Fatigue at Sea

A Review of Research and Related Literature

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CONTENTS

Introduction 3
Background 3
International Research and Guidance 4
Other Recent Fatigue Studies 5
Conclusion 7
Annotated Bibliography 9

Introduction

The review of research and related literature contained in this document is in support of the *Fatigue at Sea* study being led by VTI, the Swedish National Road and Transport Research Institute, a national research institute organised under the Ministry of Industry, Employment and Communications. The project started during the autumn of 2005, is part of the VINNOVA Maritime safety programme, and is planned to run for at least two years.

An overarching goal is to collect data about the fatigue levels of watchkeeping officers, marine pilots and boatmen, relay this information to appropriate instances and to derive innovative solutions in cooperation with maritime stakeholders. The results will consist of both objective data about fatigue levels of the studied mariners and a number of pragmatic recommendations for authorities, shipping companies and mariners. The expected impact is increased safety at sea by reducing the number of accidents and incidents partly or wholly due to fatigue.

Background

According to the International Maritime Organization (IMO) "fatigue can be defined in many ways. However, it is generally described as a state of feeling tired, weary, or sleepy that results from prolonged mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep. The result of fatigue is impaired performance and diminished alertness."[1]

Historically, fatigue has been acknowledged as a possible factor in maritime accidents. However, it was not until several high profile accidents, most notably, the 1989 grounding of the U.S. tankship *Exxon Valdez*, that fatigue was identified as a major contributor and subsequently given serious national and international attention. One of the findings of the *Exxon Valdez* investigation conducted by the U.S. National Transportation Safety Board (NTSB) was that "there were no rested deck officers on the *Exxon Valdez* available to stand the navigation watch when the vessel departed from the Alyeska Terminal."[2] It is interesting at this time to note that regulations already existed mandating rest periods for watchstanders. With this in mind, the NTSB report recommended "rigorous" enforcement of current regulations concerning watchstander time off, as well as increasing manning levels at the

[1] International Maritime Organization (2001), *Guidance on Fatigue Mitigation and Management, MSC/CIRC. 1014*, London: IMO, p.1

[2] National Transportation Safety Board (1990), *Grounding of U.S. Tankship Exxon Valdez on Bligh Reef, Prince William Sound Near Valdez, Alaska, March 04 1989. NTSB/ MAR-90/04*, Washington D.C.: NTSB.

Valdez Traffic Control Centre (the latter recommendation indicating the possibility that fatigue and inadequate manning factors affecting personnel outside a vessel may directly impact the safety of the vessel itself). This report also addressed the growing tendency toward reducing crew sizes by stating the "Exxon Shipping Company manning policies do not adequately consider the increase in workload caused by reduced manning"[3].

Serious investigation into the impact of fatigue on the safety of life and property at sea began in the 1990s and continues to this day. In the wake these investigations guidance, recommendations and regulations aimed at reducing or preventing seafarer fatigue have been put forward at both the national and international levels. It is interesting to observe that the concept of fatigue weighs so heavily in recent maritime accident investigations that most reports contain a section on fatigue, even if fatigue played little or no role. It is also interesting to note that in general, the factors of a heavy workload preventing adequate rest and reduced manning levels identified in the *Exxon Valdez* investigation continue to play a major role in many maritime accidents.

International Research and Guidance

The IMO has been the primary international body researching seafarer fatigue and developing subsequent regulation and guidance in an effort to reduce mariner fatigue levels and associated accidents in the maritime industry. Adopted on 20 November, 1973, IMO Resolution A.285(8), *Recommendation on Basic Principles and Operational Guidance Relating to Navigation Watchkeeping*, only briefly mentioned fatigue in Annex A(b)(ii) when talking about fitness for duty by stating that "The watch system shall be such that the efficiency of the watchkeeping members of the crew is not impaired by fatigue. Accordingly the duties shall be so organized that the first watch at the commencement of a voyage and the subsequent relieving watches are sufficiently rested and otherwise fit when going on duty." Following the *Exxon Valdez* grounding, the IMO issued Resolution A.772(18) on 4 November 1993, entitled *Fatigue Factors in Manning and Safety*, which was an entire 4 page document dedicated to defining fatigue, identifying specific shipboard related fatigue factors and tasking shipboard management with specific responsibilities in mitigating these factors.

The first major international regulation that specifically took into account seafarer fatigue was subsequently adopted in 1995 and is the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers,*

[3] National Transportation Safety Board (1990), *Grounding of U.S. Tankship Exxon Valdez on Bligh Reef, Prince William Sound Near Valdez, Alaska, March 04 1989. NTSB/ MAR-90/04*, Washington D.C.: NTSB

1978, as amended in 1995" (STCW 95). This regulatory instrument included specific requirements such as a minimum 10 hours rest in every 24 hours (which may be reduced to 6 hours every 24 hours for a period of not more than two days). It also established a requirement that these rest periods be enforced on watchkeeping personnel. These regulations also included additional, more specific guidance on how they should be interpreted and best executed.[4] While STCW 95 provided some specific regulation and interpretation guidance, economic factors, primarily consistent reduction in crew sizes, provided their lean interpretation of these regulations. As a result, fatigue continues to be cited as a primary factor in marine related accidents.

The IMO along with the International Labour Organization (ILO) jointly published the *IMO/ILO GUIDELINES FOR THE DEVELOPMENT OF TABLES OF SEAFARERS' SHIPBOARD WORKING ARRANGEMENTS AND FORMATS OF RECORDS OF SEAFARERS' HOURS OF WORK OR HOURS OF REST (1999 edition)*. These guidelines are designed to help Administrations, shipowners and seafarers meet their obligations under ILO Convention N. 180 (Seafarers' Hours of Work and the Manning of Ships Convention) and IMO's STCW Convention, 1978, as amended in 1995. They provide a standardized table showing shipboard working arrangements, a standard format for records of seafarer's daily hours of work and rest and guidelines for monitoring compliance.[5]

The most extensive and comprehensive publication produced by the IMO to date on seafarer fatigue is the 105 page MSC/CIRC 1014 of 2001 entitled *Guidance on Fatigue Mitigation and Management*. This document is presented in modules that are designed for self study or use during shipboard training. The primary aim of this document is to educate those involved in the maritime industry on what fatigue is, fatigue factors (especially those in the maritime environment), and how to counteract those factors. Included in the 9 modules are topics such as Fatigue and the Training Institution and Management Personnel in charge of Training, Shipboard Fatigue and the Owner/Operator/Manager, Shipboard Fatigue and the Naval Architect/Ship Designer, Fatigue and the Maritime Pilot and Fatigue and Tugboat Personnel.

Other Recent Fatigue Studies

In 2005, Massey University in New Zealand published an extensive literature review for the New Zealand Maritime Authority in an effort to provide an overview of the state of the art of fatigue management in the maritime sector

[4] International Maritime Organization (1995), *International Convention on Standards of Training Certification and watchkeeping for Seafarers, 1978 as amended in 1995*, London: IMO, Regulation VIII/1, Section A-VIII/1,B-VIII/1.

[5] International Maritime Organization (2006). Downloaded 7 March, 2006 from http://www.imo.org/HumanElement/mainframe.asp?topic_id=752

and to provide written comment to the Authority on the implications of this literature for managing seafarer fatigue in New Zealand.[6] With regard to maritime operations, the report cited several studies that indicated 25% of seafarers experienced fatigue on at least half of their trips and that 24% of seafarers saw others working in a fatigued state on at least half of their trips.[7]

The report also chronicled other studies providing significant rates of fatigue levels among mariners and even indicated over 10% of vessel owners/operators as having indicated the risk of seafarer injury or vessel accident as a result of fatigue as being high. With regard to New Zealand, the report indicated that information on the proportion of fatigue related seafarer accidents is not known and suggests that internationally, there is a lack of research in the area of systematic accident reporting and causation analysis with regard to fatigue.[8]

The report concluded by summarizing in detail fatigue factors and international regulation and guidance mentioned earlier in this review and pointed out the need within New Zealand to use these resources in developing specific fatigue management strategies for New Zealand's extensive fishing industry.

Concerned with apparent fatigue related incidents involving marine pilots, Transport Canada published a report in 2002 on the *Development of a Fatigue Management Program for Canadian Marine Pilots*[9]. The goal of this project was to investigate fatigue issues in marine pilotage and develop a fatigue management program prototype. The research involved preparing an extensive literature review of fatigue and fatigue countermeasures in the marine environment. In addition, a study was conducted of Canadian marine pilotage fatigue including the collection of data via questionnaire, on-board observations, and interviews. A prototype Fatigue Management Plan was then developed including training components, an implementation plan, and guidelines for scheduling pilots, and monitoring and evaluating the plan itself. The study indicated that schedules and peak workloads experienced by Canadian marine pilots produced a potential for significant levels of fatigue, and that a fatigue management plan was clearly needed. [10] The completed study also produced a marine pilots' Fatigue Management Guide and Trainer's Handbook.

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[6] Gander, P. (2005). A Review of Fatigue Management in the Maritime Sector, Wellington: Massey Univeristy.
[7] Ibid p.5
[8] Ibid p.6
9 Rhodes W. and Gil, V (2002) *Development of a Fatigue Management Program for Canadian Marine Pilots*, Transport Canada. Downloaded 7 April 2006 from http://www.tc.gc.ca/tdc/publication/pdf/13900/13958e.pdf
[10] Ibid, p.iii

Conclusion

With the type of research, documentation and guidance identified so far, it would seem logical that fatigue among seafarers should be a thing of the past, or at the very least, very well contained. Sadly, this is not the case. The UK Marine Accident Investigation Board (MAIB) recently noted that in an analysis of 65 incidents over a 10 year period, one-third of the groundings involved a fatigued officer alone on the bridge at night, two-thirds of the vessels involved in collisions were not keeping a proper lookout, and one-third of all the accidents that occurred at night involved a sole watchkeeper on the bridge.[11] Additionally, minimum manning practices among shipping companies are cited as directly contributing to continued fatigue levels among mariners. NUMAST recently quoted their general secretary Brain Orwell in their March 2006 issue of the *Telegraph* who stated "We desperately need stronger regulatory requirements and a transparent, objective and truly global standard process for determining operational manning"[12]. March 2006 also saw the Nautical Institute dedicating a major portion of their *Seaways* magazine to the issue of seafarer fatigue as a result of manning practices.

The March 6th issue of Lloyd's List writes "ALARMED by the incidence of accidents caused by excessive speed, lone watchkeepers falling asleep and other accidents to which poor watchkeeping has contributed, the UK Maritime and Coastguard Agency (MCA) has published an extensive Marine Guidance Note to owners, operators, managers, masters and officers of merchant ships."[13] [14]

One conclusion that can be drawn from all of this discussion is that the causes of fatigue among mariners are fairly well defined and that the results of fatigue, namely accidents of varying degrees, are known. However, in the maritime sector economic factors that include minimum required manning and tight schedule keeping directly affect a ship operator's ability to maintain the safest possible position regarding the fatigue of the seafarers involved. It would follow that, at best, these economic factors drive ship operators to seek the minimum position regarding safety in relation to fatigue so as also to reduce the associated cost. At worst, the guidance and regulations on fatigue are blurred or even ignored in pursuit of economic viability.

One area for research suggested by the literature review is to find out how widespread serious fatigue levels are among mariners of all occupations (e.g., pilots, deep sea, coastal, tugs, etc.). In order to accomplish this, a study of a

[11] NUMAST (2006), Fatigue: IMO Must Act, *NUMAST Telegraph*, March 2006, p.40.
[12] Ibid.
[13] Lloyd's List (2006), MCA Takes aim at officers over accidents, *Lloyd's List*,9 March 2006, p.1.
[14] The notice referred to is MGN 315 (M), *Keeping a Safe Navigational Watch on Merchant Vessels*, of which section 3, fitness for duty outlines responsibilities to combat fatigue. The notice was published in February 2006.

sample of all seafarers should be conducted and not limited only to those identified as a result of accident investigations. In this context, it would also be interesting to also discover if there are marked differences between the various maritime sectors. For example reputable cruise ships typically have at least two officers on watch at a time in addition to dedicated lookouts and security patrols. This would seem to provide additional depth that might offset manning related fatigue factors encountered in other sectors of the shipping industry. In a similar manner, are some ports' pilot rotation schemes and practices more prone to limit pilot fatigue levels than others? With regard to those seafarers who were involved in accidents, a detailed analysis should be made to determine the extent in which fatigue played a role.

Once this data has been collected and evaluated, specific solutions can be identified, developed and tested. These solutions would potentially span a wide range of areas from ergonomic to legislative to determine if adequate fatigue mitigation can be achieved given current manning standards and practices or, if more precise regulation and enforcement is needed to compel proper fatigue management.

Annotated Bibliography

This following list identifies additional resources in the area of mariner fatigue and is by no means exhaustive.

Allen, P., Burke. A., Ellis, N. (2003). A Cross-Vessel Survey of Seafarers Examining Factors Associated with Fatigue. *Contemporary Ergonomics 2003.* McCabe, P. Ed. London: Taylor and Francis. Pp. 125-130.
As part of the second phase of the seafarers' fatigue project, a questionnaire-based survey was administered through onboard field research and a mail shot, replicating phase one. The short sea and coastal shipping industry was investigated in contrast with the offshore oil industry examined in the first phase. Higher fatigue and lower health were found in the phase two sample, suggesting the importance of vessel type in determining levels of fatigue. Ship-based fatigue differences were detected in the stage two sample, prompting further investigation of factors which define ships at a practical level. Tour length and watch/duty schedules may be particularly useful in terms of characterising vessels and, therefore, by extension these factors may be of use in terms of ultimately accounting for seafarers' fatigue.

Baulk, S., Reyner, L., (1998) *Fatigue in Ferry Crews: A Pilot Study*. Seaman's International Research Centre, downloaded 10 April 2006 from: Http://www.sirc.cf.ac.uk/pdf/Fatigue%20in%20Ferry%20Crews.pdf.
The objectives of this pilot study were: to investigate the quality and quantity of sleep among crew employed on the short-sea ferry sector; to evaluate the extent to which poor quality sleep occurs; and to identify the factors contributing to poor sleep quality. The subjects of the study were 12 crew members of different rank and with different work patterns from two UK-flagged short-sea pax/ro ferries. Background information on the participants was collected via questionnaires. Data on the duration and quality of sleep were collected by the use of wrist-worn actimeters and by self-report sleep logs, while self reports of alertness were collected at two-hourly intervals during each wakeful period. All the above data were collected during a complete tour of duty comprising one week at sea followed by one week of leave. The week-on / week-off work schedule allowed comparisons to be made between the sleep patterns of a working week at sea and those of a rest week at home. The findings indicate that differences in both sleep quality and duration of sleep between the work and non-work weeks were greater for those crew members required to work split shifts. Furthermore, they experienced greater sleep disturbance and generally shorter sleep periods than crew members who worked a single shift every 24 hours.

Burke, A., Ellis, N. Allen, P. (2003). The Impact of Work Patterns on Stress and Fatigue among Offshore Worker Populations. *Contemporary Ergonomics 2003*, McCabe, P. Ed. London: Taylor & Francis. Pp. 131-136.
This study examined the effects of tour length on stress and fatigue in seafarers in the coastal and short sea shipping industry, in terms of both self report and objective measures. Firstly, a brief outline of the sample and measures used is given. Then, some background on the issue of tour length is provided. This is followed by analysis of length of tour for this study in terms of its impact on various measures used in testing. These included self-reports of sleep quality, fatigue, stress levels and mood and performance on reaction time and attention tasks and objectively measured sleep quality. These findings are then outlined and discussed, and the role of tour length in seafarers' stress and fatigue is evaluated.

Cole-Davies, V. (2001). Fatigue, Health and Injury Offshore: A survey. *Contemporary Ergonomics* 2001, M.A. Hanson. Eds., London: Taylor & Francis, pp.485-490.
This survey was designed to look for evidence of fatigue in both seafarers and offshore installation workers, and examined all possible contributory factors during both time spent offshore and time spent on leave. The first phase of the study is reported here and refers to crewmembers working in the short sea shipping industry. The results show that there is very little evidence of fatigue, or any detrimental effects caused either directly, or indeed indirectly by the offshore working environment.

Colquhoun, W., Watson, K., (1987) A Shipboard Study of a Four-Crew Rotating Watchkeeping System. Ergonomics, 1987, Vol 30, Issue 9, pp1341-1352.
Body-temperatures and subjective alertness ratings were obtained at 2-hourly intervals in a shipboard study of six subjects watchkeeping on a rapidly rotating system with a 4-day cycle. The results were compared with those from an earlier study of this system conducted on land in 'laboratory' conditions. The similarity of the temperature curves from the two studies indicated that prolonged exposure to shipboard conditions made no difference to the underlying circadian rhythm in this variable, which appeared to be near-normal in form. Subjective alertness showed a clear rhythm of considerable amplitude; the phasing of this rhythm suggested that, under the present system, operational effectiveness is likely to be reduced in watches held in night hours. Further analyses indicated that it was also likely to be reduced in daytime hours following these night watches, because of the disruption of sleep that results from them. An alternative 'fixed hours' watchkeeping system is proposed to overcome these unwanted effects.

Colwell, J. (2000). NATO Questionnaire: Correlation between Ship Motions, Fatigue, Sea Sickness and Naval Task Performance. *Human Factors in Ship Design and Operation. Proceedings of the International Conference, London, 27-29 September 2000.* London: Royal Institution of Naval Architects. Pp. 12-19.
The NATO Fatigue, Sea Sickness and Human Performance Assessment Questionnaire (PAQ) was developed to acquire a large database on fatigue, motion sickness and task performance problems associated with ship motions. The PAQ was administered on seven NATO frigates during two weeks of combat training exercises, in the winter on the North Atlantic. More than 1,000 PAQ booklets were completed, representing over 16,000 individual completions of the 47-item PAQ. Also, two of the seven ships were instrumented to measure ship motions. The types and severity of reported problem with sleep, fatigue, motion sickness and task performance are examined, and correlations are discussed.

Compatore, C., Carvalhais, A. (2000). The Impact of Rotating Watch Schedules on Crew Endurance Aboard High and Medium Endurance U.S. Coast Guard Cutters. *Human Factors in Ship Design and Operation. Proceedings of the International Conference, London, 27-29 September 2000.* London: Royal Institution of Naval Architects. Pp. 14-25
Crew alertness and the incidence of sleep/wake cycle disruptions were evaluated aboard a medium endurance (WMEC) and a high endurance (WHEC) cutter throughout 32 and 30 consecutive days underway, respectively. A total of sixty-four crewmembers participated in the study. Wrist activity monitors (WAMs) were used to document sleep/wake cycles and electroencephalography (EEG) techniques were used to measure alertness. Sixty-four participants wore WAMs throughout the study period, while a subset of 28 volunteers participated in short duration EEG alertness tests repeated every three to five days. Alertness tests were administered within three hours of wakefulness from daily sleep. Participants were allowed to follow their daily routine prior to reporting for the wakefulness tests. In both cases, low operational tempo and unremarkable weather characterized patrol conditions.

Comperatore, C., Kingsley, L., Rivera P. (2002). *Management of Endurance Risk Factors, A Guide for Deep Draft Vessels (report: CG-D-07-01).* New London: US Coast Guard Research and Development Center.
Crewmembers aboard deep draft vessels traditionally endure harsh working conditions, extreme temperatures, long work hours, frequent separation from loved ones, and fatigue. While a ship's endurance is determined by how long it can support operations at sea without replenishing supplies or requiring in-port maintenance, its crewmembers' endurance is determined by their ability to cope with job related physiological, psychological, and environmental challenges. Uncontrolled stress factors reduce mental and physical endurance and demand more concentration on the immediate task at hand. Crewmembers forfeit advance planning and the ability to anticipate safety risks. Safety deteriorates as a crew becomes more reactive. Controlling these decrements in performance is critical to productivity and safety. This Guide is designed as a resource for captains, department heads, and officers, as well as company safety and operations managers in the shipping industry to control crew endurance risk factors such as stress, fatigue, sleep deprivation, and problems resulting from working and living on deep draft vessels. Section I introduces the concept of crew endurance management. Section II provides specific guidance on how to recognize endurance risk factors and the detrimental effects of psychological, physiological, and environmental stress factors. Specific recommendations are provided as to how to effectively address crew endurance risk factors. Section III provides specific guidelines on how to assess crew endurance and implement improvements in crew management practices. The principles provided in this Guide have been tested in a variety of maritime environments, including marine shipping companies, towing vessel companies, U.S. Coast Guard cutters, small boat stations, and aviation units.

Council of the European Union (1999). Council Directive 1999/63/EC of 21 June 1999 concerning the Agreement on the organisation of working time of seafarers concluded by the European Community Shipowner's Association (ECSA) and the Federation of Transport Worker's Unions in the European Union (FST) –Annex: European Agreement on the organisation of working time of seafarers. Accessed 13 April 2006 from http://europa.eu.int.smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31999L0063&model=guichett.

Dawson, D, Reid, K. (1997). Fatigue, Alcohol, and Performance Impairment. *Nature,* 388, 235 (17 July 1997).
Reduced opportunity for sleep and reduced sleep quality are frequently related to accidents involving shift workers. Poor quality sleep and inadequate recovery leads to increased fatigue, decreased alertness and impaired performance in a variety of cognitive psychomotor tests. However, the risks associated with fatigue are not well quantified. This study equates the performance impairment caused by fatigue with that due to alcohol intoxication, and shows that moderate levels of fatigue produce higher levels of impairment that the proscribed level of alcohol intoxication.

Ellis, N., (2004), Fatigue: What's Known and What's Being Done, *The Sea*, London: Mission to Seafarers, Issue 172, Nov/Dec, pp 4-5.
Although many shipping companies, management agencies, and ship operators, recognise that fatigue may have important implications for the safe and efficient operation of their vessels, few have a proper understanding of what causes fatigue, or how to address this. To date, there has been limited academic research into fatigue in the maritime industry. This article describes how this deficit is currently being rectified by a study headed by Professor Andrew Smith at the Centre for Occupational and Health Psychology at Cardiff University, which was initially developed in collaboration with the Seafarers' International Research Centre. This

research uses two methods to study fatigue in the short sea and coastal industry and is one of the most sophisticated studies of fatigue in the maritime industry to date.

Ellis, N., Allen, P., Burke, A. (2003). The Influence of Noise and Motion on Sleep, Mood, and Performance of Seafarers. *Contemporary Ergonomics 2003*, McCabe, P. Ed. London: Taylor & Francis. Pp. 137-142.
The effects of noise and motion have been widely studied in transport industries. However, little research has examined these combined factors, especially in the short sea shipping industry. This paper describes the second phase of a project looking at seafarers' fatigue, in which objective measures of noise and motion onboard short sea shipping vessels were examined in order to assess their influence on performance, mood and sleep. Data were collected from 177 participants on seven vessels. As in previous offshore research, noise and motion levels were shown to affect both performance and mood. However, no effect of noise or motion was seen on measures of sleep. Multiple regression analyses further indicated that noise predicted a number of the performance variables. However, it also indicated that other factors, such as tour length, influenced performance and mood.

Elo, A. (1985). Health and stress of Seafarers. *Scandinavian Journal of Work, Environment & Health*, Vol. 11 Issue 6, pp.427-432.
The perceived health and stress of seafarers was studied in relation to work stressors and personality characteristics (self concept). The data were collected with a questionnaire. The study group consisted of 591 seafarers representing different occupations of the Finnish merchant fleet. Forty percent of the respondents sailed in ocean traffic, 31% on the Baltic Sea, and 29% in European traffic outside the Baltic Sea. The respondents' age averaged 35 (SD 11) years; 23% were women and 77% men. The amount of perceived stress varied between different occupational groups, engine crew reporting the most stress. On the average, health status was reported as rather good. Personality characteristics were important explanators of perceived stress and health status. The most important were pessimism-optimism and ego strength. Of the work-related factors, the most important explanatory factors were disturbing noise, climatic conditions on board, occupational group, and received appreciation at work. The quality of interpersonal relations at work did not predict stress or health status. In this study 15-33% of the variance of perceived health status and stress could be explained.

Evans, C (1990). Human Factors Underlying the Effective Implementation of the IMO Conventions. *Schiff und Hafen*, 1990/04 pp.3.
Attention is drawn to some of the difficulties faced by the masters and crews of ships as the direct result of regulations that are either not fully evaluated beforehand or that stop short of their ultimate objective. Note is taken of difficulties with the Safe Manning Certificate required by the IMO's Convention on Standards of Training, Certification and Watchkeeping (STCW). Attention is also given to the problem of fatigue in marine transportation, a question that the author states, is ignored by the law.

Folkard, S., Monk, T. eds. (1985) *Hours of Work: Temporal Factors in Work-Scheduling*. Chichester: John Wiley and Sons.
Collective work of research on work scheduling including the problem of scheduling watches for ships' crews at sea is closely bound up with the adjustment of circadian rhythms to unusual work-rest routines. Traditional 'fixed hours' watchkeeping systems with short watches inevitably result in split sleep. 'Rotating' systems maximize between-watch variations in performance efficiency, and on long voyages may lead to rhythm disintegration. Alternative systems have been devised for warships, but these may not be applicable to the civilian situation. A programme of research is proposed that takes account of factors such as jet-lag, the increasingly

cognitive nature of the watchkeeper's task, and known individual differences in adaptability to shifted sleep-wake cycles.

Howarth, H., Pratt, J., Tepas, D. (1999). Do Maritime Crew Members Have Sleep Disturbances? *International Journal of Occupational and Environmental Health*, 1999, Vol 5, Issue 2, pp. 95-100.
Data obtained from surveys of two samples of maritime crew members were studied for differences in self-reported sleep lengths and sleep problems. The data addressed both on- and off-duty variables. Statistical analysis of the data found that on-duty sleep length was shorter than off-duty sleep length for both groups. The two groups' responses to various sleep-problem items were significantly different. Most responses were below the scale mid-point. The differences between on- and off-duty sleep-problem items were not significant. Following a factor analysis, selected sleep-problem items were combined to form a composite Sleep Disturbance Scale. Using this composite measure, the correlation between the composite and sleep length was not significant. Overall, the results indicate that caution should be exercised before labelling shift workers as having 'disturbed sleep' or suffering from 'sleep disorders'. The results do confirm the previous findings that shiftwork reduces sleep length on workdays.

International Transport Workers' Federation (1998). Seafarer Fatigue: Wake up to the Dangers. *Safety and Health at Work.* ILO-CIS Bulletin (CIS 98-1021).

Jensen, O., Sorensen, J., (2004). Incidence of Self-Reported Occupational Injuries in Seafaring - an International Study. *Occupational Medicine*, 2004, Vol 54, Issue 8, pp 548-555.
Seafaring is known as a high-risk industry. The aims were to describe the incidence of non-fatal injuries among seafarers, including testing the hypothesis that long working hours might result in higher injury rates. A questionnaire study of injury on the latest tour of duty was carried out among seafarers in 11 countries with 6461 participants. The seafarers were asked if they were injured during the latest tour of duty and what was the number of hours worked. During the latest tour of duty, 9.1% of all seafarers were injured and 4.3% had an injury with at least 1 day of incapacity. The injury incidence rates for cargo ships and tankers: 39.5 per 1 million work hours and 37.6 per 100,000 days. Multivariate analyses: incidence rate ratios (IRR) for >70 working hours per week compared with <57 h: 0.90 [95% confidence interval (95% CI) = 0.61-1.32]; non-officers compared with officers: IRR = 1.57 (95% CI = 1.14-2.15); seafarers <35 years compared with 35 years of age: IRR = 2.11 (1.57-2.86); tour lengths 117 days compared with <117 days: IRR = 0.27 (0.19-0.39). Main work area on the deck and in the service area compared with work in the engine room: IRR = 0.37 (0.27-0.52) and IRR = 0.49 (0.26-0.91), respectively. There was no evidence that long working hours alone resulted in higher injury rates. Low self-perceived health, lack of use of personal protection and lack of occupational safety on board were significantly related to an increase in the injury risk.

Kueller, R. (1978). *The Degree of Activation on a Vessel- An Environmental Psychology Analysis*. Lund University of Technology, Sweden, Division of Design, Architectural Section, S-220 07 Lund 7.
The purpose of the study was to see how the layout of a ship can contribute to well-being, stimulation and relaxation for the crew, and to see whether results obtained onshore can be compared with those obtained on a ship. The study was based on interviews and a questionnaire.

McNamara, R., Collins, A., Matthews, V., (2000) 'A Review of Research into Fatigue in Offshore Shipping', *Maritime Review*, pp. 118-122, London: Pacific Press.
Outline of a project looking at aspects of fatigue and health in merchant seafarers being conducted by Centre for Occupational and Health Psychology at Cardiff

University and the Seafarers International Research Centre.

Miller, T. (2003). Washington State Ferries- A Crew Endurance Study. *Proceedings of the Marine Safety Council*. 2003/12. 60(4). Alexandria, VA: U.S. Coast Guard pp52-55.
One of the most notable implementations of the U.S. Coast Guard's Crew Endurance Management (CEM) programs is with the Washington State Ferry (WSF) system in Seattle. WSF is a 24-hour-a-day, seven-day-a-week operation that employs 1,800-plus crew on 26 vessels serving 10 different routes to transport more than 11 million vehicles and 26 million passengers annually. Crew endurance is a crew's ability to maintain performance within safety limits while enduring job-related physiological, psychological, and environmental challenges. Crew Endurance Management is a system for managing the risk factors that v=can lead to human error and performance degradation in maritime work environments.

Phillips, R. (2000) Sleep, Watchkeeping and Accidents: A Content Analysis of Incident at Sea Reports. *Transportation Research Part F: Traffic Psychology & Behaviour*. Vol 3(4) Dec 2000, pp.229-240.
Determines how accident investigators report sleep in Incident at Sea Reports and analyses the relationships between sleep, fatigue and accidents in these reports. 44 Incident at Sea Reports were coded and analysed using NUDIST software. This sample included collisions and groundings reported since 1991, where significant human factors contributed to the incident. The Incident at Sea Reports were electronically searched for reference to sleep and content was indexed against parameters such as fatigue behaviours, time of day and contributing personnel. Incident at Sea Reports incorporate three levels of reference to sleep, analysis of which may associate sleeping and sleepiness with accident causation. The highest level of reference unequivocally associates either being asleep, or being sleep deprived with accidents, but not always with fatigue.

Phillips, R. (2000). Sleep, Watchkeeping and Accidents: A Content Analysis of Incident at Sea Reports. *Transportation Research Part F: Traffic Psychology and Behaviour.* Vol. 3 Issue 4, 2000. pp. 229-240.
This study aims to determine how accident investigators report sleep in Incident at Sea Reports and subsequently analyse the relationships between sleep, fatigue and accidents in these reports.

Pollard, J., Sussman, E., Stearns, M. (1990). *Shipboard Crew Fatigue, Safety and Reduced Manning. Final Report*, Washington, D.C. U.S. Maritime Administration.
This early report describes an exploratory first phase of an investigation of human stress and fatigue in the merchant marine. Its principal purposes were to: survey the effects of fatigue on human performance in the transportation industries; describe the state of the art in measuring fatigue; investigate the causes of stress and fatigue on merchant ships; summarize the insights gained about the implications of reduced manning as well as measures to mitigate fatigue; and discuss the results of preliminary attempts to gauge fatigue during the routing voyages using survey methods. The findings in this report are based primarily upon about three dozen extended interviews conducted with officers on five merchant vessels during brief coastal voyages. In the course of these interviews, more than a score of variables were identified which affect fatigue and stress, which may be grouped into organizational factors, voyage and scheduling factors, ship-design factors, and physical/environmental factors. These interact in complex fashion resulting in widely different levels of fatigue on different ships and in different situations. The physiological and behavioural methods of fatigue measurement reviewed were found to be difficult to apply during routine operations, but the self-reporting survey techniques tested eventually proved quite workable. It was concluded that organization and design factors could provide opportunities under some circumstances for the design and operation of advanced merchant ships which can be

sailed safely and efficiently by well-rested crews which are smaller than are common today.

Sanquist, T., Raby, M. Forsythe, A. (1997). Fatigue in merchant Marine Personnel. Ancient Wisdom - Future Technology. *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting*, Albuquerque, New Mexico, September 22-26, 1997. pp, 983-987.
A field study of work, sleep and alertness patterns was conducted among 141 U.S. merchant marine personnel. Data were collected by means of a logbook over a 10-30 day period for each mariner. A total of 2,038 logbook days were collected. The results indicate the existence of substantial fatigue risk factors, including sleep fragmentation, low sleep durations, poor quality sleep and long work days. The risk factors have a higher incidence among watchstanders, who work on a 4 hour on, 8 hour off schedule. Of particular concern is the high incidence (23%) of severely restricted sleep (less than 4 hours per 24) among workers on the 0400-0800 watch. The data provide the basis for alternative work-rest scheduling in the maritime industry.

Smith, A., Lane, T. (2001). Fatigue Offshore: A Comparison of Short Sea Shipping and the Offshore Oil Industry. *Contemporary Ergonomics 2001*, Hanson M. Ed. London: Taylor & Francis, pp 467-472.
Mounting concern with seafarer fatigue is widely evident among maritime regulators, insurers, ship owners, trade unions and welfare agencies. The authors are carrying out a research programme to investigate this topic. The first phase of the research is concerned with specific comparisons between short sea shipping and the offshore oil industry. The overall objectives of the research are to predict worst case scenarios for fatigue, health and injury; develop best practice recommendations appropriate to ship type and trade; and produce advice packages for seafarers, regulators and policy makers.

Smith, A., Lane, T., Bloor, M. (2001). Fatigue Offshore; A Comparison of Offshore Oil Support Shipping and the Offshore Oil Industry. Cardiff: Seafarer's International Research Centre.
This is the first phase of a two part study commissioned by the Maritime and Coast Guard Agency in the United Kingdom. This report details a survey that was conducted to identify all aspects of the working environment that may lead to fatigue, and affect the health and general well being of personnel employed in all areas of the offshore oil industry.

Smith, A., Lane, T., Bloor, M. (2003). Fatigue Offshore; A Comparison of Offshore Oil Support Shipping and the Offshore Oil Industry. Cardiff: Seafarer's International Research Centre.
This is the second phase of a two part study commissioned by the Maritime and Coast Guard Agency in the United Kingdom. This report details a survey that was conducted to identify all aspects of the working environment that may lead to fatigue, and affect the health and general well being of personnel employed in all areas of the offshore oil industry.

Stevenson, C. (2002). Stress and the Seafarer. *Human Factors in Ship Design and Operation. Proceedings of the International Conference, London, 2-3 October 2002.* London: Royal Institution of Naval Architects. Pp.51-56
Employment law requires that employers have a duty of care to their employees to provide a safe working environment. The Health and Safety Executive advises employers that failure to act may leave the employer open to compensation claims from employees who have suffered ill health from workplace stress. Judgements in the UK courts relating to compensation claims reflect this advice and also indicate that this duty of care is expected to extend to their mental health. Employers are now recognising that there are additional costs associated with high levels of sickness of which stress is a significant part. There is, however, a suggestion that employers are

not recognising how important the human factor and provision of needs satisfaction are to human resource management and how this is related to stress and the well-being of employees.

Torsyall, L. Castenfors, K (1987). Sleep at sea: A diary Study of the effects of Unattended Machinery Space Watch Duty. *Ergonomics.* Vol 30(9) Sep 1987,pp. 1335-1340. Taylor & Francis, United Kingdom.
49 engineer officers (aged 24-62 yrs) in the Swedish merchant marine were asked to keep a sleep/wake diary during a 1-3 mo tour of duty on ocean-going container ships. Every 2-4 nights the Ss had watch duty during which they were allowed to sleep but were awakened by an automatic alarm system in the case of machinery malfunction. The diaries showed that 40% of all nights at sea were spent on such watch duty, and 15% were disturbed by alarms. Having watch duty, particularly with alarms, reduced ratings of sleep length, sleep quality, and recuperation. The latter was also negatively affected by the frequency of watch duty. Nights on watch were also perceived as disturbed when no alarms occurred and as characterized by a higher level of uneasiness, apparently the result of apprehension stress.

U.S. Coast Guard (2003). *Crew Endurance Management Practices, A Guide for Maritime Operations*. Washington: U.S. Cost Guard Downloaded as a PDF file on 7 April 2006 from http://www.uscg.mil/hq/g-m/cems/PDF/Guide%20for%20Maritime%20Operations.pdf
This guide presents a formal program of practices (the Crew Endurance Management System) for controlling risk factors that affect crewmember performance and shipboard safety in the commercial maritime industry. The CEMS program is overviewed; a real-world example is provided; techniques for managing crewmember energy and performance levels are provided; operational risk factors affecting crewmember energy and performance levels are addressed; procedures for implementing a CEMS program are described; and supplementary materials are provided.

Wagenaar, W, Groeneweg, J., (1987). Accidents at Sea, Multiple Causes and Impossible Consequences. *International Journal of Man-Machine Studies*. Vol 27(5-6) Nov-Dec 1987, pp.587-598.
Analyzed the role of human error in 100 cases of accidents at sea heard by the Dutch Shipping Council between 1982 and 1985. Results indicate that human error played a major role in these accidents, even when errors were not recognizable before the accident occurred and were not readily apparent. The major types of human error that contributed to accidents were wrong habits, wrong diagnoses, lack of attention, lack of training, and unsuitable personality characteristics. It is suggested that these problems require specific preventive measures directed at the change of undesired behaviours.

Wertheim, A, Kemper, H., (2002). Maximal Oxygen Uptake during Cycling Is Reduced in Moving Environments; Consequences for Motion-Induced Fatigue. *Ergonomics,* 2002, Vol. 45 Issue 3. pp. 186-202.
In previous studies on physical fatigue during simulated ship movements, the apparent exhaustion of subjects after experimentation suggested that the traditional index of physical workload, oxygen consumption expressed as the percentage of peak oxygen consumption (VO_{2-peak}) measured in a separate graded exercise test (GXT), underestimates workload in a moving environment. In these studies, the GXT was carried out in a stationary environment, as is standard practice. To explain the underestimation, it was hypothesized that VO_{2-peak} might have been less if the GXT had been carried out in the moving environment. This paper reports on three experimental tests of this hypothesis, performed with a ship motion simulator and aboard a ship at sea. In all three experiments, VO_{2-peak} was indeed significantly reduced when the GXT was carried out in the

moving environment. Theoretical reasons for this phenomenon are discussed and investigated, but a clear explanation is still lacking.

Wilson, A. (1997). Work-hours in the Maritime Environment, *Transportation Research Forum, 39th Annual Meeting, Volume 2*. Virginia: Transportation Research Forum. pp.52-525. This paper discusses the work-hours that should be kept by the crew on commercial vessels (ferries, freighters, oil tankers, etc.). Contributing causes resulting in fatigue include organizational factors, ship design factors, and scheduling factors. Environmental factors such as noise, vibration, motion, and temperature and humidity extremes are also discussed. Studies by experts are reviewed to determine the proper amount of rest required to prevent a crew from becoming fatigued, proper meal scheduling and amount of sleep required. The effects of micro-sleep and sleep deprivation are evaluated with regard to safety, productivity, and morale.

Winchester, N., Sampson, H., Shelly, T. (2006*). An Analysis of Crewing Levels: Findings from the SIRC Global Labour Market Survey*. Cardiff: Seafarer's International Research Centre. The aim of this report is to consider crewing levels aboard ocean going cargo vessels and the effect of vessel size and flag on average numbers of officers, ratings, and total crew. The report is based upon the SIRC Global Labour Market Survey and specifically upon data collected in the year 2003. It draws upon information contained in crew lists provided by 3,969 vessels calling at selected ports across the world in the month of March.

Young, M (1980). *Effects of Fatigue on Human Behaviour and Performance*. Virginia: National Technical Information Service.
This bibliography cites references on the psychological and physiological effects of mental and physical fatigue. Reports on circadian rhythm, work - rest schedules, sleep deprivation, and physical endurance are included.