Great Barrier Reef Coastal Pilots Fatigue Study

05 | **Final Report for AMSA**
November 2005

Great Barrier Reef Coastal Pilots Fatigue Study

05 | **Final Report for AMSA**
November 2005

Prepared by
Dr Sally Ferguson
Dr Nicole Lamond
Prof Drew Dawson

Centre for Sleep Research
University of South Australia

Preface

The Inner Route Compulsory pilotage area of the Great Barrier Reef Marine Park runs from just north of Cairns, at latitude 16° 40’ South, to the northern tip of Cape York, at latitude 10° 41’ South. When the Prince of Wales Channel in Torres Strait is included the pilotage route covers a distance of almost 500 nautical miles.

Since assuming responsibility for coastal pilotage from the Marine Board Queensland the Australian Maritime Safety Authority (AMSA) has been very conscious that fatigue is a very real issue for Great Barrier Reef Coastal Pilots. In 1998 AMSA commissioned the School of Human Movement Studies, Queensland University of Technology, to conduct a study into the Work Practices of Great Barrier Reef Coastal Pilots. In 1999 AMSA commissioned DNV Consultancy Services to conduct the Great Barrier Reef Pilotage Fatigue Risk Assessment (these studies are available at www.amsa.gov.au).

AMSA has put a number of controls in place to help deal with the potential for fatigue such as requiring pilots to operate under an approved fatigue management plan and the provision of minimummandatory rest breaks between pilotage tasks. AMSA also requires that the pilot provider companiesand Great Barrier Reef Coastal Pilots operate under an approved safety management system.

During the last few years a number of changes have taken place that have had an impact on pilotage in the Great Barrier Reef Marine Park. The most significant change has been the modification of the pilotage route with the introduction of the Fairway Channel/LADS Passage which starts from just north of Cape Melville and runs almost to Cape Direction, a distance of approximately 80 nautical miles.

The introduction of the Fairway Channel/LADS Passage has a number of benefits for shipping generally and in particular for coastal pilots as it reduced the length of the pilotage, took shipping away from some navigationally difficult areas and for most pilotage trips allows the pilots to obtain additional rest mid way through the Inner Route pilotage.

In addition to the changes outlined above there have also been changes in technology that allow for objective collection of sleep/rest data as against the subjective collection of data used in the previous study on work practices of coastal pilots. In the previous study data was obtained by completion of sleep diaries.

With the changes that have occurred AMSA decided that another study into work/rest patterns of Great Barrier Reef Coastal pilots was needed to determine if the current controls were effective and if improvements in monitoring and controlling the fatigue risk could be made.

Acknowledgements

The project team at the Centre for Sleep Research, University of South Australia would like to acknowledge the significant contributions that made this study possible.

Firstly, we would like to thank the Australian Maritime Safety Authority and specifically John Briggs, Jim Martin, Jeff Holden, Bob Mckay and Mark Eldon-Roberts. AMSA personnel provided great support for the project itself and the project team and answered countless questions and queries.

Secondly, the project was ably supported by the three pilotage companies working in the Great Barrier Reef Marine Park area. These companies provided access and information to their pilots through emails and meetings and supported the project team throughout the process, facilitating recruitment and verifying pilot work records. In particular, Jim London, Alan Maffina, Perry Sutton and David Ellem were of great assistance.

And finally, thanks goes to the pilots who participated in the data collection. The commitment of the pilots to the project cannot be overstated. The collection of sleep, wake and performance data represented a significant personal burden and required dedication and diligence. As is highlighted in the report, the data collected during this study was of a uniquely high standard with regard to accuracy and completeness. The invaluable contribution of the GBR Coastal Pilots has allowed us to present a comprehensive report of sleep and fatigue issues in the men tasked with the protection of this sensitive and valuable marine environment.

The study examined the work, sleep and performance patterns of GBR Coastal Pilots working in the World Heritage listed Great Barrier Reef Marine Park. Three routes were worked by pilots, the compulsory pilotage areas of the Inner Route and Hydrographers' Passage and the area of recommended pilotage, the Great North Eastern Channel.

Participants

- Seventeen participants
- Average age 55.8 years.
- Majority married and living with partner.
- Average time as a marine pilot 12.6 years.

Work Patterns

- Average length of pilotage periods (i.e. length of time on board a ship)
  > Inner Route – full (IR) – 39.5 ±10.8 hours
  > Inner Route – partial (IR-p) – 24.0±13.8 hours
  > Great North Eastern Channel (GNEC) – 9.7±1.6 hours.
  > Hydrographer's Passage (Hydro) – 12.0 ±2.2 hours.
- Pilots reported feeling significantly more fatigued after a ship than at the start of a ship, independent of the type of ship worked.
- Pilots had an average of 45.7±25.8 hours off after each ship. There was no difference in the amount of time off after different routes.
- After IR ships pilots had at least 24-hours off (with the exception of 2 occasions) with (39% of the breaks following IR ships extending for longer than 48 hours.

Sleep Patterns

- 734 sleep periods were collected, ranging in length from 15 minutes to 12.5 hours.
- There were 278 main sleeps, 334 Ship sleeps and 114 naps
  > Home sleeps - average 6.9±1.4 hours for main sleeps and 1.4±1.3 hours for naps.
  > Other sleeps (occurring ashore but not at home) average 6.3±1.6 hours for main sleeps and 1.1±0.9 hours for naps.
  > On board Ship sleep periods averaged 1.4±1.0 hours in length.
- The majority of sleep at Home or in Other locations was obtained between the hours of 2200 and 0700, with a secondary smaller peak at 1400.
- Pilots rated main sleeps at Home as significantly better quality than main sleep periods in Other locations, or on a Ship.
- Half of the sleep periods obtained on a Ship were considered good or very good.
- Prior to getting on a ship pilots obtained an average of 7.4±1.7 hours of sleep and this did not vary as a function of the ship route.
- Sleep during ships: IR – 5.1±1.5 hours per 24-hour period.
- Wake time: prior to
  > Home sleeps – 13.1±5.6 hours,
  > Ship sleep – 5.3±4.3 hours
  > Other sleeps – 11±5.1 hours.
- The average amount of time that pilots had been awake prior to beginning a ship was 4.5±3.8 hours.
- Pilots were awake for less than 15 hours prior to the majority of sleep periods that occurred on ships.

Performance Patterns

- Performance on the vigilance task did not change across the day, across a ship, or across consecutive ships.
- Performance was generally in the normal range for the task.

Discussion points

- Pilots obtained on average almost seven hours of sleep at Home and more than 6 hours sleep in Other locations during main sleep periods. The main sleep periods were supplemented with naps, either on completion of or prior to boarding a ship.
- At sea pilots averaged 5 hours of sleep per 24-hours (Inner Route ships).
- Prior to boarding a ship pilots obtained more than seven hours sleep in the preceding 24-hour period.
- The pilots in this study slept approximately every six hours on a ship, for less than two hours on average.
- The longest that pilots were awake on board a ship was less than 20 hours. However, in 96% of cases, pilots were awake for less than 15 hours while on board a ship.
- Average time off after a ship was similar for each route and averaged around 40 hours or more.
- All Inner Route ships should be associated with 24-hours of rest prior to and after the ship.The data indicates that 7% of IR ships worked were not associated with a 24-hour break period on completion of the ship. 36% of IR ships were followed by a break of 48 hours of more, ensuring two night-time sleep opportunities.

Recommendations

- A tailored training package for GBR Coastal Pilots is a vital component of managing fatiguerelated risk in this group. The training package should include practical strategies for managing sleep quality and quantity, information about the effect of sleep opportunity on recovery sleep, information for pilots to use in determining their personal fatigue risk and practical methods for maintaining alertness while conducting piloting duties.
- Introduction of a Fatigue Risk Management System employing various control measures for reducing the likelihood of fatigue would provide increased flexibility for operations. This process should incorporate a formal fatigue risk assessment, including a focus group (or series of focus groups) comprising GBR coastal pilots, pilotage companies, AMSA and a fatigue expert.

Fatigue does not appear to be a major problem in this population.

The GBR Coastal Pilots in this study appear to be getting a sufficient sleep opportunity and obtaining sufficient sleep to maintain alertness.

Index

Glossary

AMSA – Australian Maritime Safety Authority
BMI – Body Mass Index
CFSR – Centre for Sleep Research
FRMS – Fatigue Risk Management System
GBR – Great Barrier Reef
GNEC – Great North Eastern Channel
Hydro – Hydrographer's Passage
IR – Inner Route
IR-p – Inner Route Partial (voyages to and from Cape Flattery)
PVT – Psychomotor Vigilance Task

Fatigue is becoming increasingly well recognised as a factor that significantly increases the risk of human error. For industries that are high risk due to the nature of the work (i.e. transport, mining, aviation), the contribution of fatigue to accident and error rate can be significant. In particular, industries and organisations that require individuals to work long and/or irregular work hours, or to work at night, are at the highest risk for fatigue-related incidents. In Australia, industries such as mining, rail and road transport, health care and aviation are all being proactive about managing the risks associated with fatigue. A parliamentary inquiry conducted in 2000 addressed the high number of fatigue-related incidents that were occurring in the four transport modes – rail, road, aviation and maritime [1]. A series of recommendations suggested that the risk of fatigue must be managed by industries and organisations and that objective data be collected by those industries to better inform decisions about risk mitigation strategies. The Australian Maritime Safety Authority continues to be proactive in their management of fatigue-related risk and this project represents the continuation of that effort.

There is no universally accepted definition of fatigue. In general, fatigue is an increasing difficulty to perform physical or mental tasks as the consequence of inadequate sleep. However, fatigue and the subsequent reduction in alertness and performance are also dependent on the amount of wakefulness (associated with the length of the work period) the time of day, and limitations on human recovery. The human biological timing system is programmed for sleep during the dark hours and for activity during the daylight hours. For employees working long, irregular or night hours, achieving an adequate amount of sleep is difficult because of the time at which sleep opportunities occur. A sleep opportunities is the period of time available for sleep (as distinct to the actual sleep obtained during a break). In general, sleep opportunity are largely determined by work periods

Research into shiftworkers' sleep, using both subjective measures (sleep diaries and questionnaires) and objective measures (activity monitors and sleep recording equipment) indicates that shiftworkers get significantly less sleep depending on the time of the particular shift compared to day workers [2-4]. On night shift, an average length sleep was 6.8 hours [5], and on early morning shift the average sleep length was as low as 5.2 hours [6]. Afternoon shift is reported as the best shift for sleep length, with workers averaging 7.7 hours [5]. In addition to sleep length, the timing of the sleep opportunity also affects the quality of sleep.

The quality of day sleep is generally lower than sleep at night and overall, shiftworkers have poorer sleep quality than day workers [7]. Shiftworkers have more difficulty initiating sleep, more broken sleep and increased occurrence of early wakening [8]. The restorative stages of sleep such as Stages 3 and 4 of non-REM sleep and REM sleep, are less prominent during day sleep. Sleep during the day, when workers are working at night, is lighter and therefore less restorative [9]. Inadequate sleep arising from shorter and less restorative sleep periods, leads to the accumulation of sleep debt and high levels of fatigue. However, as mentioned, fatigue does not arise solely from inadequate sleep. Another important factor, closely linked to sleep history, is prior wakefulness.

The longer one is awake the more fatigued they become. This aspect of fatigue has significant implications for industries that utilise shifts of 12-hours or more. Previous research in GBR Coastal Pilots showed that extended work periods are routine for this group of individuals [10, 11]. The literature further suggests that where appropriate scheduling of shifts and/or breaks during shifts are absent, more than nine hours on task can expose workers to a higher rate of incidents and accidents [12, 13]. In general terms this refers to reduced levels of alertness, increased sleepiness and impaired physical and mental performance.

Fatigue levels also vary as a function of the time of day, independent of previous sleep history. The body's natural rhythms of alertness and performance are high across the day and fall during the night hours. Fatigue levels are highest around 3-5am and alertness and performance levels are concurrently lowest at this time. Thus, night work is conducive to high fatigue levels, purely because of the body's natural rhythms. Further, after a succession of night shifts, the combination of inadequate sleep during the day and high fatigue in the early morning hours can produce a dangerously high level of fatigue [14].

The specific aspects of performance that are affected by fatigue are well defined. Slowed reaction time, impaired decision making, memory difficulties, reduced attention and vigilance and microsleeps are all consequences of fatigue. Marine pilots utilise a range of skills and competencies that can be affected by performance decrements such as those outlined above. A fatigue risk assessment conducted in 1999 examined certain tasks performed by GBR Coastal Pilots that are impacted by decrements in performance. Lowered vigilance was reported to impact tasks such as position monitoring, reading navigational equipment and identifying relevant information; slowed reaction time was reported to impact response times to certain situations; memory difficulties impact the communication of information to crew members and the checking of the ship's position at critical times. Thus, safety-critical aspects of GBR Coastal Pilots' performance can be adversely impacted by fatigue [15].

Investigations of a number of incidents in the Great Barrier Reef showed that fatigue was a contributing factor in the incidents. One major example is the grounding of the Doric Chariot on the Great Barrier Reef in 2002 [16]. With the major potential for loss of life and damage to the extremely sensitive environment, managing the risk of fatigue-related errors and incidents is critical. The current study was designed to collect objective sleep/wake and performance data with the aim of examining the fatigue levels of GBR Coastal Pilots and to provide recommendations for reducing fatigue-related risk. The specific aims of the project were to:

a) provide a detailed, objective analysis of fatigue issues,
b) determine the effectiveness of current rest-break requirements
c) provide a template for a tailored training course for GBR Coastal Pilots
d) present recommendations for minimising the impact of fatigue in GBR Coastal Pilots through the implementation of a fatigue management system.

2. Methodology

The study protocol was approved by the University of South Australia's Human Research Ethics Committee. Participants were recruited through emails sent via pilotage companies and information from AMSA. Individuals who expressed interest in participating in the study were contacted by phone, in person or through email. The aims of the study were explained to them, in addition to the methodologies to be used and the specific requirements of individual participants. Participants also received an information sheet and instruction sheet explaining the study protocol in detail. Finally, they signed a consent form indicating that they understood what was required of them. Participants were able to withdraw from the study at any stage without adverse consequence.

Participants collected sleep/wake and performance data for either two 14-day periods (n=3) or a single 28-day period (n=14). During the data collection period participants completed the sleep diary after every main sleep or nap, the work diary for each ship completed during the data collection period and the PVT task only during work periods on ships. Participants also completed a general health and demographic questionnaire.

2.1 Measurements

2.1.1 Activity Monitors

Objective assessments of sleep/wake were made using wrist activity monitors and Actiware software (Mini-Mitter, Sunriver, Oregon). Activity monitors are small, lightweight devices that are similar to a wristwatch. For the duration of the study period, except whilst taking a shower (or in any other situation where the device was likely to be damaged), participants wore the activity monitor.

Determination of Movement

Activity monitors contain a piezo-electric accelerometer with a sensitivity of 0.1g. The analogue sensor samples movement every 125ms (i.e. at a frequency of 8Hz) and the signal is filtered by a bandpass filter of 0.25–3.0Hz. The accelerometer produces an electrical current that increases in magnitude as the degree and speed of motion increases. This information is stored in 1-minute epochs as activity counts expressed using eight-bit resolution (i.e. 0–255 steps) such that values ranged from 0 to 253. The activity monitor stores the resulting activity count as a 1-byte value in a 32-kilobyte solid state memory.

Measures

The following measures were derived from activity monitor records using the Actiware software:

Sleep Onset Time: the first epoch of twenty consecutive epochs after bedtime (from sleep diary) in which a maximum of one epoch contains a non-zero value.

Wake Up Time: the last epoch in the ten minutes prior to the get up time (from sleep diary) with a zero activity count.

Sleep Duration: the period between sleep onset time and wake up time, less awakenings.

2.1.2 Sleep Diaries

Participants made subjective assessments of their sleep/wake schedule using a personal sleep diary. Participants were provided with an instruction sheet indicating how the sleep diary was to be used prior to the study commencing. Participants recorded information in their sleep diaries as soon as practicable after waking to encourage more accurate recall.

Participants were required to complete a single line of the sleep diary for each attempted and actual sleep period (i.e. main sleeps and naps), even if they did not manage to fall asleep. In addition to recording the times that they were attempting to sleep, participants were instructed to record presleep information immediately prior to 'lights out' and post-sleep information after the sleep period ended.

Prior to each sleep, they were instructed to record:

- The location of the sleep period. Specifically, participants were required to indicate whether the sleep period occurred at 'Home', on board a 'Ship' during a work period (i.e. while on duty), or in 'Other' locations (hotel, pilot house, Thursday Island etc, and including on a ship but not on duty).
- The date/time that they started attempting to sleep (i.e. 'lights out') - rather than the time that they fell asleep. These times were not to include time spent reading, watching TV, etc.
- Their fatigue level immediately prior to 'lights out'. This was assessed using the Samn-Perelli Fatigue Checklist, a 7-point scale where 1 = 'Fully alert, wide awake', and 7 = 'Completely exhausted, unable to function effectively'.

Following each sleep, participants were instructed to record:

- The time that they got up or started reading, watching TV, etc. in bed.
- Their subjective fatigue level, approximately 20 minutes after the sleep period concluded. Again, this was assessed using the 7-point Samn-Perelli Checklist.
- The quality of the sleep compared to a 'normal' sleep period. This was rated on a 6-point scale, where 1 = 'very good', 5 = 'very poor', and 6 = 'did not sleep'.
- Any relevant comments (e.g. regarding the sleep environment, interruptions, ambient noise, etc.).

Measures extracted from the sleep diaries include:

Bedtime: the clock time that a participant went to bed to sleep (excluding time spent watching television, reading, etc.).
Wake Up Time: the clock time that a participant woke to end a sleep period.
Sleep Length: the period between sleep onset time and wake up time, less awakenings.
Subjective Sleep Quality: a participant's self-rating of sleep quality on a scale of 1 (very good) to 5 (very poor).

2.1.3 Work Diary

Participants were instructed to complete a single line of the duty diary for each ship they worked and record the following information:

- The date and time that the duty period began.
- Their fatigue level just after they boarded the ship and just before they walked off the ship (using the same 7-point fatigue scale as that used in the sleep/wake diary).
- Any relevant comments (e.g. regarding disruptions, alterations, delays, diversions, unusual pre- and post-ship travel times, etc.).

2.1.4 Reaction time task (PVT)

A 5-minute visual reaction time task was used to objectively evaluate behavioural alertness / neurobehavioural performance during work periods on ships. Participants were asked to complete a visual psychomotor vigilance task (palmPVT, Walter Reed Army Institute, Washington, Virginia, USA) as close as possible to the beginning and end of a ship, in addition to every four hours during a ship. palmPVT tasks were not to interfere with normal work tasks, nor with sleep. It was up to the discretion of participants to complete the task at a convenient time.

The task was loaded onto a PalmPilot, a commercially available, hand-held electronic device. The palmPVT software displays a bullseye target to which the participants were asked to react as quickly as possible. The test ran for a period of five minutes. The stimulus was presented at a variable interval (2,000–10,000msec) and participants responded by pressing either the right or left pushbutton with the thumb of their dominant hand. If the correct response was made, the display showed their RT in hundredths of a second in the centre of the bullseye. If the wrong push-button was pressed, an error message was given. If a response was made prior to the stimulus being presented, a false start message was given. If the push-button was not released after three seconds, a reminder message was given.

Measures that were extracted from the PVT include reaction time (RT), inverse of reaction time, fastest 10% of responses, slowest 10% of responses, and number and length of lapses.

2.2 Data Analysis

All of the data was analysed using SPSS v11.0.2. For each sleep period, an objective record of Time in Bed (TIB=the period during which sleep was attempted) and Total Sleep Time (TST=the period between sleep onset time and wake up time, minus any awakenings) was obtained from the activity monitor data, in combination with the sleep diary data. From the sleep diaries, we obtained subjective estimates of sleep quality and alertness levels prior to each sleep period. Separate mixed model Analysis of Variance (ANOVA) were used to systematically assess differences in various sleep and ship measures. Systematic changes in performance on the palmPVT (mean reaction time and lapses) were assessed separately using mixed model ANOVA.

3.1 Data collection and Demographics

3.1.1 Data set

Data were typically of a very high quality in terms of accuracy of sleep/work diary data and correlation with activity monitor traces. The GBR Coastal Pilots who participated in this study were extremely diligent about recording sleep, work and performance test data. The congruence between the sleep/work diaries and the activity monitor records was extremely high. This indicates a dedication in recording sleep information daily and a high level of accuracy in the information provided on the diary. The comments provided by participants with regard to unusual or relevant characteristics of the work and sleep periods further enabled the records to be validated easily. In our experience, data of this nature collected in other populations generally involves a 5% loss of important information as a result of inaccurate record-keeping. The high quality of records has resulted in a unique and comprehensive database of sleep/wake and performance data from this group.

3.1.2 Participants

Twenty individuals were recruited to the study. For various reasons (minimal work during the data collection period, the equipment arriving after the individual had left on a tour and illness), the final number of data sets that were collected and analysed for this report was seventeen. This represents approximately thirty percent of the population of GBR Coastal Pilots currently employed by pilotage companies in the area.

The average age of participants was 55.9 years, with a range of 37-68 years. Body mass index (BMI) was calculated using self-reported height and weight measures. Average BMI of participants was 28.3kg/m2. The normal range for males is 18.5-25kg/m2 and above 25kg/m2 is considered overweight. Sixty-five percent of individuals participating in this study were in the overweight range. However, with regard to the Australian average for men in this age group, the participants in this study are on a par. Participants reported ingesting on average 4 cups of coffee/tea per day (ranging from 0-10) and 13 alcoholic beverages per week (only during non-work time).

The majority of participants were married and/or living with their partner. Less than half had children living at home.

Working life history

Pilots reported having worked irregular work patterns for 37.4 years on average (range 18-50) and 12.6 years as a GBR Coastal Pilot (range 2 months to 32 years).

3.1.3 Routes worked

Great Barrier Reef Coastal Pilots work three main routes. Two specific areas along the GBR have been declared areas of compulsory pilotage based on the sensitive marine environment. These include the Inner Route and the Hydrographer’s Passage. In addition, the Great North Eastern Channel is an area of recommended pilotage. One of the pilotage companies works only in Hydrographer’s Passage and the other two companies work all three routes. The Inner Route involves the longest pilotage period with the pilot required to be on the bridge for a large portion of the trip. Throughout the report GNEC refers to the Great North Eastern Channel, Hydro refers to Hydrographer’s Passage and IR to the Inner Route.

3.2 Work Hours Characteristics

3.2.1 Work Hours by Ship

In total, data was collected during 124 work periods. This included 53 Inner Route (IR) ships (including 4 partial IR ships), 20 Great North Eastern Channel (GNEC) ships, 38 Hydrographers Passage (Hydro) ships and 13 office-based work periods. The average length of each type of work period is shown in Figure 1.

Overall, the ships/work periods ranged in length from 3 hours to 83 hours. Specifically, GBR Coastal Pilots working the complete IR were on the ship for between 26 and 83 hours (mean = 39.5±10.8 hours. Some of the IR trips however, did not extend the complete length of the Inner Route. The average length of work periods on partial Inner Route trips (IR-p) was 24.0±13.8 hours). Trips that involved piloting in the GNEC meant that pilots worked for between 6 and 12.6 hours (mean 9.7±1.6), those piloting the Hydro route were on the ship for between 8.3 and 20 hours (mean = 12.0±2.2 hours), while office hours ranged from 3 to 9.7 duration (mean=7.4±2.6) and were recorded by only one participant in the study.

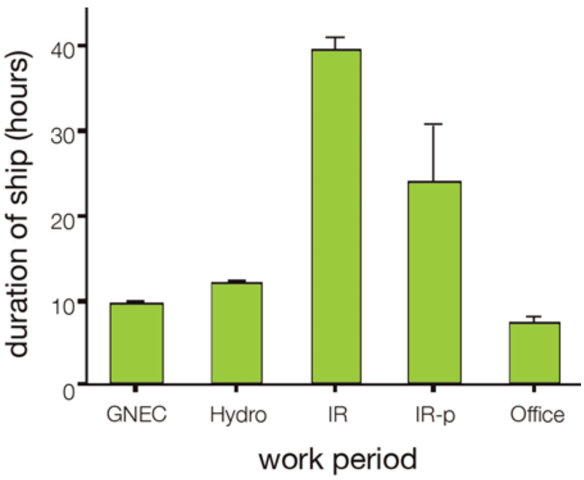


Figure 1 – The average hours (±SEM) of each of the type of work periods recorded by participants, categorised according to route worked, or office hours.

3.2.2 Pre- and post-ship fatigue ratings

GBR Coastal Pilots reported feeling significantly more fatigued following a ship than at the start of the ship, independent of the type of ship they worked (see Figure 2). On average, subjective ratings of fatigue made prior to working Hydro ships (mean rating=1.6±0.7) were lower than prior to GNEC ships (mean rating = 2.3±1.1), but not statistically different to IR (mean rating=1.9±0.8) or IR-p (mean rating = 1.8±0.5) ships.

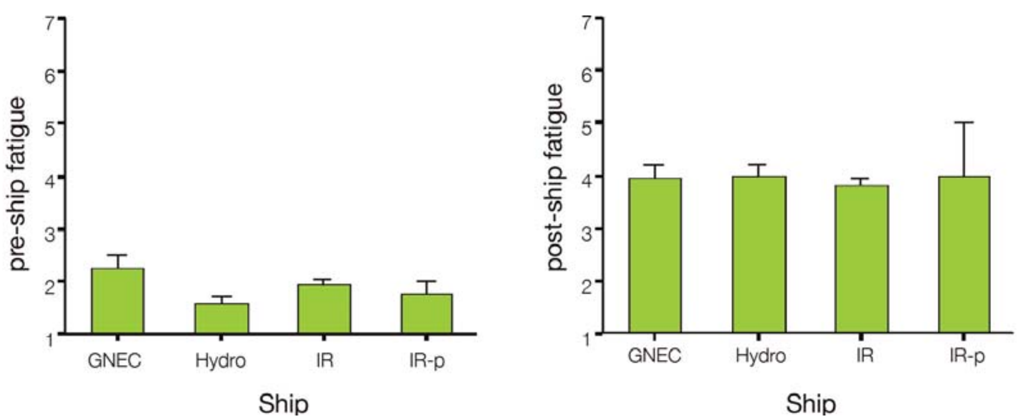


Figure 2 – The graphs show the subjective fatigue ratings provided by pilots prior to beginning a work period on a ship (pre-ship fatigue) and on completion of the ship (post-ship fatigue) on a 7-point scale. Data are means ±SEM.

Specifically, subjective fatigue ratings indicated that prior to 84% of Hydro ships, 60% of GNEC ships, 76% of IR ships, and 100% of IR-p ships, pilots felt “fully alert, wide awake”, or “very lively, responsive”. Prior to the remainder of the ships, participants generally reported feeling “okay, somewhat fresh”, with only 3 pre-ship ratings suggesting a little tiredness (Figure 3).

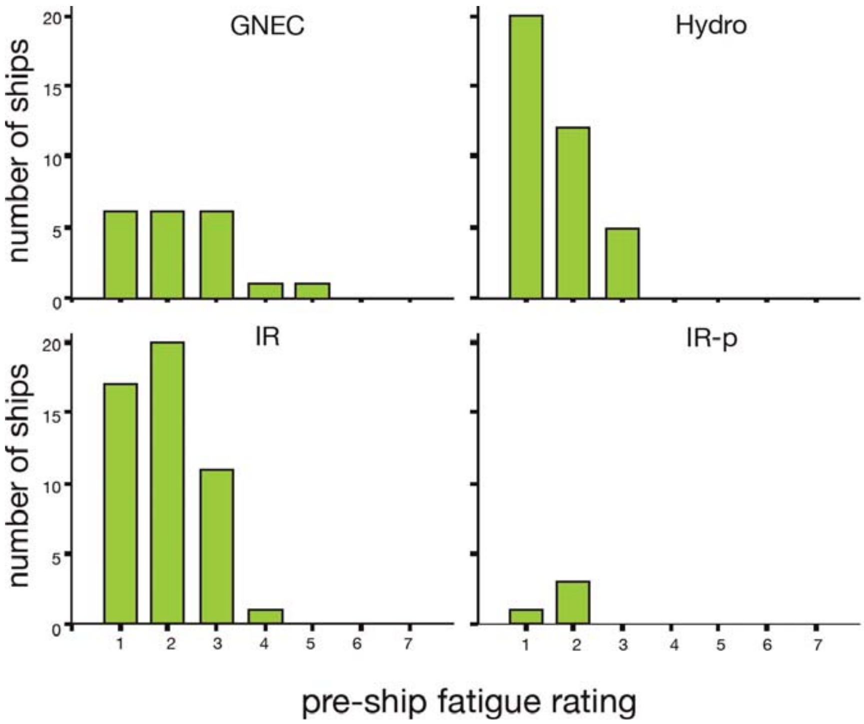


Figure 3 – Pre-ship fatigue ratings grouped according to route worked [1 = highest alertness/lowest fatigue].

Fatigue ratings made following the ships did not significantly vary as a function of ship type. Pilots reported feeling “fully alert, wide awake” or “very lively, responsive” following only 9% of the Hydro ships, 5% of GNEC ships, 8% of IR ships and 0% of IR-p ships. Following 18%-33% of ships, they reported feeling “okay, somewhat fresh”, while following 20-35% they felt “a little tired, less than fresh”. Notably, subjective fatigue ratings made following the remainder of the ships (25-35%) indicate that pilots felt either “moderately tired, let down” or “extremely tired, very difficult to concentrate” (Figure 4).

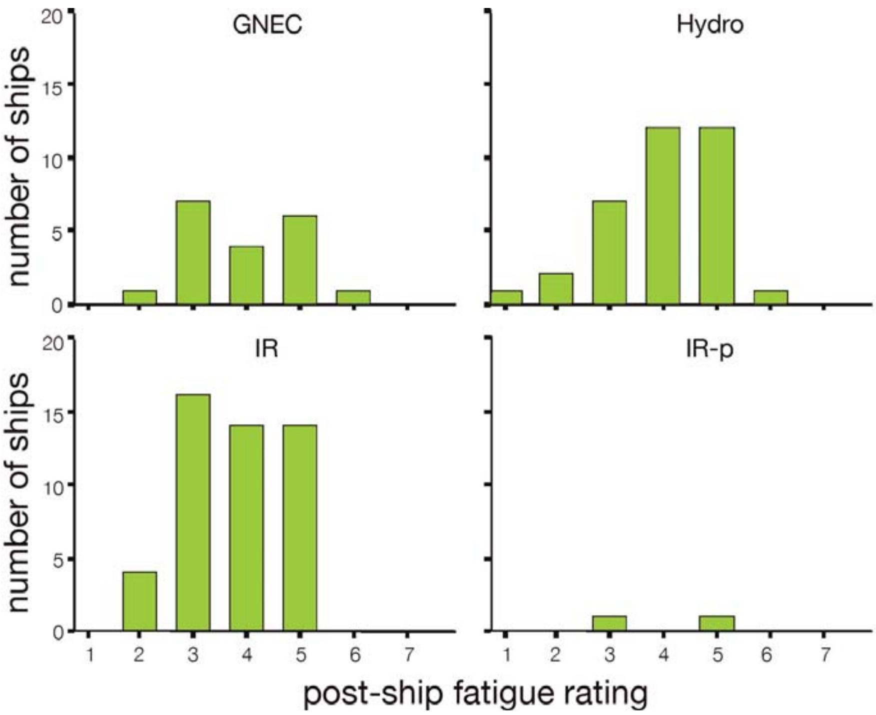


Figure 4 – Post-ship fatigue ratings grouped according to route worked.

3.2.3 Time off after a ship

On average, pilots had 45.7±25.8 hours off following each ship (range = 7 to 153.5 hours). As shown in Figure 5, the amount of time that pilots had off following each ship did not significantly vary as a function of the type of ship worked. Specifically, pilots had between 15 and 147 hours off after working an IR ship (mean = 45.9±26.7 hours), between 16.3 and 33 hours off after working an IR-p ship (mean = 24.4±8.3 hours), between 16.5 and 88 hours off after working a GNEC ship (mean = 41.4±17 hours), and between 7 and 153.5 hours off after working a Hydro ship (mean = 46.0±28.8 hours). [It should be noted that the IR trip associated with only 15 hours off after finishing was a 'check trip'].

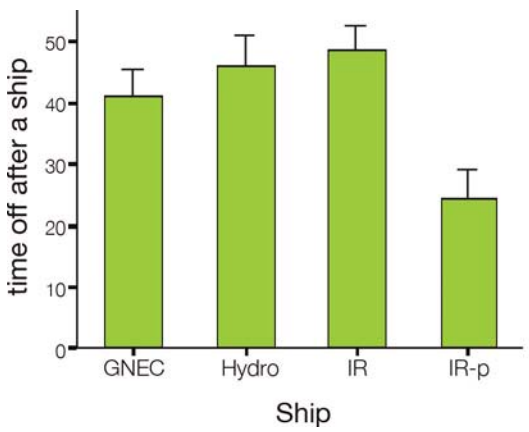


Figure 5 – The average amount of time off in hours (±SEM) after ships on each of the three routes.

While the average time off after shifts was approximately 2 days, it is clear from Figure 6 that many breaks were shorter. As can be seen in Figure 6, the amount of time that pilots had off following GNEC ships (which were between 6 and 12.6 hours in duration) was typically greater than 24hours (82%). Only two ships were associated with subsequent breaks of between 16-24, and on no occasions following GNEC ships did pilots have less than 16 hours off.

Following Hydro ships (which were between 8.3 and 20 hours in duration), pilots typically (61% of ships) had at least 36 hours off after working Hydro ships, with many breaks extending longer than 48 hours (42%). On one occasion, the time that a pilot had off following a Hydro ship was less than 8 hours, and on three occasions time off following Hydro ships was between 8 and 16 hours.

Notably, despite the fact that Inner Route ships were substantially longer (between 9 and 83 hours in duration), the amount of time off following Inner Route ships was similar to that following GNEC and Hydro ships. Specifically, pilots working Inner Route ships usually had at least 24 hours off (93% of ships), with 39% of their breaks following Inner Route ships extending for longer than 48 hours. Those breaks not meeting the 24-hour requirement included one check trip (not subject to fatigue management guidelines), one break of 23.75 hours and one of 19.25 hours.

As can be seen in Figure 6, the amount of time that pilots had off following GNEC ships was typically greater than 24 hours (85%).

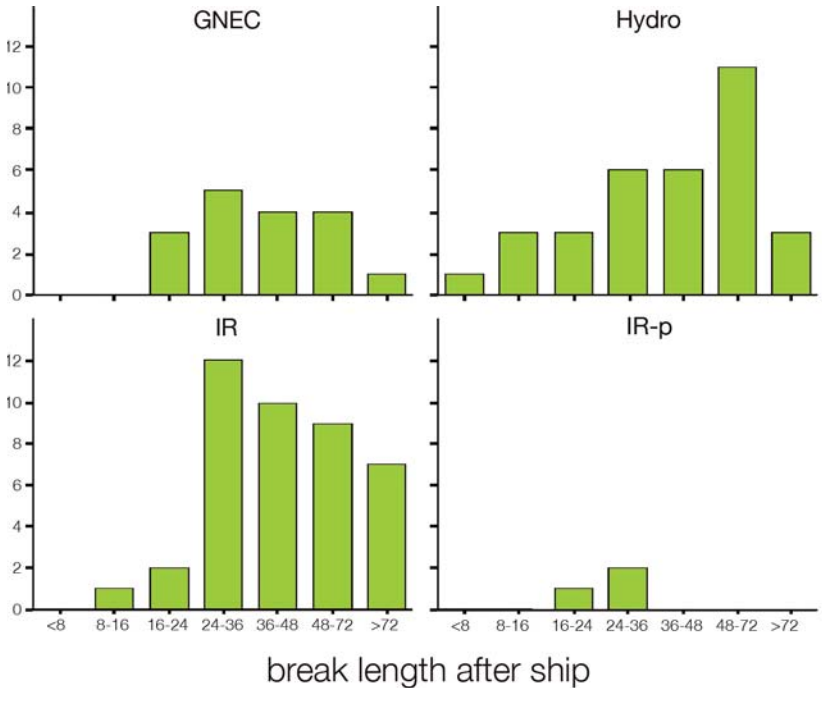


Figure 6 - The figure shows the percentage of breaks after a ship that were less than 8 hours in length, 8-16 hours, 16-24 hours, 24-36 hours, 36-48 hours, 48-72 hours and longer than 72 hours. The breaks have been categorised according to the ship worked.

Figure 7 provides an illustration of the relationship between the length of time off after a ship, and the actual ship length (length of work period), categorised by ship.

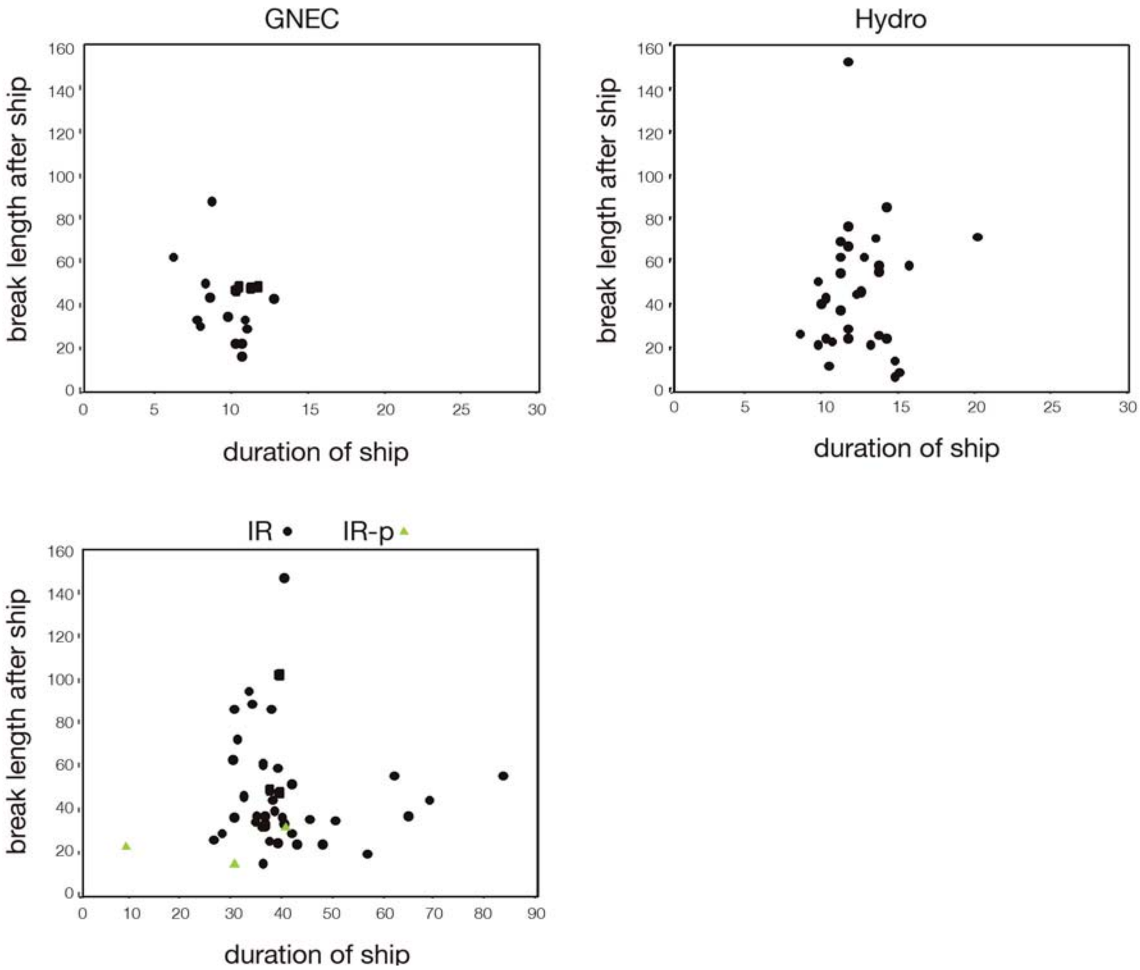


Figure 7 – The graphs are scatterplots of the length of the duty period on a ship in relation to the amount of time off after the ship. The top panel is GNEC ships, the middle panel Hydro ships and the bottom panel IR ships. The red symbols in the IR panel represent partial IR trips.

3.3 Sleep Characteristics

Overall, data was collected from 734 sleep periods. These ranged in length from 15 minutes to 12.5 hours. In the following analyses, these sleep periods are split into three categories:

- Main (the primary sleep period during a day/night),
- Ship (occurred whilst the pilot was on a ship while on duty) or
- Nap (short sleep periods, usually preceding a main sleep period).

In total, the data set included 278 Main sleep periods, 334 Ship sleep periods, and 114 Naps. The remaining 8 sleep periods could not be easily classified into one of these categories, and were thus excluded from further analysis.

3.3.1 Home Sleep Periods

In total, data was collected during 173 sleep periods that occurred at home: 133 Main sleep periods, and 40 Naps. On average, pilots spent 7.9±1.4 hours in bed during each main sleep period (range = 2.6 to 12.5 hours), and obtained between 2.2 and 10.1 hours sleep per period (mean = 6.9±1.4 hours). Their naps at home ranged from 30 minutes to 5 hours (mean = 1.8±1.4 hours), during which they obtained between 0 and 4.8 hours sleep (mean = 1.4±1.3 hours) (Figure 8).

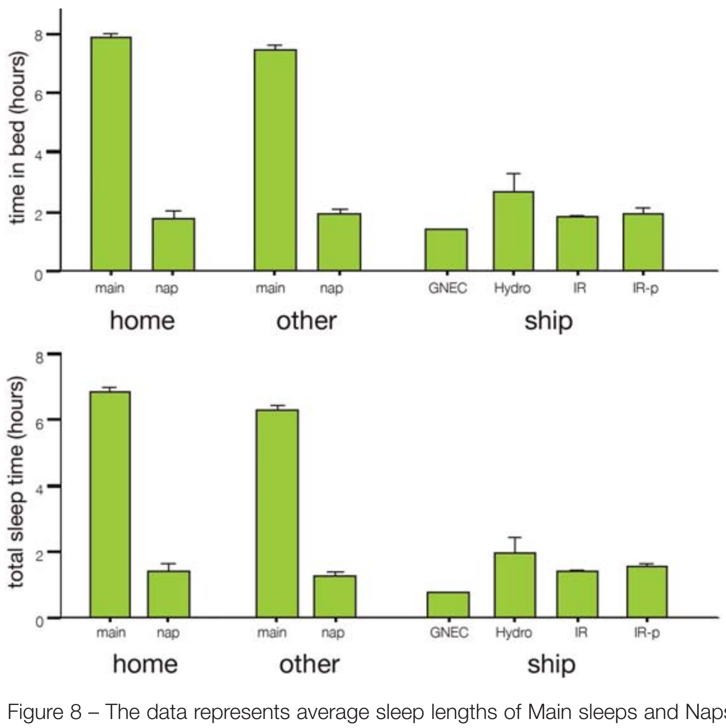


Figure 8 – The data represents average sleep lengths of Main sleeps and Naps obtained in both the Home or Other locations, in addition to sleeps obtained on board a Ship. Sleeps obtained on board a Ship were not categorised into Main or Nap.

3.3.2 Ship Sleep Periods

In total, data was collected during 334 sleep periods that occurred on ships while pilots were on duty. On average, pilots spent 1.9±1.2 hours in bed during Ship sleep periods (range = 15 mins to 9.5 hours), and obtained 1.4±1.0 hours sleep (range = 0 minutes to 7.1 hours). As can be seen in Figure 9, pilots spent less than 3 hours in bed for the majority (87%) of sleep periods on ships. Moreover, for the majority of sleep periods on ships (76%), pilots obtained less than two hours sleep. Most sleep periods while on board a ship were during trips in the Inner Route.

3.3.3 Other Sleep Periods

In total, data was collected during 219 sleep periods that occurred in other locations: 145 Main sleep periods, and 74 Naps. On average, pilots spent 7.5±1.7 hours in bed during the Other sleep periods (range = 3.25 to 12.5 hours), and obtained between 2.7 and 11.25 hours sleep per period (mean = 6.3±1.6 hours). Their naps ranged from 15 minutes to 4.5 hours (mean = 1.8±1.0 hours), during which they obtained between 0 minutes and 4.25 hours sleep (mean = 1.1±0.9 hours).

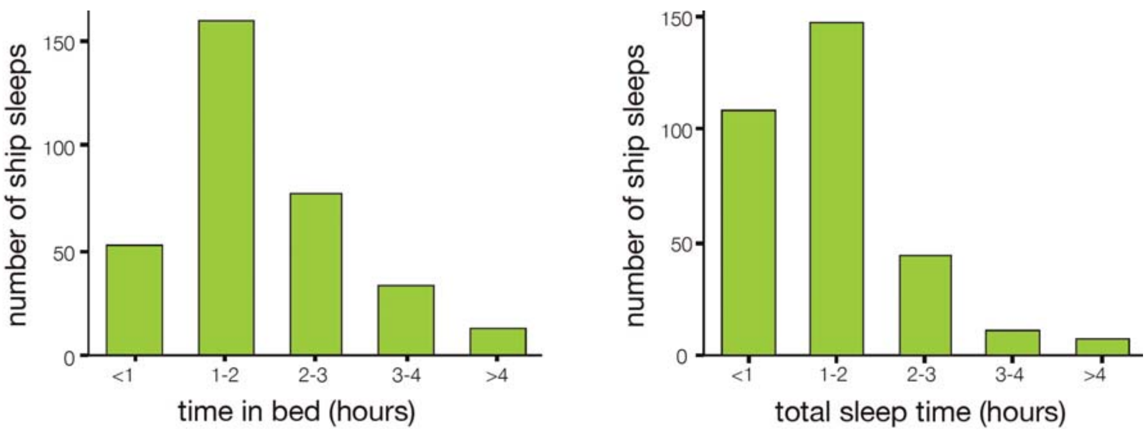


Figure 9 – The figure illustrates sleep periods according to time in bed (left panel) and total sleep time (right panel) categorised in one-hour bins from less than one hour to more than seven hours. The percentage of sleep periods in each bin is displayed on the vertical axis.

3.3.4 Sleep Quality

Following each sleep period, pilots were asked to provide a subjective rating of the quality of their sleep on a scale of 1 (very good) to 5 (very poor), and indicate if they did not obtain any sleep. Subjective reports indicated that during sleep periods that occurred at Home, pilots always obtained some sleep, except during one nap. During sleep periods that occurred in Other locations, pilots obtained sleep on all occasion, except during 5 of the naps (3% of Other sleep periods). Interestingly, pilots reported that they were unable to sleep during only 17 of their sleep periods that occurred whilst on a Ship (5%).

As can be seen in Figure 10, subjective sleep quality varied depending on the location and type of sleep period. Specifically, main sleep periods that occurred at Home were rated as significantly better quality than naps and sleep periods that occurred on Ships and Other locations. (NB. Lower scores indicate a higher level of subjective sleep quality).

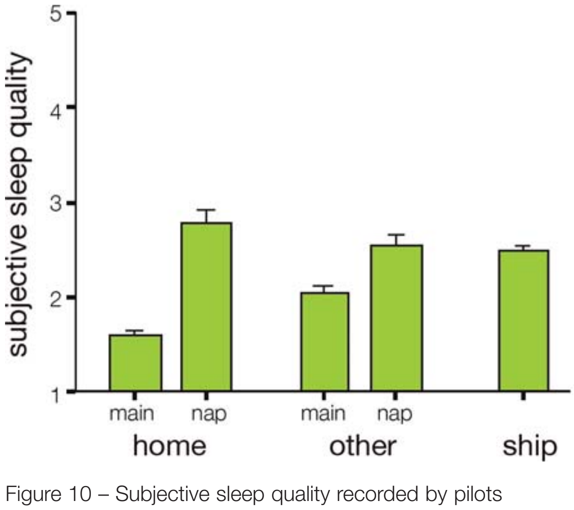


Figure 10 – Subjective sleep quality recorded by pilots (average ± SEM) for all sleeps, both Main sleeps and Naps at Home or in Other locations, and sleeps on board Ships.

Indeed, the majority (82%) of main sleep periods that occurred at Home were rated as either good or very good quality (see Figure 11). Only one sleep period was considered poor quality (1%), and no sleep periods were rated as very poor. Main sleep periods that occurred in Other locations were also rated as significantly better than naps and sleeps that occurred on Ships. Many of the main sleep periods that occurred in Other locations were rated as either good or very good (70%). The remainder were typically considered to be average (26%), with only 4 sleep periods rated as poor or very poor (3%). Overall, sleep periods that occurred on Ships were of poorer quality than main sleep periods that occurred at Home or Other locations. Specifically, only half of sleep periods that occurred on Ships were considered good or very good quality. While most of the remainder were rated as average (41%), 28 sleep periods were rated as poor or very poor (9%).

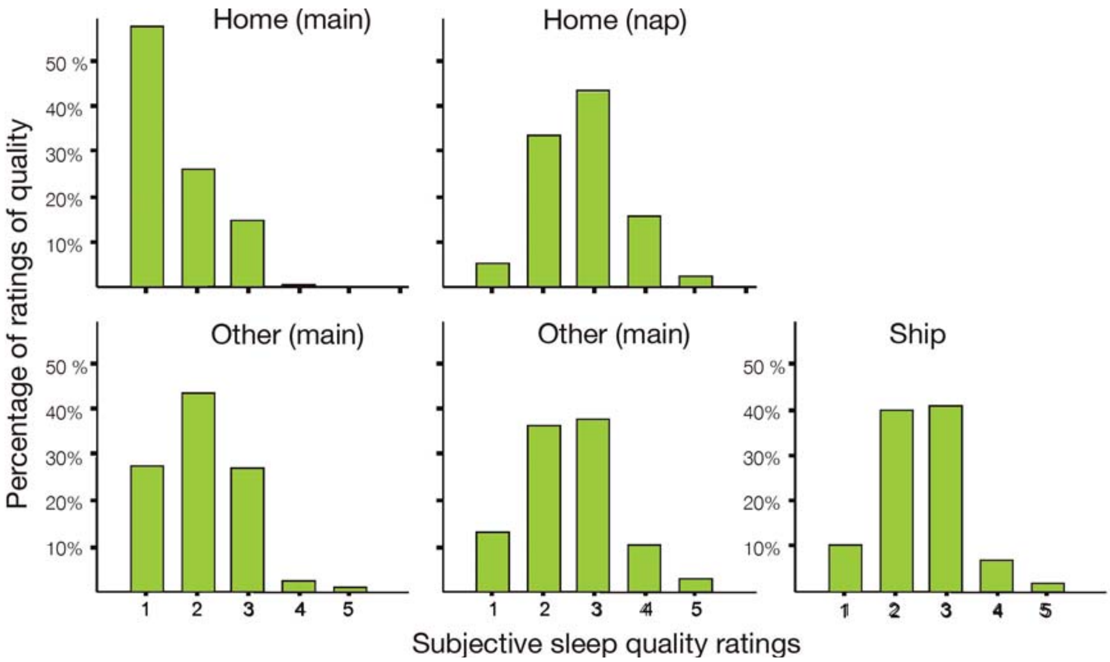


Figure 11 – Percentage of ratings of sleep quality by type of sleep.

3.3.5 Distribution of Sleep across the day

The graphs pictured in Figure 12 provide a representation of the timing of sleep obtained at Home, on board Ship and in Other locations. The results of this analysis indicate that GBR Coastal Pilots obtained the majority of their sleep while at Home, or in Other locations during the hours of 2200 and 0700. There was also a smaller peak in sleep probability in the early hours of the afternoon, which is slightly more pronounced in the curve illustrating sleep in Other locations. The curves also reiterate the fact that less sleep was obtained during Main sleeps in Other locations than during Main sleeps at Home. The area under the curve (i.e. the shaded area) indicates what percentage of the population were asleep at any given time. Thus, less area under the curve indicates less sleep in general. Sleep obtained while on board a Ship was more evenly displaced across the 24-hour period and was markedly reduced compared to sleep at Home or in Other locations. It is interesting to note however that there is a tendency for pilots to obtain less sleep on ships during the evening hours (1700-2000) and the morning (0900-1100).

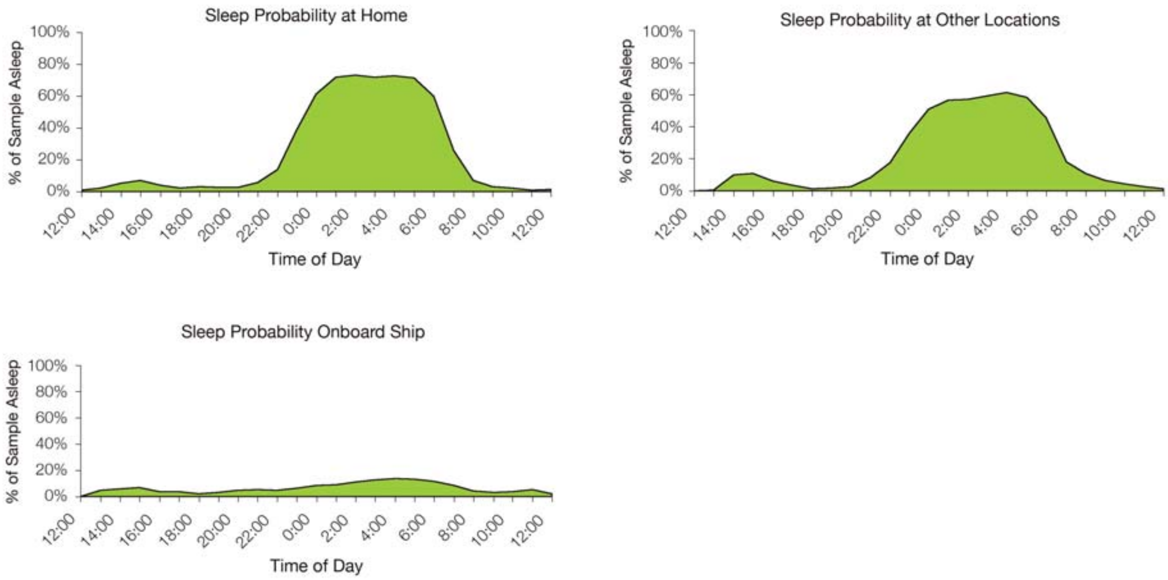


Figure 12 – Sleep probability curves. These curves illustrate the probability that individuals are asleep at a given time of the 24-hour day. The data are expressed as a percentage of the population asleep at each time point. The area under the curve provides an indication of the amount of sleep obtained in each location.

3.3.6 Sleep prior to getting on a ship

On average, GBR Coastal Pilots were in bed for 8.9±1.8 hours in the twenty-four hours prior to starting a ship (range= 5.4 to16.5 hours). During this time, they obtained an average of 7.4±1.7 hours sleep (range = 3.3 to 13.7 hours). As can be seen in Figure 13, the amount of sleep obtained in the twenty-four hours prior to starting a ship did not significantly vary as a function of the type of ship worked. Specifically, those working IR ships spent between 6.5 and 16.5 hours in bed in the twenty-four hours prior to starting a ship (mean=9.1±1.7 hours), and obtained between 3.3 and 13.7 hours sleep (mean = 7.6±1.7 hours). Those working IR-p ships spent between 6 and 14.8 hours in bed in the twenty-four hours prior to starting a ship (mean = 9.8±3.7 hours). Pilots working GNEC ships spent between 6.5 and 13.2 hours in bed in the twenty-four hours prior to starting a ship (mean = 8.9±2.0 hours), and obtained between 3.8 and 11.9 hours sleep (mean=7.2±1.9 hours). Pilots working Hydro ships spent between 5.4 and 13 hours in bed in the twenty-four hours prior to starting a ship (mean = 8.7±1.7 hours), and obtained between 4.9 and 10.6 hours sleep (mean = 7.2±1.4 hours).

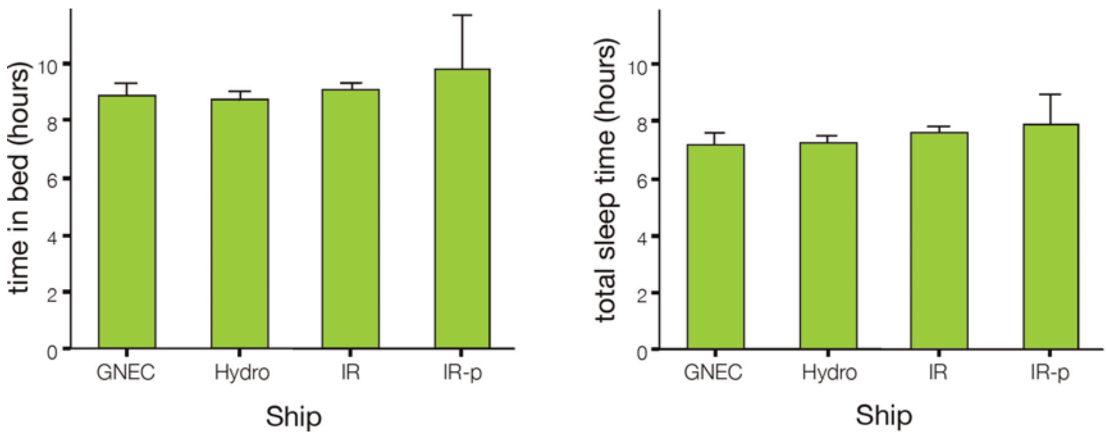


Figure 13 – The graphs show the average (±SEM) for time in bed (left panel) and total sleep time (right panel) obtained by pilots in the 24-hours prior to boarding a ship. The sleep parameters have been categorised according to ship.

Pilots working the Inner Route were on the ship for between 26 and 83 hours (mean =40.3±12.0 hours). On average, each IR ship was associated with 6.3±1.6 sleep periods (range = 3 to 11 periods). In total, pilots spent between 4.3 and 25.6 hours in bed attempting sleep (mean = 11.5±4.1 hours) during each IR ship, and obtained between 1 and 16.5 hours sleep (mean = 8.5±3.1 hours). Per twenty-four period on the IR ships, pilots obtained an average of 5.1±1.5 hours sleep (range = 35 minutes to 8.4 hours).

Another way to examine the sleep patterns of the GBR Coastal Pilots prior to them boarding a ship is to calculate the amount of sleep they achieved in the previous 24-hour period and the previous 48-hour period. Figure 14 shows the distribution of prior sleep for all ships. The vast majority of GBR Coastal Pilots in the study obtained more than 6 hours of sleep in the 24-hours prior to boarding a ship and 13 hours in the 48-hours prior to boarding a ship.

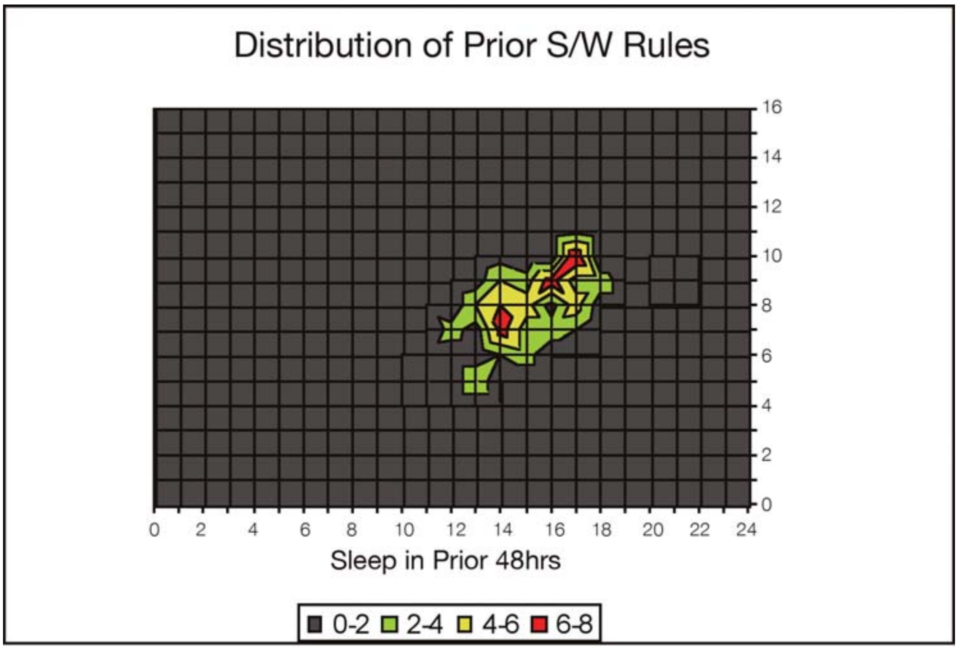


Figure 14 – The graph provides a representation of the amount of sleep individuals obtained in the 24-hour, and 48-hour periods prior to beginning a work period. Colours indicate the number of data points at each juncture.

Figures 15 and 16 use the same prior sleep information and examine the relationship with pre-ship and post-ship fatigue ratings. The data reiterates that pilots felt more fatigued after completing ships (indicated by the increased amount of blue, yellow and red on the graph).

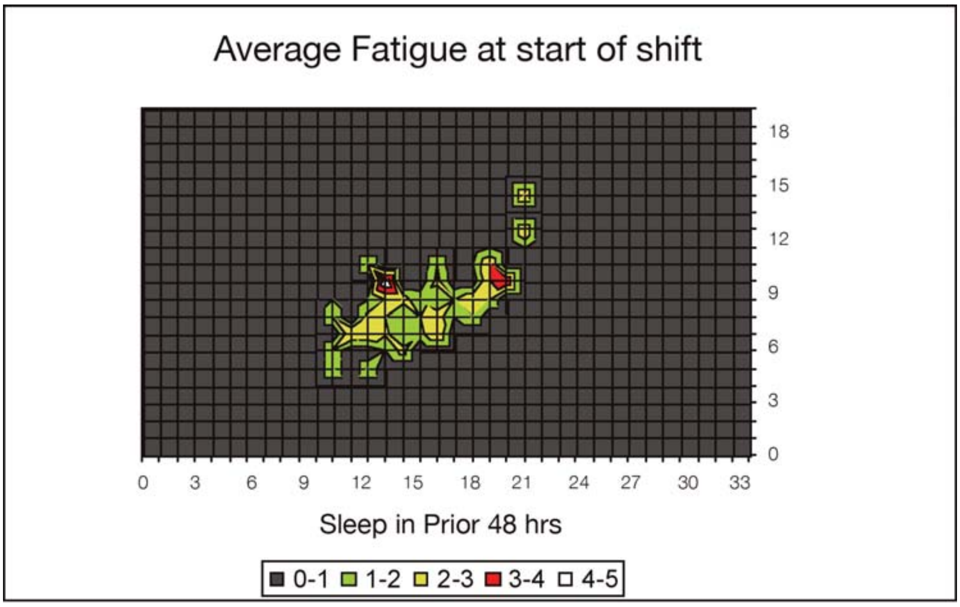


Figure 15 – The graph provides a representation of the average pre-ship fatigue levels as a function of the amount of sleep individuals obtained in the 24-hour, and 48-hour periods prior to beginning a work period. Colours indicate the number of data points at each juncture

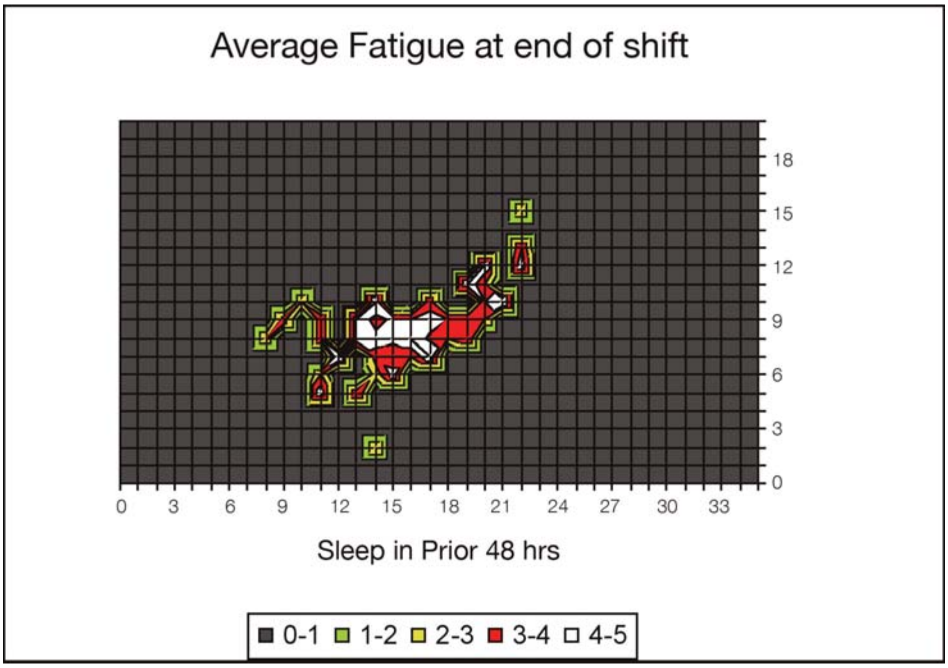


Figure 16 – The graph provides a representation of the amount of sleep individuals obtained in the 24-hour, and 48-hour periods prior to beginning a work period. Colours indicate the number of data points at each juncture.

3.3.7 Average wake periods

The length of time that pilots were awake between consecutive sleep periods (those that involved actual sleep, rather than just attempted sleep), ranged from 14 minutes to 42.4 hours (Figure 17). Notably, pilots were awake for significantly longer prior to Home sleep periods compared to prior to Other and Ship sleep periods, and in turn, were awake for significantly longer prior to Other sleep periods, compared to Ship periods. Specifically, prior to sleep periods that occurred at Home, pilots were awake for between 1.75 and 42.4 hours (mean=13.1±5.6 hours), prior to sleep periods occurring on Ships, they were awake for between 13 minutes and 19.8 hours (mean = 5.3±4.3 hours), and prior to Other sleep periods, they were awake for between 2.3 and 25.3 hours (mean = 11.0±5.1 hours).

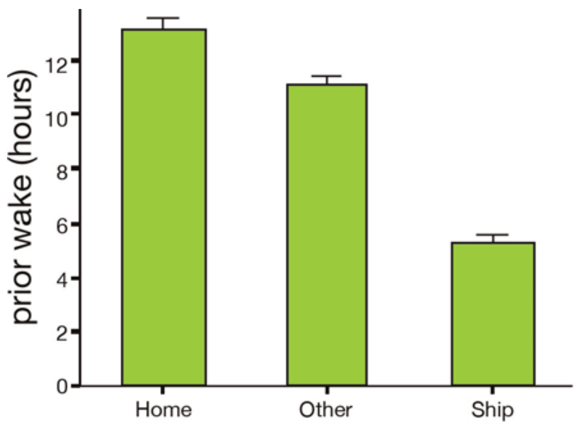


Figure 17 – The average (±SEM) length of wakefulness for pilots prior to a sleep period categorised according to location.

As can be seen in Figure 18, pilots were awake for less than 15 hours prior to the majority (96%) of sleep periods that occurred on Ships. Prior to sleep periods that occurred in Other locations, they were awake for less than 15 hours on 70% of occasions. In contrast, pilots were awake for more than 15 hours prior to nearly half (48%) of sleep periods at Home. Notably, they were awake for more than 20 hours prior to sleep periods that occurred in Other locations (4%), 9 Home sleep periods (6%) and no Ship sleep periods.

3.3.8 Prior wakefulness

The length of time that individuals had been awake at the time they started work on a ship was assessed as 'prior wakefulness'. This refers to the length of time in hours from waking until the beginning of a ship. The average prior wakefulness for all ships was 4.5 hours (SEM=0.35). The average prior wakefulness for GNEC ships was 3.4 hours (±0.69), for Hydro ships 4.4 hours (±0.73) and for IR ships it was 5.2 hours (±0.58). The maximum length of wakefulness prior to starting a ship was 16.2 hours.

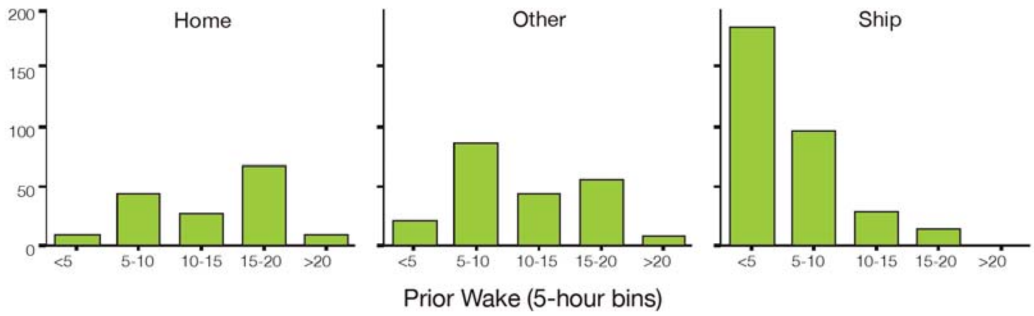


Figure 18 – Prior wake was binned into 5-hourly bins to illustrate the number of sleep periods that were associated with varying periods of wakefulness.

3.4 Performance characteristics

3.4.1 Vigilance Task

Participants were asked to complete a 5-minute visual Psychomotor Vigilance Task (PVT) at regular intervals during their ships, to objectively evaluate behavioural alertness. In total, 565 PVTs were completed (excluding practice tests) during the ships. Specifically, 53 PVTs were completed during GNEC ships, 78 were completed during Hydro ships and 411 were completed during IR ships with 23 on IR-p ships. The two measures that were extracted from the PVT for this report include the average response times (RT) for each test, and the number of lapses (responses greater than 500 milliseconds) during each test. Significant increases in these measures are often indicative of elevated levels of fatigue and decreased alertness.

3.4.2 Time-of-day effects

The palmPVT results were binned into 2-hourly bins across the 24-hour day to determine any effect on performance of time of day. As can be seen in Figure 19, PVT performance did not vary as a function of the time of day at which the test was performed. This was the case for all types of ships. The variation shown in the graphs indicates that some pilots were performing better than others, though in general the reaction times and number of lapses were with the normal range of performance.

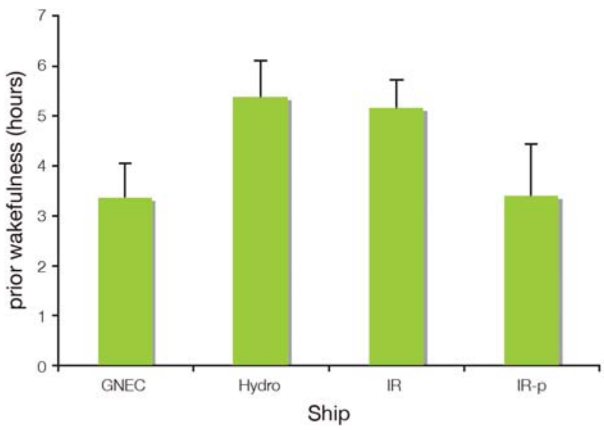


Figure 19 – The length of time individuals were awake prior to beginning work on a ship.

3.4.3 Time into Ship Effects

Similarly, time into the ship did not significantly impact on PVT performance (Figure 20). Average number of lapses per test and average reaction time per test were assessed in 2-hourly bins of time from the beginning of a ship. There was no difference in the performance between ships.

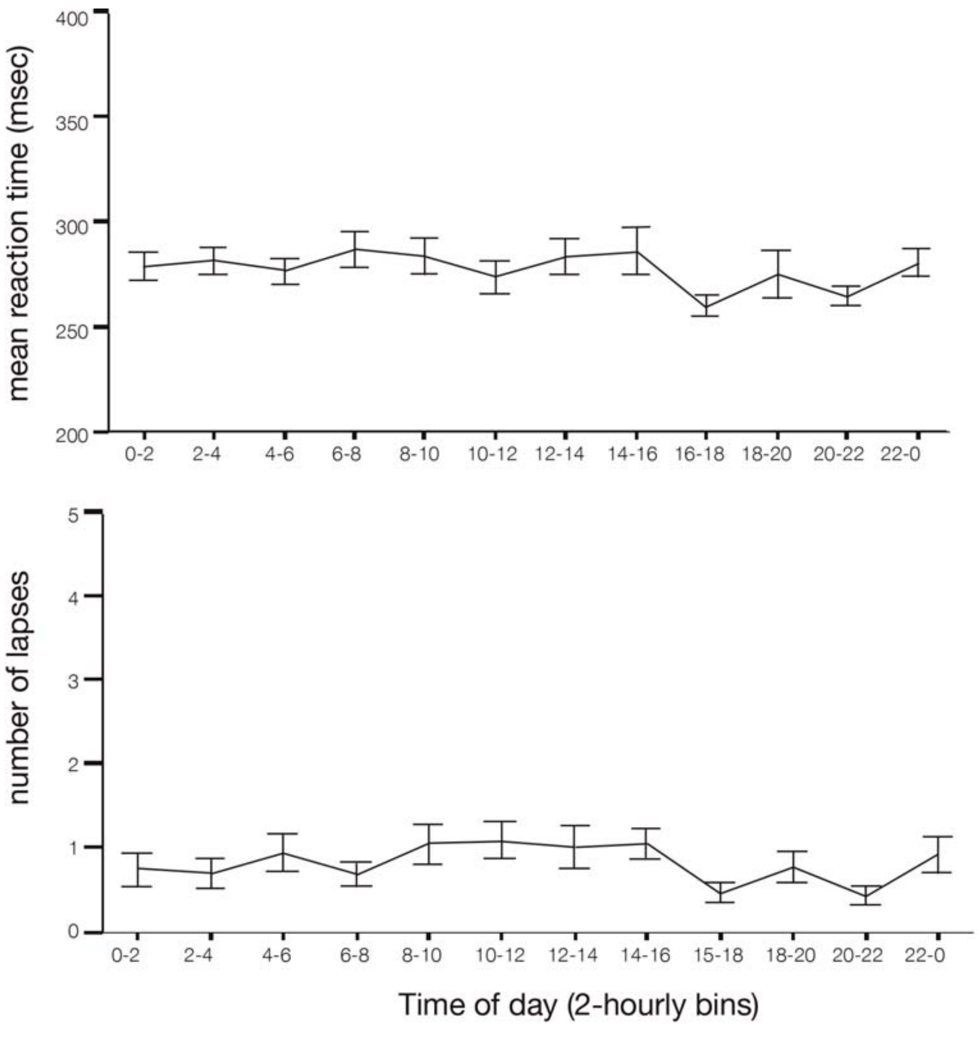


Figure 20 – Average reaction time per test (top panel) and average number of lapses per test (bottom panel) were collated for all tests on all ships and binned in 2-hourly bins across the 24-hour day. The data set represents the mean ±SEM for all participants.

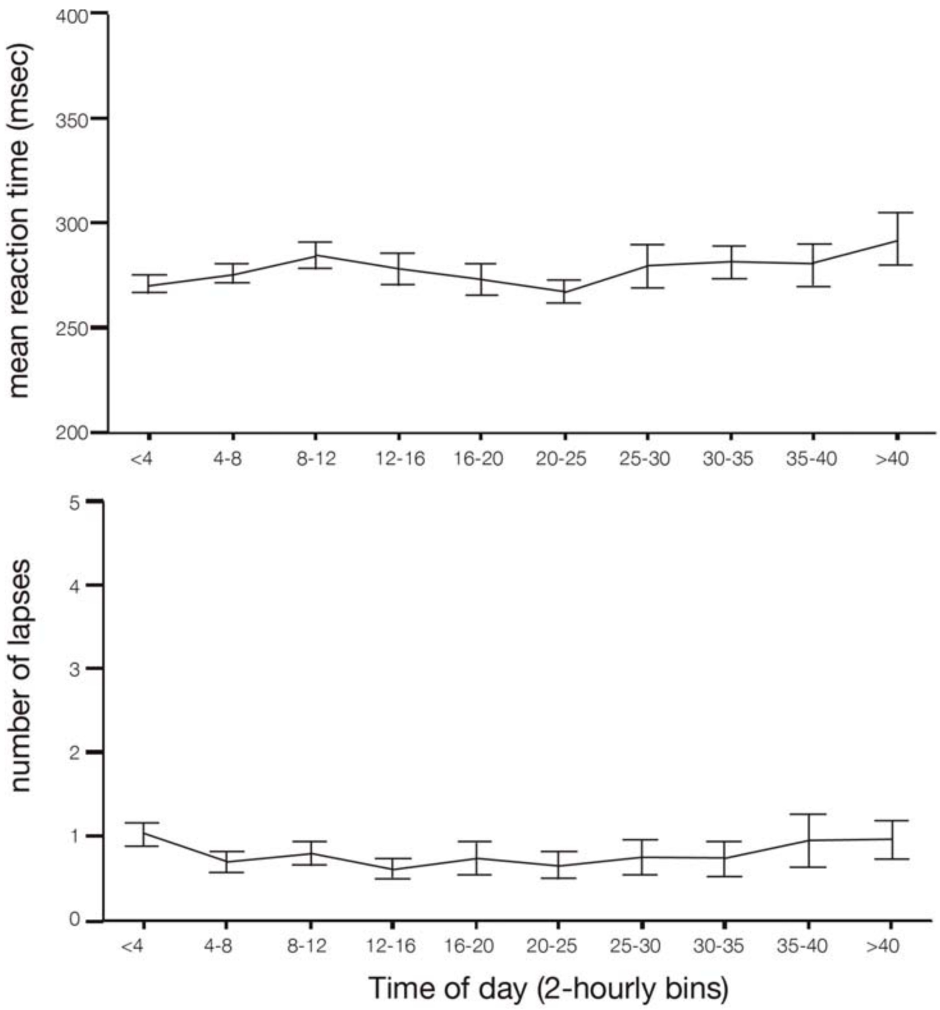


Figure 21 - Average reaction time per test (top panel) and average number of lapses per test (bottom panel) were collated for all tests on all ships and binned in 2-hourly bins across the length of a ship. The data set represents the mean ±SEM for all participants.

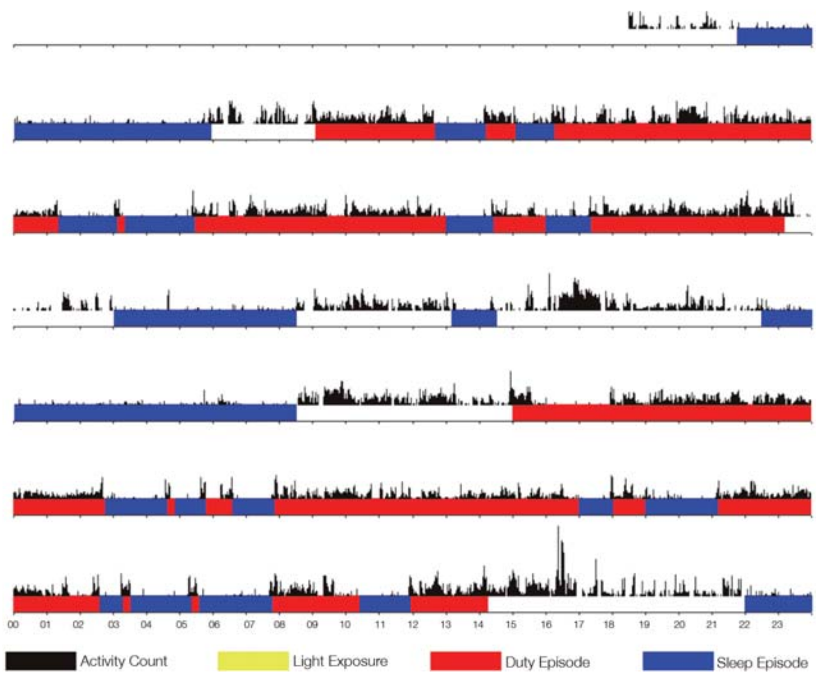
4. Discussion

The data collected in this study was generally of an extremely high quality. GBR Coastal Pilots were asked to collect sleep and work information using a diary, wear an activity monitor and complete a 5-minute reaction time task periodically while on board ships. The data collection period was 4 weeks for the majority of pilots. This represented a significant burden for the volunteers, and one which they primarily bore in isolation. Though project team members were available to answer questions, and often did over the phone or via email, due to the nature of the work of GBR Coastal Pilots, frequent personal contact was not possible. Despite these challenges the participants in this study provided exceptional records of their work and sleep patterns which have resulted in a unique and comprehensive database of information on which to base future decisions about fatigue management in the area.

Pilots obtained their sleep either at Home, on board ships or in other locations such as pilot houses in Cairns, Mackay or Thursday Island, in hotels, or at friends places. While sleep quality for main sleeps was rated significantly higher at Home, the subjective quality of main sleeps in Other locations were still rated fairly highly. Less than half of the sleep periods taken on board ships were considered good or very good. The distribution of sleep across the 24-hour day indicated that pilots obtained the majority of their sleep between the hours of 2200-0700. A similar distribution pattern has been reported previously by our group in train drivers working an irregular roster pattern [17]. This also means the pilots are getting a large portion of their recovery sleep away from ships during the night hours, thereby further enhancing the recovery value of the sleep. Further, it is well known that sleep is easiest to achieve and most restorative when obtained at this time [18]. Another peak time for sleep was demonstrated in the early afternoon hours. Pilots obtained naps between approximately 1400-1600, another well known time for increased sleepiness [10]. On board ships however, sleep patterns were quite different.

The average length of sleep periods on board ships was approximately two hours. These naps were essentially evenly distributed across the 24-hour day indicating opportunistic napping occurred. This means that rather than simply obtaining sleep at times of highest sleep propensity, pilots napped when the work allowed. The majority of Ship sleeps occurred during the long pilotage period associated with the Inner Route. The frequent napping meant that pilots were generally awake for only six hours at a time on average while on board a ship, though this did vary significantly. In some cases pilots were awake for 20 hours or more, however, in 95% of cases pilots were awake for 15 hours or less.

The amount of sleep obtained on board ships per 24-hour period provides an indication of the amount of recovery sleep that pilots obtained while actually on board. In this study pilots obtained an average of five hours sleep per 24-hours of piloting in the Inner Route. This is slightly lower than that recorded in a previous study in this population which reported 5.5 hours of sleep in every 24-hours on board [11]. In that study the methodologies used were subjective tools. A survey was used to record information about sleep. While survey tools and diaries alone can provide invaluable information about sleep quality and quantity, the objective measure employed in the current study provides more accurate information that will not be impacted by individual biases or subjective views of sleep quality and amount. The current study may in fact slightly underestimate the amount of sleep that GBR Coastal Pilots achieve on board due to the movement of the ship. Having said that however, sleep periods on board ships are very obvious in the records (See example below).



Recent studies suggest that less than five hours of sleep per 24-hours is associated with impairments in mental and physical aspects of performance [19-21]. It is important to note that these studies all examined sleep periods that were obtained in single unbroken blocks and during the night hours. The sleep recorded by GBR Coastal Pilots while on board ships was achieved in short naps and distributed across all times of the day. Therefore, the recovery value of sleep while on board is likely to be less than if it were taken ashore and at night. Despite this, there was no indication of alterations in performance associated with time into a ship. Data from the palmPVT showed that reaction time and lapse frequency did not change significantly across time. This was also supported by subjective measures of fatigue.

Although GBR Coastal Pilots reported feeling higher levels of fatigue on completion of a ship, the average post-ship rating was 'a little tired, less than fresh'. Less than 10% of GNEC and Hydro ships were associated with a response of 'extremely tired, very difficult to concentrate' on completion. Minimal sleep was obtained on these routes as very few of the participants napped while piloting in these areas. Together, the data suggests that implementing measures to increase alertness and performance will be beneficial for safety. This could be done through either increasing total sleep time on board, increasing the quality of sleep on board, manipulating alertness levels, or ensuring individuals are fully recovered prior to boarding a ship.

In the 24-hours prior to boarding ships pilots generally obtained on average 7.4 hours of sleep. This ranged from as little as 3.3 hours to as much as thirteen hours. However, there were only six occasions (out of more than 100) where pilots obtained less than 5 hours of sleep in the 24-hours prior to boarding a ship. Importantly also, the majority of sleep obtained at Home or in Other locations occurred between the hours of 2200 and 0700, the optimal times for sleep quality and quantity. Thus, prior to boarding ships pilots had a significant amount of sleep at an optimal time of their circadian cycle. This is reinforced by subjective ratings of fatigue prior to the commencement of a pilotage task. The fatigue rating prior to ship was on average 1.6 indicating subjective feelings of fatigue between 'fully alert, wide awake' and 'very lively, responsive, but not at peak'. Further, an average of more than 7 hours of sleep in the 24-hours prior to starting a work period is higher than that recorded in a mining and a smelter operation, and on a par with individuals working in the rail industry.

The data indicate that GBR Coastal Pilots appear to be commencing ships with a low level of fatigue and after having obtained an adequate amount of sleep in the preceding 24-hour period. Further, the average amount of wakefulness experienced by pilots prior to beginning a duty period was 4.5 hours. Prior wakefulness is also an important determinant of fatigue. This study showed that on average, pilots began a ship within 5 hours of a sleep period. There were six occasions where prior wakefulness (wake time before beginning a ship) was between 12 and 16 hours in length (out of approximately 120 ships worked in total). This may be of some concern on ships piloted in the Hydrographer's Passage where sleep is rare, however, the duty period for that route is on average 12 hours. The implementation of strategies for maintaining alertness towards the end of a Hydrographer's Passage ship would be beneficial in managing the risks associated with fatigue arising from sustained wakefulness.

Performance testing showed that there was no effect of time of day, time into ship, or ship in sequence on either reaction time or lapse frequency. Indeed, the performance of the participants in this study was maintained at baseline levels at all times. Comparison with other industries such as mining and rail indicate that the reaction times of the participants in the current study were well within the normal range (indeed comparable with healthy young volunteers during the daylight hours) and did not slow with work hours or time of day. The results suggest that pilots are obtaining sufficient recovery sleep prior to boarding ships, and between ships. Further, the results also indicate that the amount of sleep obtained while on board ships, in particular on board IR ships, is sufficient to maintain baseline levels of performance throughout the pilotage period. While the performance task used in this study has been validated as being sensitive to fatigue, and for use in both laboratory and field-based settings, it is important to remember that it assesses only specific aspects of performance. It is also important to note that the PVT task is generally sensitive to short naps. Thus, the sleeping strategies of participants in this study ensure that performance on the palmPVT is maintained at baseline levels throughout the day and throughout a pilotage task. The subjective fatigue data would tend to support that notion.

It is apparent that the current rest break requirements are providing adequate sleep opportunity between work periods, and more importantly, that on the whole, GBR Coastal Pilots are obtaining adequate recovery sleep. However, the subjective fatigue ratings of pilots after completing ships were higher than on boarding ships. Thus, although the palmPVT results indicate no decrements in reaction time and lapse frequency, there may be other aspects of pilots' performance that are affected, particularly towards the end of a pilotage period or in the early hours of the morning. This should be monitored closely through the collection of error/incident data, with specific reference to fatigue issues and/or monitoring signs and symptoms of fatigue.

The average time between sleep periods on board a ship was 5.6 hours. This means that pilots generally went for less than six hours between naps on board a ship (primarily Inner Route ships). The longest period of time prior to a sleep period on board a ship was 19.8 hours and this also incorporated time prior to boarding the ship. Thus, while pilots were awake for less than 15 hours prior to 95% of sleep periods that occurred on ships, there were some occasions when the work pattern did not allow recovery sleep to occur, or for other reasons, sleep was difficult (e.g. environment, noise etc). In these situations, risk mitigation strategies should be available and employed to ensure that the risk of a fatigue-related error or incident is minimised. Further, fatigue risk management strategies should be put in place to continue to ensure that sleep opportunity provided by work hours is sufficient, and that actual sleep obtained is adequate for recovery (see section below on FRMS). Supplementary risk mitigation strategies should also be employed such as methods for the detection and reporting of fatigued behaviours and action plans developed where fatigue-related behaviours are exhibited.

Summary

The current objective analysis of GBR Coastal Pilots' sleep and work patterns indicates that the work schedule provides adequate sleep opportunity and that pilots obtain reasonable amounts of sleep, both prior to boarding a ship, and during extended pilotage tasks. Based on the data collected during this study, fatigue due to inadequate sleep does not appear to be a significant issue in this population. However, continued monitoring of work patterns, actual sleep obtained and implementation of fatigue risk management systems will help ensure that the Coastal Pilots charged with the protection of the invaluable marine environment of the Great Barrier Reef remain safe and fit for the task.

5.1 FRMS Framework.

Organisations should aim to implement a full Fatigue Risk Management System, based in Safety Management System theory and with a foundation of risk management. In the short-term, it is possible to introduce individual elements of a FRMS in order to reduce immediate risk and to increase awareness of fatigue-related risk. However, it is important to understand that without the underpinning framework and support, the introduction of strategies or procedures in isolation may not produce the desired outcomes. An undertaking by management and employees to implement a full FRMS is essential.

Key Elements.

The following are the minimum requirements that would comprise a Fatigue Risk Management System.

1. Policy and supporting procedures.
2. Training program.
3. Risk mitigation strategies.
4. Audit and on-going improvement process.

5.1.1 FRMS Policy and Procedures.

The following section provides general information about the requirements for an FRMS policy document. Organisations should develop an appropriate FRMS policy in order to identify, assess and manage the risks associated with fatigue in the workplace. A policy should be developed in conjunction with employees and their representatives to provide support for consistent responses to fatigue-related risk. It should also be emphasised that the process of managing fatiguerelated
risk in the workplace is a shared responsibility. The GBR Coastal Pilots are a unique group as they are self-employed contractors. Further discussion may therefore be required with regard to the design of a FRMS policy and this should occur with the pilotage companies, with individual pilots themselves, and with AMSA. From a general perspective however, following is a general framework for FRMS.

From a fatigue management perspective:
It is the employer's responsibility to ensure that the roster system or working time arrangements:

- Provide adequate opportunity to obtain sufficient rest prior to commencing work,
- Prevent periods of excessive wakefulness while working.

Conversely, it is the employee's responsibility to:

- Use time off appropriately to obtain sufficient sleep and prevent excessive wakefulness.
- Where this has not been possible, to follow written guidelines on how to appropriately mitigate the risk associated with the degree of insufficient sleep.

The policy should be reviewed on a regular basis (at least annually) to reflect changes in work and improvements in the methods of fatigue management. Additionally, the policy should ensure that there is:

- an appropriate reporting process,
- an "Accountable Individual" and
- an appropriate responsibility gradient within the organisation.

5.1.2 FRMS Training Program

GBR Coastal Pilots are self-employed contractors. Consequently, existing training programs may not be sufficient to provide all the relevant competencies in fatigue risk management for this group. Currently, training programs generally address strategies that can be applied specifically by individuals. However, for this population, more comprehensive information and a number of what may be termed 'management level competencies' are essential.

It is therefore recommended that coastal pilots operating in the Great Barrier Reef area demonstrate competencies in fatigue risk management through the successful completion of a training program that ensures individuals can:

- identify the determinants of fatigue,
- demonstrate understanding about how fatigue affects them and others,
- demonstrate understanding of human limitations with regard to mental and physical performance,
- identify the risks associated with fatigue and be exposed to specific examples of adverse consequences in the marine environment,
- identify and implement appropriate strategies for minimising fatigue-related risk,
- identify the different components necessary for an effective fatigue risk management system,
- assess work hours with regard to the sleep opportunity they provide,
- assess personal sleep and wake with regard to fatigue likelihood,
- determine whether their behaviour and the behaviour of the people who report to them, is consistent with relevant FRMS policy and procedures,
- assess fatigue-related risk and design appropriate action plans to manage the risk.

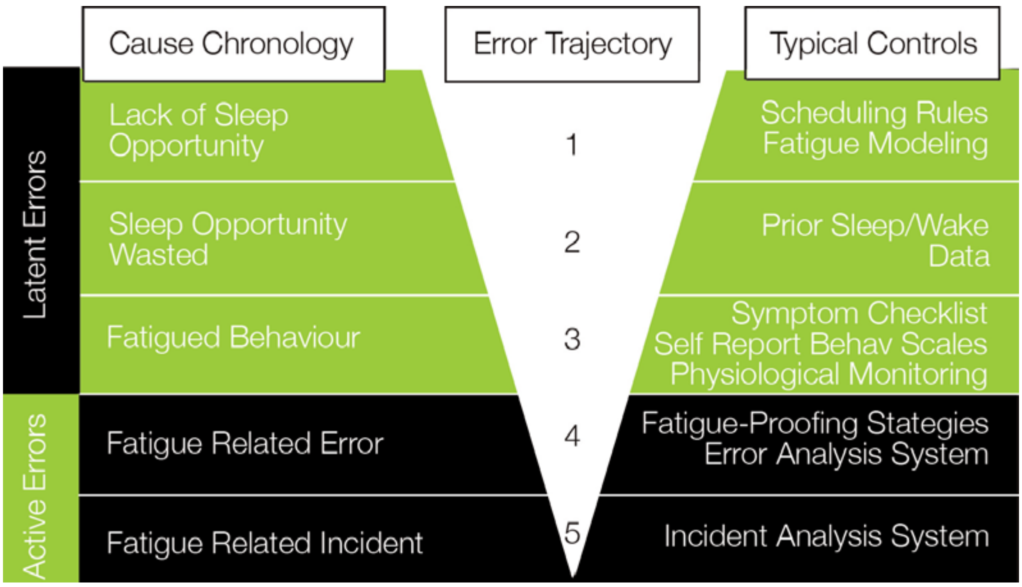
It is important to note that a training program developed on the above template should deliver much more than general interest 'fatigue awareness' training. Much of the fatigue awareness training undertaken by industry in Australia to date has focussed on ensuring that employees optimise their use of the sleep opportunity provided in order to gain sufficient sleep. There has been little or no focus on organisational responsibilities to actually provide adequate sleep opportunity (other than compliance with hours of work regulations). To date, there are no programs available that clearly define the competencies required by managers to ensure that fatigue-related risks are minimised. As mentioned, GBR Coastal Pilots are a somewhat unique group in that they work as self-employed contractors. Thus, the template above has been designed to incorporate both the 'individual' and 'management' level competencies required of this group of pilots.

5.1.3 Mitigating Fatigue-related risk

A risk assessment of the work practices of GBR Coastal Pilots was conducted in 1998 [15]. Since that time a series of studies have been conducted on the fatigue issues associated with this population, with the current study being the most recent. It may be timely therefore, to conduct another assessment of fatigue-related risk taking into account the current objective data that has been collected, in addition to the risk mitigation strategies that have been implemented in the past 5-6 years. This risk assessment should be conducted through a focus group of GBR Coastal Pilots, and involve the pilotage companies and AMSA. The following section provides a framework for the risk mitigation strategies that form a large component of a FRMS.

There are various levels at which the risk of fatigue-related errors/incidents can be reduced (See schematic below). The first, and potentially the most obvious control measure for fatigue-related risk is through roster design. This is primarily the responsibility of an employer. There are various options for assessing rosters in light of the amount of opportunity they provide for employees to obtain adequate recovery sleep while away from work and to not be awake for excessive periods while at work. However, the provision of sleep opportunity does not necessarily guarantee that sleep is actually obtained. It is also important therefore, to take account of the amount of sleep that individuals actually obtain and the extent of actual wakefulness. This is mainly the responsibility of the employee.

Assessment of actual sleep and wake can be conducted through self-reporting mechanisms or through the collection of objective data as used in this study. The next tier of controls focuses on (1) identifying and acting on fatigue-related behaviours and symptoms, and (2) reducing the risk of fatiguerelated behaviours and symptoms resulting in fatigue-related errors or incidents. That is, processes are put in places such that if an individual is exhibiting signs of fatigue these are picked up on and more importantly, action is taken. Other examples of controls at these levels include double-checking systems that ensure that a lapse in concentration on behalf of a fatigued individual does not translate into an adverse outcome. Finally, error and incident investigation form the final layer of defences and ensure that organisations learn from them and further strengthen higher levels of control.



6. References

1. House of Representatives Standing Committee on Communication. Beyond the Midnight Oil. An inquiry into managing fatigue in transport. 2000, The Parliament of the Commonwealth of Australia.

2. Siebenaler, M.J. and P.M. McGovern, Shiftwork: Consequences and considerations. 1991. 39: p. 558-567.

3. Smith-Coggins, R., et al., Rotating shiftwork schedules: can we enhance physician adaptation to night shifts? Academy of Emergency Medicine, 1997. 4: p. 951-961.

4. Smith-Coggins, R., et al., Relationship of day versus night sleep to physician performance and mood. Annals of Emergency Medicine, 1994. 24: p. 928-934.

5. Tepas, D. and A. Carvalhais, Sleep patterns of shiftworkers, in Occupational Medicine State of the Art Reviews: Shiftwork, S. AJ, Editor. 1990, Hanley & Belfus Inc: Philadelphia. p. 199-208.

6. Kecklund, G., T. Akerstedt, and A. Lowden, Morning work: Effects of early rising on sleep and alertness. Sleep, 1997. 20(3): p. 215-223.

7. Chang, C.J., S.Y. Wang, and H.W. Liu, The effect of shift system on sleep quality, sleep quantity, psychological disturbance, and family function of workers in Taiwan. Gaoxiong Yi Xue Ke Xue Za Zhi, 1993. 9: p. 410-417.

8. Escriba, V., S. Perez-Hoyos, and F. Bolumar, Shiftwork: its impact on the length and quality of sleep among nurses of the Valencian region in Spain. International Archives of Occupational and Environmental Health, 1992. 64: p. 125-129.

9. Fischer, F.M., et al., Do weekly and fast-rotating shiftwork schedules differentially affect duration and quality of sleep? International Archives of Occupational and Environmental Health, 1997. 69(5): p. 354-260.

10. Australian Maritime Safety Authority, Our tour analyses of the work and rest patterns of Great Barrier Reef pilots: implications for fatigue management. 1998, AMSA.

11. Australian Maritime Safety Authority, A survey of the work and sleep patterns of Great Barrier Reef pilots. 1998, AMSA.

12. Monk, T., et al., Circadian rhythms in human performance and mood under constant conditions. Journal of Sleep Research, 1997. 6: p. 9-18.

13. Hanecke, K., et al., Accident risk as a function of hour at work and time of day as determined from accident data and exposure models for the German working population. Scandinavian Journal of Work and Environmental Health, 1998. 24: p. 43-48.

14. Folkard, S. and P. Tucker, Shift work, safety and productivity. Occupational Medicine, 2003. 53(2): p. 95-101.

15. Det Norske Veritas Consultancy Services, Great Barrier Reef Pilotage Fatigue Risk Assessment. 1998, DNV Consultancy Services: Sydney.

16. Australian Transport Safety Bureau, Independent Investigation into the grounding of the Greek registered ship Doric Chariot at Piper Reef, North Queensland on 29 July 2002. 2003, Department of Transport and Regional Services Australian Transport Safety Bureau: Canberra.

17. Roach, G.D., K. Reid, and D. Dawson, The amount of sleep obtained by locomotive engineers: Effects of break duration and time of break onset. Occupational and Environmental Medicine, 2003. 60: p. e17.

18. Carskadon, M.A. and W.C. Dement, Normal Human Sleep: An Overview, in Principles and Practice of Sleep Medicine, Third Edition., M. Kryger, T. Roth, and W. Dement, Editors. 2000, W.B. Saunders Company: Philadelphia. p. 15-25.

19. Van Dongen, H.P.A., et al., The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioural functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep, 2003. 26(2): p. 117-126.

20. Belenky, G., et al., Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. Journal of Sleep Research, 2003. 12: p. 1-12.

21. Dinges, D., et al., Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep, 1997. 20: p. 267-277.