Loughborough University
Transport Safety Research Centre

vti

Understanding seafarer fatigue in ferry operations

July 2024

Professor Ashleigh Filtness
Dr Anna Sjors Dahlman
Dr Sally Maynard
Dr Wendy Jones
Dr Christer Ahlstrom
Mr Adam Asmal
Dr Andrew Pooley
Dr Anna Anund

Table of Contents

Glossary of terms

Biomathematical Model (BMM): A model to predict the fatigue levels of individuals, or of work schedules, based on an understanding of the key factors which are known to contribute to fatigue.

Bosun: serves as the senior deckhand and is responsible for overseeing the deck department's operations. They ensure the maintenance, cleanliness and safety of the vessel. Short for boatswain.

Circadian rhythm: the internal biological clock that regulates various physiological and behavioural processes over a roughly 24-hour cycle. It includes the circadian low, occurring roughly from 2 a.m. to 6 a.m., and a second more minor circadian low at roughly 2 p.m. to 4 p.m., these are times when physiological sleepiness is greatest (the ability to maintain wakefulness is at its lowest) and performance capabilities are lowest.

Fatigue: a psychological and/or physical impairment experienced by a person that can affect their ability to perform effectively. There are many factors which influence fatigue including sleepiness due to lack of sleep or time of day; fatigue from physically demanding tasks; and fatigue from tasks which are either mentally demanding (overload) or too undemanding or boring (underload)

ILO (International Labour Organization): United Nations agency whose mandate is to advance social and economic justice by setting international labour standards.

IMO (International Maritime Organization): United Nations specialised agency with responsibility for the safety and security of shipping.

Incident: A safety critical failure, often referred to as an accident. The word accident is avoided in this research report due to the term being connected with the idea of being unavoidable. Instead, the word incident suggests a failure which was not inevitable, and could have been avoided had different actions been taken or under different circumstances.

Karolinska Sleepiness Scale (KSS): A 9-point scale used in scientific studies where people are asked to self-report how alert they feel at that moment. It is an established and respected method used in scientific studies for measuring fatigue.

Live-on-board: Seafarers required by their employer to sleep onboard the vessel during work periods of the roster.

Master: the highest seafarer rank, also known as the captain. Has ultimate responsibility for everything that happens on their vessel, including the security of the ship, as well as the safety of the crew and cargo and any passengers, both when in port and at sea. Guides or assists the ship in and out of harbours or through difficult waterways.

Muster list: a list of the functions each member of a ship's crew is required to perform in case of an emergency. It must be displayed at every conspicuous location onboard.

Psychosocial issues: those issues encompassing the mental, emotional, social and spiritual aspects of a person's life.

PVT (Psychomotor Vigilance Test): objectively assesses fatigue-related changes in alertness associated with sleep loss, extended wakefulness, circadian misalignment, and time on task.

Roll-on/Roll-off Passenger vessels (Ro-Pax): Ships designed to carry both passengers and vehicles. They have specialised decks for vehicles, allowing them to be driven on and off the ship, while also providing facilities which may include cabins, restaurants, and amenities for passenger comfort.

Roll-on/Roll-off (Ro-Ro) vessels: Cargo ships equipped with ramps or platforms that allow vehicles to be easily driven or rolled on and off the ship, facilitating efficient transport of wheeled vehicles. This may be under their own propulsion or by use of port-based tractor units.

Roster: For shipping vessels this is a structured schedule that determines the rotation, duties, and rest periods of crew members, e.g., 4 weeks on, 4 weeks off. It ensures adequate staffing, regulatory compliance, and crew fatigue management, while maintaining operational efficiency and the safety of the vessel and its crew during shipping operations.

Route intensity: Refers to the level of activity or demand experienced by a specific shipping route. It considers factors such as the frequency of vessel departures, cargo volume, passenger traffic, and overall operational activity along the route.

Shift: The pattern of hours worked across a given day's work, e.g., 12 hours on, 12 hours off.

Sleep-at-home: Crew who travel home every day after working their required hours, as employees would in most non-maritime workplaces.

Sleepiness: The experience of feeling sleepy due to insufficient sleep or time of day. This is a state related to human biology.

Tiredness: Commonly used word to express the experience of fatigue and/or sleepiness.

1. Executive summary

Background

Shipping is an industry that operates 24 hours a day, 7 days a week. Seafarers are shift workers and are susceptible to experiencing fatigue. For this research, fatigue is defined as a psychological and /or physical impairment, which has the potential to reduce optimal performance. Fatigue is multifaceted and could be caused by limitations in the body's response to sleep pressures[1] and circadian[2] pressures, as well as impacts from activities related to work tasks such as cognitively over or underloaded. The risk of fatigue that seafarers face arises from multiple factors, including:

- Sleep related factors: not enough or poor-quality sleep or the time of day.
- Active task fatigue: e.g. doing activities that are physically demanding.
- Passive task fatigue: e.g. doing activities that are monotonous.

There has been a lack of research investigating fatigue in seafarers, particularly for those operating ferries in UK waters. The Department for Transport (DfT) commissioned Loughborough University Transport Safety Research Centre (TSRC) and the Swedish National Road and Transport Institute (VTI) to conduct research into seafarer fatigue, with the following objectives:

1. To determine the most appropriate method/s to assess and monitor seafarers' fatigue.
2. To understand what the possible consequences of fatigue for different roles on the muster list are.
3. To determine what are the most important factors that cause and exacerbate fatigue and what should be the appropriate corresponding mitigations.
4. To understand what fail-safe measures are currently used by Ro-Ro and Ro-Pax vessels to prevent an accident caused, partially or wholly, by seafarer fatigue.
5. Drawing upon best practice from other transport sectors, such as the aviation industry's CAP 371, to explore how a model that predicts the maximum number of hours and weeks for a seafarer could work in practice, accounting for the identified relevant risks and mitigations against fatigue.

Methodology

A programme of five research strands was used to fulfil the research objectives.

---

[1] A result of time since last sleeping: increased time without sleep or sleep loss increases pressure to sleep.
[2] Our circadian rhythms programme sleep to occur during the night, and we have increased sleepiness between 2am-6am and also between 2pm-4pm. The pattern runs on a near 24h cycle, but is influenced by external factors, such as the light/dark cycle of the local environment.

1. A Biomathematical Model (BMM) workshop and a review of fatigue risk management documents. Six maritime industry experts from ferry companies participated in the workshop.
2. A survey. 446 seafarers completed the survey, representing a response rate of approximately 9%.
3. Interviews with seafarers in managerial roles. 11 one-to-one interviews with masters and bosuns were conducted, lasting 30 – 45 minutes each.
4. Focus groups with seafarers working in customer-facing roles. A total of 45 participants took part across nine groups.
5. A field trial, involving 63 participants. Of these participants, 30 worked on vessels where they returned home to sleep at night and 33 slept on board.

Those who participated and the stakeholders who facilitated the research were supportive and engaged in the data collection activities. It is a testament to the commitment of participants and stakeholders that such rich data has been generated as part of this research.

Measuring fatigue is challenging. It is not possible to make an objective absolute measure of fatigue, as it is, for example, to measure alcohol impairment by calculating blood alcohol concentration. Rather, fatigue is estimated by measuring things which are known to be strongly related to it such as subjective experience and reaction time. Subjective sleepiness has been proven to be particularly accurate at indicating fatigue as most people have strong insight into their own fatigue experience. However, willingness to share subjective experience will be influenced by workplace culture and how comfortable seafarers feel in sharing this information with those asking about it.

Findings

It is evident that seafarers are committed to their industry (survey participants had worked as a seafarer on average for 17 years), take their responsibilities seriously and many enjoy their job. For example, during focus group discussions, those with customer focused roles, reported being pleased that they had changed from more office-based work to become seafarers. There was a general feeling of being part of a team, wanting to do the job well and feeling responsible for the safe sailing and care of passengers. Participants reported having an awareness of times when their colleagues were fatigued and felt able and willing to support them as needed.

Many interviewees spoke highly of their employers, noting that fatigue is investigated as a potential factor in incidents by considering the number of hours an individual had worked prior to incident. Several interviewees noted that industry attitudes towards fatigue are changing in a positive direction. Examples of positive action to minimise fatigue which were cited in either interviews or focus groups included: having two complete sets of crews (day and night crews), employers discouraging overtime, employers covering the cost of a taxi home and captains who would delay a sailing if they felt that the crew were too fatigued to sail.

59% of survey respondents reported fighting sleepiness at work on a monthly basis. Approximately 18% of seafarers said they had fallen asleep whilst on duty within the previous year and 41% said they had experienced a fatigue-related incident at work within the previous 10 years. Of those who had experienced such an incident, 85% reported that their employer would not be aware that this was due to fatigue. There were no major differences in the experience of fatigue between job roles, except for services crew (housekeeping, onboard services, and stewards) being most likely to experience sleepiness every day and reporting the lowest sleep quality. The reason for this is not clear but may reflect role factors (e.g. the demands of customer facing work) or differences in sleeping facilities between crew roles. In this study, female respondents were more than twice as likely as males to report fighting sleepiness, this is possibly because females are overrepresented in services crew roles, which was the role most likely to experience low sleep quality. This is a topic which would be beneficial for further research.

Various features of the work, the workplace culture and the opportunity for sleep and rest were identified as being able to cause or exacerbate fatigue. These included: working extra days or overtime; disturbed sleep; poorer sleep rating in the last three months; feeling restless off duty; greater work stress; undiagnosed sleep apnoea; variability in work start times; lack of a direct counterpart to take over responsibilities when they are off duty; and sleep environment factors such as noise and vibration and adaption to dynamic work changes. This might include changed working hours due to weather, tides, or cargo loading. These were reportedly less common for double-crewed ships (i.e. two full crews, working opposing shifts), where crew would be relieved by a colleague at the end of their scheduled shift. No specific work shift was found to exacerbate fatigue more than any other. However, it should be noted that sample sizes when broken down into work shift type may not have been large enough to detect subtle differences. Difficulty in relaxing was associated with fatigue in the survey findings and during the focus groups relaxing after work was reported as a key mechanism by which to manage fatigue. The interplay between relaxing, stress and fatigue would benefit from further research.

There is limited formal fatigue risk management within the industry nor is training consistently provided to crew about fatigue. Some research participants, particularly those in more senior roles did not believe that there is strong association between fatigue and incidents. This may be influenced by underreporting and therefore fatigue not being present in official records, e.g. incident reports, as well as reported difficulties in accurately recording work hours. Seafarers use informal measures to individually manage fatigue such as: caffeine use (most popular); getting fresh air; self-limiting/pacing themselves; and informal napping. Captains and other managers sometimes take decisions to mitigate the short-term impact of fatigue, for example by changing sailing times or even cancelling a sailing.

There was no clear answer to maximum safe days at sea. None of the outcome measures from the field trial showed a statistically significant deterioration over consecutive workdays. There were some indications of an increase in the share of shifts with high levels of sleepiness (KSS≥7) after five consecutive workdays but the pattern was not consistent with increasing number of days at sea. The range of roster patterns represented among the field trial participants limits the parameters within which safe days at sea could be considered. Within the field trial data collection window, only two participants worked more than 16 consecutive days meaning that it is not possible to draw conclusions about longer on-duty periods. Many participants had schedules with a maximum of seven consecutive days and only 11% had rosters with more than 14 consecutive workdays. Moreover, the data collection period was limited to four weeks. Further research with a longer data collection window and a wider range of rosters represented would be beneficial.

Biomathematical models are not used currently in ferry operations, and there are substantial limitations to their use in this context. If a model were to be designed for this environment, it would need to consider the following as a minimum, in addition to those features which are common to most existing models:

- Two different models to reflect both live-on-board model and sleep-at-home operations.
- Flexibility to incorporate the many common patterns worked including split shifts and working annualised hours.
- Ability to consider the weather which disrupts timetables and sleep.
- Work intensity, such as the number and length of crossings.
- Dynamic changes to working patterns to adapt to delayed sailings.
- Acceptability to crew.
- Individual variation including different job roles and stressors.

A series of recommendations were made for improving fatigue management in seafaring. These were informed by the data collection but were not evaluated as it was out of scope of this research.

Recommendations

The following recommendations may be beneficial in the context of UK seafaring.

Procedure and training:

- Develop fatigue risk management programmes. This would increase focus on fatigue, highlight that it is a serious issue and promote discussion.
- Provide education consistently across the ferry sector on fatigue management for all. Specific training should also be provided consistently across the ferry sector for those with responsibilities for managing fatigue in others.
- Consider the features of work patterns against checklists of optimal shift work practice.

Working patterns:

- Seek to limit the number of extra workdays and overtime seafarers can undertake, whilst recognising this might affect seafarers earning potential. This could be through awareness raising in the work force as seafarers can often control the choice of working overtime and extra days. Both factors have been found to increase sleepiness and fatigue, therefore fatigue training could highlight the potential risk factor of additional work and allow seafarers to perform a cost-benefit analysis of salary vs sleepiness. However, it is likely that personal economic drive may override education in deciding to accept overtime or not. A better option might be to educate or encourage employers to take measures to reduce the need for overtime.

- Instigate a screening programme for Obstructive Sleep Apnoea (OSA) and ensure that those with OSA are able to manage it effectively when on board.
- Seek to reduce variability in shift start times.
- Consider options for two full crews to avoid the need to wake a crew member who is sleeping while on rest or to delay the start of an off-duty period.
- Seek solutions to mitigate the impact of and improve recording of dynamic changes to workload. In particular, ensure engagement in drills contributes towards work hours and that Hours of Rest records are accurately completed.

Organisational culture and seafarer facilities:

- Seek to influence organisational culture within the sector to focus more on the safety and wellbeing of the seafarers rather than on profit margins.
- Support seafarers in access to communication with their significant social group to ensure they remain connected, as an approach to mitigating the stress experienced from work.
- Seek to minimise factors influencing gender disparity in fatigue, for example, tackling psychological and physical barriers to employment and work tasks.
- Recommend taking seafarers' individual preferences and characteristics into account where possible, e.g. where they have strong preferences for early mornings or late nights (so called 'larks' or 'owls'), this could reduce the risk of sleepiness on duty.
- Seek to support fatigue management in onboard services staff and minimise disparity between experiences of this group and other job roles, for example, rest facilities and after care in the aftermath of incidents.
- Consider managed napping opportunities (brief, planned naps during break times) as potential countermeasures to fatigue.
- Encourage development of a culture which encourages and normalises reporting of fatigue and enables its impact to be monitored.
- Promote the notion that fatigue in seafaring is not inevitable, that it is a safety issue for seafarers and to ensure that it is adequately managed.
- Incentivise operators to invest in employee rest facilities, seeking options to minimise the impact of noise, vibration, other staff, and vessel operations on sleep opportunity.

The wide range of aspects covered by these recommendations reflects the wide range of factors which can lead to fatigue. There is no single solution to fatigue management as there is no single cause of fatigue. Implementing a range of recommendations is likely to have most benefits. Recommendations could be enacted by any who have potential to influence, including, individual seafarers themselves, masters, managers, employers, unions, regulators, and policy makers. There is no quick fix to reducing fatigue. Long-term commitment is necessary.

2. Background and purpose of the research

Background

Fatigue in shipping

Inherently global in its nature, the shipping industry is complex, capital-intensive, increasingly technologically sophisticated and of immense economic and environmental significance. The intensive nature of some shipping operations means that seafarers may be subject to long and/or irregular work hours, as operators which employ seafarers rely on unconventional working patterns to accommodate the demands of the industry. Under the International Labour Organization (ILO) Maritime Labour Convention (2006) it is permissible for seafarers to work up to 91 hours a week and a minimum 10 hours rest each day. Under the International Maritime Organization's STCW 2010 amendments, a 98-hour working week is allowed for up to two weeks in 'exceptional' circumstances. For operators working solely within UK inland waters, for example sailing to the Isle of Wight, Isle of Man or Scottish Islands, regulation is through the UK's Merchant Shipping (Working Time: Inland Waterways) Regulations (2003). This permits seafarers to work up to 84 hours within a week rather than the 91 hours stated in the ILO's Maritime Labour Convention (2011). The Inland Waterways regulations also set a maximum of 48 hours working hours per week, averaged over one year.

Although not all ferry operators schedule their employees to work the maximum of 91 hours a week, these conventions mean that seafarers' working hours may deviate from more usual patterns and instead rely on shift work, variable rosters, and irregular watch schedules.

One outcome of these working patterns can be fatigue. Galieriková et al defines fatigue as "a state of feeling tired or sleepy that results from prolonged mental or physical work, extended period of anxiety, exposure to harsh environments, or loss of sleep" (Galieriková et al., 2020, p 35). The effects of fatigue are particularly dangerous in shipping as the technical and specialised nature of this industry can require constant alertness and intense concentration from seafarers. Two projects, HORIZON (2012) and MARTHA (2016) have previously investigated how these unconventional hours had an impact on seafarers.

HORIZON examined the effects of sleepiness on the cognitive performance of maritime watchkeepers under different watch patterns through simulation studies. Overall, seafarers in all departments had relatively high levels of subjective sleepiness, which was measured using the Karolinska Sleepiness Scale (KSS) scale. Findings included:

- The particularly adverse impact of some split-shift patterns on sleepiness levels;
- that off-watch disturbances increased sleepiness and reaction time;
- that on all patterns some watch officers fell asleep, particularly during night and early morning watches; and

- that the quality of handover between crews deteriorated over the course of the study.

MARTHA built on the HORIZON study, using a sample of volunteer seafarers in the naturalistic setting of work onboard their vessels to explore levels of sleepiness and the psychosocial issues associated with long term fatigue and motivation. Findings included that captains were more at risk of fatigue than other ranks, whilst night watch keepers (second officers) had significantly less sleep than others. Furthermore, both fatigue and stress levels were perceived as higher at the end of a voyage than the beginning by most crew, and port work was seen as more demanding than work at sea.

In summary, both projects confirmed sleepiness and fatigue to be important issues for seafarers and managers, with safety, long-term physical and mental health implications. They found that the working patterns led to a high probability of reduced sleep and of increased fatigue, with an ensuing accident risk (HORIZON, 2012; MARTHA, 2016).

Ferry operations

Ferries carry passengers from port to port for business, commuting and leisure. In the UK this involves around 37,000 crossings each year, carrying almost 30 million passengers (Gov.UK, 2024). However, limited research on fatigue has occurred within this important subsector of the industry. Research involving a literature review conducted for DfT (Behavioural Insights team, 2023) found very little recent ferry-related literature, and particularly a lack of evidence around the impact of different week-by-week roster patterns.

The ferries operating within UK waters use a range of shift and roster patterns to enable them to meet the demands of their routes. Some operators expect their crew to travel home every day after working their required hours, as employees would in most non-maritime workplaces. Other operators require seafarers to sleep onboard the vessel, typically for two weeks on followed by two weeks at home, off duty; or one week on, one week off. There is a wide range of patterns, with some involving much longer periods on board the vessel. During their time onboard, seafarers' hours are split into work hours and rest hours. Typical patterns include a single long shift each day (e.g. 12 hours) or a split shift, for example, six hours on, six hours off (HORIZON, 2012; Behavioural Insights Team, 2023).

As ferry operators can have different sleeping arrangements within their fleet and crew, there is opportunity to measure how different working patterns impact on the fatigue levels of their crew. For example, it was shown by HORIZON (2012) that split shifts can have a detrimental impact on seafarers. It is important to understand whether similar effects occur in the ferry industry. It is also important to investigate whether the findings of MARTHA are applicable to ferries, particularly regarding the high levels of fatigue or sleepiness amongst masters and other watch officers.

Regulations relevant to fatigue management

Operators need to comply with the minimum safe manning and muster list requirements for their vessel, which determines how many employees are required to be on board for sailing. Minimum safe manning is the level of crewing that will ensure the safety and security of the ship, the prevention of human injury or loss of life, and the avoidance of damage to the environment and property (IMO, 2011). The muster list identifies the functions each member of a ship's crew is required to perform in case of emergency. The number of crew required to fulfil this may vary depending on the number of passengers on board (IMO, 2016). How many crew are on a vessel will influence the opportunity that any particular individual has for rest, for example, if two complete crews are on the same vessel it is not necessary for anyone to be "on call" while at rest.

The number of crew specified to satisfy safe manning and muster list requirements is agreed with the vessel's flag state. This is the jurisdiction under whose laws the vessel is registered or licensed and is deemed the nationality of the vessel; and which has the authority and responsibility to enforce regulations over vessels registered under its flag. Typically, a vessel will be registered in the state of its owners, but operators may also choose to register vessels with other states. Ferries operating in the UK are registered with a wide range of different flag states.

There are also legal constraints relating to land territory. An area extending from the coastline to 12 miles offshore is known as the territorial sea and falls within the legal jurisdiction of that state (The United Nations Convention on the Law of the Sea (UNCLOS), 1982). However, the actual implications of this are complex, given the international nature of the maritime industry. For example, the national minimum wage of the UK technically applies to those who 'ordinarily work' within this area, but in practice, application and enforcement are complex. Recent legislation within France will require all cross-channel operators to ensure that crew work no longer than two weeks without a day off, in addition to being paid the minimum wage (Assemblée Nationale, 2023). At the time of research, within the UK, the Seafarers Charter (DfT, 2023) advocated a baseline pattern for high intensity routes of two weeks on-two weeks off, but compliance is voluntary. Increasing number of consecutive work days has potential to increase fatigue, therefore variability in regulations related to this could impact fatigue.

Fatigue is a recognised risk factor for incidents in seafaring, as it is in other transport sectors such as rail and aviation. High-profile fatigue-related incidents in the last 30 – 40 years have involved tankships including the Exxon Valdez and the Eagle Otome, naval vessels such as the USS Fitzgerald and the USS John S.McCain and passenger vessels such as the Star Princess (Shattuck, 2023). Investigations into these found common underlying fatigue triggers including long hours, shift work, missed sleep, and nighttime operations: all of these can be present throughout the maritime sector. Fatigue led to crew being cognitively impaired, making errors of judgement and unable to communicate effectively. In some cases, multiple crew members were fatigued at the same time, compounding the difficulties. Similar incidents have occurred in the ferry sector, a recent example being the Alfred, a passenger ferry which ran aground in Scotland in 2022, causing 41 injuries. Fatigue was found to be the primary cause of the incident, with the master falling asleep for around 70 seconds whilst navigating the vessel close to shore (MAIB (Marine Accident Investigation Branch), 2024).

Biomathematical models

Biomathematical modelling (BMM) is a way of predicting the fatigue levels across work schedules, based on an understanding of the key factors which are known to contribute to fatigue. It can therefore be used when planning shift rosters when seeking to identify a work pattern to minimise the chance of fatigue occurring. For most models, the user inputs information such as planned or actual work schedule, or an individual's prior sleep timings into a software programme. This then produces outputs associated with fatigue risk, alertness, and/or sleepiness.

BMMs have been used particularly in the rail and aviation industries, as well as in manufacturing contexts, and construction. They are particularly used to assess or compare different shift patterns, so it is reasonable to consider that they may be useful in seafaring. However, because they have been used relatively rarely in this context, their exact applicability needs further investigation.

Three common BMMs are described below:

- ***HSE Fatigue and Risk Index*** *(HSE FRI):* This provides an indicator of expected fatigue/sleepiness for each day in a shift pattern; and a score for each day of the relative risk of making an error. It was provided free by the HSE (Health and Safety Executive) until 2021 and has therefore been widely used in sectors including construction and the rail industry.
- ***Fatigue Assessment Tool by InterDynamics*** *(FAID)*: This gives a fatigue score which increases with hours worked; and a sleepiness score, showing the length of time for which a pre-set threshold is exceeded on each day. It can be used with real sleep data or will make assumptions about likely time spent asleep based on shift data. It has been used in a maritime environment to assess the likely contribution of fatigue to a fatal accident on board the Thor Gitta in 2009 (ATSB, 2009).
- ***Sleep, Activity, Fatigue, and Task Effectiveness model and Fatigue Avoidance Scheduling Tool*** *(SAFTE-FAST):* This provides a score for cognitive effectiveness and shows how this is expected to vary throughout each day of a shift pattern. It can be used with real sleep data to give individual predictions or can make predictions about likely performance based on population fatigue data. It has been used to predict fatigue for a shipping pilot as part of a research study (Hobbs et al., 2018).

FAID and SAFTE-FAST are used in this research to assess seafarer fatigue.

Research scope

Working definition of fatigue

Although there are various definitions of fatigue, it can be characterised by features such as subjective sleepiness, changes in psychological state, reduced ability to perform a task or achieve a desired outcome, reduced alertness, and difficulty maintaining focus on a task or activity for an extended period (Williamson, 2007). For this research, fatigue is considered to be a psychological and/or physical impairment which has the potential to reduce optimal performance. It is considered to be multifaceted, encompassing pressures from both endemic sleepiness relating to the body's homeostatic and circadian pressures, and task related fatigue.

Therefore, for seafarers, fatigue could be caused by various factors, including:

- Sleep related factors: Insufficient sleep and the time of day.
- Active task fatigue: overloading, demanding activities.
- Passive task fatigue: underloading, monotonous activities.

Many activities could influence seafarer task related fatigue including:

- The nature of their work resulting in task-related fatigue and impairment in performance.
- Physical exertion, such as securing vehicles on a car deck, carrying out cooking or cleaning activities or moving frequently up and down stairs between decks, leading to muscle fatigue.
- Cognitive demands leading to potential overload during times of exposure to demanding workload (for example ship manoeuvring, engaging with passengers) or underload during monotonous activity (for example watch keeping at sea).

Consequently, it is possible to make changes to activities and timing of activities to reduce fatigue meaning that changing the working pattern or the workload could lead to lower fatigue.

Ferry operations in scope

The current research specifically focused on the roll-on roll-off passenger (Ro-Pax) and freight (Ro-Ro) ferries operating in the waters around the UK. The research covered a range of vessel sizes, length of routes and route intensity.

3. Research design and methods

Engagement with the industry

A range of initial activities was undertaken to familiarise the research team with the ferry industry and to ensure that those with expert knowledge had an opportunity to influence the research design.

- Two researchers spent a 24-hour period on a ferry during normal operations. They spoke with several senior members of staff, visited various areas of the ship and spent time on the bridge observing docking and undocking in port; and open water sailing during the day and at night.
- Online discussions were conducted with two trade unions involved in UK ferry operations.
- Members of the research team attended meetings of the DfT cross government seafarer fatigue research steering board.
- The research team consulted with an Expert Advisory Board (EAB), whose members are international (Sweden, USA, Australia) experts in maritime fatigue management. They provided independent feedback on the proposed data collection tools and research methodology.

These activities provided the research team with insights into the challenges of the industry. The information gathered was used in the design of the survey, interview questions, and field trials.

Research ethics

Ethical approach

All the tasks in this research involved human participants and were therefore subject to approval from Loughborough University's Human Ethics Sub-Committee. The Committee requires detail on what personal information is to be collected, why, and how it will be stored and protected; this was provided, and ethical approval was granted. The provision of incentives to the participants in some of the research strands was also cleared by the ethical process; these were offered as a means of thanking the participants for the time spent supporting the research.

Only personal information that was of direct relevance to the research was collected. Prior to data collection, participants were provided with a participant information sheet and explicit consent form. These clearly explained the procedure and process for data collection and storage to the participant and were approved by the Ethics Sub-Committee. Participants signed to say that they understood these processes and consented to take part. The University's ethical principles go beyond statutory, regulatory or funders' requirements, and all academic activities must adhere to the ethical principles. The principal investigator was responsible for ensuring that appropriate ethical review was undertaken, and appropriate permissions were in place to conduct research activity. The recruitment of participants was recognised as being a key step in the research which was planned, executed and monitored carefully. The methods used for each research strand can be seen in Table 1 below.

Due to the special category personal data being collected as part of the research and to ensure compliance with data protection legislation, a Data Protection Impact Assessment was completed, in conjunction with DfT.

Avoiding bias

The research team recognises that sleepiness and fatigue management in a workplace can be a contentious issue. To obtain useful data, it was important that workers are willing to share information and so, building an open and honest relationship was essential. For this research, contact was made with the stakeholders early on to discuss their interest in supporting the research. This early informal observation helped the team to understand some of the usual operation of the ferry industry and the role of various seafarers within it and to help structure data collection approaches so they were more targeted at the participants. For example, the observation confirmed that the survey should be administered online rather than on paper and that participants to the field trial should be approached in person whilst onboard a vessel. Throughout the research, participating seafarers were encouraged to express their honest opinions by reiterating that their views and data will be kept confidential. Ensuring the objectivity and independence of all research is a principle of Government Social Research ethical assurance (GSR, 2021). To avoid bias and ensure those involved understood the research team's independence from DfT, the following steps were taken:

- University ethical requirements were met.
- Data was anonymised and aggregated in all reports and feedback to DfT.
- The research team were careful that knowledge gained during data collection did not influence the continuing collection of data elsewhere in the research. For example, the survey analysis was carried out after the completion of the field data collection, and by different researchers.
- The conclusions of the research team in all outcomes were evidence-based.
- All conclusions have been drawn independently of DfT, employers, unions and participants of the research.

An Expert Advisory Board was engaged, comprising international experts in fatigue management (from Sweden, USA and Australia). The Board provided independent appraisal of the proposed research materials and their comments were implemented where appropriate.

In all data collection methods, steps were taken to ensure that participation was as broad as possible, with recruitment being disseminated to everyone who was eligible. Where there were restrictions on the type of participants, these were always for research reasons. For example, the focus groups were intended to investigate the experiences of a particular seafaring group which might otherwise be under-represented in the research. Balance was offered by the survey being anonymous and open to all seafarers, allowing for data from a wide variety of voices and opinions. The key recruitment groups for each strand are shown in Table 1.

Table 1: Participant groups for each research strand

Strand	Key recruitment group	Method(s) of recruitment
1: BMM workshop	Representatives from the participating operators with experience in shift and roster scheduling, that is, those making decisions about working patterns	Invitation via DfT
2: Survey	All seafarers employed by participating operators	Survey link provided to participating operators by DfT
3: Interviews	Masters/captains and bosuns. Masters were interviewed due to their role as a manager and because project MARTHA identified them as being at risk of fatigue. Bosuns were included in the interviews because they are also managers and potentially closer to the frontline crew	Via participating operators, trade unions and contacts made by the research team
4: Focus groups	OSS (onboard sales and services) staff and ABs (able-bodied seafarers)	Via participating operators (face-to-face groups) and via trade unions (online)
5: Field trial	Seafarers from the participating operators who • Worked as a seafarer on regular basis • Had been working as a seafarer for at least two years • Were healthy (self-reported) and not been on sick leave for more than three days during the previous two months • Agreed to use a wearable sleep and activity tracker 24 h for four weeks • Agreed to complete questionnaires and sleep/wake diaries • Agreed to complete a reaction time test before and after each work shift	Via contacts at participating operators; through word-of-mouth amongst colleagues

Data collection

A research summary is provided in Annex E.

BMM workshop and fatigue risk management documentation review

Six maritime industry experts, each representing a different ferry operator, attended a two-hour face-to-face workshop in January 2024. Participants were recruited through DfT, who shared a participant information sheet with the ferry operators who registered their interest with this research. The workshop was conducted by a Professor of Transport Human Factors and Sleep Science, supported by other members of the research team. It was audio recorded and transcribed. The structure of the workshop can be found in Annex A.

Attendees were given information to read in advance about BMMs. Further explanations were then given during the workshop about how fatigue and sleepiness are typically defined, and about what BMMs are, how they have been used and their limitations.

The BMM workshop was initially intended to focus on the current use of BMMs in seafaring, and which model or models might be best suited to the industry. However, it became apparent through literature review and early conversations with stakeholders that BMM use and experience in the sector is minimal, therefore the workshop addressed the broader questions around roster planning and the potential for the use of BMMs.

Structured discussions at the workshop focused on:

- How rosters are usually designed and evaluated in maritime.
- The features a BMM would need to have to be useful in maritime.
- How BMMs might be used in maritime and any challenges or limitations.

After the workshop, all participants were asked if their employer had a fatigue management plan. They were asked to share copies of any existing fatigue management plans with the research team; none were shared because none of the participating operators had such a plan.

Impact of the BMM workshop on research design

The BMM workshop was the first research strand. There were two specific findings that highlighted potential limitations in the original research programme design. Firstly, there is a substantial difference in operation between live-on-board ferries and those with a sleep-at-home model. The research team identified the need for a larger data set to ensure that both of these, and the differences between them, could be properly considered.

Secondly, the importance of services staff, particularly their role during emergency situations, and whether being fatigued would affect their ability to fulfil this. As noted by one participant:

"*the first role of anybody on board any vessel is the safety of life at sea. The end. It doesn't matter whether they can serve a cup of coffee, drive a ship, (it's) the first line in everybody's job description" (BMM workshop participant).*

As a consequence of these early findings, changes were made to the original research design. These changes also reflected feedback from the unions and advisory board during initial engagement activities. The changes were as follows:

- The number of participants recruited to the field trial was increased to ensure good representation from people working both live-on-board and sleep-at home shifts.
- The number of participants for interviews was increased to ensure good representation from people working both live-on-board and sleep-at home shifts.
- The research design was modified to include focus groups with services staff. This was to address the recommendations of workshop participants that researchers should *“try and speak to all of the crew”* rather than relying only on interviews with senior managers such as captains and also their concerns that the research should consider the safety impact of services staff being fatigued.

Survey

Procedure

All seafarers employed by participating operators were eligible to complete the survey. The survey was developed to identify the prevalence of fatigue and identify factors which are associated with experiencing fatigue. The survey was available to be completed online in either English, French or Ukrainian. The survey was distributed from DfT to the operators, and from the operators to employees using a hyperlink or QR code. Once the survey was completed, there was an optional prize draw to win one of ten £50 cash payments.

The core questions were adapted from previous work by this research team (Anund et al., 2016; Filtness et al., 2019; Miller et al., 2020). Additional questions were added which arose from the prior knowledge and expertise of the researchers, informed by the initial engagement with the industry activities (see section 3.1). The survey was split into six sections:

1. Questions about work as a seafarer.
2. Questions about work patterns and arrangements.
3. Questions about sleep.
4. Questions relating to themselves as a seafarer.
5. Questions about health.
6. Background questions.

The full list of survey questions can be found in Annex D.

To ensure that the survey was only completed by people, several dummy questions were included where an incorrect answer would lead to the survey being terminated. This approach was successful in filtering for bots and ensuring only people submitted responses to the survey.

Analytical approach
The survey was open to respondents for three months between January and March 2024. In total 446 participants completed the survey, representing a response rate of approximately 9%. Four types of analyses were conducted as follows:

1. General descriptive statistics to explore the extent and nature of maritime fatigue.
2. Univariate logistic regressions to determine which factors significantly predicted fatigue.
3. Multivariate logistic regressions which combine the significant predictors of the univariate logistic regression.
4. One-Way Analysis of Variance[3] (ANOVAs) to determine whether particular roles, roster patterns or shift patterns are associated with different fatigue levels.

The survey contained 23 statements related to sleep and respondents were asked to indicate the degree to which the following happened to them during the last three months. Seafarers responded to each statement with one of six options ranging from “never” to “always (five or more times a week)”. The answers to these statements were used to create seven indices, four of these (sleep quality index, sleepiness index, impaired waking index, suspected sleep apnoea index) are part of the Karolinska Sleep Questionnaire (KSQ) as used by Anund et al. (2016). The fatigue index has previously been used in other workplace settings (Filtness et al., 2019; Miller et al., 2020). The disturbed sleep index and the cabin index were created specifically for the current research. Based on statement responses a numerical average was calculated across several statements to form each of the seven indices, as follows:

- **Sleep quality index**: Difficulty falling asleep, repeated waking, disturbed, or worried sleep, overly light sleep.
- **Sleepiness index**: Being constantly tired throughout the day, the need to fight to stay awake during daytime.
- **Fatigue Index:** Physically fatigued, mentally fatigued or both.
- **Impaired waking index**: Difficulty in waking up, oversleeping.
- **Suspected sleep apnoea index**: snoring, difficulty catching your breath whilst sleeping, interrupted breathing during sleep.
- **Disturbed Sleep index:** Sleep being disturbed by the movement of the ship, vibration, noise, by being too hot or too cold, anxiety about family, and tiredness being influenced by a change in time zones.
- **Cabin Index:** Sleep being disturbed by a colleague you share your cabin with, cabins on board unsuitable for sleeping, comfort of the bed and the cleanliness of the cabin.

---

[3] Analysis of variance (ANOVA) is a collection of statistical models used to analyse the differences among means.

Descriptive statistics were used to examine background factors, the extent and nature of fatigue, as well as the occurrence of sleep related incidents amongst seafarers. To examine which factors contributed to seafarer sleepiness two outcome variables were used: fighting sleepiness and having a sleep-related incident in the last 10 years. Both outcomes involved the respondents being separated into one of two groups. For the first outcome, respondents were split into seafarers who had to fight sleepiness at least 2-3 times a week (n = 122), and those who did not (n = 324). The second outcome compared those who had experienced a sleep-related incident in the last 10 years (n = 139), and those who had not (n = 261). A two-stage regression method was used.

For the first stage, a series of univariate logistic regressions were used to determine which individual factors best predicted whether respondents had to fight sleepiness often, and whether they had encountered an incident. These factors were related to sleep, work, health, or demographic information. For the second stage, any univariate predictors with a significant odds ratio ($p < .05$) were entered as predictors into a multivariate logistic regression using the stepwise method.

To deliver on research objective two, a one-way ANOVA with Tukey post-hoc corrections[4] was conducted between different job roles and outcomes which measure different areas of sleepiness from tiredness to fatigue. For this analysis, seafarers were not split between sleeping arrangements or shift type. The muster list was split into six categories: the first category was captains and masters.

Captains and masters are the highest authority on a ship and are responsible for the entire operation of the vessel. They direct, coordinate, and control all activities on board, and are responsible for the ship's safety, crew, cargo, navigation, and work organisation. In addition, the captain or caster is the shipowner's representative before third parties.

The second category was managerial roles that were not bridge related, for example, bosuns, chief stewards and chief engineers and head chefs. These group roles take on managerial positions of their respective department. For example, the bosun is in charge of planning, scheduling and assigning of work to the deck crew on the ship.

The third category was bridge crew which consisted of officers and mates. The bridge crew’s primary duties are navigational, which includes updating charts and publications, keeping them current, making passage plans, and all aspects of ship navigation. Other duties relate to matters of safety such as inspecting gear lockers, lifeboats, and all equipment on board ensuring that it is safe and operational.

The fourth category was service crew which consisted of on-board cervices (OSS), stewards and restaurant employees. This crew typically attend to the passengers on board the vessel and ensure their safety in an emergency.

[4] Tukey's post hoc test is commonly used to assess the significance of differences between pairs of group means.

The fifth category were deck crew which consisted of ratings and able bodied (AB) seafarers. The AB's role is to work mooring lines, operate deck gear, standing anchor details, and manage cargo, including securing loads or vehicles where necessary.

Finally, the sixth category were the engine crew which comprised engineers and electricians. The engineering crew are responsible for keeping the ship and the machinery running. This includes not only the engine and the propulsion system, but also, for example, the electrical power supply, devices for loading and discharging, garbage incineration and freshwater generators. An engineer is commonly considered an officer high in ranking on the ship.

All statistical analyses were conducted using IBM SPSS 29.0 statistical software. The alpha criterion was set to 0.05.

Interviews

A total of 11 one-to-one interviews with masters and bosuns were conducted, lasting 30 – 45 minutes each. The interviews were intended to explore the participants' understanding of fatigue and sleepiness in the industry, its effects, and how it is managed.

Masters were interviewed because project MARTHA identified them as being at risk of fatigue because of their manager role. Bosuns were also included in the interviews because they are the managers of a certain group of seafarers. The data collection took place in March and April 2024.

Participants/recruitment

Initial recruitment was intended to be via the maritime unions, particularly Nautilus which represents masters and bosuns. There was little interest expressed by union members, as a result the researchers invited individuals with whom they had come into contact during other data collection activity. One operator advertised the interviews to the relevant personnel on behalf of the research team and another operator provided the names of potential interviewees who had agreed to participate. Interviews were undertaken with seven masters and four bosuns; one participant was female and the remainder were male.

Procedure

At the beginning of each group, participants were provided with an information sheet explaining the background to the research and providing contact details of the research team. They were then asked to sign an explicit consent form which included details about the recording of the discussion. An interview question guide was produced to ensure each interview followed a similar format (Annex B). The interview questions were specifically designed to gain an understanding of:

- The possible consequences of fatigue for different roles on the muster list and how any risks are managed.
- The most important factors that cause and exacerbate fatigue and current related mitigations.

- The overarching themes that managers and captains associate with fatigue/sleepiness.

Analysis

The interviews were audio recorded, transcribed and analysed using a thematic approach allowing themes to develop organically. The themes were discussed and devised by two researchers.

Focus groups

Discussion groups were held to explore the experiences of fatigue for customer-facing staff. The focus groups were intended to identify the participants' views on the causes and consequences to their fatigue experience at work. A focus group discussion guide of questions and prompts was developed to ensure each group followed the same format (see Annex B). The questions considered day-to-day experience and emergency situations. Participants were also asked to describe events at different stages of a voyage. The focus group guide was informed by issues identified via the prior knowledge of the researchers.

Participants/recruitment

The research study contact at each operator was asked to assist with the focus groups by identifying a suitable time and vessel on which to hold the discussions. A group of up to eight seafarers working in a customer-facing role was then invited to attend the discussion. The researchers also requested that a room be made available which was suitable in size and privacy for the discussion. In addition, the opportunity to attend an online discussion was advertised via the trade unions; this was intended to extend the opportunity to participate to as wide a population as possible. A total of nine focus groups were completed – seven onboard and two online.

Procedure

At the beginning of each group, participants were provided with an information sheet explaining the background to the research and giving contact details of the research team. They were then asked to sign an explicit consent form which included details about the recording of the discussion. The participating seafarers were encouraged to treat the experience as an informal discussion about their experiences of fatigue and how it is managed at work, and to express their honest opinions. Participants were urged to talk to each other and to the researchers during the discussion and thereby share experience. It was emphasised to participants that all information they provided would be confidential, with no individuals or operators being identified in any reports.

The discussion occurred in a private room where it could not be overheard by anyone outside, and no managers were present. Each focus group was facilitated by two researchers working together; they were taken from a total of four available researchers. An incentive was offered to the participants (£20 per participant) to compensate them for their time.

Analysis

The discussions were audio recorded, transcribed, and analysed using a thematic approach allowing themes to develop both from the research questions and from the narratives of the participants. The themes were discussed and devised by two researchers. Where themes were found in both interviews and focus groups they were named and defined in the same way to ensure consistency in the analysis.

Field trial

The exact procedure experienced by participants was tailored by job role so as not to impact safe operations. The data were collected onboard during normal operation on specific routes. Participants kept a sleep/wake diary and wore a sleep and activity tracker (Fitbit Charge 6) for approximately four weeks documenting sleep quantity, quality and timing. Wearables continuously recorded movement. The recording continued throughout the 4-week period including rest and work days and nights Work schedules were recorded for all participants. The short version psychomotor vigilance task (PVT) (Basner & Rubinstein, 2011) was completed at the start and end of each on-duty period. In addition to objective measures, sleepiness rated on the Karolinska Sleepiness Scale (KSS) (Åkerstedt & Gillberg, 1990) was recorded every day. Daily reporting gave the opportunity to record any workplace impact of fatigue. The procedure was piloted by the research team for a period of approximately one week prior to the main data collection; five researchers wore FitBits and completed daily sleep diaries and PVT testing. Each participant ID had a personalised link for completing the sleep diaries and PVT testing.

Participants

63 participants were enrolled in the study. Recruitment was completed onboard seven vessels operated by three different ferry companies. It was intended to recruit at least four job roles including captains and night watchkeepers as these were the roles with greatest fatigue risk identified by the previous project MARTHA (2016). The job roles represented a range of work schedules. An incentive was offered to participants (£100 per participant after completing the full data collection). The onboard data collection was adapted to the participants' work schedules and included at least two weeks of data collection while on duty.

To be eligible to take part, seafarers must have:

- Been working as a seafarer on regular basis.
- Been working as a seafarer for at least 2 years.
- Been healthy (self-reported) and not have been on sick leave for more than three days during the last two months.
- Agreed to use a wearable sleep and activity tracker 24 h for four weeks.
- Agreed to complete questionnaires and sleep/wake diaries.
- Agreed to complete a reaction time test before and after each work shift.

Procedure

The seafarers received written information about the study procedures and the opportunity to discuss participation with a researcher. The seafarers also received a form for explicit consent which was signed before the start. The study was approved by the Loughborough University ethics committee.

On enrolment, an entry questionnaire was completed with questions about the participant's background as a seafarer, education, sleep and fatigue issues, health, and sleep-related incidents in the past.

App based sleep and fatigue diaries, and a wearable device (Charge 6, Fitbit Inc., San Francisco, CA) were administered to keep track of the seafarers´ sleep/wake history. Before the first day of onboard data collection, the participants started to wear the Fitbit and fill in sleep diaries. The Fitbit was worn around the wrist day and night like a watch and recorded sleep by tracking movement and heart rate.

Fitbit data was uploaded automatically to a cloud service, and this was monitored to ensure that it was consistently recorded. The sleep diary, other daily questionnaires, and the reaction time tests were completed using a mobile phone web application.

Onboard data collection was performed on all on-duty days during the 4-week period. The participants continued wearing the Fitbit and completing sleep and fatigue diaries. Before the start of the work shift, the participants performed the PVT which is a simple 3-minute reaction time task that provides an objective measure of alertness. The PVT consists of a response task completed on a mobile phone with the participant seated in front of the mobile phone screen. A letter appears on the screen at random intervals; the seafarer is instructed to press a button on the screen as soon as it appears, and the response time and lapses are measured. Of most interest are the lapses that have been proven to increase with increased sleepiness. The participants then performed their normal work tasks.

The PVT was set up according to Basner & Rubinstein (2011), with random stimuli onsets with an interval of 1–4 s between stimuli, and a maximum stimulus duration of 2 s. Performing the test in a web application on a mobile phone results in longer reaction times compared to when doing the test in an alert state due to time lags in the touch screen and the phone. The time lag is approximately 300ms[5] and varies between phones. The threshold criterion for lapses was therefore set individually as the participant's median reaction time plus 300ms. This roughly corresponds to the 500ms threshold that is normally used to define a lapse.

During the work shift, the seafarers regularly reported how sleepy they were on the KSS scale. They were instructed to report their KSS score in the web app every two hours, if their work tasks allowed. They reported how sleepy they had been feeling in the past 5 minutes. The exact timing for reporting KSS during the day differed between participants depending on their schedule and work tasks. After the work shift, the seafarer answered the KSS and performed the PVT.

At bedtime, the participants answered questions about current sleepiness, perceived stress and workload during the work shift, and indicated whether it was a workday or

[5] 300 ms is 300 milliseconds. A millisecond is one thousandth of a second

a day off. When they woke up, participants reported if they had slept well, how long it took to fall asleep, and how sleepy they were when waking up.

After completion of data collection at home and onboard, the participants completed an exit questionnaire, returned the Fitbit, and received compensation of £100 for their participation.

Data processing

The data were anonymised and the results are only presented on a group level. Schedule data and diary entries between February and April 2024 were used in the analysis. In the entry questionnaire, questions about sleep, daytime sleepiness, and sleepiness related incidents were the same as those used in the survey.

The participants' work schedules were described and categorised based on hours worked per 24 h, and whether they worked daytime or nighttime. Three main types of work hours were defined: 12 h on 12 h off, 12 h split shift, and 6-9 h on 15-18 h off. Typical work hours in the 12 h split shift category were: 6h on, 4h off, 6h on, 8h off, but there was some variation between participants in the distribution of work and rest. In the 6-9 h on 15-18 h off category, the participants worked one shift per 24 h and the starting times varied between participants. Most seafarers in this category had a rotating schedule, with varying lengths of the shifts (from 6 to 9 hours) and changing between morning and afternoon shifts. Night work was defined as at least 3 h work between 11 pm and 6 am. Regular night work was only seen in participants working a 12 h on 12 h off schedule. The categorisation was based on the hours worked during the study. Some participants could therefore have worked other schedules before the study started.

Rosters were categorised based on the number of days worked per week or number of weeks on duty and off duty. Four main types of rosters were defined: 1 week on 1 week off, 2 weeks on 2 weeks off, 8 weeks on 4 weeks off, and 5 days of work per week. Participants working 5 days per week either had a 5 days on 2 days off schedule or a more irregular pattern of days on and off duty adding up to between 35 and 37 h work per week. A few participants had irregular rosters or were the only ones with a particular roster. They were categorised as 'other'. Six participants had ship maintenance duties during the first two weeks of the study which meant they worked a different schedule than they normally do. Their roster was categorised as 'exception for 2 weeks and then 5 days per week'.

Not all participants had complete data for all outcome variables. Actual work hours were available for 50 participants whereas work schedules for 12 participants were based on information that the participants gave at onboarding combined with standard work schedules and diary entries. One participant had incomplete information about work schedule and was not included in BMM analyses. A total of 1,364 work shifts from 62 participants were available for the BMM analyses. Sufficient diary entries to allow analysis of self-reported sleepiness were available from 56 participants.

In the diary entries, data was available from 914 working days, the participants did 1,718 PVT tests and 4,274 KSS ratings. Approximately 24% of the working days did not have any PVT tests, 28% did not have a sleep diary and the accompanying KSS and stress ratings, and 45% did not have ratings at bedtime. There are various reasons for the high share of missing values. Some participants skipped or ignored filling in the information, but there were also technical problems with the web application that occasionally led to data loss when internet connection was weak or unavailable at the same time as the webpage was closed.

Inspection of the Fitbit data revealed that ship movements had interfered with the automatic sleep scoring for many of the participants sleeping onboard the vessels. All Fitbit sleep data was therefore visually inspected and sleep duration was manually corrected based on movement data from the Fitbits combined with diary entries of bedtime and wakeup time. Automatic sleep scoring was used in 69% of the sleep duration data.

Work schedules were evaluated using two different BMM tools, FAID Quantum (Darwent et al., 2010; Darwent et al., 2012) and SAFTE-FAST (Sleep, Activity, Fatigue, and Task Effectiveness-Fatigue Avoidance Scheduling Tool) (Hursh et al., 2004). The commercially available FAID Quantum and SAFTE-FAST modelling software packages were utilised to determine predicted levels of sleepiness (predicted KSS) relative to the actual work schedules. The primary output of FAID Quantum is FAID score where a higher score represents a higher fatigue exposure and for SAFTE-FAST the main output is effectiveness (%), where higher is better. In this study, predicted KSS, which is provided as a secondary output from both tools was analysed to enable comparisons between tools and between predicted and self-reported sleepiness on duty. More information about the BMM tools can be found in Annex A: Detailed methodology descriptions. The variables used in the comparison of tools were: KSS, max KSS per shift, number of shifts with KSS≥7, sleep duration 24h before shift (h).

Statistical analyses are described in Annex A: Detailed methodology descriptions.

Recording actual hours worked

To gather evidence of hours actually worked participants were messaged on up to two occasions during the study to ask whether their hours had been as expected and were also asked to share records of their working hours at the end of the study. Records were provided for 54 participants, and 39 participants responded to at least one message asking about their hours.

A review of these responses showed multiple occasions where hours worked were different from the working patterns predicted. Additionally, some participants stated at the beginning of the study that they did not know in advance what their working hours would be. Reasons for changed or unpredictable hours included the need to cover colleagues who were absent due to sickness, working extra or different hours to support vessel maintenance or prepare for inspection, working different hours due to delayed sailings, or working different hours due to a change of role or position on the vessel. For example, one participant said “*I’ve been working way beyond my hours every day in order to close out defects for [an upcoming inspection]”* and another said “*it's been all over the place due to equipment breakdowns and workload”.*

Some staff were employed specifically to cover absent colleagues or to move between vessels and this contributed to high variability for these individuals. For example:

"*my own roster included working on 2 different ships (and) included 3 x different work and rest hour patterns ... this added to my fatigue overall due to the rapid changes in work/rest patterns and working on different ships over a short timescale"*.

Some changes were relatively small, for example, working a few hours overtime, or moving a work shift by one day, but there was also evidence of:

- Quick changes between day and night shifts, for example, days 1-8: working 5pm – 4am; day 8: working 10am – 5pm; day 9: working 5am to 5pm.
- Working extended periods on board (e.g. delayed start to shore leave) Working very long hours, e.g. '*starting at 0500, planned finish 1700, actual finish between 2000 and 2100*'.

4. Findings

BMM workshop and fatigue risk management documentation review

Summary of findings

- BMMs were not typically used in roster planning for UK ferries. Operators constructed their rosters to meet the needs of specific routes, often following a set of internal (company based) guidelines or parameters. There was a key focus on meeting regulatory requirements and ensuring commercial viability.
- In general, workshop participants seemed confident that they were managing fatigue well enough despite challenges, whilst recognising that compliance with the law does not by itself guarantee safety.
- Working patterns could change at short notice due to operational factors such as weather, cargo loading, and tides.
- There was limited scope for BMM use, given the factors which constrain working patterns in seafaring. They could be useful to enable operators to compare patterns and assess the impact of planned changes.
- For a BMM to be suitable for use in seafaring, it would need to take account of different operating models such as live-on-board and sleep-at-home and the working patterns which typically operate in these situations. It would also need to accommodate the impact of weather on sleep and fatigue, the demands of particular routes and the impact this has on work intensity, and the preferences and experiences of the workforce.

The findings from the workshop centre around four main themes: current use of BMMs and other fatigue management tools; factors which influence roster planning; the limitations of BMMs for use in maritime; and what a maritime BMM would need to include. Each theme is discussed in turn.

Current use of BMMs and fatigue management plans

No participants were currently using BMMs as part of their job role, and they were not aware of them being used within their employer. One participant had prior experience of using a BMM in seafaring (the HSE Fatigue and Risk Index), but use of this had ended when it was no longer available free of charge. It had, in that situation, been used to assess rosters after they had been designed and was mostly used by the unions as part of their evaluation of proposed rosters.

After the workshop, participants were asked whether operators had a formal plan or procedure for fatigue management. None said that they did. However, it was apparent from the workshop and subsequent email exchanges that several operators had internal policies or guidelines which were used when designing rosters, these are discussed further below. Some also had agreements with unions about working patterns. One workshop attendee recognised that an FMP could be, *"a good way to formalise in one document all of our existing TU (trade union) local agreements and working practices" (email from BMM workshop participant)*.

Factors which influence roster design

The key drivers of roster design in ferry operations were identified as regulatory requirements and commercial factors. These must always be met. There were also other influences (such as internal guidelines, route logistics, worker preference, union input), where there seemed to be more flexibility to respond to changing circumstances.

Regulations

A priority for roster design for all operators was compliance with the relevant regulations. For example, one participant said,

"*we're all compliant with law, there's not a single ferry operator, Ro-Pax or any kind of shipping company, that is operating outside the rules*" *(BMM workshop participant).*

However, there were strong opinions amongst workshop participants that compliance with the law was not by itself sufficient to prevent fatigue. As one explained,

"*to be quite blunt… the law is the law and it has no impact on fatigue, or whether they're getting their rest hours*" *(BMM workshop participant).*

This concern reflected the many factors not covered by the regulations which can influence fatigue such as work intensity, opportunities to take breaks, how working patterns are organised, and travel to and from work. It was suggested that some operators would contend that "*I'm complying with the law"* and use this as a justification to pay less attention to any difficulties experienced by their staff.

There were also some specific examples given of limitations in the regulations. Firstly, that attendance at training drills to practice emergency procedures was not classed as work under the MLC rules. Therefore, employees could be required to attend drills during the time they were scheduled to be asleep. It was also suggested that working hours regulations are intentionally "*vague"*, to give operators flexibility to respond to changing circumstances, and hence the regulations allow for relatively high working hours:

"If you do 12 hours on, 12 hours off, which a lot of operators are working, (it) more than complies with that, that's 84 hours a week and 84 hours off" (BMM workshop participant).

Participants also pointed out that work can be averaged over long time periods (under the Inland Waterways Regulations), and there is no barrier to employees working for many consecutive days (21 days was mentioned, although the regulations actually permit 31 days in some circumstances).

Finance and commercial factors

At the same time as complying with the legal requirements, operators also had to be commercially viable. It was noted that, "*you'd have to explain yourself if you were way, way in excess of crewing a vessel"*; and that staff numbers were kept to a minimum, "*You'll be looking to sort of find the minimum number, to do everything safely" (BMM workshop participant).*

However, workshop participants also gave examples of where they were operating to standards which were above the legal minimum due to the agreements with unions or just from the way crewing was structured for practical purposes (e.g. two crews working opposite each other).

"*Because I know our crews work well under the hours that they could potentially work, under the [regulations]" (BMM workshop participant).*

In general, participants recognised that commercial factors were a priority. It was considered that some companies might make changes to their fatigue management arrangements if they considered risks to be too high. However, change at an industry level would require regulation rather than recommendations.

Nature of route (ports, length of crossing, timetable)

Roster patterns are designed around timetables and sailing times: what times ships enter and leave port, duration of crossings and so forth. For employees who commute home at the end of their shift, crew changeover times must necessarily coincide with when the ship is scheduled to be in port. For crews living on board, changeover can occur at sea, but crossing times and frequencies still influence rosters. For more intense routes with frequent short crossings, ships are often 'double crewed' to ensure regulatory rest hour requirements are met: two full crews work complementary shifts (e.g. one on 12-hour days, one on 12-hour nights). Where crossings are longer, ships can operate with less than two full crews, as the crew could have legally required rest of a minimum six hours in one period whilst at sea. However, if there are changes to sailing times due to weather and other delays, crew working patterns in this scenario are more likely to be adjusted. This is because they will need to remain on shift until their duties (e.g. navigating into port, unloading or loading the ship) are completed if there is no other member of crew to relieve them.

Route factors also influence roster length. Crew on some ships might be onboard for eight or as much as 17 weeks. On others, particularly those operating more intense routes, rosters might involve only one or two weeks on board at a time.

Rosters were generally seen as being quite stable. Once they had been designed to suit a particular sailing schedule, they were unlikely to change, often for many years.

Internal guidelines and policies

Participants identified several internal company principles or parameters which were used when designing rosters. These varied between operators, particularly according to whether they had staff living on board. Examples given included:

- Limiting the number of consecutive working days to four or five, followed by at least two days off.
- Avoiding quick turnarounds, where staff might finish on a late shift and start on an early shift.
- Setting limits based on hours e.g. 9.5 hours per day, 67 hours per week.

- Patterns of seven days on and seven days off.
- Having two full crews, who work opposite each other on a twelve-hour rotation; twelve hours between shifts was identified as allowing for "*a good rest".*
- Avoiding changing between night and day shifts within a single rotation.
- Having staggered changeovers so that different roles change at varying times. This might be done for job-related reasons (e.g. maintenance crews need to be available at night) or to avoid losing "*all your experience"* in one changeover.

These guidelines were viewed as a way of limiting the adverse impact of working in a 24-hour industry. It was highlighted that "*they're only recommendations"* and are less binding than regulations but were important control measures which operators used to minimise fatigue. Overall, the impression from workshop participants was that shift patterns were designed to be as good as they realistically could be, managing fatigue effectively within the constraints of the industry.

Dynamic changes (the roster is only part of the picture)

Although rosters and planned hours were identified as being generally stable over time, hours actually worked could change within this in response to operational needs. This need for dynamic change was voiced by all participants. Example factors reported were:

- Short term changes to sailing, "*if the boat doesn't need to go for 3 days, you're probably not going to put a full crew on board*".
- Changes due to weather, cargo issues or tides, resulting in the ship arriving in port later than expected. Where crews live on board, changes to crew working times may be made by the master or other senior managers to meet the operational requirements. These would always be planned to comply with regulations, and if necessary, sailing might be delayed to ensure compliance. Such changes were said to be more common for ships which operated with fewer than two full crews. They were much less likely to happen for ships which operated with two full crews working opposite each other, as staff could start or end their shift as planned, regardless of whether the ship was running to schedule.
- For sleep-at-home ships, late arrival in port might require crew to be brought in from their rest days to cover subsequent sailings. The decision on which staff to call in will be made by the company's planning department who may have limited information about the recent work patterns of the off-duty crew.
- Staff absence due to sickness or holiday might also need to be covered by staff working overtime. Again, this would be managed by the planning department and might involve short notice changes, *"you can get a phone call at God knows what time in the morning."*

Employee preference (including union input)

Some operators had avenues for employees to influence roster patterns. For example, they might consider changes at an individual level such as allowing an employee to work two weeks on/off rather than one week on/off provided their manager was supportive of this arrangement.

Others had collective agreements. For example, in one company, all staff would get the chance to vote on which of several roster patterns they preferred, with the majority view being adopted. Employee preferences were reportedly influenced by dislike of change (employees were likely to choose the same pattern they had worked before), age (younger workers were more likely to prefer to work fewer, longer days) and social factors, such as being able to meet colleagues at mealtimes. It was suggested that the attractiveness of a working pattern might be a consideration in future roster design, given recent challenges in recruiting new staff. Some participants had experience of employees choosing which operator to work for based on whether they liked how the work was organised.

Collective agreements with trade unions were also reported to be very important for some operators. This typically involved strict formal agreements around working patterns and hours, with approvals needed to make changes to these. Some participants observed that their agreements with the union were for working hours which were considerably lower than regulatory limits.

Fatigue and accident risk

Fatigue was acknowledged as a risk in seafaring, occurring due to both practical and cultural factors.

"*I think it's always been just an accepted thing in the industry, that people are just tired on ships. … because it is a 24-hour industry, you're awake when the ship needs you" (BMM workshop participant)*.

By comparison, aviation was seen as managing fatigue more effectively due to its safety critical nature making it less tolerant of fatigue, as well as being a younger industry and more highly visible than the ferry industry.

There was a lack of clarity over what the perceived impact of fatigue might be, if any. There was acknowledgement of an impact on decision making, "*being a little bit tired is one thing, being fatigued may lead to different decisions"* but there was no strong association perceived between fatigue and increased accident risk in ferry operations,

"*There's not been very many, if any, marine casualties attributed to fatigue in the watch patterns that are currently employed on Ro-Pax ships" (BMM workshop participant).*

Increased accident risk was more commonly associated with bad weather, with catering operations, newly recruited staff and with higher passenger numbers.

The limitations of BMMs in maritime work

Limited scope for change

There was a perception that BMMs were of limited use for seafaring work, given the low likelihood of change within the sector. Whilst it was accepted that applying a model would show that fatigue was "*a huge factor in our industry"'* that would not by itself result in change. Firstly, companies would resist recruiting more staff than required by law.

”Ships come with their Safe Manning documents ... any models that show that you need more seafarers, I think companies in general would resist” (BMM workshop participant).

Additionally, change is difficult due to the ways in which shift patterns and rosters are designed, as there is a step change needed to modify work patterns. For example, changing from a 12 hour on 12 hour off pattern would require a complete extra crew. As one participant described it, such a change would be “*pie in the sky”* i.e. completely unrealistic.

A further challenge to using BMMs would be the need ”*to take the seafarers with you”.* A model which recommended a change in shift pattern could be poorly tolerated amongst seafarers, particularly if the new pattern did not align with workforce preferences and experiences.

A third limitation of BMM use is the difference between work as intended and work as done. Rosters and working times are often required to change at the last minute due to weather, cargo load or tidal issues. Therefore, a BMM model might be used to plan an ideal working pattern, but the hours actually worked might end up being different to this.

Finally, it was identified that a BMM which was suitable for operators whose staff travel home at the end of each shift would be quite different from one for operators whose staff live on board for a week or longer, working 12 hours every day (either 12 hours on/off or split shifts). This is not a barrier to BMMs *per se*, but different models would be needed because of different factors associated with each.

“Rest does not mean sleep”

The assumption made within BMMs is that employees sleep when they are off duty, whereas in seafaring work, this is not always the case. Firstly, staff who are on their rest time on live-on-board ships might sleep poorly due to the weather,

”*If you’ve got really crap weather for two weeks and a ship’s bouncing around, your cabin’s rearranging itself, you do not sleep very well. And that has an accumulative effect*” *(BMM workshop participant)*.

They may also experience sleep disturbances due to the ship sailing in and out of port every hour or two, the noise of other crew members moving around the ship and also just due to a high state of alertness,

“*I think you just always had one ear open for the engine – oh, crap, the engines have gone off. There was always something, you just slept with one ear, and I think you didn’t realise*” *(BMM workshop participant)*.

It was identified that BMMs do not consider the accumulative impact of multiple days with shortened sleep? which can occur in these situations. They particularly do not allow for the difference between a person who has recently joined the ship, only worked for a few hours or days, or someone who has been working on board for many months.

It was also believed that models take inadequate account of the impact of night shift working, particularly the change from day to night shift. Participants had experienced that it was very difficult to sleep before a first night shift, and that shift would typically be extremely difficult:

"You've got up as normal, 7 o'clock in the morning, you join the ship. You don't get to sleep because you're not tired at 3 o'clock in the afternoon, so you start your night shift at 6 o'clock at night, you work through the whole night. Between 2 and 6 in the morning, you're manoeuvring a ship with 1,000 passengers on it, struggling to keep awake. And then 6 o'clock in the morning comes, absolutely shattered. Get into bed, 9:30, wide awake, and you can't sleep" (BMM workshop participant).

After that, there would be adjustment over two or three shifts, and then night shift working would be relatively easy. It was noted that BMMs typically identify a progressively increased risk with additional night shifts, but this was not considered accurate for those working on live-on-board vessels,

"*Once you get into the sleep pattern, you can work for weeks and weeks and weeks and weeks" (BMM workshop participant).*

For crews who sleep at home it was recognised that there are also the additional challenges of things outside of work which can restrict sleep. This includes commuting, which could be up to two hours each way in some cases, and other life activities such as eating meals and doing "*the school run."*

Work is not all the same

It was identified that workload and work intensity vary between ships and routes, and it is difficult for BMMs to fully take this into account. Some routes are very intense, with sailings every hour or even more frequently, which puts high pressure on the crew. Other longer routes can be less demanding. This also affects whether breaks can be taken during work time.

For many operators, there are no formal in-shift breaks, "*so you will do 9 hours solid, just driving back and forth".* Others might have more time for informal breaks around the sailing patterns, for example, "*they'll go and have a cup of tea for 15 minutes before the ship arrives"* and "*once you're away from port, you hand over to the officer on watch, generally, if I wanted to shut my eyes for 20 minutes, you can."*

Individual variation

Some participants were concerned that BMMs were unable to consider individual variation. This includes variations between individuals, "*that's going to be unique to me",* and for individuals at different times. For example, being new to a role might increase stress and therefore fatigue. Other factors, such as the stress of navigating into port in bad weather, would also increase fatigue. A model would not take account of this, nor of any preferences between individuals for different patterns (for example, longer days or shorter days). Neither can a model account for individual preferences to tolerate fatigue to achieve pay offs in other areas: "*The crew on board* *bake-in the fatigue in their decision-making process, and possibly (do) not see it – 'Oh, I don't mind if I'm a bit tired then, because I'd rather have dinner when everybody's up at 6'".*

What would a maritime BMM need to include?

Workshop participants identified barriers to employing a BMM, particularly those models which are currently available. They did not feel they should be introduced to set new rules or limits. Nevertheless, they acknowledged that there could be benefits from using models to inform operators' wider decision making. For example, a model could be used:

- To enable measurement and comparison, to help identify the best pattern or best practice.
- To test out the likely impact of proposed changes to how rosters are. constructed within a working week, for example, changing to longer, fewer days.
- To inform and challenge the workforce on their preferred working patterns.
- To demonstrate to unions that the chosen shift patterns are safe.

There were several factors which were identified as being required for the BMM to be useful to reflect the way the working rosters are constructed in the industry and the additional challenges it faces. Some of these elements are found in existing models to a greater or lesser extent, many are not.

- **Two different maritime BMMs** would be needed: one to suit the live-on-board model and one to accommodate the sleep-at-home model.
- **Flexibility to incorporate the common patterns worked.** For live-on-board crews, patterns may include between one and many (e.g. 17) weeks on-board; 12 hours on-12 hours off or split shifts (6-6, 8-4 etc), and shift changeovers at different times to accommodate route and passenger demands. For live-at home crews patterns included 4-8 days worked in a block, shift start and end times which coincide with sailing times and agreed minimum/maximum working hours or days per year.
- **Ability to consider the weather.** Weather has an effect on sleep quality, stress and on the likelihood of timetable disruption. It was suggested that having a summer and a winter version of a BMM would be one way to address this, recommending shorter time onboard during the winter months.
- **Work intensity,** taking into account the length of crossings, and how demanding work is; and the likelihood of breaks, both formal and informal.
- **Circadian factors,** particularly the difficulty of sleeping during the day, and the transition into night working; but also taking into account that many of those on live-on-board vessels reportedly have good tolerance to working long stretches of nights.
- **Commuting**, particularly for those on sleep-at-home vessels. This might also be a factor for those who travel long distances prior to the start of their one or two weeks onboard a live-on-board ship.

- **Dynamic changes.** The ideal model could be used to assess the impact of dynamic changes made by onboard managers or offboard planning departments to ensure these do not introduce unacceptable fatigue risks, or that at least they are the best option available under certain circumstances.
- **Acceptability to crew.** The patterns recommended by a BMM should align with crew experiences of when they feel most fatigued, or they will not be accepted by seafarers. They should also align with their preferences where possible e.g. ensuring they can take meals with colleagues.
- **Individual variation**. A model would ideally allow for variation between different job roles, stressors and situations. It could also allow for personal tolerances for particular working patterns.
- **Identification of high risk**. In addition to distinguishing between shift patterns it would be helpful to be able to identify high risk times within particular shifts, so that decisions could be made to mitigate this or to spread workload around.

Survey

Summary of findings

- 59% of all crew member fight sleepiness on a monthly basis.
- Services crew were most likely to experience tiredness every day; they had the lowest sleep quality score of all job roles on the muster list.
- Over 18% of all seafarers have fallen asleep whilst on duty within the previous year.
- Over 40% of seafarers have experienced a fatigue-related incident/accident within the previous 10 years. With 85% of those who have reporting their employer would not know that this incident was due to fatigue.
- On average, seafarers report having 89min less sleep per day than they need to feel rested and do their job safely.
- The factors most strongly predicting being in the frequent fatigue group were: a belief perception that working hours were leading to sleepiness, difficulty relaxing, being female, working extra days, disturbed sleep index, poorer sleep rating in the last 3 months, feeling restless off duty, choosing to work overtime, impaired waking index, greater work stress, higher chance of undiagnosed sleep apnoea and decreased work enjoyment (the more people enjoyed work the less likely they were to experience fighting sleep).
- Training to manage fatigue is unusual, only 8% of survey respondents reported having had some.
- Individual techniques used to manage fatigue include have a caffeinated drink (65%), talking to a colleague (43%) and going out on deck (39%).

The following section presents a focused analysis of the survey findings. It covers the following topics:

- Descriptive information about survey respondents and their working arrangements.
- The extent and nature of fatigue in ferry operations.
- Factors associated with increased fatigue.

- The consequences of fatigue.
- The management of fatigue.

In each case, the findings are presented for the whole sample. Where appropriate, results are then broken down to examine variations between different sub-groups, particularly differences relating to job role and to working patterns.

Sample description

In total, 446 seafarers completed the survey (80% male) with at least one respondent from each operator who shared the survey link. This represents approximately 9% response from the sector. The time participants had been seafaring ranged from 2 months – 49.5 years (M = 17.72 years, SD = 12.70 years). Most respondents (68%) felt that their health was either very good or quite good, with 33% saying their health was poor. 7% reported having a sleep related disorder such as sleep apnoea or insomnia.

In terms of job role, the highest number of responses was from service crew (n=166) and deck crew (n=70). Survey responses were received from representatives of all common roles on the muster list including first and second officers, engineers, bosuns, pursers and cabin managers. 52% had some level of watch duty as part of their role either on all their shifts (36%) or some of their shifts (16%). The summary breakdown of responses by job role is shown in Table 2. To support analysis ensuring adequate grouping sizes, job roles were combined into the six groups listed in Table 2.

Table 2: Survey responses by job role (n = 446)

Role	Number
Service crew (housekeeping, onboard services, stewards)	166
Deck crew	70
Non-bridge-managers (Chief Officer, Cabin Manager, Bosun, Chief Engineer)	57
Engine crew (First Engineer, Second Engineer)	56
Bridge crew (First Officer, Second Officer)	45
Captain/master	42
Missing response	10
Total	**446**

Regarding sleeping arrangements for their employment, 87% of responding seafarers lived on board the ship during their shift and 13% returned home to sleep at the end of each shift.

Considering only the respondents living on board the ship, there were two common roster patterns, with 41% of respondents having a one week on, one week off roster and 41% working two weeks on, two weeks off. Other roster patterns included three, four or six weeks on/off and a small number reported working four or even six months on board at a time. Working days in this group were most commonly 12 hours long (44%), many (10%) also indicated under an ‘other’ category that they worked 13 hours each day. Split shifts of 6 hours on, 6 hours off were reported by 26% of this group. Other examples of split shift include 8 hours on, 8 hours off, 4 hours on, 4 hours off (3%), 7 hours on, 7 hours off, 5 hours on, 5 hours off (2%) and 8 hours on, 16 hours off (2%).

Considering on the respondents who slept at home, 19% worked four out of seven days, 24% worked five out of seven days. The remaining respondents worked a variety of patterns including seven days on/off or had patterns which varied week on week or varied between summer and winter.

For respondents who slept at home, their commute time often extended their day substantially beyond their working hours. According to the respondents, it took an average of 46 minutes (Standard Deviation (SD) = 1 hour 3 minutes) to travel to work, with 27% having a commute of an hour or longer.

The extent and nature of fatigue and sleepiness in ferry operations

The extent of fatigue and sleepiness in survey respondents is illustrated by the number who struggled to stay awake, had actually fallen asleep at work, had either stopped work or wanted to stop work due to fatigue. Fatigue is also shown by the difference between actual sleep and ideal sleep and by the high prevalence of a range of symptoms of sleepiness.

Ideal versus actual sleep

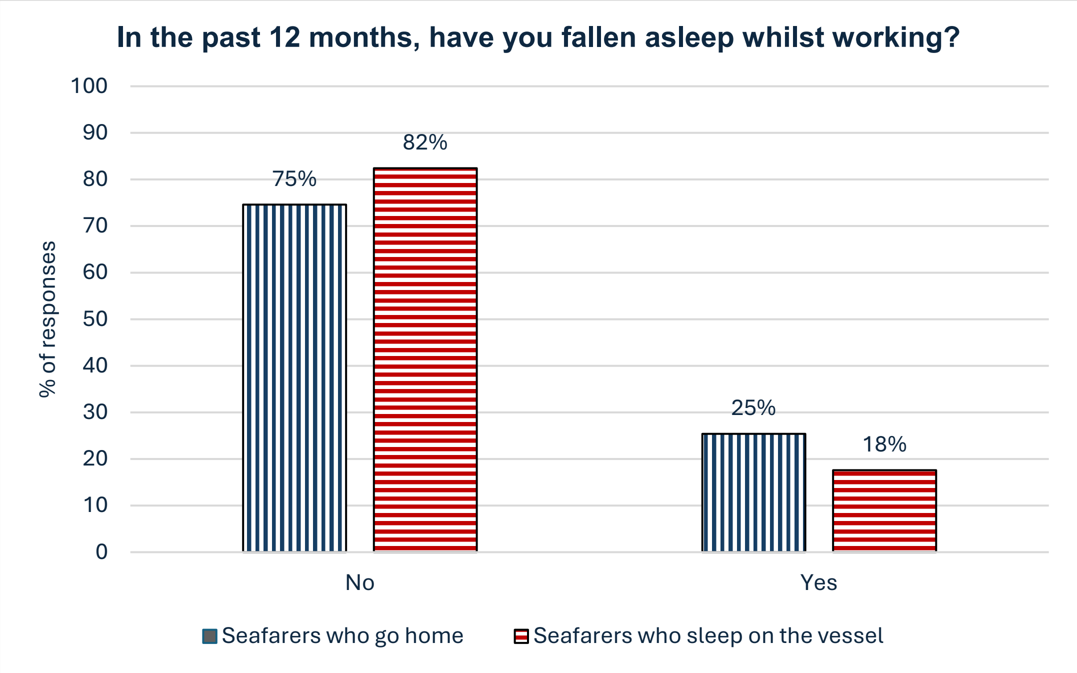
There was a significant difference between ideal sleep and actual sleep ($t(441)=22.256$, $p<.001$; Cohen’s d =1.06). On average, seafarers reported they needed 7h 38m sleep (SD = 1h 3m) between shifts to feel rested and do their job safely. However, the actual hours of sleep reported were, on average 6h 10m (SD = 1h 19m), around 90 minutes less per night on average.

Falling asleep

As shown in Figure 1, when split into their respective sleeping arrangements, at least 26%% of seafarers who slept at home reported having fallen asleep at least once while on duty in the past twelve months while 17.6% of seafarers who slept on board had fallen asleep at least once while on duty during the past twelve months. The difference between the two groups was not statistically significant ($F(1, 444)=1.6$, $p=.21$).

Overall, 18% of respondents had fallen asleep at least once whilst working in the previous 12 months, comparable with a similar study of bus drivers also recognised as a high-risk group for fatigue. Miller et al. (2020), which found that 17% of bus drivers had fallen asleep at least once whilst driving in the last twelve months. Further, 5% of respondents in the current study had fallen asleep at work three or more times during the past 12 months.

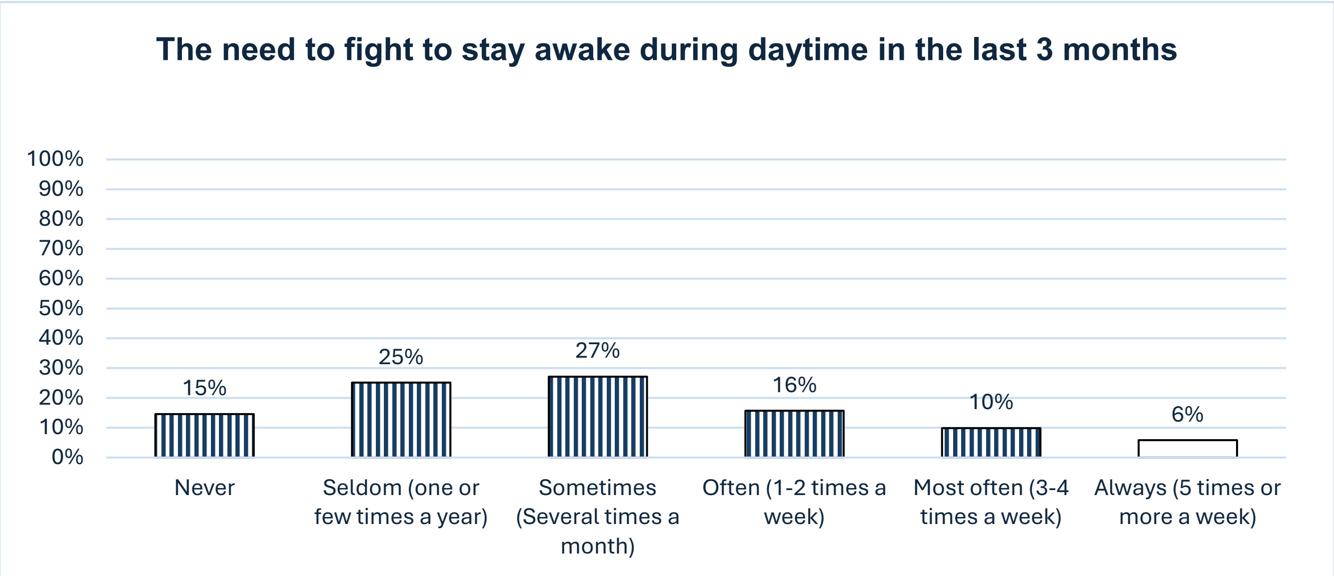
Figure 1: Seafarers who have fallen asleep whilst on duty according to sleeping arrangements (%) (n = 446)



Fighting to stay awake

Overall, 85% of respondents had to fight to stay awake at least once in the last 3 months with 60% of respondents having to fight to stay awake at least once a regular monthly basis. There were no statistically significant differences between those living on board and those returning home to sleep ($F(1, 436)=0.55$, $p=.93$). There were also no statistically significant differences between job role and fighting to stay awake. ($F(5, 422)=1.9$, $p=.10$). See Figure 2 for details.

Figure 2: Frequency of seafarers fighting to stay awake in the last 3 months (%) (n = 446)



Needing or wanting to stop work

As shown in Table 3, 57% of respondents had wanted to stop work at least once in the previous 12 months due to being tired but were unable to, while 34% had stopped work due to tiredness.

Job role had a statistically significant impact on wanting to stop work due to tiredness but being unable to do so ($F(5, 430)=2.61$, $p<.05$, $\eta p2=.03$). Service crew ($M = 2.80$, $SD = 1.70$), reported this most often, and this was significant when compared to the engine crew, who reported it the least ($M = 1.95$, $SD = 1.34$, $p<.05$). There were no significant differences between any other job role on wanting to stop work due to tiredness.

There was also a significant difference between job role and actually stopping work due to tiredness ($F(5, 435)=4.0$, $p<.001$, $\eta p2=.04$). Non-bridge-managers ($M = 2.23$, $SD = 1.62$, 12% of total respondents) were significantly more likely to stop compared to bridge crew ($M = 1.40$, $SD = 0.65$, $p<.01$), service crew ($M = 1.66$, $SD = 1.09$, $p<.05$) and deck crew ($M = 1.41$, $SD = 0.84$, $p<.001$). This may reflect the greater opportunity for this group to stop when required. There were no significant differences for other job roles.

Table 3: Responses by job role to questions about stopping work due to tiredness (n = 436)

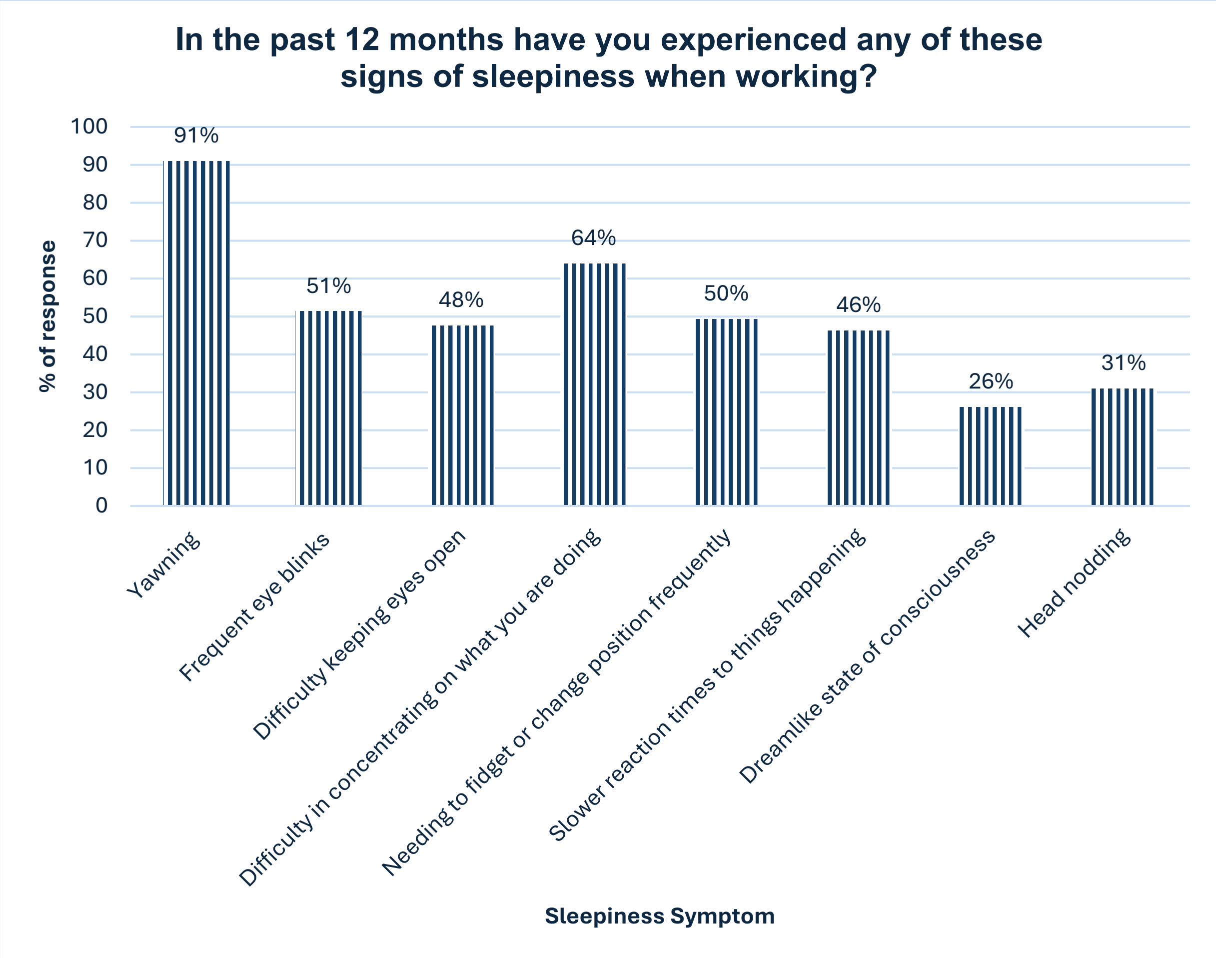
Question	Role	Number	Mean	Standard deviation
In the past 12 months, have you wanted to stop working due to tiredness but been unable to? (1 = Never to 5 =more than three times)	Captain/master	42	2.48	1.78
	Non-bridge-managers	57	2.42	1.66
	Bridge crew	45	2.51	1.69
	Service crew	166	2.80	1.70
	Deck crew	70	2.79	1.61
	Engine crew	56	1.95	1.34
In the past 12 months, have you had to stop working due to tiredness? (1 = Never to 5 =more than three times)	Captain/master	42	1.79	1.28
	Non-bridge-managers	57	2.23	1.62
	Bridge crew	45	1.40	0.65
	Service crew	166	1.66	1.09
	Deck crew	70	1.41	0.84
	Engine crew	56	1.73	1.26

Signs of sleepiness

Almost all participants had experienced at least one sign of sleepiness whilst at work in the previous 12 months. As shown in Figure 3, the most frequent sign reported was ‘yawning’ followed by ‘difficulty in concentrating on what you are doing’; respondents could choose more than one response.

Overall, 31% of all seafarers had experienced sleepiness to the most extreme outcome of head nodding. Muscle relaxation to the extent of head nodding would be associated with momentary loss of consciousness due to sleep onset. In the moment of head nodding, no attention would be given to work tasks.

Figure 3: Symptoms of sleepiness (%) (n = 446)



Differences in Sleepiness and Sleep Quality by job role

To enable comparison between groups, two constructed variables, sleep quality index and sleepiness index, were used.

Job role had a significant impact on overall sleep quality. ($F(5, 430)=5.6$, $p<.001$, $\eta p2=.06$) (see Table 4). Specifically, the service crew had significantly worse quality of sleep ($M = 3.89$, $SD = 1.26$) compared to the captains ($M = 3.30$, $SD = .99$, $p<.05$), bridge crew ($M = 3.23$, $SD = 1.05$, $p<.05$) and engine crew ($M = 3.11$, $SD = 1.10$, $p<.001$). Additionally, the engine crew ($M = 3.11$, $SD = 1.10$) had better sleep quality than non-bridge-managers ($M = 3.79$, $SD = 1.20$, $p<.05$).

Overall, 85% of respondents felt sleepy several times a month. Job roles had a significant impact on differences on the sleepiness index ($F(5, 427)=3.36$, $p<.001$, $\eta p2=.04$). Specifically, service crew scored more highly for sleepiness ($M = 3.61$, SD

= 1.31) than engine crew (M = 2.85, SD = 1.14) and this difference was statistically significant (p.001). There were no significant differences between any other job role on the sleepiness index.

Table 4: Means (M) and standard deviations (SD) of muster list roles and fatigue outcomes (n = 436)

Question	Role	N	M	SD
Sleep Quality Index (difficulty falling sleep, repeated waking, disturbed, or worried sleep, overly light sleep) Higher score = poorer sleep quality	Captain/master	42	3.30	.99
	Non-bridge-managers	57	3.79	1.20
	Bridge crew	45	3.23	1.05
	Service crew	166	3.89	1.26
	Deck crew	70	3.58	1.22
	Engine crew	56	3.11	1.10
Sleepiness Index (constantly tired, fighting to stay awake) Higher score = higher sleepiness	Captain/master	42	3.17	1.41
	Non-bridge-managers	57	3.32	1.38
	Bridge crew	45	3.24	1.04
	Service crew	166	3.61	1.31
	Deck crew	70	3.45	1.34
	Engine crew	56	2.85	1.14

Impact of shift patterns and roster patterns on fatigue.

To understand whether fatigue is associated with particular shift patterns, two ANOVAs were conducted, one for seafarers who slept on board and another for seafarers who slept at home. This analysis used the constructed variables, the sleepiness index (being constantly tired throughout the day, the need to fight to stay awake during daytime) the impaired waking index (difficulty in waking up, oversleeping) and the fatigue index (physical fatigue, mental fatigue).

Seafarers who slept onboard might work either a single shift each day or a split shift. When comparing all shift types, there were no differences on the sleepiness index (($F(7, 374)=0.67$, $p=.66$), fatigue index ($F(7, 225)=1.21$, $p=.70$) or impaired waking index ($F(7, 374)=1.68$, $p=.11$) when comparing single shift and split shift patterns.

For the seafarers who slept at home, common shift patterns included 8 hours, 10 hours, or 12 hours work per day. When comparing shift length there were no differences on the sleepiness index (($F(3, 54)=.29$, $p=.83$), fatigue index ($F(3, 28)=1.04$, $p=.39$) or Impaired waking index ($F(3, 55)=.11$, $p=.95$).

There were also no differences between roster patterns on the sleepiness ($F(4, 53)=.16$, $p=.96$), impaired waking ($F(4, 54)=1.39$, $p=.25$) or fatigue indices ($F(3, 28)=.75$, $p=.53$) for respondents who slept at home. Finally, there was no difference in roster patterns on the sleepiness index ($F(5, 379)=2.2$, $p=.051$), impaired waking ($F(5, 379)=.76$, $p=.58$) or fatigue indexes ($F(5, 228)=.32$, $p=.90$) for respondents who slept on board.

Factors associated with increased fatigue

Analysis was conducted to identify which factors are statistically associated with fatigue/sleepiness and therefore are potentially causative or contributory factors. Respondents were assigned to two groups, those who reported fighting sleepiness at least 2-3 times a week (*n* = 122), and those who did not (*n* = 324). A two-stage regression method was used.

For the first stage, a series of univariate logistic regressions were used to determine which individual factors best predicted whether respondents had to fight sleepiness often (See Annex D). For the second stage, any univariate predictors with a significant odds ratio ($p < .05$) were entered as predictors into a multivariate logistic regression using the stepwise method (Table 5).

Statistical analyses were used to first determine whether individual variables were able to predict whether a person would have to fight sleepiness. The variables remaining in the model are shown under three categories: (1) sleep related factors, (2) work related factors, (3) demographic factors.

Table 5: Multivariate logistical regression to determine factors associated with seafarer sleepiness (n = 446)

	Factors vs Sleepiness			
	OR	**95% C.I.**		**p**
Sleep Related Factors		Lower	Upper	
Impaired Waking Index	1.486	1.191	1.854	<.001
Sleep Apnoea Index	1.295	1.040	1.612	.05
Sleep rating in the last 3 months	1.942	1.361	2.770	<.001
Disturbed Sleep Index	1.956	1.472	2.598	<.001
Work Related Factors				
Working extra days	2.069	1.228	3.488	.01
Perception that working hours lead to sleepiness	3.626	1.361	9.665	.01
Choosing to work overtime	1.572	1.067	2.317	.05
Work Enjoyment	.880	.793	.976	.05
Work Stress	1.396	1.225	1.591	<.001
Demographic Factors				
Difficulty Relaxing	2.301	1.656	3.198	<.001
Restless off duty	1.807	1.351	2.416	<.001
Sex male vs female (ref)	2.123	1.190	3.784	.01

Table key: OR = odds ratio, CI = confidence intervals, p = significance

For sleep related factors, several factors were found to be significant predictors of whether seafarers had to fight sleepiness at least 2-3 times a week. The strongest predictor was the disturbed sleep index. Seafarers who had disturbed sleep were 1.96x more likely to fight sleepiness ($p<.001$). This suggests that onboard factors such as movement of the ship, noise, temperature and vibration and home factors such as a noisy home environment, or an inadequate home temperature may lead to increased sleepiness Self-reported sleep quality rating was also a significant predictor, with those reporting bad sleep quality being 1.94x more likely to have to fight sleepiness than those who reported good sleep quality ($p<.001$). Another predictor was the impaired waking index. If respondents struggled to wake up there was a 1.49x likelihood of having to fight sleepiness ($p<.001$). The final predictor was having sleep apnoea, with those who experience symptoms of sleep apnoea being 1.2x more likely to have to fight sleepiness than those without sleep apnoea ($p<.05$).

Work related factors were also predictive. The strongest predictor of sleepiness was respondents answering yes to the question 'do you think your working hours contribute to sleepiness'. This was associated with a 3.62x likelihood of fighting sleepiness ($p<.01$). Some additional working behaviours were also associated with fighting sleepiness. Working extra days is when seafarers work more days than scheduled to and this can increase the likelihood of fighting sleep by 2.07x ($p<.01$) while choosing to work overtime (i.e. working past their regular hours of that day) could lead to a 1.57x likelihood of fighting sleepiness ($p<.05$). Work stress also increased the likelihood of fighting sleepiness by 1.39x ($p<.001$). Finally, the more people enjoyed work the less likely they were to experience fighting sleep, however, this effect was small (.88x).

In terms of health factors, difficulty relaxing led to a 2.3x likelihood of flighting sleepiness ($p<.001$). and restlessness while off duty led to a 1.81x likelihood of fighting sleepiness($p<.001$).

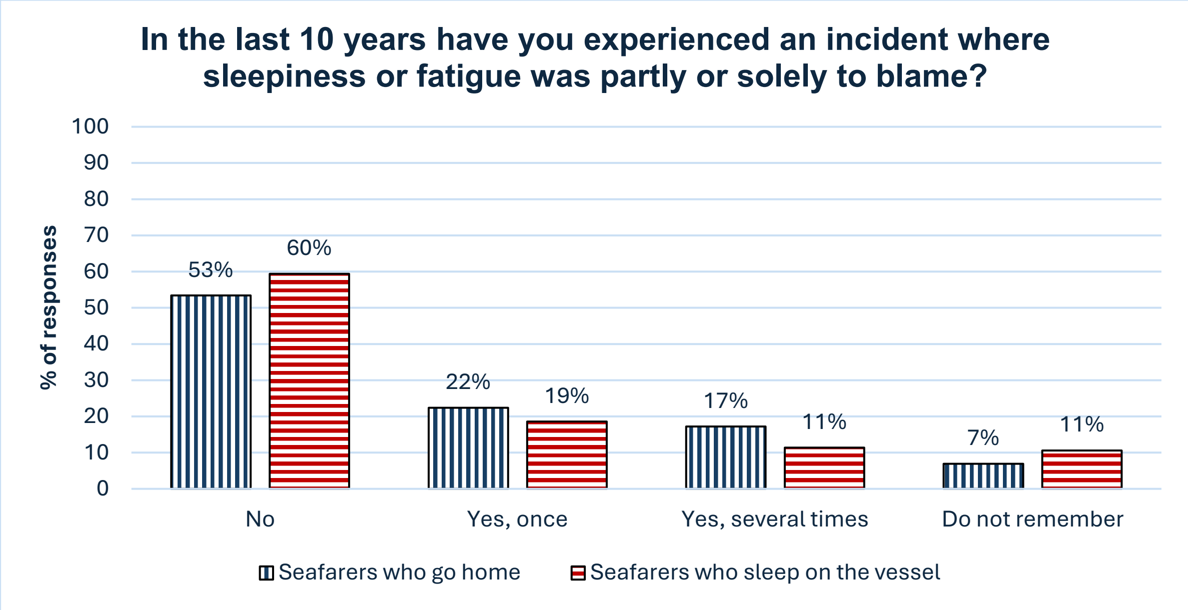
Finally, when looking at demographic factors, sex was the only significant predictor of sleepiness. Females were 2.12x more likely to fight sleepiness than males ($p<.01$).

The consequences of fatigue

Fatigue related incidents

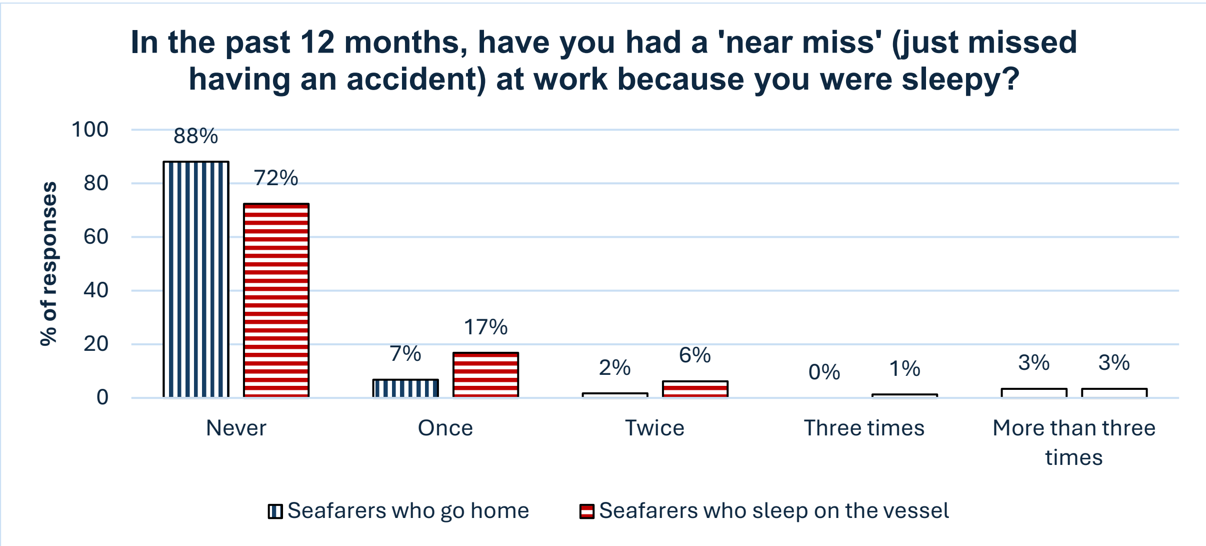
When an individual is sleepy or fatigued there is a potential for a fatigue related incident to occur. Within the last ten years, 31% of respondents had experienced an incident which they attributed to fatigue. As Figure 4 shows, results separated by those who sleep at home and those who sleep on the vessel, but the differences between them are not significant. Where incidents have occurred, it is likely that the employers are unaware of the impact of fatigue and sleepiness in these circumstances: 85% of those who had experienced an incident believed their employer did not know that it occurred due to fatigue.

Figure 4: Seafarers' experience of a sleep-related incident in the last 10 years according to sleeping arrangements (%) (n = 446)



Within the last year, 6% respondents reported having at least one near miss due to being sleepy, and 26% reported one or more near misses. The likelihood of a near miss was significantly higher for those sleeping onboard (t(83.8)=2.0, p<.05; Cohen's *d* =1.02; see Figure 5).

Figure 5: The extent to which seafarers almost had a sleep-related incident according to sleeping arrangements (%) (n = 446)



The management of fatigue

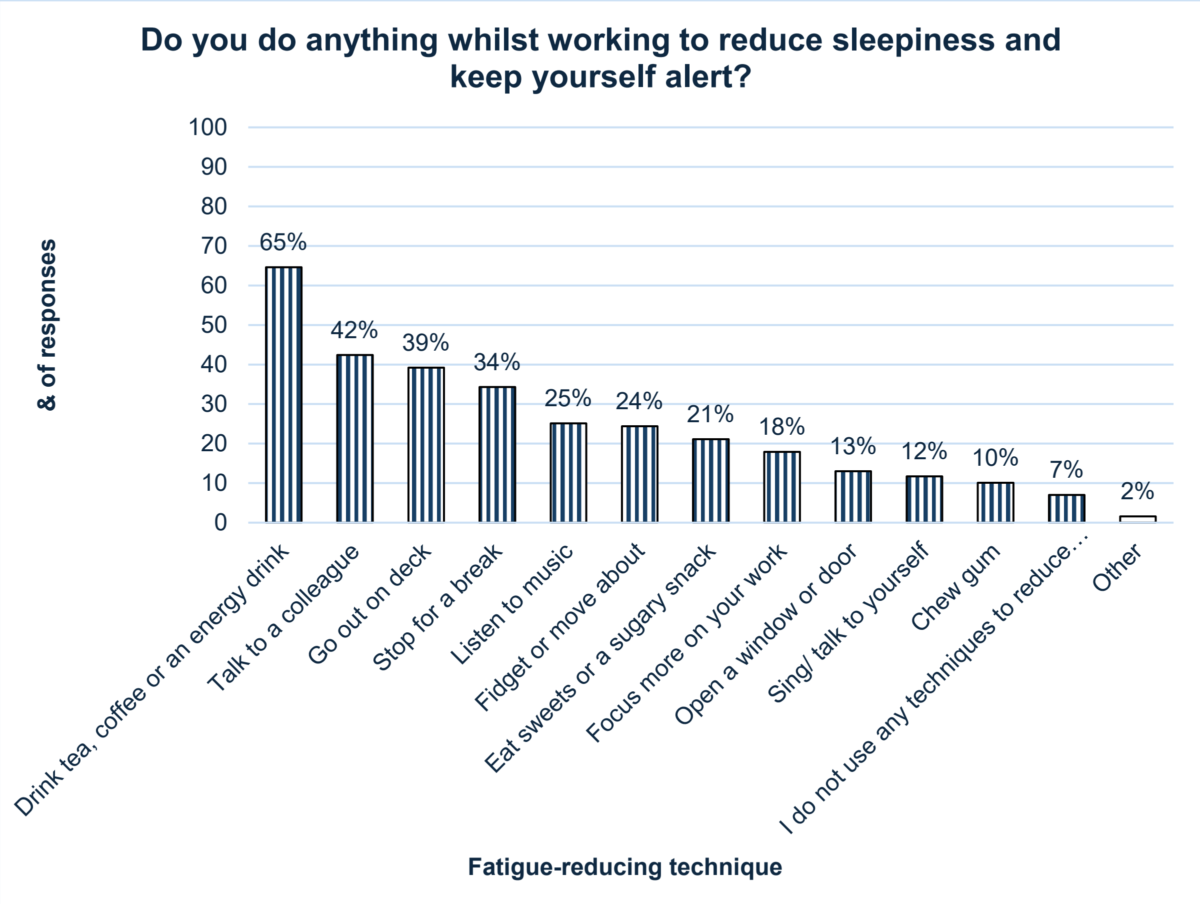
Training in fatigue management

Training in how to manage fatigue was not commonly provided. Only 8.3% of respondents said they had been given any training or advice on this subject. This training was provided by a range of operators. Of these 37 respondents, 22 (59.4%) said they had found it useful.

Techniques used to manage sleepiness

Respondents were asked what techniques they used to manage sleepiness. For all seafarers, the most popular techniques to reduce fatigue was to have a caffeinated drink (65%) followed by talking to a colleague (42%) and going out on deck (39%). See Figure 6 for percentage usage for all techniques measured; the question allowed for multiple choices.

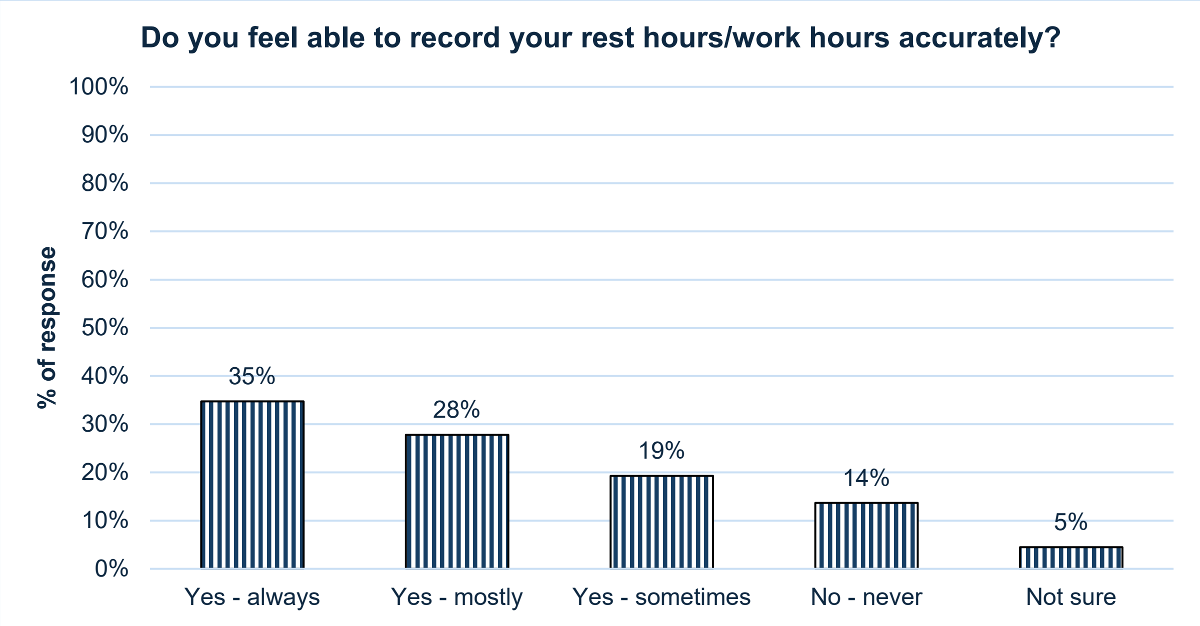
Figure 6: Techniques used to fight sleepiness (%) (n = 446)



Recording work hours

Respondents were asked whether they felt able to complete their record of rest/work hours accurately. As shown in Figure 7 (below) only 35% reported that they were always able to do so.

Figure 7: Do you feel able to record your rest hours/work hours accurately? (%) (n = 446)



Interviews

The interviews investigated the impact of fatigue on the maritime industry from the perspective of bosuns (n=4) and masters (n=7). Participants had substantial experience of seafaring, up to 40 years, with all except two having previously worked in other parts of the sector, such as deep-sea cargo or cruises before moving to ferries, often for family reasons, that is, not wishing to be away from home for long periods. Experience in their current role ranged from two years to 30 years. Six of the eleven people interviewed worked on a vessel where the crew were routinely living; the remaining five went home at the end of the shift. The interview data collection took place during March and April 2024. Interviews were conducted either by telephone or online (via MS Teams) by two individual researchers from Loughborough University. The thematic analysis developed four overarching themes: accident reports and control measures; factors leading to likely fatigue outcomes for seafarers and ways to address it; interviewees' personal experience of fatigue and their associated job responsibilities; and organisational culture around fatigue.

Summary of findings

- Most bosuns and masters have not undertaken formal fatigue training but did consider it would be useful if provided.
- The culture of fatigue within the maritime industry is not openly discussed, and although bosuns and masters are largely willing to support fatigued crew members, many are unlikely to admit to discussing fatigue as it is commonly associated with a weakness amongst peers.
- All bosuns and masters have experienced some form of fatigue personally when working. Some senior staff may be woken while asleep if needed. All saw this as part of the role and preferred to be woken than not if the crew needed them.

- Fatigue was considered by some to increase the risk of accidents. However, it was reported that it would be more likely to be identified as a potential contributing factor rather than a direct cause of incidents.
- Roster patterns, e.g., day-to-night shift transition and vessel type, e.g., the impact of noise and vibrations, were two of the most cited causes of fatigue.
- Countermeasures for fatigue focused on regulatory rest time between shifts, with other strategies being highly personalised. For example, showering, access to fresh air, and altering the bridge temperature were some methods used to combat fatigue.
- There was confidence in the minimum rest time requirement of 10 hours as a good way to mitigate fatigue.
- Interviewees reported relieving crew of their duties if needed due to fatigue. However, this was unusual and maybe considered compassionate leave and resisted, as long working hours were considered to be part of the job.
- A few individuals who were interviewed commented on how the industry attitudes towards fatigue are changing in a positive direction.
- Many interviewees spoke highly of their employers, noting that they would investigate fatigue as a potential factor in an incident by reviewing the individual's number of hours worked and the amount of rest time between shifts.
- Other control measures were also noted, including the reassuring nature of having both day and night crews and operators discouraging overtime. The potential impact of fatigue on crew was recognised by one interviewee describing their employer covering the cost of a taxi home or even providing accommodation.

Accident reports and control measures

Fatigue was viewed as a mental state that significantly hampered physical performance and also as a potential safety hazard. It was often described as a strong desire to fall asleep, with terms like "*sleepiness*", "*yawning*", and "*tiredness*" used to convey its meaning. Interestingly, some participants associated fatigue with emotional states like "*unhappiness*", "*ratty*", and "*angry*". The potential safety risks that fatigue could pose when onboard a vessel were a major concern for some. As one bosun said,

"*… if we're putting too much stress and strain on a person throughout a shift and they became fatigued, they're obviously dangerous to themselves and others onboard*" (*Interviewee*).

Some of the participating bosuns and masters had experienced incidents on board, but many of them discussed hypothetical scenarios regarding whether fatigue could be a likely cause for an incident. When fatigue incidents were discussed, many spoke highly of their employers, mentioning that they would investigate fatigue as a potential factor in an incident by reviewing the individual's number of hours worked and the amount of rest time between shifts. However, some commented that fatigue is difficult to prove and would likely be considered a contributing factor rather than a direct cause of an incident. Three masters mentioned that fatigue would be unlikely to be identified as a direct cause for several reasons, including the individual taking more care when starting to feel fatigued, fatigue not being reported as a factor or cause, and the fact that they believed their crew are provided with adequate rest time.

In other parts of discussions interviewees noted that crew members are either not aware of, or do not receive, fatigue training. It was also suggested that there is a culture discouraging individuals from talking openly about fatigue in the maritime industry, and external factors like weather can drastically impact the quality of rest time. All of these may have an impact on the quality of incident reports conducted by the operator and the accuracy with which they record fatigue as a potential factor.

The individuals interviewed emphasised the importance of limiting the number of hours worked to prevent crew fatigue. However, they mentioned that training drills sometimes conflicted with crew rest time, affecting their ability to get sufficient rest. Other control measures were also mentioned but were not supported widely by interviewees; this is likely to be due to differences in the operating practices of their employer. For instance, some noted the reassurance of having both day and night crews, another mentioned that their operator did not encourage overtime. One stated that if a crew member felt very fatigued at the end of their shift, the operator would cover the cost of a taxi home or even provide accommodation, highlighting the recognised impact of fatigue on crew, especially when undertaking mentally demanding tasks such as driving.

Most of the interviewees mentioned that they had not received any training on fatigue or were unaware of any such training provided by their operators. This lack of training is an important gap in the industry's approach to managing fatigue. Almost everyone stressed the need for more comprehensive fatigue training and could articulate some of the benefits it could provide, such as how to manage those who are experiencing fatigue. The only exception was a Master who stated that training was not necessary, citing the role of an independent service which could be contacted to discuss fatigue concerns. This interviewee also suggested that the availability of the service should be more widely promoted.

Interviewees' personal experience of fatigue and their associated job responsibilities

Almost all the interviewees discussed how fatigue had affected them personally when working. Several of the interviewees discussed how the roster impacted on them becoming fatigued, particularly towards the end of the shift and when first getting up in the early hours of the morning. For example, one participant stated that they felt like a "*zombie*" and another commented that they got to a "*low point*" at the end of the shift. These comments highlight the impact that long, accumulative hours can have on senior staff. Another interviewee stated that when commuting home after their night shift they had fallen asleep behind the wheel several times, indicating the potential impact of fatigue for those who commute to and from work. One interviewee reported that on several occasions crew members operating the ramp on a Ro-Pax vessel had mistakenly raised the wrong ramp where cars were parked, only to realise their mistake later, illustrating the risk fatigue poses for those operating machinery.

Some interviewees emphasised the significant impact of the time it takes for them to commute home and how this affected their available rest time. This observation suggested that individuals with long commutes after work may face an elevated risk of experiencing fatigue during working hours, potentially impacting their productivity and well-being. Some of the masters also commented on experiences of fatigue when staff had disturbed them whilst sleeping. Those who discussed this issue unanimously stated that being available for such interruptions was an integral part of their role. They all expressed a preference for being woken up when necessary. However, they also highlighted that these disruptions impacted the quality of sleep of the master. The interruptions often led to fragmented and insufficient rest, which in turn could affected the master's overall well-being and daily performance when on duty. A good quality of sleep could be characterised by minimal disruptions. However, one interviewee mentioned that less experienced staff can be more cautious, leading to multiple interruptions per night. This master mentioned being called out three times at night in the last month, with some callouts lasting up to an hour.

Both bosuns and masters discussed instances or commented hypothetically on how they had or would manage staff members experiencing fatigue issues. Masters reported this responsibility almost twice as frequently as bosuns, likely due to their overall seniority on the vessel. All those who commented on this issue gave similar responses, which would be to relieve the fatigued individual of their responsibilities. One master even referred to this as "*compassionate leave"* (Interviewee), aligning with their overarching responsibility for maintaining the safety and well-being of those on the vessel. However, a bosun did mention that "*they [the crew] would get slated [by their peers]"* if they came to the bosun wanting time off for fatigue-related reasons. Where fatigue was particularly severe, one master emphasised their responsibility to stop the ship, for example during bad weather, to relieve fatigued crew members of their duties if they had worked excessive hours to avoid fatigue-related incidents.

Likely causes of fatigue for seafarers and ways to address it

Whether a bosun or a master, many of the interviewees had personally encountered fatigue in their current position. As far as possible, they had supported others who have approached them with signs of fatigue and often recommend a replacement for that individual, giving them adequate rest. However, although the interviewees said they were empathetic, the frequency of crew members actually speaking to a bosun or a master about fatigue is reportedly low. The interviewees emphasised that changes in an individual's mood, facial expressions, and behaviour all indicate signs of fatigue. These observations suggested that regardless of the crew's living status on a vessel, both bosuns and masters could identify changes in crew behaviour as indicators of fatigue.

The bosuns and masters identified several reasons why they believe seafarers experience fatigue. They found that the biggest contributor to seafarer fatigue was the roster patterns. One of the most significant factors in fatigue and roster patterns was shift transition, especially when moving from the day shift to the night shift. Those who commented on the challenges of moving from day to night shift mentioned that it had both mental and physical impacts. They also noted that during the first couple of shifts at the new time there would be a heightened risk of exposure to fatigue. A handful of interviewees also mentioned the seasonal changes (e.g., summer) affecting passenger numbers and crew demand, potentially leading to fatigue. Many also commented on the vessel's impact on causing fatigue and disrupting rest time. For example, weather conditions were particularly emphasised as having the greatest impact on individuals' ability to get adequate rest, followed by the vibrations and noises created by the vessel. In addition to these factors, other contributors to the perception of fatigue included lighting conditions during night shifts, the warm temperature inside the vessel, and the comfort of the seating.

Many interviewees mentioned that the crew's poor health and well-being significantly contributed to fatigue. They observed that if the crew did not manage their off-duty time and spent time for example, playing video games or partying, rather than getting enough rest, that could contribute to fatigue. Job-related stress and mental health issues were also cited as playing a role in causing fatigue.

Many interviewees mentioned that the time restrictions on crew members' work hours were seen as an effective way to prevent fatigue, i.e., within a 24-hour window, an individual will get a minimum of 10 hours of rest time. They also noted other countermeasures , such as personal health choices and individual efforts to combat fatigue e.g. caffeine use, but saw these as less important for combating fatigue than the minimum rest time requirements. For example, some individuals mentioned using food and drinks like nutritious food and caffeine, as well as practical tactics such as getting fresh air, taking a shower, or having short naps. This aligned with the findings of the survey which found that the most popular technique to reduce fatigue was to have a caffeinated drink (65%). Some suggested organisational control measures such as increasing staffing levels and reducing working hours. increasing staffing levels and reducing working hours.

Organisational culture around fatigue

It was suggested that the culture and mentality of seafarers meant they did not openly discuss fatigue, and it was thought of as an inconvenience that comes with the job role. This lack of open discussion was an important barrier to addressing and managing fatigue in the maritime industry. One bosun stated:

"The fatigue word is not one you use lightly here, because it's literally saying you're not actually fit for your job, which is obviously a big concern for people. They'll [the crew] be scared to say it". (Interviewee)

This highlighted the fear of admitting fatigue to senior staff, which may imply the employee is unfit for work and result in unpaid leave. However, this culture of silence is slowly changing, and many of the interviewees would proactively support those who voiced fatigue concerns whilst at work.

Many of the interviewees mentioned that fatigue among seafarers is viewed as an unavoidable aspect of working in the maritime industry. The language used by interviewees to describe fatigue was often negative, such as "*struggle throughout the shift*", "*weakness*", and "*not fit for your job*". These were just some of the phrases used, portraying what one Master called "*Bravado… not wanting to appear weak or tired*".

Some crew members would call in sick instead of admitting they were tired due to industry norms surrounding fatigue. One Master mentioned that having experienced the long hours worked by the crew, they were reluctant to provide support for fatigue, saying, "*they won't get much sympathy from me today*". Some interviewees noted positive changes in the industry's views on fatigue, highlighting the introduction of increased regulations protecting minimum rest time.

Focus groups

As noted above, the workshop dedicated to discussion of BMMs (Biomathematical Models) (Task 1) identified that should a major incident occur during a sailing, those in customer-facing roles will have an effect on the impact of the incident on passengers. This includes the potential for injury and loss of life.

As a result, the research was extended to include discussion groups with those in customer-facing roles. The aim of the focus groups was to investigate the impact of fatigue for customer-facing staff (e.g. catering, housekeeping and shop workers) who have responsibility for safe passenger care or evacuation in emergency situations.

A total of eight facilitated group discussions with customer facing staff were completed; seven of these were face-to-face and were organised via the operator at which the participants were employed. These groups took place on the ferry on which the participating seafarers were currently employed. The remaining group was undertaken online using MS Teams and was advertised through trade union channels; it was available to anyone working in a customer facing role e. A second online group was planned and advertised in the same way. Only one participant was able to attend this group; it was undertaken with this one attendee being asked the list of focus group questions, so the analysis was included here. The focus group data collection took place during March and April 2024.

Table 6: Summary of focus group participants

	Job role	Number
FG1	OSS	8
FG2	OSS	8
FG3	OSS	8
FG4	AB	2
FG5	AB	2
FG6	AB and bosun [6]	5
FG7	OSS	7
FG8	OSS	4
FG/Interview	OSS	1
Total		**45**

As can be seen in Table 6 above, six of the groups (including the focus group with one attendee) involved OSS staff. There were 36 participants with OSS roles; their job titles included steward, mess man, chief cook, cabin assistant and cleaner, amongst others. In addition, three focus groups were held with the participation of a total of eight ABs and one bosun. These groups were included since ABs also had responsibilities for passenger safety, particularly in emergencies, and had some day-to-day interaction with passengers albeit more limited than OSS. It was therefore of value to investigate the opinions of seafarers working in the AB role.

Summary of findings

- Causes of fatigue were considered to be: commuting (both for those living on board and those sleeping at home); external factors such as the weather and vibration and noise on the ship; seasickness; shift patterns and particularly the first shift on a roster; shift swapping and overrunning; and roster patterns.
- Seafarers were able to recognise fatigue in others but were unlikely to have had training or advice on how to handle it.
- Organisational culture around reporting fatigue is variable across job roles as well as amongst operators and even across vessels.
- Countermeasures to fatigue included caffeine (coffee and energy drinks); drinking water; fresh air; exercise; relaxing outside work and naps.
- Participants reported being able to detect fatigue in their colleagues, especially where they were accustomed to working together in the same crew.

[6] The focus group was targeted at ABs, and the attendance of the bosun was not anticipated. The other participants, however were happy with the bosun staying. It was judged that the advantage of them being there and making the group bigger (there were only three others present at that time) outweighed the potential risk of participants being afraid to speak honestly. The bosun was keen to participate and have their opinions heard, rather than wishing to oversee the participation of the ABs.

- Some participants did not find countermeasures useful or feasible due to their work commitments.
- Drills are the key method of training for emergencies; these can occur during rest time and seafarers are not generally compensated for any time lost.
- Seafarers are very aware of their responsibilities in an emergency and feel they are on call all of the time.
- Emergencies can have an effect on fatigue, as well as mental health.
- The after-care for those experiencing incidents was variable across operators.
- Relaxing at the end of a shift was seen as a key measure in avoiding fatigue, particularly for those living-on-board. The importance of having time to relax before going to bed to sleep was noted both by those living-on-board and those sleeping at home.

The findings from the focus groups centre around five main themes: causes of fatigue; recognising and reporting fatigue; countermeasures to fatigue; training for emergencies; experiences during emergency incidents. Each theme is discussed in turn.

Causes of fatigue

Definitions of fatigue

As an introductory question all participants were asked to describe their understanding of the concept of 'fatigue'. The responses included words and phrases such as "*tiredness*", "*exhaustion*" and "*lack of concentration*"'. For example, "*… it'll be something along those lines, of tired, exhausted, burnt out"*. Views of fatigue also encompassed both mental and physical fatigue, for example, "*fatigue to me is physical, emotional, mental tiredness"*.

This accorded with the research project definition of fatigue which was then discussed with participants. This definition considers that fatigue is multifaceted, encompassing pressures from both the sleepiness related to human biology and task-related fatigue. This might include sleepiness due to insufficient sleep and/or time of day but may also refer to task-related fatigue due to the nature of work as a seafarer.

Commuting

An important cause of fatigue identified by the participating seafarers was commuting to their workplace. As might be expected, this was particularly the case for those seafarers who sleep at home because they travel more regularly but was also a factor for those who live on board. One participant suggested that commuting "*has a massive bearing*" on experiences of fatigue.

For those participants who slept at home, the commuting necessarily involved travelling daily. This might be a quick journey, "*I walk to the ship. I live ten minutes outside of port, so I can walk"*, or it might be by car or public transport, "*you might have to use a bus or train … so it's a long way to your home"*. This would have an effect on participants' opportunity to sleep during their time off work, "*so even though we've got our 12 hours, we don't because we're travelling at least a good hour and a* *half sometimes"*. In addition, those driving home at night suggested that their tiredness might be felt just as they finish work, describing this as a "*tricky time"*.

For those living on board the journey to the vessel might be significantly longer, with participants discussing colleagues being "*dotted around the whole country"*. This is particularly the case for those living outside the UK as their journey might be counted in days. This was cited as a key cause of fatigue. Indeed, one of the participants noted that they have requested to work a two-week roster, rather than one week), because their journey to the port takes around six hours. To avoid the reduction in sleep caused by travelling during the night, their practice is to travel the night before their first day of duty to break the journey and join the shift in the morning having had a good night's sleep. This way they could avoid losing too many days of their rest time.

Another concern related to commuting was the ship running behind its planned schedule at the beginning of the shift. This would mean that individuals would be unable to join the vessel at the expected time which could in turn affect their plans for sleep. Particularly for a night shift, this would mean reporting straight for work when a seafarer had been up for a longer period than they might otherwise have been. As one participant said,

"*If the ship's late … you join and you're on nights, you're straight into it. You'll have no time for rest" (Focus Group participant).*

External factors

A range of factors somewhat outside the control of participants were identified as being contributors to fatigue. The first was lack of crew, either due to sickness amongst workmates, or colleagues having left because of various reasons including unhappiness with the company or job role. Having insufficient workers will necessarily lead to an increase in the workload expected of those who are present, although this is mitigated somewhat by the legal requirement to have a minimum number of crew on board the ferry before it can sail. It is worth also noting that this legal requirement may lead to certain seafarers being required to work extra shifts to cover for missing colleagues, which is a fatigue risk in itself due to the potential increase in their number of work hours.

Another key concern expressed by the participants who live on board was the general noise associated with the operation of the ferry. This included the Tannoy system and any alarms which may be broadcast at all times of day and night. Furthermore, some of the alarms may require participants to leave their cabin. Another source of noise is the docking of the vessel which is likely to be combined with the vibration of the ship's thrusters which rattles their possessions within the cabin. This is therefore a stage of the voyage which may contribute to seafarer fatigue. Heat on board the vessel may also be a cause of tiredness, and may also affect the seafarer's ability to carry out their work.

Noise may also emanate from colleagues living on board, with seafarers attempting to sleep at a variety of times across the day and night. Sharing a cabin may also be a source of disturbance to sleep, although attempts are made to minimise the possibility by assigning those on the same shift, or those on directly opposing shifts to a cabin so they are both on rest at the same time or at opposite times.

The weather is a particular concern for seafarers, with the vessel being subject to this as an uncontrollable force. Rough seas make the work itself harder and meant that it can be difficult to sleep on board, for example, "*… sometimes when the weather is bad and you don't sleep, well then you are more physically fatigued"* and *"when it's rough weather I seem to be more tired"*. Another problem connected with rough weather was the effect on the ferry schedule, with journeys likely taking longer than usual. This may result in longer shifts or changes in start and end times of working periods, resulting in feelings of fatigue.

The passengers themselves can also be a source of tiredness for the participants, this may either be due to large numbers or demanding passengers. For example,

"*another thing that I'd say is, adds a lot of stress and tiredness is angry … abusive passengers because we get a lot of that as well … once you get them off the ship all of a sudden, you … drop right down and it becomes real tired, really tired really quickly" (Focus Group participant)*.

Notably, rough weather may cause the passengers to be more demanding and may subsequently add to the workload of the participants.

Seasickness

The participants confirmed that seasickness can be a concern for them, particularly on rough days. It was also dependent on which vessels they were working on, reportedly because of some ships vibrating to a greater extent than others. Those who take medication for seasickness also noted the possibility that it can cause them to feel drowsy. For example:

"*I took two. I literally was just falling asleep, like completely just passing out in [area]. I do find that it's also the sea sickness tablets that's meant to help you make you fall asleep as well, it just tires you out even more" (Focus Group participant)*.

The seasickness itself can also render the participants so ill that they are unable to work. However, there are also occasions when the seafarers noted carrying on with their work,

"*you'll run off, be sick, do what you need to do, then you're back working. You can't think about it … you're just working" (Focus Group participant)*.

This was thought to be a drain on the participants, meaning they are losing nutrients and not having time to drink thereby contributing to their feelings of fatigue.

Shift patterns

A clear cause of fatigue for the participating seafarers is shift working, and it was usually the first response from them when they were asked about this. It is thought to be a cause of participants receiving insufficient sleep, with many quoting eight hours as the accepted requirement for sufficient sleep. As noted previously in this report, the seafarers involved in this research worked a variety of shift patterns, some of which may be split and others which are straight shifts usually lasting 12 hours.

Regarding split shifts, these were reported as being potential barriers to sleep, so those working six hours on/six hours off would not be able to have a useful period asleep and, as noted by one participant,

"*getting four hours twice a day is not the same as getting eight hours uninterrupted at all"* (*Focus Group participant)*.

Straight shifts (usually 12-hours with 12-hours of rest) were preferred by some of the participants, mainly due to the longer period of rest. It should be noted that breaks during work would customarily be scheduled into this kind of shift. Some of the participants were working 13-hour shifts (with three unpaid 20-minute breaks) which they found tiring, particularly when the shift over-ran and they were working for a longer period.

Night shifts were generally considered to be the most difficult for the participants, particularly during the first day of the roster period and towards the end. One participant summed this up by saying,

"*the only time I'm really tired is when I'm on nights. I think my whole body goes all over the place" (Focus Group participant).*

Another participant suggested that it took a longer period to recover from a week of nights than from a week of days.

This changeover between night and day shifts was particularly reported as a source of fatigue, for example,

"*it's constantly changing, one week you're early, the next week you're late, or it could even be the same week … it does … take its toll"* (*Focus Group participant)*.

Furthermore, the frequent changes in start time daily for those who slept at home were thought to disrupt the body clock, which caused fatigue and were hard to become accustomed to. Variations in shift start patterns were generally attributed to the times when the ship was in port.

Constant alterations in the participants' shift patterns were also discussed, with changes being due to external factors such as the weather and the tides. This meant that participants believed that they could not arrange events or appointments outside of work and that they could not "*really get into a routine because it's always changing" (Focus Group participant)*.

Swapping shifts

There were some arrangements to allow the participating seafarers to voluntarily swap shifts, although this had to be approved formally through the operator and usually in good time before the swap would happen. Some of the participants seemed reluctant to ask to swap, and others suggested it would need to be for a very good reason.

Another reason for swapping was due to staff absence, with staff being recalled to the ship during their time off. This could happen at any time, with staff being required to return to work sometimes at very short notice. It was suggested that those making the requests do not always take account of participants' rest time, although those seafarers who are asked can refuse to return. For example, one of the participants noted:

"*it has happened a few times … what will happen, for example, [name] is to down to come on days and he can't come in … personal reasons, and we have voluntary recall. And [name] will go, "I'll stay for a few days" so we have to keep [name] on days, so that person who was going to come on days, then they'll have to swap" (Focus Group participant).*

Overrunning shifts

As might be expected, overrunning shifts are a concern to the participants in terms of causing fatigue. These are generally due to the vessel being delayed due to inclement weather or other factors. It could be argued that this was a particular stage of a voyage when fatigue levels may be higher. It may involve the seafarers working a shift longer than it should be or beginning at a different time from when they had planned. For example (in a very unusual situation):

"*last year we did … a 16 to 18-hour shift …, where the boat was that delayed. We had a medical emergency on-board and one of the engines went, so we were four, five hours late back, we were really late in and we were all so tired after that shift" (Focus Group participant).*

If the vessel was severely delayed over several days, the effect can be to change the shift pattern of the staff:

"*all of a sudden you've gone from working your normal day shift to almost flipping and being on a night shift because you're that late" (Focus Group participant)*.

However, the master might mitigate for this by keeping the vessel in the port. For example, in the case of a ship which was 12 hours behind schedule due to rough weather:

"*it had been such a rough night and we were doing four knots ... just not going anywhere. And by the time we got back, we were all knackered. And he said, "We're not going anywhere" … it's them as well on the bridge" (Focus Group participant)*.

Roster pattern

The roster patterns of the participants can vary across different operators, vessels and across job roles. In a similar way to the shift patterns, roster patterns were cited as a cause of fatigue by the participants. When asked about the effects of the two-week roster, one participating seafarer said:

"*I think it's mainly the last few days before the end … because it's just that getting up at 5am every morning, and sometimes I go to bed at 9 or 10, and if you don't sleep well … say you didn't sleep well for a few days in the week, at the end, you're struggling to get up and wake up" (Focus Group participant)*.

It was suggested that particular roster patterns may contribute to fatigue. For example, one participant said that the roster can lead to them working "*two weeks compressed into one week".* As a result they then need that week off to recover, "*so* *basically three days, four days out of that you're just winding down, catching up with the world"*. Another participant also noted that even rest periods at home may not allow complete respite:

"*when you're off, you're still very adjacent to that work environment so you could never fully decompress and get away … you're never completely away from it" (Focus Group participant).*

Recognising and reporting fatigue

Detecting fatigue in others

Most of the focus groups took place on board a vessel which meant that the seafarers participating were accustomed to working together on that same ferry. This brought about feelings of working within a regular team, with one participant remarking "*it's like [a] second family for us"*. The participants suggested that they were able to detect fatigue in their colleagues, for example, "*when the heads are like nodding dogs"* with a general understanding that fellow workers are likely to be especially tired on their first shift of a rotation. As a result of such recognition, it was suggested that familiar teams would step in and help others, perhaps even allowing them to take a break.

Training and advice

When asked whether they had been provided with any training on how to deal with fatigue, most of the participants were not aware of any such training. Although it was acknowledged that the trade union has widely recognised interests in the potential for fatigue amongst their members, it was clear that participants were generally proactive in seeking out information about fatigue rather than the companies providing it. Furthermore, it was suggested that companies may provide minimal fatigue training and advice because they are obliged to. The point was also made that, if the operator provides information about fatigue they should "*on the same hand respect it if you are suffering with that"*. The implication here from the focus group participants was that they do not.

Reporting fatigue

The picture was varied regarding feeling able to report fatigue to someone else when at work. Some of the participants felt they would not be taken seriously and that they would be required to carry on working regardless, "*I feel like you'd be laughed at"* and "*you'd get the sack"*. Others suggested that the tiredness would be considered to be the fault of the individual who was allowing their life outside of work to impinge on their work time.

In contrast, for one group of ABs there was a general feeling of responsibility to report their fatigue. For example, one AB said, '*You've got to say to a bosun, "I need to have a lie down*"'. For these participants the consequences of reporting were not feared, and they believed that they would be allowed some time off to rest. For example, "*I think if you actually went up to your senior and said, "Look, I really need a break", they would do it for you"* (*Focus Group participant).*

It therefore seems that the organisational culture around reporting fatigue for seafarers is variable across job roles as well as amongst operators and even across vessels.

Countermeasures to fatigue

There was a wide variety of countermeasures to fatigue noted by the participants, with the most common being coffee, closely followed by energy drinks. As one participant said, "*the shift runs on coffee*". Comments were made that energy drinks are more popular amongst the younger colleagues.

Staying hydrated was also important for the participating seafarers, with several noting that they find that water helps them in avoiding fatigue. It should be noted, however, that in busier times the participants said that they struggle to find time to drink, and some have very limited access to water, being prohibited to drink in front of the passengers. This is particularly a problem in the summer, when greater levels of water are required, but is also when the ferries are busiest with passengers. Similarly, food was cited as an effective countermeasure to fatigue, but the point was made that breaks may be too short to provide sufficient time to eat anything substantial, particularly food which needs heating up.

Fresh air was cited as an effective countermeasure, with some participants going up on the deck of the vessel for a walk or to smoke a cigarette. This is likely to be as part of a short informal break, which was also considered to be of use in avoiding fatigue. Such a break might also incorporate a short nap or "*snooze*", which is an additional countermeasure used by participants. It should be noted here, though, that comments were made suggesting that a nap carries with it a danger of not waking up in time. This was also described as being a short period of relaxation.

Some of the participants considered that exercise can help in avoiding fatigue, with a gym being available on board some of the vessels. However, other participating seafarers noted not having time or energy to use the gym or said they did not have those facilities.

Another view of feeling fatigued whilst at work was that there were no countermeasures that could work, and it was necessary to just carry on working. For example, one participant said they would *"just carry on. Just get on with it"*. Another said they would endeavour to "*work in energy saving mode"* and a third said they would just keep their mind active. Other participating seafarers said they did not use countermeasures because they were kept so busy working that they did not have the time to do so.

Relaxing

Relaxing at the end of a shift was seen as an important measure for combatting fatigue, particularly for those living on-board the vessel. There was inevitably a range of methods of relaxing, including attending the gym and other sports, watching the TV, reading, and playing computer games. Those participants living on board were away from their family for extended periods. They therefore relied on online communication with home and so noted the importance of an effective internet connection. There was a feeling of isolation associated with not being able to connect with family and friends.

Importantly, many of the participating seafarers, whether living on-board or going home at the end of the shift noted the importance of having time to relax before going to bed to sleep. This was summed up by the participant who said:

"*I take quite a while to unwind … when I get home, I'll have a shower, get ready for bed and everything, and I have to kind of sit there, either watch a bit of telly or go on my phone … because if I try and go to sleep straightaway, it doesn't work for me" (Focus Group participant)*.

Training for emergencies

Drills

Drills on board the vessel are an essential part of seafarer training to ensure maritime safety. Drills aim to refresh basic safety training and add an element of reality of working as part of a team on board. All the staff on a ship are assigned a muster number, which signifies their role during an emergency and the drill is intended as a practice for such an emergency.

Notably, the drills may take place at any time of the day or night and therefore this will necessarily be during the rest periods of several seafarers on board the ship. Generally, participants are not compensated for this time with further rest periods, although in some instances attempts are made to do so. Therefore, drills, whilst being of utmost importance in the safe operation of the ship, may also compromise the rest and sleep time of the staff on board.

Experiences during emergency incidents

Incidents

Most incidents which the participants had encountered were of a medical nature, including passengers who had died or been injured on board the ship. There were well-understood protocols for such incidents; this included asking for help from passengers where appropriate. For example, it was quite common for there to be medical professionals on board:

"*by the law of large numbers, given how many people work for the NHS, a percentage of people onboard at any given moment would be NHS members" (Focus Group participant)*.

More senior OSS staff tend to be first aid trained, in addition to the master.

Another type of incident being met by the participants was fire, which seemed to be a routine incident that was anticipated, with well-understood actions to be taken, for example, "*I've had a fire … that was along the bridge area, and we just had to get all the passengers away … but the crew put it out in the end" (Focus Group participant)*.

Other, more serious, incidents included the collapse of a mezzanine deck, responding to a yacht in distress, and people going overboard the ship. There was no particular stage of the voyage at which incidents would be more or less fatiguing.

The participants were clearly very aware of their responsibilities in an emergency situation, describing it as being on call all of the time, including during rest periods in the case of those who live on board the vessel. This could lead to "*the anxiety of worrying about something happening or something might happen"* (Focus Group participant). As noted by one participant:

"*my muster duty would be to go down the MES chute first to help passengers … as they come down it. So that's a hell of a responsibility knowing that I'm responsible for everybody coming down that chute" (Focus Group participant).*

The participants agreed that some incidents had an effect on them, including on their feelings of fatigue as well as their mental health. The general agreement was that their adrenaline would hit them at the time of the incident enabling them to carry out their responsibilities as practiced during the drills, even if they were tired. However, it would be afterwards that they would feel fatigued. For example:

"*you're definitely on a rush of like you just get on with it and do what you have to do, but you definitely feel it afterwards … once it dies down" (Focus Group participant)*.

Regarding the care given to participants after an incident, the experiences of care were variable. The reaction and facilities offered by different operators were also inconsistent. For example, a participant discussed finding a deceased person in a cabin and commented:

"*we were asked if we wanted counselling, that was it, and we just had to get on with our jobs … because this was at 8 o'clock in the morning. We weren't asked if we wanted to come off the ship or be replaced" (Focus Group participant)*.

A second participant noted a colleague not receiving any time off work after a similar incident involving a co-worker. A third participating seafarer discussed their workmate being involved in a medical emergency as follows:

"*He couldn't stay awake. But … the company … did not say … "Do you need an extra sleep? Do you need a time off?" No, there is that thing you can call up for advice" (Focus Group participant)*.

This same participant went on to expand on the advice line:

"*it's independent it's there … if you want to access it but doesn't transfer over onto the ship to give you required time off if you're tired or exhausted due to that. So it doesn't mean that it deals with the problem of fatigue essentially" (Focus Group participant).*

The group of participants who had described working in a close-knit team suggested that this would be an advantage in the aftermath of an incident, with colleagues being able to help the affected workmate, "*we're like a second family on here … everybody would come … to help out with whatever situation you were in" (Focus Group participant).*

There was some agreement that fatigue can lead to incidents, for example, "*that's where generally all mistakes are made when people are tired … that's what it comes down to – a lot of it comes down to fatigue". (Focus Group participant)*

Field trial

Summary of findings

- Three main types of shift patterns were represented: 12 h on 12 h off, 12 h split shift, and 6-9 h on 15-18 h off.
- Four main types of rosters were represented: 1 week on 1 week off, 2 weeks on 2 weeks off, 8 weeks on 4 weeks off, and 5 days of work per week.
- 30 participants slept at home each night, 33 slept on the vessel.
- Average sleep duration in the whole sample of seafarers participating in the field trial was 7.1 h (SD 1.5). Participants working 8 weeks on 4 weeks off had significantly shorter sleep durations compared to all the other defined roster categories. Shortest sleep durations were found in participants working a 12 h split shift.
- Sleep durations ≤ 5h was found in 7% of all working days.
- Sleepiness increased with increasing hours of work. This indicates that a component of task related fatigue could contribute to the sleepiness ratings
- 27% of the work shifts had KSS≥7. Participants working 2 weeks on 2 weeks off had more work shifts with KSS≥7 compared to the other defined roster categories.
- Actual work hours often deviate from planned work hours.
- 33% of the participants indicated having to fight to stay awake on a monthly basis whereas 14% indicated that they had to fight to stay awake 2-3 times a week or more often.
- The participants rated their sleepiness level as KSS≥7 at some point during the work shift in 27% of all shifts, which is considerably more often compared to the estimations from FAID Quantum (12%) and SAFTE-FAST (10%).
- Reaction time (PVT) was not significantly influenced by any of the work factors except for job role, where non-bridge-managers had significantly more PVTs with≥3 lapses compared to captains/masters.

Results

Approximately half of the participants (52%) slept onboard the ship and 48% went home to sleep between work shifts. Details about the participants' background are presented in Table 7. Most of the participants (97%) worked full-time. There were no statistically significant differences in background variables between participants sleeping on board versus at home.

Table 7: Participants' background characteristics from the entry questionnaire

	Sleep at home		Sleep on board		Total	
	N=30		N=33		N=63	
Age group (n, %)						
16-24 years	5	17%	2	6%	7	11%
25 to 34 years	9	30%	14	42%	23	37%
35 to 49 years	8	27%	12	36%	20	32%
50 to 64 years	8	27%	5	15%	13	21%
Gender (n, %)						
Female	8	27%	5	15%	13	21%
Male	22	73%	28	85%	50	79%
Experience as a seafarer (years)						
Mean (SD)		11 (11)		14 (11)		13 (11)
Nationality (n, %)						
British	25	83%	24	73%	49	78%
Other	5	17%	9	27%	14	22%
Education (%)						
No schooling completed	1	3%	0	0%	1	2%
Secondary school degree	4	13%	6	18%	10	16%
Sixth form or college	7	23%	6	18%	13	21%
Bachelor's degree	9	30%	8	24%	17	27%
Master's degree	1	3%	3	9%	4	6%
Trade or technical training	3	10%	6	18%	9	14%
Other	5	17%	3	9%	8	13%
Prefer not to say	0	0%	1	3%	1	2%
Relationship status (n, %)						
Married/ Civil partnership	13	43%	14	42%	27	43%
Living with a partner	9	30%	8	24%	17	27%
Separated/ Divorced	2	7%	0	0%	2	3%
Single	6	20%	11	33%	17	27%
Children living at home (n, %)						
Yes	12	40%	12	36%	24	38%
No	18	60%	21	64%	39	62%

Five main types of work schedules and rosters were identified in this group of seafarers. There were some differences in work schedules and rosters between participants sleeping on board and at home as seen in Table 8. It was not possible to perform statistical tests of these differences due to a low expected count in several categories. The mean work shift length was 9.0 h (SD 2.9).

Table 8: Participants' work details from the entry questionnaire and work schedules

	Sleep at home		Sleep on board		Total	
	N=30		N=33		N=63	
Employment (n, %)						
Permanently employed by the Operator	27	90%	25	76%	52	83%
Engaged by an agency	0	0%	6	18%	6	10%
Directly employed by the Operator on a fixed term basis (e.g. for a voyage)	3	10%	2	6%	5	8%
Working time (n, %)						
Full time	30	100%	31	94%	61	97%
Part time	0	0%	2	6%	2	3%
Job role (n, %)						
Captain/Master	3	10%	2	6%	5	8%
Non-bridge-managers	5	17%	4	12%	9	14%
Bridge crew	3	10%	8	24%	11	18%
Service crew	5	17%	7	21%	12	19%
Engine crew	3	10%	5	15%	8	13%
Deck crew	11	37%	7	21%	18	29%
Watch duties (n, %)						
Yes, on all or most of my shifts	16	53%	13	39%	29	46%
Yes, on some of my shifts	5	17%	10	30%	15	24%
No	9	30%	10	30%	19	30%
Shift schedule (n, %)						
12 h on 12 h off day	7	23%	9	27%	16	25%
12 h on 12 h off day and night	5	17%	11	33%	16	25%
12 h split shift day	0	0%	12	36%	12	19%
6-9 h on 15-18 h off day	12	40%	0	0%	12	19%
12 h on/off then 6-9 h on day	5	17%	0	0%	5	8%
Other	1	3%	1	3%	2	3%
Roster (%)						
1 week on 1 week off	4	13%	7	21%	11	18%
2 weeks on 2 weeks off	0	0%	18	55%	18	29%
8 weeks on 4 weeks off	0	0%	7	21%	7	11%
5 days per week	13	43%	0	0%	13	21%
Exception 2 weeks then 5 per week	6	20%	0	0%	6	10%
Other	7	23%	1	3%	8	13%

By cross-tabulating schedule types and roster types (see Table 9) only certain combinations of rosters and schedules were represented in this sample of seafarers. This was expected since certain combinations of rosters and schedules are more common in ferry operations, but it should be kept in mind when interpreting the results.

Table 9: Cross-tabulation of schedule and roster types

	Schedule category					
Roster category	**12 on 12 off day**	**12 on 12 off day and night**	**12 h split shift day**	**6-9 on 15-18 off day**	**12 on/off then 6-9 on day**	**Other**
1 week on 1 week off	3	8	0	0	0	0
2 weeks on 2 weeks off	7	5	6	0	0	0
8 weeks on 4 weeks off	0	0	6	0	0	1
5 days per week	1	0	0	12	0	0
Exception 2 weeks then 5 per week	0	1	0	0	5	0
Other	5	2	0	0	0	1

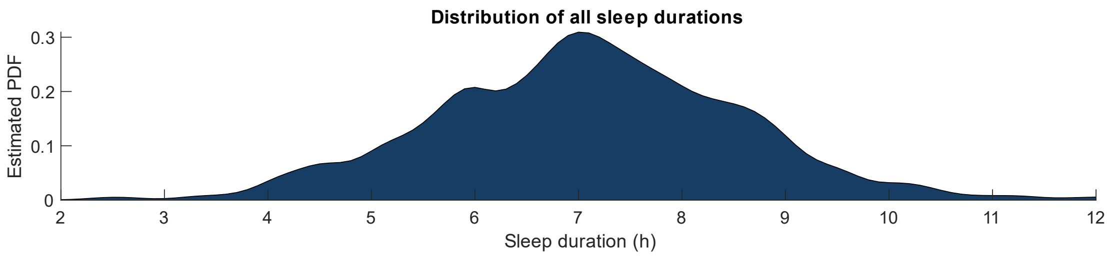
Sleep quantity and quality

Average sleep duration in the whole sample of seafarers participating in the field trial was 7.1 h (SD 1.5). The distribution of sleep durations is shown in Figure 8. Probability distributions per factor can be found in Annex D: Detailed results. Participants sleeping onboard the ship at the end of their shift had a mean sleep duration of 7.0 h (SD 1.5) and participants going home to sleep had a mean sleep duration of 7.2 h (SD 1.5). ANOVAs of sleep duration in relation to sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively, revealed statistically significant differences between roster patterns and between work schedules (Table 10). Post-hoc tests showed that participants working 8 weeks on 4 weeks off had statistically significantly shorter sleep durations compared to all the other defined roster categories. Participants working 1 week on 1 week off had the longest sleep durations and their sleep durations were statistically significantly longer than 2 weeks on 2 weeks off, 8 weeks on 4 weeks off, and 5 days per week. Regarding schedules, the shortest sleep durations were found in participants working a 12 h split shift. Their sleep durations were statistically significantly shorter than all other defined work schedules.

Table 10: F and p values from separate ANOVAs of sleep duration, for the question How well did you sleep (scale 1 – 9), and of the Fitbit sleep score, for the five work factors.[7]

	Sleep duration	How well did you sleep?	Fitbit sleep score
Sleep location	F(1,853)=1.11, p=0.30	F(1,598)=0.45, p=0.51	F(1,578)=0.0, p=0.98
Consecutive working days	F(1,852)=0.1, p=0.75	F(1,597)=0.66, p=0.41	F(1,577)=0.0, p=0.94
Job role	F(5,853)=3.03, p=0.02	F(5,598)=3.38, p=0.01	F(5,578)=2.37, p=0.05
Schedule type	F(5,853)=4.65, p=0.001	F(5,598)=1.32, p=0.27	F(5,578)=2.21, p=0.07
Roster type	F(5,853)=4.32, p=0.002	F(5,598)=3.24, p=0.013	F(5,578)=2.28, p=0.06

Figure 8: Probability density estimate of sleep durations in the full dataset (n=914)



The participants rated how well they slept on a scale from 1 to 9 in the diary. There was a statistically significant effect of job role on sleep quality (Table 10), where bridge crew reported sleeping better than all other categories except non-bridge-managers, and non-bridge-managers reported sleeping better than deck crew, engine crew and service crew. There were no statistically significant differences in Fitbit sleep scores (Table 10).

The logistic regression analyses of sleep durations ≤ 5h did not show any statistically significant differences in any of the work factors. Sleep durations ≤ 5h was found in 7% of all working days (Table 11). That is, most participants did not suffer from chronic sleep restriction. However, acute sleep loss may still have negative consequences for work performance and safety on board.

[7] B is the estimated coefficient, t is the test statistic, p is the p-value, N is the number of observations, and -2LL is the log likelihood ratio. The significance level is set to p≤0.05 (p≤0.01 after Bonferroni correction)

Table 11: Mixed-effects logistic regression models of sleep durations ≤ 5h for the five work factors. [8]

Sleep duration ≤ 5h	Predictors	B	t	p	N	-2LL
Sleep location	(Intercept)	-3.13	-9.90	<0.001	914	2561.3
	Sleep location	0.36	0.82	0.41		
Consecutive working days	(Intercept)	-2.93	-13.7	<0.001	914	2581.7
	Consecutive days	0.06	1.81	0.07		
Job role	(Intercept)	-3.08	-4.86	<0.001	914	2639.3
	Bridge crew	0.78	0.65	0.52		
	Deck crew	-0.59	-0.78	0.44		
	Engine crew	0.50	0.61	0.54		
	Non-bridge-managers	0.004	0.004	1.00		
	Service crew	0.53	0.72	0.47		
Schedule type	(Intercept)	-2.08	-4.57	<0.001	914	2619.8
	12 on 12 off day/night	-0.87	-1.34	0.18		
	12 h split shift day	-1.37	-2.09	0.04		
	12 on/off then 6-9…	-1.72	-2.03	0.04		
	6-9 on 15-18 off day	-1.29	-1.87	0.06		
	other	0.69	0.98	0.32		
Roster type	(Intercept)	-4.07	-5.71	<0.001	914	2659.4
	1 week on 1 week off	1.50	1.80	0.07		
	2 weeks on 2 weeks off	0.82	0.97	0.33		
	8 weeks on 4 weeks off	1.78	2.06	0.04		
	Exception 2 weeks…	0.11	0.11	0.91		
	Other	1.68	1.91	0.06		

In the entry questionnaire, the participants reported having on average 6.5 hours of sleep (SD 1.1) in a 24 h period. This was statistically significantly less than what they reported they would ideally need (7.4 hours SD 1.2) to feel rested (t=5.4, p<.001). There were no statistically significant differences in reported actual sleep between different job roles. However, there were statistically significant differences between job roles in sleep needed to feel rested (F=4.7, p<.001). Tukey post-hoc tests

[8] B is the estimated coefficient, t is the test statistic, p is the p-value, N is the number of observations, and -2LL is the log likelihood ratio. The significance level is set to p≤0.05 (p≤0.01 after Bonferroni correction)

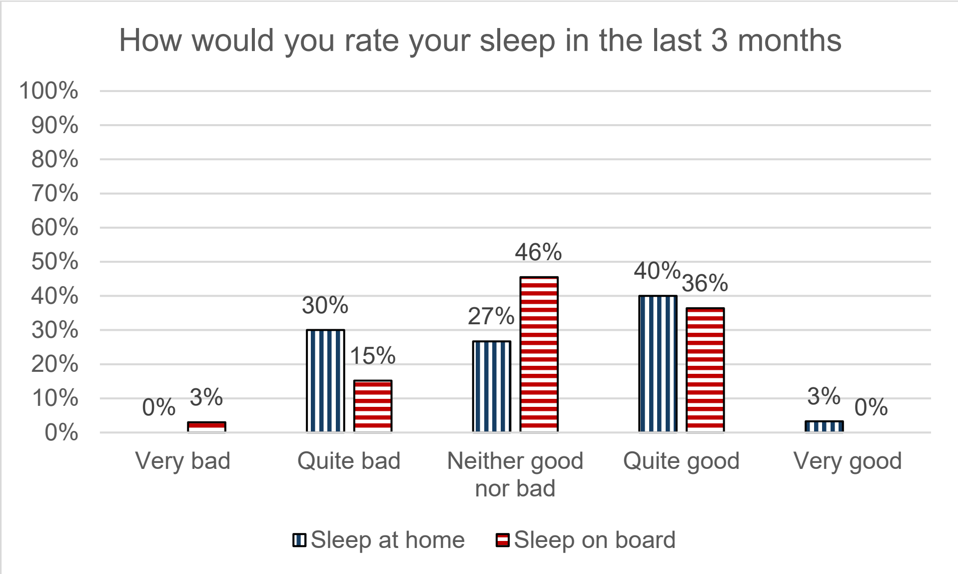
revealed that captains reported needing more sleep than non-bridge-managers (p=.010) and engine crew (p=.036). Managers not on the Bridge reported needing less sleep than service crew (p=.010) and deck crew (p=.035). There were no statistically significant differences in self-reported sleep hours between seafarers sleeping on board and at home or between different schedules and rosters. There were no general sleep problems revealed by the sleep indices from the KSQ (Table 12) and no statistically significant differences between job roles, schedules or rosters in these indices. The sleepiness index was higher for seafarers sleeping onboard (mean 3.1, SD 1.1) than seafarers sleeping at home (mean 2.6, SD 0.8), but the difference was not statistically significant after correction for multiple comparisons.

Table 12: Sleep indices (mean and SD) in different job roles (range 1 to 6)

		Sleep quality index		**Impaired waking index**		**Sleep apnoea index**		**Sleepiness index**		**ESS**	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Captain/ Master	5	3.1	1.1	2.7	0.8	2.0	0.3	3.1	0.7	5.6	2.8
Non-bridge-managers	9	3.1	1.0	2.1	0.8	1.9	1.1	2.7	1.0	6.6	3.2
Bridge Crew	11	2.7	0.6	2.8	0.8	1.5	0.4	3.1	1.1	6.7	3.7
Service Crew	12	2.4	0.8	2.9	1.1	1.9	1.0	2.9	0.6	9.6	3.9
Deck Crew	18	2.5	1.2	2.6	1.3	1.5	0.7	2.6	1.0	5.5	3.3
Engine Crew	8	3.2	1.0	1.8	0.5	2.3	1.3	3.3	1.4	7.8	7.0
Total	**63**	**2.7**	**1.0**	**2.5**	**1.0**	**1.8**	**0.9**	**2.9**	**1.0**	**6.9**	**4.2**

On a general question about sleep quality the last 3 months, 25 participants (40%) rated their sleep as quite good or very good and 15 participants (24%) rated it as quite bad or very bad (Figure 9).

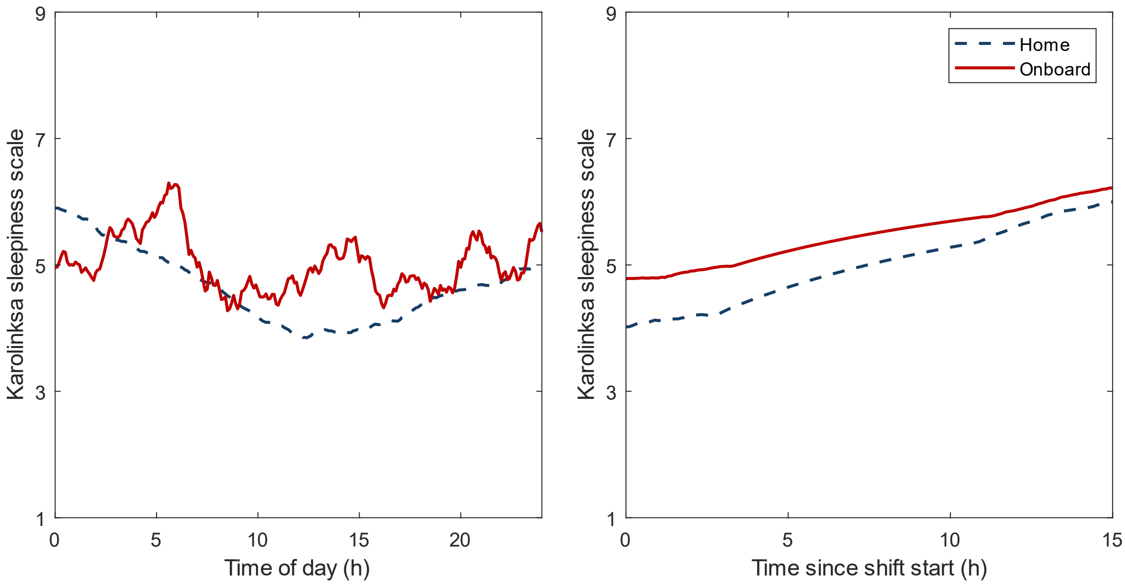
Figure 9: General rating of sleep quality in the previous three months before the study (%, n=63)



Sleepiness on duty

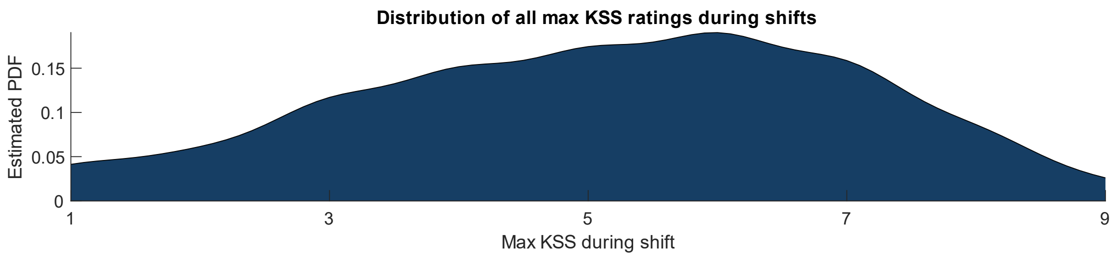
The overall mean KSS rating from the diary entries was 4.9 (SD 2.0). Participants sleeping on board had an overall mean KSS of 5.2 (SD 2.0) and the corresponding number for participants going home to sleep was 4.4 (SD 2.0). KSS scores varied depending on the time of day and time since start of the work shift. As seen in Figure 10, KSS patterns differed between participants sleeping onboard versus participants going home to sleep. Ratings by participants going home to sleep were highest around midnight and lowest in the afternoon, while ratings by participants sleeping onboard showed peaks in the early morning hours, in the afternoon, and in the evening. This is likely to be a reflection of differences in schedules between the two groups. For instance, only participants sleeping on board worked split shifts and only participants sleeping at home worked single 6-9 h long daytime shifts. Both groups show an increase in sleepiness with increasing hours of work. This indicates that a component of task related fatigue could contribute to the sleepiness ratings.

Figure 10: Mean KSS as a function of time of day and time since shift start for participants sleeping on board versus participants going home to sleep (N=2434)



The distribution across KSS scores (from 1 to 9) of the highest KSS score reported in each work shift (Max KSS) is shown in . Probability distributions per factor can be found in Annex D: Detailed results. Approximately 24% of all KSS ratings were 7 or higher and 27% of the work shifts had KSS≥7. The share of work shifts with KSS≥7 for different subgroups of participants is shown in Figure 12. 45 participants had one or more work shifts with KSS≥7.

Figure 11: Probability density estimate of max KSS reported during shifts in the full dataset (n=564)



Statistical tests were performed on the maximum KSS reported per work shift. There were no statistically significant results from the ANOVAs testing the factors sleep location, number of consecutive working days, job role, schedule type, and roster type. Max KSS ratings were higher amongst those who sleep onboard the ship compared to participants going home to sleep, but the difference was not statistically significant.

Table 13: F and p values from separate ANOVAs of max KSS reported per shift for the five work factors.[9]

	KSS
Sleep location	F(1,508)=5.33, p=0.02
Consecutive working days	F(1,507)=0.97, p=0.32
Job role	F(5,508)=0.21, p=0.95
Schedule type	F(5,508)=1.59, p=0.18
Roster type	F(5,508)=1.95, p=0.10

The logistic regression analyses showed that roster type and work schedule category were related to the risk of having a work shift with KSS≥7 (Table 14). Participants working 2 weeks on 2 weeks off and 1 week on 1 week off had more work shifts with KSS≥7 compared to the other defined roster categories. However, 1 week on 1 week off was not statistically significantly more frequent after correcting for multiple comparisons. Regarding schedules, the share of work shifts with KSS≥7 was fewer for participants working 6-9 h on 15-18 h off day and 12 h on/off then 6-9 h on day compared to the other shift categories. Only 6-9 h on 15-18 h off day remained statistically significant after correcting for multiple comparisons. Approximately 17% of the working shifts for participants sleeping at home, and 34% of the working shifts for participants sleeping onboard, had KSS≥7. The difference was not statistically significant.

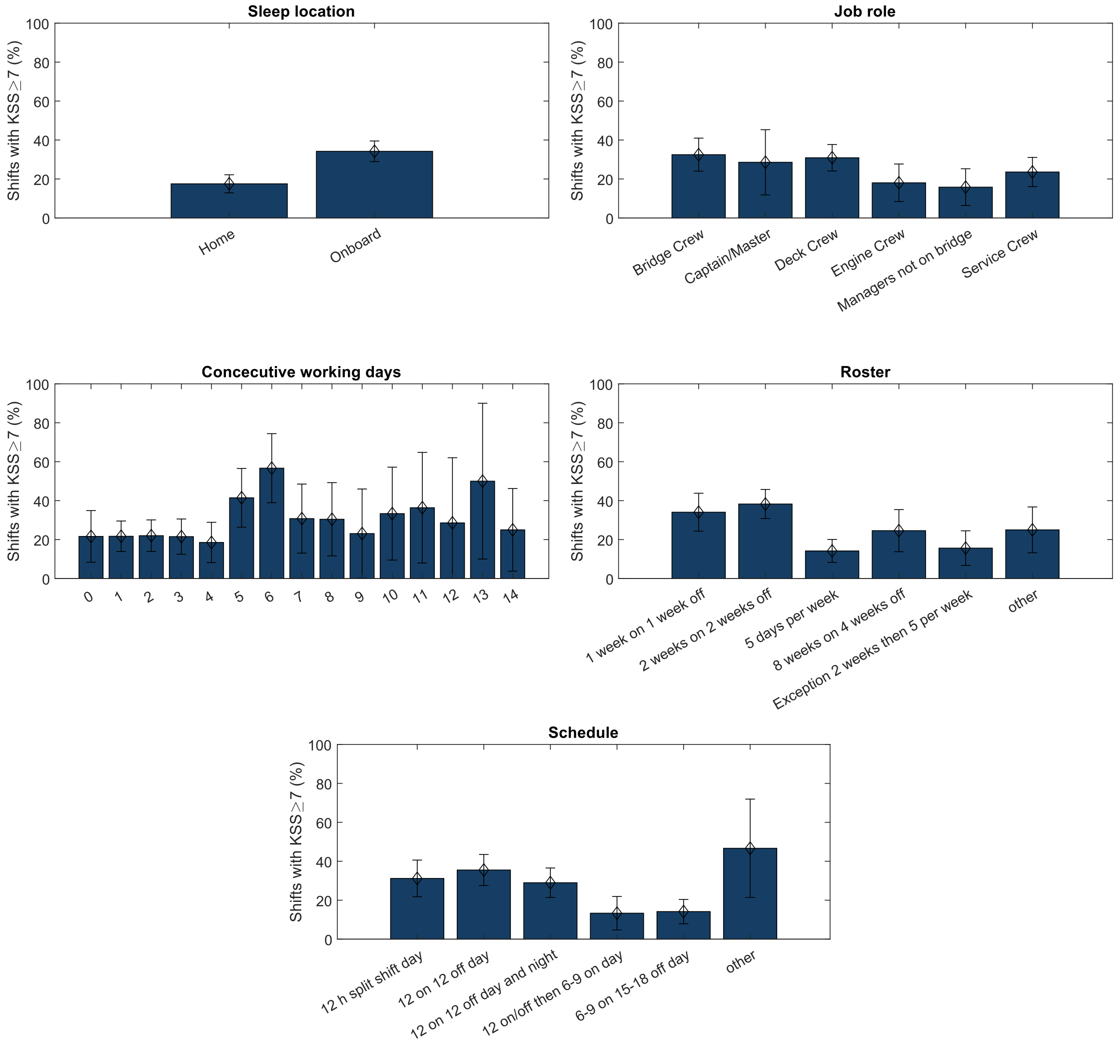
[9] The significance level is set to p≤0.05 (p≤0.01 after Bonferroni correction)

Table 14: Mixed-effects logistic regression models of KSS≥7 for the five work factors.[10]

KSS≥7	Predictors	B	t	p	N	-2LL
Sleep location	(Intercept)	-1.551	-5.90	<0.001	564	1313.5
	Sleep location	0.83	2.28	0.02	n/a	n/a
Consecutive working days	(Intercept)	-1.18	-5.1	<0.001	564	1314.2
	Consecutive days	0.02	0.45	0.65		
Job role	(Intercept)	-0.92	-1.47	0.14	564	1314.8
	Bridge crew	0.04	0.05	0.96	n/a	n/a
	Deck crew	0.12	0.16	0.87	n/a	n/a
	Engine crew	-0.72	-0.82	0.41	n/a	n/a
	Non-bridge-managers	-0.80	-0.85	0.39	n/a	n/a
	Service crew	-0.32	-0.41	0.68	n/a	n/a
Schedule type	(Intercept)	-0.53	-1.62	0.10	564	1319.1
	12 on 12 off day/night	-0.50	-0.95	0.35	n/a	n/a
	12 h split shift day	-0.18	-0.34	0.74	n/a	n/a
	12 on/off then 6-9…	-1.33	-2.26	0.02	n/a	n/a
	6-9 on 15-18 off day	-1.27	-2.72	0.007	n/a	n/a
	other	-0.56	-0.47	0.63	n/a	n/a
Roster type	(Intercept)	-1.80	-6.10	<0.001	564	1318
	1 week on 1 week off	1.31	2.38	0.02	n/a	n/a
	2 weeks on 2 weeks off	1.17	2.67	0.008	n/a	n/a
	8 weeks on 4 weeks off	0.71	1.39	0.16	n/a	n/a
	Exception 2 weeks…	0.18	0.33	0.74	n/a	n/a
	Other	0.02	0.02	0.98	n/a	n/a

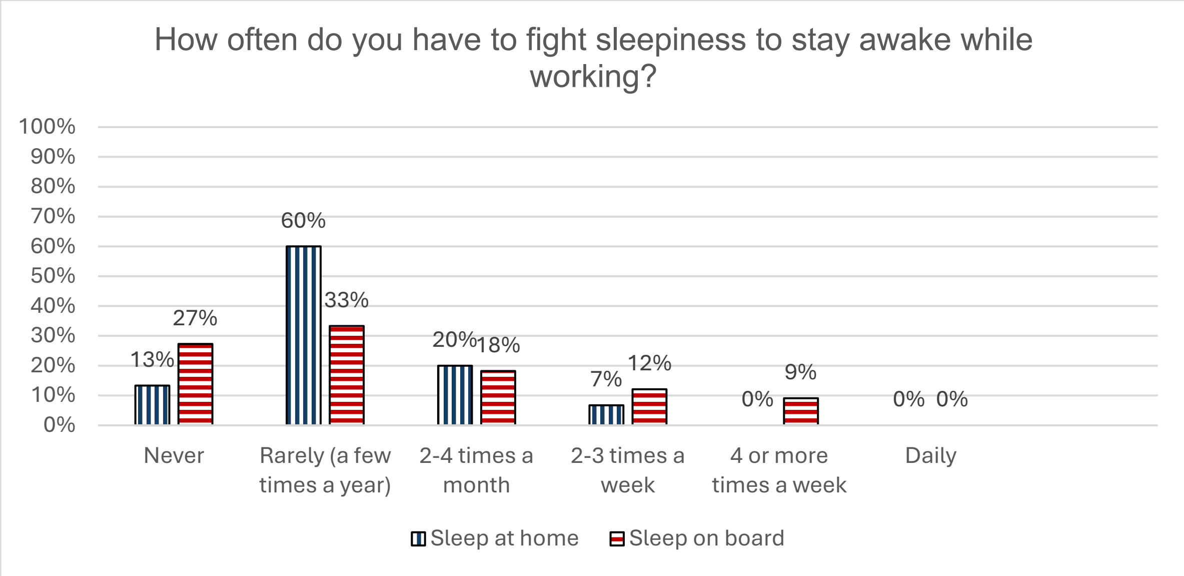
[10] B is the estimated coefficient, t is the test statistic, p is the p-value, N is the number of observations, and -2LL is the log likelihood ratio. The significance level is set to p≤0.05 (p≤0.01 after Bonferroni correction)

Figure 12: Share of shifts in the field study where the participants rated themselves as sleepy. Each bar represents the percentage of shifts in that category where KSS≥7 was reported at least once (n=564).



In the entry questionnaire, daytime sleepiness was rated using the Epworth Sleepiness Scale (ESS). Mean score was 6.9 (SD 4.2) with 15 seafarers (24%) scoring above the cut-off for excessive daytime sleepiness. There was no statistically significant difference between job roles, schedules, rosters, or seafarers sleeping on board or not in ESS scores. The seafarers rated how often they have to fight sleepiness to stay awake while working. One third (33%) of the participants indicated having to fight to stay awake on a monthly basis whereas 14% indicated that they had to fight to stay awake 2-3 times a week or more often (Figure 13). This was not statistically significantly different between seafarers sleeping at home or on board.

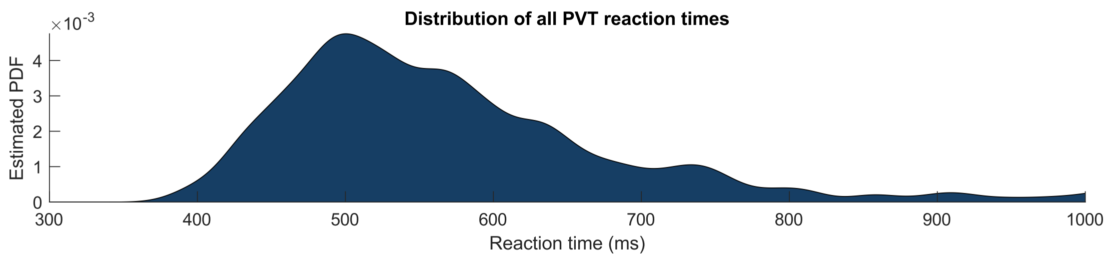
Figure 13: Frequency of having to fight to stay awake while working (%, n=63)



Performance

Alertness was evaluated using PVT installed on the participants' own smartphones. The mean reaction time was 584 ms (SD 148 ms) and the mean number of lapses per test was 5.2 (SD 5.4) for the whole sample. There were no statistically significant results from the ANOVAs of RT or lapses for the factors sleep location, number of consecutive working days, job role, schedule type, and roster type (Table 15). The distribution of reaction times is provided in Figure 14. Probability distributions per factor can be found in Annex D: Detailed results.

Figure 14: Probability density estimate of reaction times in the full dataset (n=683).



Logistic regression analyses were performed to investigate which work factors were related to having three or more PVT lapses. Separate analyses were performed with the factors sleep location, number of consecutive working days, job role, schedule type, and roster type as covariates and lapses (3 or more lapses or 2 or fewer lapses) as the dependent variable. No statistically significant differences were found between any of the work factors except for job role, where Non-bridge-managers had statistically significantly more PVT lapses ≥3 compared to captains/masters (Table 16).

Table 15: F and p values from separate ANOVAs of PVT reaction time for the five work factors.[11]

	PVT Reaction time	**PVT Lapses**
Sleep location	F(1,637)=1.72, p=0.19	F(1,637)=4.67, p=0.03
Consecutive working days	F(1,636)=1.31, p=0.25	F(1,636)=0.10, p=0.74
Job role	F(5,637)=0.96, p=0.45	F(5,637)=1.56, p=0.19
Schedule type	F(5,637)=0.70, p=0.62	F(5,637)=0.56, p=0.73
Roster type	F(5,637)=0.32, p=0.90	F(5,637)=0.55, p=0.73

[11] The significance level is set to $p \leq 0.05$ ($p \leq 0.01$ after Bonferroni correction).

Table 16: Mixed-effects logistic regression models of the number of PVT lapses ≥3 for the five work factors.[12]

Number PVT lapses ≥3	Predictors	B	t	p	N	-2LL
Sleep location	(Intercept)	0.39	1.17	0.24	564	1257.2
	Sleep location	-0.21	-0.56	0.58		
Consecutive working days	(Intercept)	0.01	0.05	0.96	564	1256.5
	Consecutive days	0.06	2.06	0.04		
Job role	(Intercept)	-0.75	-1.84	0.07	564	1260.8
	Bridge crew	0.94	1.91	0.06	n/a	n/a
	Deck crew	1.24	2.23	0.03	n/a	n/a
	Engine crew	1.03	1.67	0.09	n/a	n/a
	Managers-not-on - Bridge	1.92	2.90	0.004	n/a	n/a
	Service crew	0.49	0.83	0.41	n/a	n/a
Schedule type	(Intercept)	0.17	0.46	0.65	564	1260
	12 on 12 off day/night	-0.16	-0.30	0.77	n/a	n/a
	12 h split shift day	-0.14	-0.32	0.75	n/a	n/a
	12 on/off then 6-9…	0.05	0.05	0.96	n/a	n/a
	6-9 on 15-18 off day	0.54	1.08	0.28	n/a	n/a
	other	1.70	2.02	0.04	n/a	n/a
Roster type	(Intercept)	0.48	1.15	0.25	564	1259.7
	1 week on 1 week off	-0.71	-1.08	0.28	n/a	n/a
	2 weeks on 2 weeks off	-0.17	-0.37	0.71	n/a	n/a
	8 weeks on 4 weeks off	-0.48	-0.72	0.47	n/a	n/a
	Exception 2 weeks…	0.10	0.10	0.92	n/a	n/a
	Other	0.003	0.004	1.00	n/a	n/a

In the entry questionnaire, the participants were asked about sleepiness related incidents at work in the past 12 months. Eleven participants (17%) reported that they had stopped working due to tiredness at least once and 33 participants (52%) reported that they had wanted to stop working due to fatigue but been unable to at

[12] B is the estimated coefficient, t is the test statistic, p is the p-value, N is the number of observations, and -2LL is the log likelihood ratio. The significance level is set to $p \leq 0.05$ ($p \leq 0.01$ after Bonferroni correction).

least once. Nine participants (14%) reported having a ‘near miss’ at work at least once and two participants (3%) reported having an accident at work because they were sleepy. The participants also reported if they had experienced an accident where sleepiness or fatigue was partly or solely to blame in the last 10 years. Five participants (8%) reported that it had happened several times and 10 participants (16%) reported that it had happened once.

Stress

The overall mean subjective stress ratings (possible score from 1-9) from the diary entries was 5.2 (SD 5.4). Approximately 4% of all work shifts had stress levels ≥7. Twenty-four participants had one or more work shifts with a stress level ≥8. Probability distributions per factor can be found in Annex D: Detailed results.

ANOVAs of subjective stress levels per work shift in relation to sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively, revealed statistically significant differences between job roles (F=3.4, p=.01;Table 17). Post-hoc tests showed that bridge crew provided higher stress ratings than all other categories except non-bridge-managers. Non-bridge-managers had higher stress levels than deck crew, engine crew and service crew. Captains/Masters had lower stress ratings than bridge crew. Other work factors were not statistically significant.

Table 17: F and p values from separate ANOVAs of subjective stress ratings for the five work factors.[13]

	Subjective stress
Sleep location	F(1,598)=0.44, p=0.51
Consecutive working days	F(1,597)=0.66, p=0.42
Job role	F(5,598)=3.38, p=0.01
Schedule type	F(5,598)=1.32, p=0.27
Roster type	F(5,598)=3.24, p=0.013

BMM evaluation

Work schedules were evaluated using FAID Quantum and SAFTE-FAST separately. The results were thereafter compared with the subjective KSS ratings from the diaries and with actual sleep hours.

[13] The significance level is set to p≤0.05 (p≤0.01 after Bonferroni correction).

FAID Quantum

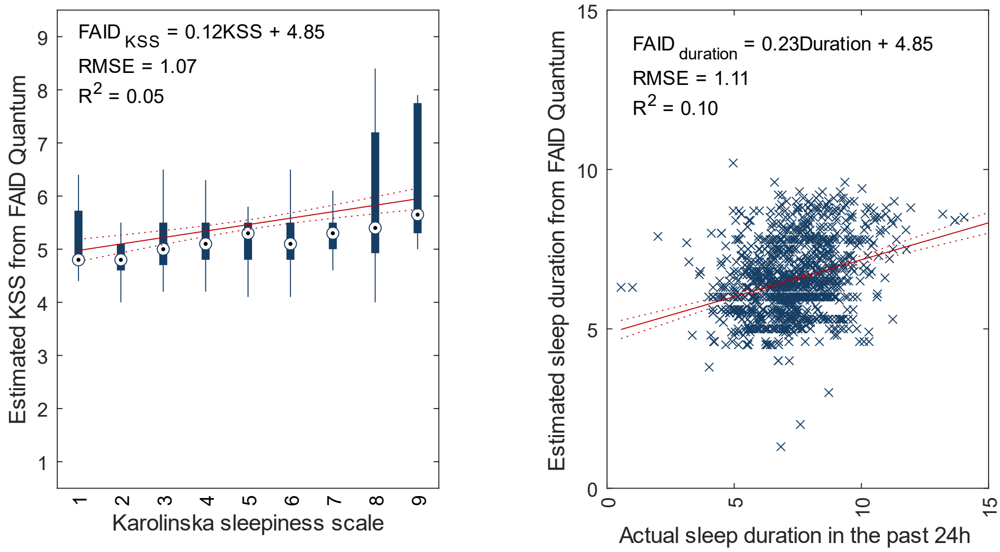
The tolerance level was set to KSS 7.0 in the FAID Quantum analyses, meaning that predicted KSS levels of 7.0 and higher were considered high risk. The analysis of the participants' actual work hours showed that KSS levels 7 or higher were estimated in 4.8% of the hours worked. Approximately 12% of all work shifts had estimated KSS≥7 at some point during the shift. All except two work shifts with estimated KSS≥7 included work during nighttime hours, i.e., between 11 pm and 6 am. The two exceptions were on daytime work shifts the day after working a night shift. All night shifts had predicted KSS≥6 and only a couple of night shifts had a max KSS<7. These were all the first shift in the dataset for the respective participant and thus had no prior data to use in the modeling.

Twenty-three of the participants had one or more work shifts with estimated KSS≥7. Most of these participants (n=16) worked a 12 h on 12 h off rotating schedule with both daytime and nighttime work. Three worked a 12 h split shift with only daytime work. For participants working daytime spit shifts, high levels of fatigue were estimated only in shifts that started before 6 am or ended after 11 pm. These shifts included less than 3 h work between 11 pm and 6 am and were thus not categorised as night work. Roster patterns that were most common among participants with high-risk shifts were 1 week on 1 week off (n=9), 2 weeks on 2 weeks off (n=7), and 8 weeks on 4 weeks off (n=3). Work shifts with predicted KSS≥7 were more common among participants sleeping onboard (n=15) versus at home (n=8).

A subset of the full dataset was created where max KSS ratings per shift could be matched to max KSS estimates from FAID Quantum. The subset consisted of 56 unique participants and 564 shifts, with a mean max KSS value of 5.2 (SD = 1.9) and a mean estimated FAID Quantum max KSS per shift of 5.5 (SD = 1.1). The participants rated their sleepiness level as KSS≥7 at some point during the work shift in 26.6% of all shifts, which is considerably more often compared to the estimations from FAID Quantum (12.4%). The percentage of drivers with one or more work shift with KSS≥7 was about the same when rated by the participants (39.9%) and when estimated by FAID Quantum (36.6%). The correlation coefficient between the participants' max KSS rating during the shifts and the estimated max KSS values from FAID Quantum was moderate (R=0.21) yet statistically significant (Figure 15).

The measured mean sleep duration in the subset was 7.3h (SD = 1.6h) whereas the mean sleep duration estimated by FAID Quantum from the work schedules was 6.5h (SD = 1.2h). The correlation coefficient between measured and estimated sleep durations was moderate, R=0.32.

Figure 15: FAID estimates of max KSS during shifts (n=474) and sleep durations (n=1107) versus self-rated KSS scores and measured sleep durations.[14]



SAFTE-FAST

SAFTE-FAST did not have automatic identification of shifts with KSS≥7 but provided Max KSS for each work shift which enabled classification of high-risk work shifts in the exported data. Max KSS≥7 was estimated in 10.1% of all work shifts. There were 22 participants with one or more work shifts that reached KSS≥7. Twenty of these were the same as in the FAID Quantum analyses. That is, high KSS levels were mainly estimated during night work. The two schedules that were above the KSS threshold in SAFTE-FAST but not in FAID Quantum had single shifts during nighttime hours but no regular night work. The three schedules that did not have work shifts above the KSS threshold in SAFTE-FAST but were flagged by FAID Quantum also had irregularities in the schedules with single shifts extending into nighttime hours.

A subset of the full dataset was created where max KSS ratings per shift could be matched to KSS estimates from SAFTE-FAST. The subset consisted of 56 unique participants and 474 shifts, with a mean max KSS value of 5.0 (SD = 1.9) and a mean estimated SAFTE-FAST max KSS per shift of 4.3 (SD = 1.4). The participants in the matched subset rated their sleepiness level as KSS≥7 at some point during the work shift in 24.5% of all shifts, which is considerably more often compared to the estimations from FAID Quantum (10.1%). In the subgroup of matched

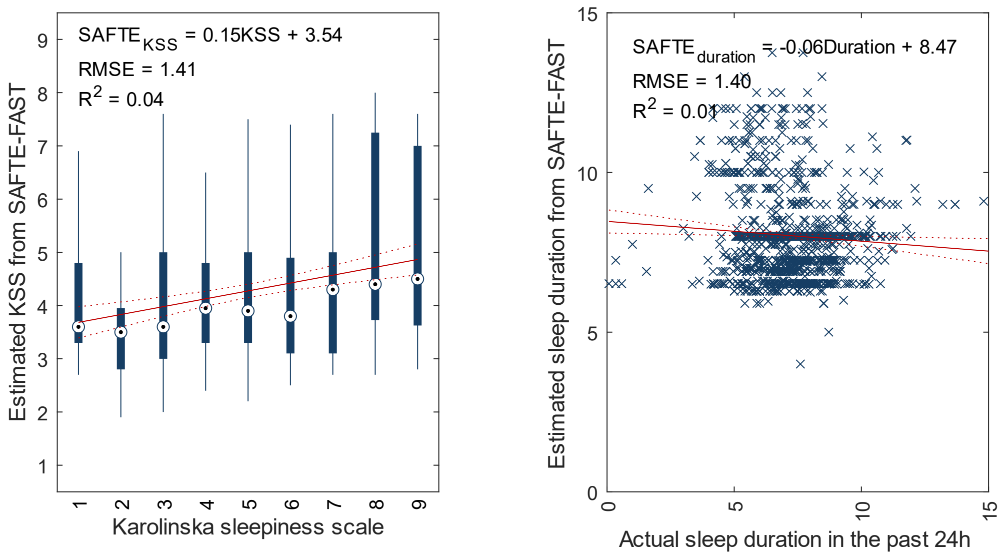
---

[14] The lines show linear regression best fits (RMSE – Root Mean Square Error, R2 – Coefficient of determination).

participants, the percentage of seafarers with one or more work shift with KSS≥7 was about the same when rated by the participants (37.4%) and when estimated by SAFTE-FAST (35.3%). The correlation coefficient between the participants' max KSS rating during the shifts and the estimated max KSS values from SAFTE-FAST was moderate (R=0.20) yet statistically significant (Figure 16).

The measured mean sleep duration in a matched subset (61 participants, 1107 shifts) was 7.3h (SD = 1.7h) whereas the mean sleep duration estimated by SAFTE-FAST from the work schedules was 8.0h (SD = 1.4h). The correlation coefficient between measured and estimated sleep durations was weak, R=0.07.

Figure 16: SAFTE-FAST estimates of max KSS (n=474) during shifts and sleep durations (n=1107) versus self-rated KSS scores and measured sleep durations.[15]



[15] The lines show linear regression best fits (RMSE – Root Mean Square Error, R2 – Coefficient of determination).

5. Discussion and Recommendations

How this research has built on findings from MARTHA

The current research brings new insights into understanding fatigue in UK seafarers. Despite the differences in scope and scale, the current research adds to our understanding in relation to 5 of the key findings reported by the MARTHA project.

MARTHA project reported that captains (fatigue) and night watch keepers (less sleep) suffer worse than other crew

This finding is not supported by this research. In the field trial captains/masters actually had a lower share of shifts with multiple PVT attention lapses compared to other job roles. This difference was only statistically significant in comparison to non-bridge-managers. Captains reported a requirement for greater sleep needed for safe working than non-bridge-managers ($p=.010$) and engine crew ($p=.036$). In the survey, there were no statistically significant differences between captains/masters and any other job role in any of the analysis, other than that they reported statistically significantly better quality of sleep than services crew.

Amongst survey participants 52% had responsibility for watch duty as part of their job role and 70% of field trial participants had watch duty as part of their job role. Having responsibility for watch keeping was not predictive of experiencing fatigue.

During the field trial, in survey responses, and in interviews with captains there was evidence that they experienced fatigue at work, suggesting that it is a problem for this job role, but there was no evidence that this was worse than for other crew members. However, this does not consider the implications for fatigue within a role. It could be argued that as a high safety critical role the risk threshold for fatigue in captains should be lower than for other job roles.

Fatigue and stress increase over time on a voyage

This finding is somewhat supported by the current research. From the field trial results there was no statistically significant effect of number of consecutive days at sea in the analyses of sleepiness on duty and stress; it should be noted there was some influence on extreme subjective sleepiness (KSS≥7). The percentage of shifts with KSS≥7 was relatively stable around 20% for the first four consecutive days and then increased after five consecutive work days as seen in Figure 12. There was also an influence on the share of shifts with prior sleep ≤5h, with this being stable in the first 5 days but increasing from the 6th day onwards.

In contrast, there was some evidence that it is the earliest days at sea which present some concern for fatigue. The PVT lapses increased for the first few days but tended to stabilise after 3–4 days in work. In both the interviews and the focus groups, participants suggested that the first few shifts (particularly night shifts) were subjectively the hardest for dealing with fatigue. They said that this then improved with consecutive work days.

Port work is seen as more demanding than work at sea

The current research somewhat supports this finding. In the BMM workshop, it was identified that intensity of route is a factor in roster planning e.g. busier routes would only schedule crew for 1 or 2 weeks on board at a time, compared to longer rosters on quieter routes. It may be that this mitigation approach has reduced the impact of this demand in the current results compared to those in the MARTHA project.

The current research did identify a relationship between ports and fatigue, with port activity impacting the fatigue of those on rest. The survey identified disturbed sleep as being a significant contributor to fatigue. The focus groups identified that activity in port is a disruptor to sleep when off-duty for those who sleep on board. Port activity was also identified as having a potential to be impaired by fatigue. In interviews, examples of consequences to fatigue were given which related to port work, including errors in ramp application. Overall, this suggests a complex relationship between port work and fatigue.

Motivation decreases with time away from home, potential for increased company short cuts (therefore increased potential for accidents)

This finding was not supported by the current research. However, the time away from home in the current research was not comparable with the MARTHA study. Within the field study, the roster with the longest work period had eight consecutive weeks of work but the study only lasted for four weeks making it difficult to evaluate long-term effects. No other aspects of the current research were longitudinal in nature. Reduced motivation over time was not apparent in the interviews and focus groups.

Sleep quality deteriorates over the length of voyage, even if amount of sleep does not

The current research did not support this finding. In the field trial, the Fitbit sleep score and subjective ratings of sleep quality did not deteriorate with number of consecutive days worked. It is possible that this is because of the difference in the length of rosters and study period. It could be that deterioration may be seen over months rather than days/weeks. Both sleep quality and sleep quantity were of concern in the current research. From the survey, sleep disturbance was a contributor to fatigue at work, and participants reported getting significantly less sleep than they thought ideal for safe operations. On average, seafarers reported they needed 7h 39m sleep (SD = 1h 3m) between shifts to feel rested and do their job safely. However, the actual hours of sleep reported were, on average 6h 10m (SD = 1h 19m), around 90 minutes less per night on average. In the field trial participants were observed to sleep for around 7 hours on average, around 25 minutes less than they said they required, which was a smaller discrepancy.

Overall, the current research supports the findings of MARTHA that fatigue is present in seafarers. This includes in captains and those with watch keeping duties although it is not limited to these crew. Although port work itself was not specifically investigated, the current research supports the findings of MARTHA that this is an important part of a voyage to consider. Particularly for those who are sleeping on board and not at work, docking in port is likely to disturb sleep. The findings of MARTHA related to the impact of consecutive days at sea on fatigue, stress, sleep quality and motivation were not supported. However, it is important to note that the duration of consecutive workdays was variable within the participants in the current research and noticeably shorter than that experienced in the deep sea voyages investigated as part of project MARTHA.

What are the most appropriate method/s to assess and monitor seafarers' fatigue?

Measuring fatigue is a challenge in all settings. In an ideal situation it would be possible to objectively assess an individual's fatigue level, monitor it over time and intervene at a point before any fatigue experienced became safety critical. However, there are multiple factors which limit the ability to do this accurately, most of which are universal challenges faced by the transportation industry (Sallinen & Kecklund, 2023).

Firstly, and perhaps most importantly, it is impossible to measure fatigue directly: all measures of fatigue are measures of a proxy for fatigue. Fatigue is multidimensional and can manifest itself in a variety of ways. Therefore, there are multiple options which could be measured as the proxy indicator. The particular ones chosen must be appropriate for the context within which fatigue is occurring, recording the element(s) of most relevance.

Monitoring of subjective sleepiness is one useful approach, as the experience of fatigue is personal, and one person obtaining four hours sleep will not have the same experience as another person with the same short sleep. The Karolinska Sleepiness Scale (KSS) (Åkerstedt et al., 2014), is a well validated and robust measure of sleepiness. In the current research it was used effectively in the field trial. However, as with all subjective accounts it relies on the accuracy and honesty of the person reporting. It is generally well recognised that individuals have accurate insight into their sleepiness (Cai et al 2021) so should be able to report KSS accurately. The limitation is therefore whether a person feels "safe" to do so, this will be influenced by the organisational culture. Workplace culture was considered in both the interviews and the focus groups of the current research, and the findings were mixed. In some settings and circumstances it appeared possible to report personal fatigue. However, for many this was a topic that would not be openly discussed.

Reaction time is a strong indicator of fatigue, in particular the number of lapses in attention are known to increase with increasing fatigue (Basner & Dinges, 2011). The current research used the short PVT as a reaction time test during the field trial. This was achievable within a fixed term study although there were multiple missing data points. Participants were instructed not to compromise operations to complete the study, so it is likely that regular reaction time tests are not appropriate for monitoring fatigue in seafarers.

Both subjective sleepiness and slowed reaction times are themselves consequences of fatigue. An alternative approach to fatigue monitoring is to measure causes of fatigue. The biggest cause of fatigue due to sleepiness is insufficient sleep. The most accurate way to measure sleep is through electroencephalography (EEG) where electrodes are used to record brain activity but this is clearly not appropriate in real-life settings. Actigraphy (movement monitoring) as a method to monitor sleep has an established history in sleep research and been shown to be a valid proxy for EEG measured sleep (Mullaney et al 1980). Assessment of sleep obtained can then be used to predict the potential of fatigue occurring. This has been used in various transport modes. For example, in rail, the Rail Safety Standards Board recently reported that actigraphy can be used to improve fatigue predictions at a shift planning (group) level, but that also that more work is needed before this approach could be used to make decisions at an individual level (RSSB, 2021). Recently, wrist worn sleep trackers have become common place with many commercial devices offering this service. Fitbit technology is now comparable with the accuracy of research grade actiwatches (Haghayegh et al., 2019). This presents a new opportunity for widespread sleep monitoring through the proxy of movement at relatively low-cost using devices which are attractive to end users. It was for this reason that the current research used the latest Fitbit technology in the field trial. the movement monitoring itself proved successful but, unfortunately, sleep monitoring using the automated scoring system with Fitbit was not reliable at sea, most likely due to ship motion interfering with the wrist motion-based sleep scoring algorithm. Sleep duration for field trial participants who slept on board was manually calculated in the current research as the automated scoring system could not be used. Objective monitoring of seafarers' sleep using e.g., wearable devices, would thus require careful testing of the validity and reliability in the maritime environment. There have been successful trials at sea with other commercially available devices, such as the Oura ring and ReadiBand (Kubala et al., 2024). It is also well known that motion-based sleep scoring may overestimate sleep duration because of difficulty distinguishing between sleep and wakefulness when the wearer lies still in bed trying to sleep but is actually awake.

Another tool for monitoring fatigue over time is a biomathematical model (BMM). These tools use an algorithm through which imported data on usual work hours and sleep are processed to predict times during a roster when fatigue might be expected. There are several commercial services available making this a practical option to employ. In the current research it was identified that BMMs are not routinely used in UK seafaring and there are many limitations to their accurate use. One big barrier is the difference between planned working hours and actual working hours. During the field trial of the current research BMMs were used to get an overview of their general usefulness in ferry operations, although it was very time consuming to document the actual working hours of participants as there were many deviations from planned work. The BMM tools underestimated participants' peak sleepiness, at least when default settings were used. It is possible that prediction can be improved by taking more factors into consideration, such as individual commuting times, workload, and sleeping facilities. This would require thorough investigation of individual employees' commuting and mapping of workload and fatigue hazard for different roles on the muster list. More accurate modelling would be expected if additional operator specific or individual factors were added to the models. Tailoring the model for individual operators is therefore recommended if BMM tools are to be used for evaluation of work schedules. However, given that large individual differences in sleepiness are seen in seafarers working the same type of schedule and roster, monitoring of the seafarers' subjective experience is needed to get the full picture of fatigue in ferry operations, further adding to the challenges of widespread use of BMMs.

Overall, subjective sleepiness is a robust method of assessing sleepiness, as individuals have strong insight into sleepiness (Cai et al 2021). The limitation to subjective sleepiness is around honesty of reporting this subjective experience to others. Objective monitoring of sleep duration was possible using movement monitors, however, the automatic sleep scoring function of Fitbit was not robust for use with those sleeping at sea. Future research should consider other alternatives such as Oura ring. BMMs have potential and work well in other transportation industries which typically rely on lone vehicle operators e.g. road, rail, and aviation. Future research should consider possibilities for adapting BMMs for seafaring, as in their current format there are limitations to their use. Although attempts should be made to monitor fatigue, it is vital to recognise that this is not the final step in fatigue management, rather it is a tool for use to inform fatigue management (Sallinen & Kecklund 2023).

What are the consequences of fatigue for different roles on the muster list?

The current research identified that there can be severe consequences to fatigue and this experience can occur across different roles on the muster list. From the survey, it was reported that over 50% of all crew members fight sleepiness at work on at least a monthly basis. This was supported by qualitative results from the interviews and focus groups evidencing fatigue to be a part of life for seafarers. The consequence of this fatigue was also apparent, with over 18% of all seafarers reporting having fallen asleep whilst on duty within the previous year and 31% having experienced one or more fatigue-related incidents/accidents at work within the previous 10 years. For comparison, in a similar survey of London bus drivers it was reported that 17% had fallen asleep at least once whilst driving in the last twelve months, and 17% of drivers had experienced one or more incidents or crashes in the past 10 years where sleepiness was at least partly to blame (Miller et al., 2020). This high prevalence of fatigue related incidents is a hidden issue within the seafaring industry, as of those who had experienced one of these incidents, 85% reported that their employer would not know that this incident was due to fatigue. For comparison, where bus drivers who had an incident which they attributed to sleepiness, 78% did not believe that their employer would know that fatigue was a factor (Miller et al., 2020). It should be noted that the methodology was not identical so comparison should be made with caution. Nonetheless, this does suggest that fatigue related incidents may be more prevalent in ferries operating in UK waters than in UK bus workers, but the propensity for this to be absent from official incident records are similar. It is not clear from these results why seafarers consider their employer not to know that an incident is due to fatigue.

The experience of fatigue appears to occur across all seafaring job roles. There were no major differences identified in either the survey or the field trial; where any difference could be found it is the services crew who were most impacted. In the survey, services crew were most likely to experience tiredness every day and reported the lowest sleep quality score of all job roles on the muster list but otherwise, the survey reported limited differences in fatigue between the different muster lists. As the univariate analysis did not identify job role as a significant predictor, this feature was not entered into the multivariate logistical regression. Overall, 85% of respondents felt some level of fatigue several times a month, with this experience occurring in all job roles, meaning that the organic difference between groupings was not sufficiently large to meet the threshold of prediction of sleepiness for the univariate analysis.

An additional statistical analysis of a one-way ANOVA was employed with the survey data to intentionally explore differences in fatigue levels between job roles. This reported an overall slight significant difference in sleepiness between roles. The post-hoc analysis suggested this difference to be driven by differences in the experience of the service staff compared to other roles. It was found that the service crew had the worst sleep ratings compared to other job roles.

Similarly, the field trial also reported no major differences between job roles regarding hours slept and on duty sleepiness. There were some differences in sleep quality, stress and PVT performance. For example, bridge crew and non-bridge managers reported sleeping better than deck crew, engine crew and service crew. However, bridge crew and non-bridge-managers also reported being more stressed than other roles on the muster list. These findings suggest that deck crew, engine crew and service crew may be more likely to experience fatigue due to sleep related factors, whereas bridge crew and non-bridge-managers may be more likely to experience fatigue due to stress. The relationship between fatigue and stress is complex, for example in bus drivers it has been found that long term stress is one of the strongest predictors of fatigue (Anund et al., 2016). High stress can impact sleep and influence the pattern of cortisol secretion which in turn influences fatigue (Dahlgren et al., 2005).

There are several reasons why service crew might be more susceptible to fatigue in addition to poorer sleep quality. First of all, the service crew are customer facing. Unlike other crew whose busiest periods are during port operations (Kahveci, 1999), the service crew must attend to passengers for most of the voyage. Dealing with passengers for long periods of time can be stressful as the service crew have the responsibility of ensuring customer satisfaction during the crossing (Sonnentag & Zijlstra, 2006). Being the public face of the company at sea, the service crew also have to uphold the company's reputation (Abd-El-Salam et al., 2013). This high level of stress and responsibility can lead to fatigue (Jiandong et al., 2022). It may be that the shorter opportunity for lower activity within the job role and fewer breaks could lead to increased fatigue in this job role.

There has been little previous research in fatigue experiences of customer-facing service crew, and what is available is based on research outside of the seafaring environment as research of customer service of seafaring remains limited (Dohrmann & Leppin, 2017). Additionally, the hierarchy of seafaring operations would suggest that for most services staff in live-on-board operations, sleeping facilities may be less supportive of restful sleep than for more senior officers. For example, focus group participants reported sharing a cabin as a factor which disturbed their sleep, in addition to aspects such as general noise, vibration, weather and Tannoy systems. Findings from the BMM workshop also suggested that fatigue of services crew was an issue. Participants at the workshop hypothesised that this fatigue would be a risk for emergency situations but focus group participants suggested that this was not an issue as adrenaline carries them through in these situations, rather it was the fatigue experienced after an incident which was of greater concern to them.

What factors cause and exacerbate fatigue and how can these be mitigated?

A specific intention of the field trial in the current research was to investigate the relationship between shift patterns, rosters and fatigue. It is apparent that the relationship between work schedules, rosters and fatigue is not straight forward in this sample of seafarers. Participants working 12 h split shifts had the shortest sleep durations, but their on-duty sleepiness scores were not statistically significantly different from participants working other schedules. Similarly, 8 weeks on 4 weeks off was the roster type with shortest sleep durations but no statistically significant differences were seen in sleepiness scores between participants with this type of roster and other rosters. Participants working 1 week on 1 week off had the longest sleep durations but still had a high risk of reaching KSS≥7. All of this makes it difficult to specifically identify a work pattern which is a dominant cause of fatigue. The conflicting results for the participants working 1 week on 1 week off could be because many of the night workers had this type of roster. One conclusion could thus be that even if you prioritize sleep between shifts, night work is still a risk-factor for sleepiness on duty.

Another reason for not being able to isolate the effect of a certain schedule or roster is the limited number of participants in the study who work the same schedule, and because not all combinations of roster patterns and work schedules were represented in the sample. Schedules and rosters vary between operators and between different ferry routes within the same operator. Additionally, dynamic work changes mean that seafarers often do not work set hours as prescribed. This is evidenced by the difficulty in recording the actual hours worked.

Variability in work schedules was anticipated and the BMM analysis of the field study sought to clarify which work schedules could cause or exacerbate fatigue. The outcome of the BMM analyses identified schedules including nighttime as being predicted to be the most problematic in terms of KSS levels. This is to be expected because of the circadian low experienced at this time; this is a known safety risk within transportation (Folkard et al., 2006; Horne and Reyner, 1995). However, the diary results in the field trial showed that sleepiness on duty was experienced by participants working all types of schedules, not only night workers. Moreover, three participants working night shifts had no shifts with subjective KSS≥7, despite having up to 14 consecutive night shifts. This indicates that schedules and rosters are not the only factors that influence seafarer fatigue.

Previous research has shown that there are considerable differences between individuals in how well they tolerate shift work (Härmä, 1993). The sensitivity to fatigue is highly influenced by the individual's chronotype, which represents the individual preference to be active early or late in the day and to sleep early or late in the night. In other occupational groups, such as bus drivers, it has been concluded that personal preferences regarding schedules, that is whether someone finds a specific schedule problematic, is related to stress, poor health and negative psychosocial work conditions (Ihlström et al., 2017). Taking seafarers' individual preferences and characteristics such as chronotype into consideration in scheduling could thus reduce the risk of sleepiness on duty.

A further cause of fatigue identified by the field trial was irregular work start times, along with night work. The schedules with the most variation in start times in this study were the 12h on 12h off with both day and night shifts. Some variation was also seen in the 6-9 h daytime work category. Variability in start time (along with night work) has previously been associated with reduced sleep and increased risk of fatigue in seafarers (Gregory et al., 2020). To mitigate the risk of fatigue, it should be ensured that the seafarers have sufficient time for sleep before a work shift with a different start time compared to the previous shift. Forward rotating schedules are therefore recommended (van Leeuwen et al., 2021).

Causes and exacerbations of fatigue were also identified in the survey. Respondents were classified as either frequently experiencing fatigue or not. Frequently experiencing fatigue was defined as fighting sleepiness at least 2-3 times a week (n = 122), compared to reporting fighting sleepiness less often or not at all (n = 324). The factors most strongly predicting being in the frequent fatigue group were: a belief or perception that working hours were leading to sleepiness, difficulty relaxing, being female, working extra days, disturbed sleep index, poorer sleep rating in the last 3 months, feeling restless off duty, choosing to work overtime, impaired waking index, greater work stress, higher chance of undiagnosed sleep apnoea and decreased work enjoyment. Broadly speaking these can be split into sleep related factors, work related factors and health related factors.

Of the sleep factors, the disturbed sleep index, the impaired waking index and the sleep apnoea index were significantly associated with sleepiness. Additionally, the self-reported sleep rating was significantly associated with sleepiness. Insufficient sleep through partial sleep deprivation is a common experience for all shift workers in the transportation industry (Kosmadopoulos, 2023), this occurs through the frequent experience of getting less sleep than is needed to be fully alert during work hours. The duration of time between work shifts and the time of day when this non-work time occurs both influence the amount of sleep which can be obtained. For example, in train drivers with 12-hour breaks between consecutive shifts the amount of sleep achieved varied from 8 hours when breaks occurred at night down to as little as 3 hours when breaks occurred during the day (Roach et al., 2003). Insufficient sleep appears to be a problem for seafarers as on average survey respondents in the current research reported getting an average of 90min less sleep than they would consider ideal. This is in line with findings from MARTHA (2016), although it should be noted that in this research what is considered to be both the ideal amount of sleep and actual amount of sleep are lower than that reported by MARTHA (2016). The current research also identified disturbed sleep as a causal factor to fatigue in the interviews, as being woken during sleep was reported by some captains. Where there are fewer than two full crews, captains and some other key roles are never completely off duty, as they can be called on while off duty. This was reportedly more likely to happen if other bridge crew were inexperienced. It is important to note that captains were more concerned about not being woken than being woken up; they trusted their crew only to wake them if needed and were happy to help when woken. Nonetheless, the experience of it did cause disturbed sleep. An additional consideration in this circumstance is sleep inertia. Sleep inertia is the transient period of reduced alertness and impaired cognitive performance experienced immediately after waking from sleep (Hilditch and McHill, 2019). It typically dissipates within 30min of waking but can have serious safety consequences if those being woken were asked to make immediate safety critical decisions (Hilditch and Fischer 2023).

Sleeping on a vessel can lead to disturbed sleep (Hystad & Eid, 2016) and consequently insufficient sleep. For example, noise and vibration have been identified as stressors to seafarers (Lutzhoft et al., 2010; Oldenburg et al., 2009; Wadsworth et al., 2006; Allen et al., 2008; Ellis et al., 2003) and also came out in the focus groups of the current work. Furthermore, as the ship is moving on an unstable surface, there is also the issue of the motion of the vessel leading to motion sickness (Dobie & Dobie, 2019), particularly during rough weather or storms that the seafarers are not accustomed to. This was reported by some services staff, particularly in relation to certain vessels. Repeated experience of disturbed sleep leads to both short term fatigue and longer-term implications e.g. potential burnout (Ekstedt et al., 2006). During a work shift following sleep disturbance there will be greater risk of fatigue as sleep pressure will not have been sufficiently reduced (Ma et al., 2022).

Indication of obstructive sleep apnoea (OSA) was also predictive of regularly having to fight sleepiness. OSA is a sleep disorder where the airways frequently collapse during sleep, this is followed by a brief waking to resume breathing and then back to sleep (Veasey and Rosen, 2019). The waking is so brief that OSA sufferers may not be aware of the condition as they would believe they have slept uninterrupted. Since the apnoea is often associated with snoring or other loud choking noise others around e.g. a cabin mate will likely be aware. Undiagnosed OSA is often accompanied with excessive daytime sleepiness (EDS) and has been shown to impair safety such as through increased crash risk when driving (Tregear et al., 2009). However, there is limited evidence as to the impact of undiagnosed OSA on seafaring. Once successfully treated, OSA patients driving performance is comparable to that of similar aged drivers without OSA (Filtness et al., 2012). There is no reason to suggest that treated OSA in seafarers would pose any risk to operations as long as EDS is no longer apparent. In the current research, the indication of sleep apnoea suggests that undiagnosed or unmanaged OSA is a problem in seafaring which is influencing fatigue at work.

Work factors are important influencers of fatigue. The strongest predictor of regular fatigue at work was the belief that work schedules contributed to fatigue. It is important to note that this is a belief about the influence of work schedules rather than evidence that the schedule is an actual cause of fatigue. However, subjective experience is very important when managing fatigue. There was very minimal reporting of training related to fatigue, therefore participants had come to this conclusion based on their own understanding of fatigue and work without formal guidance. This is a positive sign for the industry that workers have some natural insights into the relationship between work and fatigue but without guidance it is possible that appropriate countermeasures will not be enacted.

Work related stress was reported in relation to fatigue in multiple data collection tasks. It has previously been attributed to sleepiness and fatigue (de Vries et al., 2015; Rose et al., 2017) and can impact both physical (Honkonen et al., 2006) and mental health (Rose et al., 2017). Work stress at sea has a similar impact on rates of sleepiness as on land (Miller et al., 2020). For work stress to be reduced on ships, a focus on improving seafarers' wellbeing would be necessary. As reported by others there are many workplace requirements which can impact stress and wellbeing, such as the proliferation of procedures (Knudesn, 2009) and influence of job conditions (Akamangwa, 2016).

Health factors were also identified by the survey as being predictive of fatigue. Within the health factors, 'difficulty relaxing during leisure time' was the strongest predictor. Difficulty relaxing has been found to link with work-related stress in other fields such as healthcare where the link between stress, relaxations and sleep have been widely studied (Epstein et al., 2020; Gillet et al., 2020). Poor relaxation behaviours and difficulty sleeping have also been linked in non-seafaring populations (Jakobsson et al., 2020; Hedin et al., 2020).

Although it is difficult to implement relaxation techniques outside of work, it may be beneficial to promoting relaxation techniques to aid sleep during work time as this could embed techniques which may be used at home. Within seafaring, an empirical study by Allmer (1996), observed that focusing on coping strategies on board including a variety of passive recreation techniques such as calming down and settling down, relaxing, sleeping, listening to music, or watching DVDs are beneficial. It could be argued that Allmer's (1996) research may be outdated as modern seafaring conditions have improved and more recent research has found that power napping may also be a helpful short term relaxation technique (Jensen & Oldenburg, 2020), which would also have benefits for counteracting insufficient sleep. Short naps were reported by participants in both the interviews and focus groups so could be a possible strategy for fatigue management.

Alongside difficulty relaxing at work, seafarers who are restless at home also have increased likelihood of fighting sleepiness at work. Returning home should be an opportunity to rest and reset, particularly when a seafarer is rostered onboard. If there are also significant life stressors outside of work which make it difficult to relax, then a seafarers sleep routine could be compromised (Geiger-Brown et al., 2011). For seafarers who sleep on board there is a higher probability that they may miss important family and social events when at sea which could lead become a life stressor outside of work.

The final factor of sleepiness is gender differences. Within the current study women were over twice as likely to fight sleepiness than men. It should be noted that there were fewer female than male participants in the survey, and 85% of the women who completed the survey were service crew. It is possible that the overrepresentation of service crew is influencing the finding, as service crew were more likely to report poor sleep. Seafaring is a male-dominated profession (Narayanan et al., 2023; Thomas, 2004). For example, the latest 5-yearly Seafarer Workforce Report (BIMCO/ ICS, 2021) indicated that currently women constitute only about 1.28 % of active seafarers globally. Of these, a large majority are employed on cruise/passenger vessels (IMO, 2021), and mostly in lower strata jobs in hotel, catering, and other non-technical departments (Pineiro & Kitada, 2020). Pinerio & Kitada's (2020) findings are supported by the current survey as of the 85 women who took part in the survey, 72 (85%) worked as part of the services crew. As the research has highlighted that the service crew are more fatigued, an over-representation of women in the service roles could be a reason why women are over-represented in the group who regularly fight sleepiness. Further research would be beneficial to determine what challenges women are facing in seafaring that could be contributing to their fatigue.

What are the current measures used to prevent incidents from seafarer fatigue?

Participants in both the interviews and the focus groups were able to discuss the things that they do to manage fatigue. However, they also reported that they had received little or no training in fatigue management, so for the most part these were considered informal solutions which they had come to themselves through personal experience and not something they were formally directed to do by their employer. An example of a personal strategy being used by both captains/bosuns and service staff/ABs is going on deck to get fresh air. Cold air is a commonly cited countermeasure for fatigue used by the general public when wanting to counteract driver sleepiness (Anund et al., 2008), so it is to be expected that it would also be cited as a countermeasure to fatigue in seafarers. However, it is important to recognise that although this may be beneficial for relieving task related fatigue it is not effective at alleviating sleepiness related fatigue. Under experimental conditions, driving when sleepy has been shown to be unimproved and objective signs of sleepiness not mitigated (Reyner and Horne, 1998; Schwarz et al., 2012). This is likely because air is not addressing the cause of sleepiness therefore, following the short exposure to cold air the same pressures (sleep pressure and circadian pressure) remain and continue to pressure themselves on the individual.

Participants in the focus groups were likely to report countermeasures which could quickly be achieved often in their work location, such as caffeine, talking to a colleague, drinking water, or carrying on with reduced performance. These are in line with experiences in the rail (Filtness and Naweed, 2017) and bus industry (Miller et al., 2020), although, preference for caffeine was notably high in seafarers. The effectiveness of countermeasures will depend on the cause of the fatigue being experienced. Caffeine is effective at mitigating sleepiness as it acts on the brain to reduce the impact of sleep pressure, and even in low to moderate doses can effectively reduce the impact of sleep loss on alertness (McLellan et al., 2016). It should be noted that individuals can become habituated to caffeine as repeat exposure reduces its acute effectiveness. For example, truck drivers who consume large amounts of caffeine also reported poorer health behaviours, more crashes and worse driving safety indicators than truck drivers who are lower caffeine consumers (Filtness et al., 2020). High caffeine consumption has been shown to be associated with high blood pressure, increased heart rate, high cholesterol, increased heart rate variability, morbidity and mortality, taken together, it has been recommended that healthy adults consume no more than 400mg of caffeine (approx. 2 cups of coffee) per day to minimise these adverse health impacts (Wikoff et al 2017).

Napping was also mentioned by both interview and focus group participants, although focus group participants did so in the context of relaxing rather than seeking sleep, possibly due to relatively shorter break opportunities. Generally napping has been shown to be an effective countermeasure to sleepiness (Pilkington-Cheney, 2023). Within some aviation operations, controlled napping has been shown to be beneficial (Hartzler, 2014), although there are organisational (‘not seen as correct’) and operational (no facility to sleep) reasons why this might not be suitable.

In contrast to the focus groups, interview participants cited the regulations on rest time between shifts as being a countermeasure to fatigue. This is likely influenced by their managerial position on the vessel and greater experience in the industry in general. Forward rotating shift patterns where duty start time gets progressively later have been shown to be easier for the circadian rhythm to adjust to than backwards rotating. In addition, it is recommended to leave at least 11 hours of rest time between work duties to ensure that sufficient sleep is obtained, as optimal health in adults is observed in those who sleep 7 hours or more per night on a regular basis (Watson et al., 2015).

The survey results corroborate that of the qualitative activities, suggesting that very little training is provided to seafarers in how to manage fatigue, although many of those who have had training found it useful. Only 8% of respondents said they had been given any training or advice on this subject. The bosuns and masters who were interviewed and reported that they had not been given training in this area felt strongly that it would be helpful to enable them to fulfil their management responsibilities. However, whilst it would be beneficial for individuals to receive education on how to manage fatigue it is necessary to recognise that this will not remove all causes of fatigue as it may be that there are barriers to enacting what is learnt in fatigue education. For example, it is accurate to inform people that caffeine will reduce sleepiness, but if a person does not have easy access to caffeine or to a toilet then they may be unable or unwilling to use this countermeasure at work (Pilkington-Cheney et al., 2020).

The findings from the BMM workshop suggest that there are very few active measures currently in place to specifically prevent incidents from fatigue. In fact, there was no real acknowledgement that incidents are caused by fatigue on ferries, and consequently this was felt not to be a key driver when planning rosters and operators did not have an overall fatigue management plan. This perception that fatigue is not a contributor to incidents may not be accurate as in the survey approximately 40% participants reported having had an incident due to fatigue in the last ten years. Why this was likely considered not important is because 85% of these did not believe that their employer would know that fatigue was a factor. The hidden nature of fatigue as a “taboo” subject is not unique to seafaring as it has been reported in other industries such as bus driving (Miller et al., 2020) and rail (Filtness and Naweed, 2017).

Participants at the BMM workshop also reported that internal policies are used to reduce fatigue impact for example by limiting number of days at sea, avoiding quick changeovers where possible. It should be noted that there is evidence from the field trial and qualitative data that these rules are broken in response to operational needs if they arise. On sleep-at-home vessels, people are called in to work at short notice if it is necessary to cover staff absence; and, within the field trial there were some records showing people changing days to nights mid roster, changing patterns because they changed ships and working over their planned two weeks on. These dynamic changes make it hard for BMMs to be used effectively as their value is in predicting the potential impact of work schedules on fatigue assuming that work is conducted as planned.

How could BMMs and modelling of maximum ‘safe’ days at sea be used in roster planning?

Unfortunately, the field trial data did not provide a clear answer to this aim. There was no statistically significant effect of number of consecutive days at sea in the analyses of sleepiness on duty, PVT performance or stress, possibly due to the limited number of participants with each roster/shift pattern. The percentage of shifts with KSS≥7 was relatively stable around 20% for the first four consecutive days and then increased after five consecutive workdays, additionally the share of shifts with prior sleep ≤5h is stable the first 5 days but increases on the 6th day. This might suggest that setting a limit of no more than five or six consecutive workdays may be beneficial for minimising sleep loss and subjective sleepiness. In contrast PVT lapses increased for the first few days but tended to stabilise after 3–4 days so some uncertainty remains. These results should be interpreted with caution since the number of participants decreases with increasing number of consecutive days.

In theory a BMM should be a useful tool for informing shift patterns in any industry (Hursh and Devine, 2023). A BMM uses a mathematical equation to represent sleep need, circadian rhythm and sleep inertia to predict fatigue risk. Models work at a population level, considering average fatigue risk not individual risk. They can predict an accumulative development of fatigue, but they are not able to take into account dynamic and specific work activities which people undertake across their working day. As individual tasks themselves can have an impact on fatigue (e.g. active fatigue and passive fatigue) it is possible that at any given time a person's experienced fatigue does not match the prediction of a BMM (as evidenced in the field trial where experienced KSS does not exactly align with BMM predicted KSS).

The value of BMMs is at a population level, so considering the workforce as a whole, in roster planning would be to support comparisons between different rosters and to assess the impact of planned changes to working patterns. Currently none of the operators represented at the BMM workshop were using BMMs. The workshop participants felt that for a BMM to be effective it would need to take account of:

- Different operating models such as live-on-board and sleep-at-home and the working patterns which typically operate in these situations.
- The impact of weather on sleep and fatigue.
- The demands of particular routes and the impact this has on work intensity.
- The preferences and experiences of the workforce (partly to improve staff morale, but also to be attractive as an employer as there is a considered to be a limited employment pool).

From the use of BMMs in the field trial it is apparent that existing tools do not have the capability to meet these needs. In particular it was found that a limitation with fatigue modelling in maritime operations is that scheduling tools cannot take day-to-day variations in weather conditions into consideration, nor the impact that this has on sailing schedules. The impact adverse weather conditions and rough seas have on fatigue is difficult to incorporate into BMMs.

To increase the usefulness of BMMs for the ferry industry, sleeping conditions should also be taken into consideration to properly account for whether the seafarers are living onboard the vessel or going home after each shift. Aspects like bedding, ambient light and temperature are known to influence mood and sleepiness in seafarers (Matsangas & Shattuck, 2021), in addition to external factors like sea state. The inclusion of a rating of whether the onboard facilities provide good opportunities for sleep could potentially further improve the models' predictions.

Overall, the BMM workshop participants felt that BMMs would only be used if regulations required it. The main motivation of work planning was to deliver the service at minimal cost, within safe operation regulations and in a manner that was attractive enough to maintain staffing. As part of consideration of BMMs being included in regulations there was an expectation that the BMM would also take into account the regulatory constraints for staffing, including the inland waterways limits for ships operating only within UK waters and the IMO limits for those sailing in international waters, as a "one stop shop" facility to meet all needs.

Evaluation of BMM tools for use in ferry operations

FAID Quantum is developed for group-level evaluation of schedules and rosters. The best practise utilising this tool is to address the outcomes as responses from a general population, not to predict the condition of a specific individual. It focusses on the sleep periods consequential to the work periods and is particularly sensitive to sleep pattern disruptions and day-time sleep. Several outcome measures are calculated on a group level to enable evaluation of fatigue exposure of an entire crew. Work shifts with KSS or FAID score below the tolerance thresholds are colour coded. External results such as incidents, accidents or near-misses onboard, employee sick days or other relevant data can be imported which enables tracking of KSS and FAID Score in relation to hours of work and occupational outcomes. SAFTE-FAST has more possibilities for adjustments of an individual's day-to-day schedule in terms of sleep periods and types of activities. Sleep Quality Settings can be configured for sleep at different locations, such as at home, at a hotel (or onboard a vessel) and in a rest facility at work. Summary data on group level are based on the effectiveness score. The share of work shifts with effectiveness scores below a certain threshold (hazard duties) are colour coded by the software. Both tools have the possibility to also take criticality of various job roles into account by providing estimated workload or fatigue hazards for specific roles as an input variable. In FAID Quantum it is possible to apply different tolerance levels for KSS and FAID score for different individuals, to match the fatigue hazard of specific job roles. In SAFTE-FAST, workload can be included as an input variable and critical times during a shift can be defined.

The BMM tools underestimated the number of work shifts with high KSS levels, whereas group-level means of max KSS and sleep durations were estimated to be worse than actual by FAID Quantum and better than actual by SAFTE-FAST. Previous research comparing various BMMs have found that different models have very similar performance, given that they have a common basis in the three process model (Van Dongen, 2004). Van Dongen (2004) tested six BMMs on a set of scenarios and the results suggest that substantial additional development is necessary to create reliable tools for prospective prediction of fatigue and performance across a broad range of circumstances.

Sleep was overestimated by SAFTE-FAST with the current settings. One reason for the difficulties in achieving a good sleep estimation for this sample was the variety in work schedules. If the tool were used for a single operator, it would probably be possible to fine tune the settings for the type of schedules and rosters used by the operator. This would, however, require measurement and comparison of actual sleep in the crew to validate the settings. In this study, split shifts with one longer daytime off-duty period and a relatively short nighttime rest period were most problematic. Similar problems with split shifts were found in a study of rail workers by Riedy et al. (2020). In their study, sleep tended to be underestimated during breaks with split-sleep behaviour, while sleep tended to be overestimated during breaks with consolidated-sleep behaviour. In general, underestimating sleep during a given break resulted in an overestimation of sleepiness predictions during the subsequent shift, and overestimating sleep during a given break resulted in an underestimation of sleepiness predictions during the subsequent shift. Their predicted sleep–wake data demonstrated high overall agreement, sensitivity, and specificity against the actual sleep–wake data at the group-level but there was considerable variation at the individual level.

To summarise, the FAID Quantum tool can be useful to get a quick overview of the fatigue hazard of an entire crew, keeping in mind that predicted peaks in sleepiness might be underestimated. The software is easy to use and provides various visual presentations of fatigue hazards for individual schedules and entire crews. SAFTE-FAST requires more specifications of assumptions, adjustments of settings, and preparations of input variables before use. This implies a higher threshold for starting to use the tool, but it also provides more possibilities to tailor the BMM predictions for a specific operator. Moreover, the desktop version of SAFTE-FAST would be preferable to use for the ferry industry as it allows the users to change and fine-tune the settings themselves. A general conclusion is that BMMs can be useful for an operator to get an overview of fatigue risk in the total crew or for a group of seafarers working a specific roster or schedule, but they cannot be used to predict a specific individual's fatigue risk.

Alternative approaches to fatigue management

The scope of the current research included a strong focus on BMMs, but unfortunately an ideal BMM approach to fatigue management in seafarers was not identified. However, given the fatigue present in the studied population it is vital to continue exploration into how best to manage fatigue in seafaring. Until such time as a robust BMM for use in seafaring is developed, alternative approaches are needed to support fatigue management. For example, it is important to ensure that risk assessment is undertaken for rosters to identify and avoid or at least mitigate working arrangements or patterns which are most likely to increase safety risk due to fatigue.

A qualitative approach such as the use of checklists to highlight optimal shift work practices to promote responsible fatigue management could also be beneficial. Checklists could include elements relevant to seafaring which appear on the HSE fatigue checklist (HSE 2006), such as: avoiding split shifts, allowing two nights of full sleep opportunity as a minimum when switching from day to night shift, and providing guidance on the best times to schedule potentially hazardous work. Further research is needed to determine the most effective approaches to fatigue management in seafaring.

Historically fatigue management has often taken a prescriptive approach whereby set rules are imposed by a regulator around maximum working (hours of service rules) (Sprajcer et al., 2023). While this can be beneficial (particularly in comparison to no fatigue management approach), prescriptive systems do not allow for management of worker fatigue which may occur within the prescriptive envelope (Honn et al., 2019). In recent times risk-based approaches to fatigue management have become more widely used. Fatigue Risk Management Systems (FRMS) seek to understand the specific risks within working operations and empower organisations to address them in the most effective way for their context, rather than imposing set rules on all. The fatigue risk can then be managed irrespective of the hours worked. FRMS includes ongoing monitoring and evaluation of safety data to allow for adaption and development of fatigue management practices (Sprajcer et al., 2023). A BMM would be one tool used within a wider FRMS.

Recommendations

Based on the evidence gathered in this research programme it is possible to draw some conclusions around interventions which may benefit fatigue management in seafaring. However, it is important to note that the recommendations outlined here have not been evaluated and have been informed by work directly focused on fatigue. There may be broader operational issues that would need to be considered when considering if or how to implement these recommendations.

When seeking countermeasures to fatigue it is recommended to first consider what factors are causing fatigue in the specific context (Filtness and Anund, 2023). Factors which can cause and exacerbate fatigue can be broadly divided into sleepiness related fatigue, active task fatigue and passive task fatigue.

Sleepiness is biologically driven; everybody sleeps therefore everybody will experience sleepiness every day. As such there is potential for all seafarers to experience sleepiness at some point (Filtness and Anund, 2023). The feeling of sleepiness is influenced by how much sleep they have previously obtained, how long it has been since they last slept and the body clock (circadian rhythm) (Akerstedt et al., 2008). The specificness of sleepiness means that it can only be counteracted by sleep itself or by influencing biology e.g. with caffeine which is a chemical compound which acts on the brain.

Fatigue is a broader concept with multiple causes. Active fatigue is the experience of being overloaded doing something which is cognitively or physically demanding. Passive fatigue is the experience of being underloaded doing something which is monotonous and makes it difficult to maintain vigilance. Sleepiness can exacerbate both active and passive fatigue. The personal experience of each is often described as tiredness, but to successfully mitigate the experience it is necessary to introduce countermeasures which target the specific cause of the fatigue.

The following recommendations may be beneficial in the context of UK seafaring. They are grouped into similar types but there is no meaning to the order of presentation:

Procedure and training:

- Develop fatigue risk management programmes. This would increase focus on fatigue, highlight that it is a serious issue and promote discussion.
- Provide education consistently across the ferry sector on fatigue management for all. Specific training should also be provided consistently across the ferry sector for those with responsibilities for managing fatigue in others.
- Consider the features of work patterns against checklists of optimal shift work practice.

Working patterns:

- Seek to limit the amount of extra workdays and overtime seafarers can undertake, whilst recognising this might affect seafarers earning potential. This could be through awareness raising in the work force as seafarers can often control the choice of working overtime and extra days. Both factors have been found to increase sleepiness and fatigue, therefore fatigue training could highlight the potential risk factor of additional work and allow seafarers to perform a cost-benefit analysis of salary vs sleepiness. However, it is likely that personal economic drive may override education in deciding to accept overtime or not. A better option might be to educate or encourage employers to take measures to reduce the need for overtime.

- Instigate a screening programme for Obstructive Sleep Apnoea (OSA), and ensure that those with OSA are able to manage it effectively when on board.
- Seek to reduce variability in shift start times.
- Consider options for two full crews to avoid the need to wake a crew member who is sleeping while on rest or to delay the start of an off-duty period.
- Seek solutions to mitigate the impact of and improve recording of dynamic changes to workload. In particular ensure engagement in drills contributes towards work hours and that Hours of Rest records are accurately completed.

Organisational culture and seafarer facilities:

- Seek to influence organisational culture within the sector to focus more on the safety and wellbeing of the seafarers rather than on profit margins.
- Support seafarers in access to communication with their significant social group to ensure they remain connected, as an approach to mitigating the stress experienced from work.
- Seek to minimise factors influencing gender disparity in fatigue, for example, tackling psychological and physical barriers to employment and work tasks.
- Recommend taking seafarers' individual preferences and characteristics into account where possible, e.g. where they have strong preferences for early mornings or late nights (so called 'larks' or 'owls'), this could reduce the risk of sleepiness on duty.
- Seek to support fatigue management in onboard services staff and minimise disparity between experiences of this group and other job roles, for example, rest facilities and after care in the aftermath of incidents.
- Consider controlled napping opportunities (brief, planned naps during break times) as potential countermeasures to fatigue.
- Encourage development of a culture which encourages and normalises reporting of fatigue and enables its impact to be monitored
- Promote the notion that fatigue in seafaring is not inevitable, that it is a safety issue for seafarers and to ensure that it is adequately managed.
- Incentivise operators to invest in employee rest facilities, seeking options to minimise the impact of noise, vibration, other staff and vessel operations on sleep opportunity.

6. Research Strengths, Limitations and Important Knowledge Gaps

Research Strengths

This research is the first of its kind to examine fatigue in a wide range of seafarers operating in UK waters. Within a very limited time window (Nov 2023 – June 2024) substantial data has been collected across five data collection activities. The breadth of data gathered has created a strong foundation for any future in-depth investigations considering fatigue in Ro-Ro and Ro-Pax vessels. The inclusive approach to engagement with the industry presented a range of opportunities for seafarers to engage with the research activities. The research team advocated an open approach engaging with individual workers, unions, operators, Department for Transport and various other stakeholders. This inclusive outlook has created opportunity for as many people as possible to contribute to the collective narrative which represents this industry. A particular novelty of this research is that it is the first to gather direct measurements of sleep and fatigue from the UK ferry workforce, and a wide range of participants were successfully recruited to the field trial. The use of multiple methods within the research has enabled triangulation and increases confidence in the findings. Nevertheless, there are limitations due to the complexity of the ferry industry and the realities of field research.

Operator engagement

Eight of the UK ferry sector's operators took part in at least one element of the research. It is possible that those operators who were most engaged are also those who are already the most committed to managing fatigue. This means that the results may underrepresent the challenges of fatigue management in the UK ferry sector.

Sample size limitations

The response rate to the survey was low (approximately 9%) – this is likely to be due to the known difficulties involved in reaching seafarers. The consequence of the low response rate is that the findings of the survey should be interpreted with caution, in particular, findings related to the prevalence of certain characteristics.

There is very high variability in working patterns across the UK ferry industry. The workforce is split into those who sleep at home and those who live on board. Within these groupings there is substantial variance in the number of hours, days or weeks worked, and shift start and finish times. This can include variations for individuals from one week to the next. This is in addition to variations in job role and the physical and mental demands associated with this.

Inevitably there were limited numbers of participants per roster/schedule combination; as a result participants were grouped to enable analysis. This may account for the lack of significant differences between different working patterns, even where qualitative findings would suggest there might be a difference. Additionally, there are other working patterns in the industry which were not featured in the study sample.

Incomplete data sets

There were a number of gaps in the field study data due to:

- Participants forgetting to complete tasks such as PVT.
- Participants being unable to access the app on occasions; this was presumed (from anecdotal evidence) to be due to poor internet/Wi-Fi access.
- The difficulty of obtaining accurate records of hours worked. Some participants did not know at the outset of the study what hours they would work, others had changes to their hours during the study. Hours of Rest records were requested to compensate, but some participants declined to provide them, and some records were incomplete (e.g. due to participants working on multiple vessels).

Adjustments were made during analysis to compensate for missing data, but this may have reduced the likelihood of finding statistically significant differences between groups.

Language and cultural effects

Ferry operators in the UK draw their employees from many countries. The survey tool was translated into French and Ukrainian to encourage participation, but non-English speakers may still have been less likely to participate due to language barriers. The interviews and focus groups were conducted in English and the study materials for the field trial were not translated which may have limited participation. There may also be cultural factors which can influence the likelihood of participation or willingness to make negative comments.

Reflections on data collection

It was suggested that this population would be 'hard to reach' – in fact they were keen to participate and have their voices heard, and there was no evidence that they were unwilling to speak honestly about their experiences. However, there were logistical challenges. It is essential to have the support of the operator to overcome the logistic challenges of recruiting from this population and facilitating them being able to participate.

Recruitment needs to be carefully planned, because there are limited opportunities when crew are accessible for joining a research study (either between or during sailings). Onboarding takes a long time, especially when there are language challenges and considering the complexity of the data collection.

When considering hours worked, it is essential to ensure that working hours are logged in real time for all participants in addition to collecting detailed records of planned schedules.

Paper sleep diaries might be more satisfactory than online ones. This would reduce the data loss from poor data connection and might also act as a visual reminder to participants to record information each day.

Fitbits were not a satisfactory tool for collecting sleep data as the movement of the ship obscured the sleep/wake changes, therefore additional data processing was required to map sleep/wake times. It was still possible to manually extract sleep durations from the data collected by the Fitbits.

Important knowledge gaps

The presence of fatigue across all job roles in the industry suggests the existing prescriptions within regulations are not sufficient to manage fatigue. Instead, a comprehensive fatigue risk management system (FRMS) is likely to be more beneficial. Likely this would have most benefit if implemented at an industry level, however, the complex nature of maritime operations may make this difficult. Future research should address the knowledge gap around what FRMS approach would be most effective for use in this industry. In particular, effort is needed in accurate risk threshold identification and consideration of whether this should differ between job roles.

Furthermore, the maritime industry has an established hierarchical system, which in many cases is a barrier to open discussions about fatigue, particularly when an incident has occurred. Future research should consider methods for capturing the impact of fatigue on incidents in an open and transparent manner.

As a discipline, Sleep Science is lacking in robust evaluations (e.g. randomised control trials) of countermeasures for fatigue management. As countermeasures to seafarer fatigue are developed it would be beneficial for future research to evaluate these approaches on introduction to evidence their effectiveness (or not) and allow for informed improvements over time.

The findings of the current research are limited to the populations studied, future research may wish to expand the study population to consider different types of seafarers e.g. experienced compared with inexperienced, or to seek to compare between different types of seafaring e.g. including deep sea operations, fishing vessels etc.

7. Acknowledgements

The research team would like to thank the Department for Transport and each of the ferry operating companies and trade unions for their support and cooperation throughout this research, and all of the participants for taking part in this research. We would also like to thank Karl Miller and Evita Papazikou for assistance with data collection, Jiota Nusia and Iaco Kircher for assistance with data processing, the steering board for their input and the advisory board (Nita Shattuck, Michelle Grech and Göran Kecklund) for their guidance during research design. Finally, we would like to thank Göran Kecklund for reviewing and proving valuable feedback on a draft of this final report.

8. References

Abd-El-Salam, E. M., Shawky, A. Y., & El-Nahas, T. (2013). The impact of corporate image and reputation on service quality, customer satisfaction and customer loyalty: testing the mediating role. Case analysis in an international service company. *The Business & Management Review*, 3(2), 177-196.

Abeysiriwardhane, H., Lutzhoft, M. H., & Ghosh, S. (2021). Learning and learning-to-learn by doing: An experiential learning approach for integrating human factors into maritime design education.

Akamangwa, N. (2016). Working for the environment and against safety: How compliance affects health and safety on board ships. *Safety Science*, *87*, 131-143.

Åkerstedt, T., & Folkard, S. (1997). The Three-Process Model of Alertness and Its Extension to Performance, Sleep Latency, and Sleep Length. *Chronobiology International*, *14*(2), 115–123. https://doi-org.vti.idm.oclc.org/10.3109/07420529709001149

Åkerstedt, T., & Gillberg, M. (1990). Subjective and Objective Sleepiness in the Active Individual. *International Journal of Neuroscience*, *52*(1-2), 29-37. https://doi.org/10.3109/00207459008994241

Åkerstedt, T., Anund, A., Axelsson, J., & Kecklund, G. (2014). Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. *Journal of Sleep Research*, *23*, 240–252.

Allen, P., Wardsworth, E., & Smith, A. (2008). Seafarers' fatigue: a review of the recent literature. *International maritime health*, *59*(1-4), 81-92.

Allmer, H. (1996) *Recovery and health: basics, results and measures*. Hogrefe Verlag, Göttingen.

Anund, A., Ihlström, J., Fors, C., Kecklund, G., & Filtness, A. (2016). Factors associated with selfreported driver sleepiness and incidents in city bus drivers. *Industrial health,* 54(4), 337-346.

Assemblée Nationale (2023) LOI n° 2023-659 du 26 juillet 2023 visant à lutter contre le dumping social sur le transmanche et à renforcer la sécurité du transport maritime. Available from https://www.legifrance.gouv.fr/dossierlegislatif/JORFDOLE000047368506/#:~:text=le%20panneau%20lat%C3%A9ral-,LOI%20n%C2%B0%202023%2D659%20du%2026%20juillet%202023%20visant,la%20s%C3%A9curit%C3%A9%20du%20transport%20maritime

ATSB TRANSPORT SAFETY REPORT, 2009 Fatality on board Thor Gitta at sea off Western Australia 21 May 2009 Marine Occurrence Investigation No. 265 MO-2009-004. Available from: https://towmasters.wordpress.com/wp-content/uploads/2009/03/atsb_thorgitta.pdf

Basner, M., & Dinges, D. F. (2011). Maximizing Sensitivity of the Psychomotor Vigilance Test (PVT) to Sleep Loss. *Sleep*, *34*(5), 581-591. https://doi.org/10.1093/sleep/34.5.581

Basner, M., & Rubinstein, J. (2011). Fitness for Duty: A 3-Minute Version of the Psychomotor Vigilance Test Predicts Fatigue-Related Declines in Luggage-Screening Performance. *Journal of Occupational and Environmental Medicine*, *53*(10), 1146-1154. https://doi.org/10.1097/JOM.0b013e31822b8356

The Behavioural Insights Team and Transport Research Laboratory (2023), Understanding seafarer roster patterns and fatigue on vessels, Department for Transport. Available from https://assets.publishing.service.gov.uk/media/65687723cc1ec500138eef95/understanding-seafarer-roster-patterns-and-fatigue-on-vessels.pdf

BIMCO/ICS, Seafarer Workforce Report: The global supply and demand for seafarers in 2021, 2021. https://www.ics-shipping.org/press-release/new-bimco-ics-seafarer-workforce-report-warns-of-serious-potential-officer-shortage/

Cai, A. W., Manousakis, J. E., Lo, T. Y., Horne, J. A., Howard, M. E., & Anderson, C. (2021). I think I'm sleepy, therefore I am – Awareness of sleepiness while driving: A systematic review. *Sleep medicine reviews*, *60*, 101533.

Caldwell, J. A., Caldwell, J. L., Thompson, L. A., & Lieberman, H. R. (2019). Fatigue and its management in the workplace. *Neuroscience & Biobehavioral Reviews*, *96*, 272-289.

Department for Transport (DfT) (2023) *The Seafarers Charter: Detailed Requirements*. Available from https://assets.publishing.service.gov.uk/media/64be251506f78d000d742732/seafarers-charter-details.pdf

de Vries, G., Koeter, M. W., Nieuwenhuijsen, K., Hees, H. L., & Schene, A. H. (2015). Predictors of impaired work functioning in employees with major depression in remission. *Journal of Affective Disorders*, *185*, 180-187.

Dahlgren, A., Kecklund, G., & Åkerstedt, T. (2005). Different levels of work-related stress and the effects on sleep, fatigue and cortisol. *Scandinavian journal of work, environment & health*, 277-285.

Darwent, D., Dawson, D., & Roach, G. D. (2010). Prediction of Probabilistic Sleep Distributions Following Travel Across Multiple Time Zones. *Sleep*, *33*(2), 185-195. https://doi.org/10.1093/sleep/33.2.185

Darwent, D., Dawson, D., & Roach, G. D. (2012). A model of shiftworker sleep/wake behaviour. *Accident Analysis & Prevention*, *45*, 6-10. https://doi.org/https://doi.org/10.1016/j.aap.2011.09.017

Dobie, T. G., & Dobie, T. G. (2019). Motion sickness. *Motion Sickness: A Motion Adaptation Syndrome*, 1-32.

Dohrmann, S. B., & Leppin, A. (2017). Determinants of seafarers' fatigue: a systematic review and quality assessment. *International Archives of Occupational and Environmental Health*, *90*, 13-37.

Drake, C., Roehrs, T., Shambroom, J., & Roth, T. (2013). Caffeine effects on sleep taken 0, 3, or 6 hours before going to bed. *Journal of Clinical Sleep Medicine*, *9*(11), 1195-1200.

Ekstedt, M., Söderström, M., Åkerstedt, T., Nilsson, J., Søndergaard, H. P., & Aleksander, P. (2006). Disturbed sleep and fatigue in occupational burnout. *Scandinavian journal of work, environment & health*, 121-131.

Ellis, N., Allen, P., & Burke, A. (2003). The influence of noise and motion on sleep, mood, and performance of seafarers. *Contemporary ergonomics*, 137-144.

Epstein, M., Söderström, M., Jirwe, M., Tucker, P., & Dahlgren, A. (2020). Sleep and fatigue in newly graduated nurses—Experiences and strategies for handling shiftwork. *Journal of clinical nursing*, *29*(1-2), 184-194.

Filtness, A. J., & Anund, A. (2023). A practical human factors method for developing successful fatigue countermeasures. In *The Handbook of Fatigue Management in Transportation,* pp. 65-78. CRC Press.

Filtness, A. J., Hickman, J. S., Mabry, J. E., Glenn, L., Mao, H., Camden, M., & Hanowski, R. J. (2020). Associations between high caffeine consumption, driving safety indicators, sleep and health behaviours in truck drivers. *Safety Science*, *126*, 104664.

Filtness, A. J., & Naweed, A. (2017). Causes, consequences and countermeasures to driver fatigue in the rail industry: The train driver perspective. *Applied Ergonomics, 60*, 12-21.

Filtness, A. J., Reyner, L. A., & Horne, J. A. (2011). Moderate sleep restriction in treated older male OSA participants: greater impairment during monotonous driving compared with controls. *Sleep medicine*, *12*(9), 838-843.

Folkard, S., Lombardi, D. A., & Spencer, M. B. (2006). Estimating the circadian rhythm in the risk of occupational injuries and accidents. Chronobiology International, *23*(6), 1181– 1192. https://doi.org/10.1080/07420520601096443

Geiger-Brown, J., Trinkoff, A., & Rogers, V. E. (2011). The impact of work schedules, home, and work demands on self-reported sleep in registered nurses. *Journal of occupational and environmental medicine*, *53*(3), 303-307.

Gillen, P. A., Sinclair, M., Kernohan, W. G., Begley, C. M., & Luyben, A. G. (2017). Interventions for prevention of bullying in the workplace. *Cochrane database of systematic reviews*, (1).

Gillet, N., Huyghebaert-Zouaghi, T., Réveillère, C., Colombat, P., & Fouquereau, E. (2020). The effects of job demands on nurses' burnout and presenteeism through sleep quality and relaxation. *Journal of Clinical Nursing*, *29*(3-4), 583-592.

Department of Transport (DFT). (2024). Sea passenger statistics. Available from https://www.gov.uk/government/statistical-data-sets/sea-passenger-statistics-spas

Gregory, K., Hobbs, A., Parke, B., Bathurst, N., Pradhan, S., & Flynn-Evans, E. (2020). An evaluation of fatigue factors in maritime pilot work scheduling. *Chronobiology International*, *37*(9-10), 1495-1501. https://doi.org/10.1080/07420528.2020.1817932

GSR (2021) GSR Professional Guidance Ethical Assurance for Social and Behavioural Research in Government. Available from https://www.gov.uk/government/publications/ethical-assurance-guidance-for-social-research-in-government

Haghayegh, S., Khoshnevis, S., Smolensky, M. H., Diller, K. R., & Castriotta, R. J. (2019). Accuracy of wristband Fitbit models in assessing sleep: systematic review and meta-analysis. *Journal of medical Internet research*, 21(11), e16273.

Hedin, G., Norell-Clarke, A., Hagell, P., Tønnesen, H., Westergren, A., & Garmy, P. (2020). Facilitators and barriers for a good night's sleep among adolescents. *Frontiers in neuroscience*, *14*, 92.

Hilditch, C. J., & McHill, A. W. (2019). Sleep inertia: Current insights. *Nature and Science of Sleep, 11*, 155–165. https://doi.org/10.2147/ nss.S188911.

Hilditch, Cassie J., and Dorothee Fischer (2023) Jet Lag, Sleep Timing, and Sleep Inertia. In *The Handbook of Fatigue Management in Transportation,* pp. 195-213. CRC Press.

Hobbs, Alan & Gregory, Kevin & Parke, Bonny & Pradhan, Sean & Caddick, Zachary & Bathurst, Nicholas & Flynn-Evans, Erin. (2018). San Francisco Bar Pilot Fatigue Study. Available from: https://ntrs.nasa.gov/api/citations/20190002704/downloads/20190002704.pdf

Honkonen, T., Ahola, K., Pertovaara, M., Isometsä, E., Kalimo, R., Nykyri, E., ... & Lönnqvist, J. (2006). The association between burnout and physical illness in the general population—results from the Finnish Health 2000 Study. *Journal of psychosomatic research*, *61*(1), 59-66.

HORIZON (2012). Project Horizon – a wake up call. Available from https://www.slideshare.net/slideshow/final-report-horizon/59632946

Hursh and Devine (2023). Biomathematical Modelling for Fatigue Risk, and its role in fatigue risk management processess. In *The Handbook of Fatigue Management in Transportation,* pp. 287-297. CRC Press.

Hursh, S. R., Balkin, T. J., Miller, J. C., & Eddy, D. R. (2004). The fatigue avoidance scheduling tool: Modeling to minimize the effects of fatigue on cognitive performance. *SAE transactions*, 111-119.

Hystad, S. W., & Eid, J. (2016). Sleep and fatigue among seafarers: the role of environmental stressors, duration at sea and psychological capital. *Safety and health at work*, *7*(4), 363-371.

Härmä, M. (1993). Individual differences in tolerance to shiftwork: a review. *Ergonomics*, *36*(1-3), 101-109. https://doi.org/10.1080/00140139308967860

Hartzler, B. M. (2014). Fatigue on the flight deck: the consequences of sleep loss and the benefits of napping. Accident Analysis & Prevention, 62, 309-318.

Honn, K. A., van Dongen, H. P. A., & Dawson, D. (2019). Working time society consensus statements: Prescriptive rule sets and risk management- based approaches for the management of fatigue- related risk in working time arrangements. *Industrial Health*, 57(2), 264– 280.

Horne, J. A., & Reyner, L. A. (1995). Sleep related vehicle accidents. *British Medical Journal, 310*, 565–567.

Ihlström, J., Kecklund, G., & Anund, A. (2017). Split-shift work in relation to stress, health and psychosocial work factors among bus drivers. *Work*, *56*(4), 531-538.

IMO, 2016. International Convention for the Safety of Life at Sea (SOLAS), 1974. Available from: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx#:~:text=The%20main%20objective%20of%20the,ships%2C%20compatible%20with%20their%20safety.

IMO, Women in Maritime - IMO's Gender Programme, 2021. Available from https://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx

ITF (2024) Fatigue, available from https://www.itfseafarers.org/sites/default/files/paragraph/issues-attachments/files/A4%20-%20Fatigue.pdf

Jakobsson, M., Josefsson, K., & Högberg, K. (2020). Reasons for sleeping difficulties as perceived by adolescents: a content analysis. *Scandinavian journal of caring sciences*, *34*(2), 464-473.

Jensen, H. J., & Oldenburg, M. (2020). Training seafarers to deal with multicultural crew members and stress on board. *International maritime health*, *71*(3), 174-180.

Jiandong, S., Fan, X., & Haitian, L. (2022). How do high-performance work systems affect work fatigue: The mediating effect of job responsibility and role overload. *Plos one*, *17*(7), e0269452.

Kahveci, E. (1999). *Fast turnaround ships and their impact on crews* (p. 11). Cardiff: Seafarers International Research Centre.

Kosmadopoulos, A. (2023) Sleep Pressure and Circadian Rhythms. In *The Handbook of Fatigue Management in Transportation,* pp. 181-193. CRC Press.

Kubala, A. G., Roma, P. G., Jameson, J. T., Sessoms, P. H., Chinoy, E. D., Rosado, L. R., . . . & Markwald, R. R. (2024). Advancing a U.S. navy shipboard infrastructure for sleep monitoring with wearable technology. *Applied Ergonomics*, *117*, 104225. https://doi.org/https://doi.org/10.1016/j.apergo.2024.104225

Knudsen, F. (2009). Paperwork at the service of safety? Workers' reluctance against written procedures exemplified by the concept of 'seamanship'. *Safety science*, *47*(2), 295-303.

Lützhöft, M., Dahlgren, A., Kircher, A., Thorslund, B., & Gillberg, M. (2010). Fatigue at sea in Swedish shipping—a field study. *American journal of industrial medicine*, *53*(7), 733-740.

Ma, Z., Chen, X. Y., Wang, D., Zhu, Z., Niu, H., Huang, S., ... & Fan, F. (2022). Who is the hardest to wake up from sleep? An investigation of self-reported sleep inertia using a latent profile analysis. *Journal of Sleep Research*, *31*(5), e13552.

MAIB (2024) Grounding of roll-on/roll-off passenger ferry Alfred. Available from https://www.gov.uk/maib-reports/grounding-of-roll-on-slash-roll-off-passenger-ferry-alfred

MARTHA 2016, Project Martha – The Final Report. Available from https://www.solent.ac.uk/research-innovation-enterprise/research-at-solent/projects-and-awards/martha

Matsangas, P., & Shattuck, N. L. (2021). Habitability in Berthing Compartments and Well-Being of Sailors Working on U.S. Navy Surface Ships. *Human Factors*, *63*(3), 462-473. https://doi.org/10.1177/0018720820906050

Miller, K. A., Filtness, A. J., Anund, A., Maynard, S. E., & Pilkington-Cheney, F. (2020). Contributory factors to sleepiness amongst London bus drivers. *Transportation research part F: traffic psychology and behaviour*, *73*, 415-424.

Mullaney, D. J., Kripke, D. F., & Messin, S. (1980). Wrist-actigraphic estimation of sleep time. Sleep, 3(1), 83-92.

Narayanan, S. C., Emad, G. R., & Fei, J. (2023). Key factors impacting women seafarers' participation in the evolving workplace: A qualitative exploration. *Marine Policy*, *148*, 105407.

Nehlig, A. (2018). Interindividual differences in caffeine metabolism and factors driving caffeine consumption. *Pharmacological reviews*, *70*(2), 384-411.

Oldenburg, M., & Jensen, H. J. (2019). Needs and possibilities for ship's crews at high seas to communicate with their home. *International Journal of Occupational Medicine and Environmental Health*, *32*(6), 805-815.

Oldenburg, M., Jensen, H. J., Latza, U., & Baur, X. (2009). Seafaring stressors aboard merchant and passenger ships. *International journal of public health*, *54*, 96-105.

Pilkington-Cheney, F. (2023). Individual Countermeasures to Fatigue. In *The Handbook of Fatigue Management in Transportation*, pp. 341-350. CRC Press.

Pilkington-Cheney, F., Filtness, A. J., & Haslam C. (2020). A qualitative study exploring how city bus drivers manage sleepiness and fatigue. *Chronobiology International, 37*(9–10), 1502–1512.

Pineiro, L. C., & Kitada, M. (2020). Sexual harassment and women seafarers: The role of laws and policies to ensure occupational safety & health. *Marine Policy*, *117*, 103938.

Reyner, L. A., & Horne, J. A. (1998). Evaluation of 'in-car' countermeasures to sleepiness: Cold air and radio. *Sleep*, *21*(1), 46–51

Riedy, S. M., Roach, G. D., & Dawson, D. (2020). Sleep–wake behaviors exhibited by shift workers in normal operations and predicted by a biomathematical model of fatigue. SLEEP, 43(9)

Roach, G. D., Reid, K. J., & Dawson, D. (2003). The amount of sleep obtained by locomotive engineers: Effects of break duration and time of break onset. *Occupational and Environmental Medicine*, *60*(12), e17. https://doi.org/10.1136/oem.60.12.e17

Rose, D. M., Seidler, A., Nübling, M., Latza, U., Brähler, E., Klein, E. M., ... & Beutel, M. E. (2017). Associations of fatigue to work-related stress, mental and physical health in an employed community sample. BMC psychiatry, *17*, 1-8.

RSSB. (2021b) Fitness for Duty Decision Aids (T1130). RSSB. Available from: www.sparkrail.org/Lists/Reco rds/DispForm.aspx?ID=27314

Sallinen, M., & Kecklund, G. (2023) Measuring operator fatigue and sleepiness. In *The Handbook of Fatigue Management in Transportation,* pp. 25-39. CRC Press.

Schwarz, J. F. A., Ingre, M., Fors, C., Anund, A., Kecklund, G., Taillard, J., Philip, P., & Åkerstedt, T. (2012). In-car countermeasures open window and music revisited on the real road: Popular but hardly effective against driver sleepiness. *Journal of Sleep Research, 21*(5), 595–599.

Shattuck, N.L., Lawrence-Sidebottom, D., Matsangas, P. and Nicholson, M., Awakening to the challenge of fatigue management in Maritime Transportation. In *The Handbook of Fatigue Management in Transportation* (pp. 111-123). CRC Press.

Sonnentag, S., & Zijlstra, F. R. (2006). Job characteristics and off-job activities as predictors of need for recovery, well-being, and fatigue. *Journal of applied psychology*, *91*(2), 330.

Sprajcer, M., Thomas, M. J., & Dawson, D. (2023). Approaches to Fatigue Management: Where We Are and Where We're Going. *In The Handbook of Fatigue Management in Transportation* (pp. 259-271). CRC Press.

Stannard, S., Vaughan, C., Swift, O., Robinson, G., Altaf, S. A., & McGarry, A. (2015). Women seafarers' health and welfare survey. *International maritime health*, *66*(3), 123-138.

Tregear, S., Reston, J., Schoelles, K. & Phillips, B. (2009) Obstructive sleep apnoea and risk of motor vehicle crash: Systematic review and meta-analysis, Journal of Clinical Sleep Medicine, *5*(6), 573-581.

Thomas, M. (2004). ‘Get yourself a proper job girlie!’: recruitment, retention and women seafarers. *Maritime Policy & Management*, *31*(4), 309-318.

Van Dongen, H. (2004). Comparison of mathematical model predictions to experimental data of fatigue and performance. Aviation, space, and environmental medicine, 75(3), A15-A36.)

van Leeuwen, W. M. A., Pekcan, C., Barnett, M., & Kecklund, G. (2021). Mathematical modelling of sleep and sleepiness under various watch keeping schedules in the maritime industry. *Marine Policy*, *130*, 104277. https://doi.org/https://doi.org/10.1016/j.marpol.2020.104277

Veasey, S. C., & Rosen, I. M. (2019). Obstructive sleep apnea in adults. *New England Journal of Medicine*, *380*(15), 1442-1449.

Wadsworth, E. J., Allen, P. H., McNamara, R. L., & Smith, A. P. (2008). Fatigue and health in a seafaring population. *Occupational medicine*, *58*(3), 198-204.

Wadsworth, E. J., Allen, P. H., Wellens, B. T., McNamara, R. L., & Smith, A. P. (2006). Patterns of fatigue among seafarers during a tour of duty. *American Journal of Industrial Medicine*, *49*(10), 836-844.

Wikoff, D., Welsh, B. T., Henderson, R., Brorby, G. P., Britt, J., Myers, E., ... & Doepker, C. (2017). Systematic review of the potential adverse effects of caffeine consumption in healthy adults, pregnant women, adolescents, and children. *Food and chemical toxicology*, 109, 585-648.

Williamson, A. (2007). Fatigue and coping with driver distraction. In: I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter & J.D. Irwin (Eds.). *Distracted Driving* (611-622). Sydney, NSW: Australasian College of Road Safety

9. Annexes

Annex A: Detailed methodology descriptions

Biomathematical Model (BMM) workshop

Background - Introduction to Biomathematical Modelling (BMMs)

Biomathematical modelling is used to predict fatigue levels of individuals, or of work schedules, based on an understanding of the key factors which contribute to fatigue. A range of models are available, each with different approaches and assumptions. BMMs have been used particularly in rail and aviation industries as well as in manufacturing contexts, construction, and the military. They have been used only occasionally in maritime: for example in a research context to assess the work/rest of shipping pilots, and in one case to evaluate whether fatigue might have been a factor in a fatal shipping accident.

The most common theory which has been used to develop BMMs is the **two-process model of alertness**, which explains that the timing and duration of sleep is an interaction between two processes, Process S and Process C.

- *Process S* (sleep) – increased time without sleep or sleep loss increases pressure to sleep
- *Process C* (circadian) - refers to the pattern of our circadian rhythms, which programmes sleep to occur during the night (with increased sleepiness between 2am-6am and between 2pm-4pm). The pattern runs on a near 24h cycle, but is influenced by external factors, such as the light/dark cycle of the local environment. This process runs independently from Process S, or time since last sleep, and is affected by irregular work patterns such as shift work or night work.

The **three-process model** of alertness includes a third factor, Process W (waking), relating to sleep inertia, and predicts level of alertness. Sleep inertia refers to the lowered alertness and decreased performance which occurs immediately after waking.

For most models, the user inputs information such as work schedule or prior sleep timings into a software programme, which then produces outputs associated with fatigue risk, alertness, and/or sleepiness.

Background - Limitations of BMMs

In general, the makers of BMMs advertise them as being an effective tool for use within a comprehensive fatigue risk management system, but it is recommended that they are not used in isolation. There are several limitations of biomathematical modelling overall, which are highlighted below:

- BMMs predict ‘potential’ fatigue and may not consider individual factors such as age, lifestyle, and family life.
- As the outputs are predictions, there is an element of probability within scores.
- Outputs could potentially over or understate fatigue, depending on input, with most models not taking account of chronic fatigue effects.

- The models also focus on ‘fatigue’ rather than performance, with the relationship between fatigue and performance varying depending on type of task.
- Roster patterns or shift options usually need to be compared within the model to assess the lowest fatigue option.
- Although most of the models account for the circadian factor of day and night, they may not account for shift workers working rotating shifts with reduced access to natural light over an extended period.
- Many models rely on the user (e.g. employer) to set a threshold or fatigue risk level i.e. to decide what level of fatigue they consider acceptable.
- Overall, as most of the models have been validated with or are used within shift work populations, there is some applicability to the seafaring industry. However, to date, there is limited use of the models within this specific industry.

Background - Commercially available Biomathematical models

Table 18 summarises four commercially available models:

The HSE Fatigue and Risk Index (HSE FRI)

- Fatigue Assessment Tool by InterDynamics (FAID)
- Sleep, Activity, Fatigue, and Task Effectiveness model and Fatigue Avoidance Scheduling Tool (SAFTE-FAST)
- Sleep / Wake Predictor (SWP)

Table 18: Biomathematical model comparison table

Model	Pop'n aimed at/used for development	Theory	Inputs	Outputs	Disadvantages
HSE FRI	Aircraft personnel, rail workers, industrial shift workers	Based on risk of a 2Day 2Night 4off schedule with 12h shifts	- Work schedule - Time of day - Rest Periods - Breaks	- Fatigue Index, 0-100, chance of fatigue during duty (based on KSS). - Risk Index, relative risk of making an error, which could lead to accident	- Predictions based on population averages - Not suitable for building rosters - Provides an indication of expected risk
FAID Quantum	Validated in field studies with shift workers in the rail industry, FAID Quantum validated with aviation data	Two-process model of alertness. Assumes fatigue is related to work length: the longer the work length, the greater the fatigue	- Work schedule - 'Tolerance levels' and 'target compliance percentage' - FAID Quantum can incorporate sleep/wake data	- FAID score, increases as sleep opportunity decreases - Apparent Fatigue Tolerance Level = 98% historical work hours below score Karolinska Sleepiness Scale (KSS) score [16]	- Predictions based on population averages - Cost - Requires a history of 7days or 168h - Provides an indication of expected risk - May not consider commute lengths

[16] The KSS is a 9-point scale measuring feelings of sleepiness, ranging from 1 = very alert, to 9 = very sleepy, fighting sleep. It has been used extensively within sleep research and has been correlated to brain wave output and several performance measures.

Model	Pop'n aimed at/used for development	Theory	Inputs	Outputs	Disadvantages
SAFTE-FAST	Designed for use in industrial settings and with shift workers, aviation and aircraft personnel	Two-process model of alertness, fatigue is related to 'cognitive effectiveness'	-Work schedule - Sleep timing - Multiple sectors/duties - Several aviation specific inputs	- 'Cognitive effectiveness' score 0-100, ≤ 70 associated with an increased relative accident risk % change in performance	- Predictions based on population averages - Additional features specific for aviation - Cost - Provides an indication of expected risk - Auto sleep may not consider commute lengths
SWP	Shift workers. Used within several industries including rail, aviation, navy, trucking, nuclear power, and military	Three-process model of alertness	- Work schedule - Sleep timings - Time of day - Commuting - Chronotype ('lark' or 'owl')	- Predicted alertness curve or Karolinska Sleepiness Scale - Percentage of time where sleepiness levels above the critical level, risk of fatigue	- Predictions based on population averages - Not suitable for large scale roster development - Provides an indication of expected risk - Predicted sleep may not account for differences in commute length

Participants

Recruitment to the BMM workshop was achieved through DfT. Eight operators were invited to nominate someone with experience of shift and roster planning. Six operators were able to provide someone who had suitable experience who was available on the day set for the workshop.

Procedure

Participants attended a two-hour face-to-face workshop in January 2024. The workshop was conducted by a Professor of Transport Human Factors and Sleep Science, supported by other members of the research team. The workshop was audio recorded and later transcribed, with the consent of all participants. Assurances were given that all data would be anonymised and the confidentiality of operators and participants would be protected.

The aims of the workshop were:

- To understand how rosters and shift patterns are designed/chosen in seafaring
- To explore if/how biomathematical models (BMMs) are used in seafaring
- To discuss how BMMs could be used in seafaring, and what they would need to include

Participants were given information to read in advance about BMMs. This included general information about the theory and design of BMMs, and detailed descriptions of four commonly used models. Additional information provided during the workshop included:

- An explanation of how sleep and fatigue are typically defined
- A summary of previous fatigue research in maritime (MARTHA and Horizon)
- An explanation of the two and three process models of level of alertness (Process S, process C and Process W)
- Further details about what BMMs are, how they have been used and their limitations
- Examples of the outputs from BMMs and explanation of measures including the Karolinska Sleepiness scale.

The specific topics discussed at the workshop were:

Current roster planning

- How are the MLC convention rules translated into roster and shift patterns?
- How is a decision made on the number and type of crew needed?
- How are working hours evaluated?
    - Compliance with the rules
    - Impact of the chosen patterns

The ideal biomathematical model

- Expectations from the industry
- Beneficial features

If you were told that a BMM is being used to plan shift patterns in your organisation what would you expect it is able to do and what benefits would you expect?

Existing BMM models

- How helpful would models be in maritime?
- What did you like/what didn't you like about the different models?
- What is missing, what don't they do? How helpful are the outputs?
- What are the benefits to using models in this industry?

- What are the challenges?

Survey

Design

The survey contained 122 questions. The core questions were translated from previous surveys of Swedish bus drivers (Anund et al., 2016) and London bus drivers (Miller et al., 2020). Most questions were multiple choice or required a response on a Likert scale.

Additional questions were added which arose from the prior knowledge and expertise of the researchers, as well as the responses from initial scoping on board a ferry The survey was split into six sections: (1) questions about your work as a seafarer, (2) questions about your work patterns and arrangements, (3) questions about your sleep, (4) questions relating to yourself as a seafarer, (5) questions about your health (6) background questions.

Section 1 contained questions relating to respondents' work as a seafarer, including length of service, working hours and shift patterns. Section 2 focused on seafarers' work patterns and arrangements. As seafarers sleep onboard or at home, this section was split to accommodate both types of seafarers' sleeping arrangements. Some the questions were included in both sections e.g. type of roster patterns, how many breaks were seafarers allowed to have and shift length and patterns. Seafarers who go home were asked about their daily commute whereas seafarers who sleep on board were asked about their commute when they go off duty. Section 3 asked about work satisfaction, work patterns and work performance.

Section 4 contained questions about seafarers' sleep, with questions relating to sleep quality, sleep disorders, and the amount of sleep obtained before shifts. Within Section 4, seafarers were also presented with 20 statements related to sleep and were asked to ‘‘indicate the degree to which the following have happened to you during the last 3 months". Seafarers responded to each statement with one of six options ranging from ‘‘never" to ‘‘always (5 or more times a week)". Responses to these statements were used to create five sleep indexes. All indices (apart from the fatigue index) were part of the Karolinska Sleep Questionnaire (KSQ) and were previously used by Anund et al. (2016). The indices consisted of the following items:

- **Sleep quality index**: difficulty falling sleep, repeated waking, disturbed, or worried sleep
- **Sleepiness index**: fighting to stay awake throughout the day
- **Fatigue index**: physical fatigue, mental fatigue
- **Impaired waking index**: difficulty in waking up
- **Suspected sleep apnoea index**: snoring, difficulty catching your breath whilst sleeping, interrupted breathing during sleep
- **Disturbed Sleep index:** Sleep being disturbed by the movement of the ship, Sleep being disturbed by vibration, Sleep being disturbed by noise, Sleep being disturbed by being too hot or too cold, Sleep being affected by anxiety about family, Tiredness being influenced by a change in time zones
- **Cabin Index:** Sleep being disturbed by a colleague you share your cabin with, Cabins on board are unsuitable for sleeping, Sleep being affected by the comfort of the bed, Sleep being affected by the cleanliness of the cabin

Alongside the sleep indices section 4 also included questions relating to how sleepy seafarers felt while working, what time of their shift did seafarers feel sleepy, whether seafarers could stop working or not due to feeling fatigued fatigue. Finally, there were questions about the occurrence of sleep related incidents in the past 12 months. Questions in Section 5 related to seafarers' health and concerned general health, smoking, exercise, and stress. Finally, section 6 contained basic demographic questions. Response times showed that the survey took an average of 40 min to complete.

Participants

The survey was open to all seafarers working for any of the 10 operators within the United Kingdom who received the survey link to share (excluding Scotland), regardless of how long they had been working as a seafarer, or whether they worked as a seafarer full time or part time.

Procedure

The primary distribution of the survey to seafarers was through Department for Transport (DfT) who contacted each of the 10 individual operating companies who registered their interest in supporting this research and asked if they would promote the survey to seafarers within their company. They were provided with several resources to do so. These resources included the survey URL to be shared with seafarers and posters containing a QR code linking to the online survey. Emails were also sent to the operators which they could forward directly to seafarers containing the online survey URL. A PowerPoint Presentation with QR codes and survey links were also used when the researchers had an opportunity for a face-to-face meeting with the seafarers for a select number of operators taking part in other studies within the research study. A self-selection sampling method was used in which all seafarers were eligible to participate and could choose to do so through the various promotional methods. Although, the survey was promoted to all operators, there was variability in uptake between seafarers employed by different operators.

Analysis

Descriptive statistics were used to examine background factors, the frequency of whether seafarers fight sleepiness well as the occurrence of sleep related incidents (such as crashes and near misses) amongst seafarers. To examine which factors contributed to seafarer sleepiness three outcome variables were used to assign respondents to one of two groups.

Firstly, respondents were split into those who had to fight sleepiness at least 2–3 times a week (n = 122) and those who did not (n = 324). The second outcome was those who had experienced a sleep-related incident in the last 10 years (*n* = 184), and those who had not (*n* = 261). The third outcome was whether respondents had experienced a sleep-related incident within the last 12 months (n= 26) or not (n= 420).

For all outcomes, two stage regression methods were used. For the first stage, a series of univariate logistic regressions were used to determine which individual factors best predicted whether or not respondents had to fight sleepiness often, and whether or not they had encountered a sleep-related incident in the last 10 years and finally, whether or not they experienced a sleep-related incident in the last 12 months. These factors were related to sleep, work, health, or demographic information. For the second stage, any univariate predictors with a significant odds ratio ($p < .05$) were entered as predictors into a multivariate logistic regression using the stepwise method. All statistical analyses were conducted using IBM SPSS 23.0 statistical software. The alpha criterion was set to 0.05.

Field trial

FAID Quantum

FAID Quantum uses work schedule as input to predict the level of fatigue and performance, considering the time of day and the length of the work periods, as well as the number time zones crossed (although that feature has not been applicable for this study). The input information was participant-ID and start/finish dates and times of the working shifts. FAID Quantum uses the work schedule input to estimate a sleep/wake-schedule. The FAID Quantum tool does not consider any individual factors, such as sleeping conditions or the quality of sleep, in the predicted sleep output. Based on the predicted sleep periods, the FAID Quantum predicts the KSS scores by implementing the 'Three Process Model' of fatigue (Åkerstedt & Folkard, 1997), excluding the model's sleep inertia component. The predicted KSS scores can be exported with one hour resolution, both during work, as well as the hours between the working shifts. The level of KSS fatigue exposure during work is being estimated by comparing the estimated KSS score against a KSS Tolerance Level (KTL) of choice. In the FAID Quantum analyses, default settings were used and the tolerance threshold was set at KSS 7.0.

FAID Quantum uses the following assumptions. Commute time of 45 minutes is assumed before and after a working shift. Hence, this time was not included to be part of the recovery time. Breaks shorter than 4 hours within and between duty periods are not considered as non-working time. That is, the tool does not incorporate rests within shifts and the start of a new work shift requires a minimum of 4 hours of rest after the prior. The default setting for Sleep Buffer was set to 1 hour post work. Sleep buffer specifies how soon an individual can start sleeping after the end of a work shift. The Sleep Buffer-time can be changed in the settings. The FAID score considers a rolling 7-day history in the analysis. However, as mentioned above, FAID score was not evaluated in this study.

SAFTE-FAST

A web-based version of SAFTE-FAST was used for the analyses. This tool does not have all features of the desktop version but includes the main features needed for evaluation of work schedules. The input variables were participant-ID, start/finish dates and times of the working shifts, event type, and location of work. Sleep periods (Auto Sleep) were estimated from the work schedule input and from assumptions made by the model.

SAFTE-FAST analyses were done with the following assumptions. Commute time was set to 45 min before and after each shift. Sleep periods are only inserted if the break between shifts is longer than 4 hours (interim release). An awake zone was defined between 3 pm to 7 pm where Auto Sleep is normally not added. Sleep quality was set to Good for sleep on interim releases and Excellent for the main sleep periods. Excellent sleep assumes no interruptions in sleep from environmental disturbances. Good sleep averages two 5-minute interruptions per hour resulting in 50 minutes of restorative sleep per hour or 83% of excellent. The event type was set to ‘crewing’, meaning actual work activity, for all shifts. Location of work was set to London to account for local light conditions.

Statistical analyses

Separate ANOVAs were used to model each outcome variable as a function of sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively. The variable Participant was included as a random nested factor to account for inter-individual variations, and number of consecutive working days was treated as a continuous variable. The outcome variables were sleep duration, sleep quality, KSS, PVT reaction time, PVT lapses, and perceived stress. The factor participant was included to control for individual differences, which are very common in sleep data. As expected, all variables showed significant individual variability. It should also be noted that the number of data points decrease with the number of consecutive working days since more participants worked fewer days in a row.

In addition, logistic regression analyses were performed to investigate which work factors were related to reaching KSS≥7, subjective stress levels ≥7, and 3 or more PVT lapses, during a work shift. Separate analyses were performed with the factors sleep location, number of consecutive working days, job role, schedule type, and roster type as covariates and KSS threshold (KSS≥7 or KSS<7) as the dependent variable. Captain/Master was chosen as the reference level for job roles, 5 days per week for schedule types, and 12 h on 12 h off day for roster type. Captains were set as the reference since they were shown to suffer worse than other crew from fatigue in the MARTHA project (2016). Five days per week and 12h on 12h off day were selected since those schedules/rosters are most similar to ‘normal’ work schedules/rosters. The thresholds KSS≥7 and number of PVT lapses≥3 were chosen based on previous research. Both performance-based indicators and physiological indicators of sleepiness starts to increase exponentially at KSS≥7 (Åkerstedt et al., 2014), while 10 lapses on a 10-minute PVT test separates sleep-deprived from non-sleep deprived participants (Basner & Dinges, 2011). Since a shorter 3-minute PVT test was used here, the threshold was adapted to the shorter test time.

Comparisons between BMM predicted sleep and KSS levels and actual sleep and reported KSS from the diaries were completed with linear regression and correlation analyses. Differences between subgroups of participants in background characteristics and work details derived from the entry questionnaire were analysed with chi-square tests, one-way ANOVA and t-test, when applicable.

Statistical analyses were conducted using IBM SPSS statistical software version 29.0 and MATLAB 2024A. The alpha criterion was set to 0.05 and Bonferroni correction was used to compensate for multiple comparisons. Separate analyses were done partly due to the limited amount of data per participant, the limited number of participants per work category, and collinearity and nested relationships between several work factors.

Annex B: Data collection tools

Survey– questionnaire introduction

The question list is shown, together with the results, in section 0

Welcome and thank you for considering taking part in this online survey

Researchers at Loughborough University are running this survey as part of a project funded by the Department for Transport (DfT) in the UK. Before you decide to take part, we want to explain why the research is being done and what it involves. Please contact one of the researchers using the contact details below if you have any questions.

The project is considering seafarers' experiences of fatigue. As defined by the International Maritime Organisation (IMO), fatigue is "a state of feeling tired, weary, or sleepy that results from prolonged mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep". We want to find out what might increase tiredness, and to understand the consequences of fatigue for people in different jobs. We also want to know about measures used on Ro-Ro and Ro-Pax vessels to prevent an accident caused, partially or wholly, by seafarer fatigue. The findings from this research, including the survey, may be published on Gov.UK and may also be published in academic journals.

You will be asked to complete an anonymous online survey, which should take approximately 20 minutes to complete. Please complete this survey based on your own current state. You do not need to do anything before completing the survey. This is a low-risk activity and no disadvantages or risks have been identified if you decide to participate.

You must only complete the survey if you are currently employed as a seafarer, or have previously worked as a seafarer (within the last five years). You must also be over the age of 18 years and have the capacity to fully understand and consent to this research.

If you finish the survey, you will be able to enter a prize draw to win one of 10 payments of £50. Prizes will be paid by bank transfer so your bank account does not need to be a UK one. We will ask for your contact details so that we can let you know if you win. Your contact details will be stored separately from your survey answers, and it will not be possible to link your contact details to the survey. Terms and conditions for the prize draw can be found here.

Loughborough University will be using your information/data to undertake this research and will act as the data processor for the study. This means that the University is responsible for looking after your information and using it properly. All information will be securely stored on the University computer systems. Having commissioned the study, the data controller will be the DfT. Excluding your contact details for the prize draw (which will not be linked to the survey data) no identifiable personal information will be collected and so your participation in the study will be confidential.

No individual will be identifiable in any report, presentation, or publication.

After you have read this information, if you are happy to participate please read the consent page (on the Next page) and confirm your consent by checking the tick box at the bottom of the page. You can withdraw from the survey at any time by closing the browser. If you wish to withdraw your data from the survey after submitting your responses, you can do this by emailing a member of the research team with your response ID shown at the end of the survey. However, after the survey closes your responses will be fully anonymised so it will not be possible to remove your data from the study.

If you have any questions about this survey, please feel free to contact a member of the research team:

Ashleigh Filtness, a.j.filtness@lboro.ac.uk

Sally Maynard, s.e.maynard@lboro.ac.uk

Wendy Jones w.jones2@lboro.ac.uk

Adam Asmal a.a.asmal@lboro.ac.uk

Loughborough University Accessibility Statement

Jisc Online Surveys Accessibility Statement

What if I am not happy with how the research was conducted?

If you are not happy with how the research was conducted, please contact the Secretary of the Ethics Review Sub-Committee, Research & Innovation Office, Hazlerigg Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU.

Tel: 01509 222423. Email: researchpolicy@lboro.ac.uk

The University also has policies relating to Research Misconduct and Whistle Blowing which are available online at https://www.lboro.ac.uk/internal/research-ethics-integrity/research-integrity/

If you require any further information regarding the General Data Protection Regulations, please see: https://www.lboro.ac.uk/privacy/research-privacy/

Interviews – Question Guide

<u>Introductory Question</u>

- What brought you to this role?
- What does your job entail?
- How long have you been doing your current role?
- If I say 'fatigue', what do you think about?

[DEFINITION: a psychological and/or physical impairment experienced by a seafarer which has the potential to reduce best performance. Fatigue is multifaceted, encompassing pressures from both the sleepiness related to human biology and task related fatigue. So it may be:

  - Sleepiness due to insufficient sleep and/or time of day
  - Task related fatigue due to the nature of work on board the vessel resulting in an inability to continue or impairment in performance caused by
  - Time on task due to the same activity going on too long.
  - Overload of cognitive demands during times of exposure to demanding workload.
  - Underload of cognitive demands during times of monotonous activity.
  - Physical muscle fatigue due to physical exertion, for example raising the anchor.]

What is the interviewee's view of the prevalence of fatigue and sleepiness among ferry crews?

- What is the general culture around fatigue in your organisation?
- What do you believe the industry is doing well in the management of fatigue/sleepiness?
- What do you believe the industry is doing poorly in the management of fatigue/sleepiness?

Managing sleepiness at work in others

- What do people do if they feel too tired to work?

Focus Groups – Discussion Guide

Introduction

Welcome, and thank you for joining us. Allow us to introduce X and X and explain Loughborough's role in this project. Provide an overview of the project.

We will be having an informal discussion about your experiences with fatigue and how it is managed at work. Your feedback is crucial for improving fatigue management in the industry, so please do not hesitate to share your thoughts and be honest. It's important that we communicate with each other and share our experiences. We are here to observe and learn from you, as you are the experts.

All information you provide will be kept confidential, and no individuals will be identified in any reports.

Can we audio record the discussion?

Introductory Question

Before we go into specific fatigue questions, we'd just like to learn a little bit about you and your backgrounds, whatever you're prepared to share. We are interested in what brought you to into seafaring, how long you've been in the industry and what shift pattern are you working?

Does fatigue occur, is it a problem

If I say 'fatigue', what do you think about?

[Project definition: a psychological and/or physical impairment experienced by a person that can potentially reduce optimal performance. Fatigue is multifaceted, encompassing pressures from both the sleepiness related to human biology and task-related fatigue.

Fatigue can be caused by various factors for seafarers, including:

- Insufficient sleep and the time of day
- The nature of their work resulted in task-related fatigue and impairment in performance
- Physical exertion, such as directing vehicles onto a car deck, leading to muscle fatigue
- Cognitive demands could lead to overload during times of exposure to demanding workload or underload during monotonous activity.]

Focus group main questions
• Probing participants' experiences of causes of, and consequences of, their fatigue experience at work. This will consider both standard experience and experience during emergencies. Consideration will be given to different stages of a voyage.

Understanding fatigue in workplace culture and personal experiences

- Do you think sleepiness or fatigue is a problem in your industry?
- What do you think are the main reasons people feel tired at work? Maybe thinking about it in relation to your job.
- Have you ever experienced fatigue at work? Can you share a situation where you or someone you know felt tired at work?
- Can you give examples of situations that commonly lead to fatigue during your work routine?
- What would you do if you felt fatigued or sleepy at work?
- How would you talk to your employer about it if you were tired at work? What kind of response would you expect?
- Have you received any training or advice on how to handle fatigue? If not, would you like some? What topics would you like it to cover?

Exploring the Impact of Shift Work on Fatigue

- Do you feel more tired when you have to work the same shifts every day or when you have the option to swap shifts with your colleagues?
- How much notice do you get for shift patterns and holiday allocation?
- How do external factors, such as environmental conditions or external pressures, contribute to your fatigue? How might these factors vary across different work stages?
- Do you feel more fatigued or sleepy based on how you spend your time outside of work, including your commute?
- How do you unwind and relax at the end of a work day?

Exploring the Impact of Fatigue in Daily Work and in High-Pressure Situations

- Do different stages of a voyage impact your fatigue levels? Are there specific stages that you find more challenging?
- How does the nature of your work tasks influence your experiences of fatigue? Are there particular tasks that you find more demanding in this regard?
- How do people cope with fatigue at various stages of a voyage? Are there strategies or interventions that you consider particularly effective, like sleeping before shifts or drinking coffee to remain alert?

- Do you have any responsibilities when faced with a high-pressure emergency situations on the vessel?
- Can you describe any previous experiences with high-pressure emergencies on the vessel and how you managed them?
- How do you think tiredness affects workers in regular work settings compared to high-pressure emergency situations?
- What training or certifications do you possess that prepare you for dealing with high-pressure situations on the vessel?
- Are there any general issues within the organisation that may exacerbate fatigue, and do you believe these issues become more pronounced during emergencies or specific voyage stages?

Closing
• Any other comments/questions? • Thanks

Field trial – questionnaires

Onboarding questionnaire

Field trial participants were required to answer a questionnaire at the beginning of their period of study; it was provided online using JISC Online Surveys v3. The questionnaire was a subset of the questions asked in the main survey. An additional section relating to alcohol consumption was added for the onboarding questionnaire. The section consisted of two questions, as follows: “How often do you have a drink containing alcohol?” and “How many drinks containing alcohol do you have on a typical day when you are drinking?”

In addition, the questions which make up the Epworth Sleepiness Scale (ESS) were added to the onboarding questionnaire.

The introductory text was as follows:

Welcome and thank you for considering taking part in this research

Researchers at Loughborough University are running this study as part of a project funded by the Department for Transport (DfT) in the UK.

The project is considering seafarers’ experiences of fatigue. As defined by the International Maritime Organisation (IMO), fatigue is "a state of feeling tired, weary, or sleepy that results from prolonged mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep". We want to find out what might increase tiredness, and to understand the consequences of fatigue for people in different jobs. We also want to know about measures used on Ro-Ro and Ro-Pax vessels to prevent an accident caused, partially or wholly, by seafarer fatigue. The findings from this research, including the survey, may be published on Gov.UK and may also be published in academic journals.

Before you begin your participation you will be given an information sheet and further instructions by one of our researchers. We will also ask you to complete an informed consent form. Please speak to one of the researchers if you have any questions.

Exit questionnaire

The exit questionnaire was provided online using JISC Online Surveys v3. The questionnaire thanked participants for their participation in the study and requested their bank details so that their payments could be made. It also included details of how participants preferred to return their FitBit.

Annex C: Coding structures

Coding structure for BMM workshop

Main code or theme	Sub code(s)	Lower level code(s)
Current use of BMMs	FM plans	
Factors in roster design	Accident and fatigue risk	Acceptance of fatigue risk
		Employee responsibility in managing fatigue
		Lack of evidence that fatigue causes accidents
		Shift patterns are not evaluated for fatigue impact
		We think we are doing enough
	Dynamic changes	
	Employee choices around shift and rosters	Age and experience affect preference
		Change avoidance
		Employees don't always make good decisions
		Groups of employees
		Individual Employee choice
		Longer shifts fewer days
		Shorter periods of travel
		Social factors
		Unions
		You have to appeal to the workforce
	Importance of commercial and Financial factors	
	Nature of route including ports, timings etc	24 hour working
		How many sailings
		Visiting ports
	Policies and internal rules	Rosters do not change often
		Staggered changeovers
		We are better than legal minimum
	Regulations	Compliance with the law is key driver
		Limitation of regulations
		Muster list requirement
		Working time regulations
Why BMMs are problematic	Breaks and work intensity: work isn't all the same	
	Dynamic change to shifts	
	Individual variation	New to the role
	Limitations and challenges of BMMs in maritime	Conflict with commercial and regulatory factors

		Different models of operation
		Help us, don't tell us what to do
		How it might be useful
	Rest doesn't mean sleep	Circadian rhythm and time of day
		Circadian rhythm night shifts etc
		Commuting
		Frequency of port visits
		Sleeping with one ear open
	Workforce need to be happy with working patterns	
What a maritime BMM needs to include	Compare different options	
	Different ways of working and rostering	
	Different roles	
	Dynamic changes	
	Easy to use	
	Identify areas of very high risk	
	Improve on current models	First night or two are bad then its ok
		Impact of commuting
		Sleep debt builds over time
	Meet workforce expectations	Individual variation
	Weather	
Factors that influence how research is conducted	Difference between walk on walk off and sleep on board	
	Inland versus international ferries	
	Need to talk to or work with frontline crew	
	Services staff fatigue	
Information about ferries and routes - for reference	Common patterns worked	
	Route length	

Coding structure for Interviews

Themes and main codes	Subcodes	Lower level codes
Accident reports and fail-safe measures		
Fail-safe measures	Captain and Masters management	Bad weather
	Checklist	
	double up crew working	
	health and safety director	
	Investigation measures	
	Limiting time worked	
	Maintaining high safety standards	
	Mental health first aider	
	Motion detection	
	Not incentivising overtime or double shift	
	Operator using taxis and hotels to stop people driving if fatigued	
	Performing drills	
	Planning office cover and monitoring	
	Rest days	
Reported or known accidents	Consequences of fatigue being a factor of an accident	
	Difficult to prove	
	Fatigue is always a factor	
	Fatigue to be a clear and obvious incident factor to be investigated	
	Inquiry into rest time	
	Job roles that carry risk when fatigued	

	Near miss	
	Fatigue not as a contributing factor	
	Taking on more work	
Factors leading to likely fatigue outcomes for seafarers and countermeasures		
Cause of fatigue	Demographic factors	Age
		Geographic location
		House set up (not dealing with heat)
		Young family
	Financial implications	Missing a day's pay
		Overtime (ship running late)
	Implication of roster pattern	Ability to unwind
		Duration of shift pattern
		Early starts and cutting corners
		Lack of flexibility in schedule
		Not being able to sleep during the day
		Off time being reduced to catch up with sleep
		Roster patterns favoured by majority (crew)
		Running late
		Seasonal changes in shift work (gets busy)
		Shift start times
		Shift transition (e.g., day to night)
		Sleepiness at end of shift and pattern
	Job task	Crewing dept not understanding
		Disturbance from staff
		High workload
		Mental fatigue
		On your feet all day
		Repetitiveness of task
		Staffing issues
		Understaffed
		Working beyond shift hours
	Poor health and wellbeing	Lack of sleep
		Low mood
		Not being responsible for their actions (own time)
		Not maintaining a healthy lifestyle
		Poor mental health
		Stress
	Vessel and journey type	Comfy seating
		Frequency in changing vessel type
		High-speed ferries more demanding
		Increased darkness

		Increased fatigue for deep-seagoing ships
		Motion of the vessel
		Noise of the vessel
		On board nutrition
		Sea sickness
		Tide patterns
		Vessel age
		Vibration of the vessel
		Warm rooms
		Weather conditions (season)
Fatigue countermeasures	Food and drink	Caffeine intake
		Food as nutritious
		Healthy lifestyle
		Hydration
	Increase staff	Crew member support
		Double staff
		More staff (desired but cost impact)
	Night captain to share responsibilities	
	Regulation	Compliance
		Flag state involvement
		Risk assessment
		Time between shifts (minimum rest)
	Shift pattern and start times	Adjustment of working hours
		Rest time to relax
		Shorter working days
		Standardising start times
		Working duration
	Showering	
	Sleep and rest quality	Additional cabins for crew (desired but cost impact)
		Improving sleep condition at home
		Micro nap
		Off time on board
	Working conditions (environment)	Alarm (Motion detection)
		Busyness of the bridge
		Engaging in conversation to keep mind busy
		Fresh air
		Reducing temperature on the bridge
		Ship type (freight or passenger)
		Slowing down work (to gain time to rest)
Job role, responsibilities, and experiences of fatigue		
A need for fatigue training and advice		

(Bosun and Master)		
Bosun	Association of fatigue	Living on board as a reduce to fatigue
		People's expressions (tiredness)
		People's mood
		Taking on extra shifts
		Team napping on the job when possible
		Understanding of fatigue (definition)
	Experience of fatigue	Experience of the vessel route
		Falling asleep on the commute home
		Falling asleep standing up
		Fatigue influence accidents
		Having a nap
		Impact of fatigue
		Monotonous work - non taxing
		Not being aware when tired
		Not remembering tasks
		Time of day
		Told a manager they are fatigued
	Responsibilities	Crew management responsibilities
		Dealing with complaints from passengers
		Health and safety Ensure that the car deck is secure Managing staff with fatigue Monitoring who is taking on extra shifts –Timesheets Passenger safety
		Loading of the ship Load the vessel Maintenance of the ship
		Personal responsibilities Awareness of risk if working extra Deciding if you're fit enough to commute home
Master (and Captain)	Association of fatigue	Awareness of the problem
		Difference in how sleepiness impact staff
		People's behaviour
		People's expressions (tiredness)
		People's mood
		Understanding of fatigue (definition)
	Experience of fatigue	Duration of working contract
		Fatigued watch keeping officers
		Feeling of tiredness when working
		Feeling worse after a nap
		Leaving work commuting home
		Post night shift experience

		Precautionary measure taken
		prep eating into rest time
		Small crew adds to problems
		Stopping the ship
		Undertaking night shifts (positive)
	Responsibilities	Admin (such as crew rest hours) Changing the roster pattern Discipline Finding staff replacements Human resources
		Managing staff Broad responsibilities Intervening if staff are fatigued (regs) Looking after the crew Managing declaration of medicine Managing employees with fatigue Management responsibilities (generic) Overseeing training of new staff Supporting and educating staff To motivate staff
		Navigation Parking the vessel Piloting, plotting and docking the ship
		Responsible for own quality of rest
		Ship and passenger safety
Organisation's culture around fatigue		
Availability to fatigue support	Face to face	Captain daily briefing
		Speaking to captain or master
		Talking about fatigue to others
	Media	FitNurse system
		health monitoring
		'Help assured' phoneline
		Leaflets
		Mental health support
		Noticeboard
		Seably (training system)
		Support from absent manager
	Operator fatigue safety support	
Caffeine consumption (not always related to staying awake)		
Perceptions of fatigue in	Crew knowing their legal rights	

industry (i.e., as an employee in that industry)	Crew not understanding what fatigue is	
	Fatigue not an issue	
	Feeling of change in industry	
	No training on fatigue	
	Putting up with fatigue	Call in sick (when feeling fatigued)
		Not reaching out for help (not standing out)
	Roster created around social than fatigue	

Coding structure for focus groups

Themes and main codes	Subcodes
Breaks	
Commuting	
Countermeasures	
Detecting fatigue in others	
Drills	
Effect of fatigue on incidents	
Effect of incidents on fatigue	
Emergency responsibilities	
External factors	
Fatigue	Causes
	Definitions
	Mental fatigue
	Physical fatigue
	Shifts causing fatigue
	Sufficient or insufficient sleep
Fatigue advice and training	
Incidents	
Relaxing	
Organisational culture	
Reporting fatigue	
Roster pattern	
Sea sickness	
Shiftwork	Shift patterns
	Swapping shifts
	Overrunning shifts
Training for emergencies	

Annex D: Detailed results

Logistical Regressions for Survey

Table 19: Survey - univariate logistic regressions for having to fight to stay awake.

OR = odds ratio, CI = confidence intervals, p = significance. Significant values are presented in bold.

	Factors Vs Sleepiness			
Sleep Factors		Lower	Upper	
Sleep Quality Index	2.315	1.860	2.882	<.001
Impaired Waking Index	1.825	1.505	2.214	<.001
Sleep Apnoea	1.588	1.319	1.912	<.001
Fatigue: Physical only (ref)				.95
Mental only	1.254	.623	2.526	.08
Physical & Mental	2.052	1.019	4.135	.05
Self-Reported Sleep Rating	2.923	2.191	3.900	<.001
Disturbed Sleep Index	2.524	1.988	3.203	<.001
Cabin Index	1.703	1.395	2.080	<.001
Work Factors				
Captain (ref)				.14
Non-bridge-managers	1.143	.454	2.876	.78
Bridge Crew	.492	.161	1.501	.21
Service Crew	1.629	.747	3.552	.22
Deck Crew	1.280	.531	3.084	.58
Engine Crew	.967	.377	2.484	.95
Watch Duty: no (ref vs yes	.705	.464	1.070	.10
Sleep at Home (ref) vs on-board	1.387	.721	2.669	.33
Split Shift	.594	.350	1.009	.05
Start of shift	1.482	.918	2.391	.11
Early shift	2.383	1.380	4.114	.01
Half way through shift	2.478	1.612	3.808	<.001
Close to end of shift	1.229	.809	1.867	.34
End of shift	1.043	.634	1.713	.87
Staying late	1.330	.827	2.139	.24
Starting early	1.791	1.162	2.759	.01
Working extra days	2.039	1.294	3.212	.01
Working hours lead to sleepiness	5.476	2.452	12.229	<.001
Working hours lead to fatigue	3.069	1.352	6.965	.01
Choosing to work overtime	1.385	.999	1.920	.05
Work Enjoyment	.798	.730	.873	<.001

Work Stress	1.419	1.268	1.588	<.001
Health Factors				
Self-reported health: Good (ref)				<.001
Neutral	2.659	1.671	4.231	<.001
Bad	5.021	2.233	11.287	<.001
Smoker status: non-smoker (ref) vs smoker	1.294	.839	1.997	0.24
Stressed	2.859	2.082	3.926	<.001
Difficulty Relaxing	2.997	2.248	3.995	<.001
Tense	2.495	1.854	3.357	<.001
Worried	2.045	1.567	2.669	<.001
Restless in general	2.517	1.913	3.312	<.001
Restless off duty	2.300	1.799	2.940	<.001
Sex male vs female (ref)	2.324	1.418	3.808	<.001
Age: 16-24 (ref)				.04
25-34	.312	.126	.772	.01
35-49	.258	.109	.611	.00
50-64	.404	.170	.959	.04
65+	.738	.160	3.414	.70
Education				0.01
No schooling completed(1)	.283	.049	1.628	.158
Secondary school(2)	.264	.044	1.574	.144
Sixth form or college(3)	**.127**	**.022**	**.734**	**.021**
Trade/Technical/Vocational(4)	.218	.038	1.261	.089
Bachelor's(5)	**.028**	**.003**	**.255**	**.002**
Masters(6)	.000	.000	.	1.000
Doctorate(7)	.158	.023	1.087	.061
Other(8)	.333	.040	2.769	.309

Table 20: Survey - multivariate logistic regressions for having to fight to stay awake

OR = odds ratio, CI = confidence intervals, p = significance. Significant values are presented in bold.

	Factors Vs Sleepiness			
	OR	95% C.I.		p
Sleep Factors		Lower	Upper	
Impaired Waking Index	1.486	1.191	1.854	<.001
Sleep Apnoea Index	1.295	1.040	1.612	.05
Self-reported sleep rating	1.942	1.361	2.770	<.001
Disturbed Sleep Index	1.956	1.472	2.598	<.001
Work Factors				
Working extra days	2.069	1.228	3.488	.01
Working hours lead to sleepiness	3.626	1.361	9.665	.01
Choosing to work overtime	1.572	1.067	2.317	.05
Work Enjoyment	.880	.793	.976	.05
Work Stress	1.396	1.225	1.591	<.001
Health Factors				
Difficulty Relaxing	2.301	1.656	3.198	<.001
Restless off duty	1.807	1.351	2.416	<.001
Sex male vs female (ref)	2.123	1.190	3.784	.01

the last 10 years

OR = odds ratio, CI = confidence intervals, p = significance. Significant values are presented in bold.

	Incident within the last 10 years			
Fatigue reduction technique		Lower	Upper	
Having a break	1.031	.693	1.533	0.88
Opening a window	1.221	.698	2.136	0.48
Caffeinated drink	1.812	1.207	2.720	0.01
Sugary snack	1.479	.936	2.338	0.94
Chew gum	1.895	1.018	3.526	0.05
Talking to yourself	3.253	1.756	6.028	0.001
Fidgeting	1.673	1.081	2.589	0.05
Go on deck	1.152	.783	1.693	0.47
Listen to music	1.526	.992	2.348	0.06
Concentrate on your work	.721	.436	1.194	0.20
Talk to a colleague	1.592	1.086	2.335	0.05
Other	3.617	.694	18.851	0.13
No technique	.470	.206	1.076	0.47

Table 22: Survey - multivariate logistic regressions for having an incident within the last 10 years

OR = odds ratio, CI = confidence intervals, p = significance.

	OR	95% CI		p
Caffeinated drink	1.812	1.207	2.720	0.01
Talking to yourself	3.253	1.756	6.028	0.001

Complete results from the Survey

Informed Consent

1. Consent to participate*

I voluntarily agree to take part in this study (100%)

Questions about your work as a seafarer

2. How long have you been working as a seafarer?

2 months – 49.5 years (M = 17.08 years, SD = 12.77 years)

- What is your current job role?*

Job role	**N**	**%**
Captain/Master	42	9.4%
Non-bridge-managers	57	12.8%
Bridge crew	45	10.1%
Service crew	166	37.2%
Deck crew (Ratings/AB)	70	15.7%
Engine crew (Engineers)	56	12.6%
Missing	10	2.2%
Total	**436**	**100%**

3. Other role
4. Do you undertake 'watch' duties as part of your role?*

	N	**%**
No	213	47.8%
Yes, on all or most of my shifts	161	36.1%
Yes, on some of my shifts	72	16.1%
Total	**446**	**100%**

5. How are you employed?*

	N	**%**
I am permanently employed as a seafarer by the Operator	392	87.9%
I am directly employed as a seafarer by the Operator on a fixed term basis (e.g. for a voyage)	31	7.0%
I am engaged as a seafarer by an agency	18	4.0%
Other	5	1.1%
Total	**445**	**100%**

6. Please give more details of your employment

7. Do you work full-time or part-time in this role?*

	N	%
Full-time	422	94.6%
Part-time	24	5.4%
Total	**446**	**100%**

8. Please give further details of your part-time work

9. Which of the following best describes your current sleeping/living arrangements?*

	N	%
I go home to sleep at the end of each shift	59	13.2%
I sleep on board ship at the end of each shift	387	86.8%
Total	**446**	**100%**

Questions about your working patterns and arrangements (travel home each day)

These questions are for people who go **home at the end of each shift**

10. What roster pattern are you currently working? *

	N	%
I work 4 days out of 7	11	2.5%
I work 5 days out of 7	14	3.1%
I work 6 days out of 7	1	0.2%
I work 13 days out of 14	1	0.2%
Other	32	7.2%
Live Onboard	387	86.8%

11. If you selected Other, please briefly explain your roster pattern

12. On the days you work, how long is your usual shift/working day?*

	N	%
8 hours	14	3.1%
10 hours	7	1.6%
12 hours	31	7.0%
Other	7	1.6%
Living Onboard	387	86.8%

13. If you selected Other, please give brief details

14. How many breaks (e.g. meal breaks) do you usually have during your working day?*

	N	%
0	9	2.0%
1	25	5.6%
2	16	3.6%
3	9	2.0%
Living Onboard	387	86.8%

15. Thinking about your commute, which of the following do you use to get to work? Please select all those which apply*

	N	**%**
Walk	9	2.0%
Car	49	11.0%
Train	2	0.4%
Bus	1	0.2%
Underground	0	0%
Cycle	2	0.4%
Fly	1	0.2%
Taxi	1	0.2%
Motorbike	7	1.6%
Car Passenger	3	0.7%
Motorbike Passenger	0	0%
Other	9	2.0%

16. If you selected Other, please specify:

17. How long does it take you to get to work from home? Please answer in Hours and Minutes e.g. 1 hour AND 15 minutes*

Range = 5 minutes – 8 hours (M = 0:46; SD = 1:03

18. Is this your only job?*

	N	%
Yes, this is my only job	54	12.1%
I have another job as well as this one	1	0.2%
This is my only paid employment but I am also studying	3	0.7%
This is my only paid employment but I am also volunteering	1	0.2%
Living Onboard	387	86.8%

Questions about your working patterns and arrangements (live on-board)

These questions are for people **who sleep on board**

19. What roster pattern do you have?*

	N	%
One week on, one week off	157	35.2%
Two weeks on, two weeks off	157	35.2%
Three weeks on, three weeks off	4	0.9%
Four weeks on, four weeks off	14	3.1%
Eight weeks on, four weeks off	2	0.4%
Other	53	11.9%
Missing	59	13.2%

20. If you selected Other, please describe briefly:

21. Do you have any days off while you are rostered on board?*

	N	%
I get one day off every week	5	1.1%
I get one day off every fortnight	6	1.3%
I get time off unofficially when the ship is in port	11	2.5%
I never get days off while I am rostered on board	349	78.3%
Other	16	3.6%
Missing	59	13.2%
Total	**446**	**100%**

22. If you selected Other, please briefly explain

23. When you are on board, what is your usual working pattern?

	N	%
6 on, 6 off, 6 on, 6 off	27	6.1%
6 1/2 on 6 1/2 off 5 1/2 on 5 1/2 off	6	1.3%
7 on, 7 off, 5 on, 5 off	7	1.6%
8 on, 8 off, 4 on, 4 off	12	2.7%
8 on, 16 off	6	1.3%
12 on, 12 off	167	37.4%
Other regular hours	97	21.7%
My working hours vary	62	13.9%
Missing	62	13.9%
Total	**446**	**100%**

24. Split Shift

	N	%
No	304	68.2%
Yes	106	23.8%
Missing	36	8.1%
Total	**446**	**100%**

25. If you selected Other regular hours, please give brief details

26. If your working hours vary please briefly explain what hours you might work and what affects these

27. How many breaks do you have during your on-duty time?*

	N	%
None	36	8.1%
1 break in a 24 hour period	60	13.5%
2 breaks in a 24 hour period	187	41.9%
3 breaks in a 24 hour period	104	23.3%
Missing	59	13.2%
Total	**446**	**100%**

28. When you travel home (or somewhere else) at the end of your roster period, which of the following do you use? Please select all those which apply*

	N	%
Walk	43	9.6%
Car	253	56.7%
Train	99	22.2%
Bus	59	13.2%
Underground	13	2.9%
Cycle	5	1.1%
Fly	71	15.9%
Taxi	62	13.9%
Motorbike	3	0.7%
Car Passenger	32	7.2%
Motorbike Passenger	0	0%
Other	9	2.0%

29. If you selected Other, please specify:

30. How long does this journey typically take? Please answer in Hours and Minutes e.g. 1 hour AND 15 minutes*

Range = 2 minutes – 36 hours (M = 4:17; SD = 5:20)

31. Is this your only job?*

	N	%
Yes, this is my only job	367	82.3%
This is my only job now but I will move to a non-seafaring job once this roster period finishes	4	0.9%
I do another job on my days off from this one	16	3.6%
Missing	59	13.2%
Total	**446**	**100%**

Questions about your working patterns (home and on-board)

32. In general, how satisfied are you with your working hours?

	N	%
Very satisfied	44	9.9%
Quite satisfied	126	28.3%
Neither satisfied nor unsatisfied	148	33.2%
Quite unsatisfied	82	18.4%
Very unsatisfied	45	10.1%
Missing	1	0.2%
Total	**446**	**100**

33. Do your working patterns as a seafarer include getting less than 10 hours rest in a 24-hour period at least once (or more) each month?*

	N	%
No	265	59.4%
Yes	181	40.6%
Total	**446**	**100%**

34. What is the impact of this on your work performance?

	N	%
No impact (1)	7	3.9%
2	12	6.6%
3	60	33.1%
4	65	35.9%
High impact (5)	37	20.4%
Total	**181**	**100%**

35. Do your working patterns as a seafarer include staying late at the end of your shift at least once (or more) each month?*

	N	**%**
No	128	28.7%
Yes	318	71.3%
Total	**446**	**100%**

36. What is the impact of this on your work performance?

	N	**%**
No impact (1)	59	18.6%
2	92	28.9%
3	110	34.6%
4	35	11.0%
High impact (5)	22	6.9%
Missing System	128	28.7%
Total	**446**	**100%**

37. Do your working patterns as a seafarer include being required to start your shift early at least once (or more) each month?*

	N	%
No	199	44.6%
Yes	247	55.4%
Total	**446**	**100%**

38. What is the impact of this on your work performance?

	N	%
No impact (1)	20	4.5%
2	20	4.5%
3	79	17.7%
4	74	16.6%
High impact (5)	54	12.1%
Missing System	199	44.6%
Total	**446**	**100%**

39. Do your working patterns as a seafarer include working extra days at the end of your roster at least once (or more) each month?

	N	%
No	331	74.2%
Yes	114	25.6%
Missing System	1	0.2%
Total	**446**	**100%**

40. What is the impact of this on your work performance?

	N	%
No impact (1)	10	2.2%
2	17	3.8%
3	29	6.5%
4	35	7.8%
High impact (5)	23	5.2%
Missing System	332	74.4%
Total	**446**	**100%**

41. Do your working patterns as a seafarer include being required to start your roster earlier than expected at least once (or more) each month?*

	N	%
No	337	75.6%
Yes	109	24.4%
Total	**446**	**100%**

42. What is the impact of this on your work performance?

	N	%
No impact (1)	29	6.5%
2	28	6.3%
3	33	7.4%
4	9	2.0%
High impact (5)	10	2.2%
Missing System	337	75.6%
Total	**446**	**100%**

43. Do you think your working hours contribute to sleepiness when you are working?*

	N	%
No	88	19.7%
Yes	358	80.3%
Total	**446**	**100%**

44. What is the impact of this on your work performance?

	N	%
No impact (1)	2	0.4%
2	38	8.5%
3	119	26.7%
4	107	24.0%
High impact (5)	90	20.2%
Missing System	90	20.2%
Total	**446**	**100%**

45. Do you think your working hours are associated with any health risks?*

	N	%
No	96	21.5%
Yes	350	78.5%
Total	**446**	**100%**

9.

46. What is the impact of this on your work performance?

	N	%
No impact (1)	99	22.2%
2	118	26.5%
3	103	23.1%
4	22	4.9%
High impact (5)	7	1.6%
Missing System	97	21.7%
Total	**446**	**100%**

47. Do you think your working hours are associated with an accident risk?*

	N	%
No	135	30.3%
Yes	311	69.7%
Total	**446**	**100%**

48. What is the impact of this on your work performance?

	N	%
No impact (1)	3	0.7%
2	35	7.8%
3	106	23.8%
4	87	19.5%
High impact (5)	80	17.9%
Missing System	135	30.3%
Total	**446**	**100%**

49. Do you think sleepiness in your work increases the risk of serious mistakes?*

	N	%
No	71	15.9%
Yes	375	84.1%
Total	**446**	**100%**

50. What is the impact of this on your work performance?

	N	%

No impact (1)	6	1.3%
2	36	8.1%
3	97	21.7%
4	116	26.0%
High impact (5)	119	26.7%
Missing System	72	16.1%
Total	**446**	**100%**

51. Do you think your working hours cause fatigue when working?*

	N	%
No	58	13.0%
Yes	388	87.0%
Total	**446**	**100%**

52. What is the impact of this on your work performance?

	N	%
No impact (1)	117	26.2%
2	104	23.3%
3	125	28.0%
4	35	7.8%
High impact (5)	6	1.3%
Missing System	59	13.2%
Total	**446**	**100%**

53. Are you able to swap shifts with other seafarers?*

	N	%
No	206	46.2%
Yes, with employer permission	164	36.8%
Yes, with or without employer permission	33	7.4%
Not sure	43	9.6%
Total	**446**	**100%**

54. How often does this occur?

	N	**%**
Every month	13	2.9%
Every 2-3 months	22	4.9%
Every 4-6 months	20	4.5%
Once or twice a year	141	31.6%
Missing	250	56.1%

Total	446	100%

55. Are you able to influence your working hours (e.g. choosing which roster patterns the company should adopt)?*

	N	%
No	328	73.5%
Yes	49	11.0%
Not sure	69	15.5%
Total	**446**	**100%**

56. Please give more details about how you are able to influence your working hours

57. Can you choose to work overtime?*

	N	%
No	143	32.1%
Yes	247	55.4%
Not sure	56	12.6%
Total	**446**	**100%**

58. How often does this occur?

	N	%
Every month	101	22.6%
Every 2-3 months	52	11.7%
Every 4-6 months	32	7.2%
Once or twice a year	61	13.7%
Missing	200	44.8%
Total	**446**	**100%**

59. Do you feel able to complete your record of rest hours/work hours accurately?*

	N	%
Yes - always	155	34.8%
Yes - mostly	124	27.8%
Yes - sometimes	86	19.3%
No - never	61	13.7%
Not sure	20	4.5%
Total	**446**	**100%**

Questions about your sleep

60. In general, how would you rate your sleep in the last 3 months?*

	N	%
Very good	11	2.5%

Quite good	83	18.6%
Neither good nor bad	133	29.8%
Quite bad	176	39.5%
Very bad	43	9.6%
Total	**446**	**100%**

61. Have you ever been diagnosed with a disorder or condition which affects your sleep? e.g. obstructive sleep apnoea*

	N	**%**
Yes	29	6.5%
No	417	93.5%
Total	**446**	**100%**

62. If yes, which disorder or condition?

63. Have you declared this to your employer?

	N	%
Yes	4	0.9%
No	22	4.9%
Missing System	420	94.2%
Total	**446**	**100%**

64. Please indicate the degree to which the following have happened to you during the last 3 months.*

64.1 Difficulty in falling asleep

	N	**%**
Never	32	7.2%
Seldom (one or few times a year)	39	8.7%
Sometimes (Several times a month)	108	24.2%
Often (1-2 times a week)	106	23.8%
Most often (3-4 times a week)	103	23.1%
Always (5 times or more a week)	55	12.3%
Not Applicable	2	0.4%
Missing	1	0.2%
Total	**446**	**100%**

64.2 Difficulty in waking up

	N	**%**
Never	88	19.7%
Seldom (one or few times a year)	75	16.8%
Sometimes (Several times a month)	85	19.1%
Often (1-2 times a week)	78	17.5%
Most often (3-4 times a week)	69	15.5%
Always (5 times or more a week)	47	10.5%

Not Applicable	2	0.4%
Missing	2	0.4%
Total	**446**	**100%**

64.3 Oversleeping

	N	%
Never	206	46.2%
Seldom (one or few times a year)	130	29.1%
Sometimes (Several times a month)	62	13.9%
Often (1-2 times a week)	28	6.3%
Most often (3-4 times a week)	11	2.5%
Always (5 times or more a week)	5	1.1%
Not Applicable	3	0.7%
Missing	**1**	**0.2%**
Total	**446**	**100%**

64.4 Repeated waking up with problems falling asleep again

	N	%
Never	45	10.1%
Seldom (one or few times a year)	63	14.1%
Sometimes (Several times a month)	112	25.1%
Often (1-2 times a week)	79	17.7%
Most often (3-4 times a week)	87	19.5%
Always (5 times or more a week)	58	13.0%
Not Applicable	2	0.4%
Total	**446**	**100%**

64.5 Severe snoring (own)

	N	%
Never	111	24.9%
Seldom (one or few times a year)	75	16.8%
Sometimes (Several times a month)	80	17.9%
Often (1-2 times a week)	47	10.5%
Most often (3-4 times a week)	47	10.5%
Always (5 times or more a week)	55	12.3%
Not Applicable	29	6.5%
Missing	2	0.4%
Total	**446**	**100%**

64.6 Difficulty catching your breath during sleep

	N	%
Never	291	65.2%
Seldom (one or few times a year)	53	11.9%
Sometimes (Several times a month)	40	9.0%
Often (1-2 times a week)	18	4.0%
Most often (3-4 times a week)	13	2.9%
Always (5 times or more a week)	3	0.7%
Not Applicable	25	5.6%
Missing	3	0.7%
Total	**446**	**100%**

64.7 Interrupted breathing during sleep (sleep apnoea)

	N	%
Never	312	70.0%
Seldom (one or few times a year)	42	9.4%
Sometimes (Several times a month)	22	4.9%
Often (1-2 times a week)	17	3.8%
Most often (3-4 times a week)	9	2.0%
Always (5 times or more a week)	5	1.1%
Not Applicable	35	7.8%
Missing	4	0.9%
Total	**446**	**100%**

64.8 Nightmares

	N	%
Never	130	29.1%
Seldom (one or few times a year)	158	35.4%
Sometimes (Several times a month)	82	18.4%
Often (1-2 times a week)	48	10.8%
Most often (3-4 times a week)	13	2.9%
Always (5 times or more a week)	6	1.3%
Not Applicable	7	1.6%
Missing	2	0.4%
Total	**446**	**100%**

64.9 Disturbed or worried sleep

	N	%
Never	50	11.2%
Seldom (one or few times a year)	95	21.3%
Sometimes (Several times a month)	116	26.0%
Often (1-2 times a week)	80	17.9%
Most often (3-4 times a week)	67	15.0%
Always (5 times or more a week)	30	6.7%
Not Applicable	6	1.3%

Missing	2	0.4%
Total	**446**	**100%**

64.10 Involuntary tremors in the legs that interfere with sleep ('restless legs')

	N	**%**
Never	218	48.9%
Seldom (one or few times a year)	85	19.1%
Sometimes (Several times a month)	54	12.1%
Often (1-2 times a week)	32	7.2%
Most often (3-4 times a week)	23	5.2%
Always (5 times or more a week)	18	4.0%
Not Applicable	15	3.4%
Missing	1	0.2%
Total	**446**	**100%**

64.11 Overly light sleep

	N	**%**
Never	75	16.8%
Seldom (one or few times a year)	90	20.2%
Sometimes (Several times a month)	104	23.3%
Often (1-2 times a week)	82	18.4%
Most often (3-4 times a week)	44	9.9%
Always (5 times or more a week)	39	8.7%
Not Applicable	9	2.0%
Missing	3	0.7%
Total	**446**	**100%**

64.12 Being constantly tired throughout the day

	N	**%**
Never	23	5.2%
Seldom (one or few times a year)	64	14.3%
Sometimes (Several times a month)	130	29.1%
Often (1-2 times a week)	86	19.3%
Most often (3-4 times a week)	77	17.3%
Always (5 times or more a week)	62	13.9%
Not Applicable	3	0.7%
Missing	1	0.2%
Total	**446**	**100%**

64.13 The need to fight to stay awake during daytime

	N	**%**
Never	65	14.6%
Seldom (one or few times a year)	112	25.1%

Sometimes (Several times a month)	121	27.1%
Often (1-2 times a week)	70	15.7%
Most often (3-4 times a week)	44	9.9%
Always (5 times or more a week)	26	5.8%
Not Applicable	6	1.3%
Missing	2	0.4%
Total	**446**	**100%**

64.14 Sleep being disturbed by the movement of the ship

	N	**%**
Never	46	10.3%
Seldom (one or few times a year)	74	16.6%
Sometimes (Several times a month)	115	25.8%
Often (1-2 times a week)	68	15.2%
Most often (3-4 times a week)	57	12.8%
Always (5 times or more a week)	47	10.5%
Not Applicable	36	8.1%
Missing	3	0.7%
Total	**446**	**100%**

64.15 Sleep being disturbed by vibration

	N	**%**
Never	62	13.9%
Seldom (one or few times a year)	66	14.8%
Sometimes (Several times a month)	91	20.4%
Often (1-2 times a week)	63	14.1%
Most often (3-4 times a week)	61	13.7%
Always (5 times or more a week)	65	14.6%
Not Applicable	36	8.1%
Missing	2	0.4%
Total	**446**	**100%**

64.16 Sleep being disturbed by noise

	N	**%**
Never	33	7.4%
Seldom (one or few times a year)	69	15.5%
Sometimes (Several times a month)	99	22.2%
Often (1-2 times a week)	81	18.2%
Most often (3-4 times a week)	69	15.5%
Always (5 times or more a week)	67	15.0%
Not Applicable	27	6.1%
Missing	1	0.2%

Total	446	100%

64.17 Sleep being disturbed by being too hot or too cold

	N	%
Never	54	12.1%
Seldom (one or few times a year)	109	24.4%
Sometimes (Several times a month)	112	25.1%
Often (1-2 times a week)	62	13.9%
Most often (3-4 times a week)	55	12.3%
Always (5 times or more a week)	34	7.6%
Not Applicable	19	4.3%
Missing	1	0.2%
Total	**446**	**100%**

64.18 Sleep being disturbed by a colleague you share your cabin with

	N	%
Never	256	57.4%
Seldom (one or few times a year)	17	3.8%
Sometimes (Several times a month)	11	2.5%
Often (1-2 times a week)	6	1.3%
Most often (3-4 times a week)	11	2.5%
Always (5 times or more a week)	7	1.6%
Not Applicable	136	30.5%
Missing	2	0.4%
Total	**446**	**100%**

64.19 Sleep being affected by anxiety about family

	N	%
Never	99	22.2%
Seldom (one or few times a year)	131	29.4%
Sometimes (Several times a month)	106	23.8%
Often (1-2 times a week)	52	11.7%
Most often (3-4 times a week)	30	6.7%
Always (5 times or more a week)	15	3.4%
Not Applicable	13	2.9%
Total	**446**	**100%**

64.20 Tiredness being influenced by a change in time zones

	N	%
Never	268	60.1%
Seldom (one or few times a year)	41	9.2%
Sometimes (Several times a month)	22	4.9%
Often (1-2 times a week)	5	1.1%

Most often (3-4 times a week)	1	0.2%
Always (5 times or more a week)	4	0.9%
Not Applicable	104	23.3%
Missing	1	0.2%
Total	**446**	**100%**

64.21 Cabins on board are unsuitable for sleeping

	N	%
Never	226	50.7%
Seldom (one or few times a year)	65	14.6%
Sometimes (Several times a month)	31	7.0%
Often (1-2 times a week)	19	4.3%
Most often (3-4 times a week)	12	2.7%
Always (5 times or more a week)	21	4.7%
Not Applicable	71	15.9%
Missing	1	0.2%
Total	**446**	**100%**

64.22 Sleep being affected by the comfort of the bed

	N	%
Never	168	37.7%
Seldom (one or few times a year)	90	20.2%
Sometimes (Several times a month)	69	15.5%
Often (1-2 times a week)	26	5.8%
Most often (3-4 times a week)	20	4.5%
Always (5 times or more a week)	34	7.6%
Not Applicable	36	8.1%
Missing	3	0.7%
Total	**446**	**100%**

64.23 Sleep being affected by the cleanliness of the cabin

	N	%
Never	307	68.8%
Seldom (one or few times a year)	47	10.5%
Sometimes (Several times a month)	13	2.9%
Often (1-2 times a week)	13	2.9%
Most often (3-4 times a week)	7	1.6%
Always (5 times or more a week)	4	0.9%
Not Applicable	53	11.9%
Missing	2	0.4%
Total	**446**	**100%**

65. How much sleep do you ideally need in each 24-hour period to be able to work safely/feel rested? Please answer in Hours and Minutes. e.g. 6 hours AND 45 minutes

Ideal Sleep	N	%
5:00	5	1.1%
5:30	2	0.4%
6:00	32	7.2%
6:30	21	4.7%
6:45	2	0.4%
7:00	102	22.9%
7:01	1	0.2%
7:30	40	9.0%
7:40	1	0.2%
7:45	1	0.2%
7:55	1	0.2%
8:00	173	38.8%
8:10	1	0.2%
8:18	1	0.2%
8:30	20	4.5%
8:43	1	0.2%
9:00	19	4.3%
9:50	1	0.2%
10:00	10	2.2%
10:30	2	0.4%
11:00	3	0.7%
12:00	4	0.9%
14:00	1	0.2%
Missing System	2	0.4%
Total	**446**	**100%**

66. How much sleep do you usually get in a 24-hour period when you are working? Please answer in Hours and Minutes e.g. 6 hours AND 45 minutes*

Actual Sleep	N	%
0:20	1	0.2%
1:30	1	0.2%
2:00	1	0.2%
2:10	1	0.2%
3:00	6	1.3%

3:30	5	1.1%
4:00	15	3.4%
4:30	19	4.3%
4:35	1	0.2%
4:45	1	0.2%
5:00	48	10.8%
5:30	38	8.5%
5:45	2	0.4%
6:00	110	24.7%
6:15	2	0.4%
6:25	1	0.2%
6:30	39	8.7%
6:45	3	0.7%
6:50	2	0.4%
7:00	70	15.7%
7:15	1	0.2%
7:30	22	4.9%
7:40	1	0.2%
7:45	1	0.2%
8:00	38	8.5%
8:30	3	0.7%
9:00	5	1.1%
10:00	7	1.6%
Missing System	2	0.4%
Total	**446**	**100%**

67. Is this usually all in one period or split between two periods?*

	N	**%**
I only sleep once in a 24 hour period	281	63.0%
I have a long sleep and a short nap each 24 hour period	112	25.1%
I have two sleeps of similar length in each 24 hour period	53	11.9%
Total	**446**	**100%**

68. How many cups of tea or coffee do you drink on average in a 24-hour period? *

	N	**%**
0	47	10.5%
1	35	7.8%
2	79	17.7%
3	76	17.0%
4	84	18.8%
5	62	13.9%

6	28	6.3%
7 or more	35	7.8%
Total	**446**	**100%**

69. How many cans of energy drink (e.g. redbull, monster) do you drink on average in a 24-hour period?

	N	**%**
0	396	88.8%
1	29	6.5%
2	11	2.5%
3	4	0.9%
4	5	1.1%
6	1	0.2%
Total	**446**	**100%**

70. Do you ever take caffeine tablets (e.g. ProPlus) on a work day?*

	N	**%**
Never	423	94.8%
A few times a month	16	3.6%
At least once a week	3	0.7%
A few times a week	2	0.4%
Everyday/ almost always	2	0.4%
Total	**446**	**100%**

71. Do you take sleeping pills to help you sleep?*

	N	**%**
No	361	80.9%
Yes, sometimes	67	15.0%
Yes, on a regular basis	15	3.4%
Prefer not to say	3	0.7%
Total	**446**	**100%**

Questions about you as a seafarer

72. How much enjoyment do you get from working? Please indicate on the scale below where 1 is no enjoyment (working for income only), and 10 is high enjoyment (working is fun).

	N	**%**
1 No enjoyment	37	8.3%
2	23	5.2%
3	46	10.3%
4	35	7.8%
5	60	13.5%
6	63	14.1%

7	79	17.7%
8	64	14.3%
9	21	4.7%
10 High enjoyment	18	4.0%
Total	**446**	**100%**

73. On a scale from 1-10, where 1 is the lowest and 10 is the highest, how stressed do you feel daily when working?

	N	**%**
Not stressed (1)	15	3.4%
2	31	7.0%
3	48	10.8%
4	46	10.3%
5	78	17.5%
6	72	16.1%
7	70	15.7%
8	58	13.0%
9	14	3.1%
Very stressed (10)	14	3.1%
Total	**446**	**100%**

74. How often do you have to fight sleepiness to stay awake while working?*

	N	%
Not sleepy	324	72.6%
Sleepy	122	27.4%

	N	%
Never	42	9.4%
Rarely (a few times a year)	143	32.1%
2-4 times a month	139	31.2%
2-3 times a week	76	17.0%
4 or more times a week	29	6.5%
Daily	17	3.8%
Total	**446**	**100%**

75. In the past 12 months, have you had to stop working due to tiredness?*

	N	**%**

Never	293	65.7%
Once	75	16.8%
Twice	39	8.7%
Three times	8	1.8%
More than three times	31	7.0%
Total	**446**	**100%**

76. When you had to stop work due to fatigue or tiredness, how did you feel?*

	N	%
Physical	171	38.3%
Mental	315	70.6%
Struggle to stay awake	56	12.6%

77. In the past 12 months, have you wanted to stop working due to tiredness but been unable to?*

	N	**%**
Never	194	43.5%
Once	59	13.2%
Twice	61	13.7%
Three times	19	4.3%
More than three times	113	25.3%
Total	**446**	**100%**

78. When you wanted to stop work due to fatigue or tiredness, how did you feel?*

	N	%
Physical	133	29.8%
Mental	180	40.4%
Struggle to stay awake	69	15.5%

79. In the past 12 months, have you fallen asleep whilst working?*

	N	**%**
Never	363	81.4%
Once	32	7.2%
Twice	19	4.3%
Three times	11	2.5%
More than three times	21	4.7%

Total	**446**	**100%**

80. In the past 12 months, have you had a 'near miss' (just missed having an accident) at work because you were sleepy?*

	N	**%**
Never	332	74.4%
Once	69	15.5%
Twice	25	5.6%
Three times	5	1.1%
More than three times	15	3.4%
Total	**446**	**100%**

81. In the past 12 months have you had an accident at work because you were sleepy?*

	N	**%**
Never	420	94.2%
Once	22	4.9%
Twice	2	0.4%
More than three times	2	0.4%
Total	**446**	**100%**

82. Do you think your employer knows that this accident occurred because you were sleepy?*

	N	%
Yes	4	0.9%
No	22	4.9%
Missing System	420	94.2%
Total	**446**	**100%**

83. In the last 10 years have you experienced an accident where sleepiness or fatigue was partly or solely to blame? This could be whilst at work or at other times when not at work.

	N	**%**
No	261	58.5%
Yes, once	85	19.1%
Yes, several times	54	12.1%
Do not remember	45	10.1%
Missing	1	0.2%
Total	**446**	**100%**

84. In the past 12 months have you experienced any of these signs of sleepiness when working? Please select all those which apply*

Symptom	**N (home shift)**	**Seafarers who go home %**	**N (at sea shift)**	**Seafarers who sleep on the vessel %**
Yawning	56	94.9	350	90.4
Frequent eye blinks	27	45.8	202	52.2
Difficulty keeping eyes open	35	59.3	177	45.7
Difficulty in concentrating on what you are doing	35	59.3	250	64.6
Needing to fidget or change position frequently	28	47.5	192	49.6
Slower reaction times to things happening	25	42.4	181	46.8
Dreamlike state of consciousness	10	16.9	106	27.4
Head nodding	19	32.2	119	30.7

85. If you selected Other, please briefly explain:

86. What time of day are you most likely to feel sleepy whilst working? Please select all those which apply*

	N	**%**
4am - 8am	166	37.2%
8am - 12pm	71	15.9%
12pm - 4pm	152	34.1%
4pm - 8pm	112	25.1%
8pm - 12am	108	24.2%
12pm - 4am	156	35.0%
Not sleepy	18	4.0%

87. At what point in your shift do you feel most sleepy whilst working? Please select all those which apply*

	N	**%**
Start of shift	101	22.6%
Early shift	64	14.3%
Half way into the shift	151	33.9%
Close to end of shift	232	52.0%
At the end of the shift	100	22.4%
Other	5	1.1%
Not sleepy	26	5.8%

88. If you selected Other, please specify:

	N	%
After eating	1	0.2%
It can affect me at any time, I never feel rested.	1	0.2%

89. At what point in your roster do you feel most sleepy or fatigued when working? Please select all those which apply*

	N	**%**
1st day back	160	35.9%
2nd or 3rd day back	118	26.5%
End of the first week	77	17.3%
Half-way through the roster	72	16.1%
Last week or two	63	14.1%
Last day or two from the end of the roster	176	39.5%
Never sleepy	16	3.6%
Other	7	1.6%

90. If you selected Other, please give more details

91. Do you do anything whilst working to reduce sleepiness and keep yourself alert? If so, what do you do? Please select all those which apply*

	N	%
Have a break	153	34.3%
Open a window	58	13.0%
Have a drink	288	64.6%
Eat sugar	94	21.1%
Chew gum	45	10.1%
Talk to yourself	52	11.7%
Fidget	109	24.4%
Go onto the deck	175	39.2%
Listen to music	112	25.1%
Focus on work	80	17.9%
Talk to colleague	189	42.4%
Other	7	1.6%
No technique	31	7.0%

92. If you selected Other, please explain briefly:

	N	**%**
No Explanation	442	99.1%
Cleaning	1	0.2%
Smoke	1	0.2%
Spray face	1	0.2%

Walk around the engine room	1	0.2%

93. How often do you have to actively do something to keep yourself alert when working?

	N	**%**
Never	44	9.9%
Occasionally	221	49.6%
2-4 times a month	63	14.1%
2-3 times a week	66	14.8%
4 or more times a week	51	11.4%
Missing	1	0.2%
Total	**446**	**100%**

94. Are you encouraged to report it to your line manager if you feel sleepy or tired while working?*

	N	%
Yes	74	16.6%
No	287	64.3%
Not sure	85	19.1%
Total	**446**	**100%**

95. Do you feel able to report it to your line manager if you feel sleepy or tired while working?*

	N	%
Yes	139	31.2%
No	206	46.2%
Not sure	78	17.5%
Not applicable	23	5.2%
Total	**446**	**100%**

Please respond to the following statements*

96. I enjoy the food on board

	N	%
Strongly agree	58	13.0%
Agree	108	24.2%
Neither agree nor disagree	106	23.8%
Disagree	67	15.0%
Strongly disagree	76	17.0%
Not applicable	31	7.0%
Total	**446**	**100%**

97. I get enough to eat on board

	N	%
Strongly agree	131	29.4%
Agree	172	38.6%
Neither agree nor disagree	59	13.2%
Disagree	32	7.2%
Strongly disagree	26	5.8%
Not applicable	26	5.8%
Total	**446**	**100%**

98. I am able to eat healthily on board

	N	%
Strongly agree	61	13.7%
Agree	95	21.3%
Neither agree nor disagree	97	21.7%
Disagree	86	19.3%
Strongly disagree	83	18.6%
Not applicable	24	5.4%
Total	**446**	**100%**

99. The food on board meets my medical needs (e.g. allergies)

	N	%
Strongly agree	82	18.4%
Agree	104	23.3%
Neither agree nor disagree	74	16.6%
Disagree	23	5.2%
Strongly disagree	22	4.9%
Not applicable	141	31.6%
Total	**446**	**100%**

100. The food on board meets my religious needs

	N	%
Strongly agree	79	17.7%
Agree	62	13.9%
Neither agree nor disagree	57	12.8%
Disagree	5	1.1%
Strongly disagree	5	1.1%
Not applicable	236	52.9%
Missing System	2	0.4%
Total	**446**	**100%**

101. Meals are available on board at the times I want to eat

	N	%
Strongly agree	89	20.0%
Agree	139	31.2%
Neither agree nor disagree	72	16.1%
Disagree	66	14.8%
Strongly disagree	49	11.0%
Not applicable	31	7.0%
Total	**446**	**100%**

102. I have good access to hot and cold drinks on board

	N	%
Strongly agree	211	47.3%
Agree	181	40.6%
Neither agree nor disagree	25	5.6%
Disagree	13	2.9%
Strongly disagree	6	1.3%
Not applicable	9	2.0%
Missing System	1	0.2%
Total	**446**	**100%**

103. Have you had any training/advice on how to handle fatigue?*

	N	%
Yes	37	8.3%
No	365	81.8%
Not sure	44	9.9%
Total	**446**	**100%**

104. If you have had any training/advice on how to handle fatigue, did you find it useful?

	N	%
Yes	22	4.9%
No	9	2.0%
Not sure	6	1.3%
Missing System	409	91.7%
Total	**446**	**100%**

Questions about your health

105. In general, how would you rate your health?*

	N	%
Very good	61	13.7%
Quite good	240	53.8%
Neither good nor bad	118	26.5%
Quite bad	22	4.9%
Very bad	5	1.1%
Total	**446**	**100%**

Health		
	N	%
Good	301	67.5%
Bad	27	6.1%
Missing System	118	26.5%
Total	**446**	**100%**

106. Are you a smoker?*

	N	%
Non-smoker, never been a smoker, or only smoked a few times	202	45.3%
Non-smoker bur previously have been a smoker (not for the last 6 months or more)	86	19.3%
Smoker	98	22.0%
E-cigarette user (vaper)	54	12.1%
Prefer not to say	6	1.3%
Total	**446**	**100%**

107. Which of the following describes your exercise habits? Please select all those which apply

	N	%
Hardly exercise onboard	108	24.2%
Occasionally exercise onboard	104	23.3%
Often exercise onboard	63	14.1%
Occasional exercise at home	141	31.6%
Frequently exercise at home	109	24.4%

Please read each statement and answer about how you have been feeling on average during the last 3 months*

108. There are days when I feel very stressed

	N	%
Not at all	39	8.7%
Sometimes	247	55.4%
Quite often	131	29.4%
Almost always	29	6.5%
Total	**446**	**100%**

109. I have difficulties relaxing during leisure time

	N	%
Not at all	100	22.4%
Sometimes	225	50.4%
Quite often	88	19.7%
Almost always	33	7.4%
Total	**446**	**100%**

110. I am often tense

	N	%
Not at all	85	19.1%
Sometimes	209	46.9%
Quite often	132	29.6%
Almost always	19	4.3%
Missing System	1	0.2%
Total	**446**	**100%**

111. I often feel worried

	N	%
Not at all	77	17.3%
Sometimes	233	52.2%
Quite often	98	22.0%
Almost always	35	7.8%
Missing System	3	0.7%
Total	**446**	**100%**

112. I am often restless

	N	%
Not at all	87	19.5%
Sometimes	214	48.0%
Quite often	106	23.8%
Almost always	35	7.8%
Missing System	4	0.9%
Total	**446**	**100%**

113. I do not feel rested after being off duty and resting for a couple of days

	N	%
Not at all	97	21.7%
Sometimes	160	35.9%
Quite often	130	29.1%
Almost always	58	13.0%
Missing System	1	0.2%
Total	**446**	**100%**

Background Questions

114. How old are you?*

	N	%
16 to 24 years	25	5.6%
25 to 34 years	99	22.2%
35 to 49 years	174	39.0%
50 to 64 years	138	30.9%
65 years or over	9	2.0%
Prefer not to say	1	0.2%
Total	**446**	**100%**

115. What is your gender?

	N	%
Male	358	80.3%
Female	85	19.1%
Prefer not to say	2	0.4%
Missing System	1	0.2%
Total	**446**	**100%**

116. What is your nationality?

117. What is your height? Please respond in either feet/inches or centimetres.

118. What is your weight? Please respond in either stones/pounds or kilograms.

119. What is your current relationship status?*

	N	%
Single	100	22.4%
Living with a partner	95	21.3%
Married/ Civil partnership	216	48.4%
Separated/ Divorced	22	4.9%
Widowed	2	0.4%
Prefer not to say	11	2.5%
Total	**446**	**100%**

120. Do you have any children living with you at home?

	N	%
Yes	190	42.6%
No	255	57.2%
Missing System	1	0.2%
Total	**446**	**100%**

121. How old are the children living with you at home?

122. Do you have any carer or childcare responsibilities?

	N	%
Yes, I am a carer	21	4.7%
Yes, I have childcare responsibilities	76	17.0%
Yes, I am both a carer and have childcare responsibilities	26	5.8%
No	320	71.7%
Missing System	3	0.7%
Total	**446**	**100%**

123. What is your highest level of education? *

	N	%
No schooling completed	6	1.3%
Secondary school	94	21.1%
Sixth form or college	55	12.3%
Trade/ technical/ vocational training	128	28.7%
Bachelor's degree	89	20.0%
Master's degree	38	8.5%
Doctorate degree	1	0.2%
Other	25	5.6%
Prefer not to say	10	2.2%
Total	**446**	**100%**

124. Which operator do you currently work for?

125. Please use this space to offer any further comments relating to any of the questions in this survey, or any further comments about fatigue in general.

Probability distributions per factor from the field study

Figure 17 Probability density estimates and box plots of sleep duration as a function of the dependent variables sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively

The top plot shows the overall probability density estimate of sleep durations in the full dataset (n=914).

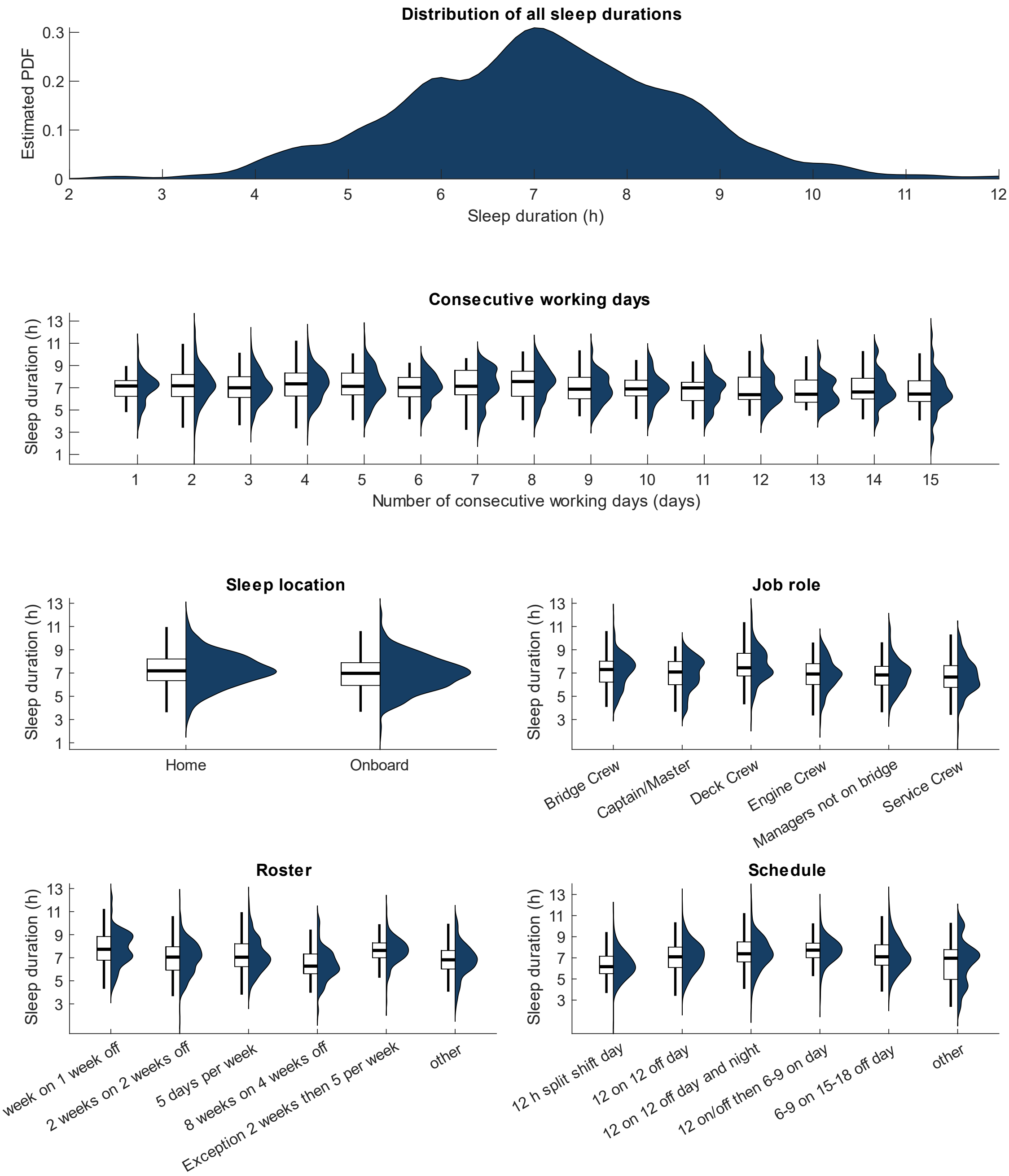


Figure 18 Probability density estimates and box plots of max KSS reported during shifts as a function of the dependent variables sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively

The top plot shows the overall probability density estimate of max KSS in the full dataset (n=564).

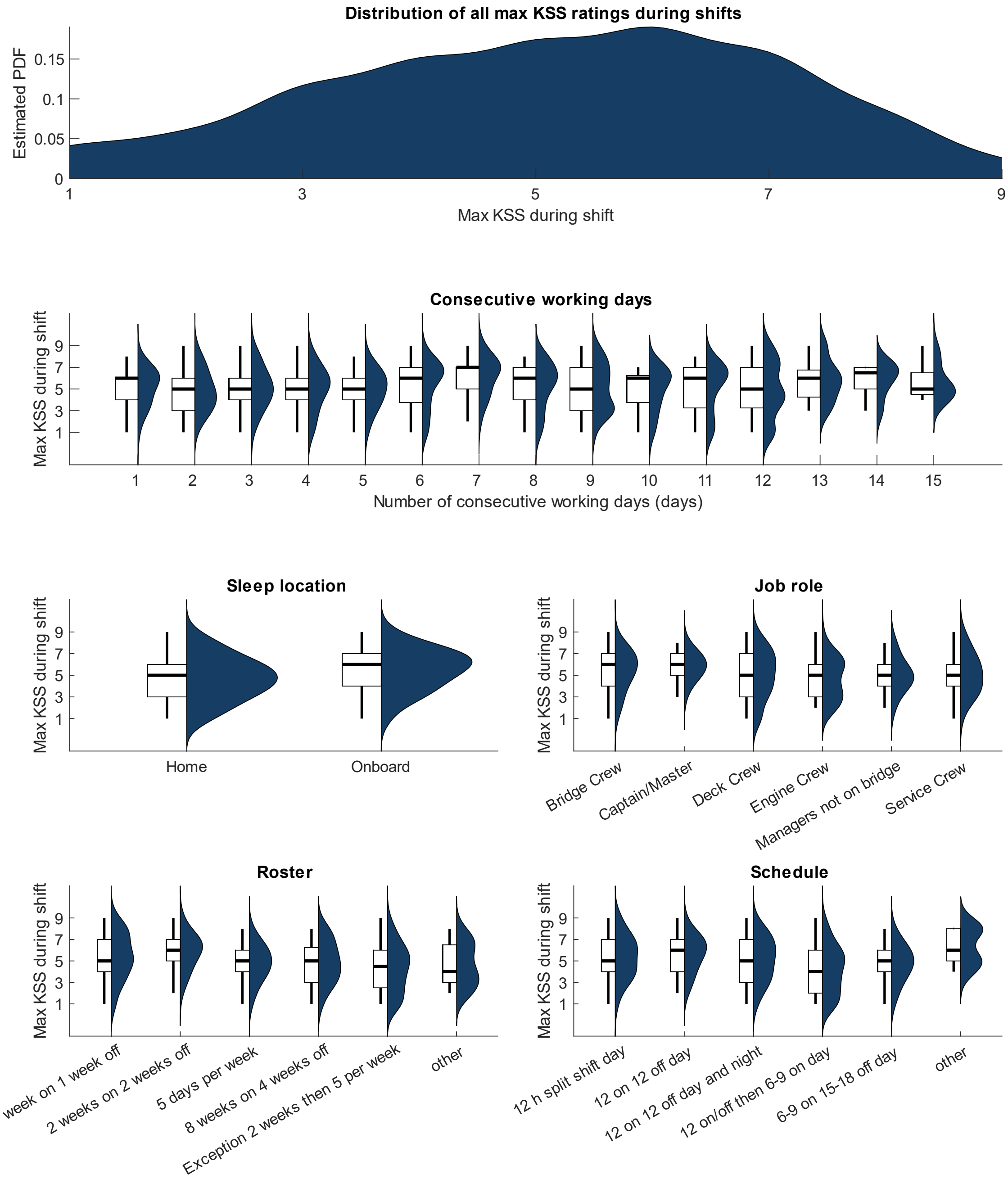


Figure 19 Probability density estimates and box plots of PVT reaction times as a function of the dependent variables sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively

The top plot shows the overall probability density estimate of reaction times in the full dataset (n=693).

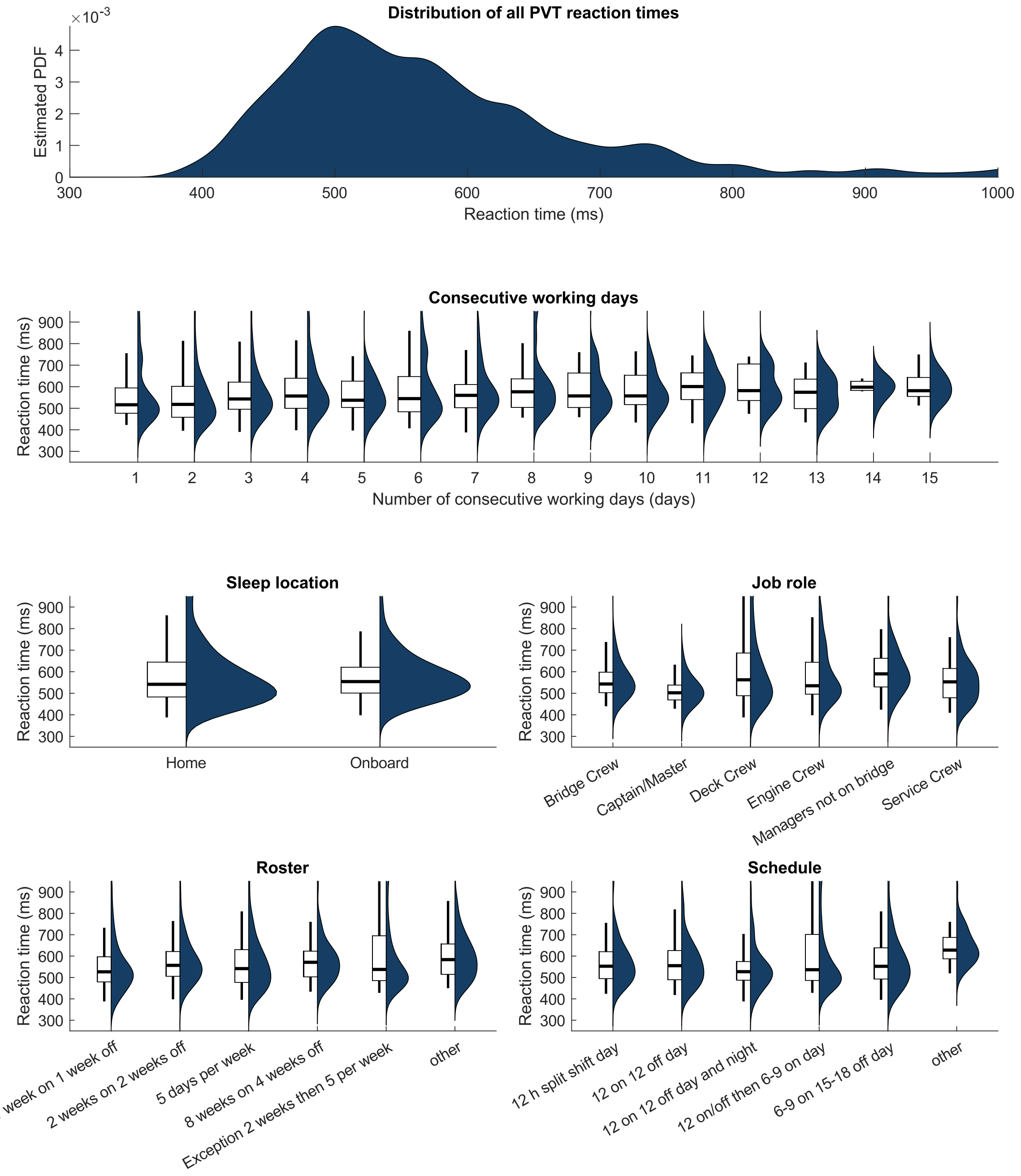


Figure 20: Probability density estimates and box plots of PVT lapses as a function of the dependent variables sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively

The top plot shows the overall probability density estimate of lapses in the full dataset (n=693).

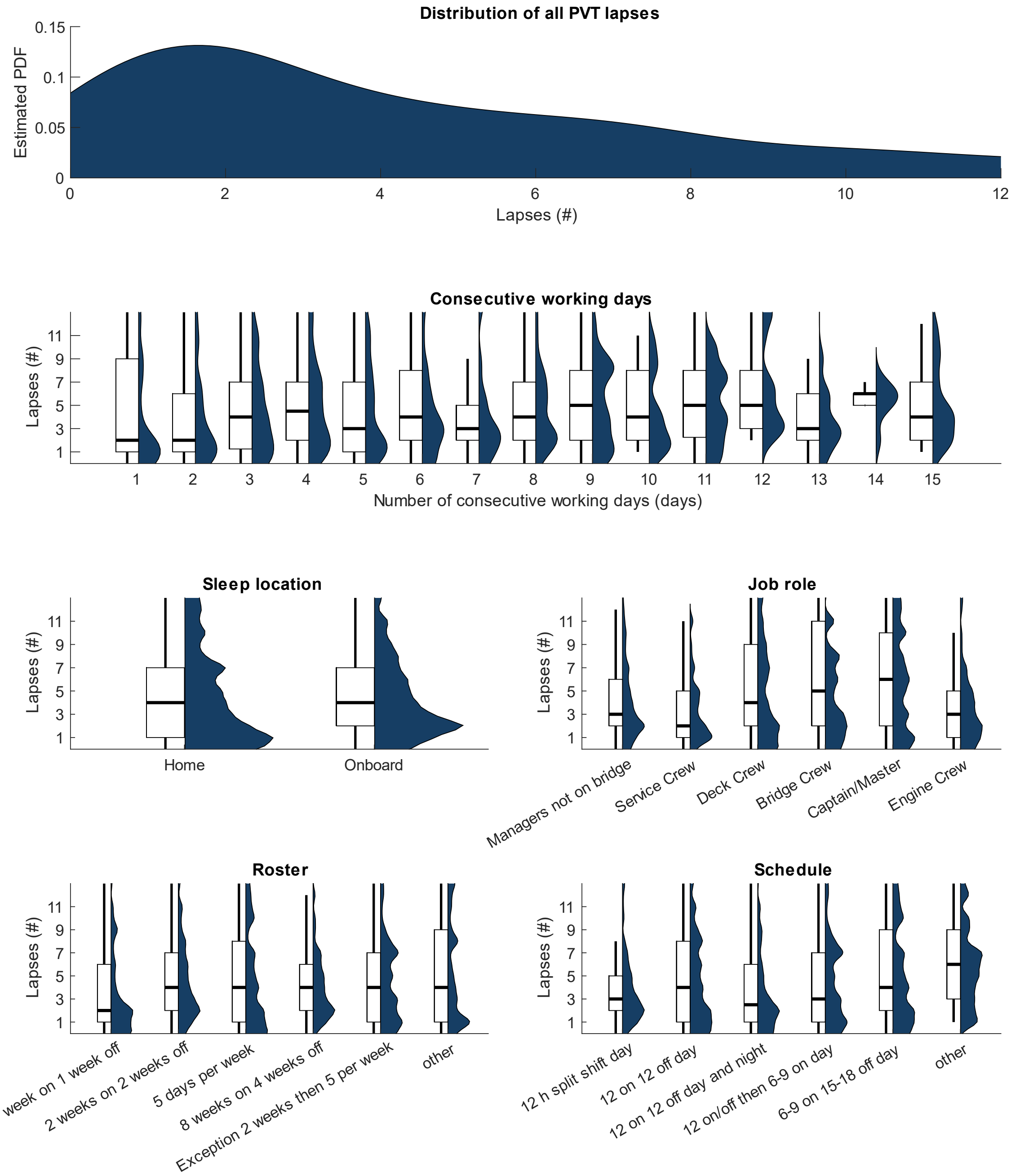
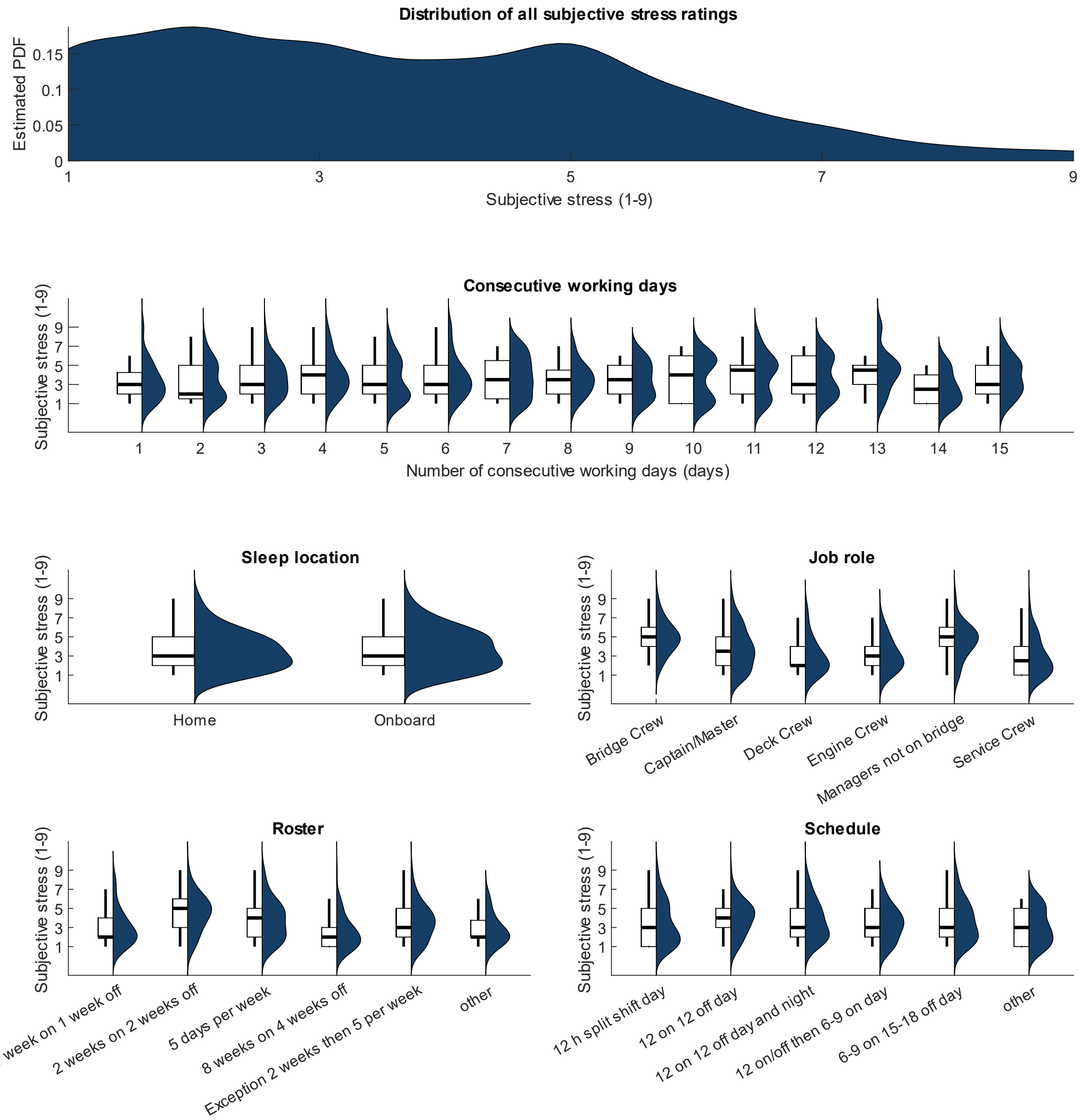


Figure 21: Probability density estimates and box plots of stress ratings as a function of the dependent variables sleep location, number of consecutive working days, job role, schedule type, and roster type, respectively (n=485)


Distribution of all subjective stress ratings
Estimated PDF
0.15
0.1
0.05
0
1
3
5
7
9
Subjective stress (1-9)
Consecutive working days
Subjective stress (1-9)
9
7
5
3
1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Number of consecutive working days (days)
Sleep location
Home
Onboard
Job role
Bridge Crew
Captain/Master
Deck Crew
Engine Crew
Managers not on bridge
Service Crew
Roster
1 week on 1 week off
2 weeks on 2 weeks off
5 days per week
8 weeks on 4 weeks off
Exception 2 weeks then 5 per week
other
Schedule
12 h split shift day
12 on 12 off day
12 on 12 off day and night
12 on/off then 6-9 on day
6-9 on 15-18 off day
other

Annex E: Research Summary

BMM Workshop Six participants, from six operators Two-hour discussion (face to face)	• BMMs are not used in seafaring. • Rosters are planned to meet regulatory and commercial requirements and the needs of specific routes • Legal compliance does not guarantee good fatigue management • BMMs may have limited value in seafaring due to the impact of the weather, dynamic changes to shifts and variations in work intensity
Maritime Survey 446 seafarers from 10 operators Open to all (online) Available in English, French and Ukrainian	• Over 50% of crew fight sleepiness at work at least once a month • OSS crew have the most tiredness and the lowest sleep quality • Over 18% of all seafarers fell asleep on duty in the previous year • Over 40% of seafarers had a fatigue-related incident/accident within the previous 10 years. 85% did not tell their employer that fatigue was a factor • Fewer than 10% of seafarers have had training in fatigue management
Manager Interviews 11 participants Masters and Bosuns 30 – 45 minutes (online)	• The culture within maritime does not support open discussion of fatigue, admission of fatigue is often equated with weakness among crew • Day – night shift transition and noise and vibration affecting sleep are common causes of fatigue • Minimum rest requirements (10 hours) are seen as generally adequate to enable sufficient sleep • There is minimal formal fatigue training
Focus groups 45 participants (nine groups: seven onboard, two online) Customer facing staff (OSS/AB) One-hour discussion (face to face)	• The culture around reporting and managing fatigue is variable across operators and vessels Fatigue is increased by weather, noise and vibration, shift swapping and overrun, commuting and aspects of shift/roster e.g. first shift on • Safety training drills can occur during rest time • Emergencies can increase fatigue. Crew do not consider that fatigue would impact their ability to respond in an emergency • There is minimal training in management of fatigue
Field study (four weeks) Fitbit sleep tracker Daily (online) sleep diary KSS scores on work days PVT (3 min) pre & post work 63 participants, three operators 13 female, 50 male 33 live-on board, 30 go home A range of job roles	• 33% have to fight to stay awake on a monthly basis • 27% of shifts had KSS≥7 • Participants working 2 weeks on/2 weeks off had more shifts with KSS≥7 than other patterns • Sleepiness level KSS≥7 occurred more frequently than predicted by FAID (12%) and SAFTE Fast (10%) • Actual work hours often deviate from planned hours • Shorter sleep durations were found for 8 weeks on 4 weeks off • Shortest sleep durations were found with 12 hour split shift