

***FATIGUE IN FERRY CREWS:
A PILOT STUDY***

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ABSTRACT

Since the 1950s, the shipping industry has undergone profound changes, comparable in scale to those resulting from the advent of steam in the last century. This transformation has been shaped by many historical events and facilitated by the introduction of new technology and new commercial, operational and managerial practices, and it has clear implications for current research into the causality of marine accidents; technological developments, for example, have led to the so-called 'radar-assisted collisions'.

It is often said in the industry that 70-80% of maritime accidents are attributable to human error. What is less well known, however, is that in the majority of these cases, the factor which has consistently been identified as a major contributory link in the chain of events leading to an accident, is fatigue. Because of this, it is important to continue research into the causes and incidence of fatigue in seafarers.

The objectives of this pilot study were: to investigate the quality and quantity of sleep among crew employed on the short-sea ferry sector; to evaluate the extent to which poor quality sleep occurs; and to identify the factors contributing to poor sleep quality.

The subjects of the study were 12 crew members of different rank and with different work patterns from two UK-flagged short-sea pax/ro ferries. Background information on the participants was collected via questionnaires. Data on the duration and quality of sleep were collected by the use of wrist-worn actimeters and by self-report sleep logs, while self reports of alertness were collected at two-hourly intervals during each wakeful period. All the above data were collected during a complete tour of duty comprising one week at sea followed by one week of leave.

The week-on / week-off work schedule allowed comparisons to be made between the sleep patterns of a working week at sea and those of a rest week at home. The findings indicate that differences in both sleep quality and duration of sleep between the work and non-work weeks were greater for those crew members required to work split

shifts. Furthermore, they experienced greater sleep disturbance and generally shorter sleep periods than crew members who worked a single shift every 24 hours.

The statistical analyses presented in the current study show a significant difference in the total number of hours sleep between the home and work schedules, and reveal a similar difference in the incidence of sleep disturbance.

While further and more substantial examination into different shift patterns is required, there are already clear indications of a need to reappraise traditional watch regimes on board. This pilot study is the first phase of an extensive investigation into sleep and fatigue in seafarers' work patterns, which is being carried out under the name of SEAFATIGUE. It is to include personal and environmental factors and is to be conducted within different shipping sectors of deep-sea and coastal trade.

The final objective of the SEAFATIGUE project is to provide the maritime industry with a resource of detailed technical data on fatigue among seafarers, in order to facilitate the formulation and implementation of sound, proactive policies in areas of employment practices, manning levels, shipboard ergonomics, shiftwork patterns and the training of seafarers in fatigue management.

This pilot study is the result of a joint collaborative project between the Sleep Research Laboratory at Loughborough University and the Seafarers International Research Centre at the University of Wales, Cardiff.

Keywords: Sleep, Fatigue, Sleepiness, Actimetry, Disturbance

ACKNOWLEDGEMENTS

The research team is particularly grateful to all those who were prepared to offer their assistance in this first phase of the SEAFATIGUE study, namely the 12 seafarers involved, the owners of the pax/ro ferries, Professor J.A. Horne, Professor A.D. Lane, Professor A. Couper, Captain C. Walsh, Miss A. Griffiths and Mr. B. Obando-Rojas.

INTRODUCTION

The world-wide concern over the effects of fatigue in the transport industry is apparent in the research into sleepiness and accidents that has been carried out with particular reference to the road-transport and air-transport industries (*Work Hours, Sleepiness and Accidents: Journal of Sleep Research, Vol. 4: Entire Supplement No. 2, 1995*). This and other such research has resulted in the introduction of improved regulations for hours of work and rest periods for professional drivers and airline pilots.

Since the 1950s, the civil aviation industry has invested considerable research and development resources in the area of safety, with particular emphasis on the human element. In contrast, the shipping industry allocates a much smaller budget in this field, only until recently addressing the issue.

Recent investigation into marine accidents and their causes suggests that around 80% of these are caused by human error. The Donaldson report, moreover, points to human error as the root cause of virtually all accidents (Donaldson, 1994). Even though the chain of causation in marine accidents is long and complex, fatigue has recurrently been identified as either the primary cause or a major contributory factor. The same is true for near-misses and unsafe practices. Too many accidents result in loss of life (as in the case of *Herald of Free Enterprise*) or major incidents of pollution (as in the *Exxon Valdez*), as well as representing enormous costs to shipowners, shippers and society in general. Widely publicised accidents, however, give just a small indication of the many other incidents attributable to fatigue that go unreported.

In recent years, the number of marine accidents and their consequences have forced the shipping industry and its regulatory bodies to reappraise their position regarding safety at sea. The current concern to make marine transport both safer and more efficient has seen a shift from a predominantly technological approach towards an increasingly human-orientation. The measures taken so far include regulations governing training, certification, and the working hours of seafarers, as well as the introduction of quality

standards by shipowners and shipmanagers. The introduction of new guidelines for the investigation of marine accidents has also been instrumental in identifying the causes and extent of fatigue within the industry.

Regulations on Working Hours and Rest Periods for Seafarers

The main measure taken by the industry against fatigue among seafarers has been the introduction of regulations on working hour limits and rest periods. In the past, this approach has had little impact, due to the low levels of participation of Flag States in ratifying relevant international conventions, the ineffectiveness of enforcement mechanisms in port states, and the lack of a holistic approach in addressing the root causes of fatigue.

The first international convention dealing with seafarers' working hours was the International Labour Organisation (ILO) Convention 109 (1958) on Wages, Hours of Work and Manning (Sea). The practical outcome of this Convention, however, was nil; as only 15 member states ever ratified it, it never came into force.

In 1996, as a replacement for Convention 109, the ILO Maritime Conference adopted Convention 180. This Convention applies to all seafarers on board (watchkeepers and day workers). Under the provisions of ILO 180, signatories to the Convention must implement EITHER a maximum working limit of 14 hours in any 24-hour period and 72 hours in any seven-day period OR a minimum of 10 hours' rest in any 24-hour period and 77 hours' rest in any seven-day period. Convention 180 allows parties to grant exemptions from these rules, based on the type of trade, leave arrangements, etc. Work schedules must be posted and records of working hours kept for inspection. To date, ILO 180 has not come into force and will do so only when a minimum of five member states ratify it.

A protocol to ILO Convention 147 (Minimum Standards Convention), adopted in 1996, incorporates the provisions of ILO 180 as a measure of inspection of labour

standards. The implications of this are that, once a member state ratifies ILO 147, its Port State Control will be able to inspect vessels to ensure that requirements of ILO 180 are adhered to by all national and foreign vessels calling at their ports, independently of whether the vessel's flag administration has ratified the convention or not.

In addition to ILO regulations, the International Maritime Organisation (IMO) has addressed the issue of fatigue and rest hours through its Convention on Standards of Training, Certification and Watchkeeping (STCW), as amended in 1995, and the International Safety Management (ISM) Code. The revised STCW Convention applies only to officers and ratings on watchkeeping duties. It does not apply to dayworkers, including the master of the vessel or the chief engineer. More often than not, these two key persons are overworked and are liable to be affected by chronic and acute fatigue. The fitness for duty requirements (Reg VIII / 1) prescribes that watchkeepers must have a minimum of 10 hours' rest in any 24-hour period, divided into no more than two periods, one of which must be at least six hours long. The 10 hours' minimum rest in 24-hours may be reduced to 6 consecutive hours, provided this reduction is only for 2 consecutive days and provided not less than 70 hours' rest is provided each seven-day period. Watchkeeping schedules must also be posted. The STCW regulations came into force in February 1997.

The ISM Code is an international standard for establishing a system for shipowners to ensure the safe management and operation of vessels and safeguard against pollution. The ISM addresses human involvement in the shipping industry, both at sea and ashore. One of its stated objectives is to prevent human injury or loss of life, both of which can occur through fatigue.

There are evident ambiguities and overlaps between ILO 180 on hours of rest or work and STCW prescriptions of minimum rest. The former may create difficulties in implementation because of the exemptions allowed, while the latter does not provide detailed guidance on working-hour regulations.

Furthermore, other maritime administrations enforce their own limits, which undermines the effectiveness of global regulations. For example, the United States of America, under the provisions of the Oil Pollution Act 1990 (OPA-90), has its own unilateral regulations governing work/rest periods, viz., 15 hours in each 24-hour period and no more than 36 hours in a 72-hour period, for all vessels calling at US ports.

The standards set in the STCW Convention already in force are applicable on an almost global basis, as 132 member states have ratified the Convention. In contrast, ILO Convention 180 has still to be ratified to come into force. The European Union may, within the next 18 months or so, incorporate the ILO provisions into European Law with the aim of enforcing it through port state control.

It remains the responsibility of signatory states to provide the pertinent national statutes to implement regulations set out in international Conventions. In Great Britain, the Maritime and Coastguard Agency (MCA) issues statutory Merchant Shipping Notices (MSN), giving guidance on the application of regulations. The mandatory prescriptions governing fatigue are contained in MSN 1682 (April 1997) in accordance with regulations specified by the Secretary of State under the Merchant Shipping Regulations (Safe Manning, Hours of Work and Watchkeeping) to implement STCW Convention requirements on rest periods. The regulations apply to all seagoing United Kingdom registered merchant ships and to foreign ships when they are in UK waters. Ships that fail to comply with these regulations may be detained until deficiencies are dealt with to the satisfaction of the UK authorities.

The crews participating in this pilot study are governed by MSN 1682, and therefore adhere to the minimum STCW fitness-for-duty requirements.

Previous Research into Fatigue Among Seafarers

From the *Torrey Canyon* to the *Exxon Valdez*, the incidence of marine accidents highlights the urgent need to investigate current work hours and watchkeeping systems that have been followed without any major modification since the last century when conditions onboard were totally different from the reality of life at sea today.

Other less well known accidents give first hand evidence of the disastrous effects of fatigue and unsound regulations. In July 1996, the *Peacock* a reefer operating in Australia with dispensation from its maritime administration for One-Man Bridge Operation (OMBO), ran aground in the Great Barrier Reef. Investigations into the accident concluded that the pilot had failed to alter course. This was caused by the pilot having fallen asleep 15 minutes before the incident took place only to be woken by the impact of the grounding.

In March 1997, the *Cita* a German-owned feeder containership, ran aground off the English Channel. The mate, who was keeping a one man bridge watch at night, had fallen asleep in the wheelhouse two and a half hours before going aground. The official investigation into the accident revealed that the solo watchkeeper was short of sleep due to the shipboard regime. The *Cita*, as many other shortsea ships, was being operated with only two watchkeepers on a six-on, six-off regime.

Several studies conducted in Europe and America have researched the extent of fatigue among seafarers working in different sectors of the merchant navy and the armed forces. These studies have provided the scientific literature on which regulations have been drafted.

Investigation of the causes and effects of fatigue at sea are complicated not least because of the huge variation world-wide in ship types, trades, manning levels and living conditions on board ship. To reach any meaningful conclusions on fatigue among

seafarers it is therefore necessary to examine the different sectors of the shipping industry.

Recent studies have used different approaches into measuring fatigue and analysing the impact of different watch patterns. Rutenfranz, et. al. (1988) used self-report measures; Condon, et al., (1984) measured physiological processes; while Colquhoun, et. al. (1988) used a combination of physiological, behavioural and self-report measures.

Sanquist, et al, (1997) carried out a survey on mariners from tankers and dry cargo ships sailing between ports on the US West coast. Based on the collection of work and sleep patterns, the study concludes that there is a fatigue problem in the shipping sectors analysed. The key features identified by the study as characteristic of the sleep of seafarers are:

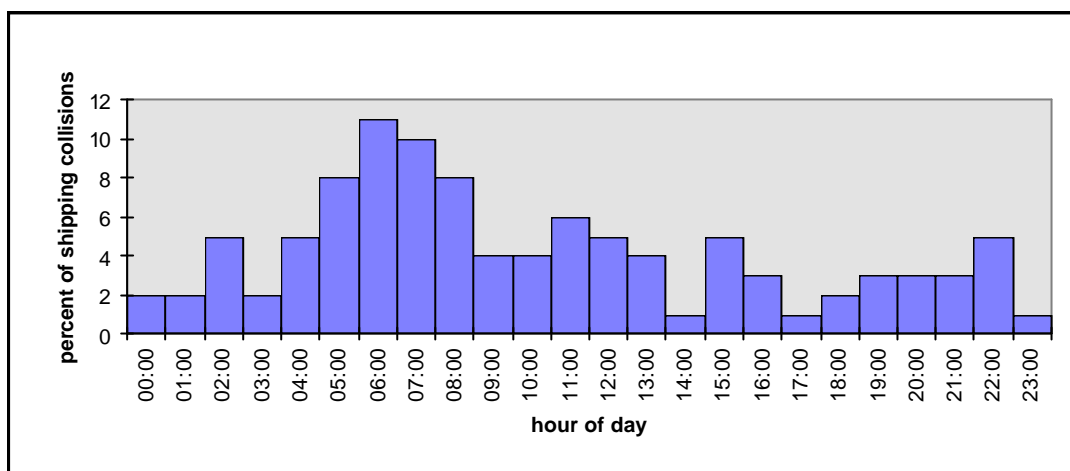
- An overall reduction in sleep time between working at sea (6.6 hours) and at home (7.9 hours).
- Fragmented (and therefore poorer quality) sleep
- Having to attempt to sleep at physiologically inappropriate times
- Insufficient breaks for rest between shifts
- Poor sleep quality in the main sleep period (due to environmental conditions, e.g. noise)
- Long work days
- Watchkeepers slept less and their sleep was of poorer quality than that of day workers

These findings suggest that the 4-on, 8-off watchkeeping pattern is the primary contributor to the fatigue problem. Sanquist et al. also report that seafarers show an inconsistency in alertness levels over the day, with a substantial drop in alertness in the 2000 to 0000 watch, overestimated alertness on the 0000 to 0400 watch, and a significant decline in alertness on the 0400 to 0800 watch. These findings are consistent

with statistics collected by the insurance sector on the incidence of shipping collisions at each hour of the day (Figure 1).

Fig 1. Incidence of Shipping Collisions at Each Hour of the Day

(UK P&I Club, 1992 at Sanquist et al, 1997)



Brown (1989) researches into the justification for regulating hours of work at sea and gives guidance to policy-makers on the form that such regulations should take. The report highlights the need for objective evidence of fatigue at sea, advising on a complete redesign of marine accident reporting and investigation. On all circumstances all detailed information should be collected on all factors linking fatigue to safety. For example, in order to determine if an accident could be attributed in whole or in part to fatigue all accident reports should include information on watchkeeping patterns, exact time of incident, how long the crew member had been on watch, and the duration of the watchkeepers' sleep/rest periods in, at least, the 48 hours prior to the incident.

Although this information cannot prove conclusively that fatigue was wholly or partly to blame in any incident, it can be used as an invaluable insight to what may have happened, and in terms of fatigue/sleepiness, is vitally important. Such information has been particularly useful in recent research into sleepiness related vehicle accidents (Horne & Reyner, 1995), and may help to explain many shipping accidents.

Brown also proposes a series of regulations encompassing minimum rest and work periods, applicability of regulations, record and inspection of watchkeeping time

records, and the liability of masters and shipowners. Most of these were incorporated in the final regulations of the STCW and ILO 180 Conventions.

The problem of fatigue at sea is further exacerbated by the lack of awareness among crew members of work hours regulations, as well as the general causes and implications of fatigue. To date there are no mandatory regulations prescribing training on management of fatigue for seafarers.

A survey carried by the United Kingdom National Union of Marine, Aviation and Shipping Transport Officers (NUMAST) among British seafarers (Give us a Break, 1997) highlights the little impact that new work regulations have had on British seafarers. Around 95% of those surveyed said that their work hours had not reduced as a result of the new hours of work regulations (STCW). 90% said that they worked 10 or more hours per day. 56% said that they considered that their working hours present a danger to health/ safety of the ship.

The International Transport Federation (ITF) carried out another survey among 2500 seafarers of different nationalities (ITF/MORI Seafarers Living Conditions Survey, 1996). The returns evidence long working hours and a widespread fatigue problem. This report also concludes that, despite recent regulations, far more work needs to be done to address the problem of fatigue among seafarers.

In May 1996, The Seafarers International Research Centre (SIRC) convened a research workshop in response to the growing need for a comprehensive review of existing research work on fatigue within the maritime and other transport industries. The discussions were conducted by a group of experts including seafarers and psychologists. The pilot study reported here emerged as a result of the workshop at which quality and quantity of sleep was identified as an initial area for research. The study was conducted on two pax/ro short sea ferries on the Irish Sea. This report outlines the study, its results and discussion with proposals for further long-term study on different sectors of the international shipping industry.

AIMS OF THE STUDY

The main aims of this pilot study were:

1. Investigate and compare the quantity and quality of sleep between day-workers and shift-workers in the short sea ferry sector, both on board and during leave periods.
2. Analyse the extent to which poor quality sleep occurs in the short sea ferry sector.
3. Identify causal factors relating to poor sleep quality.

Other general aims were to evaluate the methodology used in the pilot study for data collection and analysis, and, if necessary, revise it for use in subsequent phases of the project; and to identify other areas of research related to the issues of fatigue and sleep deprivation in the maritime industry.

METHODS

Twelve participant crewmembers were selected and divided into two separate groups of 6. They were examined during one complete tour of duty comprising one week at sea followed by one week at home.

The methodological approach to this pilot study was to combine self-report sleep logs, questionnaires and wrist-worn actimeters to gather data on the quantity and quality of sleep of the crews who volunteered to participate.

Measurement Tools

- **General Questionnaires:** Used to obtain general background information about participants. It was completed by the participants during the week at sea.
- **Log Books:** Used to obtain self-reported sleepiness data, sleep timing and duration. The log books covered the 7 day work schedule and were completed every day to show participants' work/rest activities. Each day also featured a self-assessment sleepiness scale. (The Karolinska Sleepiness Scale, KSS, Akerstedt & Gillberg,

1990) which participants completed every two hours. This is a scale which ranges from 1 ('Extremely Alert') to 9 ('Very Sleepy, great effort to stay awake, fighting sleep'). Participants are asked to rate their level of sleepiness and alertness on a scale 1-9. This scale has been used extensively in sleep research, to obtain self-reported day time sleepiness data. Participants completed two log books, the first one at the end of the week at sea and the second one at the end of the week at home.

Figure 2. The Karolinska Sleepiness Scale - Akerstedt & Gillberg, 1990

1. Extremely alert
2. Very alert
3. Alert
4. Rather alert
5. Neither alert nor sleepy
6. Some signs of sleepiness
7. Sleepy, but no effort to keep awake
8. Sleepy, some effort to keep awake
9. Very sleepy, great effort to keep awake, fighting sleep

- Actimeters: Used to determine the quality and quantity of participants' sleep. Each volunteer wore a wrist worn actimeter similar in size and weight to a wrist-watch for the two-week testing period. Data from the actimeter was downloaded to a control computer at the end of the week at sea and again when returning back on board after the week of leave. The actimeter is considered one of the least intrusive measurement instruments. The only operation required from the participant is to press an 'event' button on the top of the actimeter once when about to go to sleep, and then again upon waking up. The actimeters measure movement in 30 second epochs.

Selection of Ships

Because of the general aims and nature of the study, a short sea route was selected. The research team received the generous co-operation of a shipping company operating short sea pax/ro vessels in European waters. Access to the crews of two such vessels

was granted to the research team. To ensure confidentiality to participants neither the ships or the company are identified by their names.

Table 1: Ship description

	Ship 1	Ship 2
Ship Type	pax / ro	pax / ro
Capacity	1832 pax / 515 cars	2100 pax / 500 cars
Year Built	1980	1986
Type of trade	short sea pax / ro ferry	
Area	European waters	
Ship Schedules	2150 - 0120 at sea 0120 - 0315 port 0315 - 0645 at sea 0645 - 0900 port 0900 - 1230 at sea 1230 - 1500 port 1500 - 1830 at sea 1830 - 2150 port	

Ships deployed on this route do four crossings in any 24 hour period. The steaming time for each crossing is approximately 3.5 hours. The turnaround time in port is between 2 to 3 hours. The evening stop the longest of all (1830 - 2150; 2h 30 min) and this is the period when safety drills are carried out.

The shipowning company operates a large fleet of ferries deployed in fifteen different routes in North West Europe. The fleet is operated and maintained to the highest standards, exceeding all European and international regulations on management practices, safety, manning and pollution. The safety record of this company is excellent. To date, no vessel owned or chartered by them has ever been involved in any major marine accident.

There was no marked distinction between the standard of accommodation and amenities available to the crew on either of the ferries. The crews' living quarters conform to international standards on minimum area, vibration and noise levels, lighting, ventilation, and safety regulations. The standard of crew accommodation on board both ships is satisfactory and there is no evidence of any serious deficiency that may affect negatively the crews' sleeping patterns. Nevertheless, some crewmembers reported a degree of sleep disturbance caused by the noise of cargo operations while at port.

The ferries participating in this pilot study were predominantly manned by British and Irish nationals, hence the multicultural element, characteristic of other shipping sectors, is less marked. English was the official language on both ships.

The Participants

The subjects of the study were 12 mariners, 6 from each ship. Data were collected during the tour of duty comprising one week on board followed by one week leave at home.

Taking into account that the ferries operate on round-the-clock schedules, the study included dayworkers and shiftworkers in order to allow comparison on sleep patterns. Table 2 gives a summary of the participants and job descriptions. One crewmember per ship was drawn from the listed categories. Data from corresponding categories was then matched for the two ships. Appendix 1 shows the literature used to brief volunteers for the study.

Table 2. Position and job description of participants

Position	Watch schedules	Reported working hours per week	Responsibilities (STCW based)
Master category: dayworker, command	0800 - 2130	<ul style="list-style-type: none"> • ship 1: 90 hours • ship 2: 98 hours 	at management level: <ul style="list-style-type: none"> • navigation • cargo handling and stowage, • controlling operation of the ship, • care for persons on board
Mate / Master category: shiftworker command	2030 - 0400 0600 - 1000	<ul style="list-style-type: none"> • ship 1: 98 hours • ship 2: 84 hours 	at management level: <ul style="list-style-type: none"> • navigation • cargo handling and stowage, • controlling operation of the ship, • care for persons on board
2nd Officer category: shiftworker	1130 - 1730 2130 - 0330	<ul style="list-style-type: none"> • ship 1: 84 hours • ship 2: 98 hours 	at operational level: <ul style="list-style-type: none"> • navigation • cargo handling and stowage, • controlling operation of the ship, • care for persons on board
2nd Engineer category: shiftworker	1200 -1800 0000 - 0600	<ul style="list-style-type: none"> • ship 1: 84 hours • ship 2: 84 hours 	at management level: <ul style="list-style-type: none"> • marine engineering, • electrical, electronic control engineering, • maintenance and repair • controlling operation of the ship, • care for persons on board
3rd / 4th Engineer category: shiftworker	0000 - 0600 1130 - 1600	<ul style="list-style-type: none"> • ship 1: 75 hours • ship 2: 74 hours 	at operational level: <ul style="list-style-type: none"> • marine engineering, • electrical, electronic control engineering, • maintenance and repair • controlling operation of the ship, • care for persons on board
Hotel Repair Man category: dayworker	0700 - 2100	<ul style="list-style-type: none"> • ship 1: 84 hours • ship 2: 90 hours 	at support level <ul style="list-style-type: none"> • maintenance and repair

All crewmembers participating in this study comply with the minimum rest period (70 rest hour per week implying a maximum of 98 working hours per week) prescribed by the STCW Convention. Their working hours are divided between watchkeeping duties, routine work outside watchkeeping hours and overtime arising from the round-the-clock operation of the ferry. Routine work includes planned maintenance and paperwork while overtime covers arrival and departure manoeuvres, safety drills, and any emergency situation falling outside normal working hours. Except in the case of a life or safety threatening emergency, rest hour limits are strictly adhered to.

The watchkeeping regime kept on board the ferries is designed to accommodate the operation schedule of the ferry taking advantage of the relative short tour of duty on board (one week). Hence watchkeepers do not observe the traditional 4&8 or 6&6 watch regimes used in other sectors.

All participants were male. The mean age was 43.2 years. The age range being from 31 to 50 years. On average, participants had worked 24 years at sea and 9 for the company.

The list of responsibilities of the different crewmembers is based on the task division of STCW competence regulations. The category classification divides crewmembers between dayworkers and shiftworkers. The master and master/mate are further categorised as command personnel as they are required to be on the bridge when making a landfall and for piloting the vessel in and out of restricted waters. Additionally, according to established bridge procedures, they are on 24-hour call in case of encountering heavy traffic, reduced visibility, exceptionally heavy weather, in the event of propulsion and navigation equipment failure, in the event of a general emergency, and at any time when the watchkeeper on the bridge is in doubt as to what is the best course of action to follow.

Because of the relatively short crossing distance a great part of it is done in restricted waters. Whether the high level of stress that this will bring in the bridge team contributed to fatigue and sleep disturbance was not determined in this pilot study.

During the period data were collected on board, there were no reports of heavy weather or any other abnormal situation, e.g. an emergency, that may have affected negatively the quality and quantity of sleep of the participant mariners.

PROCEDURE

The different types of data were collected in two phases. Phase 1, corresponding to ship 1, took place in February 1997 while phase 2, corresponding to ship 2, took place in July 1997. The research protocol was similar on both vessels.

Six volunteer mariners from each vessel wore actimeters for one week at sea, and one week at home. They were asked to complete background information questionnaires regarding their sleeping habits and use of stimulants, e.g. caffeine. (see Appendix 6 for background questionnaire data). Participants also filled pocket-sized log books (see appendix 5) with supporting information on work / rest activities.

For phase 2, the research team decided to incorporate a Karolinska Sleepiness Scale in the logbook which respondents were requested to complete at two hour intervals.

In both phases, three members of the research team went onboard to explain the nature of the study and introduce the research protocol to the participants. For phase 2, one researcher remained on board the ship for the working week, to facilitate data collection and observe shipboard routine.

The logbooks were distributed to participants on the first day of the working week on board ship and collected by the end of the same week before they went for leave. They were issued with a second logbook to cover the week at home. Similarly, actimeters

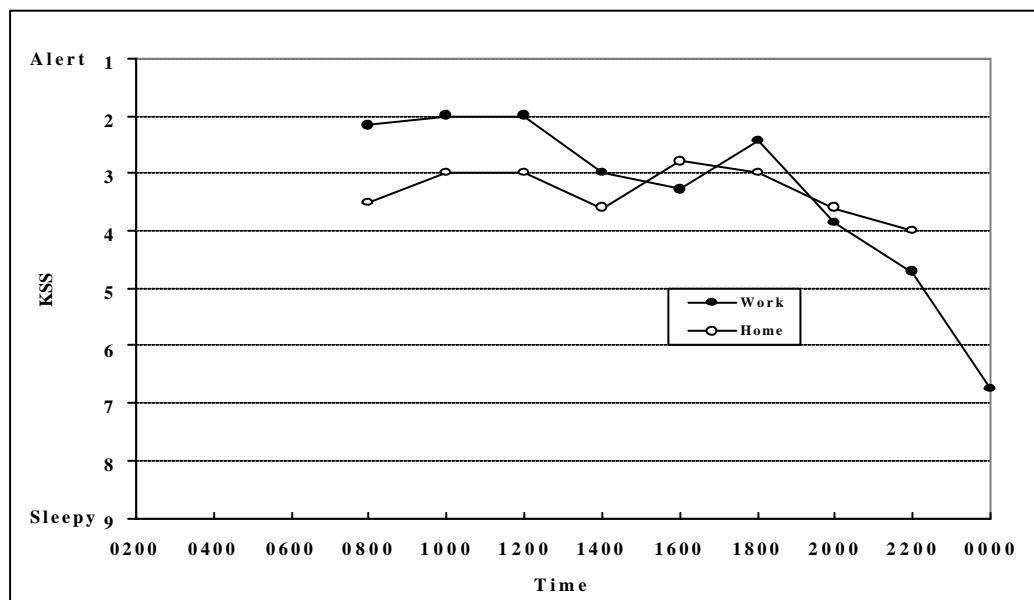
were given to participants on the first day of the working week. Data from the actimeters was downloaded both at the end of the first and second week. The background information questionnaires were completed during the first week at sea.

RESULTS

Self-Report Logbook and KSS Ratings

Figure 4 shows the mean self-reported sleepiness of a typical participant across the 24 hour period, at sea and at home. As the graph shows, during the working week at sea, he remains awake longer, although waking at a similar time, and his alertness deteriorates towards the end of the day more markedly than during the week at home. For safety considerations, participants should not feel a fatigue level equivalent to a KSS index greater than 5 while working at sea.

Figure 3. Participant 10, Mean Self-Reported Sleepiness Ratings



Self -Report / Objective Data

The data below represent the average Sleep Disturbance for all 6 subjects, for each of the 5 subjective sleep quality ratings. The graph of this data clearly shows that there is a relationship between subjective sleep quality ratings and actual sleep disturbance as measured by actigraphy.

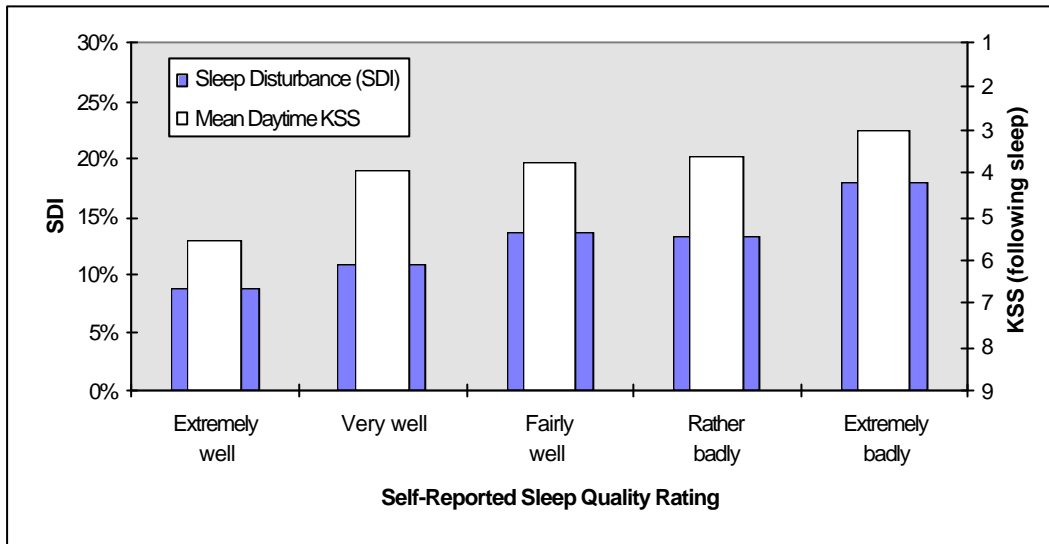
Figure 4. Mean SDI for Self-reported Sleep Quality

(as measured by: Last night I slept.....)



This data can be examined in conjunction with the mean KSS for each period of wakefulness, in order to examine the effects on self reported sleepiness, of a good / bad night sleep. the graph below shows the mean SDIU and mean daytime sleepiness following each of the self-reported sleep quality ratings.

Figure 5. Self-reported sleep quality vs. SDI and mean KSS (n = 6, 14 nights)



Self-reported sleep quality can also be examined in terms of how subjects felt a short time after waking up from their sleep period. The graph below shows this in the same way as above, in conjunction with SDI and the mean KSS of the waking period which follows each sleep.

Figure 6. Mean SDI for Self-Reported Sleep Quality

(as measured by: '15 Minutes after waking I felt.....')



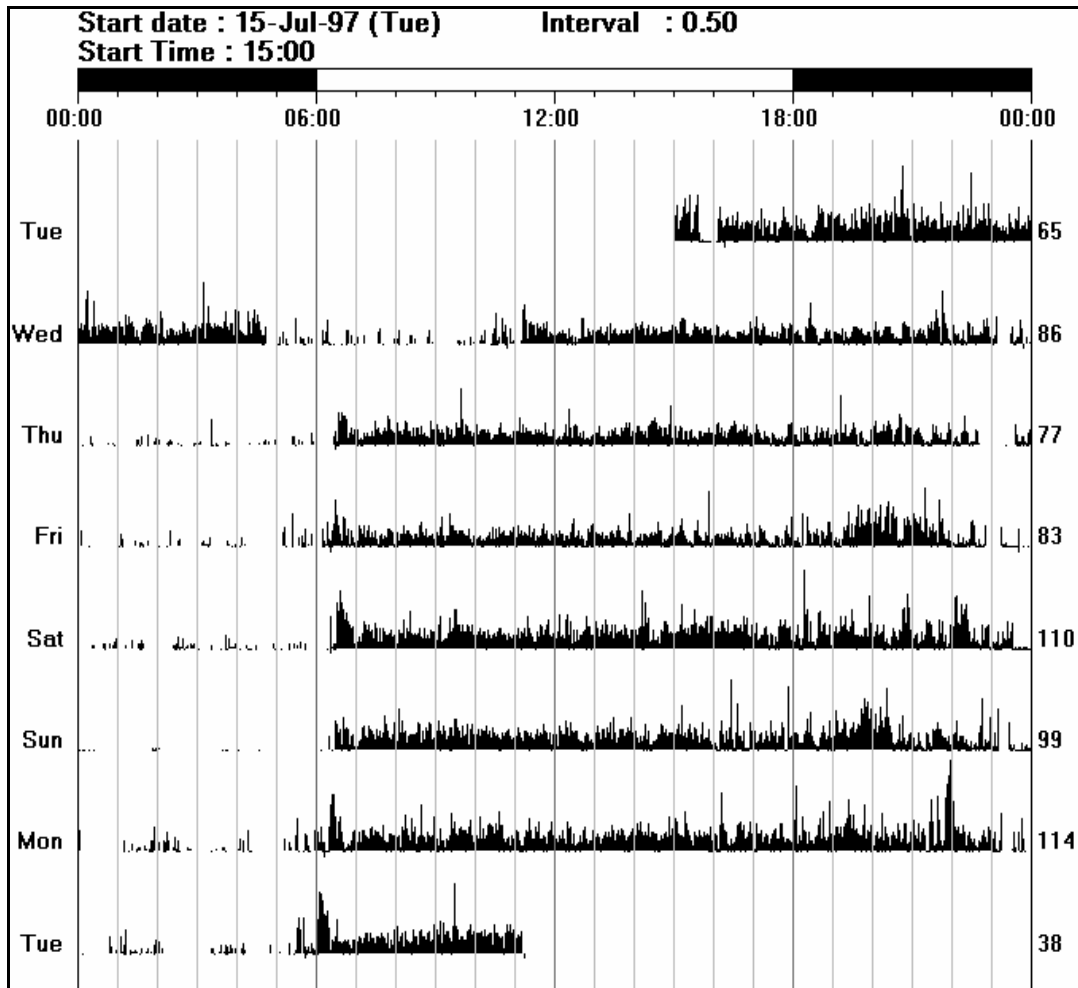
This analysis shows firstly the relationship between sleep disturbance and self-reported sleep quality (i.e. self-reported sleep quality increases as SDI decreases). This is true

for both measurements of self-reported sleep quality (immediately on waking, and 15 minutes after). Surprisingly it also shows that daytime alertness (KSS) following a poor sleep (as measure by SDI and self-reports) actually increases.

Actigraph Data

The actigraph data shows the periods of activity and inactivity throughout the 24 hour period (an example is given in fig.7). From this we can estimate the onset and offset of sleep, the duration of each sleep period, and the percentage of this sleep which is disturbed. The latter is known as the Sleep Disturbance Index, or SDI, and can then be plotted against sleep length. Figure 8 shows sleep length as a vertical bar, while the line is some indication of sleep quality (SDI). Participants can experience a lengthy sleep, but it can be greatly disturbed, and therefore less beneficial.

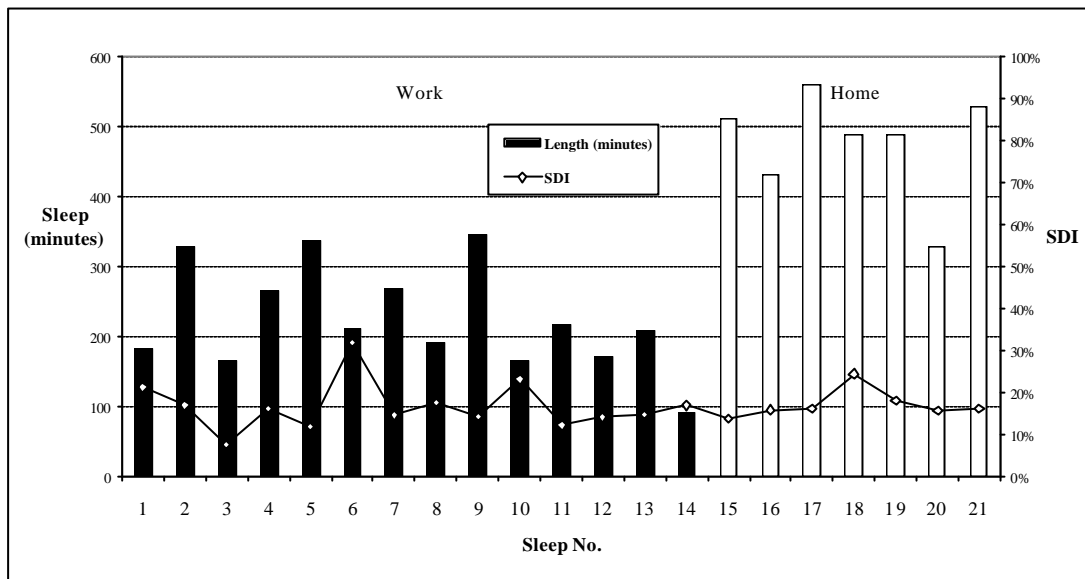
Fig 7. Example of Actigraph Data



The SDI can be compared with the KSS self-reported sleepiness data. For example, when a participant experiences a short sleep with a high level of disturbance, there is increased self-reported sleepiness during the following day (and vice-versa), which is seen in the sleep profile graph (see fig.8), displaying sleep length against SDI for one participant both at work (black) and at home (white).

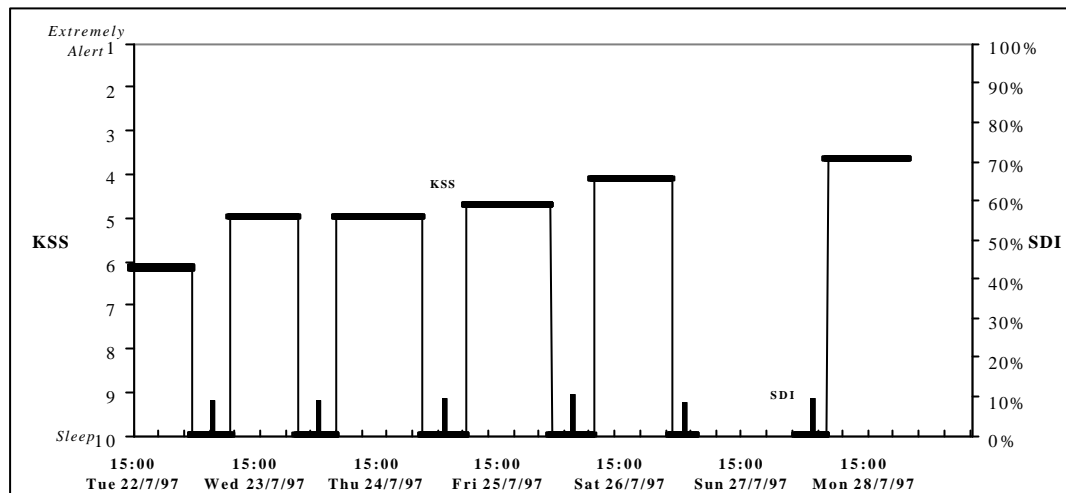
As the graph shows, this participant works a split-shift, and therefore has two sleep periods per day, compared to one per day at home. It is clear from this graph that 1) sleep length is greater and more stable at home than at work, and 2) that SDI is similarly constant at home, and less predictable at sea (see appendix 8 for actigraph data).

Figure 8. Participant 09 Sleep Length vs. SDI



This can be related to the sleep profile graph (fig.9, below) showing the mean KSS ratings for every period of wakefulness (upper black horizontal bars) the length of each sleep period (lower black horizontal bars) and the percentage of each sleep which is disturbed (SDI - sleep disturbance index - vertical black bars). As this graph (of the week at home) shows, although Sleep length and SDI remain reasonably constant throughout the week, the mean KSS at the beginning of the week is below 6 ('Some signs of sleepiness'), and this slowly increases as the week goes on. This demonstrates that it took this participant about 4 days to recover from the working week, and return to a reasonable level of self-reported alertness (i.e. above KSS 5).

Figure 9. Participant 08 Sleep Profile (Home)



The two graphs below show the mean sleep length and SDI per 24 hours for each participant at work (fig. 10) and at home (fig. 11). Participants 01-06 were tested during phase 1, while participants 07-12 were tested in phase 2. The vertical black bars show the mean sleep duration per 24 hours for each participant, at work and at home, while the smaller grey bars show the SDI or sleep disturbance index for the same period. It is immediately clear from the two graphs that firstly there seems to be a difference in sleep length between the home and work periods, and secondly that there is a similar difference for SDI.

Figure 10. Mean Sleep Length vs. SDI (Work)

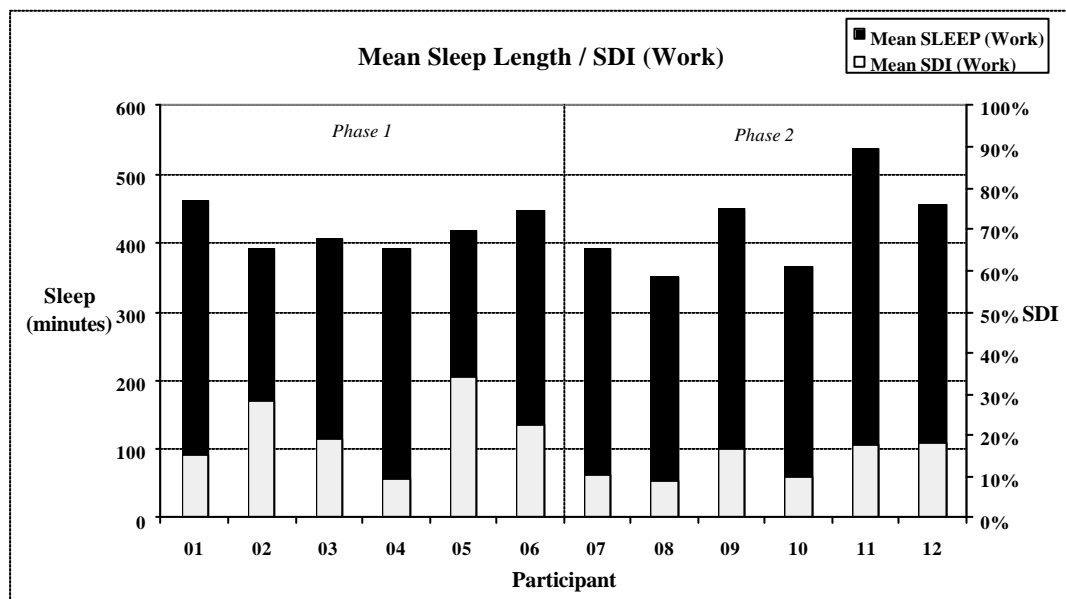
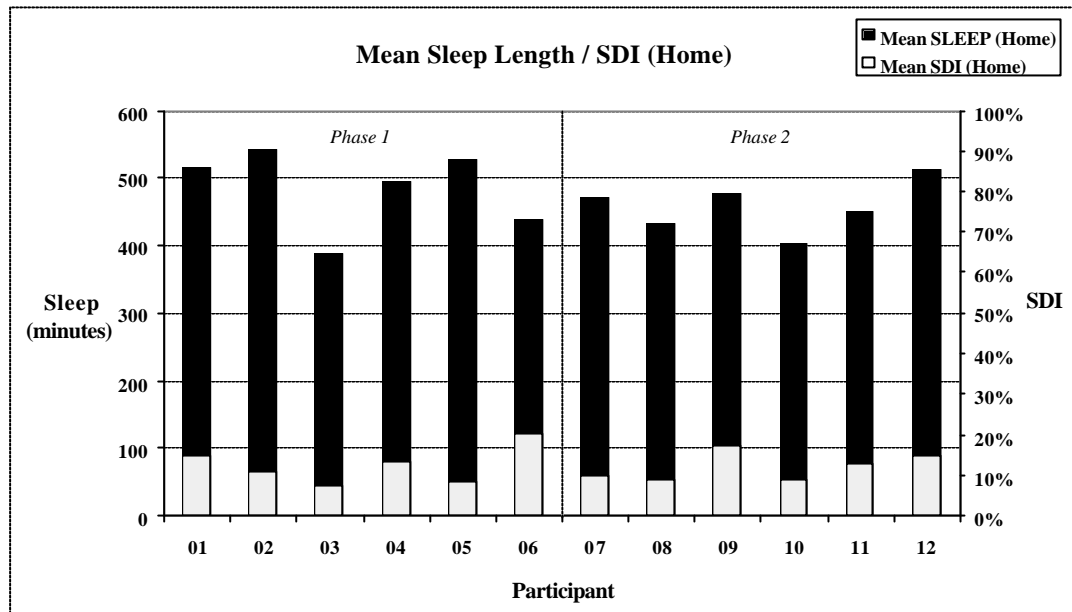


Figure 11. Mean Sleep Length vs. SDI (Home)



STATISTICAL ANALYSIS

Sleep Length

For the group of 12 participants, tested with a repeated measures t-test, the examination of work vs. home produced a significant result ($t=2.65$, $df.=11$, $p=0.023$) for sleep length, i.e. participants slept for significantly longer per 24 hour period at home than at work.

Sleep Disturbance Index

Similar analysis of the work/home data for SDI highlighted a near significant trend towards a difference in sleep disturbance index ($t=-2.09$, $df.=11$, $p=0.061$) i.e. that participants tended to experience more sleep disturbance while at sea than at home.

DISCUSSION

Overall, there appeared to be no serious sleepiness problems on these two ships.

Although the crew had significantly less sleep at sea than at home, and there was a

trend towards similar differences in the sleep disturbance index (i.e. participant's sleep was generally more disturbed at sea than at home), their daytime sleepiness measurements did not reveal any serious difficulties. However, as the KSS data from the logbooks shows, there is evidence to support an increase of self-reported sleepiness over the week at work. This in turn would suggest that performance would deteriorate. Hence there is a need for measures of performance in order to ascertain the true impact of any fatigue problem on different aspects of the seafarer's job.

This study probably represents 'the best case scenario,' and there is much need for further research into more problem areas of the industry. Therefore this study is important in terms of its use as a marker for a relatively 'good ship' in terms of fatigue etc. Investigations should be made into other areas of the shipping industry, using some of the methods developed in this study. This and related research could be applied to the controversial use of one-man bridge operations, as used in Australian waters along the Great Barrier Reef, exemplified by the grounding of the *Peacock* in July 1996.

However, there are some problems with the study design. Because of the small sample size, it was not possible to reach any conclusions about differences between the sleep of the shiftworkers and the non-shiftworkers.

It was useful to have the researcher on board during phase two of the study. The participants became familiar and were able to provide him with information. One participant aboard ship 1 mentioned the completion of work logbooks: 'that it takes longer as the shift goes on.' Another participant noted that there was no time between sleep and work to wake up, that 'work starts straight away, when we are not at our best, mentally.....it takes 12-15 minutes to wake up mentally.' Other (split-shift) participants claimed that the 'by the time your mind is working at it full rate, it is time to relax.' This causes other distractions to be made worse. Participants would like to work for longer, and then have more time off. They also suggest that the asymmetry in alertness between those coming onto-, and those going off-watch, causes problems.

Although this study produced a good response rate from participants regarding self-report data, this may be attributed to the presence of the researcher on board ship during phase 2 of the study, which leads us to suggest having reward systems, with incentives to improve response rates. Also this could be used to help in the collection of actimeter data, as participants can sometimes forget to replace actimeters after bathing etc., and this leaves 'gaps' in the data.

CONCLUSIONS

This investigation indicates that the methodologies employed within are effective, and suitable for testing seafarers while at work (at sea) and at home. There is no real evidence to suggest that there is a severe problem with fatigue aboard the ships studied. This study can contribute towards a standard with which to measure fatigue etc. aboard other types of ship, in other trades.

There is further need to conduct parallel research, on anecdotal evidence, and fatigue-related marine accident reports. Clearly there is strong support for Brown's (1989) suggestion that more information relevant to circadian factors is required in the investigation of accidents, and that this information should be logged for all watchkeepers, and available for monitoring by the Master of the ship. Recently there has been more work done on investigating fatigue among seafarers. Reports such as the 'Seafarer Fatigue: Wake up to the Dangers' publication from the ITF, and other survey based research is successfully creating awareness of the problem. But the full extent of fatigue in the maritime industry is not yet clear, due to the lack of vital information relevant to circadian biological rhythms and also a lack of any evidence on the problem. More systematic detailed investigations and investigations of fatigue on different ship types and in different areas of the world are necessary.

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