SEAFARER FATIGUE: THE CARDIFF RESEARCH PROGRAMME

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November 2006

ACKNOWLEDGEMENTS

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

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

SUMMARY

Main messages

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

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

EXECUTIVE SUMMARY

Background

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

Aims and objectives of the present research programme

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

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

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

The concept of fatigue

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

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

Methods

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

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

Results

The literature review

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

The survey

In total, 1856 seafarers took part in the survey. Most of the respondents were deck (49%) or engineering (36%) officers. Just over 40% (41%) worked on ferries, 25% on offshore support, supply or standby vessels, and 19% on tankers. Two thirds (67%) of the respondents worked on UK flagged vessels. Results from the survey showed that fatigue was consistently associated with poor sleep quality, negative environmental factors, high job demands and high stress. Other factors found to be important included: frequent port visits, physical work hazards, working more than 12 hours a day, low job support and finding the switch to port work fatiguing. The short-term consequences of fatigue (reported symptoms of fatigue, and the perception of risk to personal safety) were also associated with a similar range of factors. Those most at risk of high levels of fatigue and associated consequences were those who reported the greatest number of fatigue-inducing factors. It is therefore important to consider the combined impact of negative factors rather than considering them alone.

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

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

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

Diary studies

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

Objective testing onboard

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

Prevention and management of fatigue

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

Conclusions

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

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

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

Recommendations

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

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

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

CONTENTS

1. INTRODUCTION

Main messages

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

1.1 What is fatigue?

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

1.2 Risk factors for fatigue

Acute fatigue may be induced by a number of factors: lack of or poor quality sleep, long working hours, working at times of low alertness (e.g. the early hours of the morning), prolonged work, insufficient rest between work periods, excessive workload, noise and vibration, motion, medical conditions and acute illnesses. Chronic fatigue can either be due to repeated exposure to acute fatigue or can represent a failure of rest and recuperation to remove fatigue. Many working patterns induce acute fatigue and also lead to more chronic patterns. For example, working at night is associated with reduced alertness during the shift and may also produce cumulative problems because of poor sleep during the day. Risk factors for fatigue have been widely documented and can be split into factors which reflect the organisation of work (e.g. working hours, task demands, the physical environment) and characteristics of the individual (both stable traits, and current state). Many of the established risk factors for fatigue are highly relevant to seafarers. These potential problems often reflect organisational factors such as manning levels or the use of particular shift systems (e.g. 6 on, 6 off). Others may reflect the specific voyage cycle of the ship. What is important to recognise is that it is the combination of risk factors that is crucial; fatigue may be most readily observed when a large number of these are present.

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

1.3 <u>Prevalence of fatigue in the workforce</u>

Prevalence of fatigue in the general working population has been estimated to be as high as 22% (Bultmann, Kant, Kasl, Beurskens, & van den Brandt, 2002b) and there exists a substantial literature relating work schedules and other work stressors (e.g. high demands) to fatigue in onshore populations. High job demands and role conflict were found to be associated with fatigue in a sample of NHS trust employees (Hardy, Shapiro, & Borrill, 1997), and findings from the Maastricht Cohort Study of ‘Fatigue at Work’ suggest that work schedules and psychosocial work stressors such as high demands (physical and emotional) and low control contribute to high levels of fatigue. Overtime and shift work were significantly associated with increased need for recovery from work-related fatigue in a large sample [n=12,095] of the general working population (Jansen, Kant, Van Amelsvoort, Nijhuis, & Van den Brandt, 2003; Jansen, Kant, & van den Brandt, 2002), and in a sub-sample of men within the same cohort, psychological, physical and emotional work demands (with a protective effective of high job control) were linked with cumulative fatigue incidence during a 1-year follow-up study (Bultmann, Kant, van den Brandt, & Kasl, 2002a).

1.4 Consequences of fatigue

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

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

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

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

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

1.5 <u>Fatigue in transport</u>

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

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

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

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

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

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

2. BACKGROUND TO THE PROJECT

<u>Main messages</u>

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

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

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

<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. It also transpired that the watch alarm, which might have alerted the sleeping master, had been disconnected.

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

Shipping-owned bulker. The software, furthermore, was both "pirated" and considerably out of date.
Recommendations to the owners and UK Chamber of Shipping by MAIB included the need to impress upon owners, operators and managers the importance of fatigue-related issues, safe lookout, the inappropriate use of personal electronic equipment and closer scrutiny of hours of rest worksheets."

Interviews and focus groups also point to many of the major issues relating to fatigue at sea. Ellis (Ellis, 2005) reports a number of comments made by participants from various shipping companies, management companies and maritime colleges in the UK, Philippines and Singapore that illustrate some of the underlying issues associated with seafarers' fatigue. These included:
1. The extra burden of paperwork
2. The additional burden of the International Ship and Port Security (ISPS) drills
3. Long working hours
4. Fatigue leading to shortcuts which compromise safety
5. Falsification of documentation about working hours
6. Safety concerns due to reduction in crew sizes

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

2.1 The Cardiff Research Programme

Given the absence of extensive research on seafarers' fatigue we have carried out a research programme that generally aimed to provide the knowledge base to:
- *Predict worst case scenarios for fatigue, health and injury*
- *Develop best practice recommendations appropriate to ship type and trade*
- *Produce advice packages for seafarers, regulators and policy makers*

Specifically, the programme's aims were to provide advice on:
  - *Incidence and effect of fatigue in terms of specific ship types and voyage cycles*
  - *Optimal shift patterns and duty tours to minimise fatigue*
  - *Identification of at risk individuals and of factors which affect fatigue/quality of rest*

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

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

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

2.2 Phases of the research

The project consisted of three phases. The first involved data collection from seafarers in the offshore oil support sector (shuttle tankers, offshore supply vessels, anchor handlers, daughter craft and diving support vessels). Interest in this sector developed from research on fatigue on oil installations (Smith, 1999, 2006) and this phase not only allowed assessment of seafarers' fatigue but comparison with those on installations. A detailed account of this phase is given in Smith, Lane and Bloor (Smith, Lane, & Bloor, 2001).
The second phase of the research was concerned with the short sea sector (passenger ferries – both traditional and fast ferries; freight ro-ro's; and near sea tankers). A detailed account of this phase is given in Smith, Lane, Bloor, Allen, Burke and Ellis (Smith et al., 2003).
The final phase extended the research to other sectors (mini-bulkers, short-haul bulkers, feeder and mainline containerships, reefers, long-haul tankers and cruise ships). In addition, a survey was conducted to assess fatigue, health and injury in the fishing industry. The research continued to assess the interface between ships and installations/ports with an emphasis on the effects of fatigue on risk perception of collisions. The impact of fatigue on multi-tasking was also investigated with a view to determining which working practices may lead to greater risk. The time course of fatigue was investigated in more detail by studying the effects of different port/sea cycles and other potential risk factors for fatigue using a diary methodology. The same approach was used to investigate the after-effects of a tour at sea in terms of fatigue experienced at the start of leave. Finally, the research evaluated the impact of the working time directive and the IMO guidelines on fatigue. A detailed account of this phase is given in Smith, Allen and Wadsworth (Smith,

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

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

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

Main messages

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

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

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

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

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

3.1 Prevalence of fatigue

Grech, Horberry and Humphreys (2003) studied the Royal Australian Navy and found fatigue to be reported as a major problem. With a sample of 79 crew from 6 patrol boats questionnaire data were collected showing approximately 44% of participants worked more than 80 hours a week and 62% reported not getting enough sleep. Taylor Nelson Sofres (TNS, 2004 as cited in Gander, 2005) investigated fatigue alongside drug and alcohol use in the New Zealand shipping industry with a sample including representatives from the leisure, fishing and commercial industries. Whilst Gander (2005) points out that methodological shortcomings prohibit generalisation from the study, the fact that 16% of vessel owners/operators in the TNS sample rated the risk of a seafarer being injured in a fatigue-related accident as 'high' or 'very high' certainly supports concerns raised in the author's own work. Gander and Le Quesne (2001, as cited in Gander, 2005) conducted a study looking at masters and mates working on New Zealand inter-island ferries and found that 61% of officers felt they were often or always affected by fatigue when on duty. It was also found that 26% of the ferry sample could recall being involved in a fatigue related incident or accident in the last 6 months.

3.2 Fatigue risk factors

3.2.1 Circadian rhythms

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

3.2.2 Working patterns and shift schedules

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

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

An ITF report (International Transport Federation (ITF), 1998), based on responses from 2,500 seafarers of 60 nationalities, serving under 63 flags, demonstrates the extent of excessive hours and fatigue within the industry. Almost two-thirds of the respondents stated that their average working hours were more than 60 hours per week and 25% reported working more than 80 hours a week (42% of masters). Beyond simply long working hours, however, other evidence suggested that on many ships working hours were actually in excess of STCW 95 or ILO 180 requirements. It was found that 36% of the sample were unable to regularly obtain 10 hours rest in every 24, and 18% were regularly unable to obtain a minimum of 6 hours uninterrupted rest. Long periods of continuous watchkeeping were also reported, with 17% stating that their watch regularly exceeded 12 hours. Over half the sample (55%) considered that their working hours presented a danger to their personal health and safety. Indeed, nearly half the sample felt that their working hours presented a danger to safe operations on their vessel. Once again this was particularly prevalent in watchkeepers and also on ferries and offshore support vessels. The survey also showed that over 60% reported that their hours had increased in the past 5 to 10 years. Respondents also provided a wide range of examples of incidents that they considered to be a direct result of fatigue. The early hours of the morning were the most difficult in terms of feeling the effects of fatigue and it is important that safe manning assessments, watch systems and procedures reflect the potential decline in individual performance at these times. More than 80% of the sample reported that fatigue increased with the length of the tour of duty. Long tours of duty were also common (30% reporting usual tour lengths of 26 weeks or above). This cumulative fatigue may also reflect the reduction in opportunities for rest and relaxation ashore, due to the reduced port turn-around times now required.

3.2.3 Noise and motion

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

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

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

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

3.2.4 Sleep

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

3.2.5 Other risk factors

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

3.3 Accidents and Injuries

Roberts (2002; see also Roberts & Hansen, 2002) provides evidence to support the commonly held notion that seafarers, and in particular fishermen, are at considerably higher risk of injury or death compared to workers in other professions. When compared with other British workers seafarers were found to be 26.2 times more likely to be involved in a fatal accident at work in the period between 1976 and 1995 with this risk even higher for fishermen (52.4 times). Later work by the same author considered evidence up to 2002 (Roberts & Marlow, 2005) and confirmed that whilst fatal accidents have dramatically declined in number since the 1970s, relative to the general workforce seafaring should still be considered a ‘hazardous occupation’.
In terms of assessing factors associated with mortality at sea, Roberts (Roberts, 2000) has shown that during the period 1986-1995 British seafarers were at a higher risk of dying through ‘work-related accidents, suicides and unexplained disappearances at sea’ when working on foreign compared with

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

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

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

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

3.4 <u>Health</u>

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

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

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

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

4. METHODS

Main messages

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

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

4.1 Surveys

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

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

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

4.2 <u>Diary studies</u>

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

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

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

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

4.3 <u>Onboard testing</u>

4.3.1 Vessel motion

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

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

4.3.2 Measurement of noise

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

4.3.3 Measurement of performance and mood

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

4.3.3.1 Visual analogue mood scales

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

4.3.3.2 Variable fore-period simple reaction time task

In this task a box was displayed in the centre of the screen and at varying intervals (from 1-8 seconds) a target square would appear in the box. As soon as they detected the square participants were required to press a response key using the forefinger of their dominant hand only. This task lasted for approximately 3 minutes. A measure of mean reaction time was recorded for each minute of performance on the basis of the number of trials completed per minute. A total mean reaction time was also calculated from the total number of trials completed during the whole test. Responses below 200 ms and greater than 750 ms were eliminated from the calculation of these variables.

4.3.3.3 Focused attention task

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

4.3.3.4 Categoric search task

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

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

4.3.4 Measurement of sleep

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

Figure 1 Subjective sleep measurement

To be completed just before starting work:

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

Rate your Sleep

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

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

4.3.5 Salivary cortisol

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

5. RESULTS

Main messages

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

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

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

5.1 Results from the survey

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

5.1.1 The sample

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

5.1.1.1 Offshore support sector

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

5.1.1.2 Short sea and coastal sector

Three recruitment methods were used to access a representative sample of seafarers. 2740 questionnaires were sent to NUMAST members identified by a union representative as operating in the short sea and/or coastal sectors. Secondly, 1120 questionnaires were sent to employees of four shipping companies (2 ferry [n=760] and 2 tanker operators [n=360]). A total of 791 completed questionnaires were received using these two sampling methods (a combined response rate of 20.5%). Questionnaires were also distributed by researchers visiting short-sea vessels: a total of 145 questionnaires were completed by seafarers on 7 vessels. The total sample comprised 936 short sea and coastal workers. In terms of vessel types the short-sea sample was primarily made up of seafarers working on passenger ferries (41.4%, n=383), freight ferries (20.3%, n=188), high-speed ferries (8.5%, n=79) and products tankers (14.4%, n=133).

5.1.1.3 Deep sea sector

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

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

5.1.2 Risk factors for fatigue

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

Table 1 PFRS fatigue and associated risk factors

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

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

Table 2 Fatigue at work and associated risk factors

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

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

Table 3 Fatigue after work and associated risk factors

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

5.1.2.1 Combined effects analyses

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

Table 4 Combined effects of exposure to risk and fatigue

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

5.1.2.2 Summary of risk factors for fatigue

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

5.1.3 Prevalence of fatigue

Fatigue may be present during work, after work and may even extend into the person's leave. Fatigue-related symptoms such as loss of concentration were widespread and these have implications for safety. Indeed, about 25% of respondents reported fatigue while on watch, many reported that they had fallen asleep while on watch, and 50% of the sample reported that fatigue leads to reduced collision awareness (Wellens, McNamara, Allen, & Smith, 2005).
One issue that was addressed was whether seafarers are more fatigued than onshore workers. Initial comparisons between those on oil industry support ships and a sample of onshore workers (described in detail in Smith, McNamara and Wellens, 2004) showed little evidence of the seafarers being more fatigued. However, comparisons involving ferry crews and those studied in Phase 3 showed that these seafarers were more fatigued than both the Phase 1 seafarers and the onshore controls. Indeed, while seafarers as a whole are not necessarily more fatigued than other occupations there are certainly some groups who have excessive levels of fatigue. This issue will be returned to in a later section comparing the crew of a mini-bulker with seafarers on other short sea vessels.

5.1.4 Consequences of fatigue

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

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

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

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

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

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

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

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

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

Table 7 Perceived risk to self and associated risk factors

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

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

Table 8 Combined effects of exposure to risk and fatigue

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

5.1.4.2 Short term consequences of fatigue

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

Table 9 Symptoms of fatigue at sea and associated risk factors

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

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

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

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

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

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

One important question is whether the samples we have studied are representative of the industry. Smith et al. (Smith et al., 2003) found that the onboard samples studied were broadly representative of the participating companies, and those companies were also largely representative of the wider sampling frame. McNamara et al. (McNamara, Allen, Wadsworth, Wellens, & Smith, Submitted) continued this approach and found that the current sample should be considered representative of a ‘good’, if not ‘best case scenario’ in terms of seafarers who have extensive experience of working at sea and relatively little experience of suffering from fatigue when compared with a multi-national sample. Given this conclusion it seems tenable that problems identified here are likely to be a concern on a greater scale elsewhere.

5.1.5 Phase specific issues

5.1.5.1 Phase 1

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

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

5.1.5.1.2 *Effects of specific risk factors: Disturbed sleep*

Smith and McNamara (Smith & McNamara, 2002) examined reports of disturbed sleep in seafarers, oil installation workers and an onshore sample. Both seafarers and oil installation workers reported more sleep disturbance than the onshore sample and over 40% of the offshore workers reported noise disturbed sleep. Motion also produced sleep problems in over 40% of the seafarers. Lack of sleep was significantly related to perceptions of physical and mental fatigue amongst both seafarers and installation workers. Poor concentration was significantly related to sleep quantity amongst both groups of offshore workers. Of respondents who reported too little sleep, 70.5% of installation workers, 67.2% of seafarers and 46.9% of onshore workers felt that their working patterns seriously compromise personal safety. A similar pattern of results was observed for operational safety. These results confirm the potential problems associated with disturbed sleep. However, individual factors rarely occur in isolation and this phase of the project included the first analysis of the combined effects of risk factors for fatigue.

5.1.5.1.3 *Combined effects*

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

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

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

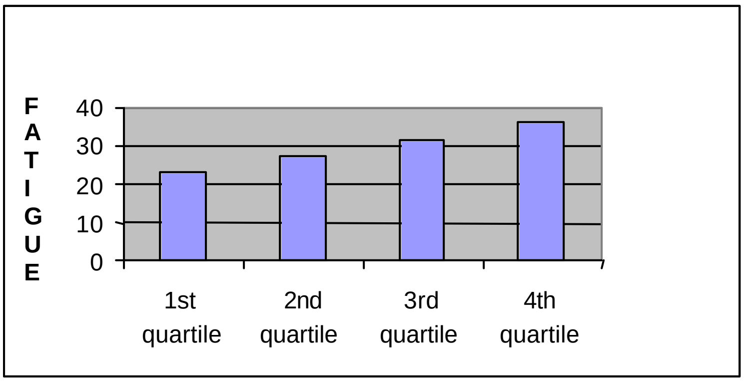
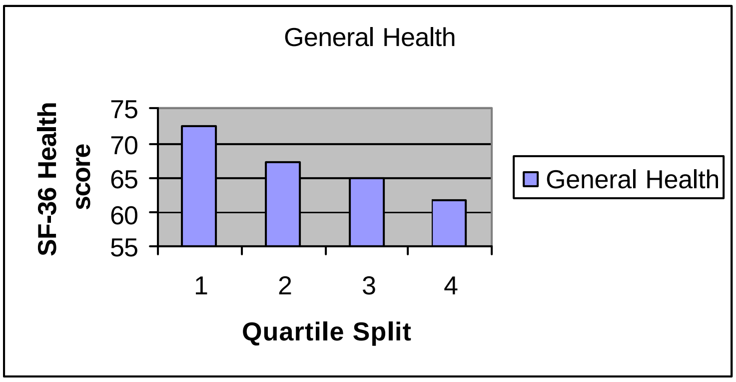


Figure 3 Combined work hazards and the General Health Score from the Short Form Health Questionnaire [SF-36]

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



5.1.5.2 Phase 2

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

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

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

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

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

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

5.1.5.3 Phase 3

5.1.5.3.1 *Validating the survey fatigue scales*

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

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

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

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

5.1.5.3.2 *Changes in fatigue over time*

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

5.1.5.3.3 *Collision awareness and fatigue*

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

5.1.5.3.4 *Multi-tasking and fatigue*

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

5.1.5.3.5 *Comparing the fatigue of seafarers with other groups*

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

5.1.5.3.5.1 Onshore workers

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

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

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

5.1.5.3.5.2 Road haulage drivers

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

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

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

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

5.1.5.3.6 *Fatigue in fishermen*

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

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

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

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

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

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

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

5.1.5.3.6.1 Comparing fishermen with the main survey seafarers sample

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

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

	OTHER SEAFARERS	FISHERMEN	F	P
PFRS fatigue[1]	27.52, 0.32	28.64, 1.75	0.50	0.48
PFRS somatic symptoms[1]	26.66, 0.28	30.66, 1.73	8.47	0.004
Fatigue at work good weather*[1]	3.67, 0.02	3.07, 0.16	25.60	<0.0001
Fatigue after work good weather*[1]	2.43, 0.01	2.02, 0.09	27.63	<0.0001
Fatigue at work rough weather*[1]	3.67, 0.02	2.68, 0.16	70.03	<0.0001
Fatigue after work rough weather*[1]	2.43, 0.01	2.49, 0.10	11.05	0.001
Fatigue at work average[1]	3.67, 0.02	2.88, 0.14	43.73	<0.0001
Fatigue after work average[1]	2.43, 0.01	2.36, 0.09	0.91	0.34
Symptoms of fatigue at sea[1]	2.68, 0.02	2.27, 0.11	17.71	<0.0001
SF36 physical functioning[2]	90.46, 0.31	84.48, 2.51	14.31	<0.0001

*Only fishermen were asked to distinguish between good and rough weather
[1]Higher score = worse
[2]Higher score = better

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

The next section summarises results obtained from the diary studies.

5.2 Results from the diary studies

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

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

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

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

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

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

5.2.1 Phase 1 Diary Studies

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

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

showed that installation workers felt less alert at the start of the day. Those working nights reported lower alertness at the end of the working day even though they perceived their job to be less physically demanding. Day workers starting their tour of duty awoke more frequently than those in their second or third week of the tour. The reverse was true for night workers. Sleep duration was reduced for the first sleep offshore, especially for installation workers doing nightshifts. The alertness levels at the end of the first day were lower for the seafarers than installation workers, with the reverse pattern being present on days 6 and 7. Physical effort was perceived by the day workers to decrease over the week whereas night workers perceived it to increase.
In the final study 43 volunteers completed weekly diaries while they were on leave. 22 were installation workers and 21 seafarers. 34 had worked day shifts before leave and 9 had worked nights. Of these 43 participants 22 had just started their leave and 21 were on their second week of leave. The results showed clear evidence that sleep duration and alertness were abnormal at the start of leave.

5.2.2 Phase 2 Diary Study

Data were collected from 177 participants from seven ships in the short sea shipping industry. These ships included 3 small oil support tankers, 2 passenger ferries, a freight ferry, and a fast ferry. Results from this study are reported in detail in Burke, Allen and Ellis (Burke, Ellis, & Allen, 2003) and the main points can be summarised as follows.
The diaries provided evidence that the cumulative effect of working, both across days and weeks, may influence levels of fatigue and performance. Across the working week, perceived job stress was found to increase which may indicate that over longer periods, seafaring work has a detrimental effect on individual well being. There was also some evidence from the daily questionnaires that seafarers' sleep improves as a function of time into tour. Also, generally habituation to noise levels onboard was observed as a function of days into tour. The diary data showed that any cumulative effects over the diary period varied as a function of weeks into tour, with some evidence of habituation, and some evidence of cumulative negative effects of time at sea (e.g. fewer effects of noise were observed further into tour, whereas the subjective impact of motion increased). The extension of the combined effects approach to the logbook data supports the cumulative negative effects hypothesis, with high levels of exposure to potentially negative work characteristics being associated with greater perceived fatigue. A relatively large number of significant correlations were found between time-specific logbook measures and more general measures employed in the survey. Whilst to a certain extent this may reflect the fact that the survey questionnaire was generally completed in the same week as the logbooks, the correlations nevertheless support the generalisation of results beyond the window of time examined in the onboard investigation.
Overall, the diary studies have shown that this method of data collection can provide important information about seafarers' fatigue over the course of their tour of duty and on leave. The next section considers objective measures taken onboard.

5.3 Performance and alertness onboard

5.3.1 Effects of risk factors for fatigue on mood and performance

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

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

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

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

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

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

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

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

5.3.2 Perceived fatigue, symptoms of fatigue and performance

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

Table 18 Perceived fatigue and symptoms of fatigue reported by the mini-bulker crew and the crews of the other ships
(Scores are the means, s.d.s in parentheses. High scores = greater fatigue)

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

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

Table 19 Performance scores for the mini-bulker crew and the crews of the other ships
(Scores are the means; s.d.s in parentheses. High scores = poor performance)

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

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

5.3.3 Objective measurement of sleep

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

Table 20 Comparison of the sleep of offshore and onshore samples
(Scores are the means, s.d.s in parentheses)

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

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

5.3.4 Cortisol

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

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

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

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

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

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

6. PREVENTION AND MANAGEMENT OF FATIGUE

Main messages

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

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

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

6.1 ILO 180

Convention 180 of the International Labour Organisation requires that States fix maximum limits for hours of work or minimum rest periods on ships flying their flags. In addition:
• Schedules of service at sea and in port (including maximum hours of work or minimum periods of rest per day and per week) are to be posted on board where all seafarers may see them.
• Records of hours of work or rest periods are to be maintained and must be examined by the flag state.
• If the records or other evidence indicate infringement of provisions governing hours of work, the competent authority is to require that measures are taken, including if necessary the revision of manning of the ship, so as to avoid future infringement.
Most European countries regulate on the basis of minimum hours of rest rather than maximum hours of work.

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

6.2 Evaluation of the European Working Time Directive

McNamara et al. (2005) report results from a survey that evaluated the impact of the EU working time directive and the results showed that a minority of seafarers within their sample reported working daily and weekly hours in excess of those set out in the working time directive (WTD). Minimum rest of 10 hours per day and 77 hours per week allow maximum working hours of 14 and 91 respectively. These levels fell within hour band response options, making it impossible to identify precise numbers reporting working over these levels. Nevertheless, 2.2% of the total sample worked 16 or more hours per day and 2.4% worked in excess of 100 hours per week. When asked about rest periods, almost a third of the sample (30.8%) did not regularly have the opportunity to gain 10 hours rest in every 24, and approximately ten percent (11.9%) did not regularly gain at least 6 hours unbroken rest within a 24-hour period. It seems therefore that nearly a third of all reported working hours violate the requirements regarding hours of rest set out in the WTD (clause 5, 1b). It is worth noting that this percentage was much greater than those reporting working hours in excess of maximum levels. These questions about rest periods were included to be identical to measures used in the ITF survey (International Transport Federation (ITF), 1998), so “rest” was not defined, and may not necessarily have been interpreted as time other than time spent working on account of the ship rather than resting. It may also be, however, that respondents felt it was easier to report violations in terms of hours of rest rather than more explicitly in terms of hours worked. Furthermore, 27.6% of the sample reported typically working 15 or more hours continuously, which contravenes the directive laid out in clause 5, 1a. A significant proportion of respondents (21.5%) also reported spending 4 or more hours per day on additional duties. The majority of respondents (61.5%) indicated that working hours had actually increased within the last 5 to 10 years. Seafarers were also asked more specifically whether recent amendments to working time regulation had altered working practice and 77% reported that their working hours had stayed the same and 16% that their hours had actually increased.

The WTD also states that records of hours of work and rest must be maintained in order to monitor compliance with the provisions as detailed in clause 5. However, a significant proportion of respondents felt that their actual working hours were at least occasionally under-reported in order to comply with working time regulations: 11.9% reported that their working hours were always or frequently mis-recorded, while a further 28.3% felt this to be the case at least occasionally. A significant proportion (15%) of the current sample denied any knowledge of international regulations in place to control their working hours, and 7.3% claimed to have no knowledge of national regulations. Seafarers operating in the deep-sea sector seem to be at most risk of working excessively long hours (in violation of working time regulations). The percentage of respondents spending 4 or more hours per day on additional duties was approximately twice that of the offshore and short-sea sectors (28.2% compared with 13.7% and 14.5% respectively). Deep sea respondents were also more likely to report their working hours as a danger to either personal or operational safety.

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

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

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

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

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

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

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

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

6.4 Prescriptive versus outcomes approaches

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

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

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

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

6.5 IMO Guidance on Fatigue

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

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

6.6.1 Management of fatigue

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

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

- expanding monitoring of fatigue causes, behaviours or consequences, including near misses.

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

6.6.2 Priorities for managing fatigue

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

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

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

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

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

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

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

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

but go on to point out that an additional seafarer authorised for the Watch, but also able to perform other duties (e.g. a 'Dual Purpose Officer' or MAROF-Maritime Officer), may give greater watchkeeping flexibility. They also suggest that using high-speed internet technology to move administrative tasks to on-shore staff is an option which may become increasingly available in the future. Houtman et al also note that in some cases paperwork and workload have been reduced by better structuring of planned maintenance and its inclusion in service contracts with suppliers. In addition, they suggest that ICT developments on board may further increase efficiency and reduce the administrative burden. The authors also describe the suggested improvement in shift system flexibility as "an interesting option" (p6), designed specifically to give seafarers at least eight hours rest in every 24 hours while keeping shift regularity in this 24 hour period (Houtman *et al.*, 2005).
In general, this Dutch report recommends that the ISM-Code is evaluated to determine any deficiencies or shortcomings related to fatigue notification, prevention or reduction (Houtman *et al.*, 2005). It is pointed out, however, that with the code only in place for around 3 years (at the time of report publication) for most ships, judgements concerning positive impact may be premature at this time. The report concludes "that understanding how the Fatigue Management Programmes in some other related sectors like road transport, have been developed and implemented may provide interesting lessons for fatigue management in the shipping industry" (Houtman et al., 2005, p.7).

6.6.3 Comments on the TNO report

Following on from the TNO report (Houtman *et al.*, 2005), there are clearly some aspects of fatigue management that can be taken from other transport industries and applied to the maritime sector. For example, it is well established that caffeine can provide a short-term countermeasure to fatigue (e.g Lieberman, Tharion, Shukkitt-Hale, Speckman, & Tulley, 2002; Marsden & Leach, 2000; Smith, 2005). Whilst reliance on a pharmacological solution is clearly not acceptable as a long-term strategy, evidence suggests that caffeine should nevertheless be recognised as a means of combating fatigue when systems have failed and danger might be inevitable without intervention. The report's suggestion that technology can provide an answer to seafarers' fatigue is often not supported by the evidence. Bielic and Zec (Bielic & Zec, 2005) argue that an automation-dominated environment leaves seafarers as passive operators, denied the opportunity for creative input. Such monotonous conditions, the authors conclude, are conducive to fatigue. Sauer et al. (Sauer *et al.*, 2002) conducted a study looking at the benefits of an integrated bridge interface design and found, in support of Bielic and Zec, that slight operational benefits might be outweighed if fatigue is found to increase.
Whilst limits might exist on how far technology, through automation, can reduce fatigue, other research has concentrated upon the issue of detection of fatigue. For example, Johns, Tucker and Chapman (2005) describe a new method of monitoring drowsiness which involves monitoring eye and eyelid movement using infrared reflectance. Whilst not conducted on seafarers, research demonstrating objective sleep detection using this device holds

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

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

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

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

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

The next section presents the conclusions from our research programme.

7. CONCLUSIONS

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

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

The research programme has addressed many specific issues and the following Table summarises these and the extent to which they have been successfully addressed.

Table 23 Addressing the programme's specific aims

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

Table 23 continued

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

Table 23 continued

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

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

8. RECOMMENDATIONS

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

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

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

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