

## **SEAFARERS' FATIGUE: A REVIEW OF THE RECENT LITERATURE**

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### **ABSTRACT**

Fatigue has been noticeably under-researched in the maritime domain compared to other transport sectors. In a review of the literature 11 databases were searched in order to assess recent developments in the field and distil those issues of greatest concern and challenge to the seafaring community. Whilst diversity in the seafaring population has the potential to make global fatigue estimates meaningless, evidence of mis-recorded working hours shows how cultural and commercial pressures are universally shared.

### **INTRODUCTION**

This review draws together research from a large number of sources including a number of reports. Where certain reports may not be readily accessible this can be considered testament to a lack of dissemination and integration in the field. The present review goes some way towards improving this situation.

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In 1989 Brown [1] 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 are overlooking this problem. Eleven years later a review focused on the British offshore oil support industry found a similar picture to Brown, concluding that fatigue has been noticeably under-investigated in the maritime domain [2]. Interestingly both reviews note a disparity between official and anecdotal sources in terms of seafarers' fatigue which is of relevance in the modern context:

“It is apparent that although a sizeable literature of anecdotal evidence exists, up until now little valid and reliable research has been conducted in the area” [2] (p.12-13).

Where such empirical evidence continues to be lacking, a review not only highlights any progress but reveals significant gaps.

Building on work by Gander [3] this paper draws together research into seafarers' fatigue since the year 2000 with focus upon ways in which the industry might best face up to current challenges defining the global market. Papers of significance from before 2000 are also considered where previously not included in an earlier project review [2] .

## MEASURING AND DEFINING FATIGUE

Defining fatigue is necessary in order to construct theoretically rooted measurement tools. In the case of fatigue, a useful working definition is included in the International Maritime Organizations (IMO) guidelines on fatigue [4] as follows: “A reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including: strength; speed; reaction time; coordination; decision making; or balance.” (p.4)

From this definition it is clear that fatigue can be understood and measured in many different ways. This adds to the difficulty in connecting together research that has been conducted in this field.

## PREVALENCE OF FATIGUE

Fatigue is only likely to be tackled as a serious issue in the maritime industry once a reliable picture concerning its prevalence is established. Unfortunately, however, a reliable picture concerning prevalence can only be built up once fatigue is taken

seriously enough to warrant accurate and reliable reporting systems. Such a state of affairs has meant that research into fatigue prevalence has often been localised and vessel specific.

Grech, Horberry and Humphreys [5] 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 [3] ) 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 [3] 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 [3]) 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.

When evaluating fatigue prevalence the use of comparative analysis alludes to the inherent difficulty defining this concept in absolute terms. Using a questionnaire incorporating standardised measures of health and fatigue, Smith, Lane and Bloor [6] surveyed seafarers in the British offshore oil support industry and compared them with installation workers and an onshore sample. Evading any over-simplistic fatigue categorisation, however, it was found that the different groups had a different fatigue 'profile' according to the symptoms used for comparison. Whilst the onshore sample was found to have a higher proportion of respondents reporting symptoms of depression and confusion, the seafaring and installation samples conversely reported higher levels of lethargy and poor quality sleep.

As well as understandable variation in levels of fatigue between seafarers and other working populations, Smith et al. [7] showed evidence of internal diversity within the maritime community. Surveying the short sea sector in the second phase of a three phase project, Smith et al. found this sample to have a higher profile of fatigue compared with the offshore oil support sample studied in the first phase. Where such diversity is evident even at a British level it must be acknowledged that the issue of prevalence can become redundant unless tied to meaningful group classifications. Considering seafarers as an homogenous population is clearly inappropriate where working patterns and way of life can vary enormously according to a number of factors including cargo, type of trade, crew nationality and flag of registration.

## FATIGUE RISK FACTORS

Seafarers work in an environment with a number of factors commonly associated with fatigue. Long working hours, sleep disturbance and night work are all present alongside factors unique to the industry such as ship motion and noise.

### *(a) Circadian Rhythms*

Circadian rhythms relates to the way in which the body operates according to an approximately 24-hour cycle with attentional peaks and troughs at different times. It is because of this inbuilt 'biological clock' that we sleep at night and are awake during the day. If this rhythm is disrupted it is possible to feel sleepy when you should be awake (e.g. during watchkeeping), or awake when you need to be sleeping. 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 [8]. Tirilly [9] conducted research onboard two vessels, one fishing and one oceanographic, in order to study the impact of fragmented work schedules on alertness over a 24hr period. Using subjective visual analogue scales (VAS) alongside actigraph measurement, it was found that although sleep was fragmented into 2/3 episodes on the oceanographic vessel and 5/6 episodes on the fishing vessel, the 24hr circadian alertness rhythm was maintained in both instances. Interestingly Tirilly [9] points out that such sleep fragmentation should be seen as more than an occupational phenomenon with social factors such as meal times likely to play a part. The seafarers studied showed a circadianly predicted dip in alertness during the night and also a pronounced afternoon dip which raises concern in terms of accident risk.

Studying crew onboard a naval vessel, Goh [10] also investigated how circadian rhythms interact with shift duty scheduling. A group of 20 day workers were compared with 40 night workers onboard a naval vessel with salivary melatonin and cortisol used to indicate circadian variation. Whilst at a general level it was shown that shift work has a detrimental impact upon circadian rhythms, it is important to note a high level of inter-individual variation was observed which should not be underplayed. Strategies addressing fatigue may need to account for the fact that different individuals may be more suited to different shifts, a subtle variation on the person-environment fit model [e.g. 11].

### *(b) Working Patterns and Shift Schedules*

Seafarers work around the clock at the mercy of both sea and market conditions. Where shift work and unpredictability are part of maritime life, it is important to assess

what impact these factors might be having in terms of fatigue. Reviewing the literature, Folkard, Lombardi and Tucker [12] highlight three key trends which have emerged from research into shift schedules and safety: (1) risk of accident is higher working at night (and to a lesser extent working in the afternoon) compared to the morning, (2) risk of accident increases over a series of shifts, again especially at night and (3) risk of accident increases as shift length increases over 8 hours. When moving from 'onshore' to 'offshore' work environments it is possible to detect an evolutionary separation in terms of how safety culture has developed. Summarising reports published by the HSE between 1996 and 2001, Parkes [13] highlights psychosocial aspects of working in the North Sea oil industry which might appear unacceptable to an industry outsider. With nearly half of a sample of offshore managers reporting work in excess of 100 hours per week, Parkes draws attention to the danger such practice presents. In light of such demanding work conditions [13] suggestion of a survival population effect appears highly tenable with those unable to adapt to the offshore work environment no longer present in the industry. In terms of shift schedules, Parkes concludes that a fixed shift system is generally a better option where workers work the same shift for their whole 2 week tour rather than changing half way through (e.g. from night to days). Working the same shift for a whole tour clearly requires less circadian adaptation however the author also points out the pervasive desire for offshore personnel to go home 'daytime adjusted', a preference not always serviceable with a fixed shift system.

Moving from offshore installation personnel to seafarers, Burke, Ellis and Allen [14] investigated the impact of shift and tour effects in an onboard environment. From research onboard 7 short sea and coastal vessels a total of 177 seafarers completed questionnaire and objective performance tests assessing fatigue, sleep quality, reaction time, mood and health with environmental parameters also measured. Interestingly it was found that counter-directional tour trends might exist where job stress and effort increase over a tour parallel to environmental habituation to factors such as noise. In a study by Wadsworth et al. [15] tour-based fatigue trends were studied further with participant seafarers required to complete a twice-daily fatigue diary over a complete tour of duty and subsequent period of leave. Whilst Wadsworth et al. found self-reported fatigue on waking to increase over a tour of duty, fatigue on retiring (to bed) showed no such trend indicating a ceiling effect of methodological relevance. Wadsworth et al. also found fatigue to increase most noticeably during the first week of duty which highlights the rapid adjustment required when first joining a vessel. Finally, they found recovery on leave to typically take a week which highlights a qualitative dimension to off-duty time of welfare significance.

When looking for working patterns predictive of risk one method is to retrospectively analyse incidents which have occurred in order to draw out factors of

commonality. In the MAIB ‘Bridge Watchkeeping Safety Study’ [16] evidence from 66 collisions, near collisions, groundings or contacts between 1994 and 2003 was reviewed with clear patterns emerging from the analysis. Using the grounding of the MV Jambo as an illustrative example, the MAIB report highlights how a large number of the accidents studied were the result of two man bridge watch systems with a 6-on/6-off schedule employed in most cases. Rather than focusing on working hours or shift schedules, however, the report puts emphasis upon watchkeeper manning levels with a recommendation that no merchant vessels over 500gt be allowed to sail without at least a master and two bridge watchkeeping officers onboard [See also 17 for discussion]. In a case study taken from research onboard a vessel similar to the Jambo, Allen et al. [18] corroborate the seriousness of the situation in certain sectors but acknowledge the difficulty of manning a vessel which has two extremely distinct and disparately demanding modes of operation. If extra crew are placed onboard a vessel to cope with the demands of a port turn-around, including pilotage, manoeuvring and cargo preparation, then during open-sailing this extra labour could prove less than essential, a costly additional expense for an operator to carry.

*(c) Noise and Motion*

When considering the uniqueness of the onboard environment motion and noise stand out as two factors in particular which characterise the seafarer’s experience. In these areas lessons learnt concerning fatigue in other industries are of considerably less relevance. Using both subjective and objective assessment tools, Tamura et al. [19] conducted a study on three men aged 29-33 and 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. Interestingly the engine noise effect was detected less in polygraphic compared with subjective measures of sleep which highlights an interesting disparity also found in later work by the same authors. Another study by Tamura et al. [20] again looked at the effect of ship noise on sleep but substituted polygraphic for actigraphic measurement alongside a subjective questionnaire evaluating habituation processes. Whilst habituation of sleep was found to a ship noise level of 60 dB (A) in subjective measures, such an effect was not evidenced with sleep as measured using actigraphy. Alongside the relevance of the specific results in terms of noise and its effects onboard ship, these studies raise the issue of how negative factors impact upon individuals. Disparity between subjective and objective measures points towards a complex understanding of negative factors where an individual’s own perceptions and attributions can determine deleterious impact.

Where Tamura [19] [20] used a standard sample of engine noise taken from a Japanese ship, Rapisarda et al. [21] 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, they 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 [22] of 11 Norwegian vessels aimed to identify factors potentially harmful to health and found exposure to noise and indoor climate to be the most common problems identified by crew. With 44% of respondents reporting noise as a problem, Omdal suggests higher standards of noise reduction be incorporated into ship design with only 8% of crew onboard a noise-reduced vessel reporting stress from this extraneous factor. Such evidence suggests that through technology and improved design traditional hardships associated with the maritime life can be challenged and indeed overcome.

Looking at the influence of noise in conjunction with motion, Ellis, Allen and Burke [23] collected data from participants onboard 7 vessels in the short sea and coastal industry. Using parallel objective and subjective measures noise and motion were found to be associated with mood and performance although trends were found to be distinct from an earlier phase [24]. Where sector distinctions thus mediate environmental impact a multi-stressor model would appear to garner clear support [e.g. 25, 26].

#### *(d) Sleep*

Working 24 hour shift patterns on a moving vessel poses a number of obstacles to gaining sufficient restorative sleep. Crew may have to work additional hours, sleep when their body feels naturally awake and face disturbances from both crew and vessel activity. Foo et.al [27] looked at sleep specifically in relation to seafarers with a sleep deprivation study involving 20 male naval volunteers onboard a landing ship in the South China sea. Whilst in terms of manual tasks and measures of mood and sleepiness an effect of sleep loss became evident after just 6-12 hours, such an impact on cognitive and perceptual skills was not shown until 30-36 hours, an interesting impairment distinction of clear watchkeeping significance [see also 28].

Moving from seafarers to fishermen, Gander, Van den Berg and Signal [29] used a combination of logbook and actigraph measurement to assess sleeping patterns during the demanding New Zealand hoki season. Amongst conclusions drawn from the study the authors interestingly note: “On board, planning in advance for fatigue management may be relatively less important than having good contingency planning for situations where circumstances combine to produce high levels of sleep loss and fatigue amongst a significant number of crewmembers” (p. 36). They observed that avoidance of fatigue may be an unrealistic goal where unpredictable maritime conditions inevitably conspire

towards disruption. Systems need to be established that respond to fatigue rather than allowing this human factor to simply be denied.

*(e) Other Risk Factors*

A number of other factors are important in terms of understanding seafarers' fatigue. Aside from environmental and organisational factors, evidence shows that certain individual characteristics can also have an impact. For example, looking at fatigue in seafarers working on high-speed craft (HSC) in Hong Kong, Leung et al. [30] found age, perceived voyage difficulty, and experience to be important in terms of predicting fatigue levels. In terms of organisational factors, they 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.

Wadsworth et al [31] conducted a survey across three sectors of the British shipping industry looking at fatigue and associated risk factors. In line with previous research [32] on the pattern of injury risk, younger seafarers and also those working shorter tours of duty were found to report higher levels of fatigue. Other factors found to be associated with fatigue included poor sleep quality, negative environmental factors (noise and vibration), high job demand and high job stress. The authors found, however, that fatigue was best understood by looking at a combination of risk factors as experienced in the real world environment.

## FATIGUE, ACCIDENTS AND INJURIES

Where fatigue can be shown to increase accident likelihood the issue is likely to draw considerably more attention. Jensen et al. [32] conducted a questionnaire study across 11 countries with 6461 seafarers looking at factors associated with injury in their 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.

Wellens et al. [33] asked seafarers about collision experience and found not only incidence to be high but fatigue to be a potentially important contributory factor. In analysis sponsored by the U.S coastguard Raby and Lee [34] 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. [35] 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 such estimates difficult [3]. 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.

## HEALTH

Understanding fatigue as the only outcome of concern is inappropriate where additional links with health have been explored. Using a range of self-report measures, Wadsworth et.al [31] considered how experiences of fatigue might affect physical and mental health status, a complex relationship where symptomatic consequences may impact at a much broader level. The link between negative work characteristics and ill health has been well explored, however Wadsworth et al. show how perceived fatigue may prove mediatorially important in this relationship, even showing unique association worth specific note.

## CONCLUSION

Fatigue would appear to be more prevalent than the seafaring world is currently able or prepared to measure. In an industry where market competition can result in compromised standards, concern needs to be raised about pocketed crises [e.g. 18] alongside cultural malpractice undermining basic legislative safe guards [e.g. 36].

Evidence suggests multiple factors are associated with fatigue at sea which is both an ecologically valid and legislatively challenging conclusion. Between shallow but exhaustive risk factor listing and single-issue campaigning the seafaring community will undoubtedly need to prioritise, implementing strategies at once both practical and policeable.

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