The work practices of Marine Pilots: a review

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Definitions and Abbreviations

Acute Fatigue: refers specifically to fatigue experienced as a direct consequence of some undertaking; e.g. following exercise or intense mental concentration.

Alertness: optimal activated state of the brain. Without alertness there can be no attentiveness, and without attentiveness, performance is affected. Alertness is a dynamic state and may vary from second to second. When people are alert, they have a better awareness of what is happening around them and are able to think clearly and take action.

AMSA: Australian Maritime Safety Authority

Boredom: a subjective experience of tedium produced by the unchanging nature of minimal task and environmental demands, and usually accompanied by impairments in attention.

Chronic Fatigue: refers to the cumulation of fatigue. When the amount of rest achieved is unable to completely restore arousal, fatigue accumulates and manifests itself in the more severe form of chronic fatigue. This condition is associated with feelings of weariness and lethargy prior to, during and following activity and requires a prolonged period of rest in order to completely recover.

Circadian adjustment: involves phasic adjustment of the circadian rhythms so as to match an unconventional sleep-wake cycle. While partial adjustment has been reported in some studies, complete adaptation has not.

Circadian dissociation: disruption of the normal relationship between circadian rhythms and zeitgebers; as occurs in night workers who are required to work and sleep at times when they are least able to perform either activity.

Circadian Rhythms: cyclical variation of biological activities which recur approximately every 24 hours. Hormone secretion rates, arousal and performance exhibit circadian patterns. In humans, circadian rhythms are generally phased to maximise arousal and activity during the day and induce sleep at night. Circadian rhythms are not dependant upon dark and light as in conditions of constant darkness or light, cyclical variations are still exhibited.

Cortisol: hormone secreted by adrenal cortex during times of stress.

Cumulative Sleep Debt: refers to the chronic build up of sleep deprivation which occurs when successive periods of inadequate sleep are experienced.

Dept. of Transport and Comm. – MIIU: the Department of Transport and Communication – Marine Incident Investigation Unit

EEG: (electroencephalogram) a recording of the electrical activity of the brain

Entrainment: process of synchronisation of circadian rhythms with the 24 hour schedule evident in society. Entrainment is achieved by the presence of social and environmental time cues.

EOG: (electro-oculogram) an electroencephalographic tracing made while moving the eyes a constant distance between two fixation points.

Epinephrine: (also termed adrenaline) chief hormone secreted by the adrenal medulla which is associated with preparing the body for action (i.e. the flight or fight response). Some of its effects include increasing heart rate, respiratory rate and alertness. Closely associated with norepinephrine.

Fatigue: all encompassing term used to describe a variety of different experiences such as physical discomfort from overworking a group of muscles, difficulty concentrating, difficulty appreciating potentially important signals and problems staying awake. In the present context, fatigue is important if it potentially reduces efficiency, erodes the safety margin or otherwise impairs cognitive or physical performance.

GBRP: Great Barrier Reef Pilots

Insomnia: sleep disorder referring to the inability to fall asleep easily, or to remain asleep throughout the night.

Maximum Oxygen Consumption: assessment of the maximum amount of oxygen able to be taken up and used by the body during physical activity. It is used as an indicator of aerobic fitness, with higher levels of maximum oxygen consumption being associated with higher levels of fitness.

Microsleep: brief periods of no response or prolonged reaction times often evident in sleep deprived individuals.

Nap: a brief period of sleep less than 4 hours in duration. Normally taken in addition to a sustained block of sleep (i.e. 4 or more hours), however in some situations a person's sleep pattern may consist of one or more naps taken at various times throughout the day instead of a sustained block of sleep.

Near Miss: an incident in which a vessel passes unacceptably close to another ship, structure or navigational aid, or where there is an unacceptable risk of grounding, or damage to the environment.

Norepinephrine: (also termed noradrenaline) hormone secreted by the adrenal medulla. Most of it actions are similar to those of epinephrine.

NRC: National Research Council

NTSB: National Transportation Safety Board

Partial Sleep Deprivation: when sleep length is significantly reduced below usual sleep duration. Even 1.5 to 2 hours of sleep loss can have adverse effects on mood and performance.

Psychophysiological State: the psychological and physiological state of the person.

Qld Transport: Queensland Department of Transport

SIRC: Seafarers International Research Centre

Sleep Debt: the difference between a person's minimum sleep requirement needed to maintain appropriate levels of alertness and performance, and the actual amount of sleep obtained by the person. It is most frequently determined by calculating the difference between sleep duration at home when the person has no work commitments and sleep duration preceding or following work commitments.

Split Sleep: taking sleep in two or more non-continuous blocks throughout a 24 hour period.

States/BC OSTF: States/British Columbia Oil Spill Task Force

Strain: any change in the individual produced by a stressor.

Stress: the subjective experience of excessive demand on one's resources and capabilities.

Stressor: a task, environmental or personal factor responsible for the experience of stress.

Total Sleep Loss: sustained wakefulness. A period of time extending beyond usual wakeful hours during which no sleep is attained.

TSB: Transportation Safety Board of Canada

Vigilance: watchfulness; the ability to monitor and respond to appropriate stimuli.

Watchkeeping: duty involving monitoring of the ship's position and ensuring course adjustments are made as required. Watchkeeping is performed from the bridge of the ship.

Zeitgebers: (German: time givers) normal social and environmental time cues; e.g. the changing light conditions across any 24 hour period, variations in social activities and clocks.

Abstract

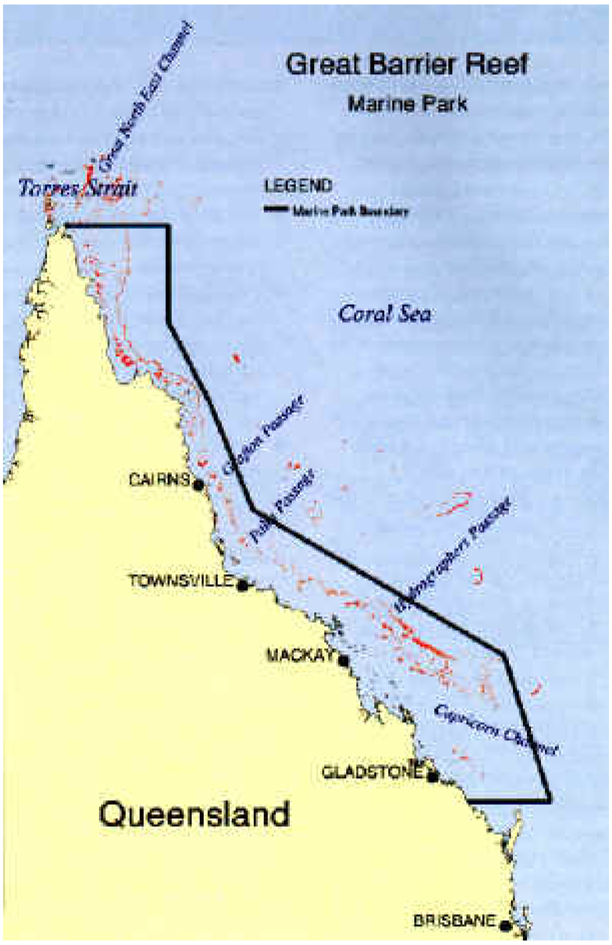
Marine pilots are a unique group of seafarers who possess high levels of local area knowledge, shiphandling skills and navigational experience. When on board vessels, the pilot's role is to work with the bridge team to ensure a safe passage through the pilotage region/s is achieved. As pilotage work is largely dependent on shipping demands and tidal conditions, work schedules are highly irregular with duties performed across all hours of the day and night. Potential stress-related outcomes of irregular work patterns are primarily associated with disrupted circadian rhythms, compromised sleep and social and domestic problems. Additionally, the long working hours, work underload, commercial pressures and on board and environmental conditions associated with marine pilotage work tends to further increase the stress experienced by pilots. This in turn can lead to a sub-optimal psychophysiological state, which may manifest as increased fatigue, mood deterioration and performance decrements.

Specifically, pilots appear to be at risk of exhibiting fatigue induced performance decrements when tasks require high levels of vigilance, decision making, judgment, memory and/or attention. When the irregular work patterns and disrupted sleep experienced by marine pilots are viewed in combination with a number of recent findings, a highly undesirable picture emerges. For instance, it has been recognised that fatigue contributes to significantly more shipping accidents than previously thought. It has also been identified that the work and sleep patterns of an individual are important factors in fatigue-related accidents and that working through the circadian troughs in alertness is associated with a higher relative risk of accidents. Hence, given the enormous environmental, economic and personal costs associated with shipping accidents, identification of the potential fatigue aspects of the work patterns of marine pilots is crucial. Additionally, training and strategies to recognise and manage fatigue in marine pilots should include both individual pilots and pilot providers.

1.0 Introduction

The Great Barrier Reef is the world's largest coral reef ecosystem, stretching 2,340 kilometers along the north-east Australian coastline. It has been registered on the World Heritage list, and in 1990, was identified by the International Maritime Organisation as the world's first, and to date only, 'Particularly Sensitive Sea Area' (Qld Transport & AMSA 1996). Navigation through the Great Barrier Reef region is made difficult by the narrowness of shipping routes, tidal effects, cross currents, and the reef itself. The high density of small boat traffic and climatic phenomena, such as cyclones, further increase the danger associated with movement through this area. These hazards, and the environmental sensitivity of the reef, resulted in legislation enacted in 1991, which enforced compulsory pilotage on the Inner Route between Cape York (latitude 10o 41' S) and Cairns (latitude 16o 40' S) and on Hydrographers Passage (Figure 1). This act applied to vessels 70 meters or more in length and to all ships carrying potential toxic pollutants (e.g. fully loaded oil tankers, chemical carriers and liquefied gas carriers) (Qld Transport & AMSA 1996).

Figure 1 *Great Barrier Reef - Torres Strait region (Qld Transport & AMSA 1996)*

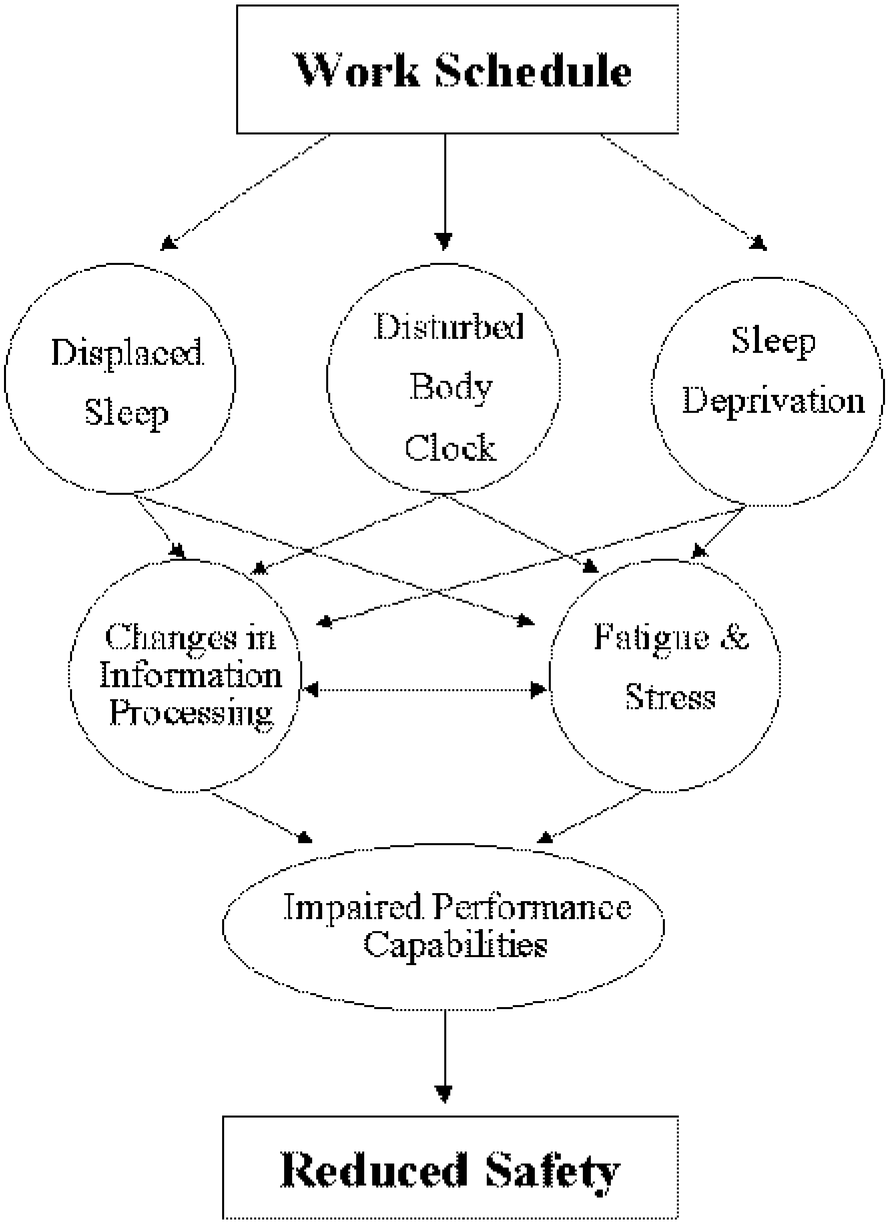


Prior to July 1993, the Queensland Department of Transport was responsible for the licencing, administration and tariff structure of marine pilotage in the Great Barrier Reef - Torres Strait region (Crone 1994). After July 1993, the regulatory functions were transferred to the Commonwealth government, at which time control over the administration of pilotage was relinquished (Crone 1994). This encouraged competition and, to date, three pilotage companies have emerged (Qld Transport & AMSA 1996). Concern over the impact privatisation of pilotage may have on safety standards has been raised, as past evidence suggests commercial pressures tend to override safety issues, whereas disciplined and regulated pilotage services enhance safety (Crone 1994; NRC 1994; States/BC OSTF 1997).

Of particular concern to regulatory bodies such as the Australian Maritime Safety Authority (AMSA), is the potential impact the work characteristics of Great Barrier Reef pilots (GBRP) may exert on fatigue. As illustrated in Figure 2, work schedules can significantly influence fatigue and stress levels by disrupting sleep, circadian rhythms and information processing. This in turn may manifest in impaired performance capabilities and reduced levels of safety. Hence, the irregular work hours, substantial amounts of night work and long on duty periods experienced by Great Barrier Reef pilots may expose this occupational group to an increased risk of fatigue development. A recent grounding in the Great Barrier Reef region highlighted the impact work practices of pilots can have on fatigue and ship handling performance (Dept. of Transport & Comm. - MIIU 1997).

Although fatigue has been recognised as a potential factor which may contribute to accidents at sea (Couper1996; McCallum et al. 1996; Osler 1997), little is known about the extent and aetiology of fatigue in marine pilots. Evidence from Australian and other seafaring groups suggests that the work and sleep conditions experienced at sea contribute to stress (Parker et al. 1997) and fatigue (Sanquist et al. 1996, 1997). To explore the potential relationship between work, sleep, stress and fatigue in marine pilots, evidence from the literature, which for the most part was not collected from studies of marine pilots, has been examined.

Figure 2 *Schematic model of the impact of work schedules on safety (Folkard, 1988)*



2.0 WORK PATTERNS OF MARINE PILOTS

Marine pilots are a unique group of seafarers who possess high levels of local area knowledge, ship handling skills and navigational experience. Their role when on board a vessel is to advise the master and navigational officers and/or manoeuvre the vessel, so that a safe passage through the pilotage region/s is achieved. At no time does the pilot's authority exceed that of the ships' master; by tradition and by law, the master remains in command at all times and is accountable for the navigation and management of his vessel (AMSA 1993; Crone 1994; NRC 1994). This, however, does not remove pilots from the responsibility they take on when guiding vessels, as their actions and conduct directly impact on the safety of the vessel, crew and surrounding environment.

Marine pilotage work is largely dependent on shipping demands and as a consequence, work schedules are highly irregular. Work may be undertaken at any time of the day or night, as is evidenced by an investigation revealing that the entire 24 hour period was represented when the starting and finishing times of marine pilotage work were analysed (Shipley & Cook, 1980). Night work is common, with preliminary findings from an analysis of GBRP work schedule files indicating that 54 percent of the ship time is undertaken between the hours of 1818 and 0525 (Parker et al. unpublished observations).

To regulate pilot workload, a number of different work roster systems are used. For example, GBRP operate on a turn system designed to ensure equality between pilots in workload, rest breaks and income, and to match pilot abilities with expected work requirements (Personal Communication - Pilot Advisory Group 4 August 1997). Work schedules involve tours of duty, during which time pilots are on call and perform one or more work assignments. Time between work assignments is spent ashore recuperating and if necessary, travelling to the next port location. For pilots who live in close proximity to their work location, recovery time may be spent at home. However, a number of GBRP live distant from their work and hence, time between work assignments is spent in pilot accommodation houses, hotels or motels. After a tour of duty has been completed, an extended period of rest at home is usually taken (Personal Communication - Pilot Advisory Group 4 August 1997).

As a result of the irregularity of pilotage work and different operations of the three pilotage companies operating in the Great Barrier Reef – Torres Strait region, the duration of tours of duty and work assignments tends to vary somewhat. However preliminary work schedule data indicated that on average, GBRP undertake just over 9 tours of duty per year, with each tour lasting approximately 17 days and involving around 5 work assignments. Work assignments averaged 40.5 hours in duration, while time between work assignments was typically around 53 hours (Parker et al. unpublished observations).

In contrast to GBRP, Port Phillip sea pilots work on a continually rotating roster system (Berger 1983, 1984). Pilots are listed on a register and work assignments are designated to those pilots whose names are at the top of the list. In this way, work assignments are performed by pilots who have had the greatest amount of rest since their last work assignment. After completing a work assignment, the pilot's name is placed at the bottom of the list.

Around 70 percent of the work performed by Port Phillip sea pilots involves guiding vessels into or out of the Port of Melbourne. Under normal circumstances, a one way voyage entails around 5 hours of navigation. However, work assignments often involve pilots performing two voyages, as the pilot first directs a ship out of the port and then guides a second vessel into the port. The voyages are usually separated by several hours, during which time the pilot tries to rest at the Queenscliff pilot house. Pilots are therefore generally away from home for some 15 hours for each work assignment, with approximately 10 hours of navigation being performed. Time off between work assignments varies, but seems to be around 30 to 40 hours (Berger 1983, 1984).

Stabilised watch systems are another type of work roster used in some pilotage districts in the United Kingdom (Shipley & Cook 1980). These systems involve predetermined on duty and off duty periods, such as 24 hours on, 48 hours off, and are far more predictable than either the turn or rotating roster systems as pilots are informed of their duty periods and time off in advance (Shipley & Cook 1980).

To reach the vessel pilots have been assigned to, it is often necessary for helicopters or launch vessels to be used. Transit times vary depending on the distance to be travelled and transportation mode used, but in some instances in the Great Barrier Reef - Torres Strait region, launch trips may be up to 3 hours in duration (Personal Communication, Iain Steverson 28 August, 1997). The pilot is then required to board the ship, which is still moving, by way of a ladder (AMSA 1993; Australian Reef Pilots Ltd. 1996).

The duration of on duty periods are influenced by a number of factors including the shipping route being travelled, the type, size, draught and speed of the vessel, the prevailing weather and tidal conditions and the amount of shipping traffic encountered (Personal Communication - Pilot Advisory Group 18 September, 1997). The immense size of the area serviced by GBRP means that some on duty periods for this group of pilots are in excess of 60 continuous hours (Dept. of Transport & Comm. - MIIU 1997; Parker et al. unpublished observations). While not all of this time is spent navigating the vessel, pilots are on call at all times while on duty and have no predetermined rest breaks in their schedules.

Throughout a work assignment, the nature of pilotage tasks in terms of physical and mental activity is quite diverse. Acts such as boarding and disembarking are associated with near maximal levels of physical exertion for some of the older pilots (Berger 1983, Shipley 1978), however at other times, physical activity

is minimal. Likewise, the type of cognitive attributes required varies, with close quarters work involving complex decision making and calculations, while watchkeeping and monitoring the ship's position in open waters necessitates high levels of vigilance.

In summary, marine pilots are a unique group of seafarers who possess high levels of local area knowledge, ship handling skills and navigational experience. Their work tends to be irregular, both in terms of its timing during the 24 hour cycle, and in relation to the duration of on duty periods and time off between work assignments. This is, to a large extent, determined by the characteristics of the pilotage region (i.e. length of shipping routes and shipping demands), however work roster systems may also influence the regularity of the work. The nature of pilotage work in terms of physical and mental activity, varies considerably throughout a work assignment.

3.0 Work and sleep

Occupations involving work outside normal hours can have a profound effect on sleep quantity and quality (Akerstedt 1991, 1995; Folkard 1996a; Knauth & Costa 1996). Sleep taken after night work and to a lesser extent, before morning work, tends to be significantly shorter and of inferior recuperative value compared with sleep taken following afternoon work (Folkard & Barton 1993; Kecklund et al. 1997; Tilley et al. 1982). Subjective ratings of sleepiness and fatigue are subsequently greater during night and morning shifts (Akerstedt 1995; Kecklund & Akerstedt 1993; Kecklund et al. 1997; Luna et al. 1997), and in some instances, sleepiness is severe enough to result in night workers unintentionally falling asleep while on duty (Gold et al. 1992; Luna et al. 1997).

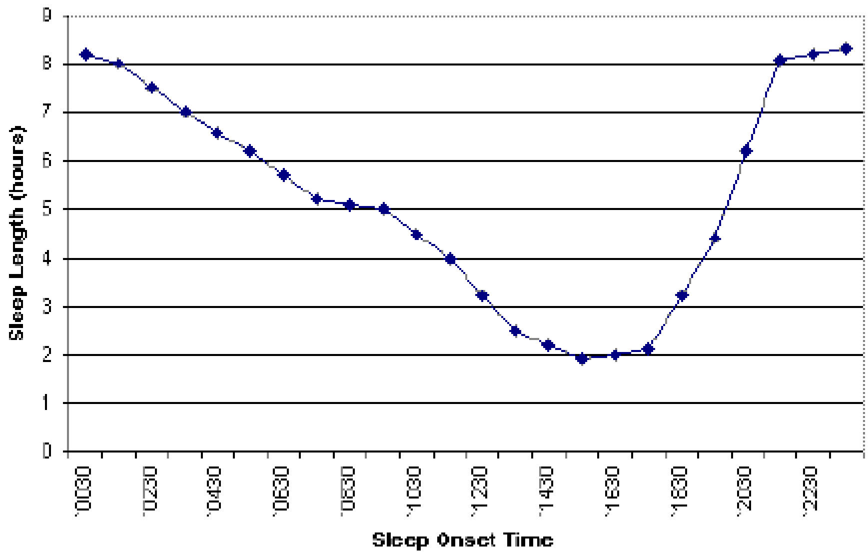
The irregular work schedules of marine pilots impact on sleep. When on duty, 31 percent of pilots servicing the Great Barrier Reef - Torres Strait region attained an average of less than 4 hours sleep per day, while 65 percent secured between 4 to 6 hours per day (Parker et al. 1997). Thus some 96 percent of GBRP were working after experiencing, at best, 6 hours of daily sleep. The sleep obtained when on duty also tended to be of inferior quality, with over 55 percent of the pilots rating their sleep as fair, poor or very poor (Parker et al. 1997). In contrast, when the same group of pilots were at home, over 75 percent reported 7 to 8 hours of sleep which was of good to very good quality (Parker et al. 1997). These findings seem to indicate that the reduced amounts of sleep experienced by GBRP when on-duty are a function of the work conditions, rather than personal choice.

Marine pilots from the United Kingdom (Shipley & Cook 1980), the Netherlands (de Vries-Grierer 1982), the United States (Sparks 1992) and the Port Phillip region of Australia (Berger 1984) have reported similar sleep problems. The irregularity of pilotage work also appears to contribute to a higher prevalence of sleep disorders, as 7 to 36 percent of marine pilots were self-reported insomniacs (Berger 1984; Shipley 1978; Sparks 1992). In comparison, only 5 to 6 percent of the general population classified themselves similarly (Lack et al. 1988; Wilson & Lack 1983).

Other occupational groups operating on irregular work schedules have also reported compromised sleep (Bisson et al. 1993). Three groups of military personnel involved in Operation Desert Shield were studied over a single 7 to 9 day round trip involving 2 to 3 flights in the United States to pick up passengers or cargo, an eastbound flight to Europe, a quick return flight to Saudia Arabia, a westbound flight back to the United States and an additional flight to home station. Duty days of 20 hours were common, with flights being performed at various times of the night and day. Crews were often required to sleep during local daylight hours, in sleeping and billeting facilities which were sometimes less than ideal. These conditions, which are similar to the conditions experienced by marine pilots, resulted in many crew members finding it difficult to obtain 4 or more hours of continuous sleep, and often crew were awake for some 7.5 to 10.3 hours prior to beginning duty. As a consequence, fatigue ratings during subsequent flights were substantially increased and there was some evidence of impaired performance (Bisson et al. 1993).

Some of the difficulties associated with achieving adequate sleep when work is performed during unconventional hours can be explained by the fact that sleep displays a strong time of day effect. Sleep onset that occurs after midnight results in a progressive shortening of sleep length, such that a 1400 to 1800 hour bedtime culminates in only approximately 2 hours sleep (Figure 3). This effect has been attributed to underlying circadian cycles and in particular, the close relationship between sleep duration and the body temperature rhythm (Akerstedt 1995; Folkard 1996a; Scott & Ladou 1990). As a consequence, morning sleep after night work is naturally shortened.

Figure 3 *Total sleep time as a function of sleep onset at different times of the day (after Folkard 1988)*



The concept of the 'forbidden zone' of sleep has also shed some light on why sleep prior to early morning work tends to be of reduced quantity. Previously it was assumed that conflicting social, domestic and/or family demands resulted in shiftworkers failing to adjust their bedtime to take into account their early rising time when working morning shifts. However, an alternative explanation proposed by some researchers is that circadian influences may greatly reduce sleep propensity during the evening hours preceding an individual's habitual bedtime (Akerstedt 1995; Cabon et al. 1991; Folkard 1996a; Folkard & Barton 1993; Lavie 1991). This period of decreased sleep propensity has been termed the 'forbidden zone' and makes the early initiation of sleep extremely difficult (Akerstedt 1995; Folkard 1996a; Lavie 1991).

Additionally, the importance of the sleeping environment on sleep quality and quantity cannot be underestimated. Ideally, sleep should be taken in a dark quiet room, which is comfortable in temperature and has an adequate flow of fresh air (Rosekind et al. 1996; TSB 1997). However, it is not always possible to achieve such conditions during daytime sleep or when sleeping in alternative accommodation as GBRP are frequently required to do. Exogenous factors such as increasing temperatures and natural sunlight can make the sleep environment uncomfortable and outside noise and activity commonly cause disruptions (Akerstedt 1995; Cabon et al. 1991, 1993; Rutenfranz et al. 1988).

When insufficient amounts of sleep are obtained over several consecutive days, a cumulative sleep debt is incurred (Folkard 1996b; Gillberg 1995; Knauth 1993, 1996; TSB 1997). Evidence supporting this concept can be sought from the work of Tilley and colleagues (1982) who noted that nightworkers obtained significantly less sleep and exhibited a progressive impairment in reaction time performance over the course of a working week as compared to day and afternoon workers. This finding was thought to represent an accumulation of partial sleep deficits and the resultant build up of fatigue

(Knauth 1996; Folkard 1996b; Tilley et al. 1982). In light of these findings, it has been suggested that shiftwork schedules should not involve anymore than three night shifts in succession (Knauth 1993, 1996).

By comparing the average sleep duration of GBRP when at home and when on duty, it can be noted that during work assignments pilots incurred an average sleep debt of 2.8 hours per night (Parker et al. unpublished observations). This result was more than double the figures reported for other Australian seafarers (Parker et al. unpublished observations) and American merchant marine personnel (Sanquist et al. 1996). Hence, it is possible that over the course of longer work assignments, GBRP may be susceptible to exhibiting fatigue-related performance decrements induced by a cumulative sleep debt.

That pilots are on call at all times when on duty may also adversely affect sleep. Torsvall and colleagues (1987, 1988) documented reductions in the duration and perceived quality of sleep of on call ships' engineers, even when sleep was not disturbed. Additionally, adjustments in temporal patterning of sleep and elevated resting heart rates were observed. As a consequence, ratings of fatigue were increased the following day. These results led the authors to conclude that the apprehension associated with this type of work induces substandard sleep (Torsvall et al. 1987; Torsvall & Akerstedt 1988). Comparable results have also been noted in physicians on night call duty (Arnetz et al. 1990) and in on call transplant co-ordinators (Smithers 1995).

Additionally, the short and fragmented nature of sleep obtained by pilots when on duty can significantly reduce recuperative value. A study examining the sleep patterns of US merchant marine personnel identified that those personnel involved in a 4 hours on, 8 hours off watchkeeping system were more likely to attain their sleep in 2 or more separate episodes and to report lower quality sleep as compared to personnel in command, daywork and steward departments (Sanquist et al. 1996). This finding was attributed to the fact that the latter groups of personnel generally obtained a single block of sleep during the night and hence, were sleeping at times which were more consistent with normal human physiology (Sanquist et al. 1996). Studies of European merchant marine watchkeepers (Rutenfranz et al. 1988) and long haul truck drivers (Hopkins 1992) have revealed similar results.

Hence it would seem that several aspects of marine pilotage work may adversely affect sleep. The irregular timing of the work, the fragmented nature of sleep obtained when on duty, and the variable quality of sleeping facilities available to pilots when staying in alternative accommodation on ship and ashore can reduce both the quantity and quality of their sleep. The reasons for this principally seem to be endogenous in nature (i.e. related to underlying circadian rhythms), however exogenous factors such as noise, light and heat may also contribute.

4.0 Work and stress

Occupational stress arises when perceived work demands exceed an individual's resources and capabilities (Hockey et al. 1989; Mendelson 1990). This source of stress is a function of several interacting variables including the nature of work tasks, the work environment, personal characteristics and the level of support available to the person (Cox & Griffiths

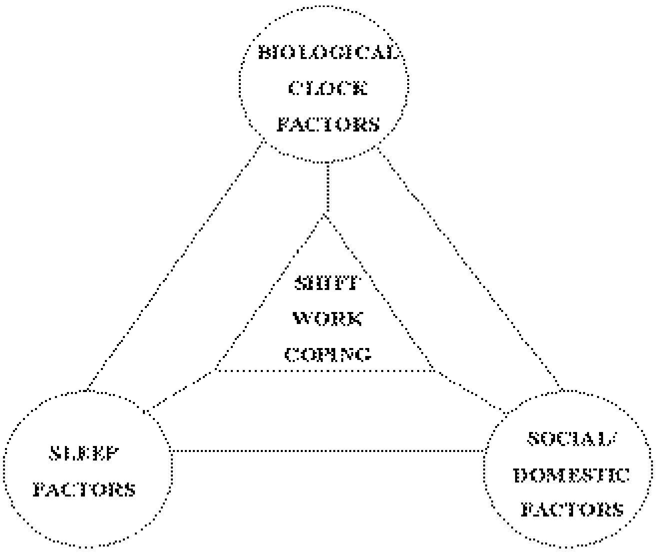
1995). A person’s perceptions are an important determinant of the amount of occupational stress experienced and as a consequence, it is difficult to quantify the stressfulness of work conditions. However, conditions which have the potential to induce stress have been identified (Kasl & Amick 1995), and in the following section, the main aspects of marine pilotage work which may contribute to pilot stress are detailed.

4.1 Irregular timing of pilotage work

A potential source of stress for marine pilots is the irregular timing of their work. Work undertaken during unconventional hours of the day places greater demands on employees than work performed during normal daytime hours. This has been substantiated by investigations showing night work to be more taxing than day work, as indicated by greater decrements in performance and well-being (Bohle & Tilley 1989; Meijman et al. 1993; Totterdell et al. 1995). Similarly, the early rising time associated with early morning work seems to cause additional strain for workers (Bauer 1993; Kecklund et al. 1997).

The increased levels of stress associated with irregular work hours relates to the impact such hours have on circadian rhythms, sleep and social and domestic factors (Monk 1989; Monk & Folkard 1983, 1992). As encapsulated in the model developed by Monk (1989) (Figure 4), these three interrelated areas affect a person’s coping ability. For strain to be completely absent, each area must be functioning well (Monk 1989; Monk & Folkard 1992). Hence, if a worker is facing imminent divorce because his partner is dissatisfied with the home/work situation, strain will be experienced irrespective of how well circadian rhythms have adapted or the quality and quantity of sleep achieved. It is therefore important that all three areas are addressed when considering the impact of irregular work hours on employee stress (Monk 1989; Monk & Folkard 1992).

Figure 4 *Schematic model of the three interactive factors determining shift work strain (after Monk 1989)*



4.1.1 Circadian factors

Circadian rhythms are cyclical variations in biological functions and behaviours which recur approximately every 24 hours (Griffiths 1993; Luna 1997; TSB 1997). Through the presence of social and environmental time cues (referred to as zeitgebers), these rhythms have become entrained to maximise wakefulness and activity during the day, and induce sleep at night (Folkard 1996a; Monk 1991; Monk et al. 1997; Monk & Folkard 1983, 1992; TSB 1997).

Work performed during unconventional hours of the day causes disharmony between a person's circadian rhythms and the normal social and environmental zeitgebers. As a consequence, circadian dissociation occurs (Griffiths 1993; Luna 1997; Rosekind et al. 1996; Scott & Ladou 1990). In such situations, people oppose the normal diurnal nature of the human body by attempting to maintain high levels of alertness when their body is anticipating sleep, and by trying to sleep when alertness and arousal are naturally increasing. This induces a sub-optimal psychophysiological state (de Vries-Griever & Meijman 1997) which may manifest in the form of increased fatigue, mood deterioration and performance decrements (Condon et al. 1988; Luna 1997; Monk 1989; Monk & Folkard 1992: Rosekind et al. 1996). Additionally, there is substantial evidence which suggests long term health consequence may arise (Costa 1996; Griffiths 1993; Monk & Folkard 1992; Scott & Ladou 1990).

While it is possible for circadian rhythms to adjust to unusual work routines, the process is slow and is inhibited by the presence of social and environmental zeitgebers (Monk 1989; Monk & Folkard 1983, 1992;

Samel & Wegmann 1987; TSB 1997). As a consequence, there is generally little, if any circadian adjustment to work schedules involving frequent changes in work times (Colquhoun 1985; Colquhoun et al. 1987; Costa 1993; Luna 1997; Monk & Folkard 1992; Samel & Wegmann 1987). In fact, even permanent night workers typically fail to exhibit complete circadian adjustment to their nocturnal work routine, as during time off they revert back to a day orientated schedule (Folkard 1996a; Luna 1997; TSB 1997). In light of these findings, there is a high probability that many marine pilots may experience circadian dissociation. Lending support to this proposal is the finding that epinephrine, norepinephrine and cortisol secretion patterns of Port Phillip sea pilots all show significant deviations from expected circadian patterns (Berger 1987).

4.1.2 Sleep factors

As was identified in the previous section of this report, schedules which incorporate work outside normal hours are associated with compromised quality and quantity of sleep, and a higher prevalence of sleep disorders (such as insomnia). In turn, the demands on the employee are increased as greater effort is required on the worker's behalf to overcome the fatigue and performance decrements induced by poor sleep.

4.1.3 Social and domestic factors

Irregular work hours can create a plethora of social and domestic problems for the worker (Monk 1989; Monk & Folkard 1983, 1992). Great Barrier Reef pilots indicated that the home-work interface (i.e. the transition from home to work and vice-versa) was the most stressful aspect of their work (Parker et al. 1997). This finding is consistent with what has been reported by other Australian seafarers (Parker et al. 1997), partners of Australian seafarers (Foster & Cacioppe 1986) and a group of US commercial airline pilots (Cooper & Sloan 1985). Dissatisfaction has also been expressed by marine pilots about their inability to commit themselves to regular outside interests, and over the fact they are often required to cancel appointments and plans due to unexpected work (Berger 1984; Shipley 1978; Sparks 1992).

The social and domestic problems induced by irregular work schedules have also been reported by other groups of shiftworkers. German nurses working morning shifts beginning at or before 0600 hours indicated married life was made more difficult due to differences in work patterns between partners, and that early starting times were incompatible with having dependent family members, such as young children or elderly parents at home (Bauer 1993). Additionally, many nurses expressed dissatisfaction over the social isolation experienced as a consequence of their irregular work hours (Bauer 1993). Likewise, 8 and 12 hour shiftworkers from a North American petrochemical company had lower levels of satisfaction with the amount of time available to them for personal and family pursuits, as compared to day workers (Jaffe et al. 1996).

The social and domestic problems experienced by shiftworkers and others involved in irregular work schedules can, at least in part, be attributed to the disalignment of their work and leisure times from society ‘norms’. All workers rate the evenings and weekends highest in terms of leisure time value (Hornberger & Knauth 1993), and hence work performed during these times interferes with the person’s ability to make regular contact with friends and relatives (Knauth & Costa 1996).

Additionally, it is not only the worker who experiences social and domestic strain as a consequence of irregular work hours, but also the worker’s partner and family. In a study of the perceptions and feelings of shiftworkers’ partners, more than 50 percent of respondents indicated that their partner’s work schedule disrupted their personal and joint social life, created conflict in their relationship with their partner and limited the amount of contact their partner had with their children (Smith & Folkard 1993).

Similarly, a survey of 52 wives of Australian seafarers revealed that 83 percent of the wives experienced stress when their partner was due home and due to return to sea, and 79 percent of children were perceived by their mothers as experiencing stress prior to and after the arrival home of their father (Foster & Cacioppe 1986). That the wives of marine pilots have expressed dissatisfaction over the disruption induced by their husband’s work schedules and the difficulties in planning family and social events (Berger 1983; de Vries Grierer 1982), suggests the partners’ of marine pilots are not immune to the social and domestic strain caused by irregular work schedules.

4.1.4 Moderating Factors

Certain individual characteristics are able to moderate the amount of stress experienced as a function of irregular work hours. The two personality traits of 'morningness/eveningness' and introversion/extroversion are related to circadian phasing and influence a person's adaptation to irregular work hours (Folkard 1983, 1996a; Harma 1993; Monk & Folkard 1983, 1992). Morning people and introverts are more alert during the morning and have slightly earlier peaks in their temperature rhythm than evening people and extroverts (Folkard 1983; Harma 1993; Monk & Folkard 1983, 1992). As a consequence, the former group tend to adapt less well and have a lower tolerance for night work (Folkard 1983; Harma 1993; Monk & Folkard 1983, 1992).

Poor levels of physical fitness can reduce one's ability to handle the stresses associated with irregular work hours. In a group of shiftworkers who underwent a 4-month training program, the significant increases in maximal oxygen consumption which occurred were accompanied by reports of less general fatigue, fewer musculoskeletal complaints and increased sleep duration. While no evidence of a direct interaction between fitness level and circadian rhythms was found, it appears that higher levels of physical fitness may improve tolerance to shift work through other avenues (Harma 1993).

Increasing age negatively affects tolerance for irregular work hours as changes in the sleep-wake cycle occur and there is a tendency for people to become more morning orientated as they age (Folkard 1996a; Harma 1993; Monk & Folkard 1983, 1992). Additionally, people with a smaller temperature rhythm amplitude and who maintain higher levels of positive moods over a sleepless 24 hour period prior to entering shiftwork, may adapt more easily and have greater tolerance for working irregular hours (Vidacek et al. 1993).

While each of the above personal characteristics can influence tolerance for irregular work hours, it has been suggested that the most important factor may be commitment to a work schedule (Harma 1993; Monk & Folkard 1983). Commitment implies the person's willingness to schedule their lives, and especially their sleeping habits, around their job. Several studies (Barton et al. 1993; Barton 1994; Verhaegen et al. 1987) have compared nurses and midwives who freely chose to work permanent night shifts to those staff on rotating shifts involving predominantly day work but some night work. Results revealed that night work caused fewer sleep, social and domestic problems in permanent night shift nurses, due to their greater commitment in scheduling their lives so as to minimise the disruption caused by night work (Barton et al. 1993; Barton 1994; Verhaegen et al. 1987).

The complete irregularity of pilotage work makes it somewhat more difficult for marine pilots to schedule their lives around their job. Pilots often have little advanced warning of when their next work assignment will be and the variable starting and finishing times prevent pilots from establishing a daily routine.

4.1.5 Summary

In summary, the interacting and compounding effects of circadian dissociation, poor sleep and social and domestic problems arising from the irregular timing of pilotage work, can significantly contribute to the stress experienced by marine pilots. These factors may reduce the psychophysiological state of the person, such that a higher prevalence of fatigue, reduced levels of well-being and performance decrements manifest. In the long term, health may also be adversely affected. Individual characteristics such as personality traits, level of physical fitness, age and commitment to a work schedule, play an important role in the adaptation and tolerance for work outside normal hours.

4.2 Long working hours

Long working hours increase the demands placed on workers by requiring greater effort to maintain performance levels in the face of heightening fatigue, and by increasing exposure to other workplace stressors (Spurgeon et al. 1997). This has been evidenced in a number of occupational groups. Intensive care unit nurses involved in 12 hour shifts reported higher levels of chronic fatigue, cognitive anxiety and emotional exhaustion, as compared to nurses working 8 hour shifts (Iskra-Golec et al. 1996).

The long working hours and resultant sleep deprivation experienced by physicians undergoing residency training adversely affects mood (Dreary & Tait 1987; Nelson et al. 1995) and has been associated with a higher prevalence of somatic symptoms such as ‘feeling run down’ and ‘feeling ill’ (Baldwin et al. 1997). Work performance may also be impaired as indicated by subjective reports (Baldwin et al. 1997) and objective measures of short term memory function (Dreary & Tait 1987) and creative thinking (Nelson et al. 1995).

An investigation examining the effect of overtime work on the cognitive performance of automotive workers (Proctor et al. 1996) revealed that workers who had engaged in overtime work during the week prior to testing, performed significantly worse on tests requiring attention and executive function skills than workers who had undertaken no overtime (Proctor et al. 1996). Mood was also found to be adversely affected, as there were increased ratings of depression, confusion and fatigue amongst workers who had performed overtime work (Proctor et al. 1996).

As marine pilots, and in particular GBRP, are often required to undertake prolonged on duty periods, it is possible they may be susceptible to stress from this aspect of their work.

4.3 Boredom

Situations of work underload can induce stress (Cox & Griffiths 1995; Fisher 1993; Hockey et al. 1989; Melamed et al. 1995) and hence, the high levels of vigilance, watchkeeping and monitoring required of marine pilots may act as stressors (Dyer-Smith 1983a, b). These tasks, which are typically conceived as representing work underload (Melamed et al. 1995), require constant attention yet provide little stimulation. As a consequence, prolonged exposure typically reduces physiological arousal and causes boredom in most people (Dyer-Smith 1983a, b; Fisher 1993; Melamed et al. 1995).

A study which examined factors associated with work-induced fatigue (Finkelman 1994) supported the concept that work underload can lead to reduced levels of arousal. A computer survey of the records of 3,705 temporary employees who had reported experiencing fatigue during their work assignments, revealed that lack of job challenge, inadequate information processing demands and low levels of job control were factors frequently associated with fatigue (Finkelman 1994). Similarly, physiological evidence in the form of heart rate measurements (Cook & Shipley 1980) and EEG and EOG data (Cabon et al. 1993) indicates work underload results in reduced levels of vigilance and fatigue.

The stressful aspect of work underload seems to be the conflict between the need for sustained alertness and the arousal reducing qualities of the task (Dyer-Smith 1983a; Melamed et al. 1995). In these situations, workers are required to exert additional effort in order to maintain appropriate levels of arousal (Costa 1993; Dyer-Smith 1983a). While performance decrements may or may not manifest, the greater effort invested by employees induces earlier and more severe fatigue (de Vries-Griever & Meijman 1987; Hockey 1997). This is especially true during nightwork when the fatigue bought about by light workloads exacerbates pre-existing fatigue from other potential stressors such as circadian dissociation, an acute or chronic sleep debt and long working hours (Luna 1997).

4.4 The work roster system

The type of work roster systems used in certain pilotage regions may impact on the stress experienced by pilots. Stable work roster systems in which pilots are advised of their duty periods and time off in advance, seem to cause less disruption to the pilot's family life and interfere less with eating and sleeping habits (Shipley & Cook 1980). Job satisfaction also tends to be higher amongst pilots on more stable work roster systems (Shipley & Cook 1980; Sparks 1992) and lower levels of sick leave reported (Sparks 1992). Additionally, there are fewer reports of 'near misses' when pilots are involved in more stable roster systems (Sparks 1992). It would therefore seem that the greater predictability associated with this type of roster system causes less strain and fewer personal problems for pilots (Shipley & Cook 1980).

4.5 The Uncertainty of pilotage work

Pilotage work is associated with much uncertainty, as often pilots are unaware of when their next work assignment will be until they receive the phone call informing them of the ship's estimated time of arrival or departure. As a consequence, stress may be experienced over this aspect of the work as the pilot's personal life can be significantly disrupted (Berger 1984; de Vries-Grierer 1982; Shipley & Cook 1980; Sparks 1992). The pilot's ability to plan ahead and organise personal, family or social events is severely limited (Berger 1984; Shipley & Cook 1980; Sparks 1992), and the uncertainty of pilotage work is often cited as a source of domestic tension (de Vries-Grierer, 1982; Shipley, 1978). Comments made by other groups of Australian seafarers about the adverse affects of the uncertainty of their work, are consistent with those made by marine pilots (Parker et al. 1997).

Additionally, it has been recognised that the uncertainty experienced during the on call period prior to a work assignment can adversely affect the mood and well-being of marine pilots. An investigation of 7 pilots from the United Kingdom revealed that during the on call period, self ratings of tension progressively increased due to the pilot's increasing level of concern over whether he would be required to work and what type of job he may be assigned to (Cook & Shipley 1980).

4.6 Commercial Pressures

Changes arising as a consequence of greater commercial pressures may indirectly increase the stress associated with marine pilotage. It has been documented that some shipping companies are cutting running costs by minimising the amount of maintenance and upgrading work being performed on their vessels, and by employing cheap seafaring labour (NRC 1994). Hence, a greater load is placed upon pilots who are required to safely guide substandard ships through difficult waters, whilst working with substandard crews (NRC 1994). Reports also exist which indicate that in certain situations the full load of passage planning and safe navigation is being placed upon the pilot, as the master of the ship is either too fatigued or unable to communicate with the pilot to provide any support (NRC 1994). Additionally, reduced crew sizes and the need for rapid port turnaround times have resulted in greater workloads for all shipboard personnel (NRC 1994).

Recent commercial changes have added to the stress being experienced by GBRP. Since the formation of the three separate pilotage companies, there have been great fluctuations in work availability for the different pilotage groups. As a consequence, concern has been expressed by pilots over issues such as job security and personal income (Personal Communication - Pilot Advisory Group 4 August, 1997).

4.7 Onboard and Environmental Conditions

There are many aspects of a ship's physical environment which can impose strains upon personnel. Noise and mechanical vibrations propagated from engines, generators, ventilators and air conditioning units are present at all times during a voyage. Both of these factors have been associated with increasing levels of discomfort and fatigue as a function of exposure time (Kjellberg et al. 1985; Kokosy 1989; Osler 1997; Pelmear 1995; Rosler 1994). Noise and vibration also contribute to poor sleep (Osler 1997; SIRC 1996) and interfere with communication (Oborne 1995). Additionally, in the long term there may be detrimental effects on the person's health (Filikowski 1989; Kokosy 1989; Oborne 1995; Pelmear 1995; Rosler 1994).

Rolling and pitching of ships tends to be minimal when aboard large cargo carriers, however it is a factor which pilots have to contend with when travelling to and from work assignments in launch vessels and when working aboard smaller ships. The constant motion of smaller vessels can be extremely onerous, even for experienced sea personnel, and rough weather further exacerbates the conditions (Filikowski 1989). The relatively high prevalence of sea sickness amongst marine pilots may be indicative of this occupational hazard (Shipley 1978). Additionally, as ship motions are mainly counteracted by motions in the lower extremities and lumbar spine, physical strain is induced in these parts of the body (Torner et al. 1994).

The design and working condition of the bridge can impact on the stress experienced by marine pilots. Modern navigational equipment which is in good working order can significantly reduce the strain associated with piloting vessels, as it enables rapid access to accurate information relevant to piloting (NRC 1994). However, in many situations the equipment on board vessels tends to be somewhat outdated and often in a poor state of repair. This in turn substantially increases the load placed on pilots, especially when guiding vessels through difficult navigation regions (Personal Communication - Pilot Advisory Group 18 September 1997).

The lighting conditions on the bridge are important. Bright lights assist in maintaining arousal however, at night, it is beneficial to have the bridge interior somewhat dimmed to enable quick adaptation of the eye to the outside surroundings (Heinecke & Dahlmann-Heinecke 1989). Additionally, it has been identified that the colour and brightness of display units influences information retrieval. Ideally there should be as little difference as possible between the outside environment and the colour of display backgrounds. At night it is therefore preferential to have a dark background, whereas during the day a light background is more favourable (Heinecke & Dahlmann-Heinecke 1989). Textual messages should be presented in a contrasting colour to the background to improve legibility (Heinecke & Dahlmann-Heinecke 1989; Oborne 1995). As a consequence, bridge systems which are adaptable have the greatest potential for reducing strain, as they allow the watchkeeper to alter the bridge set up so as to suit his own preferences and accommodate the outside conditions (Heinecke & Dahlmann-Heinecke 1989).

Furthermore, environmental conditions can significantly impact on stress levels. Unfavourable weather, poor visibility and high density shipping traffic are but a few of the factors which can place greater demands on pilots when guiding vessels through difficult waters (Filikowski 1989; Personal Communication - Pilot Advisory Group 18 September 1997).

It is therefore evident that the onboard and environmental conditions can contribute to overall stress levels experienced by personnel. These factors on their own may not be significant stressors; however in their presence, operators are required to exert more effort in order to accomplish a given task, thereby giving rise to fatigue (Boucsein & Ottmann 1996; Oborne 1995). Additionally, in situations of work overload and/or when combined with other stressors, the stress factors identified above have an additive effect which can negatively affect performance, mood and health (Oborne 1995).

4.8 Non-Work Related Issues

The stress experienced by marine pilots as a function of their work may be intensified by concern over non-work related issues. Findings from the aviation industry have indicated that factors outside the job, and in particular the stability of the pilot’s home life and marital relationship, significantly influence the pilot’s level of stress and coping ability (Cooper & Sloan 1985; Karlins et al. 1989). As many GBRP are separated from family for the duration of their tour of duty, concern over non-work related issues may add to the stress experienced by marine pilots.

4.9 Summary

In summary, there are many aspects of marine pilotage work which can potentially induce stress. As a consequence, the psychophysiological state of the pilot may be reduced to such a level that fatigue is experienced and performance, health and well-being are impaired. Personal characteristics and the effectiveness of the pilot's support network are important moderating factors in determining how much stress pilots experience.

5.0 Sleep, fatigue and performance

Research relating to sleep loss, performance and fatigue can be broadly divided into two categories: (i) studies which have examined the effects of total sleep loss, and; (ii) studies which have investigated the impact of partial sleep deprivation. As marine pilots are more susceptible to experiencing chronic reductions in sleep rather than prolonged periods of total sleep loss, the following section briefly reviews the former category of studies and more thoroughly details research relating to the effects of partial sleep deprivation.

5.1 Total Sleep Loss

There is a large body of evidence in the literature indicating that fatigue, mood and performance are adversely affected under conditions of sustained wakefulness. How and colleagues (1994) examined the effects of total sleep deprivation in 20 male naval seamen and found significant reductions in mood and performance in tasks requiring cognitive, vigilance, psychomotor and to some extent, physical functions. Performance deteriorated in basically two stages, with an initial significant drop occurring after 36 to 42 hours of sleep deprivation, followed by a further continuous decline after 66 to 72 hours.

McCarthy and Waters (1997) documented reductions in attention demanding cognitive tasks in 71 male undergraduate students following 36 hours of sleep loss. Specifically, sleep deprived individuals were slower to attend to relevant environmental stimuli, exhibited less response to stimuli, lost interest in stimuli more rapidly and were slower and more variable in their processing of stimuli (McCarthy & Waters 1997).

Similarly, progressive reductions in vigilance performance have been reported during a 30 minute monotonous tracking task after one nights sleep deprivation (Bohnen & Gaillard 1994). Interestingly, performance on a time estimation task was not significantly affected; however the higher levels of stimulation and performance feedback associated with the latter task may have enabled subjects to overcome any effects of 1 night's sleep loss for the 30 minute testing session (Bohnen & Gaillard 1994).

By examining the way in which mood and performance deteriorate over periods of sustained wakefulness, researchers have identified that both endogenous and exogenous factors are involved. For example, Babkoff and colleagues (1991a) assessed subjective ratings of sleepiness over 72 hours of sleep deprivation in 11 male subjects, and indicated that both accumulated sleep loss and circadian factors were significant in determining the subject's estimates of sleepiness. Sleepiness ratings progressively increased over the sleepless period and showed distinct circadian oscillations, with the highest ratings of sleepiness occurring between 0200 and 0600 hours, while the lowest ratings were reported at 1000 hours and between 1800 and 2000 hours.

Likewise, Horne et al (1983) noted a significant stepwise decline in intrinsic capacity to detect signals on an auditory vigilance task during 60 hours of sleep loss. Performance fell sharply over usual sleeping periods and levelled out during the day. The lack of performance deterioration over the day was thought to be a reflection of daytime circadian improvements in performance counteracting performance declines due to sleep loss (Horne et al. 1983).

Recent work by Australian researchers (Dawson & Reid 1997) has attempted to quantify the level of cognitive psychomotor performance impairment induced by sustained wakefulness with alcohol intoxication. Forty subjects participated in the study involving two counter-balanced conditions. In one condition subjects remained awake for 28 continuous hours (from 0800 to 1200 hours the following day), while in the second condition subjects consumed 10-15 grams of alcohol at 30 minute intervals (from 0800 hours) until their mean blood alcohol concentration reached 0.10 percent. In both conditions cognitive psychomotor performance was measured by way of an unpredictable tracking task, at 30 minute intervals from the start of the session. The results indicated that performance deteriorated significantly in both conditions. By equating the level of performance impairment observed in both conditions it was shown that after 17 hours of sustained wakefulness, cognitive psychomotor performance had deteriorated to a level equivalent to a blood alcohol concentration of 0.05 percent (Dawson & Reid 1997). Furthermore, 24 hours of sustained wakefulness induced performance decrements equivalent to a blood alcohol concentration of 0.10 percent (Dawson & Reid 1997). Thus it was concluded by the authors that even relatively moderate amounts of sleep loss can produce fatigue-related performance impairments equivalent to, or greater than currently accepted levels for alcohol intoxication (Dawson & Reid 1997).

In summary, it is evident from the above results and findings from other studies (Angus & Heslegrave 1985; Angus et al. 1992; Bergstrom et al. 1973) that fatigue, mood and performance decrements are a common outcome of total sleep loss. The nature of tasks and influence of endogenous and exogenous factors affect the extent to which decrements become evident. However recent work suggests that even moderate levels of sleep loss can produce fatigue-related performance impairments equivalent to or greater than decrements induced by a blood alcohol concentration of 0.05 percent.

5.2 Partial sleep deprivation

Studies examining the effects of partial sleep deprivation on mood, fatigue and performance have produced variable results. When 16 young adults (average age, 23 years) had their sleep restricted to approximately 5 hours per night for 7 consecutive nights, mood and performance reductions became apparent after 1 to 2 nights (Dinges et al. 1997). Specifically, subscale scores for fatigue, confusion, tension, mental exhaustion and stress became elevated across the period of sleep restriction, while vigilance performance significantly deteriorated. Memory performance also showed a trend towards poorer performance across days of reduced sleep, but this pattern failed to reach statistical significance (Dinges et al. 1997). The results indicated that there was a cumulative effect on performance and mood, as further significant decrements were observed towards the end of the experiment. Following the period of sleep restriction, 2 nights of recovery sleep were required before a full recovery was achieved (Dinges et al. 1997).

Restricting sleep to 4 hours per night for 2 and 4 days duration has also been shown to cause performance reductions in cognitive, vigilance and memory tasks (Tilley & Wilkinson 1984; Wittersheim et al. 1992). Placement of the 4 hour block of sleep in either the first or second half of the night had no effect on the level of impairment experienced, suggesting that the performance decrements were a function of sleep loss per se rather than the changes in sleep composition which occurred due to the different timing of sleep (Tilley & Wilkinson 1984). Residual impairment in some tasks was still evident after a single night of recovery sleep (Wittersheim et al. 1992), thereby supporting the suggestion of Dinges et al (1997) that at least 2 nights are required before a complete recovery is achieved.

Furthermore, Morris and Miller (1996) reported that performance, as measured by error rates, significantly deteriorated over the first 3.5 hours of a 4 hour simulator flight in 10 experienced pilots, when an average of only 2.4 hours sleep was obtained during the previous night. Pre and post flight scores of subjective fatigue, workload and sleepiness increased, however only the first two of these measures reached statistical significance (Morris & Miller 1996). On the day after the simulated flight, subjects reported higher than normal levels of fatigue despite having had an extended period of sleep post testing (Morris & Miller 1996). This latter finding once again indicates that recovery from partial sleep deprivation is incomplete after 1 night of sleep.

In contrast to the above, Blagrove and colleagues (1995) examined the effects of chronic sleep reduction in 3 groups of young adults and noted no performance decrements in logical reasoning or auditory vigilance tasks, as compared to a control group. One group of subjects, whose sleep had been limited to 4.3 hours per night for 4 days, did however perform worse on a task requiring focused attention, thereby suggesting they were more easily distracted (Blagrove et al. 1995). Caution should be used in reviewing these results however, as the performance tests were only conducted 3 to 6 times per week for 5 to 20 minutes at a time. Hence, subjects were probably able to increase their effort and overcome the effects of sleep deprivation for the short duration of the testing sessions (Blagrove et al. 1995). Given that most jobs would involve a greater workload than that used in the investigation, the relevance of this study to the real world is questionable.

Additionally, Angus and colleagues (1992) reviewed a number of field studies which examined the performance of military personnel during sustained operations in which sleep was limited, and indicated that when an average of 4 or more hours sleep per day was attained, performance remained stable. It is possible however, that the high levels of motivation and dedication often exhibited by military personnel may have enabled the subjects to actively overcome the effects of sleep deprivation for the duration of the studies.

The weight of evidence therefore seems to suggest that partial sleep deprivation, for even relatively short periods of time, can have detrimental effects on mood, fatigue and performance in a wide range of tasks. In fact, a meta-analysis of the effects of sleep deprivation on performance (Pilcher & Huffcutt 1996) indicated that partial sleep deprivation had considerably greater negative effect on mood and cognitive performance than total sleep loss. It was also identified that sleep loss (of either a partial or continuous nature) caused greater decrements in cognitive performance as compared to motor performance (Pilcher & Huffcutt 1996). While these results should be interpreted cautiously as a significant number of primary studies could not be included in the analysis (Pilcher & Huffcutt 1996), they seem to support the general conclusion that partial sleep deprivation negatively affects mood, fatigue and performance. Two possible exceptions to this conclusion may be when tasks are only required to be performed for short periods of time at infrequent intervals (i.e. 3-6 times per week for 5-20 minutes at a time) or when subjects are highly motivated and dedicated to their work. Additionally, as most of the studies cited above used relatively young adults for subjects, it is questionable to what extent these results are applicable to older population groups.

In spite of these limitations, the effects of sleep deprivation seem to be cumulative in nature, as performance and mood became progressively worse as the duration of sleep deprivation continued. This finding is consistent with evidence suggesting that insufficient amounts of sleep obtained over several consecutive days leads to a cumulative sleep debt (Folkard 1996b; Gillberg 1995; Knauth 1993, 1996; Tilley et al. 1982; TSB 1997). It also appears that at least 2 nights of recovery sleep are required before full recovery from partial sleep deprivation is achieved. With regards to marine pilotage in the Great Barrier Reef region, this latter finding is somewhat disconcerting as preliminary work schedule data suggests there may be times when pilots do not have the opportunity for complete recovery between work assignments (Parker et al. unpublished observations).

5.3 Mechanisms of Performance Decrements with Sleep Loss

The effects of sleep deprivation are most evident in a higher prevalence of ‘lapsing’ or ‘microsleep’ (Dinges 1992a; Dinges & Kribbs 1991; Krueger 1989; Reinhart 1995). Lapsing involves periods of delayed or non response which tend to increase in frequency and duration as sleep deprivation continues and manifests as greater variability in performance and increased errors of omission (Dinges 1992a; Dinges & Kribbs 1991; Krueger 1989; Rosekind et al. 1996). It is most evident under boring and monotonous conditions (Dinges & Kribbs 1991), and often the sleep deprived individual is unaware of its occurrence (Reinhart 1995; SIRC 1996).

Sleeplessness has also been associated with a slowed response speed to new and previously encountered stimuli (Dinges 1992a; McCarthy & Waters 1997) and an increased tendency for false positive responding; that is, responding when no signal is present (Dinges 1992a). Additionally, memory problems may be experienced, time on task decrements are accentuated and self paced tasks tend to be carried out more slowly under conditions of sleep deprivation (Dinges 1992a; Dinges & Kribbs 1991).

Furthermore, an unusual manifestation of sleepiness reported amongst a small percentage of night nurses (Folkard et al. 1984) and air traffic control officers (Folkard & Condon 1987) is that of night shift paralysis. This form of paralysis appears to be a special type of sleep paralysis which presents as a temporary inability to respond to relevant stimuli, despite being alert and coherent (Folkard et al. 1984; Folkard & Condon 1987).

The extent to which any one of these features of performance impairment are evident under conditions of sleep deprivation is dependent upon task and personal characteristics, as well as the magnitude of sleeplessness (Babkoff et al. 1991b; Dinges 1992a; Dinges & Kribbs 1991). For example, knowledge of results (Steyvers & Gaillard 1993) and stimulating tasks (Dinges & Kribbs 1991) can, in some instances, improve performance of sleep deprived individuals. Tasks performed intermittently rather than continuously also show less degradation in performance with sleep loss (Angus & Heslegrave 1985). Furthermore, high levels of motivation can enable subjects to exert additional effort for brief periods of time to overcome performance decrements (de Vries-Griever & Meijman 1987; Dinges & Kribbs 1991; Hockey 1997).

5.4 Napping

Given that irregular work hours and periods of sustained wakefulness are at times unavoidable, the effectiveness of potential countermeasures, such as naps, have been examined. While the different study protocols and results obtained make it difficult to draw a general conclusion, naps appear to have a beneficial effect on the mood and performance of sleep deprived individuals when compared to no nap conditions (Angus et al. 1992; Bonnet 1991; Dinges 1992b; Gillberg et al. 1996; Naitoh et al. 1992; Rogers et al. 1989). Naps, however, should not be considered as a replacement for normal nocturnal sleep, as mood and performance after naps generally remained somewhat impaired compared to baseline levels (Angus et al. 1992; Naitoh et al. 1992; Rogers et al. 1989) and in some studies, beneficial effects were only evident for relatively short periods of time (Gillberg et al. 1996).

Naps taken prior to work or before the beginning of a sleepless period can be beneficial, as they reduce the duration of continuous wakefulness and help dissipate any sleep need which the person may have accumulated (Rosekind et al. 1996). A study examining the effects of 2, 4, and 8 hour naps taken before 52 hours of wakefulness revealed that performance and alertness in all of the nap conditions was improved in a dose-response fashion compared to a no nap control condition (Bonnet 1991). The beneficial effects of naps lasted for up to 24 hours, after which time there were no significant differences between the nap and no nap conditions (Bonnet 1991). The finding that longer naps improved performance and alertness to a greater extent than shorter naps supports the suggestion that sleep continuity is an important factor in the restorative function of sleep (Bonnet 1986).

When reviewing the above studies, it is important to recognise some of their limitations. For example, most of the studies employed relatively young subjects who were free from sleep disorders and had no pre-existing sleep debt or shiftwork exposure (Bonnet 1991; Gillberg et al. 1996) Additionally, sleep was often taken in laboratories where an optimal sleep environment was provided by controlling noise, temperature, lighting and other potentially disruptive factors (Bonnet 1991; Rogers et al. 1989). Hence, just how applicable some of these studies are to a specific population such as GBRP is not known.

The effects of sleep inertia also need to be considered when examining the usefulness of naps in countering the effects of sleep deprivation. Sleep inertia presents as a transient period of performance impairment that occurs immediately upon awakening, and is more severe when a person has been sleep deprived and when waking occurs during the first half of the night (Dinges 1992b; Dinges et al. 1985; Dinges & Kribbs 1991). The implications of sleep inertia on performance is an important factor to appraise when a person is required to wake quickly and respond to immediate performance expectations, as marine pilots may have to do.

It is therefore evident that further research examining the effectiveness of naps as a countermeasure for sleep loss is required before definitive conclusions can be reached. Among other things, there is a need to clarify at what time into a period of sleeplessness naps are most beneficial and how long naps should be. Additionally, the impact of such factors as a pre-existing sleep debt, shiftwork exposure and age also need to be examined.

5.5 Summary

In summary, the majority of evidence indicates that sleep deprivation causes a cumulative deterioration in mood, fatigue and performance, and that at least 2 nights of recovery sleep are required before these attributes are restored to baseline levels. When relating these findings to the work practices of marine pilots, a somewhat disturbing picture arises. Marine pilots frequently experience periods of sleep loss as a

result of their work schedules, and preliminary data indicates that on some occasions, the opportunity for complete recovery between work assignments may not be available. Hence, it is possible pilots may, at times, be susceptible to mood, fatigue and performance deterioration induced by inadequate sleep. For this reason it is vital that research investigating the value of potential countermeasures, such as naps, continues.

6.0 STRESS, FATIGUE AND PERFORMANCE

Essentially there are two ways in which an individual can respond to a potentially stressful situation. Either additional resources can be recruited so that the primary task performance remains stable (termed the performance protection response), or alternatively, performance goals can be lowered and reductions in overt performance accepted (Hockey 1997). When performance outcome is the critical feature of a situation, as is the case in most work environments, the former response is generally adopted (Hockey 1997). This response avoids primary performance reductions, however it incurs additional costs in the form of higher levels of physiological activation and subjective strain. In turn, the psychophysiological state of the worker is compromised as indicated by breakdowns in secondary task performance, adoption of simpler, but riskier strategies to accomplish performance goals, higher levels of sympathetic activation and fatigue after effects (Hockey 1997).

While work conditions may encourage the adoption of the ‘performance protection’ response, motivational factors play a decisive role in determining the amount of additional effort expended to maintain performance. The worker’s response is significantly influenced by individual differences in perceived value of task goals, response to challenges, capacity for sustained work and tolerance of adversive states associated with high levels of strain (Hockey 1997). Additionally, factors such as pre-existing fatigue and prevailing affective states influence the worker’s response (Hockey, 1997). In circumstances when work requirements exceed effort, performance breakdowns occur, either in the form of errors and accidents, or psychosomatic complaints and sick leave (de Vries-Griever & Meijman 1987; Hockey 1997).

Exposure to work environments which require workers to invest additional effort for prolonged periods of time or on a regular basis, tend to be maladaptive. In such situations, there is little opportunity for complete recovery from the fatigue generated, thereby causing a gradual depletion of the person’s available resources and leading to chronic fatigue (Hockey 1997).

A study examining the mental workload experienced by resident physicians (Bertram et al. 1992) verified the concepts described by Hockey (1997) and de Vries-Griever and Meijman (1987). Mental workload was evaluated by way of a 6 item questionnaire assessing mental effort, physical effort, difficulty, performance (2 items) and psychological stress. The results indicated mental workload was positively correlated with fatigue, thereby indicating that periods of greater mental workload placed additional demands on the physicians (Bertram et al. 1992). It was also noted that performance, as measured subjectively by the residents and objectively by external measures, tended to deteriorate during periods of high mental workload, suggesting that during these times, work requirements exceeded the resident physician’s available resources (Bertram et al. 1992).

Also partly explained by the above information is the fact that night work is more taxing than work carried out during the day (Bohle & Tilley 1989; Meijman et al. 1993; Totterdell et al. 1995). In order to overcome the natural tendency to sleep during nocturnal hours and maintain appropriate levels of arousal and performance, greater effort must be invested by the night worker. As a consequence, night workers tend to experience higher levels of fatigue than their day time counterparts (Akerstedt 1995; Luna 1997; Luna et al. 1997) and show greater decrements in performance and well-being during their first recovery day after a period of work (Meijman et al. 1993; Totterdell et al. 1995). Hence, while stressful situations may or may not manifest in visible reductions in overt performance, they are associated with a greater investment of effort on the person’s behalf which subsequently results in higher levels of fatigue. When work requirements exceed the person’s available resources, performance decrements will be observed. Chronic exposure to stressful work environments can lead to a gradual depletion of the person’s available resources and in this way, tend to be maladaptive.

7.0 Fatigue and pilot performance

From the preceding sections of this report, it is evident that sleep loss and stress represent two of the major potential sources of fatigue in marine pilotage work. The irregular work schedules, long on-duty periods, on call nature of pilotage work and alternative sleeping environments cause reductions in sleep quantity and quality, while many aspects of the work conditions can induce stress. The combination of sleep loss and stress has an interactive and additive effect (Costa 1996), thereby potentially causing an earlier onset and more severe fatigue. As a consequence, marine pilots may be at an increased risk of exhibiting fatigue induced performance decrements. Table 1 summarises some of the recognised fatigue-induced performance decrements and how these decrements may affect piloting performance.

Table 1 *Fatigue-Induced Performance Decrements and Pilotage examples*

Type of Decrement	**Pilotage Examples**
Lowered levels of Vigilance	• Lack of position monitoring • Incorrect reading of navigation equipment • Failure to identify relevant stimuli
Slowed Reaction Time	• Failure to respond to situations quick enough to avoid adverse effects
Impaired Decision Making	• Inappropriate navigational actions • Inaccurate calculations
Memory Problems	• Forgetfulness in communicating information to crew • Forgetfulness in checking the ship's position at critical times
Narrowing of Attention	• Failure to fully appraise situations or to recognise the risks of situations • Increased perseverance with inappropriate responses
Lapsing or Microsleep	• Delayed or no response to relevant stimuli
Time on Task Decrement	• Slowing in response time to unexpected stimuli as work period continues • Increased errors in judgements and decisions as

	work period continues
Adoption of Simpler, but Riskier Strategies	• Over-reliance on radar and other automated equipment

(adapted from Couper 1996; Dinges 1992a; Dinges & Kribbs 1991; Rosekind et al. 1996; Sanquist et al. 1996)

That pilotage performance can be affected by fatigue in so many different ways, all of which could potentially jeopardise safety, is disconcerting. Marine pilots play a critical role in the safe navigation of vessel and crew through difficult waters and hence, it is essential that high levels of performance are maintained by pilots at all times while on duty. However, given the disruptive effects of pilotage work schedules on circadian rhythms, sleep, social and domestic issues and stress levels, there is a high probability that at various times during work periods pilots may suffer from fatigue. Under normal circumstances this may not amount to significant deviations in performance. However, in situations when demands increase (for example during poor weather or if the pilot's preceding work schedule has involved substantial amounts of night duty), the build up of fatigue may be sufficient to cause a breakdown in performance leading to an unwanted incident.

8.0 FATIGUE AND ACCIDENTS

The potential role of fatigue in accidents has been highlighted by a number of recent major transportation and industrial incidents. The following section of this report details the progress which has been made in substantiating the relationship between fatigue and accidents.

8.1 Prevalence of Fatigue-Related Accidents

While in the past, fatigue was often suspected of causing or contributing to many transportation accidents, the means to establish its presence was not available (TSB 1997). This was largely due to the fact that human fatigue generally leaves no tell tale signs and can only be inferred from circumstantial evidence (Brown 1994; Lauber & Kayten 1988; TSB 1997). Additionally, the lack of a universally accepted definition and standardised investigation procedures constrained researchers (McCallum et al. 1996; TSB 1997). As a consequence, the incidence of fatigue as a causal or contributing factor to past accidents has more than likely been under-reported (Lauber & Kayten 1988; McCallum et al. 1996; NTSB 1995).

Recent work however, has made some headway in increasing knowledge about the prevalence of fatigue and the role it may play in accidents. For example, the US Coast Guard Research and Development Centre identified that 16 percent of critical vessel casualties and 33 percent of personnel injury casualties occurring in US coastal waters between 1 July and 31 December 1995, had some fatigue contribution (McCallum et al. 1996). These figures were more than 10 times greater than the estimates established from data collected in 1993 (1.2 percent and 1.3 percent for vessel casualties and personnel injuries respectively) (McCallum et al. 1996). It has also been noted by the Japan Maritime Research Institute (1993) that 'lack of alertness' and 'dozing during navigation' accounted for approximately 53 percent of groundings and strandings and 38 percent of collisions occurring between 1985 and 1991. Additionally, while official statistics indicate 9.2 percent of shipping casualties occurring in Australian waters between January 1994 and January 1998 were fatigue-related, some authors have suggested that a figure closer to 30 percent would be more realistic when performance impairments due to chronic fatigue are considered (Filor 1988). These, and other findings (Sanquist et al. 1996) seem to indicate that fatigue is a widespread problem in the maritime industry and that a significant number of marine accidents are fatigue-related.

Research into other transport industries has revealed similar results. For example, it has been suggested that at least 25 percent of single vehicle road accidents (Brown 1994) and between 30 and 40 percent of heavy truck accidents (Hopkins 1992; NTSB 1995) are fatigue-related. Additionally, approximately 21 percent of all reported US aviation incidents (Reinhart 1995) are thought to have a fatigue contribution. Hence, the extent of fatigue and the role it plays in accidents appears to be somewhat greater than what past data has indicated, at least in transportation industries.

8.2 Indicators of Fatigue

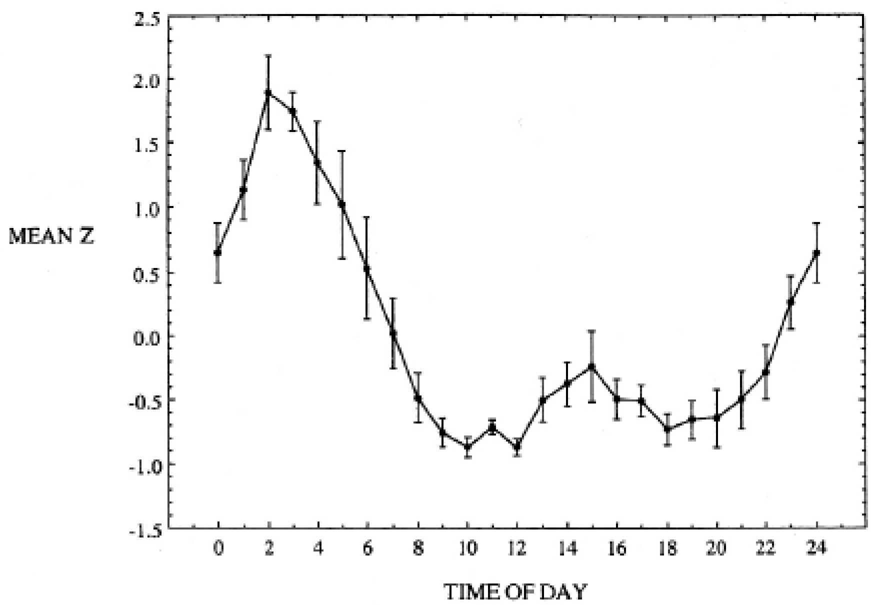
To gain a greater understanding about the potential relationship between fatigue and accidents, there is a need to identify the causes and effects of fatigue, and to develop standardised procedures for investigating, analysing and reporting the role of fatigue in accidents. Accordingly, recent and ongoing work has focused on a number of these issues, with some positive results having been achieved. For instance, the US Coast Guard Research and Development Centre have identified a number of work conditions which significantly contribute to fatigue-related incidents. Those conditions identified include the number of consecutive days work prior to the incident, the number of days worked in the 30 days prior to the incident, hours on duty prior to the incident, hours worked in the past 24, 48 and 72 hours prior to the incident, changes from the normal working schedule on the day of the incident and the absence of company or union policies governing work hours (McCallum et al. 1996). While these findings were based on preliminary data, they provide a good starting point for further work.

Similarly, the National Transportation Safety Board identified that the three most important measures in predicting fatigue-related heavy truck accidents were the duration of the last sleep period, the total number of hours slept during the 24 hours prior to the accident and whether or not a split sleep schedule had been adopted (NTSB 1995). These two studies have shed some light on what appears to be an intimate relationship between the work and sleep habits of an individual and the occurrence of fatigue-related incidents.

8.3 Work, Sleep, Fatigue and Accidents

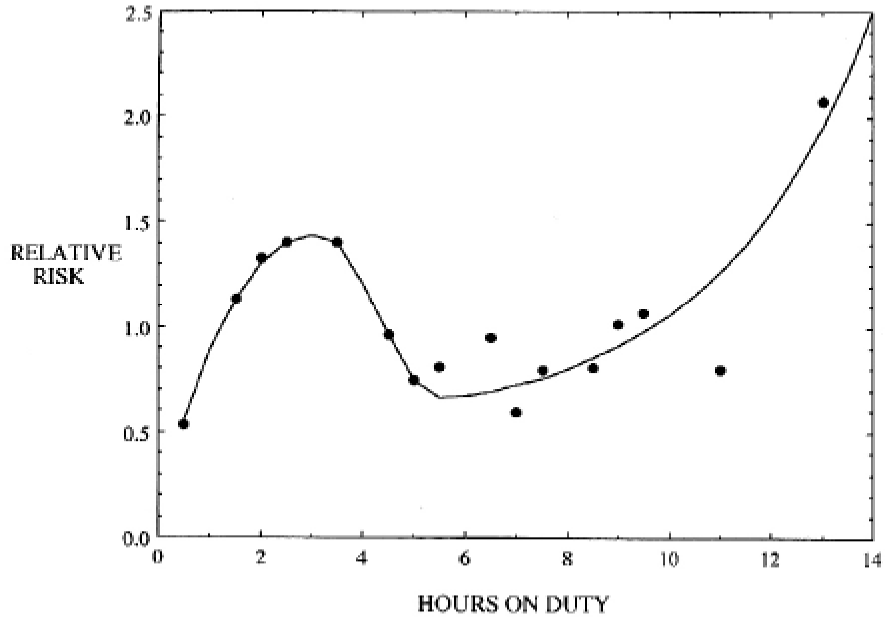
Investigations which have looked at the timing of accidents across the 24 hour cycle have revealed some interesting findings with regards to an individual's sleep and work habits and accidents. For example, the relative risk of road traffic accidents is greatest during the early morning hours, particularly at 0300 hours, with an additional but smaller peak in accident risk occurring during the mid afternoon period (Figure 5) (Brown 1994; Folkard 1997; Hopkins 1992; Mitler et al. 1988; Summala & Mikkola 1994). This characteristic pattern in accident risk, which has also been reported for other transportation and industrial accidents, has been attributed to underlying circadian rhythms (Brown 1994; Couper 1996; Folkard 1997; Mitler et al. 1988; Sanquist et al. 1996; Summala & Mikkola 1994), and suggests that working during the circadian troughs in alertness is associated with an increased risk of accident.

Figure 5 *The mean trend (and standard errors) in road traffic accident risk over the 24 hour day (after Folkard 1997)*



Time on task appears to be another factor influencing accident risk. Figure 6 displays the relative risk of accidents over the course of various shift durations. With the exception of a transient peak in accident risk between the second and fourth hours on duty, accident risk increases in more-or-less an exponential manner over time, such that shifts in excess of 12 hours are associated with substantially greater risk (Folkard 1997; SIRC 1996). This finding seems to indicate that the stress and fatigue associated with long on duty periods causes an increased risk of accident (SIRC 1996). The 2-4 hour peak in accident risk evident in the figure is, at present, unable to be conclusively explained. However, one possible explanation which has been suggested is that it may reflect the need to 're-automise' even highly learned skills during the first few hours of work (Folkard 1997).

Figure 6 *Relative risk of accident for various work shift duration (after Folkard 1997)*



Taken collectively, the results of these studies highlight the apparent relationship between sleep, work, fatigue and accidents. Work and/or sleep conditions which induce fatigue seem to be associated with a higher relative risk of accident. While this sequence of events seems logical, without standardised investigation procedures it is difficult to substantiate the relationship. Hence, the development of a fatigue index by the US Coast Guard Research and Development Centre (McCallum et al. 1996) is a positive prospect. Based upon the number of fatigue symptoms reported by the mariner, the number of hours worked in the 24 hours prior to the incident and the number of hours slept in the 24 hours prior to the incident, the fatigue index provides an objective technique for identifying those marine incidents which are likely to have a fatigue contribution. While further work is required before the fatigue index could be considered valid and reliable, the present results indicate that it should become an effective and efficient tool for establishing the likely presence of fatigue in marine incidents (McCallum et al. 1996).

8.4 Summary

It is therefore apparent that fatigue contributes to significantly more accidents than previous data indicated, and that an individual's sleep and work patterns are two important factors influencing the risk of fatigue-related accidents. That the sleep and work conditions experienced by marine pilots are associated with a number of factors which can potentially induce fatigue is concerning. The economic, environmental and personal costs which can potentially arise from marine accidents is immeasurable, and hence, it is vital that every possible means of minimising accident risk is considered. Accordingly, underlying factors contributing to accidents need to be identified so that preventative strategies can be implemented. In line with this, 'near miss' reporting systems could be beneficial as such information may help to detect risk factors prior to the occurrence of a major accident (States/BC OSTF 1997).

Additionally, the adequacy of work-rest regulations should be reviewed. While the unique features of each pilotage region make it difficult, if not impossible, to impose a rigid set of work-rest regulations applicable to all groups of marine pilots, it has been recommended that individual pilotage authorities should develop work-rest regulations specifying maximum work and/or minimum rest standards (States/BC OSTF 1997). These regulations should enable pilots to begin and finish each work assignment in an appropriately aroused state and prevent the accumulation of fatigue. Consideration should be given to the type of conditions typical of the pilotage region, the duration of work assignments (including transit times), the physical and mental demands of the work, and the timing of work and rest in relation to the 24 hour cycle (States/BC OSTF 1997).

9.0 Conclusion

The immense responsibility associated with navigating vessels, cargo and crew through difficult waters demands that marine pilots maintain high levels of work performance at all times while on duty. However, as documented throughout this report, the work conditions experienced by marine pilots are not always conducive to optimising work performance. For example, the irregular timing of pilotage work, both in terms of its placement within the 24 hour cycle and duration of work and rest periods, may lead to disrupted sleep, circadian dissociation and a multitude of social and domestic problems. The sleeping and billeting facilities available to pilots when staying in alternative accommodation on ship and ashore, often fail to promote good recuperation between work periods and work assignments. Recent shipping reforms and commercial changes have resulted in greater workloads and increased stress for all shipboard personnel. These, and other aspects of marine pilotage work, have the potential to induce fatigue. As a consequence, breakdowns in work performance may become evident, especially in situations of increased work demands, and there may be a heightened risk of fatigue-related incident.

Given that the avoidance of unwanted shipping incidents is the primary goal of marine pilotage work, there is a need to determine the extent and nature of fatigue amongst this occupational group. Specifically, future research may examine the level of fatigue induced from (i) the irregularity of marine pilotage work, (ii) displaced and disrupted sleep; and (iii) other industry specific stressors such as on board and environmental conditions. It would also be useful to document the ways in which fatigue affects piloting performance and the potential safety consequences of this.

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