

**ADEQUATE CREWING AND SEAFARERS' FATIGUE:
THE INTERNATIONAL PERSPECTIVE**

Professor Andy Smith

*Centre for Occupational and Health Psychology
Cardiff University
63 Park Place
Cardiff, CF10 3AS*

SmithAP@cardiff.ac.uk

ACKNOWLEDGEMENTS

I would like to thank the following people for their helpful comments on an earlier draft of this report:

Devinder Grewal (Australian Maritime College), Laurence Hartley (Murdoch University, Australia), Olaf Jensen (Maritime Medicine, University of South Denmark), Nebojsa Nikolic (Maritime Studies, University of Rijeka, Croatia), Wayne Perkins (Maritime New Zealand) and David Walters (Cardiff University, UK).

The views expressed in the report are those of the author.

TABLE OF CONTENTS		Page
Executive Summary		5-9
1.	INTRODUCTION	10
1.1	Aims and objectives	11
2.	BACKGROUND	11-13
2.1	Concern with seafarers' fatigue	11
2.2	Reports of fatigue at sea	11-13
2.3	Lack of formal research compared to other occupations	13
2.4	Lack of a holistic approach to fatigue	13
3.	FATIGUE: A MAJOR HEALTH AND SAFETY ISSUE	14-17
3.1	Dimensions of fatigue	14
3.2	Risk factors for fatigue	14-15
3.3	Prevalence of fatigue	15
3.4	Fatigue, impaired performance and reduced safety	15-16
3.5	Fatigue and health	16-17
4.	FATIGUE REARCH ON OTHER TRANSPORT SECTORS	18-23
4.1	Road transport	18-19
4.2	Rail transport	19-20
4.3	Air transport	20-21
4.4	Fatigue prevention legislation, recommendations and management programmes for the transport industry	21-23
4.5	Implications of the approach to fatigue in other transport sectors for seafarers' fatigue	23
5.	FATIGUE IN THE MARITIME INDUSTRY	24-37
5.1	Risk factors for seafarers	24
5.1.1	ITF Seafarer Fatigue: Wake up to the dangers	24-25
5.1.2	The New Zealand Maritime Safety Report	25
5.1.3	The Cardiff Programme	25-26
5.2	Prevalence of fatigue at sea	26-27
5.2.1	A case study of seafarers' fatigue	27-29
5.3	Association between risk factors for fatigue and health and safety	29
5.3.1	Disruption of circadian rhythms	29
5.3.2	Working patterns and shift schedules	29-30
5.3.3	Noise and motion	30
5.3.4	Sleep deprivation and reduced quality of sleep	30-31
5.4	Fatigue, accidents and injuries	31
5.4.1	Accidents	31-32
5.4.2	Injuries	32-33
5.5	Performance	33
5.6	Physiology	33-34
5.7	Fatigue and health	34-36
5.8	Summary	36-37

6.	STRATEGIES FOR PREVENTING OR MANAGING FATIGUE	38-43
6.1	ILO 180	38
6.2	Evaluation of the European Working Time Directive	39-40
6.3	The relationship between recorded hours of work, fatigue and health of seafarers	40-41
6.4	Fatigue management systems	41
6.5	IMO Guidance on fatigue	42
6.5.1	Lack of specific, implementable strategies for reducing fatigue	42
6.5.2	Focus on personal fatigue management strategies	42
6.5.3	Conclusions about the IMO guidelines	43
6.6	Houtman et al. (2005): Fatigue in the shipping industry	43
6.7	Failure to act on recommendations	43
7.	OVERALL CONCLUSIONS	44-46
7.1	Established facts about seafarers' fatigue	44
7.2	Further implications of seafarers' fatigue	45
7.3	The way forward	45-46
	REFERENCES	47-60
	APPENDICES	61-74

EXECUTIVE SUMMARY

Background

Global concern with the extent of seafarer fatigue is widely evident everywhere in the shipping industry. Maritime regulators, ship owners, trade unions and P & I clubs are all alert to the fact that in some ship types, a combination of minimal manning, sequences of rapid turnarounds and short sea passages, adverse weather and traffic conditions, may find seafarers working long hours with insufficient recuperative rest. A holistic view is needed of the effects of stress and health factors associated with long periods away from home, limited communication and consistently high work loads on seafarers. In these circumstances fatigue and reduced performance may lead to environmental damage, ill-health and reduced life-span among highly skilled seafarers who are in short supply. A long history of research into working hours and conditions and their performance effects in process industries, road transport and civil aviation, where safety is a primary concern, can be usefully compared to the situation in commercial shipping. The issue of adequate crewing and the effect of fatigue upon health and safety are clearly closely related. This report provides a review of our current state of knowledge of these problems and an evaluation of the extent to which fatigue can be prevented and managed by a variety of means. It aims to form the basis from which to review the principles for establishing safe manning levels whilst also providing an overview of the broader picture of fatigue in the maritime sector.

The Fatigue Process

Factors that induce fatigue, perceptions of fatigue and the outcomes that are associated with fatigue can all be assessed as part of a process. These outcomes relating to occupational fatigue must be viewed as a major health and safety issue. There has been considerable research on fatigue at work with onshore studies showing that as many as 20% of the working population experience symptoms that would fall into the category of extreme fatigue. Many of the established risk factors for fatigue are clearly relevant for seafarers: lack of sleep, poor quality sleep, long working hours, working at times of low alertness, prolonged work, insufficient rest between work periods, excessive workload, noise and vibration, motion, dehydration, medical conditions and acute illnesses. Many of these problems reflect organisational factors such as manning levels or the use of fatigue-inducing shift systems. It is often the combination of risk factors that leads to impaired performance and reduced well-being and few would deny that seafarers are exposed to such high risk combinations. Fatigue also increases the risk of accidents and injuries. In transport industries many jobs are “safety critical” with a strong association between risk factors for fatigue and reduced safety. The health risks associated with fatigue are well established in onshore populations and there is no reason to believe that such associations do not occur in seafarers, although information on this topic is limited and further research would enhance the evidence base.

Reports of fatigue at sea

Despite the strong *a priori case* for fatigue at sea, historically there has been relatively little research on seafarers’ fatigue compared to other transport sectors. In recent years, examples of fatigue at sea, and its consequences, have been more formally documented, not least due to the high profile pollution and accident cases linked to fatigue. Examination of this type of information supports the view that fatigue is a major health and safety issue in the shipping industry with potentially severe environmental and economic consequences. An ITF report (1998), based on responses from 2,500 seafarers of 60 nationalities, serving under 63 flags, demonstrates the extent of excessive hours and fatigue within the industry. Almost two-thirds of the respondents stated that their average working hours were more than 60 hours per week with 25% reporting working more than 80 hours a week. More than 80% of the sample reported that fatigue increased with the length of the tour of duty. Long tours of duty were

also common (30% reporting usual tour lengths of 26 weeks or above). This cumulative fatigue may also reflect the reduction in opportunities for rest and relaxation ashore, due to the reduced port turn-around times now required.

Risk factors for fatigue and the prevalence of fatigue

The *Cardiff Seafarers' Fatigue Programme* (Smith, Allen and Wadsworth, 2006) confirmed that there are a number of risk factors for fatigue, such as: tour length, sleep quality, environmental factors, job demands, hours of work, nature of shift, and port frequency/turnaround time. The likelihood of reporting impaired health as a result of fatigue increases as a function of the frequency of exposure to risk factors (e.g. 1-2 factors doubles the risk of being highly fatigued but 7 or 8 factors increases the risk 30 times). Diary data supports results from the survey.

Other studies confirm the high prevalence of fatigue at sea. For example, results from the *New Zealand Maritime Report* (Gander, 2005) show that:

- 25% of seafarers experienced fatigue on at least half their trips.
- 24% of seafarers saw others working fatigued on at least half their trips.

One survey described in the New Zealand report addressed fatigue among masters and mates working on the inter-island ferries, and found that:

- 61% of officers often or always experienced fatigue when on duty.
- 50% of officers considered that fatigue often or always affected the performance of others on duty.

Prevention and management of fatigue

Given the diversity of activities undertaken in the maritime sector, and the different profiles of fatigue risk factors in different work groups, it is clear that a range of strategies is needed to deal with fatigue. Positive input from management and workforce representatives in each sector is vital for the development of effective, practical fatigue management strategies. The International Maritime Organisation has issued guidance material for fatigue mitigation and management but voted against making fatigue education mandatory. Convention 180 of the International Labour Organisation requires that States fix maximum limits for hours of work or minimum rest periods on ships flying their flags. There is a high degree of agreement among prescriptive regimes with regard to minimum rest requirements, which are generally consistent with current scientific understanding about the amount of sleep required for people to continue to function at a reasonable level. However all efforts to prevent and manage fatigue are severely undermined if crewing levels are insufficient to carry out all necessary tasks with adequate recovery time.

Problems with existing legislation and guidance

Two pieces of research from the Cardiff research programme suggest that the legislation aimed at preventing fatigue at sea is not effective. The first examined the impact of the Working Time Directive and evaluated the IMO fatigue guidelines. With regard to the Working Time Directive, it is clear from the survey data that excessive working hours and inadequate periods of rest are still problematic onboard a range of vessels. Furthermore, hours are likely to be under-recorded, either by management, or by individual seafarers wary of jeopardising their employment by bringing their company under legislative scrutiny. Other research from the Cardiff programme evaluated the IMO guidelines on fatigue. It was concluded that lengthy, all-inclusive guidelines are no substitute for specific and implementable recommendations.

Houtman et al. (2005) found that the measures that were considered most necessary and effective in reducing fatigue were:

- Proper implementation of the ISM-Code.
- Optimising the organisation of work on board vessels.
- Lengthening of the rest period.
- Reducing administrative tasks on board vessels.

In order of priority, the following measures were suggested:

- Replacing the two-shift system with the three-shift system, with an additional crew member.
- Adding a crew member, but not an Officer in Charge (OIC), who will be able to take over some administrative tasks from the officer on watch or from the Master.
- Changing the shift system into a more flexible one, with a rest period of at least 8 hours.
- Identifying administrative tasks that can be carried out by the organisation ashore using IT facilities.
- Setting up the framework for a Fatigue Management Tool/ Programme.

Fatigue, accidents and the environment

What are the consequences of fatigue? The *MAIB Bridge Watch-keeping Safety Study (2004)* examined the association between fatigue-inducing working conditions and accidents. This study confirms that minimal manning, consisting of a master and a chief officer as the only two watch-keeping officers on vessels operating around the UK coastline, leads to watch-keeper fatigue and the inability of the master to fulfil his duties, which, in turn, frequently leads to accidents. It also found that standards of lookout in general are poor, and late detection or failure to detect small vessels is a factor in many collisions. The study concludes that the current provisions of STCW 95 in respect of safe manning, hours of work and lookout are not effective. Results reported by Houtman et al. (2005) also confirm that fatigue may be a risk factor in collisions and groundings. Such incidents can have serious economic consequences for companies. In addition accidents at sea can be devastating for the marine environment and fatal for the seafarers involved.

Fatigue and health

Aside from the environmental consequences, the impact of fatigue on seafarers must also be considered. Fatigue at sea is not limited to watch-keepers, all those involved in the safe running of the ship can be affected. Fatigue reduces well-being and is a major risk factor for mental health problems such as depression, as has been highlighted by a recent North of England P&I Club report (Signals, Issue 64 June 2006). Similarly, it increases the risk of acute illnesses, and life-threatening chronic disease, such as cardiovascular disease. It is often difficult to detect such effects in active seafarers as regular medical examinations prevent those with ill-health from working. However, the Cardiff research has shown that risk factors for fatigue are associated with impaired health. Such effects could lead to long-term disability and even premature death.

Conclusions

The evidence for fatigue at sea

The first conclusion from this review is that the potential for fatigue amongst seafarers is high. An evaluation of the fatigue process shows that seafarers are exposed to many risk factors for fatigue, often report extreme fatigue (despite the “*macho*” culture) and may have impaired performance, well-being and health due to fatigue. This statement is supported by a number of studies from different countries, using different samples and methods to evaluate the problem.

Comparisons with other transport industries

A second conclusion is that there are many more controls or regulations aimed at preventing fatigue in other comparable transport industries. It is apparent that the issue of fatigue has been approached in a more systematic way in other transport sectors than it has in the maritime sector and, on the basis of the experience of these sectors, it should now be possible to “fast track” developments in the prevention and management of fatigue at sea. Indeed, if one looks at all of the possible approaches to the prevention and management of fatigue (regulation, enforcement, awareness campaigns, training, and guidance) one finds that every one is deficient in the maritime sector. One reason for the well developed approach in other sectors has been the knowledge base that now exists about fatigue in these industries. A second reason for developments in this area in other sectors has been the interaction of all the stakeholders to advance our understanding of what underlies fatigue and what can be done to prevent and manage it.

Current legislation and guidance is not working

The third conclusion is that current legislation and guidance on fatigue has not had the desired effect across the industry. Hours of work are likely to be under-recorded, either by management, or individual seafarers wary of jeopardising their current or future employment by bringing the company under legislative scrutiny. Similarly, guidance too often involves suggestions that are beyond the control of the individual and which cannot compete with economic pressures. One approach would be to improve on current measures addressing fatigue (e.g. improved guidance; enforcement of working time directives). Another would be to focus on specific aspects of the problem and deal with those using standard health and safety approaches. Looking at manning levels from a wider perspective, there may be reasons other than fatigue that would suggest that increases are needed (e.g. safety in emergencies). Other possible organisational changes, such as changes in shift patterns need to be evaluated, since knowledge about shift work onshore may not be directly applicable to circumstances offshore. Indeed, little is known about the effects of tour length with different shifts and recent research on oil installations (Smith, 2006) shows that even 2 weeks of 12 hour day shifts can lead to cumulative fatigue.

The way forward

The evidence reviewed in this report demonstrates that seafarers’ fatigue is common and widespread. There are clearly serious risks and consequences inherent in allowing vessels to be manned by fatigued seafarers. These can be summarised as follows:

- Potential for more environmental disasters.
- Economic costs due to fines for accidents, losses, and increased insurance premiums.
- Serious health and safety implications for seafarers.

The way forward is to treat seafarers' fatigue as a serious health and safety issue. A starting point must be to take a more robust approach to regulation. Manning levels need to be addressed in a realistic way that prevents economic advantage accruing to those who operate with bare minimums. Such an approach must consider more than the minimum levels necessary to operate a vessel rather it must address the need for maintenance, recovery time, redundancy, and the additional burden of the paperwork and drills associated with security and environmental issues. Another essential requirement is to enforce existing guidelines with mandatory provisions and take serious measures to overcome the problem of false record-keeping. This must be supplemented with appropriate training and guidance regarding avoidance of fatigue and the creation of optimum working conditions. Lessons can be learned from other transport industries and it is important to seek examples of best practice and apply these in an effective way to the maritime sector. Methods of addressing issues specific to seafaring are now well developed and a holistic approach to the problem of fatigue can lead to a culture that benefits the industry as a whole.

1. INTRODUCTION

1.1 Aims and objectives

The overall aim of this report is to evaluate the evidence base for seafarers' fatigue by reviewing the international literature, considering multiple outcomes (health, safety, well-being) across a range of ranks and making comparisons with other occupations (other transport sectors; onshore jobs). A number of issues are considered in the report and all sections adopt a holistic, comparative approach.

The first section discusses current concerns about seafarers' fatigue and relates these to the potential for fatigue at sea and reports of fatigue. Compared to other transport sectors there has been a lack of formal research on seafarers' fatigue. However, to some degree, one can extrapolate from the studies relating to other occupations in order to assess the likely extent and impact of fatigue at sea. Similarly, strategies for eliminating or reducing fatigue are well-developed in other industries and one must now determine the potential efficacy of such approaches in the maritime sector. There are also maritime specific risk factors and knowledge of these will lead to applied implementation and effectiveness research rather than focusing on fundamental research on fatigue.

Fatigue can be viewed as a process with consideration given to exposure to potential risk factors, perceived fatigue and the outcomes of fatigue. This approach is adopted here and results from surveys, diary studies and onboard assessments of sleep, physiology and performance are later evaluated. Risk factors for fatigue are well established and one area of current concern is the relationship between crewing levels and the effect of fatigue upon health and safety. It is interesting to note that the newly built Emma Maersk, the world's largest container vessel with a capacity of TEU 11,000-13,500 and a GT of 170,000 has a minimum safe manning document requiring a complement of just 13 crew members.

In this report the aim is to consider multiple outcomes and not just to focus on effects of fatigue on watch-keeping and accidents at sea. Indeed, it is argued that the possible impact of fatigue is much wider than this and there are many important questions about the consequences of fatigue that need to be addressed. Some of these issues have not been investigated in detail and there is a strong need for further studies evaluating long-term health consequences of prolonged exposure to fatigue. Any discussion of fatigue must also involve an evaluation of strategies for eliminating or reducing fatigue. The present situation is considered in detail and this is followed by suggestions for improvement.

In summary, the initial aims of the report are to determine whether there is a good evidence base for the presence and consequences of fatigue at sea and to establish whether current legislation and guidance aimed at preventing or reducing fatigue has had the desired effect. Possible solutions to existing problems are suggested and further issues requiring future research identified.

2. BACKGROUND

2.1 Concerns about seafarers' fatigue

“Global concern with the extent of seafarer fatigue and the potential environmental costs is widely evident everywhere in the shipping industry. Maritime regulators, ship owners, trade unions and P and I clubs are all alert to the fact that in some ship types, a combination of minimal manning, sequences of rapid turnarounds and short sea passages, adverse weather and traffic conditions, may find seafarers working long hours and with insufficient recuperative rest. In these circumstances fatigue and reduced performance may lead to environmental damage, ill-health and reduced life-span among highly skilled seafarers who are in short supply. A long history of research into working hours and conditions and their performance effects in manufacturing and process industries as well as in road transport and civil aviation has no parallel in commercial shipping.” (Smith, Lane and Bloor, 2001).

One strong reason for investigating seafarers' fatigue is the change in crewing levels over the last few decades. Thirty years ago many large commercial vessels went to sea with crews of 40 persons. Today much larger vessels often have a crew of half that number and crews of less than 10 are common on the smaller ships. This reduction in manning reflects more than a century of gradual technical and organisational change. Reductions in crew, if not managed properly, can degrade safety and have an adverse effect on the health of seafarers. One reason for this is increased fatigue but there may also be other direct effects of unsafe manning levels, such as neglect of essential maintenance. It is argued that research on seafarers' fatigue and safe manning levels should occur as part of a maritime health and safety policy.

This section of the report considers the current state of knowledge regarding fatigue amongst seafarers and compares it with approaches to the subject in other industries, in particular other transport industries.

2.2 Reports of fatigue at sea

Anecdotal accounts of fatigue at sea have become more frequent over the last 10 years and these are now well documented (e.g. The Nautical Institute Fatigue Forum, Patraiko, 2006).

A recent example is given below:

Fatigue in frame again over bulker grounding - Lloyd's List, Tuesday April 18 2006

“A FATIGUED master, alone and asleep on the bridge of his ship, caused the grounding of a British-registered bulker in the Baltic Sea last October, a Marine Accident Investigation Branch report has concluded, writes Michael Grey.

On a voyage from Hamburg to Klaipeda, the 2,777 dwt Lerrix was being monitored by Warnemunde VTS when it failed to alter course and despite efforts to contact the ship was seen to run aground. The master, who had permitted the lookout to leave the bridge, had fallen asleep in the pilot chair. The casualty is the latest in a considerable list of incidents in which fatigue has played a major part...

Recommendations to the owners and UK Chamber of Shipping by MAIB included the need to impress upon owners, operators and managers the importance of

fatigue-related issues, safe lookout, the inappropriate use of personal electronic equipment and closer scrutiny of hours of rest worksheets.”

At the last SIRC (Seafarers International Research Centre) Symposium in 2005, Ellis reported a number of comments made by participants from various shipping companies, management companies and maritime colleges in the UK, Philippines and Singapore that illustrate some of the underlying issues associated with seafarers' fatigue. Ten focus groups were conducted with managers from 4 shipping companies, a group of engineers, two groups of deck officers, a group of cadets, a group of ratings and a mixed group of officers. Additional burdens on seafarers were found to include: extra paperwork, ISPS drills and longer working hours.

“In the past you could probably just get on with your job but now you have got all this extra paperwork to tell you how to do your job” (Deck officer).

Paperwork not only adds to the amount of work but interferes with other activities as shown by a comment from a captain who talked about finishing his paperwork instead of being on the bridge as his vessel approached port.

The ISPS code requires that vessels must carry out drills and have documented plans regarding security. Such requirements were often perceived as placing additional and unreasonable demands on the crew:

“14 drills it's impossible. OK we are doing it, but by paper. We have to follow the regulations, but practically it's not possible” (Deck officer).

The stress of long working hours is compounded by the awareness that fellow crew members are in a similar condition and may also represent a safety risk.

“I work about 14-15 hours a day, so by the start of your second week. I know I start to make mistakes because I am practically falling asleep” (Deck officer).

“I've seen situations onboard where as well as watching out for your own personal safety I'm watching everybody else's as well. It's not their fault it's just they've been so overworked and they get to a stage when they're just so tired they become a danger” (Cadet).

“I think that the majority of accidents happen due to lack of rest. I mean I know that if I have been doing some jobs I take shortcuts because I know when the jobs are finished I will get to my bed” (Deck officer).

Why do seafarers fail to report excessive working hours? A simple explanation may be fears about contract renewal.

“Even if a duty officer says I cannot do it, the company will within 24 hours say OK I will find somebody who can” (Deck Officer).

“Everyone knows that the documentation (about working hours) is fudged” (Deck officer).

In operating a vessel with the minimum levels of manning, there is no in-built contingency to allow for recovery time.

“It's no good the guy saying well if the master knew he was tired he should get someone else in to do it; you are getting to the stage where there isn't anyone else” (Captain).

Insufficient crewing also led to single crew members often doing jobs which ideally required two people for safe conduct.

“When I was a cadet the chief officer always made sure everybody worked in twos – but now the mate has got too much work to get done so he just lets people work everywhere” (Deck officer).

2.3 Lack of research compared to other occupations

Despite the increasing reports of fatigue at sea, there has been relatively little research on this topic compared to fatigue in onshore populations in general and other transport sectors in particular (see section 4). One must ask why there has been a lack of research on seafarers’ fatigue given that the industry is essential for global trade. There are several reasons for this, the most notable being the isolation of ships, mobility of the workforce, globalisation of the industry and an emphasis on economic competitiveness. The layers within the labour supply process may also lead to a lack of responsibility for the workforce on the part of the employer, which combined with a culture of discretion and commercial confidentiality overrides transparency and general acknowledgement of issues such as fatigue.

There has been substantial research into fatigue at work (onshore – see next section) the main points of which are summarised here. Recent estimates suggest that 20% of the working population experience symptoms that would fall into the category of extreme fatigue. Estimates depend on how fatigue is defined (and the sample studied) and, not surprisingly, the prevalence of fatigue varies from 7% to 45% in different studies. Risk factors for fatigue have been widely documented and can be split into factors reflecting the organisation of work (e.g. working hours, task demands, the physical environment) and characteristics of the individual (both stable traits, and current state). Many of the established risk factors for fatigue are highly relevant to seafarers: lack of sleep; poor quality sleep; insufficient rest time between work periods; excessive work load; poor quality of rest; lack of social support; boring or repetitive work; noise or vibration; motion; dehydration; medical conditions; illnesses; long distance travel to and from work (possible jet lag). Many of these potential problems reflect organisational defects such as inadequate manning or the use of fatiguing shift systems. Others may reflect the specific voyage cycle of the ship. What is important to recognise is the crucial combination of risk factors - fatigue may be most readily observed when a large number of these are present. It should also be noted that procedures have been developed to audit fatigue at work (see Section 4) and to develop occupational fatigue prevention and management guidelines. Indeed, there has been considerable investigation of fatigue in other transport sectors and features of this research are described in the Section 4.

2.4 Lack of a holistic approach to fatigue

Not only has there been relatively little investigation into seafarers’ fatigue, where research has been carried out it has been largely focused on specific jobs (e.g. watch-keeping), specific sectors (e.g. the short sea sector) and specific outcomes (e.g. accidents). This reflects general trends in fatigue research where the emphasis has often been on specific groups of workers (e.g. shift workers) and on safety rather than quality of working life (a crucial part of current definitions of occupational health). It is argued here that a more far reaching approach to seafarers’ fatigue is required.

The next section provides a framework for assessing fatigue.

3. FATIGUE: A MAJOR HEALTH AND SAFETY ISSUE

People experience a wide variety of symptoms when fatigued, and because it has not been possible to pinpoint specific physiological changes that characterise fatigue, a simple definition of fatigue continues to elude us. The main problem with fatigue is that, unlike alcohol and drugs, which can be measured by, for example, blood tests, there is no unequivocal physical or chemical test that can tell us that a person is impaired to a certain extent by fatigue. Nevertheless, the issue can clearly be addressed by considering the “*fatigue process*” and it is suggested that the study of this topic requires knowledge of *risk factors for fatigue, the prevalence of perceived fatigue, and the health and safety consequences of fatigue.*

3.1 Dimensions of fatigue

The variety of fatigue inducing situations, the time course (acute versus chronic) and the outcomes, suggest that it is unlikely that there is a single set of processes leading to a specific underlying fatigued state. This can make interpretation of the existing literature very difficult. A person may feel fatigued, performance may deteriorate and the body’s physiology may be affected. These three outcomes, subjective feelings, performance and physiological change are usually recognised as the core symptoms of acute fatigue and form the basis of many definitions such as the one given in the International Maritime Organisations (IMO) guidelines on fatigue:

‘A reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength; speed; reaction time; coordination; decision making; or balance’ (p.4)

3.2 Risk factors for fatigue

Acute fatigue may be induced by a number of factors: lack of sleep, poor quality sleep, long working hours, working at times of low alertness (e.g. the early hours of the morning), prolonged work, insufficient rest between work periods, excessive workload, noise and vibration, motion, dehydration, medical conditions and acute illnesses. Chronic fatigue can either be due to repeated exposure to acute fatigue or it can represent a failure of rest and recuperation to remove fatigue. Many working patterns induce acute fatigue and also lead to more chronic patterns. For example, working at night is associated with reduced alertness during the shift and may also produce cumulative problems because of poor sleep during the day.

The shipping industry and associated regulatory bodies have, until recently, focused on work schedules as the most important predictor of fatigue, and the role of psychological and emotional demands as potentially causal factors has not been studied in this particular occupational group. Few studies have examined how stressors might combine in terms of their effects, or attempted to bench mark the different risk factors (e.g. what are the relative contributions of factors such as isolation, long working hours and high job demands to the fatigue levels of seafarers?). Recent studies have shown that psychosocial workplace stressors tend to demonstrate cumulative associations with self-reports of work stress and poor health outcomes.

In a large survey of the general working population, high demands, high effort, low control, low support, low reward and exposure to physical hazards, combined with shift-work and long hours, were found to demonstrate significantly greater associations with work stress when considered in an additive model rather than individually. Moreover, this combined

stressor score was linearly related to the outcome measure (Smith, McNamara and Wellens, 2004). Similar results have been demonstrated for a number of health outcomes. A combination of high job strain (high demands and low control) and an imbalance between perceived efforts and rewards at work have been shown to predict acute myocardial infarction better than either model alone in a case-control study (Peter et al., 2002). Additive models of stressors have also demonstrated linear patterns of association with accidents at work using the Ergonomic Stress Level (ESL) measure, an instrument designed to calculate body motion and posture, physical effort, active hazards and environmental stressors in the workplace (Luz et al., 1990). Research has failed to examine the influence of combined risk factors specifically in relation to fatigue in seafarers, however, their particular circumstances would suggest a high level of exposure to such risks.

It is important to determine whether the nature and extent of training influence susceptibility to fatigue. Indeed, the basis of fatigue awareness training and fatigue management training is that it is possible to provide the person with skills that allow them to identify and possibly counter fatigue. The absence of fatigue training may be one of the reasons for the high attrition rate seen in those starting at sea and it may also underlie early departure from the profession. It is also important to consider the collective ability of the crew to prevent fatigue and, whilst other possible risks may be present, undermanning has been suggested as a major cause of fatigue.

3.3 Prevalence of fatigue in onshore populations

Prevalence of fatigue in the general working population has been estimated to be as high as 22% (Bültman et al., 2002a) and there exists a substantial literature relating work schedules and psychosocial work stressors (e.g. high demands) to fatigue in onshore populations. High job demands and role conflict were found to be associated with fatigue in a sample of NHS trust employees (Hardy, Shapiro and Borrill, 1997), and findings from the Maastricht Cohort Study of 'Fatigue at Work' suggest that work schedules and psychosocial work stressors such as high demands (physical and emotional) and low control contribute to high levels of fatigue. Overtime and shift work were significantly associated with increased need for recovery from work-related fatigue in a large sample [n=12,095] of the general working population (Jansen et al, 2002; Jansen et al., 2003), and in a sub-sample of men within the same cohort, psychological, physical and emotional work demands (with a protective effective of high job control) were linked with cumulative fatigue incidence during a 1-year follow-up study (Bültmann et al., 2002). Given the evident presence of risks factors for fatigue in the maritime environment, and the absence of mitigating factors, it seems likely that the prevalence of fatigue amongst seafarers would be significantly higher than in the general working population.

3.4 Fatigue, impaired performance and reduced safety

There is extensive evidence from both laboratory and field studies showing that acute fatigue is associated with impaired performance and compromised safety. Smith (1999) has reviewed the effects of fatigue on performance and concluded that many of the risk factors for fatigue are present offshore. Other research (e.g. Arnedt et al., 2001; Dawson and Reid, 1997; Fairclough and Graham, 1999; Lamond and Dawson, 1995; Roach et al. 2001; Williamson and Feyer, 2000) has compared the effects of fatigue (induced by sleep deprivation or by working at night) with those of alcohol and, generally, the results show that the impairments produced by fatigue are at least as great as those found when the person has more than the legal driving limit of alcohol. Reviews of fatigue and safety at work (e.g. Folkard and Tucker, 2003; Folkard, Lombardi and Tucker, 2005; Costa, 2003) conclude that the move to less standardised working requires a new understanding of adaptive processes. Interestingly such

trends which are now being identified ‘onshore’ have always been present at sea where 24 hour flexibility essentially defines much of the industry. Combinations of acute and chronic fatigue are known to impair safety. For example, a cross-industry review by Folkard and Tucker (2003) concludes that working at night can lead to compromised levels of safety with productivity inevitably also likely to suffer. Similarly, when reviewing the literature on working patterns and shift schedules, Folkard, Lombardi and Tucker (2005) highlight three key trends which have emerged from research into shift schedules and safety: (1) risk of an accident is higher when working at night (and to a lesser extent working in the afternoon) compared to the morning, (2) risk of an accident increases over a series of shifts, again especially at night and (3) risk of an accident increases as shift length increases over 8 hours. It is often the combination of risk factors that leads to impaired performance and reduced well-being and few would deny that seafarers are exposed to these high risk combinations. For example, if an individual is sleep deprived then this fatigue will be amplified by other factors which also induce fatigue (e.g. doing a boring task or having to work at night). In transport injuries many jobs are often “safety critical” and one would expect a strong association between risk factors for fatigue and reduced safety. This can be seen very clearly in road transport. Recent results in accident research (road transport) indicate that the risk of accidents at work is a function of hours at work and sleep deprivation. There is an exponentially increasing accident risk beyond the 9th hour at work. The relative accident risk is doubled after the 12th hour and tripled after the 14th hour at work. In general, it is recommended to have at least 8 hours of rest per 24 hours. In the majority of industries there is appropriate regulation to minimise the risk of accidents. However, ships have the potential to cause billion dollar accidents and yet there often appears to be minimal regulation of the human element in this sector.

3.5 Fatigue and health

Among the general working population, fatigue has long been associated with accidents and injuries (Hamelin 1987, Bonnet and Arand 1995). It has also been clearly linked to ill health (Leone et al. 2006, Huibers et al. 2004, Andrea et al. 2003, Mohren et al. 2001, van Amelsvoort et al. 2002, Koller 1983, Folkard et al. 2005, Costa 2003, Barger et al. 2005, Knutsson 2003, Chen 1986, Mohren et al. 2001), as well as poorer work performance (Beurskens et al. 2000, Charlton and Baas 2001), sick leave and disability (Janssen et al. 2003, van Amelsvoort et al. 2002), and is a common factor in workers’ consultations with GPs (Andrea et al. 2003). Furthermore, the concept of a *process* from negative work conditions, to fatigue, to illness has been suggested. Prospective studies have shown that psychosocial work characteristics significantly predict fatigue onset (Bultmann et al. 2002b), and that preceding fatigue is significantly related to subsequent illness (Mohren et al. 2001). Although the direction of the relationship between risk factors for fatigue and ill health has not always been conclusively established, the implication that fatigue is an intermediate stage between work characteristics that are fatigue risk factors and illness is apparent.

Today, about one in five workers in Europe are employed on shift work involving night work and over one in twenty work extended hours (Harrington, 2001). Although there are extensive publications on the health and social effects of shift work the quality of the papers does not always match the quantity. There are considerable methodological issues concerned with this topic. The most obvious is the fact that a large proportion of shift workers are a self selected population and those that remain shift workers for years are a "survivor population" which clearly also applies to the seafarers. The same problem is apparent in all studies of morbidity and mortality of seafarers where they are compared to the rest of the working population. A highly selected population of “survivors” often appears even healthier than their colleagues onshore. The real picture emerges when events after retirement are included (Hansen and Pedersen 1996). Many of the studies published are cross sectional, as there are difficulties in selecting appropriate comparison populations for longitudinal studies. Nevertheless, there are

good studies that can provide the basis for further work (e.g. Waterhouse et al. 1992; Colquhoun et al. 1996; Costa et al. 2000; Folkard 1990).

Continuous shift work is one of the main unavoidable characteristics of work on a ship and one of the main causes of fatigue. Disturbed sleep is the commonest effect of shift work on health, and shift workers report more sleep disturbances than day workers (Akerstedt, 1990; Akerstedt, 2003). The quantity of sleep may be reduced by up to 2 hours a day but there is also an effect on the quality of sleep. Rapid eye movement (REM) sleep and stage 2 sleep have been shown to be reduced. Such sleep deficits can lead to sleepiness at work, with some data showing that inadvertent napping at work can result. It should also be noted that it is not just being at work that influences sleep – those “on stand by” often showed impaired sleep. On shore these effects vary, depending on the shift timing. Normally they clear within two to three days of finishing shift work, and there is no clear indication that long-term shift work results in chronic sleep problems (Dembe et al., 2005). Shift work may also have a large influence on the work/home interface and this effect is even greater when workers are away from home for long periods of time, as is the case with many seafarers.

Other long-term problems of shift work and its effects on general health are often not as clear, but some papers indicate that gastrointestinal disorders are more common in shift workers, who complain of pain and alteration in bowel habit. Night workers seem to have the most complaints of dyspepsia, heartburn, abdominal pains, and flatulence. There is strong evidence linking shift work to peptic ulcer disease, and quite strong evidence linking shift work to coronary heart disease (Knutsson, 2003). In 1978, the general consensus was that there was no firm evidence that cardiovascular disease was more prevalent in shift workers than other groups (Harrington, 1978). Today, that opinion would have to be revised. A more recent review of the data suggests that shift workers have a 40% increase in risk (Boggild and Knuttson, 1999). Causal mechanisms are not well defined but contributing factors include disruption of circadian rhythm, disturbed socio-temporal patterns and social support, stress, smoking, poor diet, and lack of exercise, all of which are common in the maritime environment. Long working hours are also a risk factor for cardiovascular disease. An early mortality study from California showed increased rates of atherosclerotic heart disease for male occupational groups in increasing proportions of the population who worked more than 48 hours a week (Buell and Breslow, 1960).

Long-term prospective studies can study risk factors for mortality and while it is plausible to suggest that jobs that induce fatigue reduce life expectancy it will take time before results from such definitive studies are obtained. Indeed, in industries such as seafaring, where many leave at an early age, it is often difficult to investigate chronic health effects. Those who develop chronic disease, and fail their medical examination, are of course not registered as active seafarers and are often excluded in estimates of health problems.

4. FATIGUE RESEARCH IN OTHER TRANSPORT SECTORS

There is a long history of investigating the impact of fatigue in other transport sectors and this topic has been developed from three main areas. The first sources of information are anecdotal reports of the impact of fatigue. Secondly, there has been extensive research on the effects of fatigue in the laboratory, much of it starting over half a century ago (e.g. Bartley and Chute, 1947; Ryan, 1947; Floyd and Welford, 1953) and reviewed in detail many times (e.g. symptoms of acute and chronic fatigue – see Craig and Cooper, 1992; sleep deprivation – see Tilley and Brown, 1992; night work – see Smith, 1992; disruption of circadian rhythms – see Campbell, 1992; sustained work – see Nachreiner and Hanecke, 1992). Finally, there is a long history of research on fatigue in military transport operations (e.g. Bartlett, 1943) and in the process industries (e.g. Wyatt et al., 1929). These types of research have led to more focused studies of transport, with driving receiving the most attention (e.g. Crawford, 1961; Brown, 1994, 1997). This probably reflects the fact that the problem of driver fatigue is a public health issue rather than being restricted to the occupational context. International meetings (see Hartley, 1997; Akerstedt and Haraldsson, 2001) have provided overviews of the area and developed a framework for evidence-based countermeasures. The overall consensus is that transport fatigue is a major problem that has previously been underestimated (Akerstedt and Haraldsson, 2001) and where appropriate strategies for prevention and management are required. Indeed, Jones et al. (2006) have compared laws and regulations that limit working hours for safety purposes in the different transport sectors and evaluated them against eight fatigue-related criteria based on current scientific knowledge. None of the regulations assessed addressed all eight criteria. It was proposed that fatigue can best be dealt with by a hybrid approach incorporating both a prescriptive “hours of service” system and a non-prescriptive, outcomes-based approach.

The extent of recent research on transport fatigue can be seen by examining the papers presented at the *International Conference on Fatigue Management Transportation Operations 2005* (see Appendix 1 for a bibliography). The papers demonstrate the range of issues being studied – laboratory studies of fatigue on fundamental skills required in transport operations; epidemiological studies of fatigue; evaluation of countermeasures; and assessment of fatigue management programmes. What is also apparent is the limited research activity focusing on the maritime sector – 4% of the papers.

4.1 Road transport

There is a strong evidence-base confirming that fatigue increases the risk of road accidents (e.g. Connor et al., 2001; Hakkanen and Summala, 2000, 2001). Much of this research has been based in the USA, Europe and Australia but recent studies confirm that the effects of fatigue are present in many different countries (e.g. Greece – Tzamalouka et al., 2005; Yugoslavia – Milosevic, 1997; Peru – Rey de Castro et al., 2004; Israel – Sabbagh-Erlich, 2005; and Norway – Sagberg, 1999). A series of studies by the National Transportation Safety Board (NTSB) in the USA have pointed to the significance of sleepiness as a factor behind accidents involving heavy vehicles (NTSB, 1990; NTSB, 1995; Wang and Knippling, 1994). In the 1995 study, NTSB came to the conclusion that 52% of single vehicle accidents involving heavy trucks were fatigue-related, and in 17.6% of the cases, the driver admitted falling asleep. The 1990 NTSB study showed that fatigue was the most important cause (31%) of fatal accidents. A similar incidence of fatigue-related accidents has also been reported in the air-traffic sector (Philip and Akerstedt, 2006). Recent results in accident research (road transport) indicate that the risk of accidents at work is a function of hours at work and sleep deprivation (Philip et al., 2005). Other risk factors for effects of fatigue on driving have been shown to include increased day time sleepiness (e.g. induced by sleep apnoea – Haraldsson et al., 1990), sedative drugs, changes in sleep/wake cycles (Philip et al., 1996, 1999), working at night (Gold et al., 1992; Harris, 1977; Hamelin, 1987), driving in the early morning (the risk

of having an accident at this time is increased 5.5 times and the risk of a fatal accident 10 times – Akerstedt et al., 2001; Akerstedt and Kecklund, 2001) and combinations of sleep loss/circadian troughs and alcohol (Keall et al., 2005). Organisational factors are also related to the frequency of road accidents. For example, Goodwin (1996) found an increased frequency of crashes as truck fleet size decreased. Arnold and Hartley (2001) state that “one of the characteristics of practices of the long distance transport industry is the absence of supervisory oversight during driving --- they do not have moment-to-moment knowledge of what is going on”. These issues of manning and working in isolation will be returned to when considering the maritime sector.

The countermeasure for accidents caused by work/rest schedules is obviously a change of pattern, such as reducing night driving or early starts. Other countermeasures include introducing naps, which seem to reduce accident risk (Gabarino et al., 2004) or even a rest break (Landstrom et al., 2004). Another approach is to recommend consumption of caffeinated beverages (Reyner and Horne, 1997) or to use technological devices to detect fatigue and give the driver a warning (e.g. Dinges and Mallis, 1998; Lal et al., 2003). There are a variety of different forms of legislation that aim to prevent driver fatigue from developing (see Jones et al., 2006). Several countries have also convened expert panels to review regulatory options for reducing heavy vehicle driver fatigue (e.g. National Road Transport Commission, 2001; Transport Development Centre, Transport Canada, 1998; University of Michigan Transportation Research Centre, 1998). Methods of auditing potential risk factors have also been established (e.g. the Circadian Alertness Simulator – Moore-Ede et al., 2000) and modelling of fatigue has been carried out (e.g. Folkard and Akerstedt, 1992; Jewett and Kronauer, 1999; Belyavin and Spencer, 2004; Dawson and Fletcher, 2001; Van Dongen, 2004). Training in fatigue awareness and management is also in place in a number of organisations (see Gander et al., 2005; AWAKE, 2006), and this has been supported by information campaigns aimed at drivers in general (e.g. *THINK – Tiredness kills. Make time for a break*: UK Department of Transport, 2006; Fletcher et al., 2005) not just in the commercial sector.

4.2 Rail transport

Fatigue and railway operations has been studied for many years (e.g. Grant, 1971) with much of the interest being in the association between fatigue and critical incidents (e.g. signals passed at danger – Buck and Lamonde, 1993). The approach to driver fatigue has been very similar to that seen in road transport. Indeed, studies using train simulators have shown that train drivers’ performance is also impaired by fatigue (Dorrian et al., 2006a, b; Roach et al., 2001). Studies from many different countries (e.g. Poland - Malgarzeta, 1982; China - Zhou, 1991) have confirmed the impact of fatigue in rail transport. Major developments in rail fatigue research have occurred since the advent of the Federal Railroad Administration’s Fatigue Research Program. Sussman and Coplen (2000) and Pilcher and Coplen (2000) have reviewed the potential for fatigue in the rail industry. These problems can be summarised as: working 24/7 under a range of physical conditions and service demands; being on call; shorter than 24-hour work rest cycles (in over one third of locomotive engineers); and reduced sleep duration and quality. Coplen and Sussman (2001) discuss the aims of the rail fatigue research program. This program adopts a non-prescriptive approach to:

- Developing better data collection methodologies.
- Developing better measurement and evaluation tools.
- Developing more effective fatigue countermeasure strategies.

The program has led to the North American Rail Alertness Partnership which has been important in identifying specific areas of concern, developing co-operation between

government, unions and industry, and also disseminating information. It has been acknowledged that fatigue is a problem in many jobs in the rail industry (train crews, signalmen, and track workers) and that prevention of fatigue, alertness enhancement strategies and advanced technologies need to be used to address the issue. Better labour management agreements are needed, as are fatigue-related educational programs, improved schedule regularity and more practical and adaptable federal laws and regulations.

One interesting development in the UK has been the application of the HSE Fatigue index (Spencer et al., 2006) to the railway industry (Stone et al., 2005). The research consisted of diary studies of factors influencing fatigue (shift timing and length, continuous driving time, hours worked per week, consecutive shifts, shift variability, rests between shifts). Associations between these and number of signals passed at danger were then examined. On the basis of the results the following recommendations were made:

- A reduction in shift length by limiting night and early shifts to 10 hours would mitigate fatigue.
- Continuous periods of driving should be restricted to four hours.
- Limiting maximum hours over a rolling week to 55 would allow sufficient recovery time between shifts.
- Consecutive night shifts should be limited to three before a rest day, early shifts to five before a rest day, and other shifts to seven before a rest day.
- Controlling the variability of shifts will reduce fatigue and a rapid change from a late finish or night shift to an early start should be avoided.
- A rest period of 14 hours between consecutive night shifts is desirable to allow sufficient recovery.
- A change from nights to earlies should incorporate at least two rest days. All other shift changes should incorporate at least one rest day.
- The HSE Fatigue Index is currently the best option for use in assessment of the shift patterns of safety critical rail workers.

This has led to the development of a good practice guide for drivers to help them cope with shift work and fatigue. New railway safety legislation in the UK will include an approved code of practice on managing fatigue in safety critical work. Use of the HSE fatigue index will help organisations to ensure that workers do not carry out safety critical work when they are already fatigued, or have work patterns that would be liable to cause fatigue. Similar approaches are being developed in other countries (e.g. Sherry, 2005; Jay et al., 2005).

4.3 Air Transport

Fatigue has been identified as a major potential problem for many parts of the air transport industry (aircrew; air traffic controllers; maintenance personnel). Concern with fatigue in aircrew developed during the Second World War and the results from these early studies showed quite clearly that prolonged flying resulted in performance decrements (Welford et al., 1951). Problems of fatigue in aircrew became much greater as long haul flights became common place (Cameron, 1971; Grandjean et al., 1971) and this led to a systematic series of studies from the NASA-Ames research group examining flight crew fatigue in commercial pilots (Gander et al., 1998 [I-VI]). These studies measured sleep, circadian rhythms and fatigue before and after scheduled commercial flights. Short haul fixed wing, short haul helicopter, overnight cargo and long haul aircraft were studied. In all operations sleepiness increased over trips and in the overnight cargo and long haul flights there were impairments due to flying during circadian troughs. In addition, time zone shifts can increase fatigue. Recent research (e.g. Wright et al., 2005) has shown that fatigue can be detected by EEG or

eye movement recording, and that measurement of wrist inactivity can be linked to a warning device that prevents unwanted sleepiness.

Again, fatigue risk management systems have been developed for the aircraft industry (see Booth-Bourdeau et al., 2005; McCulloch et al., 2002) and the 'Fatigue Risk Management Toolbox' typically consists of:

- Policy templates and guidelines to assist in the development of global and detailed corporate policies on the management of fatigue.
- Competency-based training and assessment for employees, management and new staff.
- Fatigue audit tools to assess work schedules, verify actual fatigue levels and monitor the fatigue risk management process.

4.4 Fatigue Prevention Legislation, Recommendations and Management Programmes for the Transport Industry

In civil aviation fatigue that can appear in air cabin crews is a recognised factor for flight safety. Therefore flight-time and the duty-time are regulated by the ICAO (International Civil Aviation Organization) Agreement (1974). The aim of the ICAO agreement is to prevent the influence of fatigue on air-safety by limiting the workload which is achieved by reducing the duty hours in the case of extended flight requirements, by reducing the night-flying hours and by defining the time necessary for rest. The regulations of ten countries, all ICAO members, have recently been compared (Missoni et al., 2006 – see Appendix 2). Two countries only consider the flight time, whereas the other eight members take into account the duty time and the flight time too. Only five countries emphasise in their regulations the rest time of the flight crew before duty. Only two member countries (Switzerland and Great Britain) emphasise in their regulations the significance of the daily duty time, and three (Germany, Scandinavia and Switzerland) of the night flying hours. Night sleep has a far better effect than sleeping during day, but only three member countries (Australia, France and Scandinavia) specifically stress its importance. Three member countries out of ten (Germany, Scandinavia and Switzerland) consider flying through time zones as a significant factor in determining the duty time. Every airport takeoff/landing represents a significant workload for the pilot, and this workload is additive with those due to other factors. The number of T/Ls (take-off/landings) is emphasised as an important factor by six member countries. Air-crew augmentation (one or more assistant pilots) as a factor influencing the crew duty time and the aircraft flight-range appears in the regulations of eight countries. All the state authorities agree that it is necessary to restrict the duty time and the flight time of the aircrew during the day. This results in a conflict between the economic interests of airlines and the state regulations which set safety flight requirements. In their regulations the majority of countries rely more on the duty time than on the flight requirements as the criteria for the crew workload. In order to prevent the accumulation of fatigue all the ICAO member states provide restrictions to the total flight time per week, month and year. In Germany, Switzerland, USA and Croatia the law on air traffic restricts the annual flight operations of a pilot to 1000 hours, and duty period of up to 1600 hours. Crews of other countries have shorter annual operations in a range from 700 to 800 (Russia and Japan) and 900 – 935 (Great Britain and France). Similar regulations could be applied to seafarers and regulations such as those described above act as a good model from which to develop maritime legislation. However, the above section shows that it is very difficult to get a unanimous approach across different countries.

Transport fatigue has also been reviewed at the national level and recommendations made for appropriate regulation (e.g. the US National Transportation Safety Board, 1999). The Australian National Transport Commission Fatigue Expert Group (2001) has produced the

following comprehensive recommendations for the sleep, shift work, night work and duration of working hours of truck drivers:

- **Sleep:** A minimum sleep period in a 24-hour period is required to maintain alertness and performance levels. Continuous and undisturbed sleep is of higher quality and more restorative. The group concluded that the minimum sleep requirement in a single 24-hour period is six consecutive hours of sleep (although the average required on a sustained basis is about seven to eight hours). The group then considered the length of break that would enable the six-hour minimum which is necessarily longer than the six-hour sleep minimum period. Breaks need to take account of the activities of daily living including preparation for sleep and return to work. The impact of the circadian biological clock is critical in determining appropriate breaks in which sleep opportunity is possible. The group recommended the minimum sleep opportunity per 24 hours should be sufficient to allow for six consecutive hours of sleep.
- **The cumulative nature of fatigue and sleep loss:** Minimum sleep opportunities have to be considered over longer periods because of the cumulative nature of sleep loss and fatigue. The expert group agreed that the six hour minimum sleep requirement is adequate on one day, but not sufficient on an ongoing basis.
- **Recovery sleep:** Recovery sleep after an accumulated sleep debt is usually deeper and more efficient, and the lost hours of sleep do not need to be recovered hour-for-hour. Repaying the debt, to restore normal waking function, usually requires two nights of unrestricted sleep. As a consequence the group recommended that schedules should permit two nights of unrestricted sleep on a regular basis (preferably weekly) to provide drivers with the opportunity to recuperate from the effects of accumulating sleep debt.
- **Night work:** Driving at night was considered an important factor for the expert group as it brings together the elements that generate fatigue risks. Working at night produces an elevated risk of fatigue-related impairment, because it combines the daily low point in performance capacity with the greatest likelihood of inadequate sleep. The group concluded that the combination of risk factors associated with night driving should be recognised by ensuring that the length of breaks to enable sleep following night work are suitable and that opportunities for night sleep are available in a seven-day period. Additionally the group proposed a limitation to the number of hours (a limit of 18 hours) that could be driven in the 0000-0600 period after which two nights of unrestricted sleep should be available.
- **Rest breaks:** The expert group recommended that in a one-day period the driver should take non-work breaks equal to 10% of the total working time; these breaks should be taken at the discretion of the driver but they should not be accumulated to form long breaks. As a minimum, short rest breaks should include a non-work break of 15 minutes after every five hours work. A less flexible means of achieving non-work breaks equal to 10 per cent of total working time would be to require a 30 minute non-work break to be taken after every 5 hours of work.
- **Duration of working time:** The expert group concluded that a “safe” threshold for daily working time on a sustained basis will vary according to other factors like time of day, but the upper limit is in the 12-14 hours zone. There was evidence that longer trips could be undertaken on a one-off basis but that repeated long trips rapidly escalated fatigue risk factors. Whilst the group believed flexibility for these longer trips should be provided they needed to ensure that long trips were not combined with risks associated with night driving and circadian low points. To underpin this short

term flexibility, the expert group recommended that any one-off long trips involving over 12 hours work should not extend into the 0000-0600 period and that during a seven-day period there should be no more than 70 hours of working time.

Recent research (Rhodes et al., 2005) evaluated fatigue management processes and approaches in the transport sectors with the aim of determining best practices. The review concluded that few existing programmes consist of the crucial key components and that few have been properly evaluated. Good fatigue management programmes should have the following key components:

- Organisational commitment to the requirements of a 'Fatigue Management Programme'.
- Establishment of a 'Fatigue Management Policy and Process'.
- Involvement of all stakeholders throughout the process.
- Competency based educational modules.
- Effective change to the scheduling, dispatching and compensation processes.
- Objective and subjective measures of fatigue management effectiveness.
- Continual monitoring and improvement.

4.5 Implications of the approach to fatigue in other transport sectors for seafarers' fatigue.

It is apparent that the issue of fatigue has been approached in a more systematic way in other transport sectors than it has in the maritime sector. There are probably many reasons for this, the first being historical, the second being the extent to which occupational issues become public health issues (e.g. road transport is a public health issue as well as an occupational issue), and the final reason reflecting the extent to which the sectors reflect international or national (local) concern.

The different transport sectors clearly have some similar fatigue-related issues and the scientific approach to fatigue has attempted to define general principles that should apply to all sectors. Indeed, this forms the basis of general attempts to regulate working hours but these are often thwarted by sectors or countries with vested interests in particular sectors opting out from the regulations. Research also suggests that a "one size fits all" approach to regulation may be inappropriate. For example, while our knowledge of appropriate times for sleep is well established, this may not apply to situations where sleep quality is reduced, as is often the case at sea.

Although there has been more attention to fatigue in other transport sectors it would be wrong to assume that current approaches represent "best practice". Rather, it is the case that prevention and management of fatigue is more advanced in other sectors and, on the basis of the experience of these sectors, it should now be possible to "fast track" developments in the prevention and management of fatigue at sea. Indeed, if one looks at all of the possible approaches to the prevention and management of fatigue (regulation, enforcement, awareness campaigns, training, and guidance) one finds that every one is deficient in the maritime sector. One reason for the well developed approach in other sectors has been the knowledge base that now exists about fatigue in these industries. This extensive research on fatigue in other transport sectors (and other occupations) can now be applied to seafarers' fatigue. The need for this will become apparent after the review of studies on fatigue in the maritime industry. A second reason for developments in this area in other sectors has been the interaction of all the stakeholders to advance our understanding of what underlies fatigue and what can be done to prevent and manage it.

5. FATIGUE IN THE MARITIME INDUSTRY

In the first systematic review of work hours, fatigue and safety at sea, Brown (1989) found little objective evidence of the effects of fatigue, although he did find anecdotal evidence regarding personal fatigue experiences. Seafarers reported that they were often expected to work continuously, under conditions of task-induced or environmental stress for excessive (in relation to other industries) periods of time. Respondents attributed a number of fatigue symptoms to their working arrangements that were in general agreement with research into fatigue effects (e.g. Bartlett, 1948, cited in Brown 1989). Thus early research on seafarers' fatigue was largely based on Brown's (1989) assertion that long hours are a major contributor to fatigue and accidents at sea. Eleven years later a review focused on the British offshore oil support industry found a similar picture to Brown, concluding that fatigue has been noticeably under-investigated in the maritime domain (Collins, Mathews and McNamara 2000).

5.1 Risk factors for seafarers' fatigue

Working at sea is likely to be fatiguing for a number of reasons: fast port turn-arounds, demanding (often split) shift systems, regular periods of sustained attention, physical exertion and harsh environmental conditions have all been associated with interrupted sleep patterns and fatigue (Smith, Lane and Bloor, 2001, 2003; Smith, 2003; Smith et al., 2003; Allen et al., 2004). Minimal manning is often associated with increased automation which has led to passive jobs which themselves can cause mental fatigue (Bielic and Zec, 2006). Research on risk factors for fatigue has often focused on associations between these factors and health and safety outcomes. However, some research has been carried out on the prevalence of these risk factors, especially on working hours, and these are now reviewed. It should be noted that it is important to specify the contextual factors associated with fatigue – the different vessels, different regulatory regimes and different types of operations. Some risk factors will be common to most sectors whereas others will be sector specific.

Wigmore (1989) surveyed masters of offshore supply vessels and found they tended to work longer hours than other crewmembers, sometimes in excess of 19 hours per day. In a survey of over 1,000 officers across all sectors NUMAST (1995) concluded that reduced crew size (and therefore increased workload) was the main cause of fatigue in seafarers: shifts of between 12-20 hours (upwards of 85 hours per week) were commonly reported.

5.1.1 ITF Seafarer Fatigue: Wake up to the dangers (1997)

This report, based on responses from 2,500 seafarers of 60 nationalities, serving under 63 flags, demonstrates the extent of excessive hours and fatigue within the industry. Almost two-thirds of the respondents stated that their average working hours were more than 60 hours per week and 25% reporting working more than 80 hours a week (42% of masters). It was clear, therefore, that on many ships working hours were in excess of the STCW 95 or ILO 180 requirements. In addition, 36% of the sample were unable to regularly obtain 10 hours rest in every 24, and 18% regularly unable to obtain a minimum of 6 hours uninterrupted rest. Long periods of continuous watch-keeping were also reported, with 17% stating that their watch regularly exceeded 12 hours. Over half the sample (55%) considered that their working hours presented a danger to their personal health and safety. Indeed, nearly half the sample felt that their working hours presented a danger to safe operations on their vessel. Once again this was particularly prevalent in watch-keepers and also on ferries and offshore support vessels. The survey also showed that over 60% reported that their hours had increased in the past 5 to 10 years. Respondents also provided a wide range of examples of incidents that they considered to be a direct result of fatigue. The early hours of the morning were the most difficult in terms of feeling the effects of fatigue and it is important that safe manning assessments, watch systems and procedures reflect the potential decline in individual performance at these times.

More than 80% of the sample reported that fatigue increased with the length of the tour of duty. Long tours of duty were also common (30% reporting usual tour lengths of 26 weeks or above). This cumulative fatigue may also reflect the reduction in opportunities for rest and relaxation ashore, due to the reduced port turn-around times now required.

5.1.2 The New Zealand Maritime Safety Report (Gander, 2005)

This report draws together a variety of information about the role of seafarer fatigue in maritime safety, the factors which cause fatigue in different maritime operations, and international initiatives to reduce it. The report then assesses the implications of this literature for managing seafarer fatigue in New Zealand. A wide range of factors that can cause fatigue have been identified in maritime operations. The information available for New Zealand seafarers highlights the fact that different causes of fatigue predominate in different workplaces. For example, in one fatigue survey 60% of seafarers, largely on small ships, slept on board at least sometimes, and a third indicated that they did not get enough sleep on at least half of their last five trips. When asked about fatigue management strategies, they were most likely to identify strategies addressing adequate sleep when off duty, and the impact of manning levels.

The survey of masters and mates on the Cook Strait ferries found that the key cause of fatigue was shorter more disrupted sleep. A number of environmental factors were identified as common causes of disrupted sleep (the ship's motion, unspecified noise/disturbances; bow thruster or engine noises; and weather). In addition, the fact that officers were often required to work during scheduled rest breaks probably contributed to sleep restriction, and the age of the officers (2/3 were older than 50 years) probably contributed to the reduced quality of their sleep. The Fishing Industry Safety and Health Advisory Group (2004) identified seasonal peaks in fishing activities (for example the hoki spawning season) as tending to promote fatigue among fishermen, and identified the first and last two days of trips as times of elevated accident risk. The FISHGroup also identified the tension between safety considerations and economic pressures in the industry.

5.1.3 The Cardiff Programme (Smith, Allen and Wadsworth, 2006)

The Cardiff Seafarers' Fatigue research programme investigated this topic with the following overall objectives: to predict worst case scenarios for fatigue, health and injury; to develop best practice recommendations appropriate to ship type and trade; and to produce advice packages for seafarers, regulators and policy makers. Seafarers' fatigue was investigated using a variety of techniques to explore variations in fatigue and health as a function of the voyage cycle, crew composition, watch-keeping patterns and the working environment. The methods involved:

- Reviews of the literature
- A questionnaire survey of working and rest hours, physical and mental health
- Physiological assays assessing fatigue
- Instrument recordings of sleep quality, ship motion and noise
- Self-report diaries recording sleep quality and work patterns
- Objective assessments and subjective ratings of mental functioning
- Analysis of accident and injury data

Results from these different approaches are described below.

Reviews of the literature

Two literature reviews were carried out in the Cardiff programme, the first at the start of the research and the other at the end. In the first Collins, Matthews and McNamara (2000) reviewed

the literature on seafarers' fatigue up to 2000 and concluded that compared to other transport sectors there has been a lack of research on the topic. Allen et al. (submitted, cited in Smith, Allen and Wadsworth, 2006) have updated the literature review and reached the following conclusions. Fatigue is more prevalent than the seafaring world is currently able or prepared to measure. In an industry where aggressive economic forces have driven down standards concern needs to be raised about pocketed crises (e.g. Allen et al., 2005) alongside cultural malpractice threatening seafarers of all ranks and nationalities (e.g. Allen et al., 2006). Evidence suggests multiple factors are associated with fatigue at sea which is both an ecologically valid and legislatively challenging conclusion. Between shallow but exhaustive risk factor listing and single-issue campaigning the seafaring community will undoubtedly need to prioritise, implementing strategies at both practical and policeable levels. Accurate measurement of working hours is not the final answer, but would appear the place to start. Without honest measurement systems any success in addressing fatigue will be unquantifiable, and failure will go left unnoticed.

Evidence for the nature and extent of seafarers' fatigue has been gathered using a range of methodologies in the Cardiff programme and these are now summarised.

The Cardiff surveys

McNamara et al. (submitted, cited in Smith, Allen and Wadsworth, 2006) report results from the survey (N=1780) across three sectors of the British shipping industry looking at fatigue and associated risk factors. A large number of factors were associated with fatigue, some risk factors were sector specific and others depended on the measure of fatigue used (e.g. fatigue at work, fatigue after work etc). The 18 variables found to be associated with at least one fatigue outcome crossed all work-related dimensions with operational (e.g. port visit frequency), organisational (e.g. job support), environmental (e.g. physical hazards), health (e.g. smoking) and demographic (e.g. age) factors represented in the final models.

One of the major findings to come from this study is that exposure to a combination of risk factors greatly increases the probability of being highly fatigued. Those who were exposed to 4 or 5 risk factors were 3 times more likely to be highly fatigued than those exposed to few risk factors, and those exposed to 6 or more risk factors were 9 times more likely to be highly fatigued. This confirms results from an earlier paper based on support shipping in the offshore oil industry (McNamara and Smith, 2003). Similar results have recently been obtained in a survey in the Philippines (NMP survey, 2006) and the recommendations from this study were that the home/work interface requires further consideration; workloads are too high; environmental conditions are important; organizational factors and career development need to be addressed. These risk factors were found to be associated with physical symptoms, impaired mental health and interpersonal problems. The risk factors and negative outcomes were most prevalent on bulk carriers. Recommendations to reduce fatigue included adequate manning, stronger support networks and better communication with families and better training (not only to improve safety but to increase diversity awareness and aid career development).

5.2 Prevalence of fatigue at sea

Results from the *New Zealand Maritime Report* (Gander, 2005) show that:

- 25% of seafarers experienced fatigue on at least half their trips.
- 24% of seafarers saw others working fatigued on at least half their trips.

Fatigue among masters and mates working on the inter-island ferries was found to be at the following levels:

- 61% of officers often or always experienced fatigue when on duty.
- 50% of officers considered that fatigue often or always affected the performance of others on duty.
- 42% of officers could recall fatigue-related incidents or accidents on board, and 26% could recall such events in the last 6 months.

The Cardiff surveys (Smith et al., 2006) have also shown that fatigue is a major problem in all sectors and that about 30% of seafarers report that they are very fatigued. Fatigue may be present during work, after work and during the person's leave. Fatigue-related symptoms such as loss of concentration are widespread and these have implications for safety. Indeed, about 25% of respondents reported fatigue while on watch, many reported that they had fallen asleep while on watch, and 50% of the sample reported that fatigue leads to reduced collision awareness. Symptoms such as anxiety and depression are more prevalent in the deep sea sector and this may reflect the longer tours of duty. While seafarers as a whole are not necessarily all more fatigued than other occupations there are certainly some groups who have excessive levels of fatigue. This is shown by the following case study of fatigue onboard a mini-bulker.

5.2.1 A case study of seafarers' fatigue

Allen et al. (2005) report a study of fatigue on a mini-bulker. Bulkers are a versatile class of ship designed primarily to take bulk cargo such as grain, coal, iron ore and wood pulp with mini-bulkers normally carrying five to seven crew and are typically of around 3,000 deadweight tons (DWT). The vessel involved in the onboard testing carried 6 crew and was 3,510 DWT. During the two week research trip the vessel visited Holland, Sweden, Germany, Belgium and Portugal and carried cargoes of wood pulp and steel coils. The crew consisted of a captain, first officer, chief engineer, deckhand, deckhand/cook and deckhand/motorman who assisted the engineer.

The responsibility of navigating the vessel rested solely with the captain and first officer who alternately stood 6-hour watches on the bridge. The 6-on/6-off shift pattern worked by the captain and first officer would be disrupted when coming in and out of port when the first officer would have to oversee cargo loading/discharging operations and the captain would have to be available to deal with officials and requisite paperwork. As with many ships in the mini-bulker sector the vessel was working on a 'tramp' style charter which meant there was no set schedule with the ship taking cargos from wherever business could be secured on a week by week or even day by day basis.

The crew on the mini-bulker were mostly working 4 months-on/2 months-off. However, these work/leave periods could be variable with some crew members simply going from one ship to another in search of work. In a 4-month contract the two deck officers (captain and first officer) were unlikely to get any days off unless the ship had a malfunction which required lengthy repair. The standard working arrangement for the deck officers was therefore 12 hours a day, 7 days a week for 4 months without leave. Whilst such a working schedule appears patently excessive by onshore standards, 84 hours a week is actually very much the best case scenario for seafarers working a 6-on/6-off watch schedule. Whenever both the captain and first officer were forced to be on duty at the same time it is an inevitable fact that one or both of them was working in excess of their normal 12 hour day. Such 'overlap' of watch times consistently occurred when coming in and out of port as the captain and first officer had distinct roles to fulfill simultaneously. The captain in particular would frequently work from the start to the finish of a port visit without sleep, a stretch of as long as 24 hours.

Evidence of fatigue from the case study

From simply observing the working patterns of the crew on the mini-bulker it is apparent that excessive job demands were the norm on this ship. Whilst generalising from one case study is certainly unwise, evidence is provided from the marine accident investigation branch (MAIB) to suggest that many of the problems identified on the research trip are common to smaller vessels in general. The MAIB watch-keeping study looked at accident reports to try and determine which factors are associated with being involved in a marine accident and the two-officer watch system in particular is highlighted as being potentially dangerous, as follows:

'...minimal manning, consisting of a master and a chief officer as the only two watch-keeping officers on vessels...leads to watch keeper fatigue and the inability of the master to fulfill his duties, which, in turn, frequently lead to accidents.' (pg. 1)

Comparison of ratings of fatigue and objective measures of performance (speed of reactions, lapses of attention) showed that the crew of the mini-bulker were more fatigued than crew on tankers studied earlier in the project (Smith et al., 2006). Furthermore, a basic consideration of operational logistics should be sufficient to conclude that problems are almost inevitable. When an individual regularly works 13-14 hours a day punctuated by periods of 24 hour port work with no recovery time beyond a 4-5 hour sleep period the question of *whether* that individual is fatigued warrants little extended consideration.

Accounting for fatigue in mini-bulker crews

It could be argued that mini-bulkers are simply a class of ship on which crew members are at a higher risk of suffering from the effects of fatigue. This global conclusion, however, is of limited use when attempting to distil those underlying factors which are critical in terms of causing seafarers' fatigue. Ultimately the class of ship known as a 'mini-bulker' represents a constellation of key functional characteristics with these individual characteristics of key interest when examining fatigue across ship types. Using such a deconstructionist approach it is possible to identify a number of factors which come together to make working on a mini-bulker particularly demanding, as listed below:

- **Short port stays.** Small ships carry a small cargo and therefore loading and unloading times are relatively quick. When a port turn-around is completed within 24 hours there is no time for rest or recovery before heading back out to sea. This problem is not specific to mini-bulkers but also applies to larger ships like container ships and tankers.
- **Frequent port visits.** When port turn-arounds are demanding then a high frequency of port turn-arounds compounds the situation. Again, this problem may be apparent even on ships on international trades (e.g. chemical and parcel tankers).
- **Changing cargos.** When a vessel changes its type of cargo regularly extra demand is placed on the crew to prepare the ship accordingly.
- **Small crew- 2 officers watch.** A small ship can economically only carry a small crew which includes only two officers to cover a 24 hour watch.
- **Longer pilotage.** Small ships can travel further up river and therefore are normally involved in much longer periods of pilotage. Sailing up and down

rivers under the guidance of a pilot through locks and narrow waterways is considerably more demanding than sailing in open sea.

- **Unpredictability.** When ‘tramping’ around from port-to-port there is little predictability which can be stressful and makes planning sleep and rest periods difficult.

It is clearly the case that different combinations of risk factors will also be present in other vessels and appropriate auditing of these will allow assessment of the potential for fatigue in different operations.

5.3 Associations between risk factors for fatigue and health and safety.

5.3.1 Disruption of circadian rhythms

With a large proportion of seafarers on shift work the potential for disruption to circadian rhythms is great and may be compounded by more and more pronounced ‘jet lag’ type effects as ships get increasingly faster (Malawwethanthri 2003). Tirilly (2004) conducted research onboard two vessels, one fishing and one oceanographic, in order to study the impact of fragmented work schedules on alertness over a 24hr period. Using subjective visual analogue scales (VAS) alongside actigraph measurement, it was found that although sleep was fragmented into 2/3 episodes on the oceanographic vessel and 5/6 episodes on the fishing vessel, the 24hr circadian alertness rhythm was maintained in both instances. Tirilly points out that such sleep fragmentation should be seen as more than an occupational phenomenon with social factors such as meal times likely to play a part. The seafarers studied showed a predicted dip in alertness during the night and also a pronounced afternoon dip.

Studying crew onboard a naval vessel Goh (2000) also investigated how circadian rhythms interact with shift duty scheduling. A group of 20 day workers were compared with 40 night workers onboard a naval vessel with salivary melatonin and cortisol used to indicate circadian variation. Whilst at a general level it was shown that shift work has a detrimental impact upon circadian rhythms, it is important to note a high level of inter-individual variation was observed which should not be underplayed.

5.3.2 Working patterns and shift schedules offshore

Summarising reports published by the HSE between 1996 and 2001, Parkes (2002) highlights psychosocial aspects of working in the North Sea oil industry which might appear unacceptable to an industry outsider. With nearly half of a sample of offshore installation managers reporting work in excess of 100 hours per week, Parkes draws attention to the danger such practices present. In the light of such demanding work conditions Parkes’ suggestion of a survival population effect appears highly tenable with those unable to adapt to the offshore work environment no longer present in the industry. In terms of shift schedules, Parkes concludes that a fixed shift system is generally a better option where workers work the same shift for their whole 2 week tour rather than changing half way through (e.g. from night to days). Working the same shift for a whole tour clearly requires less circadian adaptation however the author also points out the pervasive desire for offshore personnel to go home ‘daytime adjusted’, a preference not always serviceable with a fixed shift system.

Moving from offshore installation personnel to seafarers, Burke, Ellis and Allen (2003) investigated the impact of shift and tour effects on the crew of support ships for the North Sea offshore oil industry. From research onboard 7 short sea and coastal vessels a total of 177 seafarers completed questionnaire and objective performance tests assessing fatigue, sleep quality, reaction time, mood and health with environmental parameters also measured.

Interestingly it was found that counter-directional tour trends might exist where job stress and effort increase over a tour parallel to environmental habituation to factors such as noise. In a study by Wadsworth et al. (2006) tour-based fatigue trends were studied further with participant seafarers required to complete a twice-daily fatigue diary over a complete tour of duty and subsequent period of leave. Whilst Wadsworth et al. (2006) found self-reported fatigue on waking to increase over a tour of duty, fatigue on retiring (to bed) showed no such trend indicating a ceiling effect of methodological relevance. Wadsworth et al. (2006) also found fatigue to increase most noticeably during the first week of duty which highlights the rapid adjustment required when first joining a vessel. In parallel to the first week tour trend, recovery on leave was found to typically take a week. This fatigue after a tour of duty may have implications for safety when travelling from work. It is also of great annoyance to many seafarers with the attitude often being *“I get paid to be tired at work but I don’t want to be tired while on leave.”* Travelling to ships may also be a source of fatigue and very often a replacement crew is scheduled to take on the job just a few hours after joining the vessel and without chance to recover from a long trans-continental flight. Similarly, fatigue may have rather different effects at the change over of shifts compared to later on in the shift.

5.3.3 Noise and motion

When considering the uniqueness of the onboard environment, motion and noise appear as two factors in particular which characterise the seafarers’ experience. Using both subjective and objective assessment tools, Tamura, Kawada and Sasazawa (1997) found that exposure to ship engine noise from 65 dB (A) can have an adverse effect on sleep. The engine noise effect was detected less in polygraphic compared with subjective measures of sleep which highlights an interesting disparity also found in later work by the same authors. A study by Tamura et al. (2002) again looked at the effect of ship noise on sleep but substituted polygraphic for actigraphic measurement alongside a subjective questionnaire evaluating habituation processes. Whilst habituation of sleep was found to a ship noise level of 60 dB (A) in subjective measures, such an effect was not evidenced with sleep as measured using actigraphy. Rapisarda et al. (2004) took multiple measurements of noise onboard 6 fishing vessels in order to examine how location determines exposure. Taking measurements at the engine, deck, winch, wheelhouse, mess room, kitchen and sleeping quarters Rapisarda et al. (2004) found noise levels to vary considerably by location implying global monitoring to be inappropriate. The authors suggest future onboard noise research should focus upon exposure at an individual and daily level in order to accurately understand this environmental factor.

A survey by Omdal (2003) of 11 Norwegian vessels aimed to identify factors potentially harmful to health and found noise to be the single most common problem, with 44% of respondents reporting noise as a problem. Omdal suggests higher standards of noise reduction should be incorporated into ship design. Only 8% of crew onboard a noise-reduced vessel report stress from this environmental factor. Such evidence suggests that through technology and improved design some traditional hardships associated with the maritime life can be challenged and indeed overcome.

Looking at the influence of noise in conjunction with motion, Ellis, Allen and Burke (2003) collected data from participants onboard 7 vessels in the short sea and coastal industry. Using parallel objective and subjective measures noise and motion were found to be associated with negative mood and impaired performance, confirming earlier findings in support shipping for the offshore oil industry (Smith and Ellis, 2002).

5.3.4 Sleep deprivation and reduced quality of sleep

The detrimental effects of sleep deprivation observed with onshore populations have also been found in research on seafarers. A study by Nakata et al. (2005) looked at how sleep quantity and quality are associated with accident risk by surveying a cross-sectional onshore

sample of Japanese workers. After adjusting for multiple confounders it was found that poor quality sleep was associated with significantly increased injury prevalence. An earlier study by Foo et al. (1994) looked at sleep specifically in relation to seafarers with a sleep deprivation study involving 20 male naval volunteers onboard a landing ship in the South China Sea. Whilst performance in manual tasks was shown to deteriorate very little during the experiment, tasks requiring cognitive and perceptual skill showed significant deterioration past c.30 hours sleep deprived. Moving from seafarers to fishermen, Gander, Van den Berg and Signal (2005) used a combination of logbook and actigraph measurement to assess sleeping patterns during the demanding New Zealand hoki season and found reduced quality of sleep. Wadsworth et al. (2006) concluded that fatigue on waking was the best predictor of the cumulative fatigue experienced by seafarers. This suggests that the sleep of seafarers' may not only be reduced due to operational demands but also may not lead to the same restoration of function that is usually found.

5.4 Fatigue, accidents and injuries

5.4.1 Accidents

Associations between seafarers' fatigue and accidents were rarely examined prior to 2000. Even where more thorough investigations have been carried out information relating incident occurrence to days into tour, shift and injury type is noticeably absent. An exception is Raby and McCallum's (1997) study into working conditions that contribute to fatigue related incidents. They found that hours on duty prior to the casualty and hours worked in the 24, 48 and 72 hours preceding the casualty contributed to such incidents. In fatigue related personal injury cases mariners had worked an average of 7.7 hours prior to the incident in comparison to 3.2 hours in non-fatigue related incidents. In the 24 hours preceding the fatigue related incident seafarers reported working an average of 14.3 hours, compared to 8.4 hours. Within the maritime industry Folkard (1997) found that collisions between ships at sea were more likely to occur during early morning hours with a peak between 0600 and 0700. These data were derived from a sample of 123 collision claims made between 1987 and 1991 (UK P & I Club, 1992, cited by Folkard, 1997). Marine pilotage accidents have also been found to show circadian variation, with two peaks occurring between 0400 and 1000, and 1600 and 2400 (Smith and Owen, 1989). Thus, it appears that high performance demands during the night may pose safety and occupational health hazards within the maritime industry. It should be noted that reported accidents may be just the observable portion of a much greater number of unsafe behaviours and mishaps. While collisions occur more frequently in the early morning, fatal injuries to seafarers are more likely to occur during the day, reflecting the greater likelihood of seafarers working on the decks during daylight hours. McNamara, Collins and Cole-Davies (2001), looking at accident databases from a multinational oil company and the Marine Accident Investigation Branch (MAIB), showed a time of day effect on offshore oil support vessels with a higher incidence of accidents occurring between 9am and 4pm. Without any evidence of accident incidence peaking during traditional circadian troughs, however, McNamara et al. (2001) were unable to establish fatigue as an explanatory factor. Indeed, a peak between 9am and 4pm might simply represent a day-shift manning increase.

When looking for working patterns predictive of risk one method is to retrospectively analyse incidents which have occurred in order to draw out factors of commonality. In the MAIB 'Bridge Watch-keeping Safety Study' (2004) evidence from 65 collisions, near collisions, groundings or contacts between 1994 and 2003 was reviewed with clear patterns emerging from the analysis. Using the grounding of MV Jambo as an illustrative example, the MAIB report highlights how a large number of the accidents studied were the result of watch systems with a 6-on/6-off schedule. Rather than focusing on working hours or shift schedules, however, the report firmly attributes blame to under-manning with a recommendation that no merchant vessels under 500gt be allowed to sail without at least three deck officers onboard

(see Appendix 3 for details). Bowring (2004) points out that extra costs due to increased manning can be acceptable to the industry as long as all players in the open market are forced to face the same expense, thus leveling the field competitively. In the light of inconsistent and competitive flag registration trends, the MAIB have acknowledged the need for updated and universally enforced manning legislation.

Wellens et al. (2005) asked seafarers about collision experience and found not only incidence to be high but fatigue to be a potentially important contributory factor. Raby and Lee (2001) studied U.S Coast Guard accident cases and similarly found evidence of fatigue with mode of enquiry affecting causal estimates. Where mariners were asked about accident cause fatigue was implicated in 17% of cases with investigating officers finding a higher rate of 23%. Using a more objective fatigue indicators score they found a contribution rate of 16% for critical vessel accidents and 33% for personal injury accidents (23% if outcomes combined). In reviewing the accident literature Houtman et al. (2005) found that fatigue may be a causal factor in anywhere between 11 and 23 percent of collisions and groundings although a lack of systematic reporting procedures makes estimates difficult (Gander, 2005). Houtman et al. (2005) suggest that aside from reporting inconsistencies seafarers may have a personal motivation to under-admit fatigue reflective of an industry mindset or even one shared by society at large. In understanding how such cultural notions might impact upon accident reporting a quote from Caldwell (2003), in reference to the aviation industry, perhaps best describes the attitudinal climate:

'The root of the problem is that the hard-charging, success-orientated people who make up the modern industrialized community and the world's military forces have yet to be convinced that human fatigue is a problem in terms of safety, health, efficiency, and productivity; that fatigue stems from physiological factors that cannot be negated by willpower, financial incentives, or other motivators' (p.12)

5.4.2 Injuries

Seafarers

Roberts (2002; see also Roberts and Hansen, 2002) provides evidence to support the commonly held notion that seafarers, and in particular fishermen, are at considerably higher risk of injury or death compared to other professions. When compared with other British workers seafarers were found to be 26.2 times more likely to be involved in a fatal accident at work in the period between 1976 and 1995 with this risk even higher for fishermen (52.4 times). Later work by the same author considered evidence up to 2002 (Roberts and Marlow, 2005) and confirmed that whilst fatal accidents have dramatically declined in number since 1976, relative to the general workforce seafaring should still be considered a 'hazardous occupation'. Hansen (1996) also found that accident mortality levels were much higher (> 11 times) among Danish seafarers than in the male, working-aged population of Denmark.

In terms of assessing factors associated with mortality at sea, Roberts (2000) has shown that during the period 1986-1995 British seafarers were at a higher risk of dying through 'work-related accidents, suicides and unexplained disappearances at sea' when working on foreign compared with UK flagged vessels. Hansen, Nielsen and Frydenberg (2002) looked at accidents onboard Danish merchant ships between 1993 and 1997 and found that changing ship and the first period spent onboard were particular risk factors of note.

Fishers

Commenting on epidemiological research by Roberts, Conway (2002) highlights fatigue as an increasingly critical factor in terms of seafaring and fishing in particular with increased

potential for accidents and injury as deck systems become more complex (see also Roberts, 2004). Certainly Lawrie et al. (2003) have found that it is possible to identify other risk factors which may predispose fishermen to accident and injury with experience working on a large number of vessels found to have such an association. Where accidents do occur Marshall et al. (2004) have found that independent fishermen in North Carolina most commonly reported penetrating wounds to the hand / wrist areas from marine animals and strains / sprains to the back from moving heavy objects. In similar shore-based functions suitable protective gear would be worn.

5.5 Performance

Amongst seafarers the relationship between fatigue and performance has also been neglected. Again, parallels can be drawn from onshore studies and it is highly likely that the same relationships would hold true for seafarers. Condon et al. (1986) in a study of watch-keepers, on a “4on/8off” routine and day-workers, found that the speed of a complex visual performance task, and subjective alertness ratings decreased slightly during the early hours and peaked during the day. Condon et al. (1988) also found that task speed, in relation to its peak level, is slowest at the beginning of watches starting at 0400 or after recent awakening. Thus they suggest that there should be a provision for an adequate “waking up” period before the start of the duty. They also concluded that operational effectiveness variations could be reduced by watch-keeping systems, which allow a single long sleep per day.

A more substantial body of evidence details the effects of vessel motion, which may in turn induce fatigue, on performance, although, results differ depending upon ship type and experimental tasks employed. For example, Wilson et al. (1988, cited in Powell and Crossland, 1998) using a simulator found that cognitive processing was significantly slower as a result of motion, although no information regarding total motion exposure time was available. Furthermore, it is not possible to ascertain from these data whether the accuracy, as well as the speed of cognitive processing was affected. Pingree et al. (1987, cited in Powell and Crossland, 1998) found evidence to suggest that motion degrades performance on a psychomotor tapping task, although not on computer-based cognitive tasks. It would therefore appear that certain types of cognitive task are more sensitive to the effects of vessel motion than others.

Wellens et al. (2002) analysed data from the seafarers on board support vessels for the North Sea oilrigs to assess the impact of noise and night work on performance. Noise exposure was found to be associated with increased subjective alertness but also with slower reaction times. Those working night shifts showed a large drop in alertness over the course of work and became slower at tasks requiring more difficult responses. There were some interactions between noise and shift, such as more lapses of attention (very long response times) but fewer incorrect responses in the noise/night work group. These two sets of analyses suggest that it is important to continue to examine combined effects of different factors.

5.6 Physiology

Amongst seafarers several studies have examined the physiological status of ships’ pilots in terms of stress and fatigue. Shipley (1978) examined heart rate as a stress indicator and found, broadly, that as job complexity increased, so did heart rate and therefore stress levels. Cook and Shipley (1982) studied ECG recordings of ships’ pilots and the incidence of ectopic beats, thought to be activated by stress. They found the occurrence of ectopic beats was more common under demanding or hazardous pilotage conditions, although the magnitude of the effect is difficult to determine. Furthermore, whether pilots have a higher incidence of these irregular beats than the general population is difficult to ascertain. Smith et al. (2003) also

found higher levels of cortisol, a known indicator of fatigue, in seafarers in the short-sea sector.

5.7 Fatigue and health

Seafarers

In a number of studies from different countries, seamen have been found to show increased rates of mental illness and mortality (Brandt et al., 1994; Hemmingsson et al., 1997). One explanation of this has been that there is a selection bias with individuals with unfavorable health-related characteristics entering the profession. Hemmingsson et al. (1997) conclude that seafaring itself remains a strong risk indicator even after controlling for a large number of selection factors. Looking at a cohort of Danish merchant seafarers Hansen, Tuchsén and Hannerz (2005) found evidence of poor health from examination of hospital admission records. Whilst worrying in itself, the authors note that evidence of poor health in this sample is particularly concerning in the light of Danish crew facing bi-annual health examinations, clearly bolstering any residual ‘survival population’ effect. Hansen et al. also conclude that the wide ranging health status of seafarers in their sample is evidence of seafarer diversity and the non-homogeneity of this group. Certainly evidence from Allen et al. (2003) of fatigue differences branching from sector level down to vessel type and beyond suggests that diversity is one of the most characteristic traits of the seafaring population.

Beyond physical health complaints Carter (2005) draws attention to psychosocial problems associated with working at sea. Seafarers live in their workplace 24 hours a day, a socially detached environment further compounded by divisions of rank and nationality. Carter suggests, however, that it is the adaptation from life onboard to life at home which presents perhaps ‘the most significant disturbance’ faced by seafarers, a conclusion echoed in work by Thomas, Sampson and Zhao (2003). Thomas et al. conducted interviews with 35 women, all partners of seafarers, in order to understand how the interface between home and work is played out in a family context. Whilst seafarers may benefit financially from choosing a tour-orientated lifestyle, Thomas et al. conclude that the ‘emotional cost’ to both seafarer and family may outweigh any compensatory economic reward. Certainly when attempting to understand fatigue and its consequences it would appear inappropriate to focus purely on the work situation and not consider how time on leave life might be affected, as illustrated in this quote from a Captain’s wife, transcribed in Thomas et al:

‘I found it horrendous, he would come home so tired, absolutely zonked out cos [at that time] he was still a second mate and he’d come home absolutely shattered- took him days and days to get over it...’ (p.64)

Using a range of self-report measures Wadsworth et al. (submitted, cited in Smith, Allen and Wadsworth, 2006) considered how such experiences of fatigue might affect physical and mental health status. The link between negative work characteristics and ill health has been well explored, however Wadsworth et al. showed how fatigue may be important in this relationship, even showing unique associations. These findings suggest, first, that poorer physical and mental health among seafarers is associated with work characteristics that are risk factors for fatigue. This is consistent with findings from the general population, where factors such as work stress (Akerstedt et al., 2002; Dahlgren et al., 2005), and psychosocial work characteristics (Bultmann et al., 2002; Bultmann, Kant, van den Brandt et al., 2002) have been associated with fatigue. In addition, there are links between fatigue and factors specific to seafaring. Poor sleep quality, poorer environmental conditions, length of tour, finding the switch from sea to port work fatiguing, and more than four hours on shift were all associated with poorer cognitive function. Poor sleep quality was also associated with poorer general health, and poor environmental factors with psychological distress. All these factors

were linked to fatigue among seafarers in previous work from this project (McNamara et al., submitted, cited in Smith, Allen and Wadsworth, 2006). Shorter tour lengths have also been linked with greater fatigue using day to day on board measurements among respondents in this project (Wadsworth et al., 2006), and by others (Bloor, Thomas, and Lane, 2000). Similarly, the association with switching to port work supports previous findings from the day to day on board part of this project (Wadsworth et al., submitted, cited in Smith, Allen and Wadsworth, 2006), and other research suggesting that numerous port calls may contribute to fatigue in near sea shipping (Bloor et al., 2000). Links between poor sleep quality and injury rates have been suggested among general population workers (Nakata et al., 2005), while among seafarers sleep deprivation has been shown to impair cognitive and perceptual performance (Foo et al., 1994; How et al., 1994). The majority of seafarers report poor sleep quality at sea (Gander, van den Berg, and Signal, 2005; Parker et al., 1997), so an association between that and both fatigue (McNamara et al., submitted, cited in Smith, Allen and Wadsworth, 2006; Wadsworth et al., submitted, cited in Smith, Allen and Wadsworth, 2006) and poorer cognitive function and general health has particularly wide-reaching implications. An association between fatigue and both mental and physical ill health is consistent with research from other working populations (Andrea et al., 2003; Barger et al., 2005; Chen, 1986; Costa, 2003; Folkard et al., 2005; Knutsson, 2003; Mohren et al., 2001). This was apparent among those with both lower and higher levels of the other occupational and demographic factors associated with ill health, suggesting not only an independent association, but also one that is significant over and above these other associations. The impact of fatigue over and above the other factors was also more than additive. This suggests that fatigue itself is an important factor that should be measured alongside occupational, demographic and other risk factors. Increased fatigue over time was also associated with poorer health between the first and second time points, even after taking into account any changes in other associated factors.

In the general working population fatigue is not only associated with ill health, but is also a strong predictor of later permanent work disability (van Amelsvoort et al., 2002). It has been suggested that repeated insufficient recovery from occupational fatigue leads to cumulative fatigue, and poorer health in the longer term (Sluiter, de Croon, Meijman, and Frings-Dresen, 2002; Sluiter, van der Beek, and Frings-Dresen, 1999), which is consistent with the association between fatigue and poor sleep quality within the project (McNamara et al., submitted, cited in Smith, Allen and Wadsworth, 2006; Wadsworth et al., submitted, cited in Smith, Allen and Wadsworth, 2006). The link between fatigue and personal well being, therefore, is clear, and it is also apparent among seafarers. Fatigue related accidents and injuries cost the industry dearly every year. However, fatigue related ill health may be a more hidden cost in terms of sick leave, evacuations from tour, and early retirement. Certainly evidence from the UK Protection and Indemnity Club showing rising numbers of repatriation and illness claims would support this proposition (UK P&I Club 1999, quoted in Bloor et al., 2000). The individual emotional, physical and financial cost to seafarers and their families is also, of course, potentially great (e.g. (Thomas, Sampson, and Zhao, 2003)). It has also been suggested that the working conditions that lead to fatigue make seafaring an unattractive occupation for new recruits. In countries where unemployment is high seafarers may put up with fatigue because of fear of unemployment and the consequences of this for their domestic financial situation.

These findings suggest that, as well as general fatigue risk factors, seafaring is subject to additional specific fatigue risk factors that are associated with poorer physical and mental health. Many of the factors specific to seafaring were particularly linked to poorer cognitive function. These results have clear implications for work performance at sea, which is particularly important in this safety critical industry.

Fishers

Matheson et al. (2001) used a survey questionnaire to assess the health status of Scottish fishermen alongside collecting data from Accident and Emergency departments, recruiting fishermen to complete health diaries, interviewing industry representatives and analysing medically related radio calls sent from fishing vessels. From the 1,150 questionnaires returned Matheson et al. found that lack of sleep/fatigue was reported to be the factor fishermen most believed to affect their health with lack of exercise and financial stress also found to be important.

5.8 Summary

Clearly, as shown by the range of studies reviewed here, the potential for seafarers' fatigue is high. Reports of fatigue are now being systematically documented and provide a basis for formal evaluation of the topic. Quantification of the extent of the problem can be difficult but this should not make the issue of fatigue at sea a low priority. Indeed, the *a priori* case for fatigue as a major issue at sea is strong. As well as the high exposure to established risk factors for fatigue, seafarers face additional problems that are specific to the industry. Onshore there is concern about the trend of many types of work moving to a 24/7 pattern. This is the norm at sea and tours of duty last for much longer than those typically worked onshore. Furthermore, many seafarers actually report that the situation has recently become worse. This reflects the increased workload produced by under manning, increased paperwork and economic pressures. It is now important to quantify the workload of seafarers and tools for doing this have been developed for onshore industries. These measures are moving towards models which include the combined effects of different factors and have the potential to be much better indicators of fatigue than those based on single parameters such as hours of work or opportunity for rest.

One problem with the research already conducted is that it has largely studied the "better end" of the industry, although accident studies draw attention to other types of shipping. Analysis of a wider sample would be likely to reveal problems of even greater magnitude. This can be seen when looking at fishing, where regulation is much more difficult, and where fatigue is an inherent part of the job due to economic pressures over-riding concerns about health and safety. In the oil transportation sector where fatigue has been recognised as a problem with the potential for high-cost accidents, additional crew have been recruited to minimise the risks.

The focus of much of the research on seafarers' fatigue has been on accidents. This is because most aspects of transport are safety critical and the impact of fatigue-induced errors is high. Accidents due to human error represent a more general decline in performance efficiency, often due to fatigue. Such effects can be seen in the reported incidence of errors of attention and action. Objective measurement of performance onboard ship confirms this association between fatigue and impaired performance. It should be noted that this effect of fatigue on performance is likely to be apparent in all members of the crew not just the watch-keepers. A general emphasis on reducing fatigue to improve performance needs to be balanced with an approach focusing on specific functions of specific members of the crew.

Impaired performance also leads to an increase in injuries, one of the general health problems faced by seafarers. There is evidence to suggest that fatigue is also associated with mental health problems and a greater likelihood of the need for medical care. Chronic health problems and mortality due to chronic disease are difficult to study in seafarers (see Wickramatillake, 1998) due to seafarers representing a survivor population. Medical examinations prevent those with chronic disease serving at sea and many seafarers leave the industry at a relatively early age and their deaths not categorised in the seafaring sector.

However, fatigue is strongly linked to mental health problems which are clearly risk factors for more chronic disease and early death (e.g. suicide). The link between fatigue and chronic health problems is well established in onshore populations and at the moment it appears very plausible that fatigue at sea may increase the risk of chronic disease.

Given these potential consequences of fatigue at sea, it is crucial to try and prevent or at least manage fatigue. The next section examines strategies aimed at preventing or managing fatigue.

6. STRATEGIES FOR PREVENTING OR MANAGING FATIGUE

Given the diversity of activities undertaken in the maritime sector, and the different profiles of fatigue risk factors in different work groups, it is clear that a range of strategies are needed to prevent or manage fatigue. Effective regulation is required to address occupational fatigue and this will need to be supported by effective management strategies. Input from management and workforce representatives in each sector is vital for the development of effective, practical fatigue prevention/management strategies. Existing research has highlighted a number of suggestions to reduce fatigue. The need for increased crewing levels was strongly supported. Better working environments were also called for. Changes in working hours, both in terms of the length of the tour of duty, and daily opportunities for rest and recovery were also advocated. There was also strong support for tougher laws and better enforcement of the existing regulations. In addition, the results supported the need for further regulatory measures to promote a cultural change among ship owners and operators to ensure that short-term commercial considerations do not impinge on occupational health and safety concerns. The next section considers attempts to regulate working hours at sea.

6.1 ILO 180

Convention 180 of the International Labour Organisation requires that States fix maximum limits for hours of work or minimum rest periods on ships flying their flags. In addition:

- Schedules of service at sea and in port (including maximum hours of work or minimum periods of rest per day and per week) are to be posted on board where all seafarers may see them.
- Records of hours of work or rest periods are to be maintained and must be examined by the flag state.
- If the records or other evidence indicate infringement of provisions governing hours of work, the competent authority is to require that measures are taken, including if necessary the revision of manning of the ship, so as to avoid future infringement.

There is a high degree of agreement among prescriptive regimes with regard to minimum rest requirements. They are generally consistent with current scientific understanding about the sleep required for people to continue to function at a reasonable level. However, they do not make allowance for the reduced quality of onboard sleep. Some examples of these hours of work regulations are given in Appendix 4. In 2004 it was recommended that the International Labour Conference should adopt international standards concerning work in the fishing industry. These recommendations are also described in Appendix 4. It should be noted that the impact of such measures may be minimal, due to many countries opting out. In addition the legal base of the EU directive is limited to employed fishermen, and many sea-fishermen are self-employed. The overall impression from the existing literature is that the high injury and mortality rates in the fishing industry worldwide are a serious concern, but that there is currently a total lack of workable solutions to fatigue management in this sector. Again, reports from several countries suggest that in the fishing industry commercial pressures often outweigh the need for safety.

Jones et al. (2006) examined the extent to which STCW 95 and ILO 180 address the criteria of sleep duration, sleep quality, sleep debt, working at night, circadian rhythms, predictability of shifts, length of shift and rest breaks. STCW 95 does not have a requirement that rest should take place at the same time each day. Similarly, there is no requirement for timing roster release. ILO 180 was found to be inadequate in terms of maximum working hours and sleep debt recovery.

6.2 Evaluation of the European Working Time Directive

Evaluation of working hours legislation is clearly something that needs to be carried out at an international level. As a starting point to this McNamara et al. (2003) evaluated the impact of the EU working time directive and came to the following conclusions. It was evident that a minority of seafarers within their sample reported working daily and weekly hours in excess of those set out in the working time directive (WTD). 2.2% of the total sample worked 16 or more hours per day and 2.4% worked in excess of 100 hours per week. When asked about rest periods, almost a third of the sample (30.8%) did not regularly have the opportunity to gain 10 hours rest in every 24 hours, and 11.9% did not regularly gain at least 6 hours unbroken rest within a 24-hour period. It would therefore seem that nearly a third reported working hours violating the requirements regarding hours of rest set out in the WTD (clause 5, 1b). It is worth noting that this percentage was much greater than those reporting working hours in excess of maximum levels: it may be the case that respondents felt it was easier to report violations in terms of hours of rest rather than more explicitly in terms of hours worked. Furthermore, 27.6% of the sample reported typically working 15 or more hours continuously, which contravenes the directive laid out in clause 5, 1a. A significant proportion of respondents (21.5%) also reported spending 4 or more hours per day on additional duties.

The potentially negative impact of working hours on safety was highlighted by the finding that nearly half (46.7%) of respondents felt their working hours presented a potential threat to their personal health and safety, while almost one third (32.5%) felt working hours presented a danger to safe operations onboard their vessel. A significant proportion of respondents (61.5%) indicated that working hours had actually increased within the last 5 to 10 years. Seafarers were also asked more specifically whether recent amendments to working time regulation had altered working practice and 77% reported that their working hours had stayed the same and 16% that their hours had actually increased.

The WTD also states that records of hours of work and rest must be maintained in order to monitor compliance with the provisions as detailed in clause 5. However, a significant proportion of respondents felt that their actual working hours were at least occasionally under-reported in order to comply with working time regulations: 11.9% reported that their working hours were always or frequently mis-recorded, while a further 28.3% felt this to be the case at least occasionally. The WTD also states that regulations should be posted in a highly visible place onboard vessels, yet a significant proportion (15%) of the current sample denied any knowledge of international regulations in place to control their working hours. Furthermore, 7.3% also claimed to have no knowledge of national regulations.

One of the features of the maritime industry is the considerable variation from sector to sector. Such variation is seen in terms of working hours although this should not detract from the general conclusion that excessive working hours and inadequate periods of rest are endemic onboard a range of vessels. Seafarers operating in the deep-sea sector seem to be at most risk of working excessively long hours and this can plausibly be explained in terms of the impact of additional duties. The percentage of respondents in the deep-sea sector spending 4 or more hours per day on additional duties was approximately twice that of the offshore and short-sea sectors (28.2% compared with 13.7% and 14.5% respectively). Deep-sea respondents were also more likely to report their working hours as a danger to either personal or operational safety. However, few differences were observed across sectors in terms of reported daily and weekly working hours and changes in working practice as a result of amendments to regulations.

These results show that excessive working hours are still a common feature of the maritime industry. Furthermore, hours are likely to be under-recorded, either by management, or by individual seafarers wary of jeopardising their current or future employment by bringing their company under legislative scrutiny. Therefore, auditing of ship records is unlikely to be an

adequate measure of adherence to regulations. Better enforcement of existing regulation is needed if excessive working hours and the associated problems of fatigue are to be reduced. A study by the Marine Accident Investigation Branch (MAIB) on bridge watch-keeping came to the conclusion that:

‘...the records of hours of rest on board many vessels, which almost invariably show compliance with the regulations, are not completed accurately’ (p.13)

The requirement for employees to work compulsory over-time is undesirable but necessary on occasion, however when the same employees are obliged to present records with fictitiously reduced schedules of work the situation might be classed as exploitative. Ironically, the very completion of working hours sheets appears to achieve little more at present than increase the work load for those whom the system was designed to monitor and potentially help. One of the most alarming facts about the prevalence of under-recorded working hours in the current survey was that the sample in question represents what could arguably be described as the “better end” of the industry. From the sample of 558 seafarers 75.2% reported working on British flagged ships, 94.0% were British/Irish, 94.3% were officers and 70.2% earned more than £30,000 a year. With 40% of such a sample of highly paid, well trained and highly ranked seafarers admitting to under-recording working hours it is not difficult to imagine the situation being considerably worse elsewhere. The next section shows that the situation is actually even worse: there is not only a large proportion of seafarers under-recording working hours, but seafarers who under-record are actually more fatigued and less healthy than their non-under-recording counterparts. If the recording of working hours was brought in as a proxy means of assessing the health and welfare of seafarers then it appears the procedure is failing.

6.3 The relationship between recorded hours of work, fatigue and health of seafarers

Allen et al. (2003) compared seafarers who had at least occasionally under-reported working hours (n=223) and those who never under-reported working hours (n=208). The groups were compared in terms of three fatigue scales derived from survey questions (fatigue at work, fatigue after work and fatigue symptoms), the profile of fatigue related symptoms fatigue scale (PFRS-F, Ray et al., 1992), the cognitive failures questionnaire (CFQ, Broadbent et al., 1982) and the General Health Questionnaire (GHQ, Goldberg, 1992). On all six comparisons the group who reported under-recording working hours were shown to be significantly more fatigued/less healthy than the non under-recording group, as shown in table 2 below.

Table 2: Fatigue and health scores for mis-recording and non mis-recording groups

Scale	Non under-recording Mean (SE)	Under-recording Mean (SE)
Fatigue at work	3.44 (.06)	3.64 (.05)
Fatigue after work	2.33 (.03)	2.58 (.03)
Fatigue symptoms	2.57 (.05)	3.09 (.05)
PFRS-F	24.67 (.86)	27.29 (.80)
CFQ	33.90 (.88)	36.93 (.78)
GHQ	1.15 (.16)	1.80 (.17)

(Note: for all scales a higher score = higher fatigue or poorer health status)

In terms of accounting for the result shown in table 2 it might be suggested that under-recording is associated with a particular sub-group of seafarers however analyses were

conducted which challenge this proposition. The under-recording and non under-recording groups were compared in terms of a number of key factors and it was shown that in terms of nationality, flag of vessel, job type and tour classification the two groups showed no significant differences. It is clear that the current system for recording seafarers' working hours is fundamentally flawed with company intermediation preventing honest disclosure. The problem is that without any honest disclosure of working hours there is no warning light for enforcement authorities to spot, leaving the industry to deteriorate behind a façade of compliance. With many seafarers required, when necessary, to 'flog' working hours sheets, a warped picture emerges concerning the state of the industry with the definition of 'good practice' skewed by misrepresentative paperwork.

6.4 Fatigue management systems

There are a number of codes of practice relating to Fatigue Management. For example, the Great Barrier Reef Pilotage Safety Management Code, which is mandatory under Australian Marine Orders Part 54 (Coastal Pilotage), has several features that can be recommended. All Safety Management Systems (SMS) are required to include a Fatigue Management System (FMS). A number of the features required in Australian SMS systems are expected to also be effective for managing seafarer fatigue, including the following:

- Procedures must be in place to cover the reporting of near misses, accidents, equipment failures, etc. to the appropriate regulatory authority.
- A designated person must be responsible for verifying the effectiveness and degree of implementation of the SMS, reporting deficiencies to the appropriate level of management, and identifying people responsible for rectifying deficiencies. The designated person must have direct access to the highest level of management and has the function of providing a link between the provider and the pilot on board.
- The SMS must be periodically evaluated, and if necessary revised in accordance with documented procedures. Results of reviews and audits must be brought to the attention of all personnel in the area involved, and the provider must take timely corrective action on deficiencies found.
- A Check Pilot must be appointed, as part of a continuous improvement process, to observe and make recommendations on individual pilots. The first item on the checklist for Check Pilots is an assessment of the fatigue status of the pilot at the start of each voyage. All checklists must be signed and submitted to the Australian Maritime Safety Authority.

Similar, fatigue management programmes have been developed in other countries. For example, the US Coast Guard Crew Endurance Management Program (Comparatore et al., 2005) provides guidance on how to implement a scheme that includes fatigue management, and a variety of education/ training materials. It should be noted that management programmes can play an important role but that they should not be seen as alternatives to appropriate legislation nor as reasons for minimal crewing levels.

The next section considers the IMO guidance on fatigue, representing a global approach to the topic.

6.5 IMO Guidance on Fatigue

The IMO guidelines provide an informative summary of fatigue, yet have a number of limitations which are covered in detail by McNamara et al. (2003) and summarized below:

6.5.1 Lack of specific, implementable strategies for reducing fatigue

The text of the IMO Guidelines on Fatigue reads more like a general information document than a set of specific guidelines, for example, working hours and diet are cited as factors influencing susceptibility to fatigue, yet no distinction between the two is made. It is obvious that excessive working hours will have a greater impact on fatigue than diet, although eating may mitigate or exacerbate fatigue effects. Furthermore, general phrases such as ‘an open communication environment’ are used throughout the document: although this is intuitively desirable, there are likely to be many instances where openly communicating that you are too tired to work is not necessarily possible (e.g. within a hierarchical culture and/or one dominated by male bravado).

Suggestions are often made which may be beyond the control of an individual. For example, in a section entitled ‘Fatigue and the rating’ it is suggested that crew members eat regular, well-balanced meals. In practice, ‘regular’ meals are made difficult by anti-social shift systems, and crew on small to medium sized vessels are not likely to have any say in the meals with which they are provided. Similarly, it is suggested that seafarers ‘make the environment conducive to sleep (a dark, quiet and cool environment and a comfortable bed encourages sleep)’. Unfortunately, ratings will be assigned a cabin and will have little control over noise levels, the degree of comfortable furnishing, or the exclusion of light.

Management are also advised to consider a number of factors thought to influence fatigue, but no specific information with regards implementation is given. For example, voyage length, time in port, length of service and leave ratios are all cited as important factors to be taken into account when developing fatigue management systems. However, the guidelines do not outline which voyage cycles might be most likely to induce fatigue, how long in port is acceptable for different types of ship, how length of service might impact on fatigue or how long should be spent on leave to achieve optimum recovery. Furthermore, whilst a number of concepts are listed there is little discussion of how the different factors may interact in any cumulative or combined sense.

6.5.2 Focus on personal fatigue management strategies

A distinction can clearly be made between personal and operational/legislative fatigue management approaches. Whilst both forms of approach to fatigue management have obvious strengths and limitations, the IMO guidelines fall indisputably towards the personal side of this continuum. Given that many seafarers find themselves working in situations over which they have little or no control, such an approach is of little value. It would perhaps be more appropriate to concentrate on operational and cultural change if the issue of fatigue is to be tackled effectively.

Advice and best practice cannot compete with economic pressures. There is often little contingency in terms of crew, as many vessels operate at minimum ‘safe manning’ levels and are under pressure to complete port turn-arounds quickly. Under such conditions, it appears unrealistic to suggest fatigue-reducing interventions which do not involve some form of economic trade-off, an issue that is not addressed in the IMO guidelines.

6.5.3 Conclusions about the IMO guidelines

Lengthy, all inclusive guidelines are no substitute for specific and implementable recommendations. Furthermore, the focus of responsibility for fatigue management needs to shift from the personal to the operational. Industry wide, cultural change is needed in order to manage fatigue. For example, if provision for extra manning or temporary suspension of operations were allowed for in the design of work schedules, then seafarers would have the option of working shorter hours and gaining more rest when they felt fatigued.

6.6 Houtman et al. (2005): Fatigue in the shipping industry

This report addresses measures, both on board as well as ashore, that are (potentially) effective in reducing fatigue. On the basis of the literature and the interviews, measures to manage fatigue were related to:

- a. lengthening of the resting period;
- b. optimising the organisation of work;
- c. reducing administrative tasks;
- d. less visitors/inspectors in the harbour/better coordination of inspections;
- e. reducing overtime;
- f. proper Human Resource Management;
- g. education and training;
- h. development of a management tool for fatigue;
- i. proper implementation of the ISM-code;
- j. healthy design of the ship;
- k. health promotion at work;
- l. expanding monitoring of fatigue causes, behaviours or consequences, including near misses.

The above list shows that fatigue prevention and management needs to be multi-dimensional. A possible way of achieving this is given in the concluding section.

6.7 Failure to act on recommendations

Another common feature of occupational fatigue is that there is often a failure to act on recommendations. A good example of this in the maritime sector can be seen in the USA. The National Transportation Safety Board (1999) reviewed issues relating to transport fatigue. This report confirms the role of fatigue in shipping accidents (e.g. the Exxon Valdez) and demonstrates that fatigue is often the result of high workload resulting from under manning. On the basis of this report recommendations were made to the US Coastguard. The first was to set limits on hours of work based on scientific knowledge. This was ignored and the US Coastguard developed a non-regulatory approach based on training rather than prescriptive regimes. A second recommendation was that officers on watch during departures from ports should have at least 6 hours off-duty in the previous 12 hours. Again, no action was taken on this recommendation.

7. OVERALL CONCLUSIONS

7.1 Established facts about seafarers' fatigue

High potential for fatigue in seafarers

Earlier sections of this report reviewed the evidence relating to seafarers' fatigue. Reports from diverse sources, including structured interviews and surveys, confirm that fatigue is a major issue at sea. The causes of fatigue are well-established in onshore jobs and many of the known risk factors are present offshore. Indeed, a major concern onshore has been the move to jobs that require 24/7 hours of work, and while this applies to only a small proportion of the onshore workforce it is often the norm for seafarers. In addition to fatigue-inducing conditions present in other jobs, seafarers are exposed to specific problems that add to the risk of fatigue. Furthermore, the workload of seafarers has greatly increased because of reduced manning levels, increased paperwork, faster port turnarounds and other pressures which reflect current economic demands. It is this combination of circumstances that leads to the high potential for fatigue in seafarers and those who are exposed to a large number of risk factors are the most liable to be fatigued.

Strong association between fatigue and accidents

It is now possible to assess perceptions of fatigue and these have been shown to be linked to both reduced safety and impaired health. These associations with objective indicators are important as some people suggest that reports of fatigue reflect characteristics of the individual rather than the impact of the nature of work. Accident statistics show a strong association with factors that increase the risk of fatigue, such as under manning and long working hours. Objective measures of performance efficiency are also influenced by fatigue and this suggests that it is not just watch-keepers who are likely to be affected but other members of the crew as well. Fatigue increases human error which not only increases the risk of collisions or groundings but also increases the risk of personal injury and also injuries to others.

Increased health risk to seafarers

Fatigue increases the risk of mental health problems (depression, anxiety, sleep disorders) and these not only reduce quality of life but also increase the risk of chronic disease and possibly death (May et al., 2002; Stansfeld et al., 2002). Suicide is also caused by psychopathology and there have been suggestions that the current working conditions of seafarers, especially under-manning, have increased the risk of self-harm (Tharakan, 2006).

Inadequate regulation

Given the undisputed risk of seafarers' fatigue it is surprising that little improvement in the situation has occurred in recent years. There have been some attempts to prevent or manage fatigue by legislation and guidance. The problem with these approaches is that there has been little attempt to evaluate their efficacy. Reports from different sectors and different members of the industry all show that these approaches have largely failed. Indeed, it could be argued that they may actually have made the situation worse and prevented easier detection of the levels of fatigue current in the industry. Poor regulation is undoubtedly a contributory factor and fatigue is often most prevalent in those sectors that are most difficult to regulate (e.g. the fishing industry).

Overall, the evidence base for seafarers' fatigue is strong and the negative consequences of fatigue for the individual, the ship, and society are clear.

7.2 Further implications of seafarers' fatigue

One of the problems with our current state of knowledge of seafarers' fatigue is that it is based on relatively few studies, which have often been conducted on rather selected samples. Indeed, these samples often reflect the better end of the industry and it is quite possible that the situation is far worse than described here. What are well established are the methods for assessing risk factors for fatigue, perceived fatigue and the consequences of fatigue. It is also important to take a holistic view of fatigue and address issues that have received no attention as yet. For example, it is probably the case that fatigue-inducing working conditions lead to many young seafarers leaving the industry at an early stage. Similarly, the relatively short careers of many seafarers may reflect a reduced ability to cope with fatigue later in their career. Longitudinal studies are necessary to confirm these speculations. Such studies could also inform about links between fatigue, chronic disease and mortality.

In summary, seafarers' fatigue is an occupational health and safety issue that is common and widespread. It is not being adequately dealt with by current legislation, management or working practices and there is an urgent need to rectify the situation.

7.3 The way forward

Treat fatigue as a serious health and safety issue

Walters (2005) has argued that a large proportion of the toll of work-related death, injury and ill-health amongst seafarers arises from failure to manage health and safety effectively. This failure is exacerbated by changes that have taken place in the structure and organisation of the industry internationally over the last quarter of a century that both increase risks to health and safety and make prevention of harm to workers more difficult to regulate or manage. Seafarers' fatigue should be tackled using standard approaches (e.g. regulation; appropriate training given; audits) and any increased risk dealt with in a similar way to other breaches of health and safety. Industry wide, cultural change is needed to address fatigue. There are serious risks and consequences associated with fatigued seafarers such as the potential for more environmental disasters and loss of life, the economic losses due to accidents, and the impact on the health and well being of the seafarers. The first stage of dealing with fatigue is to get the relevant people to acknowledge that there is a problem to address. The evidence base for this view is strong and has been developed by multi-disciplinary research studying a wide variety of ships in different countries. A wider perspective of the consequences of fatigue is required as our knowledge of the impact of fatigue on health shows that it reduces quality of life by increasing the risk of physical and mental health problems. Such effects are likely to be apparent in all sectors and ranks, and in some cases this may lead to an increased risk of premature death.

A more robust approach to regulation and manning

A starting point for improving the situation must be a more robust approach to regulation. It is important to ensure that potential fatigue is taken into account when setting appropriate manning levels. Manning levels need to be addressed in a realistic way that prevents economic advantage accruing to those who operate with bare minimums. Such an approach must consider more than the minimum levels necessary to operate a vessel rather it must address the need for maintenance, recovery time, redundancy, and the additional burden of the paperwork and drills associated with security and environmental issues. More sophisticated regulatory models need to be developed to allow such an approach.

Enforcement of legislation, elimination of false record-keeping, and better training and guidance

Another essential requirement is to enforce existing guidelines with mandatory provisions and take serious measures to overcome the problem of false record-keeping. This must be supplemented with appropriate training and guidance regarding avoidance of fatigue and optimum working conditions. Lessons can be learned from other transport industries and it is important to seek examples of best practice and apply these in an effective way to the maritime sector. Methods of addressing issues specific to seafaring are now well developed and a holistic approach to the issue of fatigue can lead to a culture that benefits the industry as a whole. Fatigue awareness training and the development of measures to identify fatigue and counter it are becoming common place in other transport sectors and may be a useful part in any package developed to prevent and manage fatigue at sea. However, their efficacy needs to be evaluated and the use of such approaches should not be seen as a reason for breaching regulations nor for the adoption of minimal levels of manning. Future research should, therefore, not be restricted to demonstrating that fatigue exists but be concerned with evaluation of methods of preventing and managing seafarers' fatigue (implementation and effectiveness research rather than fundamental research on the science of fatigue).

Learn from best practice in the maritime sector and in other comparable industries

This report has attempted to examine fatigue within different sectors of the maritime industry and also make comparisons with other transport sectors. Much of the report has been concerned with identification of risk factors for fatigue, the prevalence of fatigue and the consequences of it. This process has also identified the best methods of preventing and managing fatigue and it is apparent that the principles of "best practice" have been identified and operationalised in some contexts. It is important to learn from this and adopt those strategies that will lead to a culture of "best practice" and an elimination of "worst case scenarios". This approach will require the collaborative efforts of all stakeholders and good models of such teams (the work force, owners, regulators, and academics) have been developed in other areas of transport.

REFERENCES

- Akerstedt T. (1990). Psychological and psychophysiological effects of shift work. *Scand J Work Environ Health*, 16(suppl 1), 67-73.
- Åkerstedt T. (2003). Shift work and disturbed sleep/wakefulness. *Occup Med*, 53, 89-94.
- Akerstedt T, Fredlund P, Gillberg M, Jansson B. (2002). Work load and work hours in relation to disturbed sleep and fatigue in a large representative sample. *J Psychosom Res*, 53, 585-588.
- Akerstedt T, Haraldsson, PO. (2001). International consensus meeting on fatigue and the risk of traffic accidents. The significant of fatigue for transportation safety is underestimated. *Lakartidningen*, 98 (25), 3014-7.
- Akerstedt T, Kecklund G. (2001). Age, gender and early morning highway accidents. *Journal of Sleep Research*, 10, 105-120.
- Akerstedt, T, Kecklund G., Horte LG. (2001). Night driving, seasons and the risk of highway accidents. *Sleep*, 24, 401-406.
- Allen P, Burke A, Ellis N. (2003). A cross-vessel survey of seafarers examining factors associated with fatigue. In: McCabe PT, editor. *Contemporary Ergonomics 2003*: Taylor and Francis, 125-130.
- Allen P, Wadsworth E, Smith AP. (2006). The relationship between recorded hours of work and fatigue in seafarers. In: Bust PD, editor. *Contemporary Ergonomics 2006*: Taylor and Francis, 2006, 546-548.
- Allen PH, Wadsworth EJ, Smith AP. Submitted. Seafarers' fatigue: a review of recent literature.
- Allen P, Wellens B, McNamara R, Smith AP. (2005). It's not all plain sailing. Port turn-arounds and Seafarers' fatigue: A case study. In: Bust P, McCabe PT, editors. *Contemporary Ergonomics 2005*: Taylor and Francis, 2005, 563-567.
- Andrea H, Kant IJ, Beurskens AJHM, Metsemakers JFM, van Schayck CP. (2003). Associations between fatigue attributions and fatigue, health, and psychosocial work characteristics: a study among employees visiting a physician with fatigue. *Occup Environ Med*, 60, i99-i104.
- Arnedt JT, Wilde GJ, Munt PW, MacLean AW. (2001). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accid. Anal Prev*, 33(3), 337-44.
- Arnold P, Hartley LR. (2001). Policies and practices of transport companies that promote or hinder the management of driver fatigue. *Transportation Res. Part F* 4. 1-17.
- Australian National Transport Fatigue Expert Group (2001). Options for a regulatory approach to fatigue in drivers of heavy vehicles in Australia and New Zealand. www.ntc.gov.au
- AWAKE. Improving well-being in the workplace and the road. www.awakeld.info/

- Barger LK, Cade BE, Ayas NT, Cronin JW, Rosner B, Speizer FE, Czeisler CA. (2005). Extended work shifts and the risk of motor vehicle crashes among interns. *N Engl J Med*, 352, 125-134.
- Bartlett FC. (1943). Fatigue following highly skilled work. *Proceedings of the Royal Society*, 131, 147-257.
- Bartley SH, Chute E. (1947). *Fatigue and impairment in man*. New York: McGraw-Hill.
- Belyavin AJ, Spencer MB. (2004). Modelling performance and alertness: The QinetiQ approach. *Aviation, Space and Environmental Medicine*, 75, 93-103.
- Beurskens AJHM, Bultmann U, Kant IJ, Vercoulen JHMM, Bleijenberg G, Swaen GMH. (2000). Fatigue among working people: validity of a questionnaire measure. *Occup Environ Med*, 57, 353-357.
- Bielić T, Zec D. (2006). Influence of ship technology and work organization on fatigue. In: Nikolić N, Carter T. eds. *ISMH8 Book of Proceedings*. Rijeka: Studio Conex, 163-170.
- Bloor M, Thomas M, Lane T. (2000). Health risks in the global shipping industry: an overview. *Health, Risk and Society*, 2(3), 329-340.
- Boggild H, Knuttson A. (1999) Shift work, risk factors and cardiovascular disease. *Scand J Work Environ Health*, 25, 85-99.
- Bonnet MH, Arand DL. (1995). We are chronically sleep deprived. *Sleep*, 18, 908-911.
- Booth-Bourdeau J, Marcil I, Lawrence M, McCulloch K, Dawson D. (2006). Development of fatigue risk management systems for the Canadian Aviation Industry. *International conference on fatigue management in transportation operations*.
- Bowring A. (2004). Problems of minimum manning. *Seaways*, June, 23-24.
- Brandt L, Kirk N, Jensen O, Hansen H. (1994). Mortality among Danish merchant seamen from 1970 to 1985. *Am J Ind Med*, 25, 867-876.
- Broadbent DE, Cooper PF, Fitzgerald P, Parkes KR. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *Br J Clin Psychol*, 21, 1-16.
- Brown ID. (1989). *Study into hours of work, fatigue and safety at sea*. Cambridge: Medical Research Council.
- Brown, ID. (1994). Driver fatigue. *Hum. Factors*, 36(2), 298-314.
- Brown ID. (1997). Prospects for technological countermeasures against driver fatigue. *Accid. Anal Prev*, 29(4), 525-31.
- Buck, L., Lamonde F. (1993). Critical incidents and fatigue among locomotive engineers. *Safety Sci.*, 16(1), 1-18.
- Buell P, Breslow L. (1960). Mortality from coronary heart disease in Californian men who work long hours. *J Chron Dis*, 11, 615-626.

- Bultmann U, Kant IJ, Kasl SV, Beurskens AJHM, van den Brandt PA. (2002). Fatigue and psychological distress in the working population: Psychometrics, prevalence and correlates. *J Psychosom Res*, 52, 445-452.
- Bultmann U, Kant IJ, van den Brandt PA, Kasl SV. (2002). Psychosocial work characteristics as risk factors for the onset of fatigue and psychological distress: prospective results from the Maastricht Cohort Study. *Psychol Med*, 32, 333-345.
- Burke A, Ellis E, Allen P. (2003). The impact of work patterns on stress and fatigue among offshore worker populations. In: McCabe P, editor. *Contemporary Ergonomics 2003*: Taylor and Francis, 131-136.
- Caldwell JAJ, Caldwell JL. (2003). *Fatigue in aviation*. Aldershot, UK: Ashgate Publishing Ltd.
- Campbell SS. (1992). Effects of sleep and circadian rhythms on performance. In: *Handbook of Human Performance*, Vol 3. Eds: A.P.Smith and D.M. Jones. London: Academic Press. Pp.195-216.
- Cameron, C. (1971). Fatigue, problems in modern industry. *Ergon*. Vol. 14 (6). Nov. 1971. 713-720.
- Carter T. (2005). Working at sea and psychosocial health problems. Report of an international maritime health association workshop. *Travel medicine and infectious disease*, 3, 61-65.
- Charlton SG, Baas PH. (2001). Fatigue, work-rest cycles, and psychomotor performance of New Zealand truck drivers. *New Zealand Journal of Psychology*, 30, 32-39.
- Chen MK. (1986). The epidemiology of self-perceived fatigue among adults. *Prev Med*, 15, 74-81.
- Collins A, Mathew V, McNamara R. (2000). *Fatigue, health and injury among seafarers and workers on offshore installations: A review*: Seafarers International Research Centre (SIRC), Cardiff.
- Colquhoun WP, Costa G, Folkard S, et al. (1996). *Shift work: problems and solutions*. Frankfurt: Peter Lang, 1-224.
- Comperatore CA, Rivera PK, Kingsley L. (2005). Enduring the shipboard stressor complex: A systems approach. *Aviation, Space, and Environmental Medicine*, 76(6), 108-118.
- Condon R, Colquhoun P, Plett R, Knauth P, Fletcher N, Eickhoff S. (1986). Circadian Variation in Performance and Alertness under Different Work Routines on Ships. In M. Haider, M. Koller and R. Cervinka (Eds). *Night and Shift work: Long-term Effects and their Prevention*. Frankfurt: Verlag Peter Lang. pp277-284.
- Condon R, Colquhoun P, Plett R, DeVol D, Fletcher N. (1988). Work at sea: A study of sleep, and of circadian rhythms in physiological and psychological functions, in watch-keepers on merchant vessels. IV rhythms in performance and alertness. *Int. Arch. Occ. Environ. Health*, 60, 405-411.
- Connor J, Whitlock G, Norton R, Jackson R. (2001). The role of driver sleepiness in car crashes: A systematic review of epidemiological studies. *Acc Anal Prev*, 33, 31-41.

- Conway GA. (2002). Casting their lot upon the water: commercial fishing safety (Commentary). *The Lancet*, 360, 503-504.
- Cook TC, Shipley P. (1980). Human Factors Studies of the Working Hours of UK Ships' Pilots, 1: A Field Study of Fatigue. *Applied Ergonomics*, 11(2), 85-92.
- Coplen M, Sussman D. (2000). Fatigue and alertness in the United States railroad industry part.II..*Transportation Res. Part F. Traffic psychology and Behav*, 3, 221-228.
- Costa G. (2003). Shift work and occupational medicine: an overview. *Occupational medicine*, 53(2), 83-88.
- Costa G, Folkard S, Harrington JM. (2000). Shiftwork and extended hours of work. In: Baxter PJ, Adams PH, Aw TC, et al, eds. *Hunter's Diseases of Occupation*, 9th ed. London: Arnold, 581-589.
- Craig A, Cooper RE. (1992). Symptoms of acute and chronic fatigue. In: *Handbook of Human Performance*, Vol 3. Eds: A.P.Smith and D.M. Jones. London: Academic Press. Pp.289-340.
- Crawford A. (1961). Fatigue and driving. *Ergon*, 4, 143-54.
- Dahlgren A, Kecklund G, Akerstedt T. (2005). Different levels of work-related stress and the effects on sleep, fatigue and cortisol. *Scand J Work Environ Health*, 31, 277-285.
- Dawson D, Fletcher A. (2001). A quantitative model of work-related fatigue: background and definition. *Ergonomics*, 44, 144-163.
- Dawson D, Reid K. (1997) Fatigue, alcohol and performance. *Nature*, 388, 235.
- Dembe AE, Erickson JB, Delbos RG and Banks SM. (2005). The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States. *Occupational and Environmental Medicine*, 62, 588-597.
- Dinges DF, Mallis MM. (1998). Managing fatigue by drowsiness detection: Can technological promises be realized? In Hartley L.R. (ed) *Managing fatigue in transportation*. Oxford: Elsevier.
- Dorrian J, Roach GD, Fletcher A, Dawson D. (2006). Simulated train driving: fatigue, self-awareness and cognitive disengagement. *Appl. Ergon.*, 17,
- Dorrian J, Roach GD, Fletcher A, Dawson D. (2006). The effects of fatigue on train handling during speed restrictions. *Transportation Res. Part F. Traffic Psychology and Behav*, 9(4), 243-257.
- Ellis N. (2005). Safety and perceptions of risk. *SIRC Symposium*, Cardiff.
- Ellis N, Allen P, Burke A. (2003). The influence of noise and motion on sleep, mood and performance of seafarers. In: McCabe PT, editor. *Contemporary Ergonomics 2003*: Taylor and Francis, 137-142.
- Fairclough SH, Graham R. (1999). Impairment of driving performance caused by sleep deprivation or alcohol: a comparative study. *Human Factors*, 41(1), 118-28.

- Fishing Industry Safety and Advisory Group. (2004). Maritime Safety Authority of New Zealand, Wellington.
- Fletcher A, McCulloch K, Baulk SD, Dawson D. (2005). Countermeasures to driver fatigue: a review of public awareness campaigns and legal approaches. *Aust. N Z J Public Health*, 29(5), 471-6.
- Floyd WF, Welford AT. (1953). *Fatigue*. London: Lewis.
- Folkard S. (1990). Circadian performance rhythms: some practical and theoretical implications. *Philos Trans R Soc Lond B Biol Sci*, 327, 543-553.
- Folkard S. (1997). Black times: temporal determinants of transport safety. *Accid. Anal Prev*, 29(4): 417-30.
- Folkard S, Akerstedt T. (1992). A three process model of the regulation of alertness-sleepiness. In: *Sleep, Arousal and Performance*. Edited by RJ Broughton and BD Ogilivie. Boston: Birkhauser.
- Folkard S, Lombardi DA, Tucker PT. (2005). Shiftwork: safety, sleepiness and sleep. *Industrial Health*, 43, 20-23.
- Folkard S, Tucker P. (2003). Shift work, safety and productivity. *Occupational medicine* 53(2), 95-101
- Foo SC, How J, Siew MG, Wong TM, Vijayan A, Kanapathy R. (1994). Effects of sleep deprivation on naval seamen: II. Short recovery sleep on performance. *Annals of the Academy of Medicine, Singapore*, 23(5), 676-679.
- Gander PH. (2005). A review of fatigue management in the maritime sector: Massey University Sleep/Wake Research Centre.
- Gander PH, Barnes RM, Gregory KB, Graeber RC, Connell LJ, Rosekind MR. (1998). Flight crew III: North Sea helicopter air transport operations. *Aviat. Space Environ. Med.* 69(9 suppl) B16-25.
- Gander, PH, Graeber RC, Connell LJ, Gregory KB, Miller DL, Rosekind MR. (1988). Flight crew I: objectives and methods. *Aviat. Space Environ. Med.* 69(9 suppl) B1-7.
- Gander PH, Gregory KB, Graeber RC, Connell LJ, Miller DL, Rosekind MR. (1998). Flight crew fatigue II: short-haul fixed-wing air transport operations. *Aviat. Space Environ Med.* 69(9 Suppl) B8-15.
- Gander PH, Gregory KB, Miller DL, Graeber RC, Connell LJ, Rosekind MR. (1998). Flight crew fatigue V: long-haul air transport operations. *Aviat Space Environ. Med.* 69(9 suppl) B37-48.
- Gander PH, Le Quesne L. (2001). A survey of fatigue and shift work among masters and mates. Wellington: Sleep/Wake Research Centre.
- Gander PH, Marshal NS, Harris RB, Reid P. (2005). Sleep, sleepiness and motor vehicle accidents: a national survey. *Aust. N Z J Public Health*, 29(1), 16-21.
- Gander PH, Marshall ND, Bolger W, Girling I. (2005). An evaluation of driver training as a fatigue countermeasure. *Transportation Res. Part F*, 8; 47-58.

- Gander PH, Rosekind MR, Gregory KB. (1998). Flight crew fatigue VI: a synthesis. *Aviat. Space Environ. Med.*, 69(9 Suppl) B49-60.
- Gander PH, Van den Berg M, Signal L. Sleep and Fatigue on Fresher vessels during the hoki season. (2005). New Zealand: Massey University Sleep / Wake Research Centre.
- Goh VH. (2000). Circadian disturbances after night-shift work onboard a naval ship. *Military Medicine*, 165(2):101-105.
- Gold DR, Rogacz S, Bock N et al. (1992). Rotating shift work, sleep and accidents related to sleepiness in hospital nurses. *Am. J. Pub. Health*, 82, 1011-1014.
- Goldberg D. (1992). *General Health Questionnaire (GHQ-12)* Windsor, UK: NFER Nelson.
- Goodwin P. (1996). Empirical evidence on induced traffic. *Transportation*, 23, 35-54.
- Grandjean EP, Wotzka G, Schaad R, Gilgen A. (1971). Fatigue and stress in air traffic controllers. *Ergonomics*, 14(1), 159-165.
- Grant JS. (1971). Concepts of fatigue and vigilance in relation to railway operation. *Ergonomics*, 14(1), 111-118.
- Grey M. (2005). Building a case against fatigue. *Lloyds list*. Monday April 18th, 2005.
- Hakkanen H, Summala H. (2000). Sleepiness at work among commercial truck drivers. *Sleep*, 23, 49-57.
- Hamelin P. (1987). Lorry drivers' time habits in work and their involvement in traffic accidents. *Ergonomics*, 30, 1323-1333.
- Hansen HL. (1996). Surveillance of deaths on board Danish merchant ships 1986-1993. *Occup Environ Med*, 53, 269-275.
- Hansen HL, Nielsen D, Frydenberg M. (2002). Occupational accidents aboard merchant ships. *Occupational and environmental medicine*, 59(2), 85-91.
- Hansen HL, Pedersen G. (1996). Influence of Occupational Accidents and Deaths Related to Lifestyle on Mortality among Merchant Seafarers. *Int J Epid*, 25(6), 1237-43.
- Hansen HL, Tüchsen F, Hannerz H. (2005). Hospitalisations among seafarers on merchant ships. *Occupational and Environmental Medicine*, 62, 145-150.
- Haraldsson PO, Carenfeldt C, Diedrichsen F, Nygren A, Tingvall C. (1990). Clinical symptoms of sleep apnea syndrome and automobile accidents. *Otorhinolaryngol* 52, 57-62.
- Hardy GE, Shapiro DA, Borrill CS. (1997). Fatigue in the workforce of National Health Service Trusts: levels of symptomology and links with minor psychiatric disorder, demographic, occupational and work role factors. *J Psychosom Res*, 43, 83-92.
- Harrington JM. (1978). *Shift work and health: a critical review of the literature*. London: The Stationery Office, 1-28.

- Harrington JM. (2001). Health effects of shift work and extended hours of work. *Occup Environ Med*, 58, 68-72.
- Hartley LR. (1997). Introduction. *Accid. Anal and Prev*, 29, 407-408.
- Hemmingsson T, Lundberg I, Nilsson R, Allebeck P. (1997). Health related selection to seafaring occupations and its effects on morbidity and mortality. *Am. J. Ind. Med*, 31(5) 662-668.
- Houtman I, Miedema M, Jettinghoff K, Starren A, Heinrich J, Gort J, et al. (2005). Fatigue in the shipping industry. TNO, 2005.
- How JM, Foo SC, Low E, Wong TM, Vijayan A, Siew MG, et al. (1994). Effects of sleep deprivation on performance of naval seamen: I. Total sleep deprivation on performance. *Annals of the Academy of Medicine, Singapore*, 23(5), 669-675.
- Huibers M, Bleijenberg G, van Amelsvoort L, Beurskens A, van Schayck C, Bazelmans E, Knottnerus J. (2004). Predictors of outcome in fatigue employees on sick leave. Results from a randomised trial. *J Psychosom Res*, 57, 443-449.
- ICAO (1974). Convention on International Civil Aviation, Annex 6, Part I, Attachment A.
- ILO. (1986). Health protection and medical care for seafarers, Report III. In: Preparatory Technical Maritime Conference G editor Geneva: Cited in Joint ILO/WHO Committee on the Health of Seafarers (1993). Occupational accidents among seafarers resulting in personal injuries, damage to their general health and fatalities. Working paper No. 1.
- IMO (2002). Guidelines on Fatigue: International Maritime Organization.
- International Transport Federation (ITF). (1998). Seafarer fatigue: Wake up to the dangers: ITF.
- Janssen N, Kant IJ, Swaen GMH, Janssen PPM, Schroer KAP. (2003). Fatigue as a predictor of sickness absence: results from the Maastricht cohort study on fatigue at work. *Occup Environ Med*, 60, i71-i76.
- Janssen N, Kant I, van den Brandt P. (2002). Need for recovery in the working population: description and associations with fatigue and psychological distress. *Int J Behav Med*, 9, 322-340.
- Jay S, Lamond N, Ferguson S, Dorrian J, Dawson D. (2005). Predictors of recovery following acute sleep loss. International Conference on Fatigue Management in Transportation Operations. Seattle.
- Jensen OC, Sorensen JFL, Canals ML, Hu YP, Nikolic N, Thomas M. (2004). Incidence of self-reported occupational injuries in seafaring- an international study. *Occupational Medicine*, 54(8), 548-555.
- Jewett ME, Kronauer RE. (1999). Interactive mathematical models of subjective alertness and cognitive throughput in humans. *J Biol Rhythms*, 14, 598-601.
- Jones CB, Dorrian J, Rajaratnam SMW, Dawson D. (2005). Working hours regulations and fatigue in transportation: A comparative analysis. *Safety Sci*, 43(4), 225-252.

- Keall MD, Frith WJ, Patterson TL (2005). The contribution of alcohol to night time crash risk and other risks of night driving. *Accid Anal Prev*, 37, 816-824.
- Knutsson A. (2003). Health disorders of shift workers. *Occup Med*, 53, 103-108.
- Koller M. (1983). Health risks related to shift work. An example of time-contingent effects of long-term stress. *Int Arch Occup Environ Health*, 53, 59-75.
- Lal, SK, Craig A, Boord P, Kirkup L, Nguyen H. (2003). Development of an algorithm for an EEG-based driver fatigue countermeasure. *J Saf Res*, 34(3), 321-328.
- Lamond N, Dawson D. (1999). Quantifying the performance impairment associated with fatigue. *Sleep Res*, 8(4), 255-62.
- Landstrom U, Akerstedt T, Bystrom M, Nordstrom B, Wiborn R. (2004). Effect on drivers' alertness of a 30 minute exposure to bright light: A field study. *Perceptual and Motor Skills*, 98, 770-776.
- Lawrie T, Matheson C, Murphy E, Ritchie L, Bond C. (2003). Medical emergencies at sea and injuries among Scottish fishermen. *Occupational Medicine*, 53(3), 159-164.
- Leone S, Huibers M, Kant I, van Schayck C, Bleijenberg G, Knottnerus J. (2006). Long-term predictors of outcome in fatigued employees in sick leave: a 4-year follow-up study. *Psychol Med*.
- Luz J, Melamed S, Najenson T, Bar N, Green MS. (1990). The structured ergonomic stress (E-S-L) index as a predictor of accidents and sick leave among male industrial employees. Fourth International Conference on the Combined Effects of Environmental Factors, Baltimore.
- Marine Accident Investigation Branch (2004). Bridge Watch-keeping Safety Study: MAIB.
- Marshall SW, Kucera K, Loomis D, McDonald MA, Lipscomb HJ. (2004). Work related injuries in small scale commercial fishing. *Injury prevention*, 10, 217-221.
- Malawwethanthri K. (2003). Fatigue and jet lag. *Seaways*, 2003, 26-28.
- Malgorzata Z. (1982). The role of reactivity and personality traits in railroad accidents. *Polish Psychological Bulletin*, 13, 197-206.
- Matheson C, Lawrie T, Morrison S, Ritchie L, Murphy E, Bond C. (2001). Health in the catching sector of the fishing industry: University of Aberdeen.
- May M, McCarron P, Stansfeld S, Ben-Shlomo Y, Gallacher J, Yarnell J, Davey Smith G, Elwood P, Ebrahim S. (2002). Does psychological distress predict the risk of ischemic stroke and transient ischemic heart attack? The Caerphilly Study. *Stroke*, 33, 5-6.
- McCart AT, Rohrbaugh JW, Hammer MC, Fuller SZ. (2000). Factors associated with falling asleep at the wheel among long-distance truck drivers. *Accid. Anal Prev*, 32(4), 493-504.
- McCulloch K, Fletcher A, Dawson D. (2002). Fatigue management systems in aviation: an evaluation. In: IGN Susila (Ed), *Kumpular Makalah: Ergonomi*. Bali.

- McNamara R, Allen P, Wellens B, Smith AP. (2005). Fatigue at sea: Amendments to working time directives and management guidelines. In: Bust PD, McCabe PT, editors. *Contemporary Ergonomics 2005*: Taylor and Francis, 2005, 568-572.
- McNamara RL, Allen PH, Wadsworth EJK, Wellens BT, Smith AP. Submitted. Fatigue and associated risk factors in a seafaring population.
- McNamara R, Collins A, Cole-Davies V. (2001). An analysis of accidents in the offshore oil industry. In: Hanson MA, editor. *Contemporary Ergonomics 2001*: Taylor and Francis, 479-484.
- McNamara R, Smith AP. (2002). The combined effects of fatigue indicators on health and well-being in the offshore oil industry. *Archives of Complex Environmental Studies*, 14, 3-4.
- Milosevic, S. (1997). Drivers fatigue studies. *Ergonomics*, 40(3), 381-389.
- Missoni E, Nikolić N, Kovačević S. Fatigue as the main factor in determining the duration of flight duty of the crew – what about shift work on board merchant ships? In: Nikolić N, Carter T. eds. *ISMH8 Book of Proceedings*. Rijeka: Studio Conex, 293-298.
- Mohren DC, Swaen GM, Kant I, Borm PJ, Galama JM. (2001). Associations between infections and fatigue in a Dutch working population: results of the Maastricht Cohort Study on Fatigue at Work. *Eur J Epidemiol*, 17, 1081-1087.
- Moore-Ede M, Heitmann A, Guttkuhn R, Trutschel U, Aguirre A, Croke D. (2004). Circadian alertness simulator for fatigue risk assessment in transportation: application to reduce frequency and severity of truck accidents. *Aviat. Space Environ. Med*, 75(3 suppl) A119-21.
- Nachreiner F., Hanecke K. (1992) Vigilance. In: *Handbook of Human Performance*, Vol 3. Eds: A.P.Smith and D.M. Jones. London: Academic Press. Pp.261-288.
- Nakata A, Ikeda T, Takahashi M, Haratani T, Fujioka Y, Fukui S, Swanson NG, Hojou M, Akari S. (2005). Sleep-related risks of occupational injuries in Japanese small and medium-scale enterprises. *Ind Health*, 43, 89-97.
- National Maritime Polytechnic (2006). Stress management profile of Filipino seafarers. In: A better understanding of the human element in shipping through maritime researches. Manila.
- NTSB (1990). Fatigue, alcohol, other drugs and medical factors in fatal-to-the-driver heavy truck crashes. National Transportation and Safety Board, Safety Study.
- NTSB (1995). Factors that affect fatigue in heavy truck accidents. National Transportation and Safety Board, Safety Study .
- Omdal KA. (2003). A survey of health and work environment onboard Norwegian ships 7th International Symposium on Maritime Health.
- Parker AW, Hubinger LM, Green S, Sargent L, Boyd R. (1997). A survey of the health, stress and fatigue of Australian seafarers. Australian Maritime Safety Authority.
- Parkes KR. (2002). Psychosocial aspects of work and health in the North Sea oil and gas industry. Summaries of reports published 1996-2001. Research reports: Health and Safety Executive (HSE).

- Patraiko D. (2006). Fatigue onboard - Raising awareness: The Nautical Institute reporting plan. Seaways, March, 4-6.
- Peter R, Siegrist J, Hallqvist J, Reuterwall C, Theorell T. (2002). Psychosocial work environment and myocardial infarction: improved risk estimation by combining two complementary job stress models in the SHEEP study. *J Epidem Com Health*, 56, 294-300.
- Philip P. (2005). Sleepiness of occupational drivers. *Ind. Health*, 43(1), 30-33.
- Philip P, Akerstedt T. (2006). Transport and industrial safety, how are they affected by sleepiness and sleep restriction? *Sleep Medicine*.
- Philip P, Ghorayeb I, Stoohs R. et al. (1996). Determinants of sleepiness in automobile drivers. *J. Psychosom Res*, 41, 279-88.
- Philip P, Taillard J, Guilleminault C, Quera Salva MA, Bioulac B, Ohayan M. (1999). Long distance driving and self-induced sleep deprivation among automobile drivers. *Sleep*, 22, 475-480.
- Pilcher JJ, Coplen MK. (2000). Work/rest cycles in railroad operations: Effects of shorter than 24-h shift work schedules and on-call schedules of sleep. *Ergonomics*, 43(5), 573-588.
- Powell WR, Crossland P. (1998). A literature review of the effects of vessel motion on human performance. INM Technical Report No 98027.
- Raby M, Lee JD. (2001). Fatigue and workload in the maritime industry. In: Hancock PA, Desmond PA, editors. *Stress, Workload and Fatigue*. Mahwah, New Jersey: Lawrence Erlbaum associates, 566-578.
- Raby M, McCallum MC. (1997). Procedures for Investigating and Reporting Fatigue Contributions to Marine Casualties. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting.
- Rapisarda V, Valentino M, Bologini S, Fenga C. (2004). Noise-related occupational risk aboard fishing vessels: considerations on prevention and the protection of exposed workers. *Giornale Italiano di Medicina del Lavoro Ed Ergonomia*, 26(3), 191-196.
- Ray C, Weir WRC, Phillips S, Cullen S. (1992). Development of a measure of symptoms in Chronic Fatigue Syndrome: The Profile of Fatigue-Related Symptoms (PFRS). *Psychology and Health*, 7, 272-243.
- Rey de Castro J, Gallo J, Loureiro H. (2004). Tiredness and sleepiness in bus drivers and road accidents in Peru: a quantitative study. *Rev. Panam Salud Publica*, 16(1), 11-8.
- Reyner LA., Horne JA. (1997) Suppression of sleepiness in drivers: combination of caffeine with a short nap. *Psychophysiology*, 34, 721-725.
- Rhodes W, Gill V, McCulloch K, Fletcher A, Dawson D. (2005). The basis for a guidelines manual for the design of fatigue management programs for all transportation modes in Canada. International Conference on Fatigue Management in Transportation Operations. Seattle.

- Roach, GD, Dorrian J, Fletcher A, Dawson D. (2001). Comparing the effects of fatigue and alcohol consumption on locomotive engineers performance in a rail simulator. *J Hum. Ergol* (1-2), 125-130.
- Roberts SE. (2002). Hazardous occupations in Great Britain. *The Lancet*, 360(9332), 543-544.
- Roberts SE, Hansen HL. (2002). An analysis of the causes of mortality among seafarers in the British merchant fleet (1986-1995) and recommendations for their reduction. *Occupational Medicine*, 52, 195-202.
- Roberts SE, Marlow PB. (2005). Traumatic work related mortality among seafarers employed in British merchant shipping, 1976-2002. *Occupational and Environmental Medicine*, 62, 172-180.
- Roberts SE. (2000). Occupational mortality among British merchant seafarers (1986-1995). *Maritime Policy and Management*, 27(3), 253-265.
- Ryan TA. (1947). *Work and effort: the Psychology of Production*. New York: Ronald Press.
- Sabbagh-Ehrlich S, Friedman L, Richter ED. (2005). Working conditions and fatigue in professional truck drivers at Israeli ports. *Inj. Prev*, 11(2), 110-114.
- Sagberg F. (1999). Road accidents caused by drivers falling asleep. *Accid. Anal Prev*, 31(6), 639-649.
- Sherry P. (2005). A fatigue model and job performance: testing the validity of model predictions for locomotive engineers. *International Conference on Fatigue Management in Transportation Operations*. Seattle.
- Shiple P. (1978). *A Human Factors Study of Marine Pilotage*. Ship and Marine Technology Requirements Board, DTI.
- Sluiter JK, van der Beek AJ, Frings-Dresen MHW. (1999). The influence of work characteristics on the need for recovery and experienced health: a study on coach drivers. *Ergonomics*, 42, 573-583.
- Sluiter JK, de Croon EM, Meijman TF, Frings-Dresen MHW. (2002). Need for recovery from work related fatigue and its role in the development and prediction for subjective health complaints. *Occup Environ Med*, 60, i62-i70.
- Smith, AP. (1992). Time of day and performance. In: *Handbook of Human Performance*, Vol 3. Eds: A.P.Smith and D.M. Jones. London: Academic Press. Pp.261-288.
- Smith AP. (1999). The Problem of Fatigue Offshore. In: *Proceedings of Seafarers International Research Centre First Symposium*. Cardiff University. Pp. 52-73.
- Smith AP. (2003). Seafarers' fatigue, health and safety. *Personalführung*, 2, 46-52
- Smith AP. (2006). Shift work on oil installations. In *Contemporary Ergonomics 2006*. Editor: P.D.Bust. pp.561-569.
- Smith AP, Allen P, Wadsworth EJ. (2006). *Seafarers' fatigue: The Cardiff Research Programme*. Report to MCA and HSE.

- Smith AP, Ellis N. (2002). Objective measurement of the effects of noise aboard ships on sleep and mental performance. International Congress and Exposition on Noise Control Engineering, 149-154.
- Smith AP, Lane T, Bloor M. (2001) Fatigue Offshore: A comparison of Offshore Oil Support Shipping and the offshore oil industry. Cardiff: Seafarers International Research Centre (SIRC).
- Smith AP, Lane T, Bloor M. (2003). An overview of research on fatigue in support shipping in the offshore oil industry. In: McCabe PT, editor. Contemporary Ergonomics 2003,119-124.
- Smith AP, Lane T, Bloor M, Allen P, Burke A, Ellis N. (2003). Fatigue Offshore: Phase 2. The short sea and coastal shipping industry. Cardiff: Seafarers International Research Centre (SIRC).
- Smith AP, McNamara R, Wellens B. (2004). Combined effects of Occupational Health Hazards. HSE Contract Research, Report 287. HSE Books.
- Smith AP, Owen S. (1990). Time of day and accidents in marine pilotage. In: Shiftwork: Health, Sleep and Performance, Studies in Industrial and Organizational Psychology, Vol.10, (eds) G. Costa, G.C. Cesana, K. Kogi and A. Wedderburn. Frankfurt: Peter Lang, 617 - 622.
- Spencer MB, Robertson KA, Folkard S. (2006). The development of a fatigue/risk index for shift workers. HSE Contract Research Report.
- Stansfeld SA, Fuhrer R, Shipley MJ, Marmot MG. (2002). Psychological distress as a risk factor for coronary heart disease in the Whitehall II Study. Int J Epidemiol, 31, 248-255.
- Stone B, McCuffog A, Spencer M, Turner C, Mills A. (2005). Fatigue and shift work in UK train drivers. International Conference on Fatigue Management in Transportation Operations. Seattle.
- Summala, H, Mikkola T. (1994). Fatal accidents among car and truck drivers: effects of fatigue, age and alcohol consumption. Hum Factors, 36(2), 315-326.
- Sussman D, Coplen M. (2000). Fatigue and alertness in the United States railroad industry part I: The nature of the problem. Transportation Res. Part F. Traffic Psychol. and Behav, 3 (4), 211-220.
- Tamura Y, Kawada T, Sasazawa Y. (1997). Effects of ship noise on sleep. Journal of Sound and Vibration, 204(4), 417-425.
- Tamura Y, Horiyasu T, Sano Y, Chonan K, Kawada T, Sasazawa Y, et al. (2002). Habituation of sleep to a ship's noise as determined by actigraphy and a sleep questionnaire. Journal of Sound and Vibration, 250(1), 107-113.
- Tharakan J. (2006). Modern seafaring can kill you. Fairplay, April, 12.
- THINK (2006). The THINK road safety campaign. www.thinkroadsafety.gov.uk
- Thomas M, Sampson H, Zhao, M. (2003). Finding a balance: companies, seafarers and family life. Maritime Policy and Management, 30(1), 59-76.

- Tilley A., Brown S. (1992). In: Handbook of Human Performance, Vol 3. Eds: A.P.Smith and D.M. Jones. London: Academic Press. Pp.237-260.
- Tirilly G. (2004). The impact of fragmented schedules at sea on sleep, alertness and safety of seafarers. *Medicina Maritima*, 4(1), 96-105.
- Transport Development Centre, Transport Canada (1998). Options for changes to hours of service for commercial vehicle drivers. Ottawa: Transport Canada.
- Tzamalouka G, Papadakaki M, El Chliaoutakis J. (2005). Freight transport and non-driving work duties as predictors of falling asleep at the wheel on urban areas of Crete. *J Safety Res*, 36(1), 75-84.
- Van Amelsvoort LGPM, Kant IJ, Beurskens AJHM, Schroer CAP, Swaen GMW. (2002). Fatigue as a predictor of work disability. *Occup Environ Med*, 59, 712-713.
- Van Dongen HPA. (2004). Comparison of mathematical model predictions to experimental data of fatigue and performance. *Aviat Space Environ Med*, 75, 15-36.
- Wadsworth EJK, Allen PH, Wellens BT, McNamara RL, Smith AP. Submitted. Fatigue and subjective reports of health among British seafarers.
- Wadsworth EJK, Allen PH, Wellens BT, McNamara RL, Smith AP. (2006). Patterns of fatigue among seafarers during a tour of duty. *Am J Ind Med*, 49, 836-844.
- Walters D. (2005). Occupational health and safety at sea. SIRC symposium. Cardiff.
- Wang JS, Knippling RR. (1994). Single vehicle roadway departure crashes: Problem size assessment and statistical description. US Department of Transport.
- Ware JE, Sherbourne CD. (1992). The MOS 36-item short-form health survey (SF-36). *Med Care*, 30, 473-483.
- Waterhouse JM, Folkard S, Minors DS. (1992). Shiftwork, health and safety. An overview of the scientific literature 1978-90. London: The Stationery Office, 1-31.
- Welford AT, Brown RA, Gabb JE. (1950). Two experiments on fatigue as affecting skilled performance in civilian air crew. *Brit. J. of Psychology*, 40, 195-211.
- Wellens B, McNamara R, Allen P, Smith AP. (2005). Collisions and collision risk awareness at sea: Data from a variety of seafarers. In: Bust PD, McCabe PT, editors. *Contemporary Ergonomics 2005*: Taylor and Francis, London., 573-577.
- Wellens BT, McNamara RL, Ellis N, Smith AP. (2002). Combined effects of shift work and occupational noise exposure on performance tasks in a seafaring population. *Archives of Complex Environmental Studies*, 14 (3-4).
- Wickramatillake HD. (1999). Coronary heart disease deaths among British and Indian seafarers. SIRC Report. Cardiff.
- Wigmore LM. (1989). Are Our Working Hours Safe? An Independent Look at Working Practices aboard British Oil-rig Supply Vessels. *Seaways*, November, 7-8.

Williamson AM, Feyer AM. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occup. Environ Med*, 57(10), 649-655.

Wright N, Powell D, McGown A, Broadbent E, Loft P. (2005). Avoiding Involuntary Sleep during civil air operations: Validation of a Wrist-worn alertness device. *Aviat. Space Environ. Med*, 76(9), 847-856.

Wyatt S., Langdon JN, Stock FGL. (1929). Fatigue and boredom in repetitive work. Report 77, Industrial Health Board.

Zhou DS. (1991). Epidemiological features and causes of railway traffic accidents. *Zhonghus Yu Fang Yi Xue Za Zhi*, 25(1), 26-9.

Appendix 1**2005 International Conference on Fatigue Management in Transportation Operations**

Author	Title	Journal/year	Cross-ref
Aboukhalil A; Oman, CM; Popkin, S; Pollard, JK; Howarth, H.	Quantitative assessment of locomotive cab environment and engineer head movement for development of an alertness monitor	Proceeding of the 2005 Int. Conf. on Fatigue Management in Transport operation, Seattle, Sept. 11-15	Session 7B
Akerstedt, Torbjorn.	New development of Nano and Microsensors for monitoring of sleep and sleepiness	Abstract	Session 2A
Barr, Howarth; Popkin, Carroll.	A review and evaluation of emerging driver fatigue detection measures and technologies		Session 12B
Berka, Chris; Westbrook, Philip; Levendowski, Daniel J; Lumicao, Michelle; Ramsey, Caitlin; Zavora, Timothy; Offner, Travis.	Implementation model for identifying and treating obstructive sleep apnea in commercial drivers		Session 16B
Boivin DB; Casademont, A; Heslegrave, R; Smahel, T; Donderi, D; Smiley, A.	Commercial motor vehicle driver work-rest schedules and fatigue levels in the Canadian industry		Session 15A
Booth-bourdeau, Jaqueline; Marcil, Isabelle; Lawrence, Mark; Mcculloch, Kirsty; Dawson, Drew.	Development of fatigue risk management systems for the Canadian Aviation industry		Session 21C
Bourgeois-Bougrine, Samira; Mollard, Regis and Speyer, Jean-Jacques.	Cross cultural survey of fatigue effect on resource management	15 June 2005	Poster 2D
Bourgeois-Bougrine, Samira; Folkard, Simon; Philippe Cabon; Mollard, Regis; Normier, Veronique; Speyer, Jean-Jacques.	Recommendations for maintaining aircrews alertness on long-haul tours of duty	15 June 2005	Session 20C

Bridges, Bob; Johansson, Peter; Pearson, Len	Using risk engineering grading systems to assess organizational fatigue risk		Session 14D
Carvalhais, Antonio; Comperatore, Carlos; Rivera, Pik and Stevens, LT Samson	An interactive tool to identify and manage endurance risk in work environments		Session 12C
Comperatore, Carlos and Rivera, Pik	Applying systems analysis to the management of shipboard stressors		Session 19A
Craft, Ralph.	Fatigue and the large truck crash causation study	18 August 2005	Session 5D
Dick, Virginia; Knipling, Ronald R and Hendrix, James.	Fleet safety and Health impacts of the revised U.S. Hours-Of-service rules	Jun 15, 2005	Session 23B
Dougherty, Mark.	Implementing crew endurance management in tow and barge operations		Session 14C
Dorrian, Jillian and Dawson, Drew.	Modeling the relationship between sleep/wake history and fatigue-related truck accidents		Session 8B
Dorrian, Jillian; Hussey, Frank; and Dawson, Drew.	The effects of fatigue on train driving performance: A data logger study		Session 23C
Eddy, Douglas; Gibbons, John and Stevens, Kenneth.	An assessment of modafinil for vestibular and aviation-related effects		Session 19D
Emond, Bryan; Stephens, Samson; Combs, Diana; and Forbes, Diana.	Crew endurance management: A non-regulatory approach and the question of voluntary compliance		Session 25A
Flatley, D; Reyner, LA and Horne, JA.	Sleep-related crashes on UK roads during light and darkness		Session 1B
Folkard, Simon and Lombardi, David A	Can a 'risk index' replace work hour limitations?		Session 11A
Friswell, Rena and Williamson, Ann.	Evaluating fatigue management strategies for long distance road transport	22 nd June 2005	Session 18A
Gertler, J; Viale A and Raslear T	Work Schedules and sleep patterns of U.S. railroad signalmen		Poster 2B

Grundel, A; Akerstedt, T; Cabon, P; Simons, R; Spencer.	Aircrew Alertness on the Ultra long range route Singaport – Los Angeles	Sept. 2005	Session 13D
Gundel, A; Marsalek, K; Rothermel, S; Ronicke, J; ten Toren, C.	Task-related effects on fatigue	Sept 2005	Session 3B
Hanowski, Richard; Fumer, Maria C; Olson, Rebecca; Dingus, Thomas A.	Sleep of commercial motor vehicle drivers under the 2003 hours-of-service regulations	June 15 2005	Session 23A
Hitchcock, EM and Matthews, G.	Multidimensional assessment of fatigue: A review and recommendations		Session 2B
Hursh, Steven R and Eddy, Douglas.	Fatigue modelling as a tool for managing fatigue in transportation operations	June 15, 2005	Session 3A
Jay, Sarah M; Dawson, Drew; Lamond, Nicole.	Train drivers' fatigue and recovery during extended relay operations	June 15, 2005	Session 9C
Jay, Sarah M; Lamond, Nicole; Ferguson, Sally A; Dorrian, Jillian and Dawson, Drew.	Predictors of recovery following acute sleep loss		Session 22C
Johns, Murray; Tucker, Andrew; Chapman, Robert.	A new method for monitoring the drowsiness of drivers		Session 12A
Jones, Christopher B; Dorrian, Jillian and Dawson, Drew.	Lay attributions of accountability, responsibility and liability for fatigue related road accidents		Session 1C
Kandelaars, Katie; Dorrian; Jill; Fletcher, Adam; Roach, Gregory and Dawson, Drew.	A review of Bio-mathematical fatigue models: Where to from here?		Session 3D
Kandelaars, Katie; Eitzen, Guy; Fletcher, Adam; Roach, Gregory and Dawson, Drew.	Predictions of sleep timing during layovers on international flight patterns using social and circadian factors		Session 11C

Klauer, Sheila; Neale, Vicki; Dingus, Thomas; Sudweeks, Jeremy and Ramsey, David.	The prevalence of driver fatigue in an urban driving environment: results from 100-car naturalistic driving study		Session 4B
Knipling, Ronald R.	Individual differences in commercial driver fatigue susceptibility: evidence and implications		Session 8A
Krueger, Gerald and Dinges, Ddavid. et al	Truck driver responses to alertness monitoring and fatigue management technologies		Session 24A
Krueger, Gerald P and Brewster, Rebecca M.	Commercial driver wellness, health and fitness: A program for mastering driver alertness and managing fatigue		Session 20B
Lal, Sar	The neurosciences of driver psychology and fatigue effects		Poster 1D
Lal, Sara	How accurate is brain activity as an indicator of driver fatigue?		Poster 2A
Lamond, Nicole; Pertrilli, Renee; Dawson, Drew and Roach, Gregory.	The impact of layover length on the fatigue and recovery of long-haul flight crew	15 th June 2005	Session 13C
Meuter, Renata. et al	Dual vigilance task: tracking changes in vigilance as a function of changes in monotonous contexts		Poster 1A
Moller, Henry J	Simulator performance, microsleep episodes and subject sleepiness:	11 June 2005	Session 7C
Moore, Barry	Fatigue regulation in road and rail musings from the antipodes		Session 23D
Moore-Ede, Martin; Heitmann, Anneke; Dawson, Todd and Guttkuhn, Rainer	Truckload driver accident, injury and turnover rates reduced by fatigue risk-informed performance-based safety program	29 June 2005	Session 18C
Moscovitch, Adam et al	A practical approach to sleep apnea screening for commercial motor carriers		Session 16C

Moscovitch, Adam; Reimer, Marlene; Heslegrave, Ron; Kealey, Matthew; Rhodes, Wayne.	North American pilot fatigue management program (FMP) for commercial motor carriers (Alberta results)		Session 25D
Muzet, Alain; Roge, Joceline; Otmani, Sarah; Pebayle, Thierry.	Does an afternoon nap have an effect on subsequent night driving?		Session 22A
Nasvadi, Glenyth; Cooper, Peter; Ayas, Najib; Mulgrew, Alan and Cheema, Rupi.	Crash characteristics of sleepy drivers: A case-control study		Session 5A
Nolan, Darren	Fatigue management – the Australian way	11-15 Sept 2005	Session 25C
Olson, Rebecca L; Hickman, Jeffrey S; Knipling Ronald R et. al	Factors and driving errors associated with fatigue in a naturalistic study of commercial drivers	15 July 2005	Session 5B
Paul, Michael A; Miller, James C and Gray, Gary W	Fatigue countermeasures in Canadian military transport aircrew: Lessons from Bosnia and Afghanistan		Session 19C
Price, Jana M	A review of the evidence investigators use in determining operator fatigue		Session 8C
Reimer, MA; Moscovitch, A; Heslegrave, R; Kealey, M.	Snowplow operation: unique issues in fatigue risk management	15 June 2005	Poster 2C
Rhodes, Wayne; Gill, Valerie; McCulloch, Kirsty; Fletcher, Adam and Dawson, Drew	The basis for a guidelines manual for the design of fatigue management programs for all transportation modes in Canada		Session 18B
Rogers, Naomi; Unger, Gunnar; Wong, Keith; Hedner, Jan; Grunstein, Ronald.	Accuracy of a single channel nasal pressure recording device for repeated ambulatory use in suspected sleep apnea.		Session 16A
Ronicke, J; Gundel, A; ten Thoren C.	Alertness management training for truck drivers		Session 20A

Shbeeb, Lina I	Fatigue of bus drivers in Jordan		Poster 1E
Sherry, Patrick	A fatigue model and job performance: Testing the validity of model predictions for locomotive engineers		Session 11B
Smith, Andrew	Fatigue offshore: The short-sea sector		
Stewart, Simon and Abboud, Rafeef	Flight crew scheduling, performance and fatigue in a UK airline – phase 1		Session 21A
Stewart, Simon and Abboud, Rafeef	Flight crew scheduling, performance and fatigue in a UK airline – phase 2		Session 21B
Sletten, Tracy L; Roach, Greg D; Darwent, David; Dawson, Drew.	Fatigue management in aviation: the effects of timing on in-flight sleep		Session 19B
Stone, Barbara; McGuffog, Alison; Spencer, Mick; Turner, Claire; Mills, Ann.	Fatigue and shift work in UK train drivers	June 2005	Session 9A
Thiffault, Pierre and Bergeron, Jacques.	Individual differences in the reaction to road monotony: A simulator study		Poster 1C
De Valck E; Quanten, S; Berckmans D and Cluydts R.	Comparative study on simulator driving performance after 3 shifts in a fast forward versus a slow backward rotating system	13 June 2005	Session 4D
Williamson and Boufous.	A data-matching study of the role of fatigue in work-related crashes		Session 1A
Williamson, Ann M; Friswell, Rena and Feyer, Anne-Marie.	Development effective measures of fatigue for use in the real world		2C
Wilson, Bruce and Rau, Paul.	Data processing and driver performance analysis using field data from a drowsy driver warning system		Session 22B
Wu, Tsun-Ju, Liu, Yung-Ching, Ho, Ching-Heng.	A comparison study of fatigue effects of complex and monotonous roadway environments upon drivers' driving behaviour and task performance		Poster 1B

Appendix 2

Comparison of Civil Aviation Regulations in 10 ICAO countries (Missoni et al., 2006)

In civil aviation fatigue that can appear in air cabin crews is representing limiting factor for the flight safety. Therefore flight-time and the duty-time are regulated by the ICAO (International Civil Aviation Organization) Agreement. Because of the phenomenon of fatigue, preventive measures are carried out in order to prevent it. Their aim is to prevent the influence of fatigue on air-safety by limiting the workload which is achieved by reducing the duty hours in case of extended flight requirements and by reducing the night-flying hours. Also by defining the time necessary for rest, in order to secure that the crew is fully rested by defining sufficient resting time. In a paper where there were descriptively compared the regulations of ten countries, ICAO members, regarding duty and rest periods of the aircrew members. limiting factors were the limiting criteria were represented by 12 factors. Two countries were taking into consideration only the flight time, whereas the other eight members are taking into account the duty time and the flight time too. Only five countries emphasize in their regulations the rest time of the flight crew before the given duty tasks, not stressing the type of flight tasks.

The analysis of the table reveals that generally, there is agreement that flying during unusual duty time causes substantially more harm (fatigue), especially night flights. Only two member countries (Switzerland and Great Britain) emphasize in their regulations the significance of the daily duty time, and three (Germany, Scandinavia and Switzerland) of the night flying hours. Night sleep has far better effect than sleeping during day, but only three member countries (Australia, France and Scandinavia) specifically stress its importance. Three member countries out of ten (Germany, Scandinavia and Switzerland) consider flying through time zones as a significant factor in determining the duty time.

The number of T/Ls (take-off/landings) as an important factor is emphasized by six member countries with special focus on the development of accumulated fatigue in flight crew. A significant place of this factor in the regulations of these countries results from the knowledge that every airport takeoff/landing represents a significant workload on the pilot, and that these workloads are summed up with the already known flying workloads.

Table 1: Limiting factors in state regulations

		AUS	FRA	GER	JAP	SCA.	RUS	ŠWI	GB	USA	CRO	total
1	CREW AUGMENTATION	+	+	-	+	-	+	-	-	+	+	6
2	DUTY TIME	+	-	+	+	+	+	+	+	-	+	8
3	PREVIOUS REST	+	-	-	+	+	-	-	+	-	+	5
4	TIME OF DAY*	-	-	-	-	-	-	+	+	-	-	2
5	NIGHT FLYING	-	-	+	-	+	-	+	-	-	-	3
6	NIGHT SLEEP	+	+	-	-	+	-	-	-	-	-	3
7	TIME ZONES	-	-	+	-	+	-	+	-	-	-	3
8	NUMBER OF T/Ls	-	-	+	+	+	-	+	+	-	+	6
9	NUMBER OF PILOTS**	+	-	-	-	-	+	-	+	+	-	4

10	CREW AUGMENTATION	+	-	+	+	+	+	+	+	+	-	8
11	FLIGHT TIME	-	-	-	+	-	-	+	+	+	-	4
12	A/C TYPE	+	+	-	+	-	+	-	-	-	-	4
	TOTAL	7	3	5	7	7	5	7	7	4	4	

* excluding night hours ** excluding additional pilot significant (+) Insignificant (-)

The negative impact of this factor can be reduced by reducing the number of takeoff/landings during the given duty time, and/or by reducing the duty time to a suitable number of take-off / landings. Same principle could be applied to crews on board ships especially on sea pilots and crew on ferries covering short distances.

Air-crew augmentation (one or more assistant pilots) as a limiting factor regarding the crew duty time and the aircraft flight-range appears in the regulations of eight countries. For the crew rest during such flights, the regulations are requiring an adequate number of seats (double in the first class of aircraft, or special aircraft compartments separated from the pilot cockpit and passenger cabin).

All the state authorities agree that it is necessary to restrict the duty time and the flight time of the aircrew during the day. This results in a conflict between the economic interests of airlines and the state regulations, which set safety flight requirements. In their regulations majority of them rely more on the duty time than on the flight requirements as the criteria for the crew workload.

Table 2: Duty time and rest-time (in hours) in ICAO members regulations

DUTY TIME	AUS	FRA	GER	JAP	SCA	RUS	SWI	G.B.	USA	CRO
NORM.	11(8)	-	10	-	12	-	-	-	-	10
MAX.	12(9)	(10)	14	13(9)	14	12(8)	14(10,5)	14	(12)	14
MIN.	11(8)	-	10	10(6)	9	(5)	9	9	(8)	10
ADDITIONAL TIME IN FLIGHT	18	-	18	20(4)	16	-	18(15)	18	NI***	
RESTING TIME										
MIN.	10	6	10	6	16	2xDT**	8	12	2xFT*	10
MAX.	14	4x DT*	14	12	32-48	-	14	14	-	36
DESCENDING	24	36	32-96	24-48	29-36	-	17-26	-	18	-
WEEK	36	-	36	-	-	-	32	32	24	-
ADDITIONAL TIME IN FLIGHT	18	-	14	NI***	16	-	24	18	NI***	-

*FT – flight time

Rest-time is given in brackets

**DT – duty time

***NI – not indicated

In order to prevent the accumulation of fatigue all the ICAO member states provide restrictions to the total flight time per week, month and year (Table 2).

In Germany, Switzerland, USA and Croatia the law on air traffic gives restrictions in the annual flight operations of a pilot up to 1000 hours, and duty period of up to 1600 hours. That permitted flight time has also been agreed upon with. Crews of other countries have shorter annual operations in a range from 700 to 800 (Russia and Japan) and 900 – 935 (G. Britain and France).

Table 3: Limits of total crew-flight time (duty times are given in brackets)

	AUS	FRA	GER	JAP	SCA. count ries	RUS	SWI	G.B.	USA	CRO
for a week	30	-	-	-	-	(41)	-	(50)	30-32*	-
for 2 weeks	-	-	-	-	-	-	60	-	-	-
for a month	100	75-95*	(210)	80	-	70-80*	100	100	100	-
for 2 months	-	180	-	-	-	-	-	-	-	-
for 3 months	-	265	-	220	-	-	280	-	300-350*	-
for 6 months	-	510	-	-	-	-	-	-	-	-
for 1 year	900	935	1000	840	-	700-800*	1000	900	1000	1000- (1600)

*depending on the aircraft type and flight range

Appendix 3

MAIB Bridge Watch-keeping Safety Study (2004)

Summary

“At 0515, on 29 June 2003, the general dry cargo vessel Jambo ran aground, and subsequently sank, at the entrance to Loch Broom on the west coast of Scotland. The vessel was carrying 3,300 tonnes of zinc concentrate, prompting fears of an environmental disaster (Report 27/2003). This was the latest in a series of remarkably similar accidents, the common features of which included fatigued officers, one man bridge operation at night, missed course alterations and no watch alarms.”

This study was commissioned to establish the principal factors that cause nautical accidents, and to consider whether fatigue is as prevalent and dangerous as indicated by the Jambo and similar accidents.

The study reviewed in detail the evidence of 65 collisions, near collisions, groundings and contacts that were investigated by the Branch. It confirmed that minimal manning, consisting of a master and a chief officer as the only two watch-keeping officers on vessels operating around the UK coastline, leads to watchkeeper fatigue and the inability of the master to fulfil his duties, which, in turn, frequently lead to accidents. It also found that standards of lookout in general are poor, and late detection or failure to detect small vessels is a factor in many collisions.

The study concludes that the current provisions of STCW 95 in respect of safe manning, hours of work and lookout are not effective.

Recommendations have been directed at the MCA to take the conclusions of the study forward to the IMO with the aim of reviewing:

1. The guidelines on safe manning, to ensure that all merchant vessels over 500gt have a minimum of a master plus two bridge watch-keeping officers, unless specifically exempted for limited local operations as approved by the Administration.
2. The requirements of STCW 95 to change the emphasis with respect to the provision of a designated lookout to ensure that a lookout is provided on the bridge at all times, unless a positive decision is taken that, in view of daylight and good visibility, low traffic density and the vessel being well clear of navigational dangers, a sole watchkeeper would be able to fulfil the task.
3. The requirements of STCW 95 so that a bridge lookout can be more effectively utilised as an integral part of the bridge team.

BACKGROUND

In the 10 years, 1994 to 2003 inclusive, 652 collisions and groundings involving merchant vessels of over 500gt, were reported to the MAIB under the UK's Merchant Shipping (Accident Reporting and Investigation) Regulations. There were also 995 near collisions (hazardous incidents) voluntarily reported during this time, 342 of which were between fishing vessels and merchant vessels of over 500gt. Twenty-two people lost their lives in collisions involving merchant vessels since the MAIB began recording data. Many of these accidents and incidents were the subject of a full MAIB investigation. Following publication of these reports, and those of other investigating authorities, numerous press headlines have reflected the concerns of the industry, typically:

“Officers facing overload” (NUMAST Telegraph October 2003)
“Is Anyone Awake?” (Lloyds List, July 2003)
“UK takes hard line on OMBO” (NUMAST Telegraph Nov 1998)
“Waking up to the nightmare of the sleepless ship’s officer” (Lloyds List Feb 1997)
“Fatigue on board kills” (ITF Maritime News 1997)
“Collision regulations flouted” (Safety at Sea April 1997)
“Collision highlights ships’ inadequate manning levels” (Lloyds Casualty Week May 1998)
“Did good traditions of Seamanship go out with the ark?” (Safety at Sea Nov 2000)
“Watch-keeping flaws worry British yachting chiefs” (Lloyds List January 2001).

Even a cursory consideration of relevant investigations shows that a small number of causal factors are common to nearly all bridge watch-keeping accidents.

The purpose of this study was to collate the underlying human factors involved in a large number of accidents investigated by the MAIB, to graphically illustrate the principal shortfalls in bridge watch-keeping. The study’s overall objective was to produce arguments for change that would result in an improvement in the safety of this key area of marine operational practice.

METHODOLOGY

The accidents included in the data for this study were selected using the following criteria: All collisions, groundings, contacts and near collisions reported to the MAIB, which :

- occurred between 1994 and 2003;
- were the subject of an MAIB investigation or Preliminary Examination;
- involved a merchant vessel of over 500gt;
- occurred in coastal waters, port/harbour area or high seas, where the vessel was underway and, a licensed pilot was not carried.

Several factors influenced the use of these criteria. First, the MAIB had collected accident data since it was founded in 1989, but the quality of this data improved considerably in 1994, following a review of its investigation techniques and database management. Second, the study was restricted to the analysis of accidents which had been fully investigated or were the subject of a preliminary examination because of the detailed and accurate data provided by these cases. Other accidents reported to the MAIB, but not investigated, were only used to assess or validate trends, where considered necessary. Third, fishing vessels, and commercial vessels less than 500gt, were excluded because of differences in the applicable regulations, training and guidance, between these vessels and merchant vessels of more than 500gt. Finally, accidents involving vessels berthing, at anchor, or under pilotage, were also excluded to enable the study to focus on the factors affecting bridge watch-keeping when on passage, rather than the demands of specific navigational or ship handling situations.

Once selected, the accidents were then reviewed in detail by MAIB nautical inspectors in order to complete a questionnaire (Annex A) covering many aspects of bridge watch-keeping practice, which had been developed for this study. The data gathered was input to a human factors database before analysis.

RESULTS

Of the 1,647 collisions, groundings, contacts and near collisions that were reported to MAIB between 1994 and 2003, 66 accidents involving 75 vessels met the required criteria. Figures 1 to 6 show the distribution of these incidents by type, vessel type, daylight or darkness, visibility, diurnal and monthly distribution.

An initial broad review of the detailed data collected highlighted three principal areas of concern as follows:

Groundings and fatigue: A third of all the groundings involved a fatigued officer alone on the bridge at night

Collisions and lookout: Two thirds of all the vessels involved in collisions were not keeping a proper lookout.

Safe manning: A third of all the accidents that occurred at night role of the master involved a sole watchkeeper on the bridge.

The statistical base of this study is relatively small, but the quality of the data is good. The study has concentrated on areas where a high degree of confidence can be placed in its accuracy. In this way, the findings of the study, while not unexpected, are important.

The study has confirmed that watchkeeper manning levels, fatigue and a master's ability to discharge his duties are major causal factors in collisions and groundings, and poor lookout is a major factor in collisions. Endorsed by the MAIB's experiences during accident investigation, it illustrates that the hours of work and lookout requirements contained in STCW 95, along with the principles of safe manning, are having insufficient impact in their respective areas. Recommendations addressing the causal factors of fatigue, inadequate manning, and poor lookout are therefore considered to be justified.

To be effective, any action to reduce levels of fatigue, increase a master's ability to discharge his duties, or to improve the standard of lookout, must be taken on an international basis, and must be mandatory. This can only be achieved via the IMO by amending current legislation or by introducing new measures.

RECOMMENDATIONS

To combat fatigue among bridge watch-keepers operating in the short-sea trade, and to improve the standard of lookout on all merchant vessels, the Maritime and Coastguard Agency is recommended to:

Take the conclusions of this study forward to the IMO with the aim of reviewing:

2004/206 The guidelines on safe manning to ensure that all merchant vessels over 500gt have a minimum of a master plus two bridge watch-keeping officers, unless specifically exempted for limited local operations as approved by the Administration.

2004/207 The requirements of STCW 95 to change the emphasis with respect to the provision of a designated lookout to ensure that a lookout is provided on the bridge at all times, unless a positive decision is taken that, in view of daylight and good visibility, low traffic density and the vessel being well clear of navigational dangers, a sole watchkeeper would be able to fulfil the task.

2004/208 The requirements of STCW 95 so that a bridge lookout can be more effectively utilised as an integral part of the bridge team.

Appendix 4:

Some examples of working hour regulations

The UK Merchant Shipping (Hours of Work) Regulations (2002) require the following:

- a minimum of 10 hours rest in any 24-hour period, which can be split into no more than two rest periods, one of which must be at least 6 hours;
- a maximum of 14 hours between two rest periods;
- a minimum of 77 hours rest in any 7-day period;
- compensatory rest must be provided if normal rest periods are disturbed by emergency drills or emergencies;
- 4 weeks paid annual leave;
- posting of the daily schedule of duties at sea, and in port, and the minimum daily hours of rest, specified for every position (suggested forms are provided with MSN 1767). The tables must be posted in a prominent and easily accessible place on board;
- records to be kept of hours of rest (suggested forms are provided with MSN 1767). These must be retained for at least 1 year and be available for inspection at any time by the MCS surveyors; and
- normal routine vessel inspection will include a check that the appropriate schedules are posted and records maintained.

By comparison, US watch-keeping regulations have similar minimum rest requirements, but allow a reduction in minimum rest, and mandate less rest in a 7-day period:

- A minimum of 10 hours rest in any 24-hour period, which can be split into no more than two rest periods, one of which must be at least 6 hours;
- The minimum 10-hour rest period may be reduced to 6 hours as long as:
 - no reduction extends beyond 2 days; and
 - not less than 70 hours of rest are provided each 7-day period.

However, these regulations have a particularly comprehensive definition of rest:

“Rest means a period of time during which the person concerned is off duty, is not performing work (which includes administrative tasks such as chart corrections or preparation of port-entry documents), and is allowed to sleep without being interrupted.”

They also include a requirement covering rest prior to a voyage:

- An officer may take charge of the deck watch on a vessel when leaving or immediately after leaving port only if the officer has been off duty for at least 6 hours within the 12 hours immediately before the time of leaving.

In Japan the Coastal Shipping Law (2005) regulates work hours on Japanese flagged ships as follows:

- 8 hours per day, 40 hours per week (hours can be extended to deal with emergencies).
- Overtime – the work period must not exceed 14 hours in any 24 hour period and 72 hours in a 7 day period. Maximum overtime shall not exceed 56 hours in any 4 week period.
- Enforcement of working hours – a Management and Seafarers’ Labour inspection system has been developed, consisting of 160 inspectors in 62 ports, who are authorised to act on seafarers, ship operators and ship owners.

Russian guidance (1996) consists of the following working hours:

- 8 hours per day, 40 hours per week.
- Watches can be extended to 12 hours per day.
- Maximum tour length: 120 days (except where changing crew is difficult and then it can be extended to 150 days).
- When there are missing crew overtime can be worked up to 12 hours but daily rest has to be 12 hours with one interrupted period of 8 hours.

The fishing industry

The following recommendations have been made:

- Members should adopt laws or regulations or other measures requiring that owners of fishing vessels flying their flag ensure that their vessels are sufficiently and safely manned and under the control of a competent skipper.
- Members should adopt laws or regulations or other measures requiring that owners of fishing vessels flying their flag ensure that fishers are given rest periods of sufficient frequency and duration for the safe and healthy performance of their duties.

Member States may permit exceptions, as long as these adhere to general health and safety principles. For example, the UK regulations require the following:

- Total work time (including overtime) may not exceed 48 hours per 7 days, averaged over 52 weeks, or over the total time of employment if this is less than 52 weeks
- A minimum of 10 hours rest in any 24-hour period, which can be split into no more than two rest periods, one of which must be at least 6 hours;
- A maximum of 14 hours between two rest periods;
- A minimum of 77 hours rest in any 7-day period.
- In case of emergencies, the master of a fishing vessel may require workers to work any hours necessary for the immediate safety of the fishing vessel, persons on board the fishing vessel or cargo, or for the purpose of giving assistance to another ship or to a person in distress at sea.
- 4 weeks paid annual leave, which cannot be replaced by payment in lieu except where the worker's employment is terminated.
- Night work is defined as 9 consecutive hours including the period midnight-5 am (local time). An employer can only require an employee to undertake night work if free health assessments are provided prior to starting night work, and at regular intervals while night work continues.



www.itfglobal.org



FIGHT FATIGUE

safer ships demand realistic manning

ABOUT THE ITF

The International Transport Workers' Federation (ITF) is a global federation of transport workers' unions. Any independent trade union with members in the transport industry is eligible for membership of the ITF.

624 unions representing 4,400,000 transport workers in 142 countries are members of the ITF. It is one of several Global Union Federations allied with the International Confederation of Free Trade Unions (ICFTU).

The ITF's headquarters is located in London and it has offices in Nairobi, Ouagadougou, Tokyo, New Delhi, Rio de Janeiro, Georgetown, Moscow and Brussels.

FIGHT FATIGUE

Fatigue is killing seafarers. Long hours, overwork and low staffing levels are causing ship collisions and sinkings, costing lives, ruining seafarers' health and endangering the environment.

Every study, and countless accident investigations, underline the scale of the danger. All ranks are being affected by a problem that stretches from injury to individual crew members to the loss of ships, loss of lives, and damage to the seas and coastlines.

It is a systemic problem, ranging from the loss of a ship because the officer on watch was exhausted, to the loss of livelihood when an exhausted deck hand falls through an open hatch.

And because it is a systemic problem, a systemic approach is needed. It's time to examine the issue across the board, rather than focusing on just one sector.

The ITF believes that fatigue cannot be viewed separately from factors such as the number of people working on the ship (known as its manning level); the hours of work; the hours and frequency of rest; the quality of rest (is it disturbed by engine noise, cargo loading or bad weather?); the environment of the ship; the length of voyage and the isolation from normal social life.

WHAT IS IT?

There is no exact agreed legislative definition of seafarer fatigue - instead the IMO (International Maritime Organization) uses the working definition of "a reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength; speed; reaction time; coordination; decision making; or balance." It is "a biological state to which all individuals are susceptible, regardless of skill, knowledge or training".

The IMO also notes that "the effects are particularly dangerous in shipping. The technical and specialized nature of this industry requires constant alertness and intense concentration from its workers. Effectively dealing with fatigue requires a holistic approach."

As well as the immediate danger of overstretched personnel working in a hazardous environment, there are long term health risks too. And unless the role

played by fatigue in an accident can be proved then victims may lose compensation and their career. Other long term effects of overwork include depression, alcoholism, stomach and heart problems - any of which may mean the victim having to leave work without recognition or compensation.

"On previous ship, 12-15 hour days, never had six hours continuous sleep, 87 hour week for three months. Regularly made errors in passage planning and execution. Did not dare sit down on watch."

First officer on passengership, quoted in Seafarer fatigue: Wake up to the dangers

CAUSES

- Lack of sleep
- Poor quality of sleep
- Insufficient rest time between work periods
- Poor quality of rest
- Stress
- Boring and repetitive work
- Noise or vibration
- Ship movement
- Food
- Medical conditions and illnesses
- Ingesting chemicals
- Jet-lag
- Excessive work load

Condensed from IMO Guidance on Fatigue Mitigation and Management (MSC/Circ 1014)

WHAT CAUSES IT?

Fatigue is caused by lack of sleep, by rest, when it comes, being disturbed or of poor quality, by overwork and by stress. Health, diet, age and other factors affecting the circadian rhythm (the 'body clock') - such as shift work - may also play a part.

PHYSICAL SIGNS

- Inability to stay awake (eg. head nodding)
- Difficulty with hand-eye coordination
- Speech difficulties (eg. slurred)
- Heaviness in arms and legs or sluggish feeling
- Decreased ability to lift, push or pull
- Dropping objects
- Non-specific physical discomfort
- Headaches
- Giddiness
- Heart palpitations
- Rapid breathing
- Loss of appetite
- Insomnia
- Sweating fits
- Leg pains/cramps
- Digestion problems

EMOTIONAL SIGNS

- Risk taking
- Intolerance and anti-social behaviour
- Needless worry
- Reduced motivation to work well
- Mood changes (eg. irritability, tiredness, depression)

MENTAL SIGNS

- Poor judgement of distance, speed, time
- Inaccurate interpretation of a situation, eg. failing to anticipate danger
- Slow or no response to normal, abnormal or emergency situations
- Reduced attention span
- Difficulty concentrating and thinking clearly
- Decreased ability to pay attention

Condensed from IMO Guidance on Fatigue Mitigation and Management (MSC/Circ 1014)

HOW TO RECOGNISE IT

A fatigued person may be the last to recognise their condition. Exhaustion affects our judgement and it may be easier to notice the signs in others than in ourselves. Luckily the physical, mental and emotional symptoms are often visible.

WHAT'S HAPPENING AT SEA TODAY?

The modern ship can be a high work, high stress environment. Changing patterns of trade and employment mean that time spent onboard has grown. Seafarers may now not see home for six months or a year, and port calls often last hours rather than days. Increased legislation and inspections, designed to increase safety, can unwittingly undermine it, as seafarers are given additional responsibilities, almost always without additional time in which to meet them. Post 9/11, sincere efforts to increase security have restricted shore leave and added the new role of security officer to all vessels - yet almost no companies have employed someone to do this job. For years seafarers have found themselves caught in a pincer of the commercial pressure to work faster, harder, better while crew sizes are cut to the absolute minimum.

“Surely the problem is that some ships just don't have enough people on board.”

Arthur Bowring Managing Director, Hong Kong Shipowners' Association, reported in industry newspaper Lloyd's List, September 2005

WHAT'S THE PROBLEM?

One of the most extensive surveys ever made of seafarers' working hours was the ITF's research project Seafarer fatigue: Wake up to the dangers. Based on responses from 2,500 seafarers of 60 different nationalities serving under 63 different flags, it revealed just how widespread the problem is. It highlighted the enormity of the risks to health and safety and the marine environment. It found that, despite advances in regulations, more work needed to be done, with many seafarers unaware of the legal safeguards that have been introduced and many shipowners and operators either unwilling or unable to comply with the regulations.

Concern about accidents and excessive working hours resulted in two key international agreements to limit duty hours and set requirements for rest periods: the 1995 amendments to the Standards of Training, Certification & Watchkeeping Convention (STCW 95) and ILO Convention 180 on Seafarers' Hours of Work and the Manning of Ships. Additionally, many flag states have their own national regulations. Despite

this, the ITF report recorded, fatigue was endemic within shipping. One third of those questioned reported average daily working hours of 12 and more, and more than 5% averaged more than 15 hours a day. Almost two thirds said their average weekly working hours totalled more than 60, and 25% reported working more than 80 hours a week. These are way in excess of the STCW 95 or ILO 180 requirements. Over half of all those surveyed said their working hours presented a danger to their personal health and safety, and just under half said their working hours presented a danger to safe operations on their ships.

LEGISLATION ON WORK AND REST HOURS

- STCW (Standards of Training, Certification and Watchkeeping)
- Solas (International Convention for the Safety of Life at Sea)
- Principles of Safe Manning (IMO Resolution A.890(12))
- ILO Convention 180 - now incorporated in the Maritime Labour Convention (2006)

Despite these regulations and conventions seafarers are still routinely worked to dangerous levels - not just illegally and through the falsification of work and rest timesheets, but because flag states can gain dispensation by claiming to increase leave and because there is more focus on hours of rest rather than hours of work.

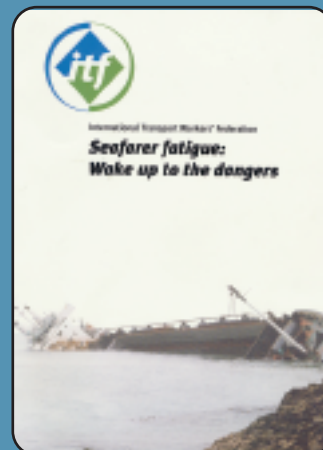
“There's no other industry that accepts a 98 hour week for watchkeepers.”

John Bainbridge, former chief engineer and ITF Seafarers' Section Deputy Secretary

Some of the longest hours were worked by watchkeepers. Over 70% of masters, chief engineers and first officers reported a major increase in workload in the preceding five to 10 years, while around 60% of watchkeepers considered that excessive hours were leading to personal health and safety risks. Some 42% of masters said they averaged more than 80 hours a week on duty.

“During port operations I was serving as chief officer and had worked continuously for 48 hours. I contributed to a chemical overflow in which serious injury occurred by not concentrating on the loading operation. (Acrylonite overflowed and covered two men when I hot-washed an adjacent tank).”

Shipmaster, quoted in Seafarer fatigue: Wake up to the dangers



Pictured on the cover, the Cita, which ran aground in the Scilly Isles after the chief officer, alone on the bridge, fell asleep. The Cita sailed through busy shipping lanes at full speed for around two hours while the officer - who had had only two three-hour periods of sleep in the preceding 36 hours - slept on.

Seafarer fatigue: Wake up to the dangers. ITF. 1997)

“Any action to reduce levels of fatigue, increase a master's ability to discharge his duties, or to improve the standard of lookout, must be taken on an international basis, and must be mandatory. This can only be achieved via the IMO by amending current legislation or by introducing new measures.”

From the Marine Accident Investigation Branch Bridge Watchkeeping Safety Study. Safety Study 1/2004, July 2004

The US Coast Guard has also investigated. It analysed 297 marine casualties (personal injuries and vessel damage/losses) in order to develop a 'fatigue index' which showed that fatigue was a contributing factor in 16% of critical vessel casualties and 33% of personnel injuries, making, they noted, 'fatigue a significant causal factor in marine casualties'. (Source: Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties. September 1996. US Coast Guard Research and Development Center.)

In 2004 Britain's Marine Accident Investigation Branch (MAIB) released a Bridge Watchkeeping Safety Study in response to a spate of “remarkably similar accidents” whose common factors included fatigued officers and one man bridge operation at night. The study examined 66 ship collisions, near collisions, groundings and contacts. It concluded that “the current provision of STCW 95 in respect of safe manning, hours of work and lookout are not effective” and that, “it is the opinion of the MAIB that the records



Seabird found 35 miles away from the Exxon Valdez spill

of hours of rest on board many vessels, which almost invariably show compliance with the regulations, are not completed accurately”

The ITF also carried out research on the effects of the ISPS (International Ship and Port Facility Security) Code introduced in response to the 9/11 attacks in the USA. The Code sets requirements for ship security plans and ship security officers, and for monitoring and control of access to the ship. While most trade unions had been supportive of ISPS and the consultative manner in which it was drawn up there were always concerns about a possible negative impact on seafarers. To learn more the ITF surveyed its 127 inspectors and 230 affiliated maritime unions. A majority of respondents felt that ISPS had indeed improved security, but that it had also resulted in extra work and adversely affected crew performance - yet 96% said there had been no increase in crew levels to deal with the additional workloads.

(Source: Access Denied: Implementing the ISPS Code. ITF. November 2005.
www.itfglobal.org/infocentre/pubs.cfm/detail/1446)



The 1989 grounding of the Exxon Valdez caused the release of 11.2 million gallons of crude oil. It was a true environmental disaster, the world's worst ever oil spill. The US National Transportation Safety Board later determined that the probable causes included “the failure of the third mate to properly maneuver the vessel because of fatigue and excessive workload” and “the failure of the Exxon shipping company to provide a fit master and a rested and sufficient crew for the Exxon Valdez”. Here an attempt is made to transfer oil from the tanker to a smaller ship.

WHAT CAN BE DONE TO REDUCE CREW FATIGUE?

Everyone can help. Flag states, which determine manning levels on ships they register, must set realistic levels and not, as some do, join the destructive spiral of allowing smaller and smaller crews as a way of attracting new business.

Port state control bodies, the national organisations which police safety standards on ships entering ports, are barred from changing the hours worked on ships, even when they have spotted dangerous practices. It may be time to let bodies other than the flag state set manning levels. Administrative and regulatory bodies such as port state control and the IMO could also build on their already valuable work by setting up mechanisms to handle complaints of long hours and overwork.

Ship owners and operators too must realise, as many already do, that a sensibly staffed ship is a safer ship, and a fit and well rested crew is a more efficient one. And seafarers themselves can help combat fatigue by raising the alarm if they are being overworked, by telling their trade union, and by looking after their own health and diet.

“Fatigue was found to be associated with a combination of factors, including working hours, sleep problems, tour length, shift schedule, job demands, stress at work and standing watch ... findings suggest that in order to reduce fatigue among seafarers it would be most beneficial to focus on controlling working hours to optimum levels.”

UK Maritime and Coastguard Agency (MCA) research projects. www.mcga.gov.uk/c4mca/mcga-the_mca/shared_content-mcga-mpb-research/shared_content-mcga-mpb-research-proposed.htm

What can you do? If you believe that the shipping industry - like other transport industries - should have sensible and humane limits on how hard those in it can be worked, and that crews, passengers and the environment are put at risk by a driven and exhausted workforce, then please ask your government to support new legislation to tackle the problem.


The ITF believes that the problem of fatigue is too widespread to be tackled by existing legislation. Its research has shown the inadequacy of the existing principles for assessment of minimum safe manning levels - leading it to call for legislation on determining crew complements that reflects actual operational requirements, trading patterns and other demands. Existing legislation, such as the International Safety Management code, is intended to provide an overarching framework. However it is often misused by ship owners to cover their responsibilities by just providing files and unrealistic instructions (this proliferation of paperwork at a time when a crew sizes are being slashed has itself increased the demands made on senior officers). Evidence is also emerging that crews are being worked beyond even the legal limits. Paris MOU (Memorandum of Understanding) - the port state control organisation covering most western European nations' efforts to seek out and eradicate unsafe shipping - has detected the falsification of work and rest time records on ships.

Seafarers are human beings with human rights, not commodities that can be exploited to fill gaps, and then discarded when damaged. The dangers inherent in their place of work demand alertness and attention. Their ships, carrying, as they may be, passengers, fuel and possibly dangerous cargoes, need to be served and steered by trained, rested and sufficient personnel. The consequences of reduced crews, long hours, and too little leave and rest can be environmental damage, increased prices for oil and goods and long term health problems for seafarers. Thankfully the will to address the problem is evident among many influential maritime bodies and flag states. Let's take it forward.

International Transport Workers' Federation
ITF House, 49-60 Borough Road, London SE1 1DR
Tel: +44 20 7403 2733 Fax: +44 20 7357 7871 E: mail@itf.org.uk

www.itfglobal.org
ISBN: 1-904676-21-9





SEAFARER FATIGUE: THE CARDIFF RESEARCH PROGRAMME

Andy Smith, Paul Allen and Emma Wadsworth

Centre for Occupational and Health Psychology

Cardiff University

63 Park Place

Cardiff

CF10 3AS

smithap@cardiff.ac.uk

November 2006

ACKNOWLEDGEMENTS

The research described in this report was supported by the Maritime and Coastguard Agency, the Health and Safety Executive, Nautilus UK and the Seafarers' International Research Centre, Cardiff. We would also like to acknowledge the contribution made by the ship owners and their employees who have participated in the research. We would like to acknowledge the contribution of our steering committee especially Tony Lane and Mick Bloor who played major roles in the development of the research. Parts of the data collection and analyses have been carried out by Rachel McNamara, Alison Collins, Victoria Cole-Davies, Neil Ellis, Geoff Boerne, Jo Beale, Ailbhe Burke and Ben Wellens.

The views expressed in the report are those of the authors and should not be taken to reflect the official position of the sponsors.

SUMMARY

Main messages

- Prior to this research programme there was very little evidence based research concerning fatigue at sea (see (Allen, Wadsworth, & Smith, Submitted), and section 3).
- The potential for fatigue at sea is high due to a range of factors, many unique to the marine environment.
- To understand fatigue at sea negative risk factors must be considered in combination rather than alone. This reflects the reality of the seafarers' working experience (see (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted), and section 5.1.2).
- Fatigue increases most significantly during the first week of tour, perhaps reflecting adaptation, a ceiling effect, or a combination of these possibilities (see (Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2).
- Recovery from fatigue after a tour of duty on average does not occur until the second week of leave (see (Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2).
- Fatigue can be addressed at three levels: legislation, company policy and personal awareness/management. Success will only be achieved if all three are co-operatively involved.
- Present reporting systems are inadequately designed to record factors relevant to fatigue (see (Allen, Wadsworth, & Smith, 2006), and section 6.3).
- Excessive working hours are a problem in the seafaring industry, hidden by the fact that a concerning number of crew falsify audited records (see (Allen, Wadsworth, & Smith, 2006), and section 6.3).
- Those who at least occasionally under-record their working hours were found to report higher fatigue (see (Allen, Wadsworth, & Smith, 2006), and section 6.3).
- Fatigue was consistently associated with poor quality sleep, negative environmental factors, high job demands and high stress. Other important factors included frequent port turn-arounds, physical work hazards, working more than 12 hours a day, low job support and finding the switch to port work fatiguing (see (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted), and section 5.1.2).
- In the diary study more frequent port calls were associated with greater fatigue among those on shorter tours, and with lower fatigue among those on longer tours. This difference would appear to reflect ship type (see (Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2).
- Mini-bulkers arguably represent a worst case scenario in terms of a ship environment conducive to fatigue, as evidenced by subjective and objective testing. The combination of negative factors on this ship type include: frequent port turn-arounds, short port stays, changing cargos, only two watchkeepers (in many cases) and long periods of pilotage (see section 5.3.2).

- Consequences of fatigue have been shown not only in terms of accident contribution but self-reported physical and mental health outcomes (see (Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wellens, McNamara, Allen, & Smith, 2005), and section 5.1.4).

EXECUTIVE SUMMARY

Background

Global concern with the extent of seafarer fatigue and its potential environmental cost is widely evident across the shipping industry. Maritime regulators, ship owners, trade unions and P & I clubs are all alert to the fact that with certain ship types a combination of minimal manning, sequences of rapid port turnarounds, adverse weather conditions and high levels of traffic may find seafarers working long hours and with insufficient recuperative rest. In these circumstances fatigue and reduced performance may lead to environmental damage, ill-health and reduced life-span among highly skilled seafarers who are in increasingly short supply. A long history of research into working hours and conditions in manufacturing as well as road transport and civil aviation industries has no parallel in commercial shipping. There are huge potential consequences of fatigue at sea in terms of both ship operations (accidents, collision risk, poorer performance, economic cost and environmental damage) and the individual seafarer (injury, poor health and well-being,). Not only has there been relatively little research on seafarers' fatigue but what there has been has been largely focused on specific jobs (e.g. watchkeeping), specific sectors (e.g. the short sea sector) and specific outcomes (e.g. accidents). This reflects general trends in fatigue research where the emphasis has often been on specific groups of workers (e.g. shiftworkers) and on safety rather than quality of working life (a crucial part of current definitions of occupational health).

Aims and objectives of the present research programme

Given the absence of extensive research on seafarers' fatigue we have carried out a research programme aimed at providing a knowledge base to:

- 1) *Predict worst case scenarios for fatigue, health and injury*
- 2) *Develop best practice recommendations appropriate to ship type and trade*
- 3) *Produce advice packages for seafarers, regulators and policy makers*

These aims have been met using several different methodologies. More specific aims set at the start of the project, and the ways in which they have been met, are summarised in Table 23 below. Other aims and objectives developed as the research progressed are separately described within the context of the report.

The concept of fatigue

Underlying this report and the research programme is a conceptualisation of fatigue as a *process*. This process begins with risk factors for fatigue (i.e. work characteristics and conditions associated with fatigue), moves on to subjective perceptions of fatigue (i.e. how and when an individual experiences and reports fatigue), and concludes with the consequences of fatigue both in the short (symptoms of fatigue such as loss of concentration; poor performance) and longer term (e.g. ill health). This process approach has been suggested elsewhere in relation to work characteristics, fatigue and ill health, and is analogous to the approach to stress widely used in studies of the general working population. The work described here approached fatigue in this way.

Both subjective and objective measures of fatigue were used, and these measures have been compared. In terms of health, however, only subjective measures were possible as seafarers identified at their medicals as having a chronic illness or condition cannot continue to work at sea. The World Health Organisation (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO). The measures used in this research fit within this definition of health, and in this report the term “health” has been used in this WHO defined sense. Furthermore, this focus on perceived ill health and well being is supported by clear findings showing that reduced psychological well being can increase the risk of some physical illness.

Methods

The aims of the programme were achieved through surveys, analysis of existing databases and field research. The methods involved:

- A review of the literature
- A questionnaire survey of working and rest hours, physical and mental health
- Physiological assays assessing fatigue
- Instrument recordings of sleep, ship motion, and noise
- Self-report diaries recording sleep quality and work patterns
- Objective assessments and subjective ratings of mental functioning
- Pre- and post-tour assessments
- Analysis of accident and injury data

Results

The literature review

A review of the international literature showed that research is increasingly revealing fatigue to be a significant problem in the seafaring industry. Present reporting systems, however, are often not designed to record this factor. Evidence shows seafarer shift and working patterns are often conducive to fatigue with two man watches and excessive working hours areas of particular concern. Research also suggests that the impact of fatigue on seafarers may be seen in terms of health, psychosocial consequences, impaired cognition and increased risk of accidents.

The survey

In total, 1856 seafarers took part in the survey. Most of the respondents were deck (49%) or engineering (36%) officers. Just over 40% (41%) worked on ferries, 25% on offshore support, supply or standby vessels, and 19% on tankers. Two thirds (67%) of the respondents worked on UK flagged vessels. Results from the survey showed that fatigue was consistently associated with poor sleep quality, negative environmental factors, high job demands and high stress. Other factors found to be important included: frequent port visits, physical work hazards, working more than 12 hours a day, low job support and finding the switch to port work fatiguing. The short-term consequences of

fatigue (reported symptoms of fatigue, and the perception of risk to personal safety) were also associated with a similar range of factors. Those most at risk of high levels of fatigue and associated consequences were those who reported the greatest number of fatigue-inducing factors. It is therefore important to consider the combined impact of negative factors rather than considering them alone.

An association between perceived fatigue, self-reported health status and cognitive function was also shown. This association was independent of work characteristics shown to be risk factors for fatigue. Subjective fatigue may therefore be a factor which impacts on health independent of other risk factors.

A high proportion of the sample reported having been involved in a collision with another vessel (most of these incidents were between two moving vessels), or with another object (in most cases the harbour side). Nearly half of the sample considered fatigue to be a key factor in reducing collision awareness. One in four watch-keepers (particularly those on longer watches) reported having fallen asleep on watch. Almost all watch-keepers were required to multi-task while on watch, and just under half of these found this to be problematic. Those who did find multi-tasking problematic reported higher fatigue levels, and were more likely to have fallen asleep while on watch. A smaller but significant number (17%) were concerned about potential collisions and were again found to have higher fatigue levels and be more likely to have fallen asleep on watch. By far the most common suggestion for helping provide more effective and alert watch-keeping was to increase manning. This was followed by shorter watches and reduced paperwork.

The research compared fatigue in seafarers with other working groups. Workers from offshore oil installations (N=388) were found to have higher levels of fatigue and poorer health than the seafaring sample. Factors associated with fatigue, however, were found to be very similar to those associated with fatigue among seafarers. The seafaring sample was found to have similar levels of general fatigue to an onshore working sample (N=99), but higher levels of fatigue at work. Comparing seafarers with a road haulage sample (N=80) suggested change of operation may be a fatigue-inducing factor irrespective of transport sector. The seafarers were also compared with a sample of fishermen. Considerable recruitment difficulties, however, enabled only a small sample to be surveyed (N=81), severely restricting the level of generalisation possible concerning the approximately 12,500 fishermen currently working in the UK. In terms of the small sample which was accessed, most reported working on smaller vessels with an average crew of 3.04 (sd=1.74, range 1-11). Many reported that they had worked to the point of collapse and fallen asleep at the wheel and over half of the sample believed that their personal safety was at risk because of fatigue. Comparisons were also made across different sectors of the shipping industry. Seafarers in the short sea and coastal sample were found to report higher levels of fatigue than those from an offshore oil support sample. This may potentially be explained in terms of type of vessel and frequency of port turn-around.

Diary studies

In a diary study of seafarers over a complete tour-leave cycle, 203 respondents completed tour diaries and 197 leave diaries (182 completed both). Fatigue was found to increase most significantly in the first week of tour. Evidence suggested recovery from tour does not typically occur until the second week of leave. In this study more frequent port calls were associated with greater fatigue among those on shorter tours, and with lower fatigue among those on longer tours. This difference would appear to reflect ship type, as those on shorter tours mainly worked on ferries, while those on longer tours mainly worked on supply, support and container or tanker vessels. Of methodological significance, the diary study found fatigue on waking to be a more sensitive measure of fatigue than a measurement taken before bed.

Objective testing onboard

Onboard performance testing showed that fatigue risk factors such as noise, night work and days into tour have an impact on alertness and performance. Crew on a mini-bulker were found to more fatigued than crew on other vessels in terms of both subjective and objective measures.

Prevention and management of fatigue

The project evaluated the efficacy of methods aimed at preventing or managing fatigue. The results showed that the impact and effectiveness of ILO 180 and the EU working time directive appear to be undermined by widespread under recording of working hours. Evidence suggests large numbers of seafarers are working hours in excess of those allowed by current legislation and that under recording of working hours is associated with higher levels of fatigue. Fatigue guidelines produced by IMO put excessive emphasis on the responsibility of individual crew members to manage fatigue without acknowledging the critical role of corporate and legislative bodies. Fatigue can only be addressed if all levels of the seafaring industry are co-operatively involved and accountable.

Conclusions

The overall aim of the present programme of research was to provide a knowledge base on seafarers' fatigue. This has been achieved using a range of methodologies and by studying samples from different sectors of the British maritime industry. The results show that the potential for fatigue at sea is high due to seafarers' exposure to a large number of recognisable risk factors, both operational (e.g. port frequency), organisational (e.g. job support), and environmental (e.g. physical hazards). Our results show, however, that it is the combined effect of these risk factors that is most strongly associated with fatigue and its both short and long term consequences (fatigue symptoms, personal risk and reduced health and well-being). The most at risk groups are those exposed to the greatest number of these factors which could be identified using an audit styled approach. We have also shown that perceived fatigue is an additional risk factor for negative outcomes and this should also

be included in any audit process. A taxonomic approach to fatigue should be used and measures of the frequency and intensity of different types of fatigue (e.g. acute versus chronic; physical versus mental fatigue) obtained. Appropriate tools for this have been developed and the use of measures of risk factors for fatigue and perceived fatigue will allow future associations with outcomes (e.g. accidents and injuries; health status) to be assessed. It is also important to consider personal characteristics of the seafarer to determine the extent to which these influence susceptibility to fatigue.

One of the problems with measuring fatigue is that there is no “gold standard” that has been used in large populations and would allow bench-marking across jobs. It is difficult, therefore, to provide global estimates of the prevalence of fatigue in seafarers and to compare these levels with onshore groups. Indeed, where diversity is one of the defining features of the seafarer population such global estimates can prove misleading, not accounting for important differences in terms of ship operation, flag of registration and crew nationality. All that can be concluded is that highly fatigued seafarers are undoubtedly working in the industry where a combination of risk factors are found together. We have investigated a ship of a type thought to be associated with excessive fatigue (mini-bulker) and shown that higher subjective reports of fatigue are associated with objective performance deficits. Indeed, our performance measures have also been shown to be sensitive to risk factors for fatigue (e.g. working at night; noise) suggesting fatigue cannot be considered a purely subjective phenomenon. This is also confirmed by associations between fatigue-inducing conditions and accidents. Our research has also shown that the consequences of fatigue are not only felt in terms of impaired performance and reduced safety but decreased well-being and increased risk of mental health problems, also known to be risk factors for future chronic disease. Such effects are not restricted to seafarers and were found to be even greater in installation workers. Part of these effects may reflect the general problems associated with being at sea and in the workplace 24 hours a day, 7 days a week for several weeks at a time and away from home. Our sample has largely come from the “better end” of the industry and the prevalence and consequences of seafarers’ fatigue may, to some extent, be underestimated here. Further research at an international level is needed to investigate this view. Similarly, it is important to study those just starting at sea to determine whether fatigue is an important factor in the high attrition seen with this group. Fatigue may also be important in early retirement from seafaring and this issue could be addressed using the methods employed here.

Given the diversity of activities undertaken in the maritime sector, and the different profiles of fatigue risk factors in different work groups, it is clear that a range of strategies will be needed to prevent or manage fatigue. Having evaluated current working time directives and a fatigue guidance publication from IMO, existing approaches seem largely inadequate. Improvement of these approaches is clearly one strategy that could reduce the problem although an awareness campaign approach, as proved successful in other transport sectors, may also have value. Similarly, fatigue management programmes have been developed in other industries and such approaches could form part of a package for dealing with fatigue at sea. Indeed, the general absence of fatigue awareness and management training in the

seafaring industry shows that fatigue has not been treated as a health and safety issue. This could be achieved using approaches designed to address other areas of health and safety (risk assessments, audits, training) and would, therefore, involve established procedures rather than development of novel approaches. This holistic approach to fatigue will require all layers of the industry (regulators, companies and seafarers) to be involved. What is crucial is that strategies for prevention and management are evaluated, for without reliable auditing systems the success of any change will be impossible to judge. There are huge potential consequences of fatigue at sea and correspondingly great benefits to be had by addressing it.

Recommendations

As described above, this research programme has provided an evidence base for the development of fatigue recommendations and guidance. These general recommendations for addressing seafarers' fatigue are summarised below.

1. **Review how working hours are recorded.** Fatigue is more than working hours, but knowing how long seafarers are working for is critical in terms of evaluating how safe current operating standards are. This study shows the current method for recording and auditing working hours is not effective and should therefore be reviewed.
2. **Fatigue management training and information campaigns.** Fatigue management training and information campaigns for seafarers are likely to prove effective but only as part of a unified approach involving all levels of authority. Such an approach will only be effective if crew are empowered to act on their training in terms of actively intervening with operations when required.
3. **Establish an industry standard measure of fatigue.** No 'gold standard' measure of fatigue currently exists which makes the task of comparing and evaluating the impact of research results extremely difficult. Work needs to be done which either sets out the case for adopting the use of one particular fatigue measure as the industry standard, or looks towards developing a new scale for industrial and research purposes. If all parties are using the same fatigue measure progress in this field will undoubtedly be accelerated.
4. **Develop a multi-factor auditing tool.** The study has shown that it is the combination of different risk factors that puts an individual at risk of fatigue. A taxonomic or checklist-style auditing tool therefore needs to be developed to include not only work characteristics known to be risk factors for fatigue but also subjective experience of this factor.

Our analysis has shown that it is the combined effect of a range of factors that is associated with fatigue. The consequence of this conclusion is that changing one or two factors can have a disproportionately large impact. The development, implementation, and, crucially, evaluation of strategies to address fatigue must be carried out jointly across all levels of the industry. However, their application must also be tailored, at a local level, to be

appropriate and practical. Tackling fatigue at sea must involve the industry as a whole because it has the potential to benefit at an equally universal level.

CONTENTS

	ACKNOWLEDGEMENTS	2
	SUMMARY	3
	Main messages	3
	EXECUTIVE SUMMARY	5
	Background	5
	Aims and objectives of the present research programme	5
	The concept of fatigue	5
	Methods	6
	Results	6
	The literature review	6
	The survey	6
	Diary studies	8
	Objective testing onboard	8
	Prevention and management of fatigue	8
	Conclusions	8
	Recommendations	10
	CONTENTS	12
1	INTRODUCTION	16
	Main messages	16
1.1	What is fatigue?	16
1.2	Risk factors for fatigue	16
1.3	Prevalence of fatigue in the workforce	17
1.4	Consequences of fatigue	18
1.5	Fatigue in transport	19
2	BACKGROUND TO THE PROJECT	21
	Main messages	21
2.1	The Cardiff Research Programme	22
2.2	Phases of the research	23
3	A REVIEW OF THE INTERNATIONAL LITERATURE ON SEAFARERS' FATIGUE	25
	Main messages	25
3.1	Prevalence of fatigue	25
3.2	Fatigue risk factors	26
3.2.1	Circadian rhythms	26
3.2.2	Working patterns and shift schedules	26
3.2.3	Noise and motion	27
3.2.4	Sleep	28
3.2.5	Other risk factors	28
3.3	Accidents and injuries	28
3.4	Health	30
4	METHODS	31
	Main messages	31
4.1	Surveys	31

4.2	Diary studies	32
4.3	Onboard testing	32
4.3.1	Vessel motion	32
4.3.2	Measurement of noise	33
4.3.3	Measurement of performance and mood	33
4.3.3.1	Visual analogue mood scales	33
4.3.3.2	Variable fore-period simple reaction time task	33
4.3.3.3	Focused attention task	34
4.3.3.4	Categoric search task	34
4.3.4	Measurement sleep	35
4.3.5	Salivary cortisol	37
5	RESULTS	38
	Main messages	38
5.1	Results from the survey	39
5.1.1	The sample	39
5.1.1.1	Offshore support sector	39
5.1.1.2	Short sea and coastal sector	39
5.1.1.3	Deep sea sector	40
5.1.2	Risk factors for fatigue	40
5.1.2.1	Combined effects analyses	43
5.1.2.2	Summary of risk factors for fatigue	44
5.1.3	Prevalence of fatigue	44
5.1.4	Consequences of fatigue	45
5.1.4.1	The impact of fatigue on perceptions of cognitive functioning and safety	45
5.1.4.2	Short term consequences of fatigue	48
5.1.4.3	Long term consequences of fatigue: well being and reported health	49
5.1.5	Phase specific issues	51
5.1.5.1	Phase 1	51
5.1.5.1.1	A comparison of seafarers, oil installation workers and an onshore sample	51
5.1.5.1.2	Effects of specific risk factors: Disturbed sleep	51
5.1.5.1.3	Combined effects	52
5.1.5.2	Phase 2	53
5.1.5.3	Phase 3	54
5.1.5.3.1	Validating the survey fatigue scales	54
5.1.5.3.2	Changes in fatigue over time	54
5.1.5.3.3	Collision awareness and fatigue	54
5.1.5.3.4	Multi-tasking and fatigue	55
5.1.5.3.5	Comparing the fatigue of seafarers with other groups	55
5.1.5.3.5.1	Onshore workers	55
5.1.5.3.5.2	Road haulage drivers	56
5.1.5.3.6	Fatigue in fishermen	56
5.1.5.3.6.1	Comparing fishermen with the main survey seafarers sample	58
5.2	Results from the diary studies	60
5.2.1	Phase 1 Diary Studies	61
5.2.2	Phase 2 Diary Study	62
5.3	Performance and alertness onboard	63

5.3.1	Effects of risk factors for fatigue on mood and performance	63
5.3.2	Perceived fatigue, symptoms of fatigue and performance	64
5.3.3	Objective measurement of sleep	65
5.3.4	Cortisol	66
6	PREVENTION AND MANAGEMENT OF FATIGUE	67
	Main messages	67
6.1	ILO 180	68
6.2	Evaluation of the European Working Time Directive	68
6.3	The relationship between recorded hours of work, fatigue and health of seafarers	70
6.4	Prescriptive versus outcomes approaches	70
6.5	IMO Guidance on Fatigue	71
6.6	TNO Report (Houtman et al., 2005): Fatigue in the shipping industry	71
6.6.1	Management of fatigue	71
6.6.2	Priorities for managing fatigue	72
6.6.3	Comments on the TNO report	73
7	CONCLUSIONS	75
8	RECOMMENDATIONS	80
9	REFERENCES	81
Table 1	PFRS fatigue and associated factors	41
Table 2	Fatigue at work and associated risk factors	42
Table 3	Fatigue after work and associated risk factors	43
Table 4	Combined effects of exposure to risk and fatigue	44
Table 5	Association between cognitive failures, perceived fatigue and fatigue risk factors	46
Table 6	Mean (se) perceived fatigue and symptoms of fatigue by perceived risk to safety from fatigue	47
Table 7	Perceived risk to self and associated risk factors	47
Table 8	Combined effects of exposure to risk and fatigue	48
Table 9	Symptoms of fatigue at sea and associated risk factors	49
Table 10	Association between perceived poorer health and fatigue independent of fatigue risk factors	50
Table 11	A comparison of survey responses from Phases 1 and 2	53
Table 12	Correlations between the study fatigue measures and standard fatigue measures for a general population sample of working men	54
Table 13	Comparison of fatigue levels between seafarers and working men in the general population study	55
Table 14	Mean (se) fatigue levels among seafarers and drivers	56
Table 15	Mean (se) fatigue and health scores for fishermen and other seafarers	59
Table 16	Effects of shift on alertness and reaction time	63
Table 17	Effects of days into tour in night workers doing 12 hour shifts	63

Table 18	Perceived fatigue and symptoms of fatigue reported by the mini-bulker crew and the crews of the other ships	64
Table 19	Performance scores for the mini-bulker crew and the crews of the other ships.	65
Table 20	Comparison of the sleep of offshore and onshore samples	65
Table 21	Cortisol levels (nmol) in saliva samples of Phase 1 and Phase 2 participants and onshore controls	66
Table 22	Fatigue and health scores for mis-recording and non mis-recording groups	70
Table 23	Addressing the programme's specific aims	76
Figure 1	Subjective sleep measurement	36
Figure 2	Combined effects of work hazards and scores on the PFRS Fatigue scale	52
Figure 3	Combined work hazards and the General Health Score from the Short Form Health Questionnaire [SF-36]	52

1. INTRODUCTION

Main messages

- No definitive measure of fatigue exists but three key areas should be considered: risk factors for fatigue, subjective perceptions of fatigue and outcomes of fatigue (changes in performance, physiology, health and safety).
- Fatigue may be induced by a number of factors including poor quality sleep, long working hours and environmental stressors. Considering the combined impact of a number of factors may prove most useful.
- The prevalence of fatigue depends on how it is measured, but estimates are as high as 22% for the general working population
- Fatigue has the potential to cause large scale accidents, especially in safety critical industries. An association with ill health has also been established.
- Large amounts of research have been conducted in other transport sectors, but not all of it is applicable to the unique onboard environment.

1.1 What is fatigue?

The technical use of the term fatigue is imprecise. Indeed, the variety of fatigue inducing situations, time courses and outcomes suggests that it is unlikely that we are considering a single set of processes leading to a specific underlying state. This makes integration of the existing literature very difficult. A person may feel fatigued, performance may deteriorate and the body's physiological functioning may be affected. These three outcomes, subjective perceptions, performance and physiological change are usually recognised as the core symptoms of acute fatigue. The condition is usually recognised by the reporting of fatigue and the objective outcomes then assessed. Estimates of the prevalence of fatigue will vary depending on which aspect of the fatigue process one uses as the indicator of fatigue. For example, if one assumes that doing shift work is a risk factor for fatigue one might simply use the number of workers doing shift work as an indicator of prevalence. However, this is based on the assumption that shift work automatically leads to fatigue which one finds is not always the case. Similarly, fatigue may be measured by the presence of negative outcomes, but the extent of the problem will often depend on the indicator chosen. There is no single "right" approach: all aspects of the fatigue process must be assessed and considered.

1.2 Risk factors for fatigue

Acute fatigue may be induced by a number of factors: lack of or poor quality sleep, long working hours, working at times of low alertness (e.g. the early hours of the morning), prolonged work, insufficient rest between work periods, excessive workload, noise and vibration, motion, medical conditions and acute illnesses. Chronic fatigue can either be due to repeated exposure to acute fatigue or can represent a failure of rest and recuperation to remove fatigue. Many working patterns induce acute fatigue and also lead to more chronic

patterns. For example, working at night is associated with reduced alertness during the shift and may also produce cumulative problems because of poor sleep during the day. Risk factors for fatigue have been widely documented and can be split into factors which reflect the organisation of work (e.g. working hours, task demands, the physical environment) and characteristics of the individual (both stable traits, and current state). Many of the established risk factors for fatigue are highly relevant to seafarers. These potential problems often reflect organisational factors such as manning levels or the use of particular shift systems (e.g. 6 on, 6 off). Others may reflect the specific voyage cycle of the ship. What is important to recognise is that it is the combination of risk factors that is crucial; fatigue may be most readily observed when a large number of these are present.

Most regulatory bodies have, until recently, focused on work schedules as the most important predictor of fatigue with the role of psychological and emotional factors not studied to the same extent. Moreover, few studies have examined how risk factors might combine in terms of their effects, or attempted to bench mark the different risk factors (e.g. what are the relative contributions of factors such as isolation, long working hours and high job demands to fatigue levels?). Recent studies have shown that psychosocial workplace stressors tend to demonstrate cumulative associations with self-reports of work stress and poor health outcomes. In a large survey of the general working population, high demands, high effort, low control, low support, low reward and exposure to physical hazards, combined with shift-work and long hours, were found to demonstrate significantly greater associations with work stress when considered in an additive model rather than individually. Moreover, this combined stressor score was linearly related to the outcome (Smith, McNamara, & Wellens, 2004). Similar results have been demonstrated for a number of health outcomes. A combination of high job strain (high demands and low control) and an imbalance between perceived efforts and rewards at work has been shown in a case-control study to predict acute myocardial infarction better than either model alone (Peter, Siegrist, Hallqvist, Reuterwall, & Theorell, 2002). Additive models of stressors have also demonstrated linear patterns of association with accidents at work using the Ergonomic Stress Level (ESL) measure, an instrument designed to calculate body motion and posture, physical effort, active hazards and environmental stressors in the workplace (Luz, Melamed, Najenson, Bar, & Green, 1990).

1.3 Prevalence of fatigue in the workforce

Prevalence of fatigue in the general working population has been estimated to be as high as 22% (Bultmann, Kant, Kasl, Beurskens, & van den Brandt, 2002b) and there exists a substantial literature relating work schedules and other work stressors (e.g. high demands) to fatigue in onshore populations. High job demands and role conflict were found to be associated with fatigue in a sample of NHS trust employees (Hardy, Shapiro, & Borrill, 1997), and findings from the Maastricht Cohort Study of 'Fatigue at Work' suggest that work schedules and psychosocial work stressors such as high demands (physical and emotional) and low control contribute to high levels of fatigue. Overtime and shift work were significantly associated with increased need for

recovery from work-related fatigue in a large sample [n=12,095] of the general working population (Jansen, Kant, Van Amelsvoort, Nijhuis, & Van den Brandt, 2003; Jansen, Kant, & van den Brandt, 2002), and in a sub-sample of men within the same cohort, psychological, physical and emotional work demands (with a protective effective of high job control) were linked with cumulative fatigue incidence during a 1-year follow-up study (Bultmann, Kant, van den Brandt, & Kasl, 2002a).

1.4 Consequences of fatigue

There is extensive evidence from both laboratory and field studies showing that acute fatigue is associated with impaired performance and compromised safety. Smith (Smith, 1999) has reviewed the effects of fatigue on performance and concluded that many of the risk factors for fatigue are present offshore. Similarly, reviews of fatigue and safety at work (e.g. (Costa, 2003; Folkard, Lombardi, & Tucker, 2005; Folkard & Tucker, 2003)) conclude that the move to less standardised working requires a new understanding of adaptive processes. Such trends have always been present at sea where 24 hour flexibility is an essential part of the industry. A cross-industry review by Folkard and Tucker (Folkard & Tucker, 2003) concludes that working at night can lead to compromised levels of safety with productivity inevitably also likely to suffer. Similarly, when reviewing the literature on working patterns and shift schedules, Folkard, Lombardi and Tucker (Folkard, Lombardi, & Tucker, 2005) highlight three key trends which have emerged from research into shift schedules and safety: (1) risk of an accident is higher when working at night (and to a lesser extent when working in the afternoon) compared to the morning, (2) risk of an accident increases over a series of shifts, again especially at night and (3) risk of an accident increases as total shift length increases over 8 hours (in any 24 hour period).

It is often the combination of risk factors that leads to impaired performance and reduced well-being and few would deny that seafarers are exposed to these high risk combinations. For example, if an individual is sleep deprived then this fatigue will be amplified by other factors which also induce fatigue (e.g. doing a boring task or having to work at night). In transport many jobs are often "safety critical" and one would expect a strong association between risk factors for fatigue and reduced safety. This can be seen very clearly in road transport. Recent results in accident research (road transport) indicate that the risk of accidents at work is a function of hours at work and sleep deprivation. There is an exponentially increasing accident risk beyond the 9th hour at work. The relative accident risk is doubled after the 12th hour and tripled after the 14th hour at work. In general, it is recommended to have at least 8 hours of rest per 24 hours. In the majority of industries there is appropriate regulation to minimise the risk of accidents. Ships have the potential to cause billion dollar accidents making the evaluation and audit of regulations crucial. To date, however, such evaluation has been minimal.

Among the general working population, fatigue has been associated with accidents and injuries (Bonnet & Arand, 1995; Hamelin, 1987). It has also been clearly linked to ill health (Andrea, Kant, Beurskens, Metsemakers, & van Schayck, 2003; Barger et al., 2005; Chen, 1986; Costa, 2003; Folkard, Lombardi, & Tucker, 2005; Huibers et al., 2004; Knutsson, 2003; Koller, 1983;

Leone et al., 2006; Mohren, Swaen, Kant, Borm, & Galama, 2001; van Amelsvoort, Kant, Beurskens, Schroer, & Swaen, 2002), as well as poorer work performance (Beurskens et al., 2000; Charlton & Baas, 2001), sick leave and disability (Janssen, Kant, Swaen, Janssen, & Schroer, 2003; van Amelsvoort, Kant, Beurskens, Schroer, & Swaen, 2002), and is a common factor in workers' consultations with GPs (Andrea, Kant, Beurskens, Metsemakers, & van Schayck, 2003). Furthermore, the concept of a *process* from negative work conditions, to fatigue, to illness has been suggested. Prospective studies have shown that psychosocial work characteristics significantly predict fatigue onset (Bultmann, Kant, van den Brandt, & Kasl, 2002a), and that preceding fatigue is significantly related to illness (Mohren, Swaen, Kant, Borm, & Galama, 2001). Although the direction of the relationship between risk factors for fatigue, perceived fatigue, and ill health has not always been conclusively established, the implication that fatigue may be a mediator between work risk characteristics and illness is apparent. Like most areas of fatigue research, the link between fatigue and health requires further investigation. Research usually starts by studying short term effects of fatigue, which in the case of health usually means an increase in mental health problems. Impaired mental health is a risk factor for more serious disease (e.g. cardiovascular disease) which clearly provides a path from fatigue to increased mortality risk.

In summary, fatigue can affect the individual by impairing performance, reducing safety, affecting well-being, increasing mental health problems and, possibly by increasing risk of chronic disease. These health problems may lead to disability and an inability to work. Fatigue can also lead to poorer social interaction with other workers which can extend to life outside work. Reduced safety due to fatigue will increase the risk of accidents that may lead to loss of life, environmental damage and huge economic cost.

1.5 Fatigue in transport

Fatigue has been identified as an important risk factor in road transport accidents, the rail industry and aviation. Driver fatigue is a major cause of road accidents accounting for up to 20% of accidents on motorways and monotonous roads in the UK. In HGV (Heavy Goods Vehicle) and PSV (Public Service Vehicle) drivers in the UK, driver fatigue was found to be a factor in 11% of accidents. Similar associations between driver fatigue and accidents have been reported in many other countries (RoSPA, 2001). Research has often shown that young drivers, truck drivers, company car drivers and shift workers are most at risk of fatigue-related accidents. Lack of sleep is not the only cause of fatigue. General health, alcohol, drugs, medicine and illness can also cause tiredness. Fatigue related accidents are also more likely to lead to fatalities and serious injuries (Horne & Reyner, 1995; Zomer & Lavie, 1990). Truck drivers report that driver fatigue is a major problem. A study of truck drivers on New York's interstate highways found that nearly two-thirds reported episodes of drowsy driving in the last month, 5% stated that they drove when drowsy on most days, and 25% reported falling asleep at the wheel in the last year.

There are a variety of different forms of legislation that aim to prevent driver fatigue developing. Methods of auditing potential risk factors for fatigue have

also been established and modelling of fatigue carried out. Training in fatigue awareness and management is also in place in a number of organisations, and this has been supported by information campaigns aimed at drivers in general, not just the commercial sector (e.g. *THINK – Tiredness kills. Make time for a break.* UK Department of Transport, (DfT)). Possible countermeasures such as napping and drinking caffeinated beverages have also been shown to be effective in providing short term relief from fatigue. Finally, technological advances have been made to help drivers identify that they are fatigued (e.g. eye blink indicators) and these have been shown to have the potential to reduce the risk of driving when fatigued.

Similar research on fatigue has been conducted in the rail industry. One interesting development in the UK has been the application of the HSE Fatigue index to the railway industry. This has led to the development of a good practice guide for train drivers to help them cope with shift work and fatigue. New railway safety legislation in the UK will include an approved code of practice on managing fatigue in safety critical work. Use of the HSE fatigue index will help organisations to ensure that workers do not carry out safety critical work when they are already fatigued, or have work patterns that would be liable to cause fatigue. Similar approaches have been developed in other countries.

Fatigue has also been identified as a major potential problem for many parts of the air transport industry (aircrew; air traffic controllers; maintenance personnel). Again, fatigue risk management systems have been developed and the Fatigue Risk Management toolbox typically consists of:

- Policy templates and guidelines to assist in the development of global and detailed corporate policies on the management of fatigue
- Competency-based training and assessment for employees, management and new staff
- Fatigue audit tools to assess work schedules, verify actual fatigue levels and monitor the fatigue risk management process

In summary, the extensive research on fatigue in other transport sectors (and other occupations) can now be applied to seafarers' fatigue. In addition, specific issues need to be addressed in the maritime sector due to the unique nature of working at sea.

2. BACKGROUND TO THE PROJECT

Main messages

- Globalisation in shipping has produced an industry vulnerable to increased fatigue-related problems.
- Compared to other transport sectors little research has been conducted into fatigue at sea
- The current project investigated fatigue in three sectors of the British seafaring industry using a wide range of research methods

Bloor, Thomas and Lane (Bloor, Thomas, & Lane, 2000) and Walters (Walters, 2005) chart the roots of globalisation in modern shipping and point to excessively competitive market conditions as critical in terms of understanding the current state of the industry. They suggest that the introduction of flags of convenience, increased reliance on technology, reduced crewing and internationally sourced labour have resulted in an increase in profits at the expense of welfare concern. This had led some observers to suggest that fatigue is a deleterious outcome of the drive for lower costs, and that crews are now 'being paid less for doing more' (Cockroft, 2003).

Global concern with the extent of seafarer fatigue and the potential environmental cost is widely evident everywhere in the shipping industry. Maritime regulators, ship owners, trade unions and P & I clubs are all alert to the fact that with certain ship types a combination of minimal manning, sequences of rapid port turnarounds, adverse weather conditions and high levels of traffic may find seafarers working long hours and with insufficient recuperative rest. In these circumstances fatigue and reduced performance have the potential to contribute to circumstances which may lead to environmental damage, ill-health and reduced life-span among highly skilled seafarers who are in increasingly short supply. Reports of fatigue at sea are now being formally documented and the following account is typical of this type of evidence:

Fatigue in frame again over bulker grounding - Lloyd's List, Tuesday April 18 2006

"A FATIGUED master, alone and asleep on the bridge of his ship, caused the grounding of a British-registered bulker in the Baltic Sea last October, a Marine Accident Investigation Branch report has concluded, writes Michael Grey.

On a voyage from Hamburg to Klaipeda, the 2,777 dwt Lerrix was being monitored by Warnemunde VTS when it failed to alter course and despite efforts to contact the ship was seen to run aground. The master, who had permitted the lookout to leave the bridge, had fallen asleep in the pilot chair.

The casualty is the latest in a considerable list of incidents in which fatigue has played a major part. It also transpired that the watch alarm, which might have alerted the sleeping master, had been disconnected.

An additional feature of this casualty was the finding that the master had, rather than using the ship's navigational equipment, been using his own personal GPS and navigational program on his laptop to navigate the Rix

Shipping-owned bulker. The software, furthermore, was both "pirated" and considerably out of date.

Recommendations to the owners and UK Chamber of Shipping by MAIB included the need to impress upon owners, operators and managers the importance of fatigue-related issues, safe lookout, the inappropriate use of personal electronic equipment and closer scrutiny of hours of rest worksheets."

Interviews and focus groups also point to many of the major issues relating to fatigue at sea. Ellis (Ellis, 2005) reports a number of comments made by participants from various shipping companies, management companies and maritime colleges in the UK, Philippines and Singapore that illustrate some of the underlying issues associated with seafarers' fatigue. These included:

- 1. The extra burden of paperwork*
- 2. The additional burden of the International Ship and Port Security (ISPS) drills*
- 3. Long working hours*
- 4. Fatigue leading to shortcuts which compromise safety*
- 5. Falsification of documentation about working hours*
- 6. Safety concerns due to reduction in crew sizes*

A long history of research into working hours and conditions in manufacturing as well as road transport and civil aviation industries has no parallel in commercial shipping. There are huge potential consequences of fatigue at sea in terms of both ship operations (accidents, collision risk, poorer performance, economic cost and environmental damage) and the individual seafarer (injury, poor health and well-being). Not only has there been relatively little research on seafarers' fatigue but what there has been has been largely focused on specific jobs (e.g. watchkeeping), specific sectors (e.g. the short sea sector) and specific outcomes (e.g. accidents). This reflects general trends in fatigue research where the emphasis has often been on specific groups of workers (e.g. shiftworkers) and on safety rather than quality of working life (a crucial part of current definitions of occupational health). It is argued here that a more far reaching holistic approach to seafarers' fatigue is required.

2.1 The Cardiff Research Programme

Given the absence of extensive research on seafarers' fatigue we have carried out a research programme that generally aimed to provide the knowledge base to:

- Predict worst case scenarios for fatigue, health and injury*
- Develop best practice recommendations appropriate to ship type and trade*
- Produce advice packages for seafarers, regulators and policy makers*

Specifically, the programme's aims were to provide advice on:

- Incidence and effect of fatigue in terms of specific ship types and voyage cycles*
- Optimal shift patterns and duty tours to minimise fatigue*
- Identification of at risk individuals and of factors which affect fatigue/quality of rest*

- *Significance of patterns of work and rest, and patterns of health and injury, in terms of seeking to improve health and safety of seafarers on board ship*
- *Suggested ameliorative/preventative procedures for minimising the effects of fatigue*
- *Appropriate guidance for seafarers on fatigue avoidance*

These aims were achieved by surveys, analysis of existing databases and field studies using a battery of techniques to explore variations in fatigue and health as a function of the voyage cycle, crew composition, watchkeeping patterns and the working environment. The methods involved:

- A review of the literature
- A questionnaire survey of working and rest hours, physical and mental health
- Physiological assays assessing fatigue
- Instrument recordings of sleep, ship motion, and noise
- Self-report diaries recording sleep quality and work patterns
- Objective assessments and subjective ratings of mental functioning
- Pre- and post-tour assessments
- Analysis of accident and injury data

2.2 Phases of the research

The project consisted of three phases. The first involved data collection from seafarers in the offshore oil support sector (shuttle tankers, offshore supply vessels, anchor handlers, daughter craft and diving support vessels). Interest in this sector developed from research on fatigue on oil installations (Smith, 1999, 2006) and this phase not only allowed assessment of seafarers' fatigue but comparison with those on installations. A detailed account of this phase is given in Smith, Lane and Bloor (Smith, Lane, & Bloor, 2001).

The second phase of the research was concerned with the short sea sector (passenger ferries – both traditional and fast ferries; freight ro-ro's; and near sea tankers). A detailed account of this phase is given in Smith, Lane, Bloor, Allen, Burke and Ellis (Smith et al., 2003).

The final phase extended the research to other sectors (mini-bulkers, short-haul bulkers, feeder and mainline containerships, reefers, long-haul tankers and cruise ships). In addition, a survey was conducted to assess fatigue, health and injury in the fishing industry. The research continued to assess the interface between ships and installations/ports with an emphasis on the effects of fatigue on risk perception of collisions. The impact of fatigue on multi-tasking was also investigated with a view to determining which working practices may lead to greater risk. The time course of fatigue was investigated in more detail by studying the effects of different port/sea cycles and other potential risk factors for fatigue using a diary methodology. The same approach was used to investigate the after-effects of a tour at sea in terms of fatigue experienced at the start of leave. Finally, the research evaluated the impact of the working time directive and the IMO guidelines on fatigue. A detailed account of this phase is given in Smith, Allen and Wadsworth (Smith,

Allen, & Wadsworth, 2006), which also provides detailed information on the methods used in the research and publications arising from it.

The next section summarises the literature reviews on seafarers' fatigue carried out throughout the project. These are described in detail in Collins, Mathews and McNamara (Collins, Mathews, & McNamara, 2000), Smith et al (Smith et al., 2003), and Allen, Wadsworth and Smith (Allen, Wadsworth, & Smith, Submitted).

3. A REVIEW OF THE INTERNATIONAL LITERATURE ON SEAFARERS' FATIGUE

Main messages

- Research is increasingly revealing fatigue to be a significant problem in the seafaring industry. Present reporting systems, however, are often not designed to record this factor.
- Evidence shows seafarer shift and working patterns are often conducive to fatigue. Having only two bridge watch-keepers may be a particular problem.
- Excessive working hours appear widespread in the seafaring industry.
- The impact of working as a seafarer may be felt in terms of health and psychosocial consequences
- Research is increasingly finding a link between fatigue and shipping accidents

This section covers international research on seafarers' fatigue. A review of strategies to prevent or manage fatigue is given in a later section.

In 1989 Brown (Brown, 1989) published a review exploring the relationship between hours of work, fatigue and safety at sea with evidence of increasing interest in the human element. Finding few accident cases citing fatigue as a direct causal factor, Brown identified inadequate reporting systems as central in understanding how legislative channels were overlooking this problem. Eleven years later our initial review focused on the British offshore oil support industry and found a similar picture to Brown, concluding that fatigue has been noticeably under-investigated in the maritime domain (Collins, Mathews, & McNamara, 2000). Interestingly both Brown and Collins et al. note a disparity between official and anecdotal sources in terms of seafarers' fatigue which is of undoubted relevance in the modern context:

'It is apparent that although a sizeable literature of anecdotal evidence exists, up until now little valid and reliable research has been conducted in the area' (Collins, Mathews, & McNamara, 2000), p.13)

Where such empirical evidence continues to be lacking a review not only highlights any progress but reveals significant gaps. Allen et al. (Allen, Wadsworth, & Smith, Submitted) have reviewed recent developments using the fatigue process framework described earlier.

3.1 Prevalence of fatigue

Grech, Horberry and Humphreys (2003) studied the Royal Australian Navy and found fatigue to be reported as a major problem. With a sample of 79 crew from 6 patrol boats questionnaire data were collected showing approximately 44% of participants worked more than 80 hours a week and 62% reported not getting enough sleep. Taylor Nelson Sofres (TNS, 2004 as cited in Gander, 2005) investigated fatigue alongside drug and alcohol use in the New Zealand shipping industry with a sample including representatives from the leisure, fishing and commercial industries. Whilst Gander (2005) points out that methodological shortcomings prohibit generalisation from the study, the fact that 16% of vessel owners/operators in the TNS sample rated

the risk of a seafarer being injured in a fatigue-related accident as 'high' or 'very high' certainly supports concerns raised in the author's own work. Gander and Le Quesne (2001, as cited in Gander, 2005) conducted a study looking at masters and mates working on New Zealand inter-island ferries and found that 61% of officers felt they were often or always affected by fatigue when on duty. It was also found that 26% of the ferry sample could recall being involved in a fatigue related incident or accident in the last 6 months.

3.2 Fatigue risk factors

3.2.1 Circadian rhythms

With a large proportion of seafarers on shift work the potential for disruption to circadian rhythms is great and may be compounded by more and more pronounced 'jet lag' type effects as ships get increasingly faster (Malawwethanthri, 2003).

3.2.2 Working patterns and shift schedules

Folkard, Lombardi and Tucker (Folkard, Lombardi, & Tucker, 2005) highlight three key trends which have emerged from onshore research into shift schedules and safety: (1) risk of an accident is higher working at night (and to a lesser extent working in the afternoon) compared to the morning, (2) risk of an accident increases over a series of shifts, again especially at night and (3) risk of an accident increases as shift length increases over 8 hours. In a similar review Costa (2003) concludes that working patterns are becoming increasingly less standardised requiring a new understanding of adaptive processes. Interestingly such trends which are now being identified 'onshore' have always been played out in the seafaring world where 24 hour flexibility is an inherent part of the job.

There has been extensive research on shiftwork on offshore installations. Parkes (Parkes, 2002), summarising research conducted in the North Sea oil industry, found that nearly half of a sample of offshore installation managers reported working in excess of 100 hours per week. In terms of shift schedules Parkes concludes that a fixed shift system is generally a better option where workers work the same shift for their whole 2 week tour rather than changing half way through (e.g. from nights to days). Working the same shift for a whole tour clearly requires less circadian adaptation but offshore personnel prefer to go home 'daytime adjusted'.

An ITF report (International Transport Federation (ITF), 1998), based on responses from 2,500 seafarers of 60 nationalities, serving under 63 flags, demonstrates the extent of excessive hours and fatigue within the industry. Almost two-thirds of the respondents stated that their average working hours were more than 60 hours per week and 25% reported working more than 80 hours a week (42% of masters). Beyond simply long working hours, however, other evidence suggested that on many ships working hours were actually in excess of STCW 95 or ILO 180 requirements. It was found that 36% of the sample were unable to regularly obtain 10 hours rest in every 24, and 18% were regularly unable to obtain a minimum of 6 hours uninterrupted rest. Long periods of continuous watchkeeping were also reported, with 17% stating that

their watch regularly exceeded 12 hours. Over half the sample (55%) considered that their working hours presented a danger to their personal health and safety. Indeed, nearly half the sample felt that their working hours presented a danger to safe operations on their vessel. Once again this was particularly prevalent in watchkeepers and also on ferries and offshore support vessels. The survey also showed that over 60% reported that their hours had increased in the past 5 to 10 years. Respondents also provided a wide range of examples of incidents that they considered to be a direct result of fatigue. The early hours of the morning were the most difficult in terms of feeling the effects of fatigue and it is important that safe manning assessments, watch systems and procedures reflect the potential decline in individual performance at these times. More than 80% of the sample reported that fatigue increased with the length of the tour of duty. Long tours of duty were also common (30% reporting usual tour lengths of 26 weeks or above). This cumulative fatigue may also reflect the reduction in opportunities for rest and relaxation ashore, due to the reduced port turn-around times now required.

3.2.3 Noise and motion

The impact of noise and motion has been assessed with both subjective and objective measuring instruments. The main interest has been on how these factors influence sleep and performance. Tamura, Kawada and Sasazawa (Tamura, Kawada, & Sasazawa, 1997) found that exposure to ship engine noise at 65 dB (A) (around average for ships over 3000 tons, citing Oguro 1975) can have an adverse effect on sleep. Tamura et al (Tamura *et al.*, 2002) found that habituation to noise occurred in the subjective measures but that this effect was not obtained when sleep was measured using actigraphy. Research has shown that noise levels vary considerably at different locations on the ship. Rapisarda, Valentino, Bolognini and Fenga (Rapisarda, Valentino, Bolognini, & Fenga, 2004) took multiple measurements of noise onboard 6 fishing vessels in order to examine how location determines exposure. Taking measurements at the engine, deck, winch, wheelhouse, mess room, kitchen and sleeping quarters Rapisarda et.al found noise levels to vary considerably by location implying global monitoring to be inappropriate. The authors suggest future onboard noise research should focus upon exposure at an individual and daily level in order to accurately understand this environmental factor.

A survey by Omdal (Omdal, 2003) of 11 Norwegian vessels aimed to identify factors potentially harmful to health and found that 44% of respondents reported noise as a problem. Only 8% of crew onboard a noise-reduced vessel reported stress and such evidence suggests that through technology and improved design some traditional hardships associated with the maritime life can be overcome.

A more substantial body of evidence details the effects of vessel motion, which may in turn induce fatigue, on performance, although, results differ depending upon ship type and experimental tasks employed. For example, Wilson et al. (1988, cited in Powell & Crossland, 1998) using a simulator found that cognitive processing was significantly slower as a result of motion, although no information regarding total motion exposure time was available.

Furthermore, it is not possible to ascertain from these data whether the accuracy, as well as the speed of cognitive processing was affected. Pingree et al. (1987, cited in (Powell & Crossland, 1998)) found evidence to suggest that motion degrades performance on a psychomotor tapping task, although not on computer-based cognitive tasks. It would therefore appear that certain types of task are more sensitive to the effects of vessel motion than others.

3.2.4 Sleep

A number of studies (e.g. Gander, Van den Berg, & Signal, 2005; Reyner & Baulk, 1998) have shown that sleep is disrupted at sea. Interestingly, it is often sleep quality rather than duration which is reduced which suggests that sleep at sea may not have the same restorative function as onshore. Split shifts also impair sleep and Condon et al. (Condon *et al.*, 1984) suggest that operational effectiveness at sea could be improved by having a single sleep period and by having a “wake up” period prior to starting work.

3.2.5 Other risk factors

Jensen et.al (2004) conducted a questionnaire study across 11 countries with 6461 seafarers looking at factors associated with injury in the latest tour of duty. Most notably no evidence was found for an association between long working hours and increased injury likelihood although a number of other significant results were shown. Those reporting significantly higher incidence of injury included non-officers compared to officers, younger seafarers compared with older seafarers (cut off point of 35 years old) and those working shorter tours of duty. Looking at fatigue in seafarers working on high-speed craft (HSC) in Hong Kong, Leung et.al (Leung, Chan, Ng, & Wong, 2006) also found younger seafarers to experience a greater detriment in performance with perceived voyage difficulty and experience operating HSCs also found to be important. In terms of organisational factors, Leung et.al found working at night to be more fatiguing but observed a greater fatigue carry-over effect from one day to the next in day-shift officers.

3.3 Accidents and Injuries

Roberts (2002; see also Roberts & Hansen, 2002) provides evidence to support the commonly held notion that seafarers, and in particular fishermen, are at considerably higher risk of injury or death compared to workers in other professions. When compared with other British workers seafarers were found to be 26.2 times more likely to be involved in a fatal accident at work in the period between 1976 and 1995 with this risk even higher for fishermen (52.4 times). Later work by the same author considered evidence up to 2002 (Roberts & Marlow, 2005) and confirmed that whilst fatal accidents have dramatically declined in number since the 1970s, relative to the general workforce seafaring should still be considered a ‘hazardous occupation’.

In terms of assessing factors associated with mortality at sea, Roberts (Roberts, 2000) has shown that during the period 1986-1995 British seafarers were at a higher risk of dying through ‘work-related accidents, suicides and unexplained disappearances at sea’ when working on foreign compared with

UK flagged vessels. Hansen, Nielsen and Frydenberg (Hansen, Nielsen, & Frydenberg, 2002) looked at accidents onboard Danish merchant ships between 1993 and 1997 and found that changing ship and the first period spent onboard were notable risk factors.

When looking for working patterns predictive of fatigue one method is to retrospectively analyse incidents which have occurred in order to identify the risk factors. In the MAIB 'Bridge Watchkeeping Safety Study' (Marine Accident Investigation Branch (MAIB), 2004) evidence from 66 collisions, near collisions, groundings or contacts between 1994 and 2003 was reviewed with clear patterns emerging from analysis. Using the grounding of MV Jambo as an illustrative example, the MAIB report highlights how a large number of the accidents studied were the result of having only two watchkeepers, with a 6-on/6-off schedule employed in most cases. The MAIB conclude that watchkeeper manning levels are one of the causal factors in collisions and groundings and the report recommends that, in general, vessels over 500gt should have a minimum of a master *and* two bridge watchkeeping officers on board. In analysis sponsored by the U.S coastguard Raby and Lee (2001) studied accident cases and similarly found evidence of fatigue with mode of enquiry affecting causal estimates. Where mariners were asked about accident cause fatigue was implicated in 17% of cases with investigating officers finding a higher rate of 23%. Using a more objective fatigue index score, Raby and Lee found a contribution rate of 16% for critical vessel accidents and 33% for personal injury accidents (23% if outcomes combined). In reviewing the accident literature, Houtman et.al (2005) found that fatigue may be a causal factor in anywhere between 11 and 23 percent of collisions and groundings although a lack of systematic reporting procedures makes estimates difficult (Gander, 2005). Houtman et.al suggest that aside from reporting inconsistencies the act of actually admitting to fatigue may be sufficiently derided so as to make seafarers' unlikely to report their experience. In understanding how such cultural notions might impact upon accident reporting a quote from Caldwell (2003), in reference to the aviation industry, perhaps best describes the attitudinal climate:

The root of the problem is that the hard-charging, success-orientated people who make up the modern industrialized community and the world's military forces have yet to be convinced that human fatigue is a problem in terms of safety, health, efficiency, and productivity; that fatigue stems from physiological factors that cannot be negated by willpower, financial incentives, or other motivators (p.11/12)

Commenting on epidemiological research by Roberts, Conway (2002) highlights how fatigue in the fishing industry in particular may be tied in with seasonal working patterns and the issue of transportation to and from fishing grounds. Lawrie, Matheson, Murphy, Ritchie, & Bond (2003) have found that it is possible to identify other risk factors which may predispose fishermen to accident and injury with experience working on a large number of vessels found to have such an association.

3.4 Health

Hansen et al. (Hansen, Tüchsen, & Hannerz, 2005) found evidence of poor health from the examination of hospital admission records for a cohort of Danish merchant seafarers. Evidence of poor health in this sample is particularly concerning in light of Danish crew facing health examinations every two years, clearly bolstering any residual 'survival population' effect. Carter (2005) draws attention to psychosocial problems associated with working at sea. Seafarers live in their workplace 24 hours a day, a socially detached environment further compounded by divisions of rank and nationality. Carter suggests, however, that it is the adaptation from life onboard to life at home which presents perhaps 'the most significant disturbance' faced by seafarers, a conclusion also reached by Thomas, Sampson and Zhao (2003). Thomas et al. conducted interviews with 35 women, all partners of seafarers, in order to understand the interface between home and work. Whilst seafarers may benefit financially from choosing a tour-orientated lifestyle, Thomas et al. conclude that the 'emotional cost' to both seafarer and family may outweigh any compensatory economic reward. Certainly when attempting to understand fatigue and its consequences it is wrong to focus purely on the work situation and not consider how time on leave might be affected, as illustrated in this quote from a Captain's wife, transcribed in Thomas et al.:

'I found it horrendous, he would come home so tired, absolutely zonked out cos [at that time] he was still a second mate and he'd come home absolutely shattered- took him days and days to get over it...' (p.64)

Matheson et al. (2001b) used a questionnaire to assess the health status of Scottish fishermen alongside collecting data from Accident and Emergency departments, recruiting fishermen to complete health diaries, interviewing industry representatives and analysing medically related radio calls sent from fishing vessels. From the 1150 questionnaires returned Matheson et al. found that lack of sleep/fatigue was reported to be the factor fishermen most believed to affect their health with lack of exercise and financial stress also found to be important.

The next section describes the methods used in the present project to extend our knowledge about seafarers' fatigue. Detailed accounts of these methods can be found in Smith et al. (Smith, Lane, & Bloor, 2001), (Smith et al., 2003) and Smith et al. (Smith, Allen, & Wadsworth, 2006).

4. METHODS

Main messages

- A survey questionnaire was designed to assess all areas of a seafarer's life. Standardised measures of health and fatigue were included alongside questions addressing seafaring-specific issues.
- A diary study was included in each of the phases, with a more extensive version assessing fatigue over an entire tour-leave cycle in phase 3
- Onboard testing was conducted in each of the three phases of the project involving performance testing, motion and noise monitoring, sleep assessment, measurement of salivary cortisol and completion of diaries.

The methodology has been consistent across the three phases of the research with only slight modifications made when studying each new sector.

4.1 Surveys

The surveys were based on the ITF survey (International Transport Federation (ITF), 1998) with additional measures included to investigate health and cognitive function. The general content of the surveys can be summarised as follows:

- Demographics and nature of the person's job
- Working hours/shift schedules (tour length; hours worked per week; shift schedule)
- Variable working hours (unpredictable hours, being on call and emergencies)
- Stress at work
- Physical hazards (exposure to fumes, handling harmful substances, ringing in the ears, background noise and vibration)
- Environmental factors (motion and poor weather conditions)
- Job demands (time pressure, constant interruptions, high level of responsibility and pressure to work overtime)
- Support at work (unfair treatment, inadequate support, insufficient respect from colleagues, and lack of respect and prestige at work generally)
- Port frequency/turn around time
- Job security (poor promotion prospects, poor job security and inadequate prospects given effort)
- The home/work interface
- Fatigue: Fatigue was measured using four scales: the fatigue subscale of the Profile of Fatigue Related Symptoms (PFRS-f: (Ray, Weir, Phillips, & Cullen, 1992)), fatigue at work, fatigue after work and symptoms of fatigue.
- Fatigue related incidents/perceptions of safety
- Knowledge of regulations/training aimed at preventing or managing fatigue
- Sleep duration/opportunity for rest

- Poor sleep quality (difficulty getting to sleep, difficulty staying asleep, often waking during sleep and feeling restless)
- Disturbed sleep (by heat, light, quality of bed and other people)
- Health-related behaviours (smoking, alcohol consumption, exercise)
- Health outcomes (sick leave; GP consultations; medication; injuries; mental health [measured by the GHQ, (Goldberg, 1992)]; general health/well-being [measured by the SF-36, (Ware & Sherbourne, 1992)]; cognitive problems [measured by the CFQ, (Broadbent, Cooper, Fitzgerald, & Parkes, 1982)]).

4.2 Diary studies

In Phase 1 volunteers completed daily diaries while they were at work and on leave. These measured:

- Quality and duration of sleep.
- Sense of well-being at work and on leave.
- Environmental/Job conditions and effects on well-being.

In Phase 2 diaries were completed before and after work recording food intake, medication, breaks, caffeine consumption, smoking, sleep, symptoms of fatigue and perception of work related issues.

A more extensive diary study was carried out in Phase 3 and compared ships from the oil support, short sea and deep sea sectors. These diaries were completed both while the volunteers were at sea and when they were on leave. The 'at sea' diaries were completed during a tour of duty. Participants completed a diary page each time they got out of, or into, bed. On waking, data were collected about the time of day, sleep length, sleep quality, and fatigue. On going to bed data were collected about the time of day, fatigue, ship operations since their last main sleep period, and time spent working. Those on shorter tours (up to 28 days) collected data throughout their tours. However, for pragmatic reasons, those on longer tours were asked to collect data for 35 days of their tour. These days were to include the first and last weeks, and three other weeks from the middle of tour. The leave diaries were designed to describe respondents' fatigue and the impact of tour on leave.

4.3 Onboard testing

4.3.1 Vessel motion

The motion of the vessel was measured using the Seatex MRU H.2 Motion Referencing Unit. The unit has a number of outputs including, roll, pitch and yaw angles and corresponding angular rate vectors relative to the vessel's frame. Symmetric Euler parameters of rotation are also available. The unit outputs relative (dynamic) heave, surge, sway-positions, velocities and accelerations in adjustable time frames. These data were logged every 2 seconds for a continuous period once the MRU was set to record. The data were download to an IBM compatible computer through a connection cable and junction box, and were recorded to files in 12 hour blocks. A graphical

output is also given whilst the data are recoded by the IO-Spy software, showing pitch and roll degrees, and amounts of heave, surge and sway.

In Phase 2 a number of adjustments were made. As in Phase 1 pitch, roll and heave, were recorded (in degrees), and accelerations within these dimensions (metres/second) were also recorded. The sampling rate was also increased, and data were logged for these dimensions every third of a second. From this data root mean squared (RMS) displacement scores (the standard deviation of the raw values) were calculated for acute time periods, and for motion of the vessel overall.

4.3.2 Measurement of noise

The noise levels on the vessels were recorded using CEL-460 Dosimeters, which log noise data over a specific period. This unit consists of two parts, the recording unit and a microphone. Each dosimeter was calibrated using the CEL-282 Acoustic calibrator. The dosimeters were set to run for approximately 24-hour periods in different locations across the vessel. Once the 24-hour periods had elapsed the data were then downloaded to an IBM compatible computer, into the CEL SoundTrack db10 programme.

4.3.3 Measurement of performance and mood

Tests were selected which have been shown to be sensitive measures of fatigue both onshore (see (Smith, Sturgess, & Gallagher, 1999) and offshore (oil installations – (Smith, 2006). The tests were carried out at the start and end of the working day and the difference between these time points enables one to determine how fatiguing the day's work has been (see (Parkes, 1993). Tests were carried out at the start of the period the experimenter was onboard ship and again 7 days later. This allowed assessment of any cumulative effects of the voyage cycle.

4.3.3.1 Visual analogue mood scales

Mood was assessed both pre and post performance testing using 18 computerised visual analogue mood rating scales. Each of the 18 bipolar scales comprised of a pair of adjectives for instance, drowsy - alert or happy - sad. Participants were instructed to move the cursor from a central position anywhere along the horizontal rule, towards either extreme of the scale, until the cursor was at a position representative of their mood state at that exact time. These 18 scales were presented successively. Three main factors were derived from these scales; alertness, hedonic tone and anxiety.

4.3.3.2 Variable fore-period simple reaction time task

In this task a box was displayed in the centre of the screen and at varying intervals (from 1-8 seconds) a target square would appear in the box. As soon as they detected the square participants were required to press a response key using the forefinger of their dominant hand only. This task lasted for approximately 3 minutes. A measure of mean reaction time was recorded for each minute of performance on the basis of the number of trials

completed per minute. A total mean reaction time was also calculated from the total number of trials completed during the whole test. Responses below 200 ms and greater than 750 ms were eliminated from the calculation of these variables.

4.3.3.3 Focused attention task

This choice reaction time task measures various aspects of attention. In this task target letters appeared as upper case A's and B's in the centre of the screen. Participants were required to respond to the target letter presented in the centre of the screen ignoring any distracters presented in the periphery as quickly and as accurately as possible. The correct response to A was to press a key with the forefinger of the left hand while the correct response to B, was to press a different key, with the forefinger of the right hand. Prior to each target presentation three warning crosses were presented on the screen, the outside crosses were separated from the middle one by either 1.02 or 2.60 degrees. The crosses were on the screen for 500 ms and were then replaced by the target letter. The central letter was either accompanied by 1) nothing, 2) asterisks, 3) letters which were the same as the target or 4) letters which differed from the target. The two distracters presented were always identical and the targets and accompanying letters were always A or B. Participants were given ten practice trials followed by three blocks of 64 trials. In each block there were equal numbers of near / far conditions, A or B responses and equal numbers of the four distracter conditions. The nature of the previous trial was controlled. This test lasted approximately 3 minutes. In this task several aspects of choice responses to a target were measured. The global measures that were assessed were mean reaction time, accuracy of response (percent correct) and lapses of attention (reaction times > 800 msec). In addition a measure of selective attention was recorded (the Eriksen effect). This provides a measure of focusing of attention, describing the effect of spatial interference caused by disagreeing stimuli placed near to or far from the target upon reaction time and accuracy of response to the target. If attention is focused, then a big difference between near and far distractor conditions should be found. If attention is set to a wide angle then this difference should be reduced. A more specific aspect of choice response was measured recording choice reaction time and accuracy with which new information was encoded (the difference in reaction time and accuracy of response between conditions when the target is alternated from the previous trial and when the target is repeated from the previous trial).

4.3.3.4 Categoric search task

This task was similar to the focused attention task previously outlined. Each trial started with the appearance of two crosses either in the central positions occupied by the non-targets in the focused attention task i.e., 2.04 or 5.20 degrees apart or further apart, located towards either left and right extremes of the screen. The target letter would then appear in place of one of these crosses. However, in this task participants did not know where the target would appear. On half the trials the target letter A or B was presented alone and on the other half it was accompanied by a distracter, in this task a digit (1-

7). Again the number of near/far stimuli, A versus B responses and digit/blank conditions were controlled. Half of the trials led to compatible responses (i.e., the letter A on the left side of the screen, or letter B on the right) whereas the others were incompatible. The nature of the preceding trial was also controlled. In other respects (practice, number of trials, etc.) the task was identical to the focused attention task. This task also lasted approximately 3 minutes. As in the focused attention task several aspects of choice responses to a target were measured. The global measures recorded were choice reaction time, accuracy of response and lapses of attention (reaction times > 1000 msec). A more specific aspect of choice response was measured, recording choice reaction time and accuracy with which new information was encoded. In addition specific aspects of selective attention were measured. For each of the variables outlined below, mean reaction time and accuracy were calculated. A measure of response organisation was recorded. This refers to the effect of compatibility of the target position and the response key upon reaction time and accuracy. A measure of spatial uncertainty was also taken which describes the extent to which not knowing the location of the target (in near or far locations) hinders both reaction time and accuracy.

4.3.4 Measurement of sleep

Sleep was measured by both subjective ratings and objective measurement of movement using actiwatches. An example of the subjective ratings is shown in Figure 1.

Figure 1 Subjective sleep measurement

To be completed just before starting work:

• Time you went to bed:	
• Time you went to sleep:	
• Time you woke up:	
• Time you got up:	
• Sleep duration:	
• Number of awakenings during a sleep period	_____

Rate your Sleep

	Least (1)	2	3	4	Most (5)
Ease of falling asleep	1	2	3	4	5
Ease of arising	1	2	3	4	5
Was this sleep period sufficient?	1	2	3	4	5
How deep was your sleep?	1	2	3	4	5
Did you wake earlier than intended?	1	2	3	4	5

Sleep data were also recorded using the Actiwatch[®] Activity Monitoring System by Cambridge Neurotechnology. This system consisted of two parts: an actiwatch, which measured motion using a piezo-electric accelerometer giving measurements of intensity, amount and duration of movement. The watch also includes an ‘Event Marker’ button which allows the user to mark certain points in time, for example when they woke up. This information is stored in the Actiwatch unit, similar in appearance to an electronic wristwatch, which can record information for a period of up to 83 days. Volunteers were asked to wear the Actiwatch on their non dominant hand during the sleep periods prior to the performance test sessions. The second part of the system is the Reader/Interface connecting cable and software. This allows the Actiwatch to be programmed to run for different periods of time and for data to be downloaded and stored. The sleepwatch analysis software uses an algorithm based on level of movement in any 5-second period and the preceding and following periods to give a value of asleep or awake for that period. A global measure of number of hours sleep per night was derived. This was the difference between sleep onset and awakening, not taking into account any waking during the night. Using this variable and the sleep/wake data from the actiwatch software, measures for actual sleep time, sleep efficiency and immobility as percentages and total activity and sleep fragmentation index as totals were derived.

4.3.5 Salivary cortisol

Cortisol is a hormone produced by the adrenal glands. It is produced in a daily rhythm, with highest levels after waking, which then fall throughout the day with lowest levels occurring at night. Cortisol is a good indicator of fatigue and it also enables one to determine whether circadian rhythms have been disrupted. Levels of cortisol can be measured in saliva samples taken using a cotton bud in the mouth (the standard operating procedure for collecting these samples is given in Smith et al. (Smith, Lane, & Bloor, 2001). Saliva samples were taken before and after work and sent to Professor Jo Arendt's laboratory, University of Surrey, so that levels of cortisol could be assayed.

5. RESULTS

Main messages

- Fatigue was consistently associated with poor sleep quality, negative environmental factors, high job demands and high stress. In addition, those on shorter tours of duty were consistently more likely to report high fatigue levels. This may reflect aspects of the work inextricably linked to tour length, such as vessel type, sector etc.
- Other factors found to be important included: frequent port visits, physical work hazards, working more than 12 hours a day, low job support and finding the switch to port work fatiguing.
- Short term fatigue consequences (symptoms of fatigue, perception of risk to personal safety) were associated with a similar range of factors
- The additive combination of different risk factors proved most highly associated with fatigue and with its immediate consequences. These relationships were shown to be multiplicative.
- An association between fatigue and self-reported health status was shown. This association was independent of work characteristics shown to be risk factors for fatigue. Fatigue may therefore be a factor which impacts on health independent of other risk factors.
- Evidence suggests the present sample may represent the better if not 'best end' of the industry. This would suggest any problems identified in the study may be considerably worse elsewhere
- Workers from offshore oil installations were found to have higher levels of fatigue and poorer health than the seafaring sample. Factors associated with fatigue, however, were found to be very similar to those associated with fatigue among seafarers.
- The cross phase seafaring sample was found to have similar levels of fatigue to an onshore working sample, but higher levels of fatigue at work
- Seafarers in the short sea and coastal sample were found to report higher levels of fatigue than those from an offshore oil support sample. This may potentially be explained in terms of type of vessel and frequency of port turn-around.
- Comparing seafarers with a road haulage sample suggested change of operation (such as from working at sea to working in port, or from driving to loading or unloading) may be a fatigue inducing factor irrespective of transport sector.
- Comparing seafarers with a sample of fishermen a suggestion was found that fishermen who sleep onboard may be no more fatigued or unwell than other seafarers, although this trend should be taken with caution due to a small sample size.
- In a diary study of seafarers over a complete tour-leave cycle fatigue was found to increase most significantly in the first week of tour. Evidence suggested recovery from tour does not typically occur until the second week of leave.
- In the diary study more frequent port calls were associated with greater fatigue among those on shorter tours, and with lower fatigue among those on longer tours. This difference would appear to reflect ship type.

- Of methodological significance the diary study found fatigue on waking to be a more sensitive measure of fatigue than a rating taken before bed.
- Onboard performance testing showed fatigue risk factors such as night work and days into tour to have an impact on alertness and choice reaction time
- Crew on a mini-bulker were found to be more fatigued than crew on other vessels in terms of both subjective and objective measures.

In this section results from aspects of the project that cover all three phases are presented first followed by phase specific issues.

5.1 Results from the survey

McNamara et al. (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted) report the results from respondents in the three different sectors investigated in the project. The main features of the study are outlined below.

5.1.1 The sample

The final total sample comprised 1856 seafarers. This sample is the combination of respondents from the three phases of the research, which corresponded to industry sectors.

5.1.1.1 Offshore support sector

In the initial phase of the survey, letters detailing the nature and purpose of the study and a copy of the questionnaire were sent to 1600 members of NUMAST selected as working in the offshore oil support sector between 2000 and 2001. A letter of support from a union official was also included with the mail shot, along with a freepost envelope in which to return the questionnaire. 439 completed questionnaires were received (a response rate of 27.4%). Questionnaires were also distributed to seafarers onboard offshore oil support vessels by visiting researchers: the total number of respondents from 6 vessels was 124, yielding a total sample of 563. In terms of vessel types, the sample was most highly represented by seafarers working on supply vessels (29.3%, n=164), support vessels (26.3%, n=147), standby vessels (13.8%, n=77), pipe layers (35, n=6.3%) and dive support vessels (6.8%, n=38).

5.1.1.2 Short sea and coastal sector

Three recruitment methods were used to access a representative sample of seafarers. 2740 questionnaires were sent to NUMAST members identified by a union representative as operating in the short sea and/or coastal sectors. Secondly, 1120 questionnaires were sent to employees of four shipping companies (2 ferry [n=760] and 2 tanker operators [n=360]). A total of 791 completed questionnaires were received using these two sampling methods (a combined response rate of 20.5%). Questionnaires were also distributed by researchers visiting short-sea vessels: a total of 145 questionnaires were completed by seafarers on 7 vessels. The total sample comprised 936 short

sea and coastal workers. In terms of vessel types the short-sea sample was primarily made up of seafarers working on passenger ferries (41.4%, n=383), freight ferries (20.3%, n=188), high-speed ferries (8.5%, n=79) and products tankers (14.4%, n=133).

5.1.1.3 Deep sea sector

The method of recruitment differed slightly for the deep sea sector: the initial mail shot comprised a letter from a union official detailing the nature and purpose of the survey sent to 3,179 potential participants. The final sample comprised 302 participants equating to a response rate of 11.2%. A key reason for achieving a lower response rate than previous phases was that deep sea workers are generally away for longer tours of duty which makes them less likely to receive and return questionnaires. A total of 18 completed questionnaires were received from members of the Transport and General Workers union (T&G) although a response rate cannot be calculated due to independent survey distribution. Finally, 36 completed questionnaires were received as a result of distribution among crew on 3 vessels visited in the third phase, producing a total deep sea sample of 356. In terms of vessel type the deep sea sample represented seafarers working on a broader range of ships including containers (19.0%, n=66), gas tankers (12.9%, n=45), products tankers (9.8%, n=34), cruise ships (9.8%, n=34), and other tankers not previously listed (17.2%, n=60).

The following analyses were carried out among the cross-phase sample (i.e. on the 1856 seafarers who completed the survey from the three industry sectors).

5.1.2 Risk factors for fatigue

Analyses showed consistent associations between fatigue and a number of variables: occupational and environmental factors were most highly associated with fatigue.

All these factors were included in multivariate models. Tour length, sleep quality, environmental factors, job demand and work stress were associated with all three fatigue measures. Switching from sea to port work and age were associated with both PFRS fatigue and fatigue at work. Variable working hours and job support were associated with fatigue at work and fatigue after work. Role, rank and smoking were associated with both PFRS fatigue and fatigue after work. Physical hazards, job security and flag were associated with PFRS fatigue and, port frequency was associated with fatigue at work. The associations are summarised in the Tables 1-3. For each variable, the reference category is the first category (and has an odds ratio (OR) of 1.00) Subsequent ORs show the odds for each category relative to this reference. For example, in Table 1 below those with high job stress levels were twice as likely as those with low job stress levels to also have high PFRS fatigue (OR=2.01), and those who were not officers were half as likely to also have high PFRS fatigue as officers (OR=0.49).

Table 1 PFRS fatigue and associated risk factors

		OR	CI	P
Tour length	Up to 7 days	1.00		<0.0001
	8 to 14 days	0.44	0.23-0.82	
	15 to 28 days	0.20	0.11-0.36	
	More	0.25	0.14-0.43	
Switching to port fatiguing	No	1.00		0.02
	Yes	1.50	1.07-2.10	
Age	Younger	1.00		0.02
	Older	0.69	0.50-0.94	
Sleep quality	Good	1.00		<0.0001
	Poor	1.91	1.39-2.62	
Physical hazards	Low	1.00		0.002
	High	1.72	1.23-2.42	
Environmental factors	Low	1.00		0.03
	High	1.42	1.03-1.96	
Security	High	1.00		<0.0001
	Low	1.80	1.32-2.46	
Demand	Low	1.00		<0.0001
	High	2.22	1.61-3.06	
Job stress	Low	1.00		0.005
	High	2.01	1.23-3.27	
Rank	Officer	1.00		0.04
	Other	0.49	0.25-0.97	
Department	Deck	1.00		0.04
	Engineering	0.95	0.67-1.34	
	Other	2.77	1.23-6.22	
Smoker	No	1.00		<0.0001
	Yes	2.31	1.62-3.29	
Flag	British	1.00		0.01
	Other	1.52	1.09-2.11	

Increased risk of general fatigue was associated with shorter tours of duty – that is, those on shorter tours of duty were consistently more likely to report high fatigue levels. This may reflect aspects of the work inextricably linked to tour length, such as vessel type, sector etc. It was also associated with: fatigue when switching to port; being younger; poor sleep quality; high exposure to physical hazards; high exposure to negative environmental conditions; low job security; high job demands; high levels of stress at work; having a rank other than officer; being a smoker; and serving on a ship with a non-British flag. The association between fatigue and younger workers (those under the sample median of 45 years) may reflect seafarers' adjustment with experience, some self-selection, or both these factors.

Table 2 Fatigue at work and associated risk factors

		OR	CI	P
Tour length	Up to 7 days	1.00		0.01
	8 to 14 days	0.79	0.43-1.44	
	15 to 28 days	0.62	0.35-1.11	
	More	0.42	0.23-0.76	
Hours per day	12 or less	1.00		0.01
	13 or more	2.19	1.19-4.05	
Shift hours on	4	1.00		0.008
	6	2.06	1.25-3.40	
	12	1.72	1.07-2.75	
	Other	1.26	0.75-2.11	
	Irregular/split	0.72	0.32-1.60	
Switching to port fatiguing	No	1.00		0.01
	Yes	1.56	1.11-2.19	
Port frequency	Low	1.00		0.06
	Medium	1.07	0.74-1.55	
	High	1.64	1.05-2.55	
Age	Younger	1.00		0.04
	Older	0.73	0.54-0.98	
Sleep quality	Good	1.00		0.001
	Poor	1.68	1.24-2.28	
Environmental factors	Low	1.00		0.001
	High	1.66	1.22-2.27	
Variable work hours	Low	1.00		0.03
	High	0.69	0.50-0.96	
Support	High	1.00		0.005
	Low	1.55	1.14-2.11	
Demand	Low	1.00		0.003
	High	1.62	1.18-2.23	
Job stress	Low	1.00		<0.0001
	High	2.78	1.73-4.46	

Increased risk of fatigue at work was associated with: shorter tours of duty; working more than 12 hours a day; working 6 or 12 hour shifts; fatigue when switching to port; high port frequency; being younger; poor sleep quality; high exposure to negative environmental factors; little variation in work hours; low social support; high job demands and high stress.

Increased risk of fatigue after work was associated with: shorter tours of duty; poor sleep quality; high exposure to negative environmental factors; variation in work hours; low social support; high job demands and high stress.

Table 3 Fatigue after work and associated risk factors

		OR	CI	P
Tour length	Up to 7 days	1.00		0.001
	8 to 14 days	0.60	0.33-1.09	
	15 to 28 days	0.35	0.20-0.60	
	More	0.56	0.33-0.96	
Sleep quality	Good	1.00		0.02
	Poor	1.47	1.08-2.00	
Environmental factors	Low	1.00		0.04
	High	1.40	1.02-1.91	
Variable work hours	Low	1.00		0.007
	High	1.57	1.13-2.17	
Support	High	1.00		0.003
	Low	1.60	1.17-2.17	
Demand	Low	1.00		<0.0001
	High	2.72	1.99-3.72	
Job stress	Low	1.00		<0.0001
	High	3.97	2.36-6.70	
Rank	Officer	1.00		0.03
	Other	0.44	0.22-0.90	
Department	Deck	1.00		0.003
	Engineering	1.48	1.08-2.03	
	Other	3.06	1.32-7.09	
Smoker	No	1.00		0.001
	Yes	1.78	1.26-2.52	

5.1.2.1 Combined effects analyses

The above tables show that multiple risk factors were associated with each fatigue outcome. The next stage was to combine the risk factors into an overall negative occupational factors score (NOF) in order to test the strength of a combined effects approach. A NOF score was calculated by first dichotomising each of the risk variables to produce high and low risk categories. Once each of the predictor variables was dichotomised an overall negative factors score was calculated for each participant by adding the number of 'high' risk factors together. The results are shown in Table 4 which indicates that all measures of fatigue increased cumulatively with the number of risk factors. Moreover, this relationship was not simply additive, but multiplicative.

Table 4 Combined effects of exposure to risk and fatigue

	OR	CI
PFRS		
0 to 3 factors	1.00	
4 to 5 factors	2.58	1.86-3.57
6 or more	8.99	6.47-12.50
At work		
0 to 3 factors	1.00	
4 to 5 factors	3.21	2.23-4.63
6 or more	8.85	6.10-12.83
After work		
0 to 3 factors	1.00	
4 to 5 factors	2.89	2.19-3.80
6 or more	9.07	6.69-12.28

5.1.2.2 Summary of risk factors for fatigue

The 18 variables found to be associated with at least one fatigue outcome in the multivariate analysis crossed all work-related dimensions with operational (e.g. port visit frequency), organisational (e.g. job support), environmental (e.g. physical hazards), health (e.g. smoking) and demographic (e.g. age) factors represented in the final models. There was found to be a cumulative association between the number of risk factors and self-reported fatigue levels, supporting the use of a combined effects approach.

5.1.3 Prevalence of fatigue

Fatigue may be present during work, after work and may even extend into the person's leave. Fatigue-related symptoms such as loss of concentration were widespread and these have implications for safety. Indeed, about 25% of respondents reported fatigue while on watch, many reported that they had fallen asleep while on watch, and 50% of the sample reported that fatigue leads to reduced collision awareness (Wellens, McNamara, Allen, & Smith, 2005).

One issue that was addressed was whether seafarers are more fatigued than onshore workers. Initial comparisons between those on oil industry support ships and a sample of onshore workers (described in detail in Smith, McNamara and Wellens, 2004) showed little evidence of the seafarers being more fatigued. However, comparisons involving ferry crews and those studied in Phase 3 showed that these seafarers were more fatigued than both the Phase 1 seafarers and the onshore controls. Indeed, while seafarers as a whole are not necessarily more fatigued than other occupations there are certainly some groups who have excessive levels of fatigue. This issue will be returned to in a later section comparing the crew of a mini-bulker with seafarers on other short sea vessels.

5.1.4 Consequences of fatigue

This section consists of three parts. The first considers the impact of fatigue on cognitive functioning and safety. This topic is also covered in the onboard testing section. The other two consider the short and long term consequences of fatigue. The second section looks at associations between risk factors for fatigue and both symptoms of fatigue and perceived risk to safety, while the third section looks at associations between fatigue and perceived well-being and health.

5.1.4.1 The impact of fatigue on perceptions of cognitive functioning and safety

The survey contained questions that measured cognitive failures (errors of attention, memory and action). It also assessed the extent to which seafarers perceived that their working hours presented a danger to themselves and the ship. Wadsworth et al. (Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted) examined the associations between perceived fatigue, risk factors for fatigue and cognitive failures. The results showed that those who reported high levels of fatigue were at a greater risk of making frequent cognitive failures. Frequent cognitive failures were also more likely to be reported by : those doing shorter tours of duty; those doing 6 or 12 hour shifts; those with poor sleep quality; those exposed to physical or environmental hazards; those with high job demands; those with high levels of stress at work; officers; and older workers (an association between older workers and more frequent cognitive failures is consistent with findings from general workers surveys (e.g. (Simpson, Wadsworth, Moss, & Smith, 2005)). These findings suggest that, as well as general fatigue risk factors, seafaring is subject to additional specific fatigue risk factors that are particularly linked to poorer cognitive function. These results are shown in Table 5.

Table 5 Association between cognitive failures, perceived fatigue and fatigue risk factors

		OR	CI
Fatigue	Low	1.00	
	High	3.66	2.61-5.11
Tour length	Up to 7 days on	1.00	
	8 to 14 days	0.69	0.35-1.32
	15 to 27 days	0.70	0.38-1.29
	28 or more days	0.46	0.25-0.85
Shift	4 hours on	1.00	
	6 hours on	2.53	1.46-4.37
	12 hours on	3.04	1.79-5.16
	Other	2.63	1.50-4.62
	Irregular or split	2.25	1.05-4.81
Switching to port work	Not fatiguing	1.00	
	Fatiguing	1.36	0.95-1.94
Sleep quality	Higher	1.00	
	Lower	1.43	1.03-1.98
Physical hazards	Lower	1.00	
	Higher	1.45	1.04-2.01
Environmental factors	Lower	1.00	
	Higher	1.68	1.21-2.33
Job demand	Lower	1.00	
	Higher	1.71	1.22-2.39
Work stress	Lower	1.00	
	Higher	1.67	0.99-2.80
Marital status	Married or cohabiting	1.00	
	Other	1.66	1.12-2.45
Education	Up to O / GCSE level	1.00	
	Higher	0.71	0.50-1.00
Age	Younger	1.00	
	Older	1.88	1.34-2.64
Rank	Officer	1.00	
	Other	0.24	0.13-0.44

McNamara et al (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted) examined the associations between risk factors for fatigue and the extent to which seafarers perceived that their working hours presented a danger to themselves and the ship. In total 870 (48%) respondents considered their working hours sometimes presented a danger to their personal safety, and 668 (37%) considered that their working hours sometimes presented a danger to the safe operations of their ship. Those who felt their working hours were a danger to themselves or the ship's operations had much higher levels of both perceived fatigue and perceived symptoms of fatigue (Table 6).

Table 6 Mean (se) perceived fatigue and symptoms of fatigue by perceived risk to safety from fatigue

	DANGER TO SELF		
	No	Yes	F, p
PFRS	23.44, 0.37	31.87, 0.49	191.64, <0.0001
Fatigue at work	3.36, 0.03	4.00, 0.03	279.43, <0.0001
Fatigue after work	2.22, 0.02	2.67, 0.02	310.50, <0.0001
Symptoms of fatigue	2.18, 0.03	2.86, 0.03	327.56, <0.0001
	DANGER TO SHIP OPERATIONS		
PFRS	24.78, 0.37	32.16, 0.55	131.37, <0.0001
Fatigue at work	3.44, 0.03	4.06, 0.03	232.21, <0.0001
Fatigue after work	2.29, 0.02	2.67, 0.02	192.07, <0.0001
Symptoms of fatigue	2.26, 0.02	2.91, 0.03	281.34, <0.0001

The perceptions of personal and operational risk from fatigue were strongly associated, with 613 seafarers reporting both (92% of those who reported a danger to the ship also felt hours were a danger to their personal safety; and 71% of those who reported a danger to themselves also felt hours were a danger to the ship). Only personal risk, therefore, was included as a dependent variable in subsequent analyses (Table 7)

Table 7 Perceived risk to self and associated risk factors

		OR	CI	P
Tour length	Up to 7 days	1.00		0.02
	8 to 14 days	0.71	0.40-1.28	
	15 to 28 days	0.46	0.26-0.82	
	More	0.73	0.41-1.32	
Hours per day	12 or less	1.00		0.003
	13 or more	2.68	1.39-5.18	
Switching to port fatiguing	No	1.00		<0.0001
	Yes	2.21	1.57-3.10	
Port frequency	Lowest	1.00		0.02
	Middle	1.06	0.73-1.54	
	Highest	1.78	1.13-2.80	
Sleep quality	Good	1.00		0.002
	Poor	1.62	1.19-2.21	
Variable working hours	Low	1.00		0.001
	High	1.70	1.23-2.35	
Support	High	1.00		<0.0001
	Low	1.77	1.29-2.44	
Security	High	1.00		0.02
	Low	1.46	1.05-1.99	
Job demand	Low	1.00		<0.0001
	High	2.19	1.60-2.99	
Work stress	Low	1.00		0.004
	High	2.01	1.24-3.26	

Again as with the perceived effects analyses described above, the perceived consequences of fatigue increased cumulatively with the number of risk factors, and this relationship was not simply additive but multiplicative (Table 8).

Table 8 Combined effects of exposure to risk and fatigue

	OR	CI
Symptoms of fatigue		
0 to 3 factors	1.00	
4 to 5 factors	2.82	1.92-4.15
6 or more	11.35	7.85-16.41
Danger to self		
0 to 3 factors	1.00	
4 to 5 factors	3.30	2.54-4.28
6 or more	13.09	8.57-19.99

5.1.4.2 Short term consequences of fatigue

McNamara et al (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted) examined the associations between risk factors for fatigue and the short term symptoms of fatigue (Table 9).

Table 9 Symptoms of fatigue at sea and associated risk factors

		OR	CI	P
Tour length	Up to 7 days	1.00		0.01
	8 to 14 days	0.57	0.30-1.07	
	15 to 28 days	0.51	0.28-0.90	
	More	0.88	0.51-1.52	
Switching to port fatiguing	No	1.00		<0.0001
	Yes	1.93	1.36-2.73	
Age	Younger	1.00		0.006
	Older	0.63	0.45-0.87	
Sleep quality	Good	1.00		0.02
	Poor	1.47	1.06-2.04	
Sleep disturbance	Low	1.00		0.04
	High	1.41	1.02-1.94	
Physical hazards	Low	1.00		0.02
	High	1.47	1.07-2.03	
Environmental factors	Low	1.00		0.001
	High	1.73	1.25-2.40	
Support	High	1.00		<0.0001
	Low	1.84	1.33-2.54	
Job demand	Low	1.00		<0.0001
	High	2.50	1.79-3.49	
Work stress	Low	1.00		0.002
	High	2.30	1.36-3.89	
Rank	Officer	1.00		0.01
	Other	0.49	0.28-0.86	
Flag	British	1.00		0.04
	Other	1.43	1.01-2.01	

Shorter tour length, sleep quality, job demand and work stress were all associated with both measures of short term fatigue consequences.

5.1.4.3 Long term consequences of fatigue: well-being and reported health

Wadsworth et al. (Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted) report results from analyses examining associations between risk factors for fatigue, perceived fatigue and reports of well-being and health. The results showed that greater psychological distress, poorer general health and more frequent GP visits were all associated with both fatigue risk factors (such as work stress and job demand) and fatigue (see Table 10). The association with fatigue was independent of work characteristics that were risk factors for fatigue. The impact of fatigue over that of the other associated risk factors was more than additive. Worsening work characteristics were associated with increased fatigue over time, and increases in fatigue were associated with deterioration in psychological and general health. This study, using self-report measures of perceived fatigue and health, suggested that fatigue was strongly linked to poorer physical and mental health among seafarers. The impact of fatigue in the industry may, therefore, be much greater and more widespread than watch-keeping and accident statistics imply. In addition, reported fatigue

could arguably be an important and measurable intermediary between fatigue risk factors and well being.

Table 10 Association between perceived poorer health and fatigue independent of fatigue risk factors

		OR	CI
Psychological distress (GHQ)			
Fatigue	Low	1.00	3.25-10.08
	High	5.73	
Environmental factors	Lower	1.00	0.97-2.34
	Higher	1.50	
Support	Higher	1.00	1.56-4.01
	Lower	2.50	
Work stress	Lower	1.00	1.94-5.11
	Higher	3.15	
Rank	Officer	1.00	0.04-0.69
	Other	0.17	
Department	Deck	1.00	1.01-2.49 0.68-10.87
	Engineering	1.59	
	Other	2.72	
Smoker	No	1.00	0.94-2.42
	Yes	1.51	
General health			
Fatigue	Low	1.00	2.15-3.82
	High	2.86	
Sleep quality	Higher	1.00	1.10-1.97
	Lower	1.47	
Work stress	Lower	1.00	0.99-2.28
	Higher	1.50	
Rank	Officer	1.00	0.29-0.75
	Other	0.47	
Smoker	No	1.00	1.14-2.16
	Yes	1.57	
GP visits			
Fatigue	Low	1.00	1.00-1.83
	High	1.35	
Job demand	Lower	1.00	0.96-1.76
	Higher	1.30	
Age	Younger	1.00	1.32-2.36
	Older	1.77	

One important question is whether the samples we have studied are representative of the industry. Smith et al. (Smith et al., 2003) found that the onboard samples studied were broadly representative of the participating companies, and those companies were also largely representative of the wider sampling frame. McNamara et al. (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted) continued this approach and found that the current sample should be considered representative of a 'good', if not 'best case scenario' in terms of seafarers who have extensive experience of

working at sea and relatively little experience of suffering from fatigue when compared with a multi-national sample. Given this conclusion it seems tenable that problems identified here are likely to be a concern on a greater scale elsewhere.

5.1.5 Phase specific issues

5.1.5.1 Phase 1

5.1.5.1.1 A comparison of seafarers, oil installation workers and an onshore sample

In this phase comparisons were made between the seafarers in the offshore oil support industry, those working on installations and an onshore comparison group (see (Smith, Lane, & Bloor, 2001; Smith et al., 2003) for details). The results showed that a significant proportion of oil installation workers feel that their working hours and shift patterns are detrimental to their health and personal safety, and that the effects of working offshore impinge considerably on leave time. Detailed analyses of the survey data suggested that rotating shift patterns, long work hours and poor sleep all have a negative impact on health and well-being, both physical and psychological. However, these issues were less of a problem amongst offshore workers than might be expected. Indeed, seafarers appeared considerably more robust than either installation workers or a comparison group of onshore workers. Furthermore, it would appear that the somewhat poorer health of installation personnel can be explained, in part at least, by poor adaptation to complex (i.e. rotating) shift systems. There was also the perception that things were considerably worse on installations than in the past whereas many of the seafarers were ex-fishermen and found their current jobs to be less demanding than being a fisherman. This suggests that perceptions of fatigue may reflect not only current working conditions but the contrast with past employment. Further studies of those starting a seafaring career are necessary to avoid the impact of previous working conditions. It would also be interesting to ascertain from future research whether the greater well-being observed amongst some groups of offshore personnel is a product of self-selection and regular health screening. This is a topic which can only be examined by a longitudinal health study following a cohort of seafarers and ex-seafarers over time.

5.1.5.1.2 Effects of specific risk factors: Disturbed sleep

Smith and McNamara (Smith & McNamara, 2002) examined reports of disturbed sleep in seafarers, oil installation workers and an onshore sample. Both seafarers and oil installation workers reported more sleep disturbance than the onshore sample and over 40% of the offshore workers reported noise disturbed sleep. Motion also produced sleep problems in over 40% of the seafarers. Lack of sleep was significantly related to perceptions of physical and mental fatigue amongst both seafarers and installation workers. Poor concentration was significantly related to sleep quantity amongst both groups of offshore workers. Of respondents who reported too little sleep, 70.5% of installation workers, 67.2% of seafarers and 46.9% of onshore workers felt

that their working patterns seriously compromise personal safety. A similar pattern of results was observed for operational safety. These results confirm the potential problems associated with disturbed sleep. However, individual factors rarely occur in isolation and this phase of the project included the first analysis of the combined effects of risk factors for fatigue.

5.1.5.1.3 Combined effects

McNamara and Smith (2002) examined the combined effects of risk factors for fatigue in both seafarers and installation workers. These results confirm that those exposed to a large number of potential risk factors are most likely to report fatigue and impaired health (Figures 2 and 3)

Figure 2 Combined effects of work hazards and scores on the PFRS Fatigue scale

(High scores=greater fatigue. Fatigue is plotted against reports of work hazards, with the first quartile representing the lowest number of hazards and the 4th quartile the highest number of hazards)

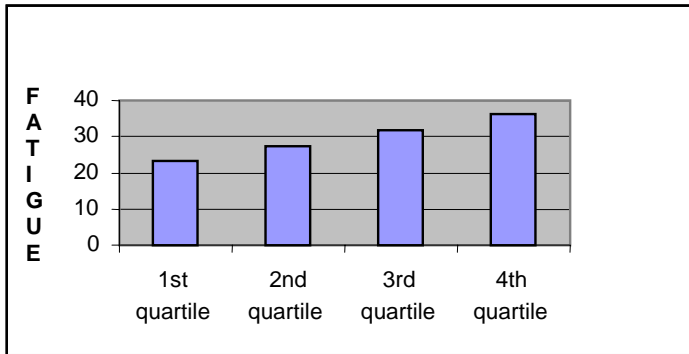
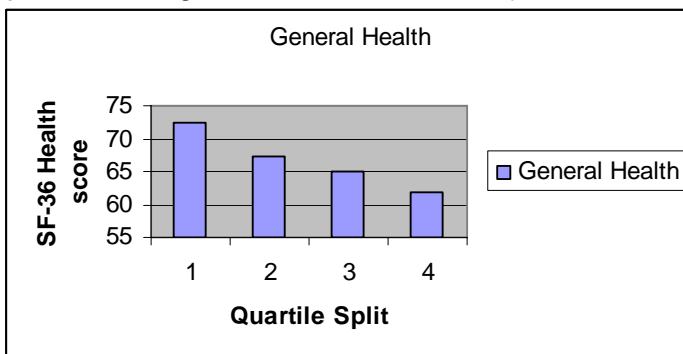


Figure 3 Combined work hazards and the General Health Score from the Short Form Health Questionnaire [SF-36]

(High scores=better health. Health is plotted against reports of work hazards, with the first quartile representing the lowest number of hazards and the 4th quartile the highest number of hazards)



5.1.5.2 Phase 2

Initial analyses compared the Phase 2 sample with the results from Phase 1 of the project. Many results were very similar (Table 11). The Phase 2 participants reported higher levels of fatigue and poorer health than the sample studied in the previous phase. Following this our analysis strategy was to try to identify factors associated with reported fatigue in the present phase. Ship type was found to be important, with those on ferries reporting higher levels of fatigue. This finding held up across ferry types and was not due to one specific type of ferry (e.g. the high speed ferries).

Table 11 A comparison of survey responses from Phases 1 and 2

	Phase 1	Phase 2
Working > 85 hours a week	49%	45.7%
Consider working hours to be a danger	43.5%	52.6%
No opportunity to have 6 hours uninterrupted sleep	43.5%	52.6%
Poor quality sleep	47.4%	52.8%
Split sleep	49.8%	56.4%
Involved in a fatigue related incident	11%	16%
No training in recognising fatigue or dealing with it	92.2%	91.7%
Performance impaired when on leave	46.4%	44.8%
Working hours increased over last 10 years	47.4%	59%
Desirable changes:		
Extra manning	57.6%	58.9%
More leave	24.7%	37.6%
Tougher laws	29.5%	36.9%
Less paperwork	39.5%	31.4%

Another issue considered in this phase was whether measures taken from the diaries were associated with the survey data. There was support for the view that the time period we examined in the diaries was representative of the “job in general” although some of the associations were modest.

The combined effects approach was used again in this phase and in addition the different risk factors were compared in order to get an indication of the magnitude of any benefit produced by reducing individual risks. The results showed that in order to reduce fatigue among seafarers it would be most beneficial to focus on controlling to optimum levels working hours which are perceived to present a danger to the individual/the ship, as well as job demands and stress, since these factors appear to have an impact across different types and manifestations of fatigue. It was apparent that subjective perceptions of risk factors predict fatigue better than objective indicators of working conditions. It is worth noting that the fatigue scales used here were based on subjective self reports. As such it is perhaps unsurprising that self-

reported job demands should predict self reported fatigue better than objective indicators.

Another issue examined was the association between fatigue and stimulant use (caffeine, nicotine). Despite issues of the direction of causality, it is apparent that, to some extent, caffeine and cigarette use are associated with symptoms of fatigue at sea. Seafarers are not therefore merely passive subjects when exposed to fatigue related factors, instead active steps are taken in order to combat the problem, even if only short term. This makes *relative* consumption of caffeine and cigarettes potentially usefully as an indicator of fatigue.

5.1.5.3 Phase 3

5.1.5.3.1 *Validating the survey fatigue scales*

In order to compare the measures used in the seafarers study with other standard fatigue measures, the PFRS fatigue, fatigue at work, and fatigue after work scales were compared with the Checklist of Individual Strength (CIS - (Beurskens et al., 2000), and the Swedish Occupational Fatigue Inventory (SOFI - (Ahsberg, Gamberale, & Gustafsson, 2000), within a general population sample. Table 12 shows that there were significant correlations between the Seafarer study measures and the relevant dimensions of the standard measures for 99 men carrying out onshore jobs.

Table 12 Correlations between the study fatigue measures and standard fatigue measures for a general population sample of working men

		PFRS FATIGUE	AT WORK	AFTER WORK
CIS	Subjective fatigue	0.80*	0.53*	0.55*
	Concentration	0.60*	0.39*	0.33***
SOFI	Sleepiness	0.60*	0.78*	0.35*
	Lack of energy	0.70*	0.46*	0.69*

* p<0.0001 **p=<0.05 ***p<0.001

5.1.5.3.2 *Changes in fatigue over time*

Volunteers who had participated in the survey were re-contacted to examine changes in fatigue over time. There was no evidence that fatigue or health had worsened over time. This may reflect no actual change, and perhaps an improvement. However, it may also be that other factors have also changed (such as job type, shift pattern etc), seafarers' coping strategies have improved (indeed, it may be that those for whom fatigue had worsened may even have left the industry), or that there is a ceiling effect.

5.1.5.3.3 *Collision awareness and fatigue*

A high proportion of the sample reported having been involved in a collision with another vessel (most of these incidents were between two moving vessels), or with another object (in most cases the harbour side). Nearly half

of the sample considered fatigue to be a key factor in reducing collision awareness.

5.1.5.3.4 Multi-tasking and fatigue

Multi-tasking analyses focused on those seafarers who reported normally standing watch. There were no fatigue or health differences overall between watch-keepers and other seafarers. Nevertheless, one in four watch-keepers (particularly those on longer watches) reported having fallen asleep on watch. Almost all watch-keepers were required to multi-task while on watch, and just under half of these found this to be problematic. This sub-group reported higher fatigue levels, and were more likely to have fallen asleep while on watch. A smaller but significant number (17%) were concerned about potential collisions and they too had higher fatigue levels and were more likely to have fallen asleep on watch. By far the most common suggested change for increasing effective and alert watch-keeping was to increase manning. This was followed by shortening watches and reducing paperwork. Multi-tasking while on watch was an almost universal experience. The analyses showed that for particular sub-groups of seafarers this was associated with greater fatigue, poorer performance, and concern about potentially disastrous consequences.

5.1.5.3.5 Comparing the fatigue of seafarers with other groups

In Phase 1 comparisons were made between seafarers and oil installation workers. In Phase 3 the seafarers were compared with an onshore sample and road haulage drivers.

5.1.5.3.5.1 Onshore workers

The onshore sample consisted of 99 working men. Their mean age was 40.0 (standard deviation 6.53) and all were married or living with a partner. They held a wide variety of jobs (e.g. train driver, baker, web designer, administrator etc) and worked an average 41.79 hours per week (standard deviation 9.44) (approximately eight hours per day). Comparing these respondents with seafarers showed that seafarers reported higher fatigue at work but had similar scores on the PFRS and after work measures (Table 13). Seafarers also worked more hours per week with 97% reporting 50 or more hours compared to 20% of the onshore sample ($p < 0.0001$).

Table 13 Comparison of fatigue levels between seafarers and working men in the general population study; higher scores=higher fatigue

	GENERAL POPULATION MEAN (SE)	SEAFARERS MEAN (SE)	F	P
PFRS fatigue	28.11 (1.37)	27.30 (0.33)	0.33	0.57
At work	3.18 (0.09)	3.67 (0.02)	29.67	<0.0001
After work	2.41 (0.06)	2.44 (0.01)	0.25	0.62

5.1.5.3.5.2 Road haulage drivers

In total 80 road haulage questionnaires were completed. All but 2 of the respondents were male, their mean age was 47.38 years (sd=10.32, min=28, max=71) and most were married or cohabiting (90%, n=72). Just over half (56%, n=41) mainly drove C+E category vehicles (large goods vehicles with trailers: vehicles over 3500kg with a trailer over 750kg), and a further 30% (22) mainly drove C1+E category vehicles (medium sized vehicles with trailers: vehicles between 3500kg and 7500kg with a trailer over 750kg – combined weight not more than 12000kg). The mean length of time they had worked in road haulage was 19.20 year (sd=11.60, min=1, max=45). Road haulage drivers and seafarers were compared on three measures of fatigue: PFRS fatigue, fatigue at work and fatigue after work. Their levels of fatigue at and after work were similar, but road haulage drivers had higher mean PFRS fatigue scores (Table 14).

Table 14 Mean (se) fatigue levels among seafarers and drivers

	SEAFARERS	DRIVERS	F, P
PFRS fatigue	27.53 (0.32)	34.10 (1.77)	17.70, <0.0001
Fatigue at work	3.67 (0.02)	3.75 (0.11)	0.74, 0.39
Fatigue after work	2.43 (0.01)	2.45 (0.07)	0.04, 0.84

Comparing seafarers and road haulage drivers on risk factors for fatigue showed no differences in terms of support at work. However, a greater proportion of seafarers had poor job security (53% compared to 38%, p=0.03), high job demand (41% compared to 24%, p=0.01), physical hazards (52% compared to 25%, p<0.0001), and worked 60 hours per week or more (89% compared to 16%, p<0.001). Among the seafarers number of port turnarounds was related to fatigue and a similar trend was seen for the drivers, where those who made the most deliveries were more fatigued. This suggests that lorry drivers and seafarers show parallel trends in terms of fatigue and that fatigue can be observed in contexts which are to some extent operationally comparable.

5.1.5.3.6 *Fatigue in fishermen*

One of the biggest challenges in conducting a survey of fishermen was obtaining a sample. Unlike the main seafaring population, fishermen in the UK rarely work for large companies and have low union representation which makes the task of surveying considerably more difficult. Without using large umbrella organisations to distribute questionnaires new techniques of data collection had to be found. Following a large research project conducted by Matheson in Scotland it was decided that as far as possible the geographical focus of the research would be upon other parts of the UK to avoid Scottish fishermen being over-surveyed.

One method of data collection which was explored was that of canvassing fishermen in ports. By approaching fishermen directly it was hoped that

relatively high response rates could be achieved. This technique, however, was never adopted on the basis that even busier fishing ports now have very low numbers of fishermen actually passing through on a daily basis.

The Sea Fish Industry Authority (SEAFISH) is a non-governmental public body funded through a levy on seafood to promote and support the UK seafood industry and its sustainable future. To ensure that industry has access to the training it needs, Seafish supports a network of industry-led Group Training Associations (GTAs) which can organise training throughout the UK wherever and whenever it is needed. Through GTA contacts survey questionnaires were distributed amongst fishermen attending safety courses in England and Wales with returns sent back to the research centre directly via free-post envelopes. In the first round of data collection an incentive was provided by means of a £2 donation to the RNLI (Royal National Lifeboat Institution) for each completed questionnaire with this increased to £4 in the second round with an option to donate the money to the RNMDSF (Royal National Mission to Deep Sea Fishermen). Approximately half of the returned surveys came back as a result of the GTA sampling approach.

'Fishing News' describes itself as 'the biggest selling weekly newspaper for the industry in the UK and Ireland' and was therefore chosen as the ideal vehicle to advertise the fatigue study and potentially recruit more volunteers. In the edition dated 29th April 2005 an advertisement appeared on the front cover of fishing news asking fishermen to get in contact and request a questionnaire. An editorial piece written by one of the research team was also included to draw attention to the whole fatigue issue and encourage interest. In addition to contacting the research team to request a questionnaire, readers of Fishing News were also given the opportunity to complete the questionnaire online (www.fishingfatigue.com) which was seen as a potential means of further increasing the number of respondents. An incentive to take part was provided by means of a £5 donation to the RNMDSF for each completed questionnaire. Approximately half of the returned surveys came back as a result of the newspaper advertisement with over half of these respondents completing the survey online.

When designing the fishing questionnaire a key priority was to keep it as short as possible after discussion with industry representatives who explained that collecting data from fishermen might prove challenging. The questionnaire was based on a stripped back version of the main seafaring survey with items left unchanged wherever possible to enable comparisons to be made. The fishing survey included questions addressing working hours, tour length, rest periods and travel as well as the same standardised scales measuring health and fatigue included in the main survey. Questions specific to fishing were also included which were refined through conducting a shortened questionnaire pilot, again with GTA attendees.

In total 81 fishermen completed the fishing fatigue questionnaire. Almost all were male (1 was female, and 2 did not respond). The mean age of the sample was 44.0 years old (sd =12.65, range 17-71) with the majority either married or living with a partner (81.1%, n=64). In terms of nationality 64.5% (n=49) described themselves as British, 22.4% (n=17) described themselves as Welsh and the remainder described themselves as either Scottish, English, Northern Irish or other (13.1%, n=10). Most worked on vessels with 2 (n=30, 37%) or 3 (n=16, 20%) crew. The mean number of crew was 3.04 (sd=1.74,

range 1-11). Twenty-eight (35%) worked on shellfish fishing vessels, 17 (21%) on trawlers less than 24m, and 10 (12%) on dual purpose vessels less than 24m. A further 15 (19%) worked on other vessels including: a 17ft Dory (n=3), a potter, a crabber, a scallop dredger and a sheltie (all n=1 each). Thirty-five (43%) worked as skipper, and a further 21 (26%) as “everything”. Mean time on their current vessel was 6.69 years (sd=6.26, range 0-25), and mean number of years at sea was 19.74 (sd=11.71, range 1-49), while time working as a fisherman was 19.81 (sd=11.98, range 0-49). Nine (11%) also had other jobs (a wide variety from farmer to lorry driver to nightclub doorman). The mean length of typical longest continuous duty for the sample was 14 hours (sd=9.32, range 2-48). Nearly a third (n=25, 31%) had considered their working hours a danger to their own health and safety, and a quarter (n=20, 26%) had considered their working hours a danger to safe operations onboard. Most of the fishermen (n=61, 81%) felt that the effects of fatigue increased the longer they were at sea, and 60% (n=48) said their personal safety had been at risk because of fatigue at work. Thirteen (16%) had been involved in a fatigue related accident, 36 (44%) said they had worked to the point of collapse, 33 (41%) had fallen asleep at the wheel, and 34 (43%) had been so tired they had slept on deck or in the gangway. Most (49, 60%) felt that season had a very important impact on the effort required to complete their normal duties.

5.1.5.3.6.1 Comparing fishermen with the main survey seafarers sample

Fishermen were compared with seafarers from other phases of the study. They were found to have higher levels of somatic symptoms and more limited physical functioning than seafarers but were also found to have lower levels of fatigue at and after work (see Table 15). Further differences were found when a distinction was made in terms of fatigue experienced in different weather conditions (see Table 15 again), however such a distinction was only included in the fishing questionnaire making comparisons on this dimension of limited value.

Table 15 Mean (se) fatigue and health scores for fishermen and other seafarers

	OTHER SEAFARERS	FISHERMEN	F	P
PFRS fatigue¹	27.52, 0.32	28.64, 1.75	0.50	0.48
PFRS somatic symptoms¹	26.66, 0.28	30.66, 1.73	8.47	0.004
Fatigue at work good weather*¹	3.67, 0.02	3.07, 0.16	25.60	<0.0001
Fatigue after work good weather*¹	2.43, 0.01	2.02, 0.09	27.63	<0.0001
Fatigue at work rough weather*¹	3.67, 0.02	2.68, 0.16	70.03	<0.0001
Fatigue after work rough weather*¹	2.43, 0.01	2.49, 0.10	11.05	0.001
Fatigue at work average¹	3.67, 0.02	2.88, 0.14	43.73	<0.0001
Fatigue after work average¹	2.43, 0.01	2.36, 0.09	0.91	0.34
Symptoms of fatigue at sea¹	2.68, 0.02	2.27, 0.11	17.71	<0.0001
SF36 physical functioning²	90.46, 0.31	84.48, 2.51	14.31	<0.0001

*Only fishermen were asked to distinguish between good and rough weather

¹Higher score = worse

²Higher score = better

When the comparisons were repeated using only those fishermen who normally slept onboard, the only significant differences were for fatigue after work in good and rough weather: fishermen had lower fatigue after work in good weather and higher fatigue after work in rough weather. Overall, the data suggest that fishermen who sleep onboard are no more fatigued or unwell than other seafarers, though there was some suggestion of higher fatigue following work in rough weather. These findings should, however, be viewed with extreme caution as the small number of responses, almost all from smaller fishing vessels, cannot be seen as representative of the approximately 12,500 fishermen in the UK fleet.

The next section summarises results obtained from the diary studies.

5.2 Results from the diary studies

Wadsworth et al. (Wadsworth, Allen, Wellens, McNamara, & Smith, 2006) report results from a diary study carried out using participants from all three phases of the project. Diaries were completed at sea and on leave. The “at sea” log books were completed during a tour of duty and the “on leave” log books during the period of leave immediately afterwards. Participants completed a log book page each time they got out of, or into, bed around their main sleep period. This was defined as the single sleep period when a participant considered they took the majority of their sleep each day. If a participant took their sleep in multiple sessions instructions were given to only complete the log book around the single main sleep period. On waking, data were collected about the time of day, sleep length, sleep quality, and fatigue. On going to bed data were collected about the time of day and fatigue. The “at sea” log books also collected data about ship operations since their last main sleep period and time spent working. Those on shorter tours and/leaves (up to 28 days) collected data throughout their tour or leave period. However, for pragmatic reasons, those on longer tours or leaves were asked to collect data for 35 days. These days were to include the first and last weeks, and three other weeks from the middle of tour or leave. The two main outcome measures were the fatigue ratings made on waking and on going to bed. Participants rated how tired they were on a visual analogue scale. They marked with a cross the place on a 10cm line (with “not at all tired” and “Extremely tired” at each end) which best corresponded to how they felt at that moment. In addition, participants completed five questions about sleep quality. They rated how easy it was to fall asleep, how easy it was to get up, whether the sleep period was sufficient, how deep their sleep was, and how interrupted their sleep was on five-point scales. These were summed to give an overall measure of sleep quality, with a minimum score of five and a maximum of 25, with a higher score indicating poorer quality sleep.

203 participants completed tour log books: 77 (38%) from the offshore support sector, 94 (46%) from the short sea and coastal sector, and 32 (16%) from the deep sea sector. These described a mean of 28 days at sea (sd=15, range 7-96). Respondents worked 12 hours per day on average (sd=2, range=8-24), and 80 hours per week (sd=15, range=38-168). Almost all the participants were officers (190, 97%). In addition, 197 (57%) seafarers returned leave log books. Of these, 182 (92%) also returned tour log books: 67 (37%) from the offshore support sector; 86 (47%) from the short sea and coastal sector; and 29 (16%) from the deep sea sector.

The results showed that fatigue on waking increased between the start and end of tour, but fatigue on retiring did not. Between the start and end of leave, though, both fatigue on waking and fatigue on retiring decreased. This suggests that fatigue on retiring may be a more stable measure, reflecting acute fatigue after work. Fatigue on waking, however, may be a more sensitive measure of emerging cumulative fatigue, which could be related to occupational performance, accident risk and perhaps longer term well being. The results showed that seafarers report being at their most tired on waking by the end of the first week at sea, and that they remain at this level for the rest of their tour of duty. Increasing fatigue on waking also suggests that the

rest and sleep respondents were getting was not providing sufficient restoration to allow full recovery from fatigue at work.

The pattern of increasing fatigue during the first week of tour was apparent in particular among those on shorter tours (i.e. tours of less than 19 days). It has been suggested previously that fatigue is likely to be less of a problem in long-haul and more of a problem in near-sea shipping (Bloor, Thomas, & Lane, 2000). The analyses of fatigue on leave suggested that fatigue at the start of leave was similar to fatigue at the end of the first week of a tour of duty. They also showed that fatigue decreased during the first week of leave, and remained constant thereafter. This suggests that tour fatigue levels impact directly on leave as they continue into the start of leave. Seafarers do not report consistently steady, lowered fatigue levels until the second week of leave, suggesting that recovery from tour may take about a week.

Fatigue levels were also greater among those who worked at night during certain periods of their first week at sea. In this study, working at night was associated with shorter sleep length and poorer sleep quality. Data from these participants showed their average sleep length was 7 hours in both the first and second weeks of time on leave, compared to 6 hours for the first week on tour. This suggests seafarers are to some extent working when sleep deprived, a situation exacerbated by working nights. Sleep quality was also associated with mean fatigue on waking and on retiring during the first week of leave. This suggests that sleep quality plays an important part in recovery. This is consistent with recent work among fishing vessel crew which suggested that sleep on board was less restorative than sleep at home, as sleepiness ratings (used to measure sleep quality) decreased less across onboard sleep periods than at-home sleep periods (Gander, Van den Berg, & Signal, 2005). Gander et al also report that high sleepiness ratings after sleep were less common at home than at sea (35% compared to 82%) (Gander, Van den Berg, & Signal, 2005).

The results also suggested that more frequent port calls were associated with greater fatigue among those on shorter tours, and with lower fatigue among those on longer tours. This seems to reflect ship type, and to make intuitive sense, as seafarers on shorter tours were mainly working on ferries, and those on longer tours on supply, support and container or tanker vessels. The possibility of numerous port calls contributing to fatigue in near-sea shipping has been suggested elsewhere (Bloor, Thomas, & Lane, 2000).

5.2.1 Phase 1 Diary Studies

Three diary studies were carried out in the first phase of the project. The first diary study compared 58 onshore day workers and 42 offshore workers (i.e. installation workers and seafarers). The results showed that the two groups differed significantly on a number of sleep variables. Offshore workers slept for a shorter time, woke up more often during the night, had greater difficulty falling asleep, and were less likely to consider that they had had a deep sleep or enough sleep. Although these differences were statistically significant the magnitude of the effects was small.

A second study compared 31 installation workers and 29 seafarers. 42 were day workers and 18 night workers. 25 were in the first week of their tour of duty and 35 were in either their second or third week offshore. The results

showed that installation workers felt less alert at the start of the day. Those working nights reported lower alertness at the end of the working day even though they perceived their job to be less physically demanding. Day workers starting their tour of duty awoke more frequently than those in their second or third week of the tour. The reverse was true for night workers. Sleep duration was reduced for the first sleep offshore, especially for installation workers doing nightshifts. The alertness levels at the end of the first day were lower for the seafarers than installation workers, with the reverse pattern being present on days 6 and 7. Physical effort was perceived by the day workers to decrease over the week whereas night workers perceived it to increase.

In the final study 43 volunteers completed weekly diaries while they were on leave. 22 were installation workers and 21 seafarers. 34 had worked day shifts before leave and 9 had worked nights. Of these 43 participants 22 had just started their leave and 21 were on their second week of leave. The results showed clear evidence that sleep duration and alertness were abnormal at the start of leave.

5.2.2 Phase 2 Diary Study

Data were collected from 177 participants from seven ships in the short sea shipping industry. These ships included 3 small oil support tankers, 2 passenger ferries, a freight ferry, and a fast ferry. Results from this study are reported in detail in Burke, Allen and Ellis (Burke, Ellis, & Allen, 2003) and the main points can be summarised as follows.

The diaries provided evidence that the cumulative effect of working, both across days and weeks, may influence levels of fatigue and performance. Across the working week, perceived job stress was found to increase which may indicate that over longer periods, seafaring work has a detrimental effect on individual well being. There was also some evidence from the daily questionnaires that seafarers' sleep improves as a function of time into tour. Also, generally habituation to noise levels onboard was observed as a function of days into tour. The diary data showed that any cumulative effects over the diary period varied as a function of weeks into tour, with some evidence of habituation, and some evidence of cumulative negative effects of time at sea (e.g. fewer effects of noise were observed further into tour, whereas the subjective impact of motion increased). The extension of the combined effects approach to the logbook data supports the cumulative negative effects hypothesis, with high levels of exposure to potentially negative work characteristics being associated with greater perceived fatigue. A relatively large number of significant correlations were found between time-specific logbook measures and more general measures employed in the survey. Whilst to a certain extent this may reflect the fact that the survey questionnaire was generally completed in the same week as the logbooks, the correlations nevertheless support the generalisation of results beyond the window of time examined in the onboard investigation.

Overall, the diary studies have shown that this method of data collection can provide important information about seafarers' fatigue over the course of their tour of duty and on leave. The next section considers objective measures taken onboard.

5.3 Performance and alertness onboard

5.3.1 Effects of risk factors for fatigue on mood and performance

The main issue addressed in the first phase of the project was whether risk factors for fatigue influenced objective measures of performance and subjective ratings of alertness taken at the start and end of the working day. Smith (Smith, 2003) reports data showing that nightwork and days into tour influence these outcomes. Nightwork was associated with lower alertness and slower reaction times after work (Table 16).

Table 16 Effects of shift on alertness and reaction time (Scores are means, s.d.s in parentheses)

	DAY SHIFT (12 HOURS) (N = 49)	NIGHT SHIFT (12 HOURS) (N = 22)
Alertness : (high scores = greater alertness)		
Before work	248 (70)	252 (60)
After work	257 (61)	219 (60)
Choice reaction time: (msecs)		
Before work	487 (75)	487 (73)
After work	463 (68)	492 (93)

Days into tour interacted with nightwork and the results showed that those doing nightwork at the start of a tour are most likely to have impaired performance, especially at the end of the shift (Table 17).

Table 17 Effects of days into tour in night workers doing 12 hour shifts (Scores are the means, s.d.s in parentheses)

	LESS THAN 5 DAYS INTO TOUR (MEAN LENGTH = 3 DAYS)	MORE THAN 5 DAYS (MEAN LENGTH = 18 DAYS)
Choice reaction time: (msecs)		
Before work	471 (75)	492 (78)
After work	494 (97)	478 (99)
Percentage of errors:		
Before work	5.6 (3.3)	2.5 (2.6)
After work	7.2 (5.9)	2.7 (3.0)

Wellens et al. (Wellens, McNamara, Allen, & Smith, 2005) examined whether there were any cognitive effects associated with working in loud noise at night that were different to working in loud noise during the day, low noise at night or low noise during the day. The participants were 62 male workers from 3 different vessels. Their mean age was 40.3 years. Individuals were from a range of different jobs onboard the vessels. There were two between-subjects factors (day/night shift and noise exposure) and one within-subjects factor (test session). Workers were asked to complete a battery of computer tests both before (Pre-shift) and after (Post-shift) their shift on one day. Four tests

were presented using laptop computers. These tests were visual analogue mood scales, a simple variable fore-period reaction time, and categoric search and focused attention choice reaction time tasks. The mood scales were presented at the beginning and end of the testing session. Occupational noise exposure (L_{eq}) was measured over a two-day period using a dosimeter. Workers were categorised into day/night workers by their shift pattern. Regression analyses distinguishing noise exposure, day/night shift and their interaction were performed on the data from each test session and the change score between the start and end of the shift. Noise exposure was associated with greater alertness but also with slower reaction times. Those working night shifts showed a large drop in alertness over the course of work and became slower at tasks requiring more difficult responses. There were also a limited number of interactions between noise and shift, such as more lapses of attention (very long response times) in the noise/nightwork condition. In the second phase of the project, Ellis, Allen and Burke (Ellis, Allen, & Burke, 2003) investigated effects of noise and motion on performance and alertness. Both factors were shown to have significant effects but, as in the case of nightwork, effects were modified by tour length suggesting that habituation sometimes occurs.

5.3.2 Perceived fatigue, symptoms of fatigue and performance

In Phase 3 analyses were conducted comparing the onboard performance of crew from a ship type known to induce fatigue (a mini-bulker) and crew on other ships where fatigue was thought to be less of a problem (tankers, a bulker and a container ship). Subjective ratings of fatigue and symptoms of fatigue confirmed that the crew of the mini-bulker reported significantly higher levels of fatigue and symptoms of fatigue than those on the other ships.

Table 18 Perceived fatigue and symptoms of fatigue reported by the mini-bulker crew and the crews of the other ships

(Scores are the means, s.d.s in parentheses. High scores = greater fatigue)

	MINI-BULKER	OTHER SHIPS
PFRS Fatigue	44.2 (5.6)	24.5 (10.8)
Symptoms of fatigue	3.96 (0.87)	2.63 (0.68)

The performance data revealed that the mini-bulker crew were more impaired than those on the other ships and that the magnitude of this became greater as the tour progressed.

Table 19 Performance scores for the mini-bulker crew and the crews of the other ships

(Scores are the means; s.d.s in parentheses. High scores = poor performance)

	MINI-BULKER				OTHER SHIPS			
	Day 1		Day 7		Day 1		Day 7	
	Before Work	After Work	Before Work	After Work	Before Work	After Work	Before Work	After Work
Simple RT (msec)	385 (70)	361 (54)	426 (51)	411 (55)	336 (61)	331 (98)	339 (132)	335 (114)
Lapses of attention (categoric search task)	18.7 (6.7)	12.3 (7.4)	20.2 (6.5)	14.3 (5.3)	5.5 (22.1)	4.6 (15.3)	3.9 (22.6)	2.7 (15.9)

This study confirms that subjective ratings of fatigue are associated with objective impairments of performance efficiency.

5.3.3 Objective measurement of sleep

In Phase 1 of the project actimeters were used to record one night's sleep in both onshore and offshore groups. Table 20 shows that the duration of sleep offshore was slightly shorter for the seafarers. Other aspects of sleep showed no differences between the groups. This suggests that global statements about the sleep of seafarers may be inappropriate – one needs to make a distinction between sleep duration and sleep quality, and also consider job characteristics such as the nature of the shift worked.

Table 20 Comparison of the sleep of offshore and onshore samples

(Scores are the means, s.d.s in parentheses)

	ONSHORE (N = 94)	OFFSHORE (N = 90)
Duration (hours)	7.14 (1.3)	6.50 (1.3)
% Actual sleep	91.1 (5.3)	90.3 (3.63)
% Immobile	90.4 (5.57)	91.0 (3.29)
% Sleep efficiency	89.3 (6.77)	88.6 (4.63)

Data collected in Phase 2 were compared with the Phase 1 sleep data. The sample studied in Phase 2 had shorter sleep periods but were asleep for a larger percentage of time than those in Phase 1. This largely reflects the different work schedules in the two phases and most aspects of the working hours profile (shift length, timing, split versus single shift etc) had an influence on some aspect of sleep. Again, this emphasises the importance of considering combinations of work characteristics rather than focusing on individual variables.

5.3.4 Cortisol

Chronic fatigue is often associated with reduced cortisol levels and less diurnal variation in cortisol. Table 21 shows the cortisol levels from Phase 1 and Phase 2 participants and a sample of onshore controls.

Table 21 Cortisol levels (nmol) in saliva samples of Phase 1 and Phase 2 participants and onshore controls

	PHASE 1 (N=29)	PHASE 2 (N=46)	ONSHORE (N=26)
Before work, day 1	7.73	4.24	9.36
After work, day 1	5.59	3.76	4.41
Before work, day 7	7.63	5.11	9.30
After work, day 7	5.57	3.53	3.67

The above results show that the seafarers had lower cortisol levels than the onshore controls ($p < 0.05$) and showed less diurnal variation in their cortisol levels ($p < 0.0005$). The Phase 2 participants had lower cortisol levels than the Phase 1 participants ($p < 0.0005$) which is consistent with the higher fatigue scores in Phase 2.

Overall, these results confirm that seafarers have a neuroendocrine profile that is consistent with high levels of chronic fatigue. Unfortunately, cortisol levels are influenced by many other factors and many volunteers have to be excluded (e.g. smokers; those taking medication). This means that salivary cortisol is unlikely to be a good fatigue test and it is better to view the present findings as further converging evidence for fatigue at sea rather than definitive proof.

The next section considers prevention and management of seafarers' fatigue.

6. PREVENTION AND MANAGEMENT OF FATIGUE

Main messages

- The impact and effectiveness of ILO 180 and the EU working time directive appear to be undermined by widespread under recording of working hours
- Evidence suggests large numbers of seafarers are working hours in excess of those allowed by current legislation
- Evidence suggests under recording of working hours is associated with higher levels of fatigue
- Fatigue guidelines produced by IMO put excessive emphasis on the responsibility of individual crew members to manage fatigue without acknowledging the critical role of corporate and legislative bodies.
- Fatigue can only be addressed if all levels of the seafaring industry are co-operatively involved and accountable.

Walters (Walters, 2005) has argued that a large proportion of the toll of work-related death, injury and ill-health amongst seafarers arises from failure to manage health and safety effectively. This failure is exacerbated by changes that have taken place in the structure and organisation of the industry internationally over the last quarter of a century that have both increased risk in terms of health and safety and made prevention of harm to workers more difficult to regulate and manage. In such a climate it is interesting to note that fatigue has now drawn the attention of insurance underwriters in other industrial sectors with inclusion as part of some general risk assessments (Bridges, Johansson, & Pearson, 2005). When aiming to address seafarers' fatigue such an insurance model would appear to hold certain promise, using an economic incentive to address an economically evolved problem (See also Bowring, 2004).

Given the diversity of activities undertaken in the maritime sector, and the different profiles of fatigue risk factors in different work groups, it is clear that a range of strategies will be needed to prevent or manage fatigue. Input from management and workforce representatives in each sector will be vital for the development of effective, practical fatigue prevention/management strategies. The ITF survey, and our own results, have shown that there are a number of suggestions to reduce fatigue. The need for increased crewing levels was strongly supported. Better working environments were also called for. Changes in working hours, both in terms of the length of the tour of duty, and daily opportunities for rest and recovery were also advocated. There was also strong support for tougher laws and better enforcement of the existing regulations. In addition, the results supported the need for further regulatory measures to promote a cultural change among ship owners and operators to ensure that short-term commercial considerations do not lead to fatigue that will influence occupational health and safety. The next section considers attempts to regulate working hours at sea. The International Maritime Organisation's (IMO) Standards of Training, Certification and Watchkeeping Convention (STCW) 78 sets minimum rest standards for watchkeeping personnel, but the following section focuses on ILO 180 and the EC working time legislation since this is what applies to EU flag ships and to non-EU flag ships in EU ports.

6.1 ILO 180

Convention 180 of the International Labour Organisation requires that States fix maximum limits for hours of work or minimum rest periods on ships flying their flags. In addition:

- Schedules of service at sea and in port (including maximum hours of work or minimum periods of rest per day and per week) are to be posted on board where all seafarers may see them.
- Records of hours of work or rest periods are to be maintained and must be examined by the flag state.
- If the records or other evidence indicate infringement of provisions governing hours of work, the competent authority is to require that measures are taken, including if necessary the revision of manning of the ship, so as to avoid future infringement.

Most European countries regulate on the basis of minimum hours of rest rather than maximum hours of work.

A survey by Allen, Wadsworth and Smith (Allen, Wadsworth, & Smith, 2006) found, however, that 40% of a sample of predominately British officers reported at least occasionally under-recording their working hours in order to comply with legislation. Whilst such a result is undoubtedly worrying, the more alarming result reported by Allen et al. is that those seafarers who reported at least occasionally under-recording their working hours were found to be significantly more fatigued and less healthy than their non-under recording counterparts (see section 6.3 below).

6.2 Evaluation of the European Working Time Directive

McNamara et al. (2005) report results from a survey that evaluated the impact of the EU working time directive and the results showed that a minority of seafarers within their sample reported working daily and weekly hours in excess of those set out in the working time directive (WTD). Minimum rest of 10 hours per day and 77 hours per week allow maximum working hours of 14 and 91 respectively. These levels fell within hour band response options, making it impossible to identify precise numbers reporting working over these levels. Nevertheless, 2.2% of the total sample worked 16 or more hours per day and 2.4% worked in excess of 100 hours per week. When asked about rest periods, almost a third of the sample (30.8%) did not regularly have the opportunity to gain 10 hours rest in every 24, and approximately ten percent (11.9%) did not regularly gain at least 6 hours unbroken rest within a 24-hour period. It seems therefore that nearly a third of all reported working hours violate the requirements regarding hours of rest set out in the WTD (clause 5, 1b). It is worth noting that this percentage was much greater than those reporting working hours in excess of maximum levels. These questions about rest periods were included to be identical to measures used in the ITF survey (International Transport Federation (ITF), 1998), so “rest” was not defined, and may not necessarily have been interpreted as time other than time spent working on account of the ship rather than resting. It may also be, however, that respondents felt it was easier to report violations in terms of hours of rest rather than more explicitly in terms of hours worked. Furthermore, 27.6% of

the sample reported typically working 15 or more hours continuously, which contravenes the directive laid out in clause 5, 1a. A significant proportion of respondents (21.5%) also reported spending 4 or more hours per day on additional duties. The majority of respondents (61.5%) indicated that working hours had actually increased within the last 5 to 10 years. Seafarers were also asked more specifically whether recent amendments to working time regulation had altered working practice and 77% reported that their working hours had stayed the same and 16% that their hours had actually increased. The WTD also states that records of hours of work and rest must be maintained in order to monitor compliance with the provisions as detailed in clause 5. However, a significant proportion of respondents felt that their actual working hours were at least occasionally under-reported in order to comply with working time regulations: 11.9% reported that their working hours were always or frequently mis-recorded, while a further 28.3% felt this to be the case at least occasionally. A significant proportion (15%) of the current sample denied any knowledge of international regulations in place to control their working hours, and 7.3% claimed to have no knowledge of national regulations. Seafarers operating in the deep-sea sector seem to be at most risk of working excessively long hours (in violation of working time regulations). The percentage of respondents spending 4 or more hours per day on additional duties was approximately twice that of the offshore and short-sea sectors (28.2% compared with 13.7% and 14.5% respectively). Deep sea respondents were also more likely to report their working hours as a danger to either personal or operational safety.

These results show that excessive working hours and inadequate periods of rest are still problematic onboard a range of vessels. Furthermore, hours are likely to be under-recorded, either by management, or by individual seafarers wary of jeopardising their current or future employment by bringing their company under legislative scrutiny. Therefore, auditing of ship records is unlikely to be a sufficient method of ensuring that regulations are adhered to. Better enforcement of existing regulation is needed if excessive working hours and the associated problems of fatigue are to be reduced. A study by the Marine Accident Investigation Branch (MAIB) on bridge watchkeeping came to the conclusion that:

'...the records of hours of rest on board many vessels, which almost invariably show compliance with the regulations, are not completed accurately' (Marine Accident Investigation Branch (MAIB), 2004, p.13)

The present results confirm this view. One of the most alarming facts about the prevalence of under-recorded working hours in the current survey was that the sample in question represents what could arguably be described as the "better end" of the industry. From the sample of 558 seafarers 75.2% reported working on British flagged ships, 94.0% were British/Irish, 94.3% were officers and 70.2% earned more than £30,000 a year. With 40% of such a sample of highly paid, well trained and highly ranked seafarers admitting to under-recording working hours it is not difficult to imagine the situation being considerably worse elsewhere.

6.3 The relationship between recorded hours of work, fatigue and health of seafarers

Allen et al. (Allen, Burke, & Ellis, 2003) compared seafarers who had at least occasionally under-reported working hours (n=223) and those who never under-reported working hours (n=208). The group who reported under-recording working hours were shown to be significantly more fatigued/less healthy than the non under-recording group, as shown in Table 22.

Table 22 Fatigue and health scores for mis-recording and non mis-recording groups

SCALE	NON UNDER-RECORDING MEAN (SE)	UNDER-RECORDING MEAN (SE)
Fatigue at work	3.44 (.06)	3.64 (.05)
Fatigue after work	2.33 (.03)	2.58 (.03)
Fatigue symptoms	2.57 (.05)	3.09 (.05)
PFRS-F	24.67 (.86)	27.29 (.80)
CFQ	33.90 (.88)	36.93 (.78)
GHQ	1.15 (.16)	1.80 (.17)

(Note: for all scales a higher score = higher fatigue or poorer health status)

6.4 Prescriptive versus outcomes approaches

Jones et.al (2005) argue that prescriptive approaches, such as using working hours as a method of measuring, auditing and preventing fatigue, may not be as effective as an 'outcomes' based approach. They describe how rather than prescribing specific rules and regulations aimed at preventing a target problem, an outcomes approach simply involves stating a standard and leaving the means of achieving this at operator discretion, as outlined by Efthimios Mitropoulos, Secretary-General of the IMO (interviewed in Tallack, 2006):

'In simple terms, a goal-based standard may be something like: 'People shall be prevented from falling over the cliff'. By contrast, in prescriptive regulation, the specific means of achieving compliance is mandated, for example: 'A one-metre high rail shall be installed at the edge of the cliff' (p.13)

Whilst a prescriptive approach to fatigue might therefore stipulate specific hours of work, an outcomes based approach focuses only on managing fatigue, a goal which might be achieved in very different ways by different companies or sectors of the industry. From an outcomes perspective, therefore, using any one specific measure to control fatigue will always result in an approximative system which fails to account for the complexity of the work situation (Folkard & Lombardi, 2005). If an officer stands on watch for 6 hours during dense fog then a prescriptive system, using working hours to assess fatigue, will consider this equivalent to a 6 hour period spent holding anchor. Whilst the flexibility inherent in an outcomes, or non-prescriptive system sounds promising, however, the practical reality is that prescriptive legislation is a more efficient way of regulating an industry which calls for

universal standards. Certainly where evidence has shown that working hours are an extremely good indicator of fatigue risk (McCallum & Raby, 1996), the inevitable fact that all variables cannot be considered appears a compromise currently accepted by all sides. Furthermore, moving away from the prescriptive use of working hours as a first line in managing fatigue would appear perhaps premature in light of evidence that such a system is still to be reliably enforced and therefore essentially tested (e.g. (Allen, Wadsworth, & Smith, 2006).

The next section evaluates guidelines aimed at preventing or managing fatigue at sea.

6.5 IMO Guidance on Fatigue

In 2001 the IMO issued a publication addressing fatigue entitled 'Guidelines on fatigue' which breaks the subject of fatigue down into separate chapters for the different areas of responsibility onboard ship e.g. fatigue and the rating, fatigue and the ship's officer, fatigue and the master etc. In an appraisal of the IMO fatigue guidelines, McNamara, Allen, Wellens and Smith (2005) suggest that over-emphasis is placed on the personal responsibility of crew to manage fatigue without due recognition of operational factors such as crewing levels over which seafarers have little or no control. Advising a seafarer that 'Boredom can cause fatigue', for example, (p.24) may be of little use when schedules dictate that a seafarer stands on watch for 8 hours with little to do beyond monitoring radar and correcting charts. Gander (2005) discusses the concept of 'shared responsibility' in relation to fatigue with guidance packages such as that provided by IMO only likely to represent single-level intervention. A recent report has outlined methods for preventing and managing fatigue and the main points are summarised below.

6.6 TNO Report (Houtman *et al.*, 2005): Fatigue in the shipping industry

6.6.1 Management of fatigue

In their recent report on fatigue in the shipping industry, Houtman et al (2005) identify 12 areas related to fatigue management:

- lengthening of the resting period;
- optimising the organisation of work;
- reducing administrative tasks;
- less visitors / inspectors in the harbour / better co-ordination of inspections;
- reducing overtime;
- proper Human Resource Management;
- education and training;
- development of a management tool for fatigue;
- proper implementation of the ISM-code;
- healthy design of the ship;
- health promotion at work;

- expanding monitoring of fatigue causes, behaviours or consequences, including near misses.
- (Houtman et al., 2005, p.4).

6.6.2 Priorities for managing fatigue

They considered four measures to be the most necessary and effective in terms of reducing fatigue:

- proper implementation of the ISM-Code;
- optimising the organisation of work on board vessels;
- lengthening of the rest period;
- reducing administrative tasks on board vessels.

(Houtman et al., 2005, p.4).

They also conclude that greater monitoring of causes, behaviours and consequences, including near misses, is important, but because shipping is an international industry, monitoring should be carried out at a world-level, rather than being restricted to a single country or to Europe (Houtman *et al.*, 2005). The authors also point out that, in relation to the proper implementation of the ISM-Code, specific measures must be identified since the Code can include any of the fatigue management measures they described depending on the needs and possibilities within an organisation (Houtman *et al.*, 2005). Houtman et al conclude that fatigue management should be an integral part of safety management, and as such could be seen “as part of the ISM-Code with specific attention to fatigue” (p5).

The report goes on to compare the potential effectiveness of five particular fatigue reducing measures prioritised by the authors, as follows:

- Replacing the two-shift system with a three-shift system. An additional crew member on watch is added to the crew.
- Adding a crew member but not an Officer in Charge (OIC). The additional crew member should be a person who will be able to take over some administrative tasks from the officer on watch or from the Master.
- Changing the shift system into a more flexible one, with a rest period of at least 8 hours. A possibility is to introduce a 4-8/8-4 shift system.
- Identifying administrative tasks that can be done by the organisation ashore using (wireless) ICT facilities.
- Setting up the framework for a Fatigue Management Tool/ Programme.

(Houtman et al., 2005, p.5).

The authors recognise that replacing a two-shift system with that involving three watchkeeping officers will have a large financial impact on the short sea shipping industry, and estimate that around 2,540 extra seafarers would be needed for the EU fleet. If this measure is implemented Houtman et.al suggest at least a sufficient transition period is needed. The other three measures are considered as options, but the authors go no further than that. Houtman et al acknowledge that adding a crew member is expensive and, in the case of some ships, not feasible because of the limited number of cabins,

but go on to point out that an additional seafarer authorised for the Watch, but also able to perform other duties (e.g. a 'Dual Purpose Officer' or MAROF-Maritime Officer), may give greater watchkeeping flexibility. They also suggest that using high-speed internet technology to move administrative tasks to on-shore staff is an option which may become increasingly available in the future. Houtman et al also note that in some cases paperwork and workload have been reduced by better structuring of planned maintenance and its inclusion in service contracts with suppliers. In addition, they suggest that ICT developments on board may further increase efficiency and reduce the administrative burden. The authors also describe the suggested improvement in shift system flexibility as “an interesting option” (p6), designed specifically to give seafarers at least eight hours rest in every 24 hours while keeping shift regularity in this 24 hour period (Houtman *et al.*, 2005).

In general, this Dutch report recommends that the ISM-Code is evaluated to determine any deficiencies or shortcomings related to fatigue notification, prevention or reduction (Houtman *et al.*, 2005). It is pointed out, however, that with the code only in place for around 3 years (at the time of report publication) for most ships, judgements concerning positive impact may be premature at this time. The report concludes “that understanding how the Fatigue Management Programmes in some other related sectors like road transport, have been developed and implemented may provide interesting lessons for fatigue management in the shipping industry” (Houtman *et al.*, 2005, p.7).

6.6.3 Comments on the TNO report

Following on from the TNO report (Houtman *et al.*, 2005), there are clearly some aspects of fatigue management that can be taken from other transport industries and applied to the maritime sector. For example, it is well established that caffeine can provide a short-term countermeasure to fatigue (e.g Lieberman, Tharion, Shukkitt-Hale, Speckman, & Tulley, 2002; Marsden & Leach, 2000; Smith, 2005). Whilst reliance on a pharmacological solution is clearly not acceptable as a long-term strategy, evidence suggests that caffeine should nevertheless be recognised as a means of combating fatigue when systems have failed and danger might be inevitable without intervention. The report’s suggestion that technology can provide an answer to seafarers’ fatigue is often not supported by the evidence. Bielic and Zec (Bielic & Zec, 2005) argue that an automation-dominated environment leaves seafarers as passive operators, denied the opportunity for creative input. Such monotonous conditions, the authors conclude, are conducive to fatigue. Sauer et al. (Sauer *et al.*, 2002) conducted a study looking at the benefits of an integrated bridge interface design and found, in support of Bielic and Zec, that slight operational benefits might be outweighed if fatigue is found to increase.

Whilst limits might exist on how far technology, through automation, can reduce fatigue, other research has concentrated upon the issue of detection of fatigue. For example, Johns, Tucker and Chapman (2005) describe a new method of monitoring drowsiness which involves monitoring eye and eyelid movement using infrared reflectance. Whilst not conducted on seafarers, research demonstrating objective sleep detection using this device holds

promise in terms of producing an emergency fail safe system for maritime workers.

We have argued that potential risk factors for fatigue should be considered in combination rather than alone, as experienced in the real world setting. Support for using such a 'combined effects' strategy comes from Comperatore, Rivera and Kingsley (2005) who have investigated the onboard environment using a unique systems based approach. They suggest that 'stressors rarely act independently because most occur concurrently, simultaneously taxing physical and mental resources' (p.B108). Where a fatigued state can be induced by any constellation of different factors a range of solutions arguably needs to be employed (Gander, 2005). A focus upon company-based strategic solutions perhaps overlooks the responsibility held by both legislator and seafarer who form critical layers in any fatigue management structure (Gander, 2005). If the problem of fatigue is to be truly conceived in multi-faceted terms then all layers of responsibility need to be transparently involved in an holistic approach.

The TNO report also suggests a fatigue management programme (Houtman *et al.*, 2005). Research is required to determine whether the nature and extent of training influence susceptibility to fatigue. Indeed, the basis of fatigue awareness training and fatigue management training is that it is possible to provide the person with skills that allow them to identify and possibly counter fatigue. The absence of fatigue training may be one of the reasons for the high attrition rate seen in those starting at sea and it may also underlie early departure from the profession. It is also important to consider the collective ability of the crew to prevent fatigue. Under manning has been suggested as a major cause of fatigue but other possible risks may be present even where manning levels are appropriate (e.g. multi-cultural crews).

Recent Canadian research has evaluated fatigue management processes and approaches in the transport industries with the aim of determining best practices. The review concluded that few existing programmes consist of the crucial key components and that few have been properly evaluated. Good fatigue management programmes should have the following key components:

- Organisational commitment to the requirements of a Fatigue Management Programme
- Establishment of a Fatigue Management Policy and Process
- Involvement of all stakeholders throughout the process
- Competency based educational modules
- Effective change to the scheduling, dispatching and compensation processes
- Objective and subjective measures of fatigue management effectiveness
- Continual monitoring and improvement

The next section presents the conclusions from our research programme.

7. CONCLUSIONS

The overall aim of the present programme of research was to provide a knowledge base on seafarers' fatigue. This has been achieved using a range of methodologies and by studying samples from different sectors of the British maritime industry. The results show that the potential for fatigue at sea is high due to seafarers' exposure to a large number of recognisable risk factors, both operational (e.g. port frequency), organisational (e.g. job support), and environmental (e.g. physical hazards). Our results show, however, that it is the combined effect of these risk factors that is most strongly associated with fatigue and its both short and long term consequences (fatigue symptoms, personal risk; and reduced health and well-being). The most at risk groups are those exposed to the greatest number of these factors which could be identified using an audit styled approach. We have also shown that perceived fatigue is an additional risk factor for negative outcomes and this should also be included in any audit process. A taxonomic approach to fatigue should be used and measures of the frequency and intensity of different types of fatigue (e.g. acute versus chronic; physical versus mental fatigue) obtained. Appropriate tools for this have been developed and the use of measures of risk factors for fatigue and perceived fatigue will allow future associations with outcomes (e.g. accidents and injuries; health status) to be assessed. It is also important to consider personal characteristics of the seafarer to determine the extent to which these influence susceptibility to fatigue.

One of the problems with measuring fatigue is that there is no "gold standard" that has been used in large populations and would allow bench-marking across jobs. It is difficult, therefore, to provide global estimates of the prevalence of fatigue in seafarers and to compare these levels with onshore groups. Indeed, where diversity is one of the defining features of the seafarer population such global estimates can prove misleading, not accounting for important differences in terms of ship operation, flag of registration and crew nationality. All that can be concluded is that highly fatigued seafarers are undoubtedly working in the industry where a combination of risk factors are found together. We have investigated a ship of a type thought to be associated with excessive fatigue (mini-bulker) and shown that higher subjective reports of fatigue are associated with objective performance deficits. Indeed, our performance measures have also been shown to be sensitive to risk factors for fatigue (e.g. working at night; noise) suggesting fatigue cannot be considered a purely subjective phenomenon. This is also confirmed by associations between fatigue-inducing conditions and accidents. Our research has also shown that the consequences of fatigue are not only felt in terms of impaired performance and reduced safety but decreased well-being and increased risk of mental health problems, also known to be risk factors for future chronic disease. Such effects are not restricted to seafarers and were found to be even greater in installation workers. Part of these effects may reflect the general problems associated with being at sea and in the workplace 24-7 for several weeks away from home. Our sample has largely come from the "better end" of the industry and the prevalence and consequences of seafarers' fatigue may, to some extent, be underestimated here. Further research at an international level is needed to investigate this view. Similarly, it is important to study those just starting at sea to determine

whether fatigue is an important factor in the high attrition seen with this group. Fatigue may also be important in early retirement from seafaring and this issue could be addressed using the methods employed here. The research programme has addressed many specific issues and the following Table summarises these and the extent to which they have been successfully addressed.

Table 23 Addressing the programme's specific aims

AIM	ADDRESSED
Incidence and effect of fatigue in terms of specific ship types and voyage cycles	Survey and diary techniques ((McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted; Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and sections 5.1.2, 5.1.4, 5.2)
Optimal shift patterns and duty tours to minimise fatigue	Combined effects analyses ((McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted), and section 5.1.2.1) showed that this aim was over-simplistic and not necessarily applicable in the "real world"
Identification of at risk individuals and of factors which affect fatigue/quality of rest	Combined effects analyses ((McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted; Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and sections 5.1.2, 5.1.4, 5.2)
Significance of patterns of work and rest, and patterns of health and injury, in terms of seeking to improve health and safety of seafarers on board ship	Survey data ((McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted; Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and sections 5.1.2, 5.1.4, 5.2)
Suggested ameliorative / preventative procedures for minimising the effects of fatigue	Evidence base for suggestions provided (Executive Summary Recommendations and section 8)
Appropriate guidance for seafarers on fatigue avoidance	Evidence base for suggestions provided (Executive Summary Recommendations and section 8)

Table 23 continued

AIM	ADDRESSED
Aims specific to Phase 2	
The identification of characteristics of the work environment which are likely to impact upon fatigue and general health	Combined effects analyses ((McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted; Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and sections 5.1.2, 5.1.4)
The development of an applied theoretical framework from which direct legislative recommendations can be made and tested.	Evidence base for suggestions provided (Executive Summary Recommendations and section 8)
AIMS SPECIFIC TO PHASE 3	
Extend the research to other sectors (including a survey and onboard testing on the following vessels: short-haul bulkers, feeder and mainline containerships, reefers, long-haul tankers and cruise ships)	A survey was carried out and onboard testing took place on several vessels (see sections 5.1.4.1, 5.3), though access to some vessel types was not possible.
Conduct a survey to assess fatigue, health and injury in the fishing industry	A survey was carried out (see section 5.1.5.3.6), though the sample size was limited.
Continue to assess the interface between ships and installations/ports with an emphasis on the effects of fatigue on risk perception of collisions and fires/explosions	Survey data (see section 5.1.5.3.3)
Investigate the time course of fatigue in more detail by studying the effects of different port/sea cycles in long-haul shipping	Diary data ((Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2)
Investigate the impact of fatigue on multi-tasking with the view to determining which working practices may lead to greater risk (e.g. problems of the “one man bridge” where the watch-keeper may also be doing paperwork or other tasks)	Survey data (see section 5.1.5.3.4)

Table 23 continued

AIM	ADDRESSED
Examine the after-effects of tours at sea by conducting research to determine the extent of the fatigue experienced at the start of leave periods	Diary data ((Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2)
Follow-up issues that have arisen from Phases 1 and 2 (for example, collaborating with various companies to develop a system for collecting accident record data that includes information about factors relevant to fatigue)	Issues from Phases 1 and 2 were followed up (e.g. tour effects, see (Wadsworth, Allen, Wellens, McNamara, & Smith, 2006), and section 5.2), though the specific example of collaboration with various organisations was not possible because of time constraints.
Use information from the three Phases of the research to provide an appraisal of some of the main current guidance on fatigue, including the International Maritime Organization Guidance on Fatigue Mitigation and Management, and to provide guidance on the recognition of fatigue	Appraisal provided (see sections 6, Executive Summary Recommendations, 8).
Examine the initial impact of the UK's implementation of the EU working time directive in the maritime sector, and to produce recommendations on shift patterns/tour lengths that minimize fatigue	Working time directive considered (see(McNamara, Allen, Wellens, & Smith, 2005), and sections 6.2, Executive Summary Recommendations, 8); evidence base developed for the production of recommendations (though restricting these to shift patterns/tour lengths is over-simplistic and not practical in the "real world")
Provide an appropriate knowledge base about fatigue and an evaluation of the efficacy of current guidance, and to suggest means of implementing and evaluating any desirable new procedures	Knowledge base provided (this and previous reports and papers: (Allen, Wadsworth, & Smith, 2006; Allen, Wellens, McNamara, & Smith, 2005; Allen, Wadsworth, & Smith, Submitted; McNamara, Allen, Wellens, & Smith, 2005; McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted; McNamara & Smith, 2002; Smith, 1999, 2003, 2006; Smith, Allen, & Wadsworth, 2006; Smith & Ellis, 2002; Smith, Lane, & Bloor, 2001, 2003; Smith et al., 2003; Smith & McNamara, 2002; Wadsworth, Allen, McNamara, Wellens, & Smith, Submitted; Wadsworth, Allen, Wellens, McNamara, & Smith, 2006; Wellens, McNamara, Allen, & Smith, 2005))

Given the diversity of activities undertaken in the maritime sector, and the different profiles of fatigue risk factors in different work groups, it is clear that a range of strategies will be needed to prevent or manage fatigue. Having evaluated current working time directives and a fatigue guidance publication from IMO, existing approaches seem largely inadequate. Improvement of these approaches is clearly one strategy that could reduce the problem although an awareness campaign approach, as proved successful in other transport sectors, may also have value. Similarly, fatigue management programmes have been developed in other industries and such approaches could form part of a package for dealing with fatigue at sea. Indeed, the general absence of fatigue awareness and management training in the seafaring industry shows that fatigue has not been treated as a health and safety issue. This could be achieved using approaches designed to address other areas of health and safety (risk assessments, audits, training) and would, therefore, involve established procedures rather than development of novel approaches. This holistic approach to fatigue will require all layers of the industry (regulators, companies and seafarers) to be involved. What is crucial is that strategies for prevention and management are evaluated, for without reliable auditing systems the success of any change will be impossible to judge. The consequences of fatigue at sea are extremely serious, but the benefits to be had by tackling it could be equally widely felt.

8. RECOMMENDATIONS

As described above, this research programme has provided an evidence base for the development of fatigue recommendations and guidance. These general recommendations for addressing seafarers' fatigue are summarised below.

1. **Review how working hours are recorded.** Fatigue is more than working hours, but knowing how long seafarers are working for is critical in terms of evaluating how safe current operating standards are. This study shows the current method for recording and auditing working hours is not effective and should therefore be reviewed.
2. **Fatigue awareness/management training and information campaigns.** Fatigue awareness/management training and information campaigns for seafarers are likely to prove effective but only as part of a unified approach involving all levels of authority. Such guidance could become a routine part of cadet training and could also be incorporated into established health and safety courses. This approach will only be effective if crew are empowered to act on their training in terms of actively intervening with operations when required.
3. **Establish an industry standard measure of fatigue.** No 'gold standard' measure of fatigue currently exists which makes the task of comparing and evaluating the impact of research results extremely difficult. Work needs to be done which either sets out the case for adopting the use of one particular fatigue measure as the industry standard, or looks towards developing a new scale for industrial and research purposes. If all parties are using the same fatigue measure progress in this field will undoubtedly be accelerated.
4. **Develop a multi-factor auditing tool.** The study has shown that it is the combination of different risk factors that puts an individual at risk of fatigue. A taxonomic or checklist-style auditing tool therefore needs to be developed to include not only work characteristics known to be risk factors for fatigue but also subjective experience of this factor.

Our analysis has shown that it is the combined effect of a range of factors that is associated with fatigue. The consequence of this conclusion is that changing one or two factors can have a disproportionately large impact. The development, implementation, and crucially evaluation of strategies to address fatigue must be carried out jointly across all levels of the industry. However, their application must also be tailored, at a local level, to be appropriate and practical. All approaches must be evaluated and modified in the light of these audits. Tackling fatigue at sea must involve the industry as a whole because it has the potential to benefit at an equally universal level.

9. REFERENCES

- Ahsberg, E., Gamberale, F., & Gustafsson, K. (2000). Perceived fatigue after mental work: an experimental evaluation of a fatigue inventory. *Ergonomics*, 43(2), 252-268.
- Allen, P., Burke, A., & Ellis, E. (2003). A cross-vessel survey of seafarers examining factors associated with fatigue. In P. T. McCabe (Ed.), *Contemporary Ergonomics 2003* (pp. 125-130): Taylor and Francis.
- Allen, P., Wadsworth, E., & Smith, A. P. (2006). The relationship between recorded hours of work and fatigue in seafarers. In P. D. Bust (Ed.), *Contemporary Ergonomics 2006* (pp. 546-548): Taylor and Francis.
- Allen, P., Wellens, B., McNamara, R., & Smith, A. (2005). It's not all plain sailing. Port turn-arounds and Seafarers' fatigue: A case study. In P. Bust & P. T. McCabe (Eds.), *Contemporary Ergonomics 2005* (pp. 563-567): Taylor & Francis.
- Allen, P. H., Wadsworth, E. J. K., & Smith, A. P. (Submitted). Seafarers' fatigue: a review of the recent literature.
- Andrea, H., Kant, I. J., Beurskens, A. J. H. M., Metsemakers, J. F. M., & van Schayck, C. P. (2003). Associations between fatigue attributions and fatigue, health, and psychosocial work characteristics: a study among employees visiting a physician with fatigue. *Occupational and Environmental Medicine*, 60(Suppl 1), i99-i104.
- Barger, L. K., Cade, B. E., Ayas, N. T., Cronin, J. W., Rosner, B., Speizer, F. E., et al. (2005). Extended work shifts and the risk of motor vehicle crashes among interns. *New England Journal of Medicine*, 352(2), 125-134.
- Beurskens, A. J. H. M., Bultmann, U., Kant, I. J., Vercoulen, J. H. M. M., Bleijenberg, G., & Swaen, G. M. H. (2000). Fatigue among working people: validity of a questionnaire measure. *Occupational and Environmental Medicine*, 57, 353-357.
- Bielic, T., & Zec, D. (2005). Influence of shipboard technologies and work organization on fatigue. *8th International Symposium on Maritime Health*, 53.
- Bloor, M., Thomas, M., & Lane, T. (2000). Health risks in the global shipping industry: an overview. *Health, risk and society*, 2(3), 329-340.
- Bonnet, M. H., & Arand, D. L. (1995). We are chronically sleep deprived. *Sleep*, 18(10), 908-911.
- Bowring, A. (2004). Problems of minimum manning. *Seaways*, June 2004, 23-24.
- Bridges, B., Johansson, P., & Pearson, L. (2005). Using risk engineering grading systems to assess organizational fatigue risk. *International conference on fatigue management in transportation operations*, 29.
- Broadbent, D. E., Cooper, P. F., Fitzgerald, P., & Parkes, K. R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, 21, 1-16.
- Brown, I. D. (1989). *Study into hours of work, fatigue and safety at sea*. Cambridge: Medical Research Council.
- Bultmann, U., Kant, I. J., Kasl, S. V., Beurskens, A. J. H. M., & van den Brandt, P. A. (2002b). Fatigue and psychological distress in the

- working population: Psychometrics, prevalence and correlates. *Journal of Psychosomatic Research*, 52, 445-452.
- Bultmann, U., Kant, I. J., van den Brandt, P. A., & Kasl, S. V. (2002a). Psychosocial work characteristics as risk factors for the onset of fatigue and psychological distress: prospective results from the Maastricht Cohort Study. *Psychological Medicine*, 32(2), 333-345.
- Burke, A., Ellis, E., & Allen, P. (2003). The impact of work patterns on stress and fatigue among offshore worker populations. In P. McCabe (Ed.), *Contemporary Ergonomics 2003* (pp. 131-136): Taylor & Francis.
- Caldwell, J. A., & Caldwell, J. L. (2003). *Fatigue in aviation: A Guide to Staying Awake at the Stick*. Aldershot, UK: Ashgate Publishing Ltd.
- Carter, T. (2005). Working at sea and psychosocial health problems. Report of an international maritime health association workshop. *Travel medicine and infectious disease*, 3, 61-65.
- Charlton, S. G., & Baas, P. H. (2001). Fatigue, work-rest cycles, and psychomotor performance of New Zealand truck drivers. *New Zealand Journal of Psychology*, 30(1), 32-39.
- Chen, M. K. (1986). The epidemiology of self-perceived fatigue among adults. *Preventive Medicine*, 15, 74-81.
- Cockroft, D. (2003). Maritime policy and management - 30 years issue for Prof. James McConville. Editorial: IMO - The economics of intimidation. *Maritime Policy and Management*, 30(3), 195-196.
- Collins, A., Mathews, V., & McNamara, R. (2000). *Fatigue, health and injury among seafarers & workers on offshore installations: A review* (SIRC Technical Report Series): Cardiff University Seafarers International Research Centre (SIRC) / Centre for Occupational & Health Psychology.
- Comperatore, C. A., Rivera, P. K., & Kingsley, L. (2005). Enduring the shipboard stressor complex: A systems approach. *Aviation, Space, and Environmental Medicine*, 76(6), 108-118.
- Condon, R., Knauth, P., Klimmer, F., Colquhoun, P., Herrmann, H., & Rutenfranz, J. (1984). Adjustment of the oral temperature rhythm to a fixed watchkeeping system on board ship. *International Archives of Occupational and Environmental Health*, 54, 173-180.
- Conway, G. A. (2002). Casting their lot upon the water: commercial fishing safety (Commentary). *The Lancet*, 360, 503-504.
- Costa, G. (2003). Shift work and occupational medicine: an overview. *Occupational medicine*, 53(2), 83-88.
- DfT.
<http://www.thinkroadsafety.gov.uk/campaigns/drivertiredness/drivertiredness.htm>.
- Ellis, N. (2005). *Safety and perceptions of risk*. Paper presented at the SIRC Symposium, Cardiff University.
- Ellis, N., Allen, P., & Burke, A. (2003). The influence of noise and motion on sleep, mood and performance of seafarers. In P. T. McCabe (Ed.), *Contemporary Ergonomics 2003* (pp. 137-142): Taylor & Francis.
- Folkard, S., & Lombardi, D. A. (2005). *Can a "Risk Index" replace work hour limitations?* Paper presented at the 2005 International Conference on Fatigue Management in Transportation Operations, Seattle, USA, September 11-15.

- Folkard, S., Lombardi, D. A., & Tucker, P. T. (2005). Shiftwork: Safety, Sleepiness and Sleep. *Industrial health*, 43, 20-23.
- Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. *Occupational medicine*, 53(2), 95-101.
- Gander, P. (2005). *A review of fatigue management in the maritime sector*. Massey University Sleep/Wake research centre.
- Gander, P. H., Van den Berg, M., & Signal, L. (2005). *Sleep and Fatigue on Fresher vessels during the hoki season*. New Zealand: Massey University Sleep / Wake Research Centre.
- Goldberg, D. (1992). *General Health Questionnaire (GHQ-12)*. Windsor, UK: NFER Nelson.
- Grech, M., Horberry, T., & Humphreys, M. (2003). Fatigue and Human Error in the Maritime Domain. *Proceedings of the 5th International Conference on Fatigue in Transportation, Perth, Australia, March 9th-15th*.
- Hamelin, P. (1987). Lorry drivers' time habits in work and their involvement in traffic accidents. *Ergonomics*, 30, 1323-1333.
- Hansen, H. L., Nielsen, D., & Frydenberg, M. (2002). Occupational accidents aboard merchant ships. *Occupational and environmental medicine*, 59(2), 85-91.
- Hansen, H. L., Tüchsen, F., & Hannerz, H. (2005). Hospitalisations among seafarers on merchant ships. *Occupational and environmental medicine*, 62, 145-150.
- Hardy, G. E., Shapiro, D. A., & Borrill, C. S. (1997). Fatigue in the workforce of National Health Service Trusts: levels of symptomology and links with minor psychiatric disorder, demographic, occupational and work role factors. *Journal of Psychosomatic Research*, 43, 83-92.
- Horne, J. A., & Reyner, L. A. (1995). Sleep related vehicle accidents. *British Medical Journal*, 310, 565-567.
- Houtman, I., Miedema, M., Jettinghoff, K., Starren, A., Heinrich, J., Gort, J., et al. (2005). *Fatigue in the shipping industry*. TNO report 20834/11353.
- Huibers, M., Bleijenberg, G., van Amelsvoort, L., Beurskens, A., van Schayck, C., Bazelmans, E., et al. (2004). Predictors of outcome in fatigue employees on sick leave. Results from a randomised trial. *Journal of Psychosomatic Research*, 57, 443-449.
- International Transport Federation (ITF). (1998). *Seafarer fatigue: Wake up to the dangers*: ITF.
- Jansen, N. W. H., Kant, I., Van Amelsvoort, L. G. P. M., Nijhuis, F. J., & Van den Brandt, P. A. (2003). Need for recovery from work: evaluation short-term effects of working hours, patterns and schedules. *Ergonomics*, 46(7), 664-680.
- Jansen, N. W. H., Kant, I., & van den Brandt, P. A. (2002). Need for recovery in the working population: description and associations with fatigue and psychological distress. *International Journal of Behavioral Medicine*, 9(4), 322-340.
- Janssen, N., Kant, I. J., Swaen, G. M. H., Janssen, P. P. M., & Schroer, K. A. P. (2003). Fatigue as a predictor of sickness absence: results from the Maastricht cohort study on fatigue at work. *Occupational and Environmental Medicine*, 60(Suppl 1), i71-i76.
- Jensen, O. C., Sorensen, J. F. L., Canals, M. L., Hu, Y. P., Nikolic, N., & Thomas, M. (2004). Incidence of self-reported occupational injuries in

- seafaring- an international study. *Occupational medicine*, 54(8), 548-555.
- Johns, M., Tucker, A., & Chapman, R. (2005). A new method for monitoring the drowsiness of drivers. *International conference on fatigue management in transport operations*, 23.
- Jones, C. B., Dorrian, J., Rajaratnam, S. M. W., & Dawson, D. (2005). Working hours regulations and fatigue in transportation: A comparative analysis. *Safety Sciences*, 43, 225-252.
- Knutsson, A. (2003). Health disorders of shift workers. *Occupational Medicine*, 53, 103-108.
- Koller, M. (1983). Health risks related to shift work. An example of time-contingent effects of long-term stress. *International Archives of Occupational and Environmental Health*, 53(1), 59-75.
- Lawrie, T., Matheson, C., Murphy, E., Ritchie, L., & Bond, C. (2003). Medical emergencies at sea and injuries among Scottish fishermen. *Occupational medicine*, 53(3), 159-164.
- Leone, S., Huibers, M., Kant, I., van Schayck, C., Bleijenberg, G., & Knottnerus, J. (2006). Long-term predictors of outcome in fatigued employees in sick leave: a 4-year follow-up study. *Psychological Medicine*.
- Leung, A. W. S., Chan, C. C. H., Ng, J. J. M., & Wong, P. C. C. (2006). Factors contributing to officers' fatigue in high-speed maritime craft operations. *Applied Ergonomics*, 37(5), 565-576.
- Lieberman, H. R., Tharion, W. J., Shukkitt-Hale, B., Speckman, K. L., & Tulley, R. (2002). Effects of caffeine, sleep loss, and stress on cognitive performance and mood during U.S navy SEAL training. *Psychopharmacology*, 164, 250-261.
- Luz, J., Melamed, S., Najenson, T., Bar, N., & Green, M. S. (1990). *The structured ergonomic stress level (E-S-L) index as a predictor of accidents and sick leave among male industrial employees*. Paper presented at the Fourth International Conference on the Combined Effects of Environmental Factors, Baltimore, Maryland.
- Malawwethanthri, K. (2003). Fatigue and jet lag: In search of sound sleep. *Seaways November 2003*, 26-28.
- Marine Accident Investigation Branch (MAIB). (2004). *Bridge Watchkeeping Safety Study*.
- Marsden, G., & Leach, J. (2000). Effects of alcohol and caffeine on maritime navigational skills. *Ergonomics*, 43(1), 17-26.
- Matheson, C., Lawrie, T., Morrison, S., Ritchie, L., Murphy, E., & Bond, C. (2001b). *Health in the catching sector of the fishing industry*. University of Aberdeen.
- McCallum, M. C., & Raby, M. (1996). *Procedures for investigating and reporting human factors and fatigue contributions to marine casualties*. Seattle, USA: U.S Coast Guard.
- McNamara, R., Allen, P., Wellens, B., & Smith, A. P. (2005). Fatigue at sea: Amendments to working time directives and management guidelines. In P. D. Bust & P. T. McCabe (Eds.), *Contemporary Ergonomics 2005* (pp. 568-572): Taylor and Francis.

- McNamara, R. L., Allen, P. H., Wadsworth, E. J. K., Wellens, B. T., & Smith, A. P. (Submitted). Risk factors for perceived fatigue in a seafaring population.
- McNamara, R. L., & Smith, A. P. (2002). *The combined effects of fatigue indicators on health and well-being in the offshore oil industry*. Paper presented at the 10th International Conference on the Combined Effects of Environmental Factors, August 2002, Osaka, Japan.
- Mohren, D. C., Swaen, G. M., Kant, I., Borm, P. J., & Galama, J. M. (2001). Associations between infections and fatigue in a Dutch working population: results of the Maastricht Cohort Study on Fatigue at Work. *European Journal of Epidemiology*, 17(12), 1081-1087.
- Omdal, K. A. (2003). A survey of health and work environment onboard Norwegian ships *7th International Symposium on Maritime Health*.
- Parkes, K. R. (1993). *Human factors, shiftwork and alertness in the offshore oil industry*. London: HMSO Books.
- Parkes, K. R. (2002). *Psychosocial aspects of work and health in the North Sea oil and gas industry. Summaries of reports published 1996-2001*: Health and Safety Executive (HSE).
- Peter, R., Siegrist, J., Hallqvist, J., Reuterwall, C., & Theorell, T. (2002). Psychosocial work environment and myocardial infarction: improved risk estimation by combining two complementary job stress models in the SHEEP study. *Journal of Epidemiology and Community Health*, 56(4), 294-300.
- Powell, W. R., & Crossland, P. (1998). *A literature review of the effects of vessel motion on human performance - possible implications for the safety and performance of personnel aboard floating production storage and off-loading vessels*.
- Raby, M., & Lee, J. D. (2001). Fatigue and workload in the maritime industry. In P. A. Hancock & P. A. Desmond (Eds.), *Stress, Workload and Fatigue* (pp. 566-578). Mahwah, New Jersey: Lawrence Erlbaum associates.
- Rapisarda, V., Valentino, M., Bolognini, S., & Fenga, C. (2004). Noise-related occupational risk aboard fishing vessels: considerations on prevention and the protection of exposed workers. *Giornale Italiano di Medicina del Lavoro Ed Ergonomia*, 26(3), 191-196. Abstract obtained from PubMed article No. 15551949
- Ray, C., Weir, W. R. C., Phillips, S., & Cullen, S. (1992). Development of a measure of symptoms in Chronic Fatigue Syndrome: The Profile of Fatigue-Related Symptoms (PFRS). *Psychology and Health*, 7, 27-43.
- Reyner, L., & Baulk, S. (1998). *Fatigue in ferry crews: a pilot study*. Cardiff University: Seafarers' International Research Centre.
- Roberts, S. E. (2000). Occupational mortality among British merchant seafarers (1986-1995). *Maritime policy and management*, 27(3), 253-265.
- Roberts, S. E. (2002). Hazardous occupations in Great Britain. *The Lancet*, 360(9332), 543-544.
- Roberts, S. E., & Hansen, H. L. (2002). An analysis of the causes of mortality among seafarers in the British merchant fleet (1986-1995) and recommendations for their reduction. *Occupational medicine*, 52, 195-202.

- Roberts, S. E., & Marlow, P. B. (2005). Traumatic work related mortality among seafarers employed in British merchant shipping, 1976-2002. *Occupational and environmental medicine*, 62, 172-180.
- RoSPA. (2001). Driver fatigue and road accidents: a literature review and position paper. <http://www.rospsa.com/roadsafety/info/fatigue.pdf>.
- Sauer, J., Wastell, D. G., Hockey, G. R. J., Crawshaw, C. M., Ishak, M., & Downing, J. C. (2002). Effects of display design on performance in a simulated ship navigation environment. *Ergonomics*, 45(5), 329-347.
- Simpson, S., Wadsworth, E., Moss, S., & Smith, A. (2005). Minor injuries, cognitive failures and accidents at work: incidence and associated features. *Occupational Medicine*, 55, 99-108.
- Smith, A. P. (1999). *The problem of fatigue offshore*. Paper presented at the Seafarers' International Research Centre, first symposium, Cardiff University.
- Smith, A. P. (2003). Seafarers' fatigue, health and safety. *Personalführung*, 2, 46-52.
- Smith, A. P. (2005). Caffeine at work. *Human Psychopharmacology*, 20, 441-445.
- Smith, A. P. (2006). Shiftwork on oil installations. In P. D. Bust (Ed.), *Contemporary Ergonomics* (pp. 5651-5569).
- Smith, A. P., Allen, P. H., & Wadsworth, E. J. K. (2006). *Phase 3 Technical Annexe*. Available from authors on request.
- Smith, A. P., & Ellis, N. (2002). Objective measurement of the effects of noise aboard ships on sleep and mental performance. *The 2002 International Congress and Exposition on Noise Control Engineering*, 149-154.
- Smith, A. P., Lane, T., & Bloor, M. (2001). *Fatigue Offshore: A comparison of Offshore Oil Support Shipping and the Offshore Oil Industry* (SIRC Report). Cardiff: Seafarers International Research Centre (SIRC) / Centre for Occupational and Health Psychology Cardiff University.
- Smith, A. P., Lane, T., & Bloor, M. (2003). An overview of research on fatigue in support shipping in the offshore oil industry. In P. T. McCabe (Ed.), *Contemporary Ergonomics 2003* (pp. 119-124).
- Smith, A. P., Lane, T., Bloor, M., Allen, P., Burke, A., & Ellis, N. (2003). *Fatigue Offshore: Phase 2. The short sea and coastal shipping industry*. Cardiff: Seafarers International Research Centre (SIRC) / Centre for Occupational and Health Psychology, Cardiff University.
- Smith, A. P., & McNamara, R. L. (2002). *Noise and disturbed sleep aboard ships and on oil installation*. Paper presented at the 31st International Congress on Noise Control Engineering, Dearborn, Michigan.
- Smith, A. P., McNamara, R. L., & Wellens, B. T. (2004). *Combined effects of occupational health hazards*. Sudbury: HSE Books.
- Smith, A. P., Sturgess, W., & Gallagher, J. (1999). Effects of a low dose of caffeine given in different drinks on mood and performance. *Human Psychopharmacology*, 14, 473-482.
- Tallack, R. (2006). Managing legislation and regulation. *Seaways*, March, 13-15.
- Tamura, Y., Horiyasu, T., Sano, Y., Chonan, K., Kawada, T., Sasazawa, Y., et al. (2002). Habituation of sleep to a ship's noise as determined by actigraphy and a sleep questionnaire. *Journal of Sound and Vibration*, 250(1), 107-113.

- Tamura, Y., Kawada, T., & Sasazawa, Y. (1997). Effect of ship noise on sleep. *Journal of Sound and Vibration*, 205(4), 417-425.
- Thomas, M., Sampson, H., & Minghua, Z. (2003). Finding a balance: companies, seafarers and family life. *Maritime Policy and Management*, 30(1), 59-76.
- van Amelsvoort, L. G. P. M., Kant, I. J., Beurskens, A. J. H. M., Schroer, C. A. P., & Swaen, G. M. W. (2002). Fatigue as a predictor of work disability. *Occupational and Environmental Medicine*, 59, 712-713.
- Wadsworth, E. J. K., Allen, P. H., McNamara, R. L., Wellens, B. T., & Smith, A. P. (Submitted). Fatigue and subjective reports of health among British seafarers.
- Wadsworth, E. J. K., 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, 836-844.
- Walters, D. (2005). *Occupational health and safety at sea: the relevance of current experiences of regulating for a safer and healthier work environment on land?* Paper presented at the SIRC Symposium, Cardiff University.
- Ware, J. E., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (SF-36). *Medical Care*, 30, 473-483.
- Wellens, B., McNamara, R., Allen, P., & Smith, A. (2005). Collisions and collision risk awareness at sea: Data from a variety of seafarers. In P. D. Bust & P. T. McCabe (Eds.), *Contemporary Ergonomics 2005* (pp. 573-577): Taylor & Francis, London.
- WHO. Retrieved 25/07/06, from <http://www.who.int/suggestions/faq/en/print.html>
- Zomer, J., & Lavie, P. (1990). Sleep-related automobile accidents - when and who? In J. A. Horne (Ed.), *Sleep '90* (pp. 448-451). Bochum: Pentangel Press.