ADEQUATE CREWING AND SEAFARERS' FATIGUE: THE INTERNATIONAL PERSPECTIVE

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

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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 document (e.g. The Nautical Institute Fatigue Forum, Patraiko, 2006).

A recent example is given below:

> *<u>Fatigue in frame again over bulker grounding - Lloyd's List, Tuesday April 18 2006</u>*
>
> *"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, under manning 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 Haraldasson, 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 under estimated (Akerstedt and Haraldasson, 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 de 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 Knipling, 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 than 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 Straight 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 habituative 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, Tuchsen 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 riving 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.awakeltd.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 Envionmental 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. Industial 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. Otorhinolarngol 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, Lawire 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.

McCartt 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 Envionmental 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, Desomond 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.

Shipley 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. Personalfuhrung, 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, Knipling 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, Timoth; 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-Bourgrine, 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-0f-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, Kennith.	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	22nd 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	15th 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	Fatgiue countermeasures in Canadian military transport aircrew: Lessons from Bosnia and Afghanistan		Session 19C
Price, Jana M	A review of the evidence investigators use indetermining 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.	Accuracty 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		
Strewart, Simon and Abboud, Rafeef	Flight crew scheduling, performance and fatigue in a UK airline – phase 1		Session 21A
Strewart, 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. countries	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)

<u>Summary</u>

"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.

<u>BACKGROUND</u>

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.