THE USE OF HEART RATE INDICES AND SUBJECTIVE QUESTIONNAIRES IN THE DETERMINATION OF FATIGUE IN MOTOR-MANUAL TREE FELLING AND DELIMBING OPERATIONS IN NEW ZEALAND EXOTIC PLANTATION FORESTS

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ABSTRACT

This study assessed the use of heart rate indices and subjective questionnaires in the determination of fatigue in motor- manual tree felling operations in New Zealand exotic plantation forests.

The research design consisted of a causal study utilising an amalgamation of both observational and ex post facto data collection techniques employing a cross sectional case study approach within a field study research environment.

Findings from the research indicate that motor-manual tree felling and delimbing are tasks not necessarily analogous with excessively high levels of fatigue, even though the physiological measures categorised motor-manual felling and delimbing as being moderate to heavy workload tasks. Chronic fatigue was avoided, and acute fatigue mitigated by the effective use of the fallers self-pacing mechanism, combined with both structured and spontaneous rest breaks analogous with the work method adopted by motor-manual fallers. Consequently, production was not negatively affected by the progression of the working day. Poor work postures commonly adopted by the fallers encourage the progressive development musculo-skeletal damage. Hazards encountered by the subjects followed national trends for felling and trimming. Significant decreases in thermal comfort and sensation ratings occurred, accompanied by an increase in the skin wettedness rating and higher thermal regulation ratings for the majority of the fallers. No discernible increase in mental fatigue could be identified during the study. The ambient thermal environment and work site terrain had minimal effect on the subjects performance levels or physiological and psycho-physiological loadings.

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All that I can say now is, that enough is enough, and here endith my progression up the ladder of Academia, its now time for deer stalking!!.

Table of Contents

LIST OF FIGURES

List of Figures

LIST OF TABLES

CHAPTER 1: INTRODUCTION TO COMMERCIAL FORESTRY

1.0 Introduction

This chapter begins with a brief history of plantation forestry in New Zealand, the resource and the labour force. It then outlines the current and future labour requirements for both current and projected harvesting trends within the industry. The final section outlines past and present ergonomic research relating to manual forestry work in New Zealand.

1.1 New Zealand Commercial Forestry

Forestry is one of the oldest occupations known to New Zealanders. Even before the whaling and sealing colonies were established during the late 1700's and early 1800's, Europeans had been involved in the extraction of *Agathis australis* (Kauri) poles for use as ship spars. Before European settlement, the indigenous forest was an important aspect of the culture of the Polynesian (Maori) population which inhabited New Zealand from ca 1000 AD. They harvested the forest for fuel wood, shelter and, using fire, cleared areas for the purpose of raising food crops.

Commercial, or plantation, forestry commenced at the beginning of the 20th century. It was recognised that the indigenous forests could not provide the lumber requirements of the rapidly growing colony. Plantation forestry boomed during the great depression of the 1930's, when large scale planting of predominantly *Pinus radiata* was undertaken to provide gainful employment for the large number of people who were jobless during this period. This was the first evidence of the importance of plantation forestry to the nation and the employment opportunities it could provide.

In 1995, New Zealand contained 1,308,000 hectares (ha) of exotic forestry of which 89.9% was planted in *Pinus radiata*, 5.1% Douglas Fir (*Pseudotsuga menziesii*) the remaining 5% consisted of a mixture of exotic softwoods (3%) and exotic hardwoods (2%) (Forestry Facts and Figures 1995). In April 1992 (latest available figures), only 16% of the total *Pinus radiata* resource fell into the clearfell age class of 25 + years old.

More significantly, a further 43% of the total *Pinus radiata* resource was between 5 to 10 years away from clearfell age class (Forestry Facts and Figures ,1995).

Between 1920 and 1990, the annual rate of new planting's peaked at approximately 57,000 ha per year up until the early 1980's when this rate decreased dramatically in line with both the standardisation of all land based production incentives (Le Heron 1985) and the economic recession instigated by the share market crash of 1987. Since the early 1990's an increased interest in forestry investments in the form of joint venture retirement and superannuation schemes, combined with the more traditional farm based woodlot establishments, has seen the rate of new planting's increase dramatically from around 17,000 ha per year in 1990 to an estimated 85,000 ha per year in 1995 (Forestry Facts and Figures 1995). The beneficial consequences of such a trend, in terms of the continuance of a viable wood fibre source for the forestry sector, are substantial.

1.2 The New Zealand Logging Workforce

In February 1994, there were 8548 people employed in the logging and silviculture workforces in New Zealand (Forestry Facts and Figures 1995). Current figures are unavailable on the exact distribution between these two groups. However, an indication can be gained from the previous year's figures which, for a total workforce of 7394 workers, placed 4552 in silviculture and 2842 in logging (Forestry Facts and Figures, 1994). The average ± (sd) age of the logging workforce in June 1995 was 31.4 ± 8.9 years. The average logging experience for the workforce was 8.4 years. Seventy six percent of the logging workforce had at least one training module (Byers, 1995a). The logging workforce is predominantly male, with only 1.5% of the workforce being female (Byers pers.comm, 1996). The logging workforce is comprised of two major ethnic groups consisting of 57% European and 41% Maori. Unlike the silviculture workforce, where Pacific Islanders accounted for 9% of the workforce, in logging they only accounted for 1.5% (Byers, 1995a).

1.3 Future Developments

Traditionally, employment within the timber harvesting sector of the forest industry has contained a significant component of manual work. More recently this started to change with the development of technological advances which enable the partial or full mechanisation of certain harvesting tasks. Many overseas forestry nations have mechanised a large proportion of their timber harvesting and processing operations, particularly in Scandinavia and the United States. Such moves have been assisted by available and appropriate technologies, favourable timber resources, agreeable topography and most importantly, the emergence of critical health and safety issues.

New Zealand's forest industry, while beginning to mechanise, still requires a large contingent of manual labour in order for it to function effectively. This will continue to be the case for the foreseeable future due to a relatively large proportion of the timber resource being established on steep and inauspicious terrain, and economy of scale constraints associated with the large production rates generated by mechanised operations. Nevertheless, timber production from New Zealand plantation forests has consistently increased over the last decade. In 1988 2504 logging workers produced 9,688,000 m^3 of timber. By 1994 the logging workforce had increased to 3369 and production to 15,937,000 m^3. In relative terms this means that in 1988 each person employed in logging produced 3, 869 m^3 of wood per annum. By 1994 this had increased to 4,730 m^3 per annum. Whilst some of this increased production would have been generated through the use of better technologies and increased production due to mechanisation, the majority can still be attributed to increased use of motor-manual systems, that is, a person using a chainsaw.

1.4 Manual Forestry Work

Manual forestry work has been categorised by many researchers as an occupation requiring moderate to heavy physical workloads (110-145 $bt.min^{-1}$), high rates of energy expenditure (7.5 - 10.0 $kcal.min^{-1}$) and oxygen consumption (1.5 - 2.0 $l.min^{-1}$) (Cristofolini et al., 1990; Fibiger and Henderson, 1982; Hagen, 1993; Harstela, 1990;

Henderson, 1984; Kirk and Parker, 1994b; Kukkonen-Harjula, 1984; Parker and Kirk, 1994; Seixas and Ducatti, 1995). Such work is often undertaken in inhospitable working environments, and in close proximity to potentially dangerous equipment and situations (Golsse and Rickards, 1990; Vik, 1984). The hazardous nature of the fallers work requires constant vigilance in order to prevent serious or fatal injuries from occurring. A multitude of factors need to be constantly monitored, observed and corrective action taken while working in forest harvesting operations. If any one of these factors are misread, neglected or incorrectly diagnosed, then the result for the forest worker can be serious injury or death.

This has been the case with forest harvesting operations globally. Similar research findings have been found in Scandinavia (Hagen et al., 1993; Kukkonen-Harjula, 1984), Europe (Van Loon, 1976), United States (Johnson and Tabor, 1987; Smith and Sirois, 1982; Smith et al., 1985; Smith et al., 1986; Smith and Thomas, 1993), Canada (Robinson et al., 1993; Trites et al., 1993), South America (Apud et al., 1990; Apud and Valdes, 1993; Apud and Valdes, 1994; Seixas and Ducatti, 1995), Asia (Andersson, 1986), Africa (Abeli and Malisa, 1994), Australia (Henderson, 1984) and New Zealand (Gaskin, 1990; Kirk and Parker, 1993a; Kirk and Parker, 1994b; Kirk and Sullman, 1995; Parker and Kirk, 1993b; Vitalis et al., 1986) to name a few.

Most of New Zealand's forestry based ergonomics research has followed those directions identified by Gaskin in his review of past, present and future ergonomics research within New Zealand's forestry sector (Gaskin, 1986). This review laid the foundation for much of the subsequent nine years human factors based research within the industry. Consequently there has been extensive work undertaken to identify the *physical hazards* (Parker, 1991; Parker and Kirk, 1993b; Tapp et al., 1990), *accident type and frequency*, (Gaskin and Parker, 1992; Parker, 1994; Parker, 1995; Prebble, 1984; Slappendel et al., 1993), *physiological strain* (Gaskin, 1990; Kirk and Parker, 1993b; Kirk and Parker, 1994b, Kirk and Sullman, 1995; Parker and Kirk, 1993a; Vitalis et al., 1986;), *biomechanical loadings* (Gaskin, 1990; Gaskin et al., 1987; O'Leary, 1988), *socio-political factors* (Byers, 1994; Byers, 1995a; Byers, 1995b; Byers and Adams, 1995; Gibson, 1994) and *the role of personal protective equipment* (Kirk,

1992; Kirk, 1993; Kirk et al., 1992; Kirk and Parker, 1994; Prebble, 1981; Sullman, 1994) associated with forest harvesting operations.

However, the majority of these studies have traditionally utilised one single measure to determine the physiological or mental effort being exerted by the person undertaking the observed task. The work undertaken by Kirk and Parker (1994b) investigating the physiological workloads experienced in several sectors of the forest industry, gave an insight into the severity of workloads experienced by forest workers in New Zealand. The research by Kirk and Sullman (1995) took this work a step further and used a series of measures to determine the impact of physiological and psycho-physiological stressors on the safety, comfort, productivity and fatigue of hauler breaker-outs.

The objective of this thesis is to develop this research further by applying heart rate indices and subjective questionnaire protocols developed by Kirk and Sullman (1995) to motor-manual tree fallers in an attempt to determine fatigue in forest workers.

1.5 Summary

This chapter briefly outlined the history of plantation forestry in New Zealand, its resource and labour force. It then examined the current and future labour requirements for the industry. Past and present ergonomic research relating to manual forestry work in New Zealand was examined Chapter 2 identifies key issues pertaining to fatigue and reviews past and present research pertinent to each of these issues.