery that require further investigation. Firstly, an understanding of the enablers and barriers to recovery while at sea is needed. Research demonstrating the benefits of work breaks corroborate that recovery while at work is possible (Hunter & Wu, 2016) as does the variability of need for recovery over the course of this study. However, it is unclear if it is possible for individuals to fully recover from one shift to the next without leaving the work place. Once enablers and barriers to recovery have been identified policies and procedures should be implemented to enhance recovery opportunities. Furthermore, previous research has demonstrated that recovery training can enhance recovery capabilities (Hahn, Binnewies, Sonnentag, & Mojza, 2011), a greater understanding of the enablers and barriers to recovery while at sea could inform the development of recovery training interventions specific to this environment. Following the development of marine specific recovery training interventions would need empirical validation.

Due to the very small number of female participants gendered explorations were not possible with this data set. However, substantial research has indicated that women are more likely to experience fatigue which has been related to multiple and competing demands for their time (Duncan, Edwards, Reynolds & Alldred, 2003). This is in part attributed to the larger proportion of home-based work that women typically take on, which results in higher incidence of work-family conflict and ultimately fewer recovery opportunities (Behson, 2002; Frone, Russel, and Cooper, 1992). Though past research has found higher incidence of fatigue in women it would be interesting to investigate if this pattern persists in the marine environment (Duncan, Edwards, Reynolds & Alldred, 2003; Behson, 2002; Frone, Russel, and Cooper, 1992). While the captive work environment represents a fatigue risk it may also serve as a buffering mechanism for female employees who are physically removed and unable to participate in household work for the period of time that they are away at sea.

Continued research investigating the impact of the 12/12 versus the 4/8 watch systems is needed. Many studies have shown that the 4/8 watch system results in less fatigue than the 6/6. The differences between the 12/12 and 4/8, however, remains unclear as the small sample highlights the possibility that the non-significant finding may represent a Type II error. This avenue is of critical importance moving forward to ensure management is making informed decisions when assigning watch rotations.

Additionally, research over longer periods of time that include embarkation (i.e. the potentially fatiguing effect of international travel), and port visits would clarify how sleep, environmental conditions, social support and recovery impact fatigue during and following these events. Some studies have explored voyage related factors such as time into sail (e.g. Bridger, Brasher, & Dew, 2010) and sail length (e.g.Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), but no studies were found that explicitly examine the impact of travel on mariner fatigue. Previous research has indicated that port visits result in higher levels of fatigue (Bal, Arslan, &

Tavacioglu, 2015). It is unclear, however, if this dynamic is exclusive to commercial vessels whose role is primarily some form of trade or if the logistics of port visits more generally impact fatigue. If higher levels of fatigue during port visits is an issue primarily experienced by commercial trade vessels, non-trade vessels may be able to leverage port visits for social and recovery opportunities.

Conclusion

In many ways this research has generated more questions than answers, though knowing what questions we should be asking is in and of itself a valuable type of information. Considering fatigue from a COR theory perspective resources beyond sleep quantity and quality have been uncovered as relevant when trying to understand fatigue risk. That need for recovery is a significant predictor of fatigue, above and beyond objective sleep measures, provides an exciting and important avenue for future research. In an environment where getting more sleep is not always possible understanding the ways to minimize fatigue risk become of critical importance. This research indicates that effective recovery can buffer against fatigue (though it will have its limits as sleep remains a biological imperative). Additionally, this research empirically demonstrated that sea state and work stressors contribute to fatigue providing additional ways in which fatigue risk can be managed. Minimizing fatigue could save lives, marine infrastructure and reduce the environmental impact of this industry.

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Appendix A

Karolinska Sleepiness Scale (KSS)

Please, indicate your sleepiness during the 5 minutes before this rating through circling the appropriate description

1=extremely alert
2=very alert
3=alert
4=rather alert
5=neither alert nor sleepy
6=some signs of sleepiness
7=sleepy, but no effort to keep awake
8=sleepy, some effort to keep awake
9=very sleepy, great effort to keep awake, fighting sleep

Appendix B

Occupational Fatigue Exhaustion Recovery (OFER15) Scale

These Statements are about your experience of FATIGUE and STRAIN at Work OVER THE LAST FEW MONTHS
Circle a number from 0-6: “Strongly Disagree” to “Strongly Agree” which best indicates your response.

1) I often feel I’m ‘at the end of my rope’ with my work.
2) I often dread waking up to another day of my work.
3) I often wonder how long I can keep going at my work.
4) I feel that most of the time I’m just “Living to Work.
5) Too much is expected of me in my work.
6) After a typical work period I have little energy left.
7) I usually feel exhausted when I get home from work.
8) My work drains my energy completely every day.
9) I usually have lots of energy to give to my family or friends.
10) I usually have plenty of energy left for my hobbies and other activities after I finish work.

Modified intershift recovery scale for daily use.

11) I did not have enough time between work shift to recover my energy completely.
12) I feel refreshed at the start of this shift.
13) I recovered my strength fully between work shifts.
14) Recovering from work fatigue from my last shift was a problem for me.
15) I’m still feeling fatigued from my last shift.

OFER-CF; Chronic Fatigue subscale comprises items 1-5 inclusive.
OFER-AF Acute Fatigue subscale comprises items 6-10 inclusive.
OFER-IR Intershift Recovery subscale comprises items 11-15 inclusive.

Items should be included in test instruments in random order.

Scoring: Items 9,10,12 & 13 should be reverse scored

OFER-CF =sum (item 1-5 scores)/30X100;
OFER-AF =sum (item 6-10 scores)/30 X100:
OFER-IR = sum (item 11-15 scores)/30 X 100.

Produces comparable values between 0-100 for each subscale. Higher scores on each computed subscale indicate ‘more’ of the subscale construct.

Appendix C

Environmental Conditions

Over the last 24 hours how have these factors contributed to your fatigue?

1. I was exposed to extreme temperatures (hot or cold) today that …
2. I was exposed to vibration today that …
3. I was exposed to noise today that …
4. The sea state over the last 24 hours …
5. I experienced work stress over the last 24 hours that …

1 = N/A
2 = did not contribute to my level of fatigue
3 = slightly contributed to my level of fatigue
4 = moderately contributed to my fatigue
5 = significantly contributed to my fatigue

Appendix D

Scale of Social Support

Based on your feelings/perceptions over the last 24 hours please respond to the following questions.

1. How much did each of these people go out of their way to do things to make your work life easier?
    a. Your immediate supervisor.
    b. Other people at work.
    c. Your significant other, friends or relatives.

2. How easy is it to talk with each of the following people?
    a. Your immediate supervisor.
    b. Other people at work.
    c. Your significant other, friends or relatives.

3. How much can each of these people be relied on when things get tough at work?
    a. Your immediate supervisor.
    b. Other people at work.
    c. Your significant other, friends or relatives.
4. How much is each of the following people willing to listen to your personal problems?
    a. Your immediate supervisor.
    b. Other people at work.
    c. Your significant other, friends or relatives.

Each item is scored 0 – 4.

0 = don't have any such person
1 = not at all
2 = a little
3 = somewhat
4 = very much

Appendix E

Captain’s Introductory E-mail

Email Subject line: Saint Mary’s University Study – Factors Contributing to Mariner Fatigue

Fellow crew members,/

[redacted] employees will be given the opportunity to participate in a study that explores factors contributing to mariner fatigue. This project will be conducted by a researcher from Saint Mary’s University, participation or non-participation will have no impact on your employment with [redacted] .

Mariner fatigue is a serious problem in the marine industry that impacts employee well-being, results in damaged equipment and can have serious environmental repercussions. We encourage you to participate in this project, but want to be sure that you understand your participation is completely voluntary. If you choose to participate then change your mind you can stop participating at any time. The results of this study could influence organizational policies and procedures and may help us understand ways to improve your quality of life. Additional information on this study will come from the principal investigator, Alexandra Duval. This project is fully endorsed by [redacted] and has been reviewed by the Saint Mary’s University Ethics Committee (REB# : 19-031). If you have any questions or concerns, please contact the principal investigator (Alexandra Duval) at 902-717-4587 or at Alexandra.Duval@smu.ca.

Captain’s Signature Bloc