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NATIONAL INSTITUTE FOR FOREST PRODUCTS INNOVATION

Development of best-practice fatigue management for the Australian Forestry Industry

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Development of best-practice fatigue management for the Australian Forestry Industry

Prepared for

National Institute for Forest Products Innovation

Mount Gambier

by

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Executive Summary

Sleep loss and fatigue are hazards in forestry that can lead to incidents and accidents and decreased productivity. Long drives including commutes also have important implications for fatigue and fatality.

Much of the sleep loss and fatigue research in forestry has come from countries such as New Zealand, Canada, Sweden, Chile, and Indonesia. Given the broad and varied work environments across the forestry sector, more research is needed to inform forestry-specific solutions, metrics, and education and training programs that fit the local contexts.

This study was designed to address the following project objectives:

1. Examine current fatigue management systems in forestry in Australia, with an emphasis on the Green Triangle;
2. Identify recommended worker fatigue management strategies and 'myth-bust' ineffective or harmful strategies; and
3. Develop workplace guidance for systems and education.

Project innovations include:

- A focus on workers who cope well with shiftwork, identifying and evaluating individual behavioural and team-based coping strategies to manage fatigue;
- Examination of behaviour in terms of not only what is being done, but importantly, when it is being done; and
- The synthesis of research methods that will be employed to provide converging evidence for workplace guidance.

Interviews	n=23. Conducted with managers, WHS reps, and other employees. Explored FM approaches at the systems and individual levels.
Survey	n=104, international respondents=7, 34% from the GT. Information on work hours, coping strategies, physical and psychological health, sleep disturbances, and social and domestic disruption. Harvesting, silviculture, and mills were represented.
Crashes Dataset	Provided by the Victoria Department of Transport, Barwon South West. Truck crashes in the Vic portion of the GT between 2011 and 2021 n=111 with industry information.
Growers Dataset	Provided by FWPA. Includes indicators of the volume of product transported and truck rollover events for n=19 companies between November 2013 and November 2021 (97 months).
Harvesting Dataset	Provided confidentially. Included work hours, product volume indicators, and fuel use across >2,500 shifts, downloaded from harvesting machines across a one-year period.
Policy docs, websites, and rosters	Policies from six operators were mapped against nine key FM indicators. Public websites for 27 forestry operators in Australia and NZ were analysed for fatigue-related content. Example rosters were run through computer BM modelling software that uses work history to predict fatigue. For n=107 mill rosters (2,130 shifts) and the work hours from the Harvesting Dataset.

Figure 1: Summary of Data Sources.

The Steering Committee identified harvesting and transport as priority areas for investigation in forest management, and log export and sawmills ranked highly in processing areas. The project was impacted by COVID-19, which resulted in delays and limitations on face-to-face data collection. The researchers responded by including online methods and analyzing preexisting datasets across a number of areas. The mixed methods study involved synthesising data across interviews, surveys, datasets, and documentation (Figure 1).

Analyses were presented in six primary themes (Figure 2): (1) fatigue at work; (2) fatigue while driving; (3) fatigue and lifestyle; (4) policy and process; (5) shared responsibility for managing fatigue; and (6) fatigue technology and datasets.

All six themes were supported by an overarching narrative about the importance of having work and community cultures that support safety management strategies inside and outside the workplace. The safety management strategies and support cultures were underpinned by shared expectations, consistency and predictability as well as flexibility, and engaged problem-focused coping styles.

Figure 2: Summary of Themes.

The boxes on the following pages summarise the key points from each theme. Each point is accompanied by the relevant data source icon(s) from Figure 1, referencing the source(s) of the underpinning data.

Taken together, findings highlighted hazardous working conditions that exacerbated fatigue including working in heat, wind, near slopes or power lines. The fire season was identified as a time when fatigue guidelines were most needed. Sources of fatigue included perceived time pressure, long shifts, overtime, and early starts. There was a spread of circadian preference scores in the survey data and matching shift types to circadian preference was described in the interviews. Biomathematical modelling of rosters with sleep and fatigue estimation highlighted the changes in sleep and fatigue due to early starts, long and consecutive shifts, and rotating between shift types. Harvesting data analysis revealed a reduction in gross tonnes and work hours on Fridays, which showed that productivity remained constant. Driving was identified as the greatest risk area for forestry, including log and chip truck driving as well as commuting. Truck crash analysis revealed that fatigue may have contributed to the truck crashes analysed, particularly for timber vehicles driving around the clock. Success in coping well with the demands of working in the forestry industry was described as a "lifestyle" issue. Sleep problems were common, and coping strategies indicative of an engaged coping style were used more frequently than disengaged strategies.

Data Source	Fatigue at Work
	Environmental hazards exacerbating fatigue included working outdoors in the heat or under windy conditions, near to slopes or power lines. Fire season was identified as the strongest application area of fatigue guidelines and one of the biggest areas of need for fatigue management. Fatigue sources included perceived time pressure, elevated workloads, long shifts, and overtime.
	Early starts, as early as 2am, were a key topic for debate. Sleep loss resulting from early starts was exacerbated by long commute times. Workers range in circadian preference from very 'lark-like' to very 'owl-like.' There was discussion about matching shift types to circadian preference.
	Predicted ↓ sleep and ↑ fatigue as a function of early starts, long and consecutive shifts, and rotating between shift types.
	↓ gross tonnes harvested on Fridays. Reflected by ↓ work hours and ↓ fuel use on Fridays, such that productivity remained constant. Harvesting machine data and stored work hours are useful for understanding fatigue. Comparison datasets with double-shifts and/or hourly readouts would be of benefit.

Data Source	Fatigue while Driving
	Reported difficulties maintaining concentration on long trips, especially with early morning starts.
	46% reported feeling tired while driving ≥sometimes
	132 truck crashes in the Vic portion of the GT 2011-2022 (industry data for 111) 11% Fatal and 28% serious injuries 76% rollovers. There was a peak in rollovers in 2015, after which Rollover Programs were implemented 50% Timber Industry Trucks ~half of the Timber Truck crashes occurred at night vs 18% for other industries. Most crashes occurred in 100 km/h speed zones. ~70% were run-off-road, with 33% from a curve, and 26% from a straight. These types of crashes, especially those occurring during night hours, display hallmarks of fatigue as a contributing factor.
	Yearly ↓ in the amount of timber transported from 2014 to 2020 Compared to other months, ↓ transported in January and December. Controlling for amount transported as an exposure variable, rollovers have ↓ across time.

Data Source	Fatigue and Lifestyle
	Coping well was described as a "lifestyle," meaning that factors in and outside the workplace were important - "Home and work life need to complement each other."
	~7h sleep on workdays, which was ~30 mins less than perceived sleep need. Sleep was ↑ 1h on days off. Sleep problems were common with ~2% using pills and ~13% using alcohol as a sleep aid. 37% reported struggling to remain awake at work ≥sometimes.
	Domestic life was the highest rated area of negative impact from work hours, followed by social life, then sleep, and then work performance. Engaged coping styles used more frequently than disengaged coping. Most commonly used strategies were problem solving and cognitive reappraisal ("rethinking"). Engaged coping was associated with better diet and ↑ exercise. Disengaged coping was associated with ↑ GI symptoms, ↑ sleep disturbance, and ↑ work-life disturbance.
	~1 in 6 reported CV symptoms, and ~1 in 4 reported GI symptoms ≥sometimes 23% reported alcohol consumption >10 units per week, 12% reported smoking, ~1 in 5 reported consuming 4-6 cups of coffee and/or tea per day. ~13% consumed energy drinks.
	Compared to days off, workdays were associated with earlier and longer eating windows (time between first and last eating occasion), ↑ number of eating occasions, and ↑ proportion of snacks. Food timing was distributed around the clock when respondents were working afternoon, night, or split shifts.

Data Source	Policy and Process
	Fatigue management in forestry has undergone many pressures and developments in the last decade.
	While there was a focus on work hours, discussion included the importance of the task risk profile, consideration of the commute and other travel, and the importance of shared responsibility for fatigue management, including personal management of lifestyle factors.
	Average rating of how well people perceived that their organisation managed fatigue was high (71/100). 88% indicated that their organisation has a Fatigue Risk Management Policy, 4% reported that their organisation did not have one, and 8% reported that they did not know.
	Simple content review revealed that all policies included an evaluation of work hours, most policies included a hazard statement, linked to their Safety Management Systems, and made mention of fitness for duty, fatigue monitoring, and training. A definition of fatigue was provided in <50% of the policies reviewed, and none specifically mentioned post-incident evaluations or audit.
	Review of 26 public websites revealed that 38% included information about fatigue, including the causes and impact of fatigue, and how to recognise it in self and others.

Data Source	Shared Responsibility
	Highlighted the importance of a just safety culture at work, reinforced by family and community, where people feel safe to disclose when they are fatigued.
	Fatigue was described in many ways, from feeling "doughy" to feeling "slammed."
	Preference for permanent shifts, and a general move away from rotating roster designs. For many, the consistency and ability to plan ahead was particularly valued.
	Alongside consistency was discussion about the importance of flexibility, with many instances of building in flexible processes to facilitate increased or more effective rest time.
	Perceived schedule **regularity** was associated with ↑ perception of how well the organisation manages fatigue, ↑ sleep, ↓ sleep problems, ↓ GI symptoms, and ↓ work-life disturbance. Perceived schedule **predictability** was associated with ↑ sleep, ↑ health, and ↓ work-life disturbance.
	Flexible strategies reduced perceived time pressure, creating shared expectations, and supporting worker satisfaction and wellbeing.

Data Source	Technology
	Fatigue management apps can be useful, but they need to be reviewed in each unique work context to maximise efficient use.
	Electronic logbooks (or Electronic Work Diaries) automate calculations relative to work hour limits and assist with compliance.
	Wearables such as actiwatches can be used for sleep/wake patterns and physical activity, proximity sensors for people-mobile plant interactions, geofencing and cloud-based updateable maps for flagging hazards, and electronic dispatch for maximising wood flow.
	Fatigue and distraction monitoring with real time alarms such as the Guardian system were discussed as part of a "last barrier" in fatigue management.
	Discussion included potential unintended consequences of technological introduction such as the potential to feel surveiled, and the balance between amount of feedback and distracting information.
	There are many pre-existing and expanding datasets (e.g. from harvesting machines, Guardian systems, electronic roster software, in-vehicle monitoring systems, electronic dispatch) that have potential applications for fatigue management, including for monitoring and audit of fatigue management systems.

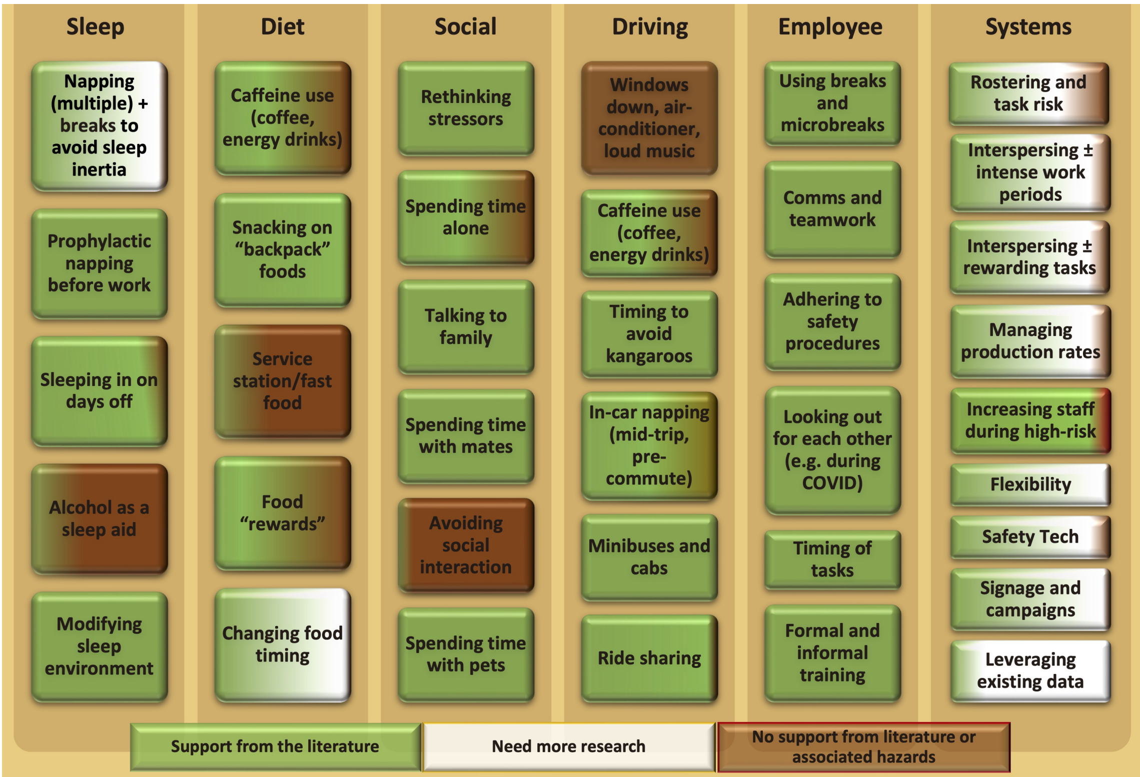


Figure 3: Examples of the safety management strategies used by individuals, companies, and communities to keep workers healthy and safe.

Figure 3 provides a summary of individual, company, and community fatigue management strategies. Strategies are organised into themes (Sleep, Diet, Social, Driving, Employee, and Systems). Each strategy is colour-coded, based on the support (or otherwise) for the efficacy of this strategy from the published literature. Green indicates that there is support from the literature, white indicates that we need more research, and brown indicates that there is no support from the literature, or that the literature has identified associated hazards. So for example, napping is green because naps help boost alertness, white, because the literature on napping at night (as opposed to the afternoon) is still growing, and brown, because naps can be associated with sleep inertia, or grogginess on waking, which can present a hazard in the workplace and must be managed. Employee strategies are mostly green. In contrast, using alcohol as a sleep aid is mostly brown due to the negative impact of alcohol on sleep quality. Reporting these coping strategies alongside their support (or otherwise) from the literature can give direction to workplace guidance for coping with shiftwork at the employee and operational level.

Activity	**Measure FM activities that are implemented**	
	● % sites with approved FM policies ● % employees who design work patterns with completed FM training ● time since last policy review	● % employees with completed FM training ● % rosters assessed for fatigue (e.g. using BMM software, FM-competent person) ● time since last FM audit or review
Outcome	**Measure whether the FM activities are having the desired effect**	
Results	● % employees with completed FM competence assessments ● % rosters with fatigue factors below certain thresholds	● % employees carrying out safety-critical tasks with completed FM competence assessments
Precursors	● % measured data within thresholds (e.g. sleepiness, sleep, performance) ● % shifts starting before 5am ● % shifts including commute starting before 5am ● % shifts where staff had <2 days notice	● instances of >4 consecutive shifts ● instances of <2 days off between shifts ● instances of >55h worked in a week ● % shifts where successive start times vary by >2h ● % shifts >14h
Incidents	● occurrence of incidents	● occurrence of fatigue-related incidents (classification required)
Balance	**Consider the potential impact of FM on the rest of the system**	
	● system costs ● % sick leave	● staff turnover rates ● employee feedback

Figure 4: Summary of potential fatigue management indicators in forestry.

Continual improvement metrics for fatigue risk management systems (FRMS) can help organisations track progress, identify areas for improvement, and evaluate the effectiveness of interventions [1]. Metrics for FRMS are tailored to individual operational contexts and cover activity (measures FM activities that are implemented), outcome (measure whether FM activities are having the desired effect), and balance indicators (consider the potential impact of FM on the rest of the system) [1]. Figure 4 provides some example indicators that may be applicable for the forestry industry to consider, in light of findings from this study. Such metrics could be systematically tracked and reported to help forestry organisations to measure and assess their approaches to managing fatigue risks.

Contents

1. Background and Literature

1.1 Fatigue and Coping Behaviours

Workers with schedules that involve long and/or irregular hours, especially those outside traditional 9am to 5pm, Monday to Friday work, are likely to experience sleep loss and fatigue, which undermines workplace safety, productivity, and wellbeing [2]. An international standard for defining fatigue has been established by the International Civil Aviation organisation [3] and is the foundation of fatigue management approaches worldwide:

> "Fatigue is a physiological state of reduced mental or physical performance capability resulting from: 1) sleep loss; 2) extended wakefulness; 3) circadian phase; and/or 4) workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety related operational duties."

Current research misses a significant opportunity to learn from workers who cope well with non-standard work schedules and fatigue. Research has investigated risk of illness and injury arising from non-standard work schedules only in relation to workers on average. Workers with healthier profiles are substantively ignored, with their data treated as a confounding 'healthy survivor effect' [4]. However, recent work suggests that there are a group of "healthy" workers among those with more than 20 years of exposure to shiftwork. These workers have developed behavioural coping strategies in their work, social, and domestic lives. Such strategies are targeted at facilitating alertness or sleep at biologically challenging times, preserving safety at work and on the roads, or maintaining healthy diet, exercise levels, and social and family relationships.

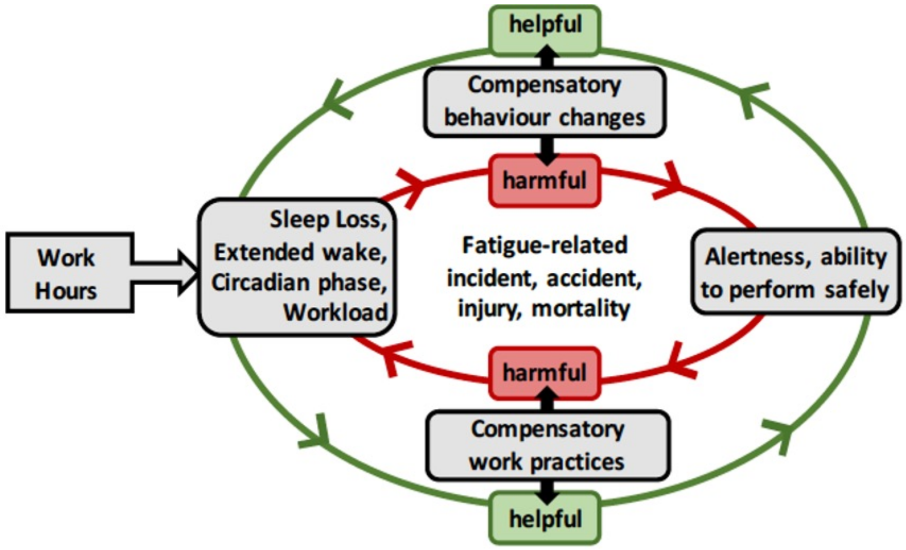


Figure 1.1: Work hours affect sleep, wake, circadian rhythms, and workload, resulting in fatigue which impairs alertness and the ability to perform safely. In turn, this can result in fatigue-related incident, accident, injury, and mortality – compensatory changes in behaviour and work practices can be helpful or harmful.

Individual strategies include use of caffeine (as a stimulant) and alcohol (as a sedative), changes in the timing of eating and sleeping, and advances/delays in undertaking safety-critical activities to avoid periods of elevated sleepiness. Shiftworkers may also employ team-based strategies where more alert workers assist their fatigued colleagues. This work suggests that while many of these strategies are likely to be helpful (e.g. preparatory napping prior to nightshift), others may be ineffectual (e.g. turning up the radio to stay awake on the drive home from nightshift), or even counterproductive (e.g. excessive caffeine use). These strategies are also implemented in the context of the work environment, and as such, are shaped by culture, recommendations, processes, and policies [5, 6].

Therefore, the proposed research, as outlined in Figure 1.1, will examine the behavioural strategies that South Australian forestry workers employ to compensate for fatigue, in the context of their work environment. This research will provide an evidence base for identifying which strategies are likely to be helpful for alertness and performance in forestry, and which are likely to be harmful. This will facilitate recommendations for strategies that are likely to prevent incident, accident, and injury.

Productivity, safety, and wellbeing are impacted not only by what we do, but when we do it. While sleep loss has been the subject of research for more than a century, we still have only an emerging understanding of how changes in sleep length and timing impact other behaviours. These behavioural changes, including when and what we eat, play a critical role in the observed relationship between sleep changes and increased risk of injury and illness in the workplace [7, 8, 9, 10]. The majority of research to date into behavioural risk factors centres on understanding what to do (e.g. what to eat, how much to exercise), rather than when to do it in any 24-hr period. This is a critical research gap which highlights the importance of chronobiology research to improve human health and safety [8, 9]. Pioneering experimental evidence suggests, for example, that manipulating the timing of food intake may have important impacts for performance, safety [11], and health [12]. The focus on not only what workers do, but when they do it (chronobehaviour), is a critical innovation for fatigue management research that is a focus of the proposed work.

The project method involves multiple, overlapping approaches and instruments, including interviews, questionnaires, observation, technological monitoring, roster analysis, and computer modelling of work processes. This project is therefore scientifically innovative due to:

- A focus on workers who cope well with shiftwork, identifying and evaluating individual behavioural and team-based coping strategies to manage fatigue;
- Examination of behaviour in terms of not only what is being done, but importantly, when it is being done; and
- The synthesis of research methods that will be employed to provide workplace guidance.

1.2 Fatigue, Safety, and Health

Nearly 40% of Australian adults experience some form of inadequate sleep [13], which contributes to fatigue. Indeed, sleep deprivation was implicated in more than 3,000 deaths in 2016-2017, with nearly 400 lives lost as a result of falling asleep at the wheel or sleep-related industrial accidents. Sleep loss and fatigue are now also known to contribute to health problems including coronary artery disease, stroke, diabetes and depression [13]. The total economic cost of insufficient sleep is estimated to be $66.3 billion, including $17.9 billion in lost productivity, and $1.8 billion in health system costs [13]. Early innovations in industry responses to the hazards of sleep loss and fatigue in Australian workplaces were sparked by the 'Beyond the Midnight Oil' Inquiry [14], which resulted in much-needed innovation in fatigue management in Australian Transportation Industries. The critical nature of this issue has been recognised again by the government, with a Parliamentary Inquiry into Sleep Health Awareness in Australia [15]. The terms of reference of the Parliamentary Inquiry include "workplace awareness, practices and assistance available to those who may be impacted by inadequate sleep" with a focus on shiftworkers, who commonly experience chronic circadian misalignment and sleep loss, and resulting fatigue [16, 17].

The primary benefits of this proposed research are in terms of safety – working to reduce accident and injury and to save lives. The proposed research will support the next steps of implementation of more robust and evidence-based fatigue risk management systems in the Forestry Industry. Outcomes of this research may also have downstream economic benefits in terms of productivity, and health system costs. As part of the research, we will develop metrics to monitor economic (e.g. productivity and lost working time) benefits as fatigue innovations are rolled out through the industry. Further details are provided below.

1.3 Local Lessons

The Green Triangle is critical to Australian forestry, with more than 334,000 hectares of softwood and hardwood plantations, and related harvesting and manufacturing, with a total of more than 3,000 workers. The estimated forest industry economic output is $1.5 billion (as summarised in [18]).

Forestry is not only a high value industry, but also a high risk industry. SafeWork Australia data indicates that the Agriculture, Forestry, and Fishing industries report among the highest fatality rates of all occupational groups. Fatality rates in these industries account for approximately one quarter of fatalities in Australia, with a 10-year average of 16.9 fatalities per 100,000 workers. The highest mechanism for fatalities is vehicle collisions [19].

Green Triangle Case Study
Survey findings indicated that nearly half of the sample reported high levels of fatigue, and the most common health problem reported, in nearly 70% of respondents, was difficulty sleeping [20].

Research indicates that forestry workers commonly experience sleep loss and fatigue, and that fatigue contributes to safety risk. Also highlighted are particular issues around driving and the commute, among workers who are frequently required to drive for long distances, and during the circadian low point (between 3am and 7am) [20, 21].

Australian Radiata Pine Case Study
Shift length (including mornings, days, and afternoons) ranged from 4.5 hours to >13 hours. Commute times ranged from 9 to 45 minutes one way. Average work day sleep was approximately 6 hours. Average sleep on days off was >8.5 hours. Productivity was more variable for participants working shiftwork [22].

1.4 International Literature

New Zealand, like Australia, has relatively high fatality rates, with fatigue identified as a primary contributing factor [23, 24]. Research suggests that while the physical nature of many of the job roles [25, 26] may play a role in the negative impacts of fatigue, the fatigue arising from forestry work is not simply explained by physical activity, and may be more related to work-related cognitive factors. Research also suggests that over time, the length of shifts has been increasing for forestry workers, coupled with additional fatigue arising from commute times [27].

> **New Zealand Case Study**
> In a survey of 367 forestry workers, nearly 80% reported that they sometimes experienced fatigue at work, and nearly 20% said that they experienced fatigue often or always at work. Over 60% of respondents reported having a near-miss injury in the preceding year, and there was a relationship between reporting fatigue at work, and reporting a near-miss injury [27].

The role of sleep in forestry worker fatigue studies from Canada also suggests that workers obtain insufficient sleep at levels likely to be associated with impairment [28, 29].

> **British Columbia Case Study**
> One in seven employees reported less than 6 hours sleep on at least 25% of work days [28], which is below the recommended amounts for healthy adults [30], as well as below the average for most shiftworkers (i.e., 7 hours) [16, 31]. The presence of insufficient sleep was also reinforced by evidence of sleeping-in to recover on days off [28].

Studies have also highlighted a number of environmental factors that may exacerbate the effects of fatigue on productivity, safety, and health. These factors include body vibration among mobile machine operators, which supports innovations in seat and machine design, as well as consideration in relation to shift length and regular breaks [25, 32].

Impacts on Productivity

A major area of research that relates to fatigue in the forestry industry focuses on productivity impacts. This research has been driven by international calls to extend operating times in order to increase overall production. This has led to a suite of studies, mainly from New Zealand and Chile, that focus on shift length and/or roster design in relation to productivity indicators including yield estimates and data from on-board loggers on machinery. Such studies have highlighted productivity benefits as a result of shorter shifts through a split shift system, as well as productivity losses as a result of extending the working day [33, 34]. Converging evidence has been found in computer-based work system simulation modelling work [35].

> **Chile Case Study**
> Average hourly productivity was reduced by up to 30% as the working day was extended from 9 hours up to 18 hours [34].

Technology and Monitoring

There has been a recent focus on the use of technology for monitoring fatigue and safety, including utility of data from wearables and mobile phones [24, 36]. Research from New Zealand has examined the accuracy and logistics of a number of trackers, concluding that the accuracy was acceptable for step counts, but not necessarily for sleep. The authors also suggested that the use of inexpensive ('disposable') devices should be a consideration for forestry, since the nature of the working environments meant that they could be damaged and/or workers would take them off to protect them [37].

> *It may be that we will not create the most effective [technological] solution or will not include the most optimal data inputs but rather we aim to find the most ethical, robust and secure solution that can do the required job* ([38], p8).

A critical aspect of the literature on wearables and fatigue in forestry outlines the ethics of monitoring and tracking [38]. The discussion relating to ethical considerations must be advanced alongside the research validating the technologies.

1.5 Chapter Summary

Compared to the literature in other industries, the fatigue literature in forestry contexts is relatively small. Much of the international fatigue research in the forestry industry comes from New Zealand, Canada, Sweden, Chile, and Indonesia. Overall, studies have identified that sleep loss and fatigue are hazards in forestry, and, as well as being associated with shift length and productivity, have broad implications for safety. These safety consequences are important for workers in the forest, as well as during log transport and commutes. There is also an interesting emerging debate about the potential role of technologies, such as wearables, in fatigue management. What is missing from the literature is research to inform the management of fatigue in forestry. This literature is needed to inform forestry-specific fatigue solutions, including metrics to monitor, enhance, and demonstrate compliance with safety regulations, and evidence-based contributions for forestry-specific education and training programs.

Taken together, local and international studies suggest that forestry industry work is associated with:

- High risk work with potential for incidents and accidents;
- Common issues with sleep loss and fatigue;
- Mental (cognitive) fatigue as well as physical fatigue;
- Links between fatigue and increases in incidents and accidents;
- Links between fatigue and decreases in productivity;
- Important implications for fatigue (and fatality) during the commute to/from work, with highly variable commute times; and
- Important emerging debate about the utility and ethics of wearables to assist in fatigue management.

2. Research Approach

Prior to the launch of the project, we sent a survey to project participants in order to identify priority research areas in forest management and processing. At the Launch and Steering Committee meetings, a data collection plan was developed to cover areas of maximum interest to participants. This was taken to the Research Meeting, where the methods were finalised. The survey revealed a key fatigue management focus on driving and operating machinery. Within forest management, harvesting and transport were rated as the most important areas for research, and within processing areas, log export (log yard, stacking and storage) and sawmills (haulage, log yard) were rated as the most important (Table 2.1). Therefore, it was decided that the priority groups for the study would be Harvesting, Transport, Log Export, and Sawmills, and data collection methods would centre on these groups. The only exception was the survey, which was distributed as widely as possible as this method has minimal implications for the project budget. This mixed methods study was designed to address the following project objectives:

- **Objective 1** – Examine current fatigue management systems in forestry in Australia, with an emphasis on the Green Triangle
- **Objective 2** – Identify recommended worker fatigue management strategies and 'myth-bust' ineffective or harmful strategies
- **Objective 3** – Develop workplace guidance for systems and education

The project objectives were investigated using a mix of interviews, surveys, dataset analysis, and examination of fatigue management documentation, as summarised in Table 2.2.

Table 2.1: Summary of pre-meeting survey asking participants to rank the priority level for fatigue management intervention for the following Forest Management (n=6) and Processing (n=5) areas (highest=most important). [a]Log yard receivals, Log stacking and storage, Log yard retrievals, Ship loading; [b]Haulage, Log yard, Green mill, Kilns, Drymill, Dispatch, Wholesale.

Forest Management	rank
Harvesting	3.14
Transport	2.96
Fire detection, suppression, and recovery	2.30
On site chipping	1.94
Tree breeding	1.28
Silviculture operations	1.03
Site establishment	1.02
Training	2.00
Planting	0.80
Seed production	0.79
Prescribed burning	0.73
Nursery	0.69
Forest assessment	0.50
Forest visitation	0.45
Office activities	0.39
Research	0.38
Processing	**rank**
Log export[a]	3.00
Sawmills[b]	2.58
Chip export	1.92
Posts	1.78
Panels	0.85

Table 2.2: Summary of data sources. FM=Fatigue Management

Source	Details	Sample
Interviews	▪ Systems level FM ▪ Individual level FM	Participants=23
Surveys	▪ Work hours, sleep, health, fatigue, FM, coping, food timing	Responses=104 (7 international)
Crashes dataset	▪ Vic GT Vehicles Crashes, 2011-2022 (+rollover program)	Crashes=132 (industry info for 111)
Growers dataset	▪ Volume and rollovers, 2013-2021	Companies=19
Harvesting dataset	▪ Work hours, volume, operation type	Shifts=2,674
Documentation	▪ Policies, guidelines, websites ▪ Mill rosters	Policies=6 Websites=21 Rosters=107 (2,130 shifts)

2.1 Interviews

Semi-structured interviews were conducted with managers, work health and safety representatives, and other employees (total n=23). Interviews explored systems- and individual-level fatigue management approaches.

Systems Level - At the systems level, interviews focused on: How fatigue is viewed in the organisation; where the critical areas are for fatigue management to maintain safety; existing policy and practice; strengths and weaknesses; knowledge and training; use of technologies; key performance indicators that may be appropriate for monitoring and auditing fatigue risk management systems; and impressions of the Fatigue Management Guideline [39] (strengths, potential implementation barriers, and proposed solutions to implementation challenges).

Individual Level - Using a Critical Incident Framework [40] participants were asked to describe a 'typical,' a 'good', and a 'bad' shift. This included what happened at home and during the commute immediately pre- and post-shift. Following this discussion, more specific questions were asked relating to coping with work-related fatigue, including individual (sleep hygiene, sleep aids, diet, exercise), team, and organisational factors (procedures, support, culture) [41].

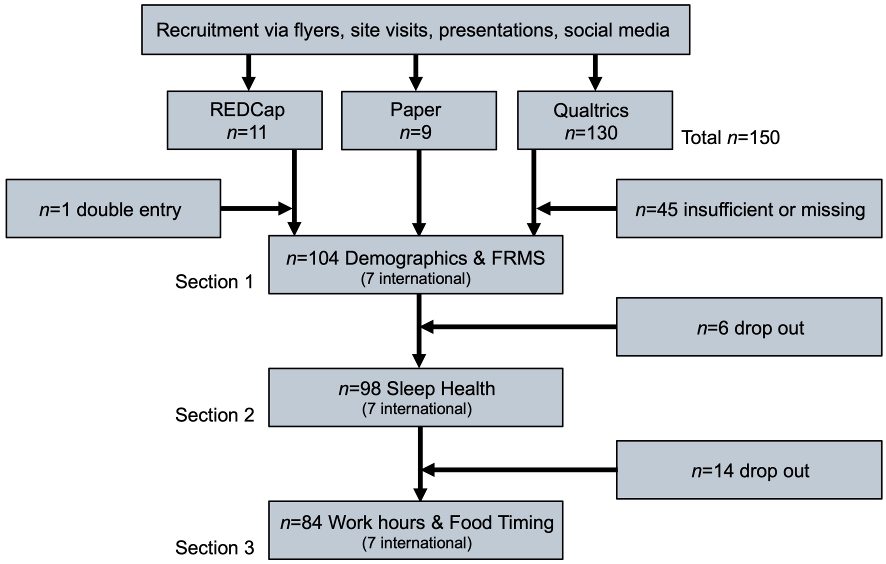


Figure 2.1: Recruitment for surveys, responses via the three methods, and the number of complete responses for analysis for each of the three sections of the survey.

2.2 Surveys

Participants completed a survey that included a shortened version of the Standard Shiftwork Index [42, 43, 44, 45], which measured work hours, coping strategies, physical and psychological health, sleep disturbances, and social and domestic disruption. Eating patterns were measured using a recently-published approach, reporting timing and frequencies of meals and snacks [46].

One hundred and four participants completed the survey with sufficient data for analysis (Figure 2.1). Seven of these were international (6.7%). One third (33.7%) were from the Green Triangle. Harvesting, silviculture, and mills were represented. The majority of respondents did not identify as shiftworkers, and reported relatively regular and predictable work hours (Table 2.3).

2.3 Existing Datasets and Documentation

Crashes dataset - A dataset was provided by the Victoria Department of Transport, Barwon South West. This dataset recorded truck crashes in the Victorian portion of the Green Triangle between 2011 and 2021.

Growers dataset - A dataset was provided by Forest and Wood Products, Australia (FWPA). This dataset includes indicators of the volume of product transported, and truck rollover events for n=19 companies between November 2013 and November

Table 2.3: Survey Respondents. *can add up to >100% since respondents can select multiple options.

Source	8.7% REDcap, 81.7% Qualtrics, 9.6% Paper
Sex	21.2% female
Age	average=44.5y (19-65y)
Region	GT (33.7%), Qld (17.3%), WA (10.6%), NSW (4.8%), Tas (9.6%), National (4.8%), international (6.7%, USA, Africa, UK)
Area*	42.3% Harvesting, 26.0% Silviculture, 9.6% Mills, 9.6% Haulage, 24.0% other (including Fauna Tech, WHS, Marketing, Research, Management)
Schedule Types	88.8% fixed mornings or days, 4.1% fixed afternoons, 7.1% other (including nights, rotating or variable shifts, split shifts)
Shift Types*	87.4% mornings or days, 7.7% afternoons, 4.8% nights
Shift Regularity	69.2% regular, 12.5% Neutral, 18.3% irregular
Shift Predictability	77.2% predictable, 7.9% Neutral, 14.8% unpredictable
Shiftworker	12.5% Yes

2021 (97 months). In order to maintain commercial confidentiality, analyses present variables in relative terms (percentage change).

Harvesting dataset - This dataset (provided confidentially) includes work hours, product volume indicators, and fuel use across more than two and a half thousand shifts, downloaded from harvesting machines across a one-year period. In order to maintain commercial confidentiality, analyses present variables in relative terms (percentage change).

Fatigue documentation - Fatigue policy documents from six operators were mapped against nine key indicators (definition of fatigue, hazard statement, link to organisational safety management system, evaluation of work hours, fitness for duty, fatigue monitoring, post-incident evaluations, audit, and training). Information from public websites for 27 forestry operators in Australia and New Zealand were analysed for fatigue-related content. Example rosters were run through computer biomathematical modelling software that uses work history information to generate predicted "fatigue" scores to identify periods likely to be associated with elevated fatigue [41]. This was done for 107 mill rosters (2,130 shifts) and the work hours from the harvesting dataset mentioned above.

2.4 Project Delays and COVID-19

The project was impacted by COVID-19 lock-downs and limitations on face-to-face data collection. Our response to initial COVID-19 delays was to move interviews and surveys to online methods. Originally, we were discussing the possibility of including data collection using sensors. A decision was made to move to analysis of pre-existing datasets (as reflected in Table 2.2).

Throughout the project, we have experienced slow and limited uptake of the surveys. In order to address this limitation, we redesigned the survey so that it captures the key information, but is substantially shorter, and removed the requirement for people to contact the research team first in order to complete the survey. We changed platforms from REDcap, to Qualtrics, which proved to be a more flexible delivery option. We were then able to share a link or QR code that takes people directly to the survey. For maximum flexibility, we also created a shortened paper version. The majority of survey completions (81.7%) were on Qualtrics, with 9.6% opting for paper, and 8.7% using the original REDcap platform (Table 2.3).

2.5 Report Structure

Thematic analyses of the interview data revealed six primary themes: (1) fatigue at work; (2) fatigue while driving; (3) fatigue and lifestyle; (4) policy and process; (5) shared responsibility for managing fatigue; and (7) fatigue management and

Figure 2.2: Themes arising from interviews.

technology. All six themes were supported by an overarching narrative about the importance of having work and community cultures that support safety management strategies inside and outside the workplace. The report will be presented in these six sections, with the data from interviews, surveys, datasets, and documentation relevant to each theme (Figure 2.2).

3. Fatigue at Work

THIS chapter will discuss the aspects of work that were identified as the most critical with regard to their interaction with fatigue. Three main sub-themes were identified: (1) work environment; (2) workload, long shifts, and overtime; and (3) early starts. These sub-themes are discussed in turn. The chapter concludes with analyses from the harvesting dataset, which sheds light on these sub-themes.

3.1 Environment

Respondents described the varied work environments across forestry that impact on fatigue and safety. Working outdoors in the heat and/or in windy conditions, as well as working on slopes or near power lines were identified as hazardous. Fire season was described as the strongest application of fatigue guidelines and the area of biggest need for hazard management.

> “Most work is pretty regular. The exception is fire... The Fatigue Guidelines have mostly been applied in the fire season... this is the biggest risk time from a fatigue perspective..." #022
>
> ---
>
> “Most safety critical tasks involve slopes, work adjacent to power lines” #005

Whether working outdoors or indoors, the importance of maintenance and the potential consequences of maintenance errors were highlighted, as was the potential hazards associated with tree felling and interactions between people and mobile plant.

> “In addition to driving, other risky areas: felling of trees, interaction between fatigue, people, and mobile plant. People being unaware of those around them. . . tired people and maintenance not done properly, can increase risk.” #023
>
> “Vulnerable, it’s probably be the truck drivers. . . . then. . . our vehicle machine operators. . . . Forklifts and log grabs. . . because the seriousness of what can go wrong if they are a bit fatigued.” #007

A particular hazard identified in indoor work environments arose from task monotony and the difficulty of maintaining vigilant attention during long monitoring tasks when fatigued.

> “He just said he was tired, he’s fatigued, he wasn’t thinking, and he just knew that he had to go over to that other area, but he didn’t look” #009
>
> “Some of the jobs aren’t that exciting. . . you see someone on the nod, you give them a little shake” #007

3.2 Workload, Long Shifts, and Overtime

Perceived time pressure was discussed, including a general feeling that work was increasingly busy, and that in order to maintain productivity, "harder and faster" work was required.

> “There only seems to be peaks, there doesn’t seem to be troughs. During establishment that’s a very busy time of the year where we have got heavy machinery working long long hours, and multiple contractors spread over large areas.” #002
>
> “They’re trying to do things harder and faster and yeah, absolutely, fatigue is a big element of that [interaction between perceived time pressure and fatigue]. That’s why we put that at a higher risk.” #008

There was accord that of the seasonal rhythms, fire season presented the most critical challenges for fatigue management.

> "In the fire season, 3 weekends in a row on call, 30 days with no day off, feels relentless. . . when there is a fire, you can be working a 24h shift on top of a normal work week. . . ” #022

Survey respondents working in Australia (n=97) reported an average of 40.8 scheduled

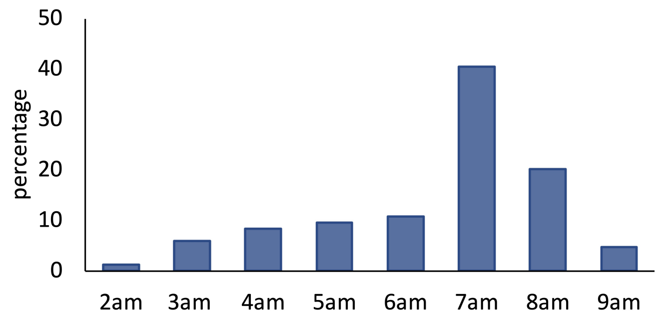


Figure 3.1: Survey data: Reported morning/day shift start times.

work hours per week (standard deviation=9.0h). They reported working on average 6.9 hours longer than scheduled, which was a statistically significant difference ($W_{94} = 103.0, p < 0.001$). In the context of the interviews, there was debate on work hours and shift length. Many people appreciated overtime. Some managers reported the concern that people can take on too much at the expense of their fatigue management. Similarly, some welcomed shorter shifts, for example, a reduction from 12-14 hour maximum shift lengths in some areas, to 10-12 hours. One area where this was noted was in cases where trucks or machinery were operating around-the-clock, and double-shifting created maximum shift times when switch-overs were scheduled. Others argued that shorter shift times limited flexibility, and in particular, the opportunity to work longer hours on four days, make quota, and have the fifth day off, referred to as the "compressed work week." The average shift length reported in the survey was 10h (standard deviation=1.9h), with 15% of shifts 12h or longer.

> “[some people ask,] I’ve been doing 14h my whole life – why do I have to stop now?...how can people still earn a living wage if work hours are limited?..[the] compressed work week is lost by the 12h cap” #023

3.3 Early Starts

Early start times across the industry were a key point of discussion and debate. Survey data revealed a range of start times for morning/day shifts from 2am-10am (Figure 3.1).

> “Why do we start so early? Why do we choose to start at 3am? It is what we’ve always done...People want to be the first truck in the queue, so they want to start early” #022

A further factor discussed in relation to early start times was the commute. From the survey, the average commute time was 42 minutes, with a range up to 3 hours, and 15% of commutes of at least 76 minutes. Participants described the way in

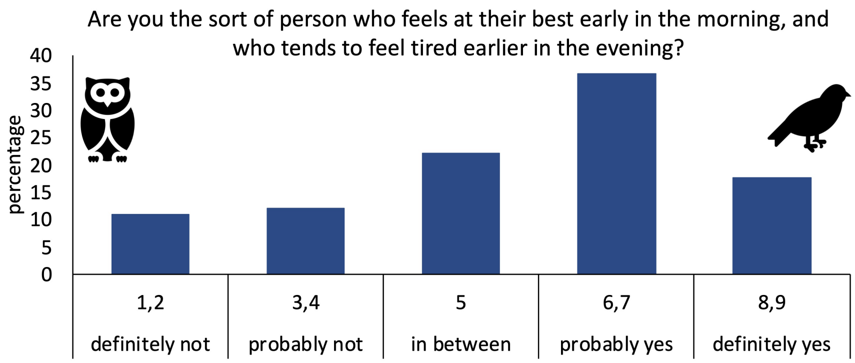


Figure 3.2: Survey data: Morningness preference - Self-reported 'Owl' (evening) or 'Lark' (morning) preference.

which longer commute times combined with early shift start times to necessitate early wakings and truncated sleep.

> "So, the 5 o'clock in the morning, if we've got people that are. . . 30 or 40 kilometres out of town. . . they're getting up at 4 o'clock in the morning, and. . . with the nightshift guys, we've got some [living] 50 kilometres away from here, and they're coming out . . . early and they're going home late, driving very slowly because. . . there's a lot of kangaroos around." #006

While some provided logistic reasons for the shift timing, others argued that the perceived negative impacts on recruitment were such that start times should be reviewed.

> "Recruiting and attracting people into the industry can be difficult, because no one wants to start at 3am. People have issues with these working hours" #022
>
> "Doesn't support the lifestyle of younger people" #023

From the survey, 48% of participants described themselves as probably or definitely larks, feeling their best early in the morning (Figure 3.2). For the 23% of respondents who are more "owl"-like (scores from 1 to 4), very early morning starts may be more difficult due to their tendency to stay awake later in the evening. Interestingly, interviews revealed that some workplaces try to fit permanent shift allocation to individual morning or evening preference (#009).

3.4 Modelling Work Hours, Sleep, and Fatigue

Biomathematical models (BMM) are used to predict fatigue, sleep, alertness, and or effectiveness using work history and scientific understanding of human sleep and circadian biology [47]. These models are often used in industries where fatigue can have serious consequences, such as transportation, including aviation and rail.

The most common BMM are based on the Two-Process Model, which proposes that sleep and wakefulness are regulated by two processes. One is a homeostatic process that reflects pressure for sleep, which increases the longer a person has been awake. The other is a circadian process that reflects the internal biological clock, which regulates the timing of sleep and wakefulness [47, 48, 49]. The circadian process is synchronised by the light and dark cycle and influences the timing of physiological and behavioral rhythms such as body temperature, hormone secretion, and cognitive performance.

Figure 3.3 illustrates an example of the interaction between the homeostatic and circadian processes. Mathematically, when these processes are combined, we produce an estimation of alertness, which fluctuates according to time-of-day, time awake, and prior sleep amounts, reducing alertness across the day and recovering alertness during sleep. This example shows an individual who is awake during the daytime and asleep during the night from Sunday to Thursday morning. They have a shorter sleep on Monday night, which results in a lower level of alertness across the day on Tuesday, which is somewhat recovered with a longer sleep on Tuesday night (example created using [50]).

BMM can be used to assess the fatigue-related incident likelihood, optimize work schedules to minimize fatigue, and evaluate the effectiveness of interventions designed to mitigate fatigue, including changes to rosters. It is important to note that the inclusion of BMM as part of a fatigue risk management system should be done in a considered way. For a discussion, the reader is directed to the article [51]. In particular, application of particular model scores as decision-making thresholds has been criticised for often been conducted in an overly simplistic way. It should be acknowledged that while BMM are informative tools, they are validated on aggregate data from laboratory and field studies, and do not take into account many sources of variability in behaviour between individuals and across circumstances. They are used well when understanding their context and applying them as part of a risk-based approach to fatigue management.

There are a number of BMM that are commercially available. One example is the Fatigue Audit Interdyne (FAID) Model [52], that requires work hours as inputs, and then uses our understanding of sleep and circadian rhythms to model timing and duration of sleep. From the sleep estimates, the model produces fatigue estimates across work periods. This approach is referred to as a "two-step" fatigue model [47,

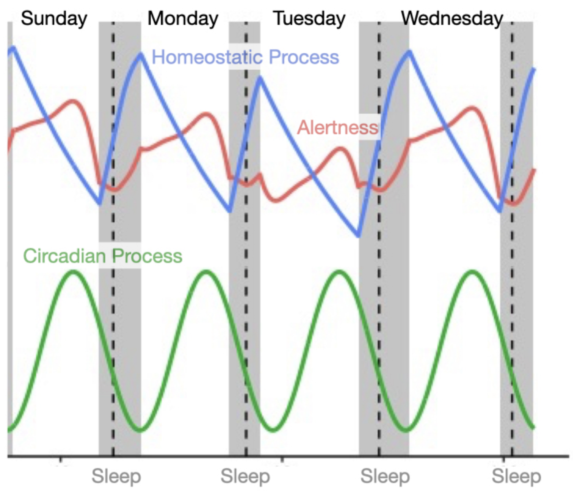


Figure 3.3: Biomathematical Models (BMM) of Fatigue Alertness are based on the Two-Process Model that proposes two interrelated biological processes regulate sleep and wakefulness - the homeostatic process (blue) and the circadian process (green). Based on timing of work/wake and sleep (grey), a model of alertness can be estimated (red).

52, 53]. In contrast, "one-step" models (e.g. [50]) require sleep inputs from which fatigue is modelled directly.

The FAID model was used to estimate sleep based on example work schedules from a saw mill (Figure 3.4). The figure shows scheduled work hours (grey bars) and predicted sleep periods (black bars). The left panel shows a permanent day shift (0500-1500h) roster and the right panel shows a permanent afternoon shift (1600-0200h) roster. Each line represents a 48h period and each 24h period is double-plotted so it can be visualised next to the proceeding 24h period. Double plotting is a common technique for visualising daily patterns with behaviours (e.g. sleep or work) that cross midnight. The figure illustrates the way in which sleep tends to be truncated in order to get up early for the 0500h start, and people will also attempt to get to sleep a little earlier (predicted sleep from 2143-0400h). On days off, sleep returns to a more typical, later pattern (predicted sleep from 2336-0738h). Average predicted sleep was 6.8h per 24h for permanent days, and 6.9h per 24h for permanent afternoons.

The example work schedules from mills included a number of different shift types and patterns, including permanent and rotating days and afternoons. Figure 3.5 shows the FAID scores for permanent days and afternoons (left) and a combination of days and afternoons (rotating, right). The FAID scores have been split into three categories (low<65, moderate 65-80, and high 80+). These are indicative categories in order to show relative differences between the schedules analysed. As a relative comparison,

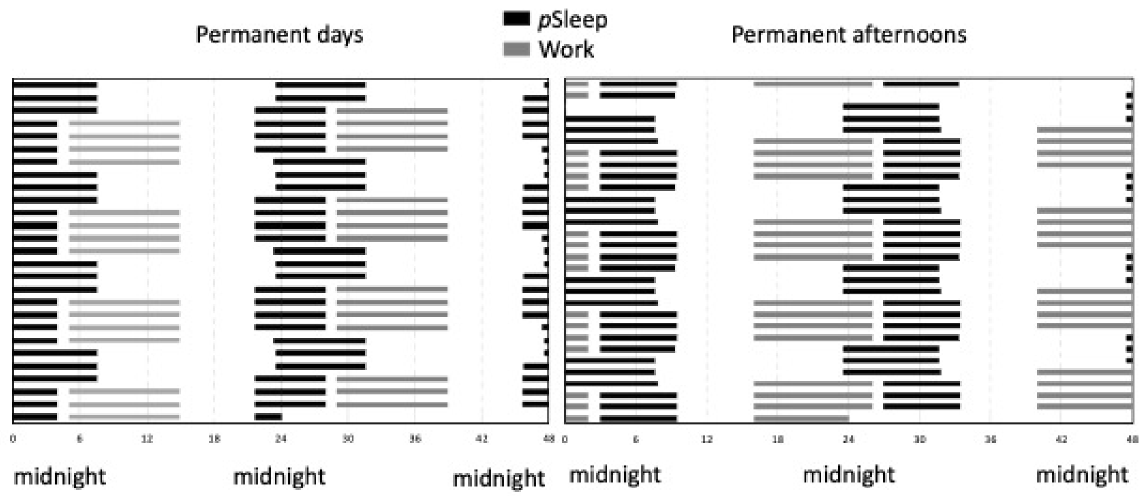


Figure 3.4: Scheduled work hours (grey bars) and predicted sleep (*p*sleep, black bars) for an example permanent day shift (left) and permanent afternoon shift (right) schedule from a saw mill.

a typical Monday to Friday, 0900-1700h work week is associated with a maximum FAID score of 40. If these work hours were scheduled during the night (2300-0700h), the maximum score would be 95 [54]. The example permanent patterns with 4 days on and three days off result in low to moderate scores. The example rotating pattern on the right, which includes seven afternoon shifts in a row, results in moderate to high scores.

Overall, we received rosters for 107 people with 2,130 shifts. Following FAID modelling, there were data with sufficient work history to calculate scores for 1,704 shifts. Rosters were classified into 15 general types, and a summary is illustrated in Figure 3.6. In addition to calculating sleep estimates and FAID scores, the FAID Quantum Software estimates sleepiness in the form of the Karolinska Sleepiness Scale (KSS)[55, 56]:

1. extremely alert
2. very alert
3. alert
4. rather alert
5. neither alert nor sleepy
6. some signs of sleepiness
7. sleepy, but no effort to keep awake
8. sleepy, some effort to keep awake
9. very sleepy, great effort keeping awake, fighting sleep

Figure 3.6 shows minimum and maximum start times and shift lengths, which included day shifts, afternoon shifts, or a mixture, alongside the peak sleepiness (KSS) and

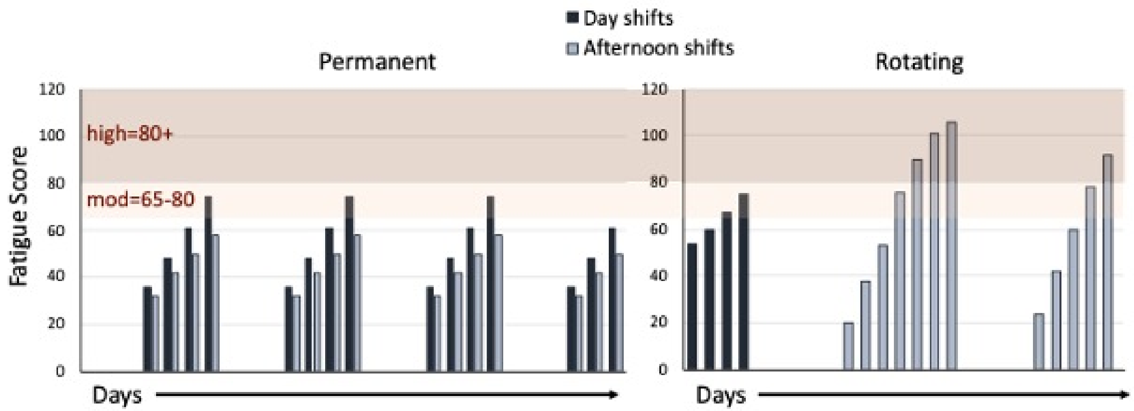


Figure 3.5: FAID Model Scores for permanent (left panel) and rotating (right panel) day (black) and afternoon (blue) shifts.

minimum 24h sleep estimates, ranked from high to low FAID score. Rosters that were associated with a mixture of shifts, as well as days starting as early as 0500h with fluctuating start times and length, were associated with the highest scores.

Further FAID score analysis is presented in the next section using work hours data from our harvesting machine dataset.

3.5 Harvesting Machine Dataset

In the interviews, participants described the transition from driving to the forest and working in the harvester as a change from driving-related safety concerns to productivity concerns. The change was explained as a function of the relatively safe environment within the harvester. That is, fatigue during the commute leads to safety concerns, but in the forest, it leads to productivity concerns.

> "Once employees get out of their trucks and into the harvesters, it transforms from a safety issue to a productivity issue" #022

The harvester dataset includes observations for 16 employees over 2,867 work shifts over a one year period. The initial dataset included some weekend work, but this was removed prior to analysis due to the relatively small number of weekend shifts, yielding 2,819 Monday to Friday shifts. Start and finish times were earlier, and shift length shorter on Fridays, with average start times between 5:12am and 5:40am, and average finish times between 12:54pm and 3:30pm (Figure 3.7). Average shift length ranged from 7.7 to 10 hours. This pattern in shift length and timing was consistent with descriptions in the interviews.

Start times		Shift length (h)		KSS	Sleep	
min	max	min	max	peak	min 24h	shift types
500	1600	6.5	11	7.2	5.4	mixture
500	700	8.1	10.5	5.2	6.5	days
500	500	9	11	7.4	4.1	days
1600	1600	10	10	6.7	6.5	afternoons
530	530	10	10	5.1	6.5	days
600	600	10	10	5	6.6	days
700	700	8	8.1	4.6	7	days
1800	1800	8.1	8.1	6.7	6.8	afternoons
1530	1530	10	10	6.5	6.7	afternoons
730	730	8.1	8.3	4.5	7	days
700	800	6.5	10	4.6	6.9	days
1700	1700	8.1	8.1	6.3	7.1	afternoons
800	800	8.1	8.1	4.3	7.2	days
530	800	6	8.1	4.8	7.2	days
830	830	8.1	8.6	4.2	7.2	days

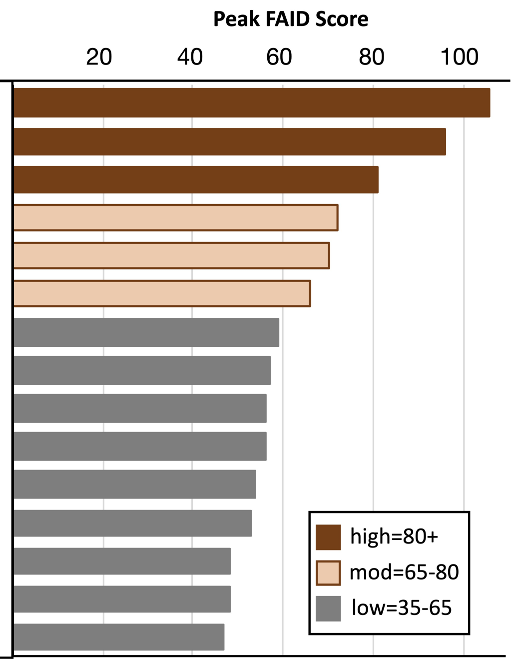


Figure 3.6: Summary of Predicted Sleep, Sleepiness, and FAID score for each of the 15 types of Mill Schedules.

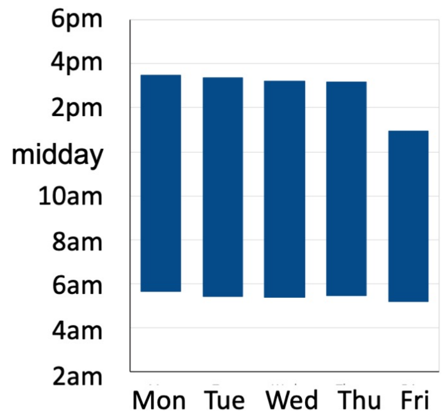


Figure 3.7: Harvesting machine average work hours (Mon to Fri).

"Finishing early on Friday may be attractive because many people travel to [the city] for the weekend" #023

FAID was used to model the actual harvester work hours across the year in this dataset. There were 2,752 shifts with sufficient work history for FAID analysis. Figure 3.8 shows example work hours (grey) and predicted sleep from the FAID model (black) over 22 weeks of work. Of note, these are actual work hours, taken from machine records of operation, and the pattern contrasts with the uniformity of planned rosters (e.g. shown earlier in Figure 3.4). As with this earlier figure, these data are shown with one line per 48h period, with 24h periods double-plotted in order to visualise sleep hours that cross midnight. Estimated sleep, based on the model, reflects the way in which sleep periods are moved earlier and shortened to accommodate early waking prior to work shifts. The average predicted 24h sleep duration for this operator was 7.2h, with a minimum of 5.6h.

Figure 3.9 shows a zoomed-in view to look at a 5 week period of work, with the work periods coloured according to three zones according to their maximum associated FAID Score. We can see that higher FAID scores occur following consecutive work days, and are worst at the end of the week (mostly Fridays), exacerbated by earlier starts.

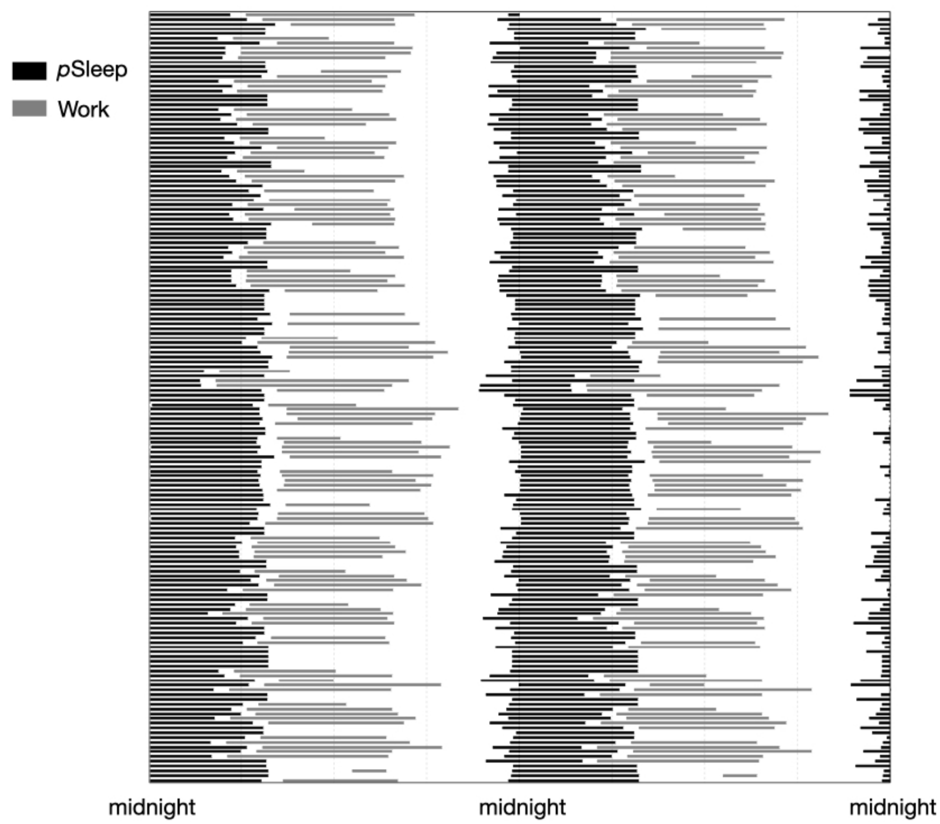


Figure 3.8: Example of work hours (grey bars) and predicted sleep (*p*sleep, black bars) from a harvesting machine over 22 weeks (157 days).

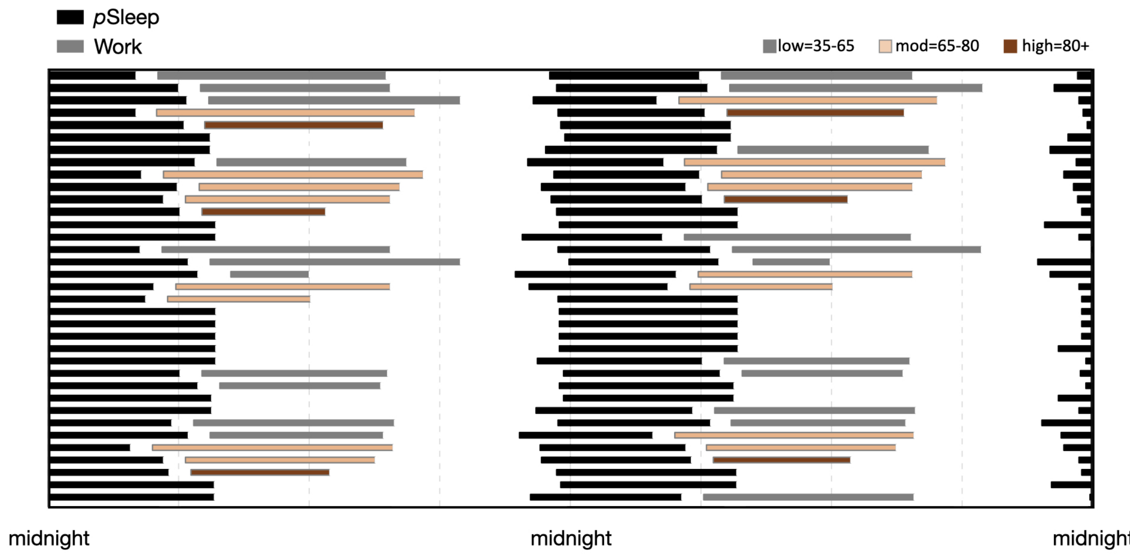


Figure 3.9: Example of work hours (grey bars) and predicted sleep (*p*sleep, black bars) from a harvesting machine over 5 weeks with FAID zones.

Preliminary analyses for productivity indicators were stratified for terrain (gradient) and operation (thinning or clearfall), however, since the relative changes were consistent across strata, results are presented collapsed across terrain and operation. Figure 3.10.A illustrates the percentage change in total volume (gross tonnes, GT), total stems, and fuel use on Tuesday to Friday, compared to Monday (comparison day, set to 100%). An approximate 20% reduction in volume, stems, and fuel can be seen on Friday.

Figure 3.10.B shows the percentage change from Monday for GT per hour, fuel per hour, and GT per litre of fuel. These measures remain consistent across the workdays, demonstrating that the reduction in volume is proportional to the reduction in work hours, and that productivity remains consistent.

Overall, analyses of this harvesting dataset support the promise of further investigating such data sources to investigate productivity changes as a function of work hours and other fatigue-related factors. This is pleasing given the large number of variables impacting on harvesting (e.g., terrain, operations type, weather, machine malfunctions). This dataset was sufficiently large to show sensitivity to expected differences using relative measures.

A key limitation of this dataset was that the data were available at the shift-level only. An hour-by-hour format would be of great benefit. This would allow investigation of productivity differences across a shift and in particular, at night. It would also be of

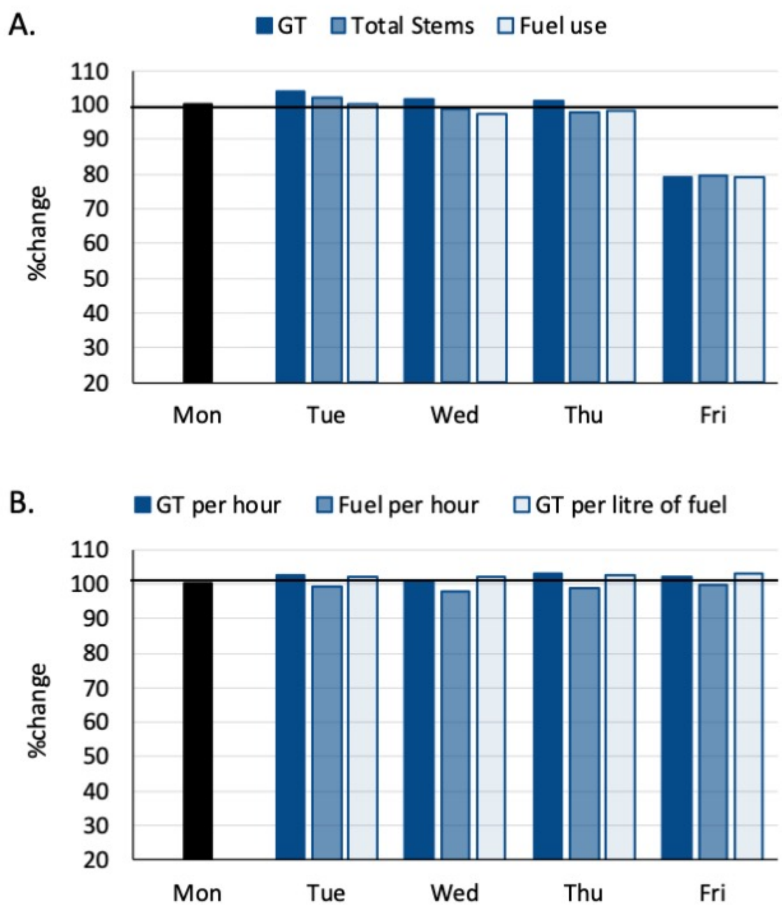


Figure 3.10: Harvesting dataset: Percentage change relative to Monday (100%). Panel A - Change in gross tonnes (GT), total stems, and fuel use. Panel B - Change in GT per hour, fuel per hour, and GT per litre of fuel.

benefit to compare operations with a single operator per vehicle (as in the current dataset) to an operation with double-shifts. Interviews revealed an interesting question about the potential trade-off in single operator per vehicle operations, which may facilitate feelings of machine "ownership" and treating the machine better, compared to the ability to run these expensive machines 24 hours to maximise use.

Interviewees also described different styles of operating harvesting machines, with some people consistently "running at 80%" and others operating at maximum. It was suggested that consistently "running at 80%" may provide more optimal performance overall due to a reduction in burnout for operator and machine. This would be very interesting to investigate. Such data would also inform the perceived time pressure, described above. Perhaps this perception is counter-productive. We discuss this further in later chapters.

> "Can people do a better job by being highly productive on a short shift? ... Consider psychological components of shorter versus longer shifts – 'pace yourself'" #023

3.6 Chapter Summary

This chapter focused on factors that exacerbate work-related fatigue including environmental factors, and work hour design. These factors were explored through survey and interview data, biomathematical fatigue modelling of planned rosters, and exploration of rhythms in work and volume through analysis of harvesting machine data. Key findings:

- Working outdoors in the heat or under windy conditions, near to slopes or power lines were identified as hazardous;
- Fire season was identified as the strongest application area of fatigue guidelines and one of the biggest areas of need for fatigue management;
- Perceived time pressure and elevated workloads, long shifts, and overtime were described as sources of fatigue;
- Early starts were a key topic for discussion and debate. Survey data revealed morning starts from as early as 2am. Sleep loss resulting from early starts may be exacerbated by long commute times;
- There was a spread of circadian preference scores in the survey data (from very "lark-like" to very "owl-like," and a discussion about matching shift types to circadian preference;
- Biomathematical modelling of rosters with sleep and fatigue estimation reflected discussion in the interviews, highlighting the changes in sleep and fatigue as a function of early starts, long and consecutive shifts, and rotating between shift types; and
- Harvesting data analyses showed a reduction in gross tonnes on Fridays. This

reflected shorter work hours and reduced fuel use on Fridays, showing that productivity remained constant. Harvesting machine data are potentially a very useful source for understanding fatigue, including through the work hours records that are stored. Accessing a comparison dataset with double-shifts and/or the ability to access data at the hourly level would be of great benefit for increasing our understanding of the influence of fatigue on productivity.

4. Fatigue and Driving

DRIVING was consistently identified as the greatest risk area for fatigue in forestry. This included log and chip truck driving, and also commuting, which can involve long distances in this industry.

> "Driving to and from work is the greatest risk. . . The only dangerous part pf the job is the travel "On a scale of 1-100, driving = 100, other risk = 10" #023

> "Yeah, I would average somewhere between 60,000 and 80,000 kilometres a year in my work ute." #001

Interviewees described interactions between fatigue, maintaining concentration on the roads, and worry and stresses from within and outside work. Other factors that interacted with driving fatigue included heat, and early morning hours. From the surveys, 46% of respondents reported feeling tired while driving at least sometimes.

> "I always worry, that's probably my biggest fear with everything I do that I'm not concentrating properly going home or even going to work because some days you might be still wound up about it tomorrow morning." #001

Drivers used many countermeasures to manage their fatigue while driving. Reports of napping were common. Some napped in the car on the side of the road. Others found a comfy spot in the forest.

"Stop on the side of road for a nap" #022

"So by starting at 7 or 8 and by finishing by 4 I tend to miss most of the roo population." #002

The timing of the driving was important. Some timed their work hours to avoid driving during times when wildlife is most frequent on the roads.

4.1 Truck Crashes Dataset

In order to further investigate driving in forestry, we were generously provided access to a dataset from the Victorian Department of Transport, which included truck crashes in the Victorian portion of the Green Triangle between 2011 and 2022 (Figure 4.1). Overall, there were 132 truck crashes in this region during this period. Of these, industry information was recorded for 111 crashes. Forestry industry vehicles made up just over half of these crashes (n=57).

The frequency of truck crashes in the Vic GT in the timber and other industries is shown in Figure 4.2. There was a peak in 2015, and a number of rollover programs were introduced, starting in 2015, across subsequent years. Rollovers account for 76% of crashes in this region. Rollover programs included the warning signs to address crash locations. The example in the upper left panel of Figure 4.3 shows a corner on the Portland–Nelson road which had a history of truck rollovers including a fatality. A solar-powered electronic warning sign was installed with a radar to detect approaching vehicles activating yellow flashing lights. Following installation in January 2017 there were no subsequent incidents at that corner. Other aspects of the rollover programs included variable message signs to thank drivers, roadside banners to reinforce key learnings from the rollover programs, and A3 brochures for distribution and display (Figure 4.3).

Figure 4.4 (Upper Panel) shows the distribution of truck crashes across months, with a peak in May. Fourteen percent of timber industry, and 18% of other industry crashes occurred in May. Crashes more frequently occur on Mondays (20% of crashes) and Tuesday (23% of crashes) (Figure 4.4, Middle Panel). While peak time of day for crashes in other industries is the afternoon, the distribution for timber industry crashes is much flatter. For timber trucks, nearly half of the crashes occurred at night compared to 18% for trucks from other industries (Figure 4.4, Lower Panel).

Figure 4.5 (Upper Panel) shows the distribution of crash severity, which is relatively consistent between timber and other truck crashes, with fatal and serious injuries accounting for 11% and 28% of crashes respectively. It can also be seen that the majority of crashes occur in 100 km/h speed zones (Figure 4.5, Middle Panel). In the Lower Panel (Figure 4.5) the distribution across the Definitions for Classifying

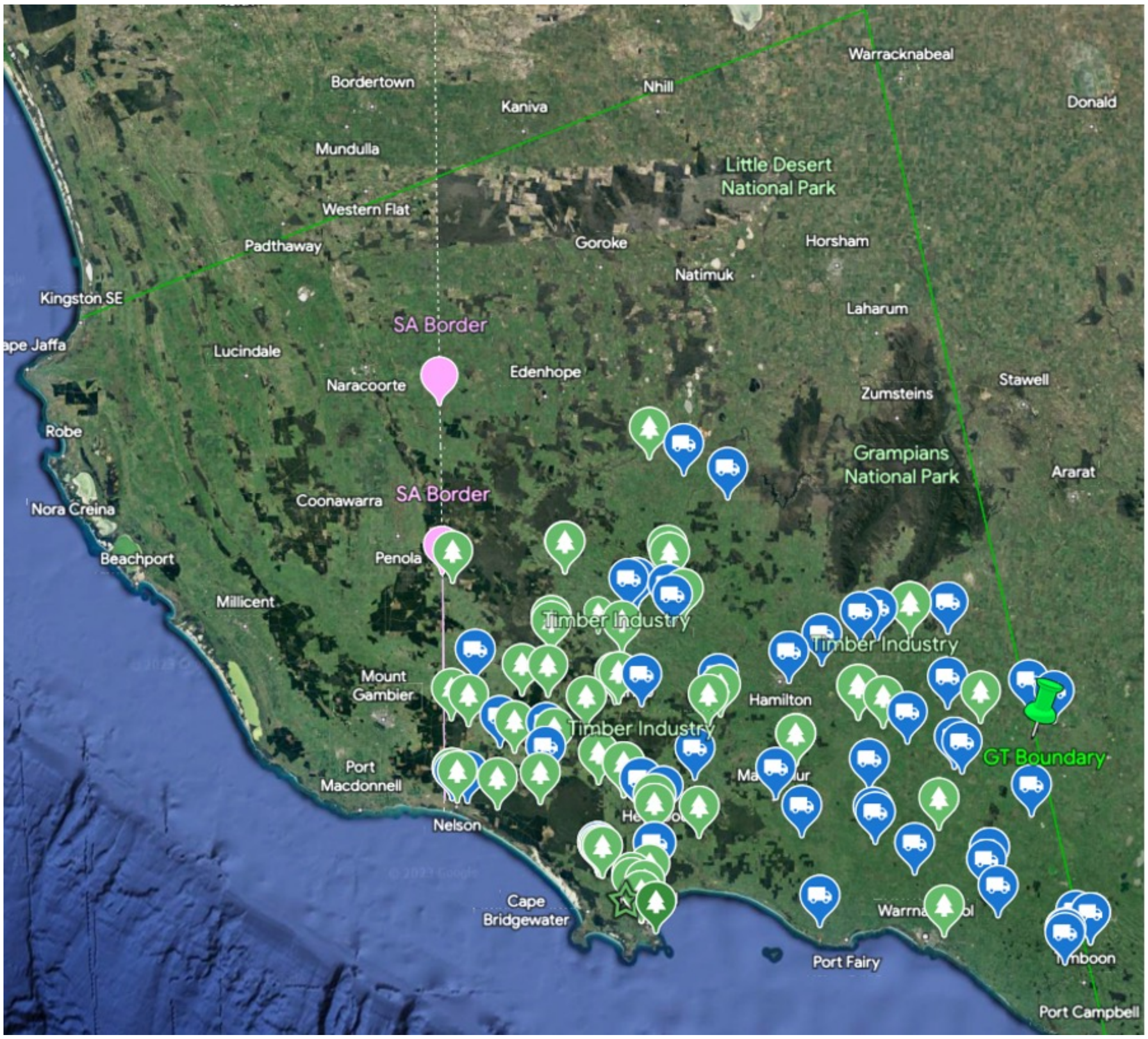


Figure 4.1: Map of the Green Triangle showing forestry industry (green trees) and other industry (blue trucks) truck crashes in the Victorian section from 2011 to 2022.

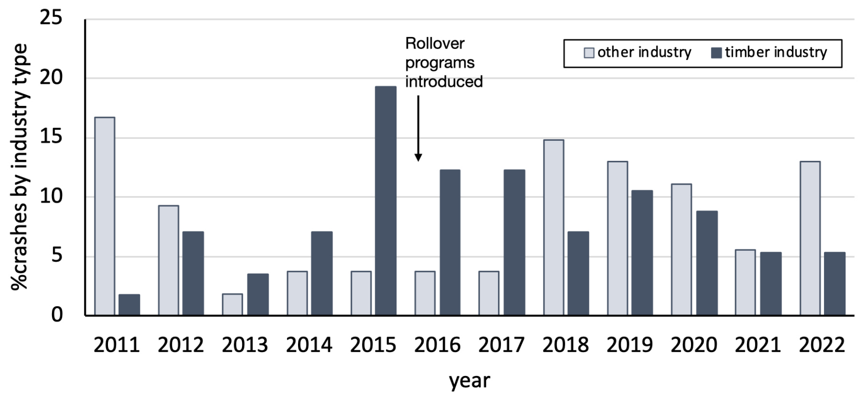


Figure 4.2: Truck crashes in the Timber industry and other industries from 2011 to 2022. After the peak in 2015, Truck Rollover Programs were introduced.

Figure 4.3: Vic Department of Transport Truck Rollover Programs: Upper left - Warning signs to address crash locations, Lower Left - Variable message signs to thank drivers, Right Panels - Roadside banners and A3 brochures to reinforce key learnings from the rollover programs.

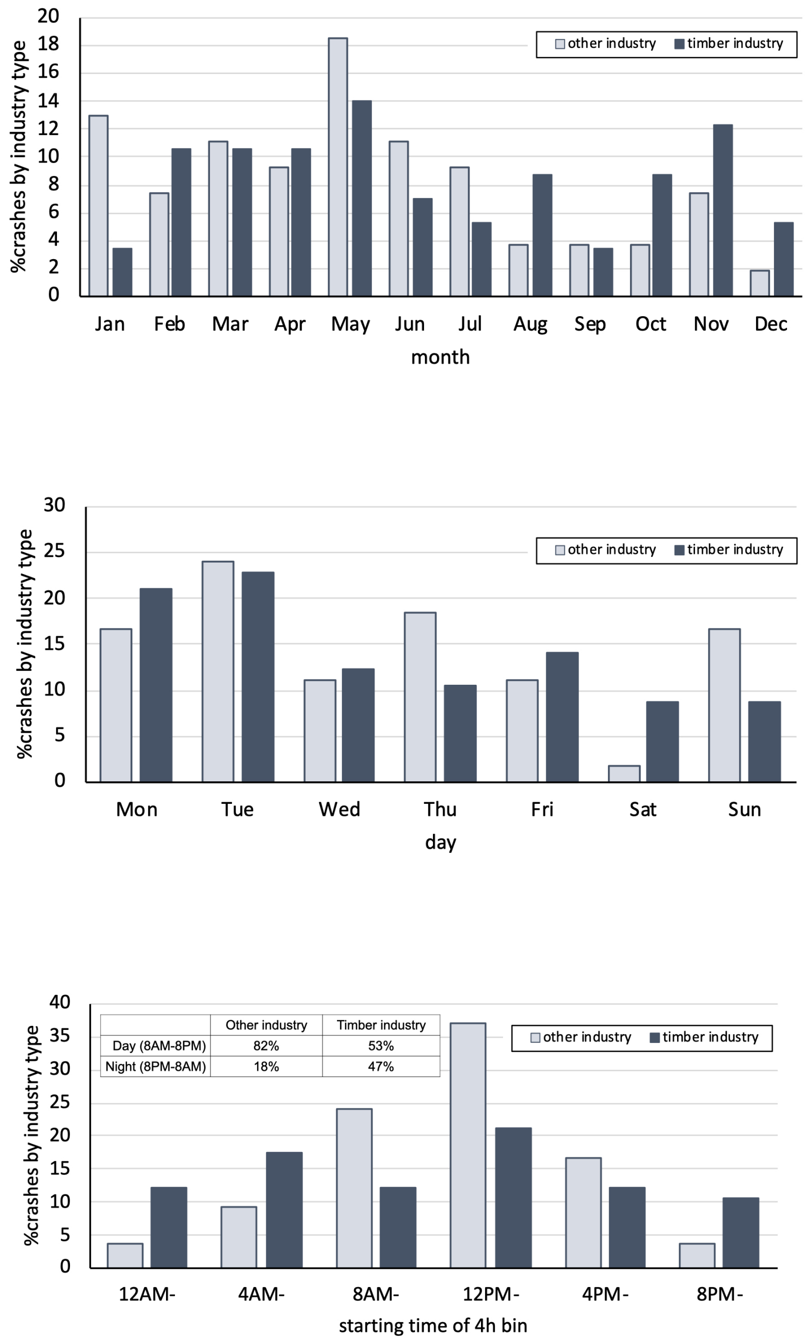


Figure 4.4: Truck crashes in the Timber industry and other industries from 2011 to 2022. Upper Panel - Data shown by month, Middle Panel - Data shown by day of the week, Lower Panel - Data shown by time-of-day.

Accidents (DCA) Codes. Approximately 70% were run-off-road crashes, with 43% on a curve, and 26% on a straight.

There is an interesting literature on the elements of a motor vehicle crash that may indicate that fatigue was a contributing factor. As reviewed in [57], there are no consistent criteria for defining a fatigue-related crash. Factors that have been suggested as signs of fatigue include accidents that involve single vehicles, no evidence of corrective action (e.g. anticipatory braking), high speed, the nighttime/early morning hours, witnesses that the driver fell asleep, or self-reports of sleepiness from the driver. In contrast, other potential causes must be ruled out (e.g. weather or road conditions, mechanical defect, alcohol or drug intoxication). In [57], the authors provide a suggested taxonomy for assessing the likelihood that fatigue was a contributor to a crash. Specifically, that it was likely that the driver was experiencing fatigue at the time of the crash (e.g. by assessing sleep and/or work history), and that it was likely that the type of error(s) that lead to the crash were fatigue-related.

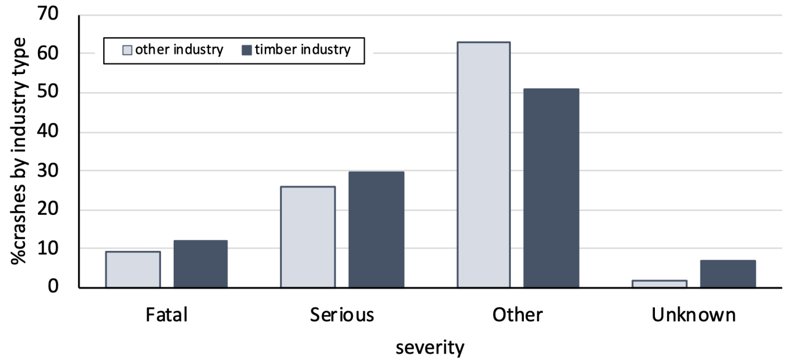
If we take these two elements in turn, given the high proportion of crashes that were in high speed areas and that involved single-vehicle run-off-road events, not only on curves, but also on straights, there is surface evidence that the type of error(s) leading to the crashes may be fatigue related. Further, if we look at the time-of-day distribution, in particular for timber industry crashes, we may deduce that across the night and early morning hours, the likelihood that the driver was fatigued, as a function of their circadian rhythm of sleepiness, was elevated.

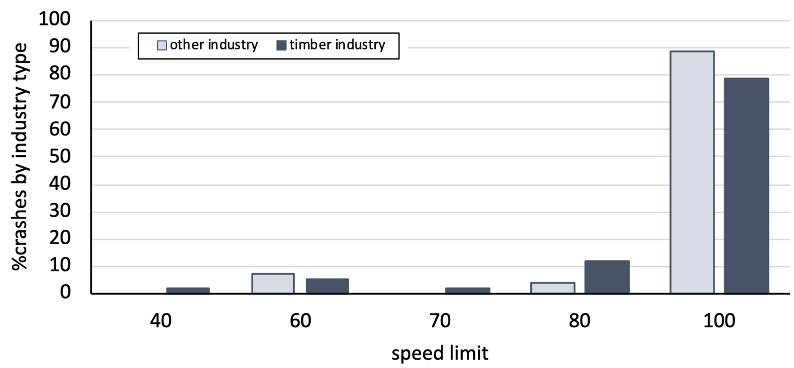
A limitation of this dataset is that there is no correction for exposure (e.g. crashes expressed relative to the number of trucks on the road during each month, and at each time-of-day in these locations). However, it is important to note the unique nature of this dataset. Vic Roads and SA Roads crash databases record many details of crash events, but they do not record industry. In addition, Police (TIS) reports were available for 73% of crashes - “if no person was injured and all involved parties have exchanged name and address details, VicPol will not normally make a formal report, and the Accidents Records Office will not have a report of the accident.” We are grateful to the Vic Department of Transport for providing these data with details about crashes that were not available in the typical accident records.

4.2 Truck Rollover Dataset

The truck rollover dataset, provided by Forest and Wood Products Australia (FWPA) is presented in relative measures to factor in exposure-related considerations. In comparison to the Victorian Department of Transport Dataset, which covered the Vic section of the GT, the FWPA dataset is national. It includes monthly survey records for 19 companies between November 2013 and November 2021.

Figure 4.6 illustrates relative changes in the quantity transported across years and





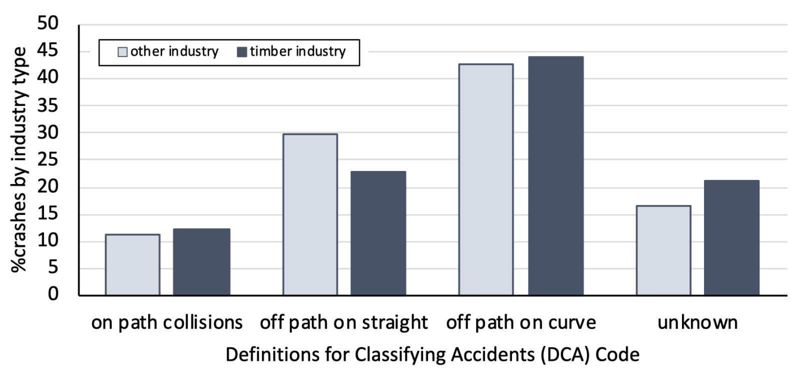


Figure 4.5: Truck crashes in the Timber industry and other industries from 2011 to 2022. Upper Panel - Data shown by severity, Middle Panel - Data shown by speed limit, Lower Panel - Data shown by DCA Code.

months. These data show that there has been an overall increase in amount transported relative to 2014, and that transported amounts tend to be lower in December and January. When we examine relative change in rollovers, we can see a decrease over the years, which is more evident when we correct for the amount transported. The pattern in relative change in rollovers across months of the year, appears flattened following correction for amount transported, with relatively fewer rollovers from October to December.

4.3 Chapter Summary

This chapter focused on driving, which was consistently identified as the greatest risk area for forestry, encompassing log and chip truck driving as well as commuting. These factors were explored through survey and interview data, a truck crashes dataset from the Victorian Department of Transport, and a truck rollover dataset provided by the FWPA. Key findings:

- Interviewees discussed difficulties maintaining concentration on long trips, especially with early morning starts. 46% of respondents reported feeling tired while driving at least sometimes;
- There were 132 truck crashes in the Victorian portion of the GT between 2011 and 2022, with industry data available for 111 crashes. Fatal and serious injuries were associated with 11% and 28% of crashes respectively. Half of the crashes were Timber Industry Trucks. Rollovers accounted for 76% of crashes. There was a peak in rollovers in 2015, after which Rollover Programs were implemented in this region;
- The peak time of day for crashes in other industries was the afternoon. For timber trucks, nearly half of the crashes occurred at night compared to 18% for trucks from other industries. The majority of crashes occurred in 100 km/h speed zones. Approximately 70% were run-off-road crashes, with 33% from a curve, and 26% from a straight. These types of crashes, especially those occurring during night hours, display hallmarks of fatigue as a contributing factor;
- The FWPA dataset suggests that across the years from 2014 to 2020, there has been an overall increase in the amount of timber transported, and that across the year, relatively less is transported in January and December. Controlling for amount transported as an exposure variable, results indicate that rollovers have been decreasing across time.
- Overall, findings suggest that the number of rollovers in the timber industry, and in other industries, has been decreasing over the years. The error profile of these crashes and the time-of-day distribution suggest that fatigue may indeed be a contributor, particularly for timber vehicles driving around the clock.

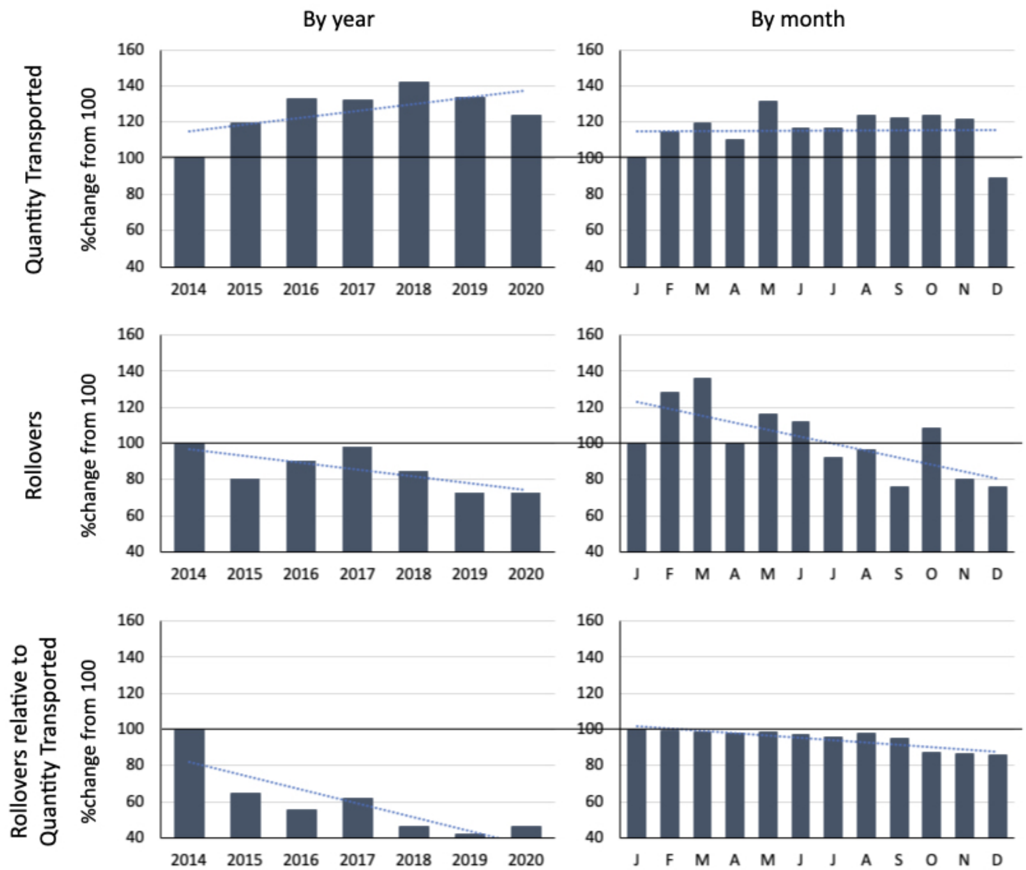


Figure 4.6: FWPA Truck Rollover Dataset: %change in quantity transported (upper), %change in rollovers (middle), and %change in rollovers accounting for quantity transported (lower). Left panels show change across years relative to 2014 (100%). Right panels show change across months relative to January (100%). Blue dotted lines show basic linear trends.

5. Fatigue and Lifestyle

The importance of factors inside and outside work contributing to fatigue was a key theme arising from the interviews. These discussions were complementary to those regarding shared responsibility for fatigue management, which is a focus of an upcoming chapter. There was an acknowledgement that the work hours in forestry were integrated into a lifestyle that supported those demands.

> "Individual success is about lifestyle – if the lifestyle supports the work from a fatigue perspective. . . Such a demand on your personal life – acknowledge this – home and work-life need to complement each other." #023

5.1 Sleep and Sleepiness

Survey respondents reported an average of 7.0 hours sleep on work days (standard deviation=1.0h). Average perceived sleep need was approximately 30 minutes more than this amount ($W_{88} = 237, p < 0.001$). Respondents reported that they slept an average of 8.0 hours on days off (standard deviation=1.3h), which was was significantly longer than workday sleep ($W_{87} = 108, p < 0.001$). This indicates that people are sleeping more on days off to recover from work days, a strategy that was described in the interviews.

A summary of the sleep and sleepiness questions from the survey is shown in Figure 5.1. In addition to sleeping in on days off, approximately 42% of participants reported napping at least sometimes. This is consistent with descriptions of napping use from the interviews.

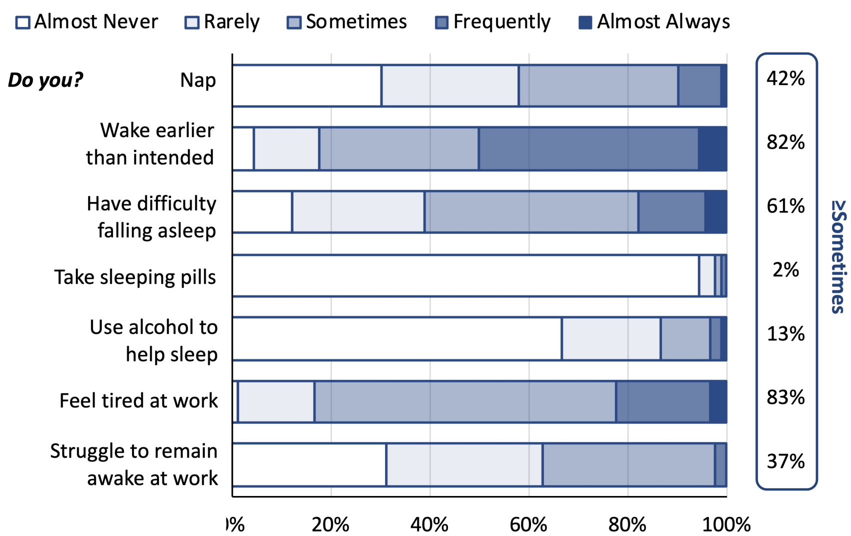


Figure 5.1: Survey data: Respondents described how frequently they experienced these sleep and sleepiness related behaviours and events.

The majority of participants report sleep problems (early waking, difficulties falling asleep) at least sometimes. Only 2% of respondents reported that they used sleeping pills to help them sleep. Approximately 13% reported using alcohol as a sleep aid at least sometimes. Approximately 17% of respondents reported feeling frequently or almost always tired at work. Consistent with interview data, struggling to remain awake at work at least sometimes was reported by 37% of respondents (Figure 5.1).

> "A lot of people say, oh he's fallen asleep... I've been guilty of sitting in front of the keyboard a few times and... you know the eyes get a bit heavy." #006

5.2 Physical Health

Over half of respondents felt that they got enough exercise and 84% reported that they ate a healthy diet at least sometimes (Figure 5.2). Approximately one in six respondents reported experiencing cardiovascular symptoms (e.g. heart palpitations, dizziness, shortness of breath) at least sometimes. Approximately one quarter reported experiencing gastrointestinal symptoms (e.g. stomach pain, nausea, bloating) at least sometimes.

Interviews yielded reports of consuming energy drinks, coffee, and tea to compensate for feeling fatigued.

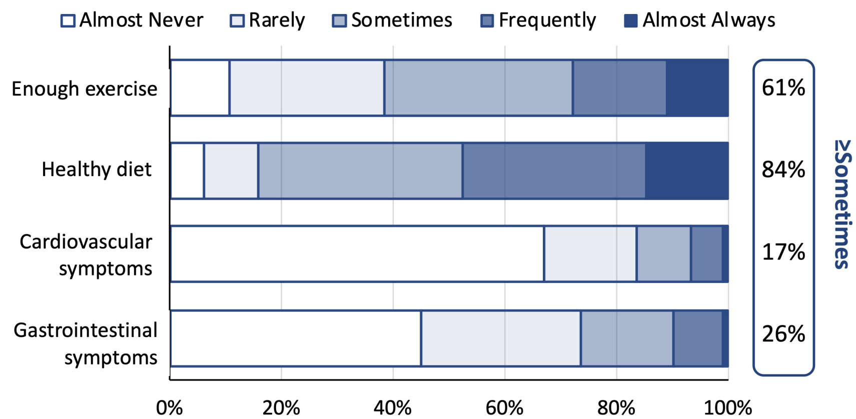


Figure 5.2: Survey data: Respondents described how frequently they experienced these health related behaviours and events.

> "Every. . . worker you see, they walk in with. . . two cans of Mother in their hand, it makes me cringe. And this is just before lunch, then they'll grab another one at lunch time" #007

Survey data revealed that the majority of respondents (68%) reported consuming up to four cups of tea or coffee per day, with 23% consuming 4-6 cups (Table 5.1). In relation to alcohol, the majority of respondents reported consuming 10 or fewer units (standard drinks) of alcohol per week, which is within the National Health and Medical Research (NHMRC) Guidelines for alcohol consumption. Nearly one quarter of respondents reported exceeding these guidelines. Twelve percent reported that they used tobacco (Table 5.1). In addition, 13% reported drinking energy drinks, ranging from one per week, to a maximum of two per day.

Survey respondents also completed information about eating occasion timing on workdays and days off. The upper panels of Figure 5.3 show that for morning or dayshift workers, there was an increased number of eating occasions (15% increase) and an increased proportion of meals on workdays (40% meals) compared to days off (31% meals).

On workdays, eating occurred earlier in the day, with more than one quarter of workday eating occasions occurring by 6am, compared to 3% on days off. The black lines in Figure 5.3 show the Average Eating Window (time between first and last meal or snack) on workdays (11.5h) and days off (10.8h). The workday Eating Window is significantly longer ($W_{71} = 1472.0, p = 0.004$) and earlier ($W_{67} = 442, p > 0.001$) compared to days off.

Table 5.1: Survey data: Smoking, alcohol consumption, and coffee and tea consumption. *consuming >10 units of alcohol per week exceeds the NHMRC Guidelines for alcohol consumption.

smoking	12%
alcohol	none 14% <=10 units per week 63% >10 units per week 23%*
coffee and tea	none 9% <4 cups per day 68% 4-6 cups per day 23%

For the afternoon or nightshift workers, Figure 5.3 illustrates the spread of meals and snacks around the clock, while eating is largely confined to daytime hours when they return to days off. Figure 5.4 illustrates these changes using 24h clocks with work hours and eating occasions superimposed. Food timing is strongly influenced by work hours.

5.3 Domestic Life, Social Life, and Coping Styles

Respondents rated the extent of the impact of their work hours on aspects of their life in and outside work (Figure 5.5). The highest rated area overall was domestic life. More than 40% of respondents indicated that work hours caused domestic and social problems at least somewhat. This was followed by problems with sleep, and finally work performance.

> "It's not great for the social life, like I have been known to fall asleep in the chair on a Saturday night when I'm watching the footy; but you'd expect that with the amount of sleep I get." #010

The reported impacts of work hours on domestic and social life are important, since these facets of life are central to many of the coping mechanisms used to compensate for work demands. Table 5.2 summarises the frequency of coping strategy use, with type of coping style indicated. Specifically, coping can be Engaged - using problem solving, cognitive reappraisal (looking at the problem in a different way), talking to someone, and letting emotions out, or Disengaged - spending more time alone, avoiding the problem, criticising yourself, or wishing the problem away. Engaged

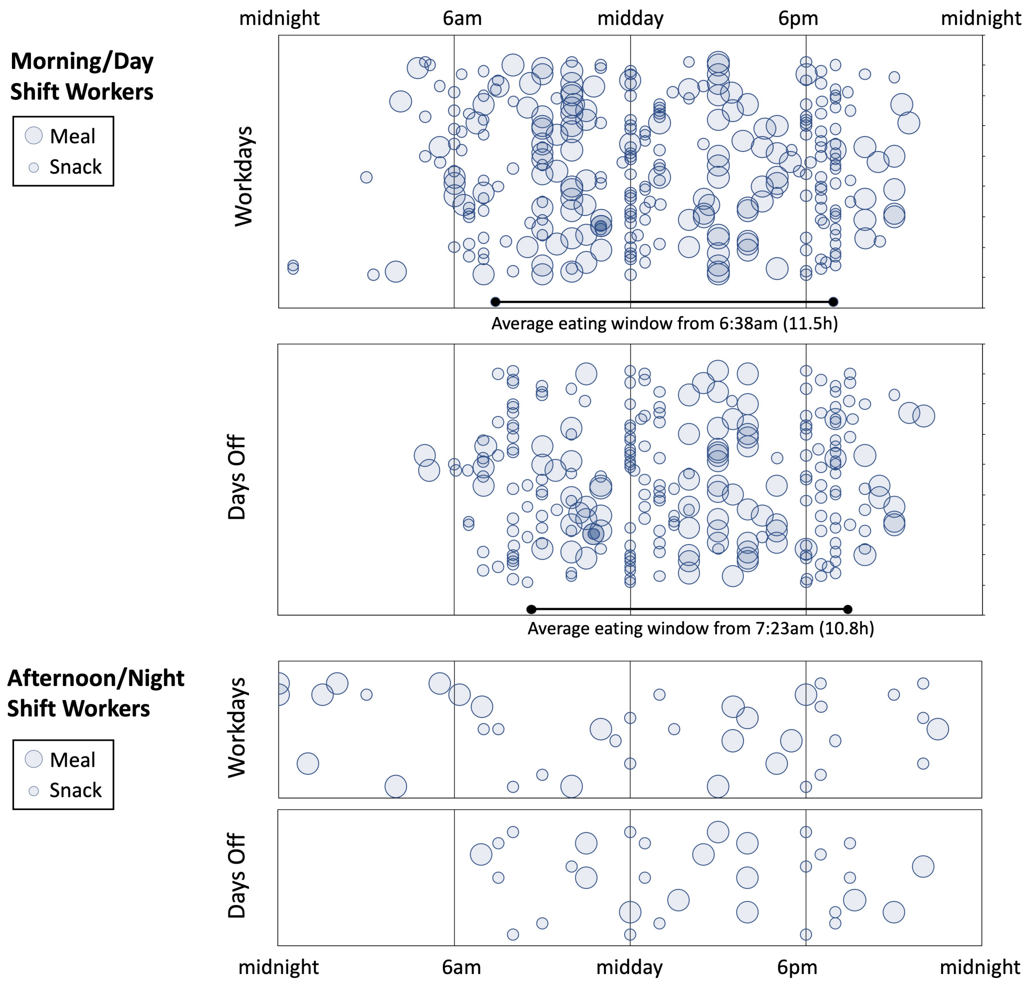


Figure 5.3: Survey data: For workdays and work free days, respondents provided information about their typical eating occasions, including main meals and snacks. Snacks included food or beverages. For each shift type worked, and on their days off, respondents provided the time of each eating occasion, and whether it was a meal or snack. Upper panel, meals (larger circles) and snacks (smaller circles) across morning/day shifts (upper) compared to days off (lower). Data are shown for those working Day or Morning Shifts, and those working Afternoon, Night, or Split Shifts.

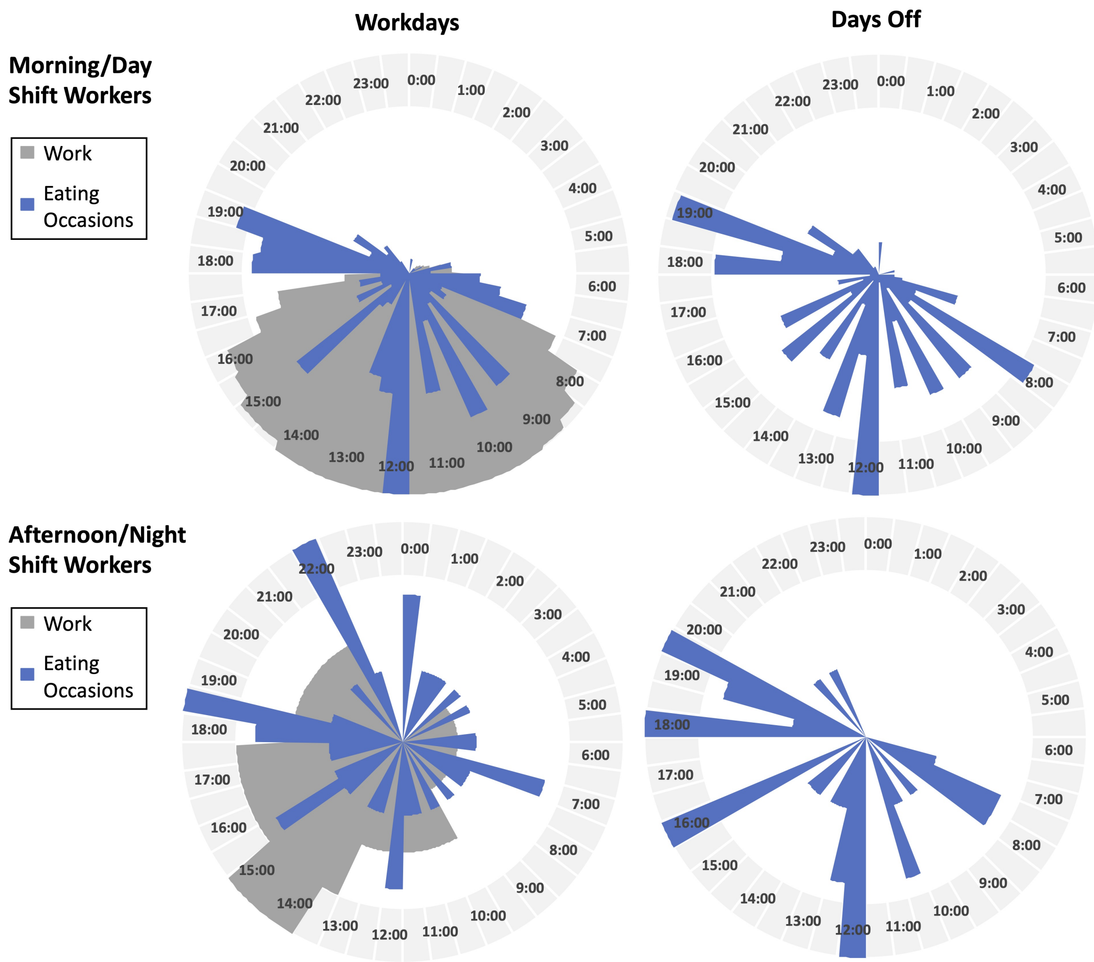


Figure 5.4: Survey data: For workdays and work free days, respondents provided information about their typical eating occasions, including main meals and snacks. Snacks included food or beverages. For each shift type worked, and on their days off, respondents provided the time of each eating occasion. Data are shown for those working Day or Morning Shifts, and those working Afternoon, Night, or Split Shifts.

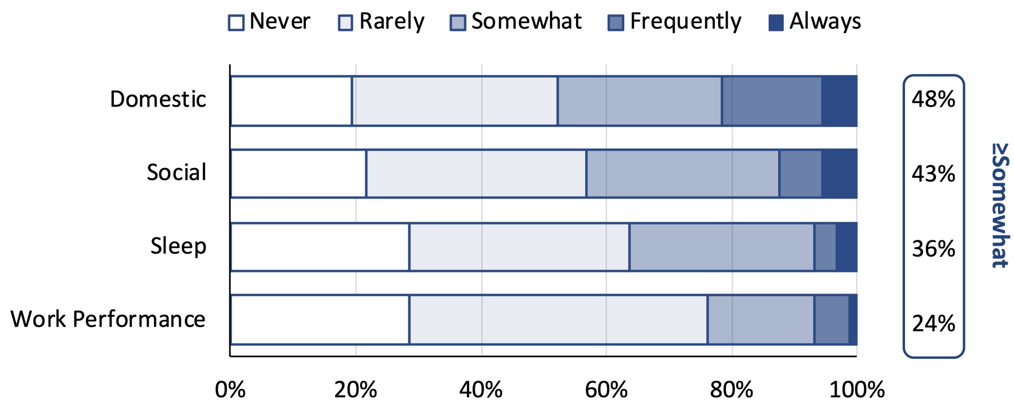


Figure 5.5: Survey data: Respondents rated the extent to which their work hours caused them problems with sleep, work performance, domestic, and social life.

coping styles are associated with more positive outcomes.

The coping strategies are ranked in the table from most to least employed. Overall, engaged coping styles were used more frequently than disengaged styles as reflected in significantly higher scores on the engaged coping scale ($W_{92} = 2558, p < 0.001$). The most frequent engaged coping styles used were problem solving and cognitive reappraisal, which are problem-focused, rather than emotion-focused approaches. Indeed, scores were significantly higher for problem-focused strategies compared to emotion-focused strategies for engaged ($W_{94} = 2895, p < 0.001$) and disengaged ($W_{94} = 845, p = 0.003$) styles.

Survey data revealed that the higher scores on Engaged Coping were associated with more positive ratings for healthy diet and exercise (Figure 5.6). Higher scores on Disengaged Coping were associated with more frequent gastrointestinal symptoms, higher Total Sleep Disturbance and Work-Life Disturbance, and reduced sleep on workdays.

5.4 Chapter Summary

This chapter focused on fatigue, lifestyle and health behaviours, primarily informed by survey and interview data. Key findings:

- Success in coping well with the demands of working in the forestry industry was described as a "lifestyle" issue, with importance placed on factors in and outside of the workplace, such that "home and work life need to complement each other";

Table 5.2: Survey data: Respondents indicated the extent to which they used a list of strategies when they have problems with their sleep, domestic life, social life, or work performance caused by work hours. Strategies are presented in rank order from most to least used.

Coping Style	**Focus**	**Strategy**	**Used quite a bit or a big deal**
Engaged	Problem	Problem Solving	49.4%
Engaged	Problem	Re-Appraisal	32.2%
Disengaged	Emotion	Social Withdrawal	25.2%
Engaged	Emotion	Talk to Someone	19.5%
Disengaged	Problem	Self-Criticism	17.2%
Engaged	Emotion	Let Emotions Out	14.0%
Disengaged	Problem	Avoidance	13.8%
Disengaged	Emotion	Wishful Thinking	9.1%

Pearson Correlation: -1.000 | -0.500 | 0.000 | 0.500 | 1.000

Note. Bolded values = *p* < .05

	EC	DC	HD	EE	GIS	CVS	TSD	WLD	WS
Engaged Coping (EC)	—								
Disengaged Coping (DC)	-0.025	—							
Healthy Diet (HD)	**0.331**	0.038	—						
Enough Exercise (EE)	**0.240**	-0.046	**0.579**	—					
GI Symptoms (GIS)	-0.010	**0.293**	-0.174	-0.119	—				
CV Symptoms (CVS)	-0.052	0.163	**-0.302**	-0.191	**0.520**	—			
Total Sleep Disturbance (TSD)	-0.153	**0.286**	**-0.259**	-0.126	0.165	**0.239**	—		
Work-Life Disturbance (WLD)	-0.151	**0.333**	-0.212	**-0.231**	**0.366**	**0.352**	**0.374**	—	
Workday Sleep (WS)	0.158	**-0.246**	0.032	-0.024	-0.008	0.035	-0.195	**-0.331**	—

Figure 5.6: Survey data: Relationships between Coping Styles, Work-Life Disturbance, sleep, and health. Values are correlation coefficients - the closer to 1.000, the stronger the relationship. Positive values (green) indicate that as one variable increases, the other increases. Negative values (red) indicate that as one variable increases, the other decreases.

- On average, survey respondents reported that they slept for approximately 7h on workdays, which was approximately 30 minutes less than their perceived sleep need. They slept an hour longer on days off.
- Sleep problems were common, with 2% of respondents reporting that they used sleeping pills, and 13% that they used alcohol as a sleep aid;
- 37% of respondents reported struggling to remain awake at work at least sometimes;
- The highest rated area of negative impact from work hours was domestic life, followed by social life, then sleep, and then work performance;
- Coping strategies indicative of an engaged coping style were used more frequently than disengaged strategies. The most commonly used strategies were problem solving and cognitive reappraisal. Engaged Coping was associated with better diet and exercise, while Disengaged Coping was associated with more frequent gastrointestinal symptoms and sleep and work-life disturbance.
- Approximately one in six respondents reported experiencing cardiovascular symptoms, and one in four reported experiencing gastrointestinal symptoms at least sometimes.
- 23% of respondents reported consuming alcohol at levels above the NHMRC recommendations (>10 units per week), 12% reported smoking, and one in five respondents reported consuming 4-6 cups of coffee and/or tea per day. 13% of respondents reported consuming energy drinks.
- Relative to days off, workdays were associated with earlier and longer eating windows (the time between the first and last eating occasion) as well as a higher number of eating occasions with a higher proportion of snacks. The earlier the workday start time, the earlier the first eating occasion. Food timing was distributed around the clock when respondents were working afternoon, night, or split shifts.
- Overall, findings support research in other industries where workers are on long and/or irregular hours. Health related behaviours (timing and quality) are influenced by work hours.

6. Policy and Process

FROM the survey, while 88% of respondents reported that their organisation has a Fatigue Risk Management Policy, 4% reported that their organisation did not have one, and 8% said that they didn't know. The average rating for how well respondents felt that their organisation manages fatigue was high (71/100), and responses were skewed to the high end of the scale (Figure 6.1). The spread of scores is also seen in the data from international respondents (n=7).

Overall, interview discussions in relation to fatigue management were positive, and reflected on the many important changes over the last decade. While some raised that there was a focus on limiting work hours, there was also discussion about the developments beyond rostering. These discussions included the importance of considering the risk profile of the activity, the concept that work hours were door-to-door (including travel times), and the importance of shared responsibility for fatigue management, which is discussed in more detail in the following chapter. It was noted that door-to-door approaches reduce possible work time during shifts for forests that are further away.

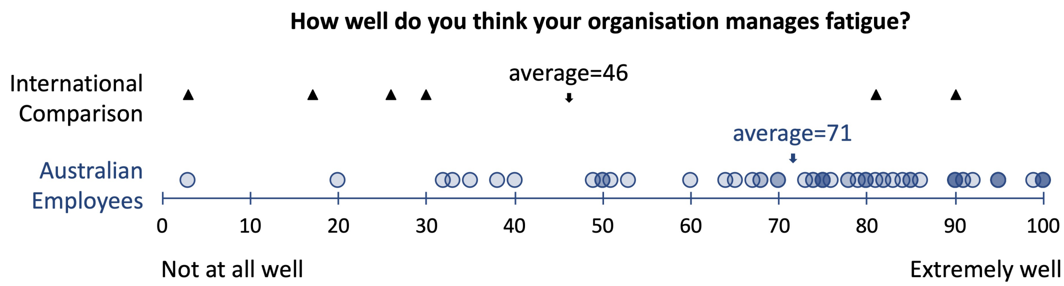


Figure 6.1: Survey data: Respondents were asked to use a 100-point slider from "Not at all well" to "Extremely well" to indicate how well they felt that their organisation manages fatigue. Respondents employed in Australia (blue circles, *n*=97) are shown relative to those employed overseas (black triangles, *n*=7).

> "Fatigue management changes over the last few years have reduced excessive work hours and injury rates...When you look back over the last ten years, we've come a long way" #008

> "We can have rostering restrictions in, time – door to door time, for example. . . but with that, it does rely on the worker to . . . manage their own fatigue and get adequate sleep. I think that's probably the most important factor is making sure they are fit for work, and also to disclose that as well" #001

In relation to critical comments about fatigue management, some felt that this was considered relatively well for trucking (consistent with the NHVR regulations) and during fire season, where demands are arguably intensified. However, it was argued that approaches could be expanded beyond these areas.

It was also raised that some of the support documentation and guidelines were "academic" in tone, and that the level of complexity could be worked through to maximise accessibility. The benefits of developing case studies from broad areas of forestry were canvassed.

Problems with recruitment and retention across the industry as a whole were also raised as a factor impacting on fatigue management initiatives.

"It works pretty well for us, but as a business sometimes you do get caught with lack of skilled employees" #006

6.1 Document Content Review

We examined fatigue management policy, procedure and/or education documents provided to us. We undertook a simple content review identifying whether they included certain elements, identified in the literature as important. These elements were: A fatigue definition; a hazard statement; linking to broader safety management systems; evaluation of work hours; fitness for duty; fatigue monitoring; post-incident evaluations; audit; and training.

Key elements of Fatigue Risk Management Systems:

1. Policy identifying fatigue as a workplace hazard
2. Fatigue training programs
3. Reporting mechanism and procedures for action
4. Monitoring mechanism for typical operations and incidents/accidents
5. Evaluating mechanism that provides an evidence-base for improvement - including data analysis from (3) and (4) and interrogation of the work system
6. Review mechanism - leveraging info from (5)

As illustrated in Figure 6.2 upper, all policies included an evaluation of work hours. This potentially reflects the sentiment from the interviews that the primary fatigue management focus in forestry had been on work hours. Most policies included a hazard statement, linked to their SMS, and made mention of fitness for duty, fatigue monitoring, and training. A definition of fatigue was provided in less than half of the policies reviewed, and none specifically mentioned post-incident evaluations or audit.

It should be noted that this does not mean that these elements are not present in the work systems of these operators, just that there was no explicit link in the policy documents.

We also undertook a content analysis of forestry websites, to examine the presence of fatigue information (Figure 6.2, lower). This included 26 websites, with fatigue information provided on 38%. Of the sites that included fatigue information, this focused on the causes and impact of fatigue, and how to recognise it in yourself and others. Interestingly, as with the policy documents, less than 50% of sites included a definition for fatigue.

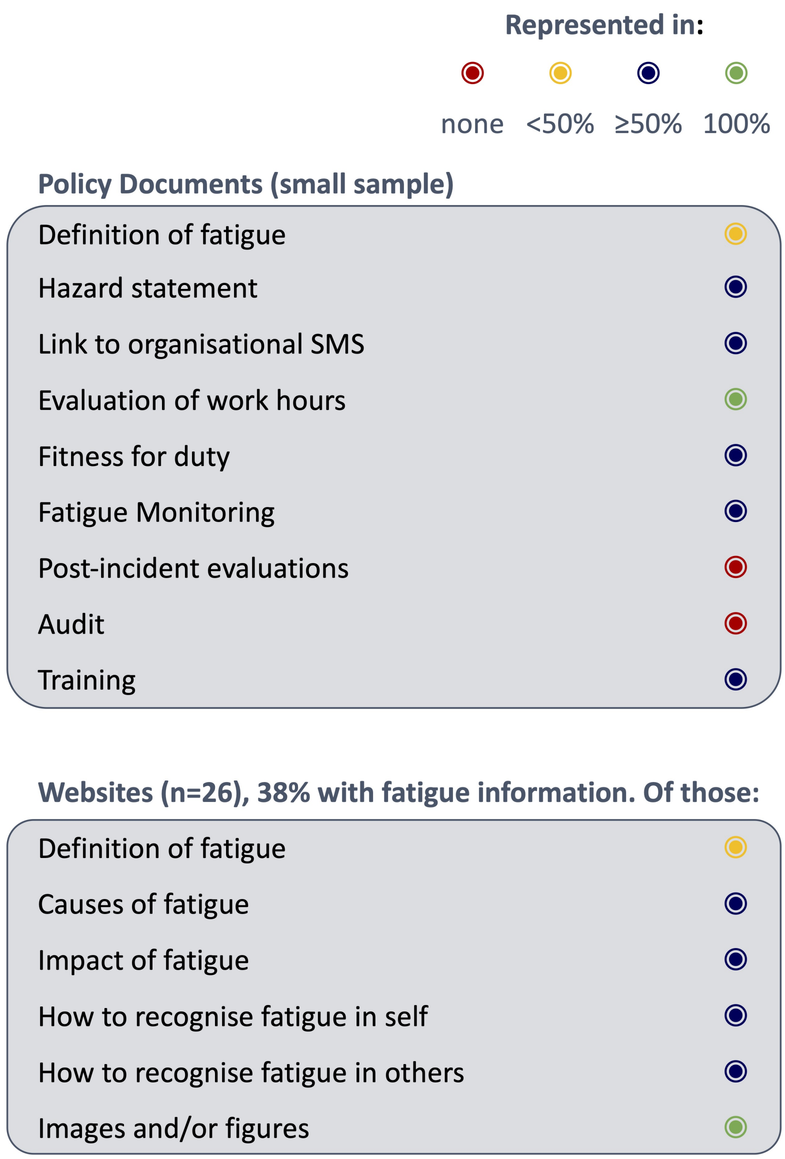


Figure 6.2: Upper: Fatigue Management Policy Documents Summary (n=6). Lower: Freely available online resources from Australian and New Zealand Forestry Company Websites (n=26).

6.2 Chapter Summary

This chapter focused on fatigue related policy and processes. This focus was primarily informed by survey and interview data, and also policy documents, training materials and public websites. Key findings:

- Fatigue management in forestry has undergone many pressures and developments in the last decade;
- While there was a focus on work hours, the discussion included the importance of the task risk profile, consideration of travel (i.e., including commute into work hour considerations), and the importance of shared responsibility for fatigue management, including personal management of lifestyle factors;
- Average rating of how well people perceived that their organisation managed fatigue was high (71/100). Nearly 90% of respondents indicated that their organisation has a Fatigue Risk Management Policy, 4% reported that their organisation did not have one, and 8% reported that they did not know;
- Simple content review revealed that all policies included an evaluation of work hours, most policies included a hazard statement, linked to their Safety Management Systems, and made mention of fitness for duty, fatigue monitoring, and training. A definition of fatigue was provided in less than half of the policies reviewed, and none specifically mentioned post-incident evaluations or audit;
- The review of 26 public websites revealed that 38% included information about fatigue, including the causes and impact of fatigue, and how to recognise it in self and others.
- Overall, findings suggest some areas where information could be expanded, particularly in terms of monitoring and audit of fatigue risk management systems.

7. Shared Responsibility

As mentioned in earlier chapters, the interviews yielded a clear focus on the importance of shared responsibility and reciprocal duty of care, and the critical underpinning conditions of safe disclosure and a 'just' culture, with support from the work environment and from community.

7.1 Talking about Fatigue

The importance of creating an environment where people feel comfortable to discuss their fatigued was highlighted. While some people reported that they felt unable to talk about fatigue with their colleagues or managers, there were many examples where the culture was described as enabling open discussion. People were thanked for disclosing that they were fatigued, and fatigue management options were available (e.g. start work a little later and have a nap first, finish earlier, switch duties, have a car or cab drive them home).

> "Need to avoid the tendency to say, 'I'll toughen up'... There is a perception that they might not want to tell their crew mates that they are fatigued – 'shift that mindset'" #001

> "Yeah, no one will admit to sleeping though" #007

Those in management and HSR positions described their commitment to facilitating open discussion, and the benefits of doing so.

"If you don't talk about it, they'll find ways around it and behind your back. It should be open to ... say I'm tired, I've had a bad night's sleep. And then we would manage that with them." #011

"If you're feeling like your drunk because you're that tired, well it's much better for them for you to leave site and get the rest that you need" #010

Managers and HSRs were also highly aware of the many ways fatigue manifested in workers, including changes in mood and level of interaction, and the varying ways in which fatigue was expressed verbally. The box below shows examples of the ways in which fatigue was described in the interviews.

"Doughy" #005
"Bloody yesterday buggered me" #007
"You'd sleep on a barbed wire fence" #002
"You're drunk because you're that tired" #010
"Much on for the weekend?", "Bloody working, I'll be here" #007
"Bit less switched on" #019
"Getting slammed" #007

7.2 Consistency with Flexibility

An interesting theme that arose, was a general move away from rotating rosters to fixed schedules across the industry. The consistency and predictability were seen as beneficial.

"It works a lot better for them to have that one fixed shift. We were doing the rotation and we were finding people burning out a lot quicker... if they've got that one scheduled shift .. they seem to be able to plan their life a lot better, and they turn up to shifts a lot more frequently" #009

Survey data revealed that those who reported that their schedules were regular felt that their organisations managed fatigue significantly better ($U = 827, p = 0.022$), and reported significantly longer sleep on workdays ($U = 675, p = 0.011$), fewer gastrointestinal symptoms ($U = 656, p = 0.006$), and lower Work-Life Disturbance ($U = 673, p = 0.037$) (Figure 7.1). Those who felt that their schedules were predictable also reported significantly longer sleep on workdays ($U = 547, p = 0.048$), fewer gastrointestinal symptoms ($U = 554, p = 0.039$), and lower Work-Life Disturbance ($U = 518, p = 0.033$) (Figure 7.1).

At the same time as striving for consistent and predictable schedules, there was a strong theme of the importance of building in room for flexibility. There were many

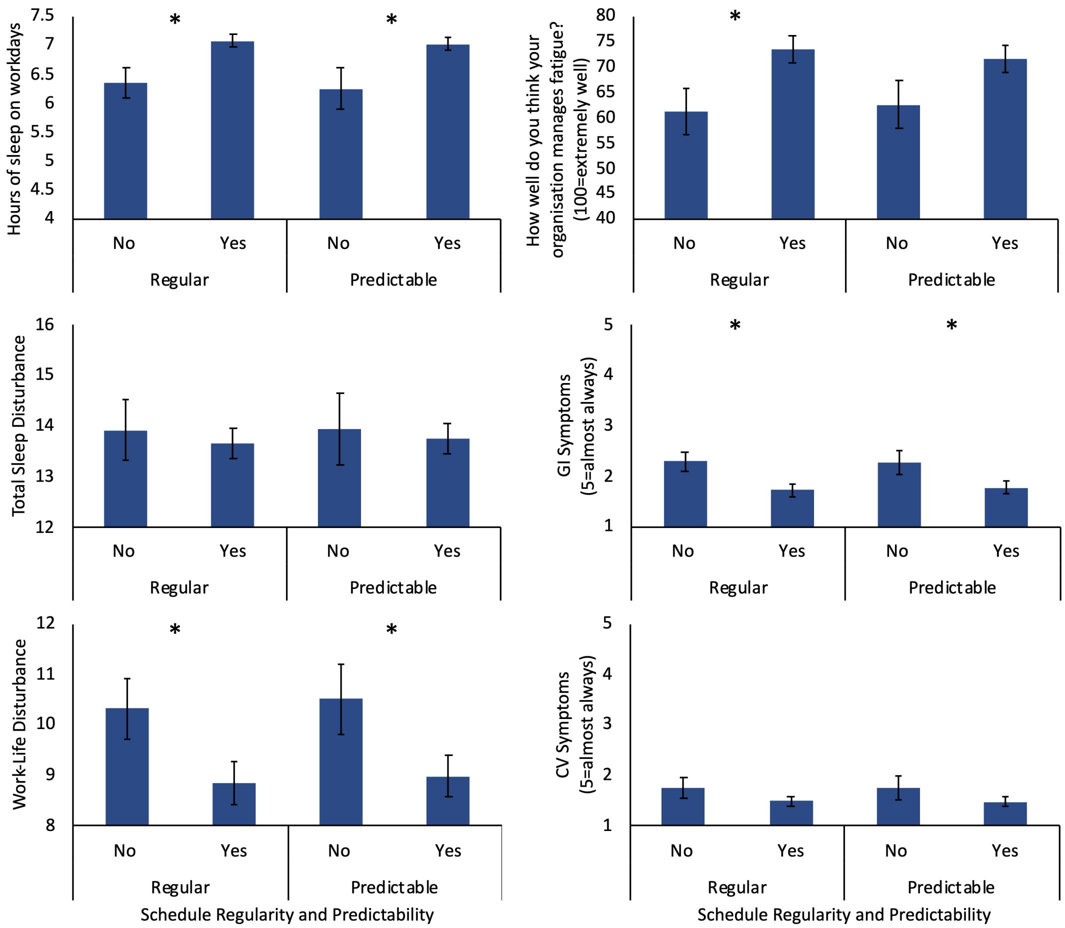


Figure 7.1: Differences in reported sleep, work, and health variables by schedule regularity and predictability. GI=gastrointestinal, CV=cardiovascular, $*p < 0.05$

examples of work design to maximise flexibility for individual workers, taking into account external social and domestic commitments as well as preferences.

> "Can build in flexibility as long as the wood flow is maintained ... Truck starts 4am, 5am, 6am, later start might be better ... Operators use individual machines, which allows more individual flexibility (e.g. with start times). Truck drivers are trained to use the loading machine so that they don't have to rely on the operators to load, which also allows maximum flexibility" #005

7.3 Shared Understanding and Satisfaction

Aligned with considerations regarding flexibility, there was a focus on work design to support worker wellbeing. Examples included:

- Timetabling mixed workload intensities - Interspersing intensive mill product runs with less intensive runs in order to spread workload,
- Managing overproduction – Spreading movement of product over multiple shifts (may be more efficient to wait to move something),
- Planning for reduced throughput - Transparent acknowledgement of lower expectations of production, such as when staff are limited (e.g. during COVID-19 absences).

These techniques were aimed at reducing perceived pressures and creating shared expectations. For example, developing a shared understanding that you don't have to do things immediately and faster isn't always better. These techniques support work satisfaction, and positive morale and wellbeing.

> "When workers feel that they are less efficient, work satisfaction drops... Distances, and worst quality bush can make the job much less satisfying and can create morale and mental health issues... try to swap so not doing distance harvests in a row" #023

7.4 Chapter Summary

This chapter focused on the shared responsibility, or reciprocal duty of care, whereby operators must provide a safe work environment, and the employee must show up fit-for-work. This focus was primarily informed by interview data. Key findings:

- Discussions highlighted the importance of a just safety culture, where people feel safe to disclose when they are fatigued. This work culture is ideally reinforced by family and community outside work;
- Fatigued was described in many ways, from feeling "doughy" to feeling "slammed";

- People described a preference for permanent shifts, and a general move away from rotating roster designs. For some, the consistency and ability to plan ahead was particularly appreciated;
- Alongside that consistency was discussion about the necessity for flexibility, with many instances of building in flexible processes to facilitate increased or more effective rest time;
- Perceived schedule regularity was associated with improved perception of how well the organisation manages fatigue, as well as lower gastrointestinal symptoms, longer sleep and reduced sleep problems, and reduced Work-Life Disturbance. Perceived schedule predictability was also associated with more positive sleep, health, and reduced Work-Life Disturbance.
- Flexible strategies also served to reduce perceived time pressure, creating shared expectations, and supporting worker satisfaction, and wellbeing.

8. Technology

Technological innovations are changing the safety profile of work, and their use at scale is also changing workforce profile. For larger implementation, resources such as staff are needed to install, service, maintain and/or repair equipment. One example is the Guardian fatigue and distraction monitoring system, which requires installation and remote monitoring of alarms. Another example is the electronic dispatch system which has been adopted by a number of the log truck operations with the aim of reducing fatigue by managing the trucks to remove downtime and delays (e.g. loader running schedules).

> "Control system manages trucks, while the contractors manage drivers"

8.1 Fatigue Apps

The use of apps to assist with fatigue management is growing. One example is the Prior Sleep Wake (PSW) risk assessment app, based on a published model [47], which requires workers to enter their prior sleep and their risk across their shift is calculated. Interestingly, due to the relative consistency of their shifts, employees tend to only need to calculate their score for their first few weeks. After this, they know what their score is, because it is consistent from day to day, so they can just put a consistent score into their pre-start record. They only need to re-calculate if there is a different circumstance (e.g. a late night, earlier shift). In some operations, the PSW score goes in their time book and is checked weekly as part of payroll. This highlights the utility of reviewing apps in each unique work context post-implementation to maximise efficiencies in use.

8.2 Making Compliance Easier

Participants commented on the utility of electronic work diaries (EWD) or log books that can be recorded on tablets in the trucks. This has helped the drivers because paper logbooks required manual calculation to check adherence to prescriptive work hour limits, and there was the possibility of calculation errors. EWD have automatic calculation to allow feedback in real time and assists with compliance reporting and monitoring and analysis of the frequency and magnitude of any limit violations.

8.3 Safety in the Cloud

Cloud-based updateable maps are in use by some operators to support safety management (e.g. John Deere machines with Timbermatic maps [58, 59]). These allow plotting of potential hazards and proximity alerts through the map. Hazards can be marked by the operator, or from the office (e.g. old stump, steep terrain, power line). This creates an electronic, updateable harvest plan and risk assessment. Compatible machines are required, and mobile phone reception can be a problem, with obstacles such as a thick tree canopy potentially influencing the signal.

> "Mobile reception is a hamstring to tech innovations for safety" #005

8.4 Guardian for Driving

Operators are increasingly installing Guardian systems in haulage and harvesting vehicles. There are also suggestions of installing it in other work vehicles to include coverage during the commute. Guardian monitors the eyes, head, and face position to detect drowsiness and distraction events. When these are detected, the system can provide auditory and seat vibration alerts to the driver, and an alert to the manager [60]. Although interviewees cited examples where they felt that the system had saved lives, they were very clear that the Guardian system is a safety net and should only be last step in fatigue management. Guardian is an example of a system that may require ancillary resources for implementation and ongoing use such as auto-electrician support for troubleshooting, fixing faults, and maintaining the fleet. Patchy mobile phone reception can create a problem for Guardian too. For example, if an event occurs in an area with no reception, notification can be delayed until the person returns to within range.

> "Guardian should only be the last step in fatigue management" #005

8.5 Resistance and Concerns

As is common for such technologies, resistance and concerns were raised, including surveillance concerns, false alarms [38, 60], and use limitations. The increasing number of devices in the truck cab was commented on, as was the potential associated interference (e.g. Guardian, Electronic Dispatch, multiple radios, UHF channels, and mobile phones). In addition to connectivity and signal limitations, concerns were raised about the mixed road conditions frequently experienced in forestry that could "belt around" the technologies and negatively impact on their accuracy and/or integrity. The issue of the rough working environments and the impacts on devices has been raised before in relation to wearables in forestry [37].

> "I know they went pretty full on with systems in the truck that you start blinking, the truck rattles and cameras on everything and all of that..." #007
>
> "So many devices, so much interference" #022

8.6 Chapter Summary

This chapter focused on health and safety support technologies, which were frequently brought up in interviews. Key findings:

- Fatigue management apps can be useful, but they need to be reviewed in each unique work context to maximise efficient use.
- Electronic logbooks (or Electronic Work Diaries) automate calculations relative to work hour limits and assist with compliance in this way;
- Other useful examples for fatigue management include wearables such as acti-watches to measure sleep/wake patterns and physical activity, proximity sensors for people-mobile plant interactions, geofencing and cloud-based updateable maps for flagging hazards, and electronic dispatch for maximising wood flow;
- Fatigue and distraction monitoring with real time alarms such as the Guardian system were discussed as part of a "last step" in fatigue management; and
- Discussion included potential unintended consequences of technological introduction such as the potential to feel surveilled, and the balance between amount of feedback and distracting information.

9. Summary and Workplace Guidance

Overall results suggested that there is a lot of strong fatigue management work in forestry, with many successes. The following section summarises the main findings from each chapter. The report concludes with mapping and discussion of fatigue management strategies in forestry, and suggestions for potential metrics for fatigue audit, monitoring, and continuous improvement.

9.1 Chapter Summaries

Chapter 1 summarised local and international studies of the impact of sleep loss and fatigue in forestry. Research suggests that forestry is associated with high risk work, common issues with sleep loss and fatigue. The literature presents links between fatigue and incidents and accidents as well as decreases in productivity, and important implications for fatigue (and fatality) during the commute and while driving at work. Chapter 2 described the mixed methods approach, synthesising data across interviews, surveys, datasets, and documentation. Analyses were presented in six primary themes. These themes were supported by an overarching narrative about the importance of having work and community cultures that support safety management strategies inside and outside the workplace (Figure 9.1).

Chapter 3 focused on contributors to work-related fatigue, including environmental factors and work hour design. Survey and interview data, as well as biomathematical fatigue modeling and analysis of harvesting machine data, were used to explore these factors. Key findings include identifying hazardous outdoor conditions, the need for fatigue management during fire season, perceived time pressure and elevated workloads as sources of fatigue, the debate surrounding early starts, the possibilities

Figure 9.1: Summary of themes arising from interviews with Shared expectations, Flexibility, Consistency, and Engaged Coping Style at the centre. These factors as supported by workplace and community safety management environment and culture.

of matching shift types to circadian preference, and using harvesting machine data for understanding fatigue and productivity. Accessing a comparison dataset and hourly data would provide further insight into the influence of fatigue on productivity.

Chapter 4 focused on driving as the greatest identified risk area for forestry. Key findings included expressed difficulties maintaining concentration during long trips, with 52.7% of respondents reporting feeling tired while driving at least sometimes. Timber industry trucks accounted for half of the crashes in the Victorian portion of the Green Triangle, with rollovers being the most common type of crash, and a peak in rollovers in 2015, followed by road safety rollover programs. Most crashes occurred in 100 km/h speed zones and had hallmarks of fatigue as a contributing factor, especially those occurring at night. The FWPA dataset suggested an overall decrease in rollovers over time, and the time-of-day distribution of crashes suggested that fatigue may be a contributor, particularly for timber vehicles driving around the clock.

Chapter 5 focused on fatigue, lifestyle, and health behaviors in the forestry industry using survey and interview data. Findings show that success in coping with work demands is a lifestyle issue that requires balance between work and home life. Survey respondents reported sleeping less than their perceived need on workdays and one hour longer on days off, with sleep problems being common. Work hours had negative impacts on domestic and social life, and engaged coping strategies like problem-solving and cognitive reappraisal were commonly used. One in six respondents reported experiencing cardiovascular, and one in four gastrointestinal symptoms at least sometimes. Nearly one quarter of respondents reported alcohol consumption above national health guidelines, and one in eight reported using alcohol as a sleep aid. Engaged coping was associated with more positive, and disengaged coping with less positive reports relating to sleep, home and social life, work, and health. Workdays were associated with earlier and longer eating windows, with a higher proportion of snacks. Findings suggest that work hours strongly influence health-related behaviors.

Chapter 6 discussed fatigue-related policies and processes in forestry. While there is a focus on work hours, factors such as task risk profile and personal lifestyle management were also highlighted as important. The average rating of how well organisations manage fatigue was high, and nearly 90% of respondents indicated that their organisation has a Fatigue Risk Management Policy. However, there are areas where information could be expanded, particularly in terms of monitoring and audit of fatigue risk management systems.

Chapter 7 focused on the shared responsibility of providing a safe work environment and showing up fit-for-work. The importance of a just safety culture where people feel safe to disclose fatigue was highlighted. Fatigue was described in many ways, and there was a preference for permanent shifts and flexible processes to facilitate increased or more effective rest time. These flexible strategies reduced perceived time pressure, created shared expectations, and supported worker satisfaction and well-being. Survey data suggested a positive relationship between schedule regularity and predictability and sleep, social and domestic life, and health.

Chapter 8 discussed health and safety support technologies for fatigue management. It highlighted the importance of reviewing fatigue management apps in each unique work context, and the benefits of electronic logbooks and wearables such as acti-watches. Other technologies mentioned include proximity sensors, geofencing, and electronic dispatch. The chapter also discussed potential unintended consequences of technological introduction, such as feeling surveilled, and the balance between amount of feedback and distracting information.

9.2 Summary of Fatigue Management Strategies

Figure 9.2 provides a summary of individual, company, and community fatigue management strategies. Strategies are organised into themes (Sleep, Diet, Social, Driving, Employee, and Systems). Each strategy is colour-coded, based on the support (or otherwise) for the efficacy of this strategy from the published literature. Green indicates that there is support from the literature, white indicates that we need more research, and brown indicates that there is no support from the literature, or that the literature has identified associated hazards. So for example, night shift naps are green because naps help boost alertness, orange, because the literature on napping at night (as opposed to the afternoon) is still growing, and brown, because naps can be associated with sleep inertia, or grogginess on waking, which can present a hazard in the workplace and must be managed. Employee strategies are mostly green. In contrast, using alcohol as a sleep aid is mostly brown due to the negative impact of alcohol on sleep quality.

Sleep Strategies:

- ***Napping*** - Forty percent of survey respondents reported that they used naps at least sometimes. Short naps are brief periods of sleep typically lasting between 10 to 30 minutes. These naps are often taken during the day to combat feelings of sleepiness or fatigue and can be beneficial for improving alertness, mood, and cognitive performance [5]. Longer naps may lead to grogginess upon waking, referred to as Sleep Inertia (SI) [61, 62]. Interview data revealed napping strategies including short naps, perhaps multiple times during shifts, and participants described allowing time to wake properly before returning to work activities, to allow any SI to dissipate. Prophylactic napping [63] prior to "afternoon" or "night" shifts was also described, as observed in other working populations [5].
- ***Sleeping in on days off*** - Survey respondents reported that they slept an average of one hour longer on days off. Sleeping in on days off, as observed across working populations [5, 31, 64, 65] can have a range of benefits for physical and mental health [5]. However, it's important to balance the need for sleep recovery with maintaining a consistent sleep schedule as much as possible, as irregular sleep patterns can disrupt circadian rhythms and negatively impact sleep quality in the long term.
- ***Using alcohol as a sleep aid*** - Approximately one in eight survey respondents reported using alcohol to help them sleep at least sometimes. Alcohol is a relatively common sleep aid [6, 10, 66, 67] as it may initially make people feel drowsy and help them fall asleep faster. Using alcohol as a sleep aid is not recommended as it can ultimately interfere with sleep quality [10].
- ***Modifying the sleep environment*** - Participants described ways that they created a home environment that supported sleep. Modifying the sleep environment can be an effective way to improve sleep quality [68]. The best sleep environments are cool (fan, air conditioning), dark (block-out blinds), and quiet (can use earplugs or white noise). The sleep environment and any pre-sleep routine can act as a signal to the brain that it's time to sleep [6].

Diet Strategies:

- ***Caffeine use*** - Approximately 90% of survey respondents reported consuming coffee or tea, with 23% reporting 4-6 cups per day, and 13% reporting energy drink consumption. While caffeine can be effective in boosting alertness and improving cognitive function, it's important to consider the timing, amount, and regularity of caffeine intake. Suggestions include avoiding caffeine consumption within several hours of bedtime and limiting intake to no more than 400 mg per day (equivalent to about four cups of coffee) to avoid negative side effects (e.g. anxiety, jitters, increased heart rate, tolerance, withdrawals) [5, 69, 70]. [5, 66].

- ***Snacking, fast food*** - Survey responses revealed that relative to days off, workdays were associated with a higher number of eating occasions with a higher proportion of snacks. Snacking at work was described frequently in the interviews, in particular, foods that were easy to travel with and consume "on the go." Workers on long and/or irregular schedules, such as those in the forestry industry, may face challenges in maintaining a healthy diet due to the disruption of normal eating patterns and access to food [7, 8]. Eating small, frequent meals throughout the shift can also help maintain energy levels and prevent eating large amounts at times of day that are not biologically ideal [7, 8, 71, 72]. This is described further below.
- ***Food as a "reward"*** - In the workplace, especially when fatigued, food may be used to cope with stress, boredom, or sleepiness. This tendency was reflected in the interview data. Food indulgences, such as consuming high-calorie or high-fat foods, can provide a reward value that may positively impact mood and psychological well-being [67, 72]. While food indulgences may provide a temporary mood boost, relying on them too heavily can have negative consequences for overall health [6], such as weight gain, impaired metabolism, and an increased risk for chronic diseases.
- ***Changing timing of food*** - In addition to increases in snacking, relative to days off, workdays were associated with earlier and longer eating windows (the time between the first and last eating occasion). The earlier the workday start time, the earlier the first eating occasion. Work scheduled in the afternoon or overnight resulted in eating occasions that were distributed around the clock. Researchers are showing increasing interest in the ways in which working time influences timing of food intake [8, 9]. Chrononutrition, the study of how nutrition and eating patterns interact with our body's natural circadian rhythms, suggests that the timing, frequency, and composition of meals can impact our health (e.g. weight management, metabolic function, cardiovascular health). Emerging evidence supports aligning meal timing and composition with our body's internal clock. For example, studies have found that reducing the amount of calories at night may lower risk of insulin resistance, a precursor to diabetes [8, 71].

Social Strategies:

- ***Rethinking stressors*** - Also referred to as "Cognitive reappraisal," this is a technique used in psychology that involves changing one's perception or interpretation of a situation in order to reduce negative emotional responses. Re-appraisal was used "quite a bit or a big deal" by nearly one third of respondents (the second most common type of coping strategy after more direct problem solving at 49%). Re-appraisal in the literature is associated improved emotional regulation, increased ability to cope with stressors, and improved mental health and wellbeing. Re-appraisal is one of the four strategies that characterise an Engaged Coping Style, which has been linked to better biopsychosocial health indicators in shiftworkers [6, 42, 67, 73].

- ***Socialising or spending time alone*** - Sleep loss and fatigue can lead to social withdrawal, which is the tendency to avoid social interaction and isolate oneself from others. Social withdrawal was used to cope with problems with sleep, domestic or social life, or work hours "quite a bit or a big deal" by one quarter of respondents. Social withdrawal is one of the four strategies that characterise a Disengaged Coping Style, which is associated with poorer outcomes. In contrast, talking to someone when faced with a problem was used "quite a bit or a big deal" by 20% of respondents, which is part of an Engaged Coping profile [6, 42, 67, 73].
- ***Time with pets*** - Non-traditional work hours can lead to feelings of isolation and loneliness [67]. Pets provide constant companionship and emotional support, which can help reduce stress and anxiety. Overall, pets can provide significant benefits for shiftworkers, including improved mental health, companionship, and increased physical activity [74, 75].

Driving Strategies:

- ***Winding the windows down and using loud music*** - Nearly half of survey respondents reported feeling tired while driving at least sometimes. Descriptions of coping strategies included winding down car windows and turning up the radio. However, these are not effective strategies for fatigue management while driving. More effective strategies include stopping for a sleep or a quick nap and swapping drivers [76].
- ***Caffeine use*** - Caffeine was also used as a countermeasure for driving. As discussed above, caffeine can help to increase alertness and reduce fatigue. While caffeine can have benefits for driving performance, it is important to use it responsibly and be aware of its potential limitations [5, 69, 70].
- ***Avoiding fauna*** - Kangaroos are most active at dawn and dusk [77], and interviewees reported that they avoided commuting during these periods as much as possible, especially when they were tired.
- ***In-car napping*** - Reports of napping included descriptions of people taking opportunities to nap in their car [5, 76]. In addition to the napping hazard considerations mentioned earlier, it is important to consider the safety of the location in which the car is parked and locking the doors. Shades can be used to darken the environment in the car, and using an alarm in order not to sleep

too long is a common technique.

- ***Minibuses, cabs, and ride-sharing*** - If transportation is necessary for fatigued workers, it is important to ensure that the driver is well-rested and alert. Allowing fatigued workers to drive themselves or others may put them at risk of accidents or other safety hazards. Interviewees described the use of minibuses and cabs to transport employees who had been working very long hours and were likely fatigued [78] as well as sharing driving on the way to work. An interesting consideration for operators is whether to provide transportation that is comfortable and conducive to rest (e.g. a shuttle bus with comfortable seating or sleeping accommodations) for travelling long distances.

Employee Strategies:

- ***Using breaks and micro-breaks*** - Interviewees reported using breaks and micro-breaks (short, frequent breaks that can be taken during tasks) to help prevent the accumulation of fatigue [79, 80, 81].
- ***Communication, teamwork, and looking out for each other*** - Effective communication and teamwork are essential components of fatigue management in any workplace. When team members work together and communicate effectively, they can help identify and address fatigue risks and ensure that all tasks are completed safely and efficiently [31, 82]. Optimally, team members would be able to identify fatigue in others and balance activity requirements to maintain safety at the team level, even when team members are experiencing fatigue-related impairment. This can be supported by team member training to identify the signs and symptoms of fatigue in themselves and others, and having the confidence to raise concerns with supervisors or managers and/or help out their colleagues [41, 67, 82]. This aspect of fatigue education was noted in the analysis of publicly viewable operator websites.
- ***Adhering to safety procedures*** - Safety procedures discussed by respondents in relation to fatigue management included scheduling policies involving limits to work hours and minimum rest periods, training on sleep hygiene, strategies for managing fatigue, and the importance of reporting fatigue-related concerns, incident and near miss reporting or analysis, disclosure processes when experiencing fatigue, access to rest areas and healthy food options, and flexibility in work schedules (particularly in relation to start times).
- ***Timing of tasks*** - Changing the timing of tasks can be an effective strategy for managing fatigue in the workplace. For example, scheduling safety-critical tasks during times of the day when employees are most alert and avoiding alertness dips such as the circadian nadir (approximately 4am-6am) or early afternoon "post-lunch dip" [41].
- ***Formal and informal training*** - Fatigue management training is essential for promoting awareness and understanding of the causes and consequences of fatigue in the workplace, as well as providing strategies and tools for managing

and mitigating fatigue risks. Training for employees and for managers was described. Manager training can include managing fatigue risks across teams and organisations through developing policies and procedures, implementing monitoring and reporting systems for fatigue-related incidents, and ensuring that workers have access to the resources and support they need to manage fatigue risks effectively [83, 84].

Systems Strategies:

- ***Rostering and task risk*** - Effective fatigue management rostering involves creating work schedules that balance the workload and rest periods of employees, to provide sufficient opportunity to recover between shifts. Interviewees described limits to their work hours, number of consecutive shifts, and break duration. Taken broadly, the primary focus of fatigue management was described as a focus on work hours. Some places also described task risk management where work hour limits were exceeded (most frequently during fire season). Risk management involves identifying and assessing the risks associated with specific jobs or activities, and implementing measures to reduce or eliminate those risks. Examples were outlined in the Fatigue Guideline [39].
- ***Interspersing more and less intense work periods*** - Interspersing more with less intense work periods is a productivity technique that involves alternating periods of focused, high-intensity work with shorter periods of lower-intensity work or rest. This approach can allow workers to recharge during the low-intensity periods, preventing fatigue and burnout. An example of this from the interviews was descriptions of managing production rates in the mill to allow for breaks between intense periods that can be physically and mentally demanding. This is consistent with planning fore-fronting human resource capacity [85].
- ***Interspersing more and less rewarding tasks*** - By interspersing more and less rewarding tasks, individuals can break up the monotony of difficult or tedious work and maintain motivation. An example of this from the interviews was organising harvesting to alternate between forest areas with "easy" and "more difficult" terrain, access, and distance.
- ***Increasing staff during high risk periods or tasks*** - Interviewees described instances were two people were assigned to a duty typically done by one person in order to manage fatigue-related hazards. This can be an effective way to minimise hazards through workload distribution and/or provision of another colleague to contribute, assist, and safety check. One example where this is done routinely is the rail industry [86]. Cross-training and task rotation can help support capacity to take on high-risk tasks, and can also support staff substitution in the case where a worker needs to stop work.
- ***Use of safety technologies*** - Safety technologies were a key theme in this report (summarised in Chapter 8). These included wearables, fatigue detection systems, in-vehicle monitoring systems, and electronic work records.

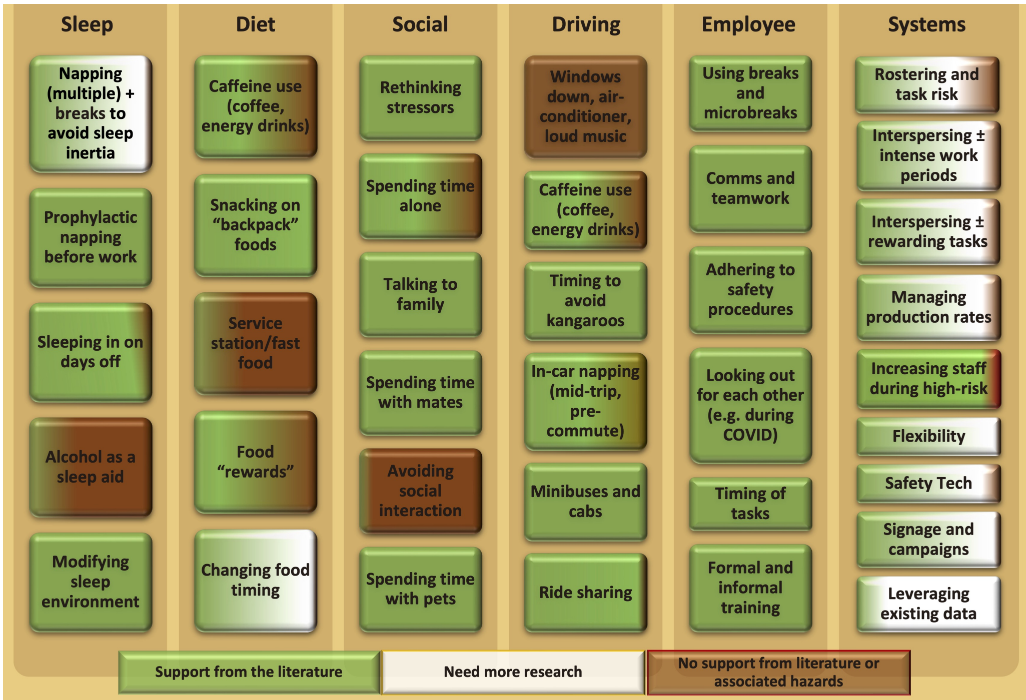


Figure 9.2: Examples of the safety management strategies used by individuals, companies, and communities to keep workers healthy and safe.

- ***Signage and Campaigns*** - Half of the truck crashes in the Victorian portion of the Green Triangle between 2011 and 2022 involved Timber Industry Trucks. Three quarters of truck crashes were rollovers. Vic Roads began a truck rollover campaign in 2015. The proportion of truck rollovers relative to amount of product seems to be reducing over time. This campaign provided a case study example of road safety campaigns relevant to fatigue management [87].
- ***Leveraging existing data*** - A significant amount of potentially useful data is being generated daily across forestry. Sources identified in this study include work schedules (planned and actual), data from wearables to inform sleep/wake patterns, harvesting machine data, incident/accident/near miss records, survey databases, in-vehicle monitoring data (e.g. location, driving duration and timing, speed, acceleration, braking), and distraction and fatigue event data from monitoring systems such as Guardian. Preliminary analyses of such data sources in this report highlight the promise and the challenges associated with these data sources. Development of processes to analyse, present, and review data from such sources could form a useful part of a safety management system. The following section explores this idea further through discussion of examples of potential fatigue management metrics.

Activity	**Measure FM activities that are implemented**	
	• % sites with approved FM policies • % employees who design work patterns with completed FM training • time since last policy review	• % employees with completed FM training • % rosters assessed for fatigue (e.g. using BMM software, FM-competent person) • time since last FM audit or review
Outcome	**Measure whether the FM activities are having the desired effect**	
Results	• % employees with completed FM competence assessments • % rosters with fatigue factors below certain thresholds	• % employees carrying out safety-critical tasks with completed FM competence assessments
Precursors	• % measured data within thresholds (e.g. sleepiness, sleep, performance) • % shifts starting before 5am • % shifts including commute starting before 5am • % shifts where staff had <2 days notice	• instances of >4 consecutive shifts • instances of <2 days off between shifts • instances of >55h worked in a week • % shifts where successive start times vary by >2h • % shifts >14h
Incidents	• occurrence of incidents	• occurrence of fatigue-related incidents (classification required)
Balance	**Consider the potential impact of FM on the rest of the system**	
	• system costs • % sick leave	• staff turnover rates • employee feedback

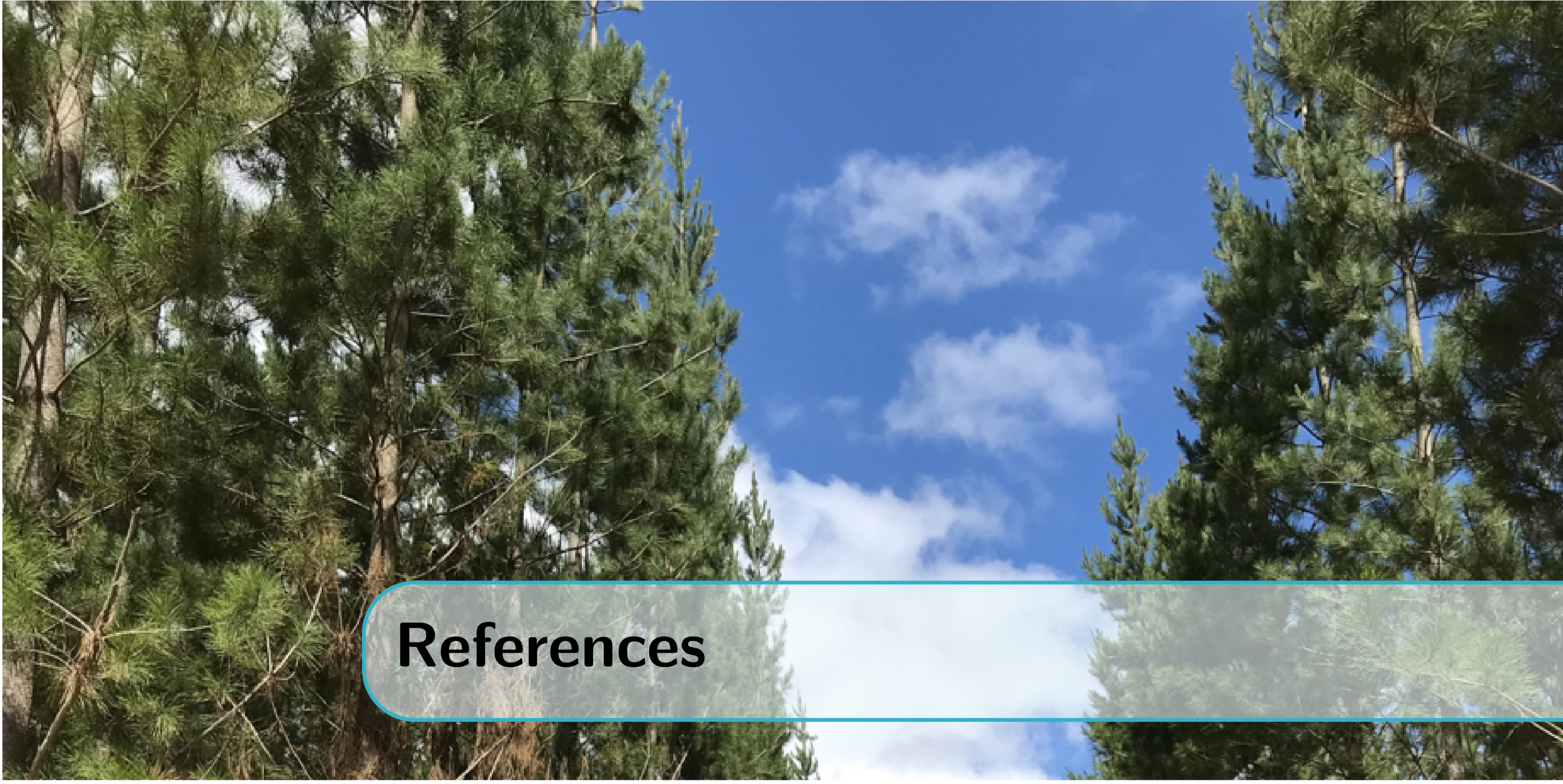
Figure 9.3: Summary of potential fatigue management indicators in forestry.

9.3 Summary of Potential Fatigue Management Indicators

Fatigue Risk Management Systems (FRMS) are current international best practice for addressing fatigue in workplaces [49, 83]. Benefits and impacts of FRMS include some or all of the following: Reduction of fatigue; reduction in errors, incidents, and accidents; improvements in productivity and health; and reductions in injuries. FRMS operate on continual improvement principles, which include monitoring, review, and audit procedures. This approach ensures that FRMS remain relevant and effective in addressing the constantly evolving challenges of managing fatigue. Continual improvement metrics for FRMS can help organisations track progress, identify areas for improvement, and evaluate the effectiveness of interventions [1]. Example areas include tracking: Fatigue-related incidents; employee feedback; compliance with FRMS policies; employee sleep duration and quality; workload and schedule factors; and the effectiveness of FRMS training and education. Metrics for FRMS are tailored to individual operational contexts and cover activity (measures FM activities that are implemented), outcome (measure whether FM activities are having the desired effect), and balance indicators (consider the potential impact of FM on the rest of the system) [1]. Figure 9.3 provides some example indicators that may be applicable for the forestry industry to consider, in light of findings from this study.

9.4 Overall Summary

In this report, we presented findings of our study on fatigue in the forestry industry. This was a mixed methods study involving interviews, surveys, document review, roster analysis, and data from truck crashes and rollovers. Findings highlighted hazardous working conditions such as working in heat or wind, and near slopes or power lines. The fire season was identified as a time when fatigue guidelines were most needed. Sources of fatigue included perceived time pressure, long shifts, overtime, and early starts. There was a spread of circadian preference scores in the survey data and interviews discussed matching shift types to circadian preference. Biomathematical modelling of rosters with sleep and fatigue estimation highlighted the changes in sleep and fatigue due to early starts, long and consecutive shifts, and rotating between shift types. Harvesting data analysis revealed changes in work hours and volume across the week, with overall productivity remaining constant. Driving was identified as the greatest risk area for forestry, including log and chip truck driving as well as commuting. Truck crash analysis revealed that fatigue may have contributed to the crashes, particularly for timber vehicles driving around the clock. Success in coping well with the demands of working in the forestry industry was described as a "lifestyle" issue. Sleep problems were common, and coping strategies indicative of an engaged coping style were used more frequently than disengaged strategies. Reporting these strategies alongside their support (or otherwise) from the literature can give direction to recommendations for coping with shiftwork at the employee and operational level. Results also gave rise to potential continual improvement metrics, to help forestry organisations to measure and assess their approaches to managing fatigue risks.



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