Hazard Exposures for Mechanized Logging Systems in the US South

by

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Abstract

Logging is a very dangerous occupation with high injury and fatality rates. The logging industry in the U.S is dynamic and has substantial variability by region. This research focuses on the hazard exposures for mechanized logging systems in the U.S. Characteristics, causes, consequences, and interventions of injury and illness in mechanized logging were identified and summarized. Due to the inadequacy of surveillance data for logging, workers compensation claims data from 12 southern U.S. states from the National Council on Compensation Insurance (NCCI) were analyzed to find injury rate and trend data. Results revealed terrain and product harvest that indicated motor manual felling and processing affected logging injury and fatality rate and trends.

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Chapter 1: Review of safety and health in the mechanized logging industry

1.1 Introduction

Logging is one of the most hazardous occupations in the world (Fosbroke et al. 1997, Seong and Mendeloff 2004, Fischer et al. 2005). Injuries and illnesses that resulted from exposures and accidents in logging workplace cost the industry billions of dollars each year (Pine et al. 1994). Injury and illness surveillance is critical for avoidance of hazards to decrease injury and illness frequency and associated costs. Logging system and methods are likely to impact the characteristics of injuries and illnesses. Since the 1980's by far the largest change in the logging systems has been the mechanization of tree felling and processing and the resulting increase in productivity (Axelsson 1998, Axelsson 1995, Baker and Greene 2008). Mechanization has reduced the number of people needed in logging and changed injury and health issues associated with logging (Shaffer and Milburn 1999).

The principle factors in these changes as they related to safety and health are 1) hazard avoidance by relocating workers in machine cabs, 2) de-emphasis on the use of hand tools, particularly chainsaws, and 3) the change in the physical demands of the work. Coincident with these changes have been consistent improvements in machines and tools, changes in logging economics, and a general change in logging personnel probably in terms of both personal characteristics and professionalism or training.

There are glimpses of recent improvement in logging safety and health due to increased mechanization and safety training (Shaffer and Milburn 1999). However the impact from suggested engineering and procedural interventions are largely unknown to the logging industry in part because they have been difficult to assess by safety and health professionals who propose them. The objectives of this review are to address current surveillance and hazard exposure in mechanized logging, the effects of safety and health interventions in mechanized logging, and how mechanization is related to specific aspects of logging safety and health. Understanding the characteristics of mechanized logging injuries and illnesses can help to target the development of safety training programs and materials to reduce occupational illness and injury.

The review summarizes previous literature with regard to worker demographics like age, work cycle and fatigue, worker activity, event/exposure, and part of body affected to explore changes in hazard exposure which accompanied increased mechanization in logging (NAICS 1133).

The review of the scientific literature was augmented by data from Safety Alerts published by the Forest Resources Association. Safety alerts are a significant component of logging surveillance in the U.S. Incidents which could be identified as incidents possible on mechanized logging were chosen for summarization and analysis. Mechanized logging refers to machine felling, delimbing, and bucking. For the Safety Alerts hazard event/exposure, source of injury, and nature of injury were collected and coded based on the Occupational Injury and Illness

Classification Manual (BLS 2007). Then FRA injury characteristics were compared with previous research.

1.2 Role of mechanization

The extensive mechanization involved decreasing hazard exposures to logging workers because more workers were protected in the cabs (Axelsson 1998, Axelsson 1995). Machine operators had less than 15% of the accidents suffered by chainsaw operators in harvesting the same volume of timber (Slappendel et al. 1993).

Modern mechanized logging work demands highly qualified operators who have good cognitive and motor-sensory processes (Gellerstedt 2002). There is a strong demand for professionals in forestry who are competent in their fields of action (Zoscher 2010). The machine operators need skills and knowledge and the ability to take many decisions within a very short period of time. The operator needs to be in good fitness and focused on the job because small deviations from perfect conditions may lead to serious economic result and poor performance (Bohlin and Hultaker 2006). Meanwhile, some logging tasks involve skills which may be difficult to learn. For example, learning to steer the machine may take about a month and may take two years to reach full capacity (Bohlin and Hultaker 2006).

Logging injury rates have declined over the past twenty years due to increased mechanization, logger training programs, increased safety awareness, and minimization of chainsaw use (Cabecas 2007, Roberts and Shaffer 2005). For example, in Washington, the non-mechanized claims rates were 4 to 6 times greater than mechanized rates (Pilkerton and Wimer 2008). However the mechanized rate remained high compared to other industries and occupations (Sygnatur 1998, Shaffer and Milburn 1999, Bell 2002, Bell and Helmkamp 2003). From the Census of Fatal Occupational Injuries (CFOI), fatal injuries in logging industry (NAICS 1133) and the logging occupation (SOC 454020) have generally declined with some annual variability. The decline in the number of fatalities has followed a similar decrease in employment, leading to only a minor reduction in fatality rates in U.S. A comparison of forestry fatalities from countries across Europe showed that the number and rate of fatal injuries had declined over a 25 year period (Klun and Medved 2007). Differences in rates among countries were attributed to logging techniques (mechanization) and safety management (Klun and Medved 2007).

Mechanization may result in increased financial pressure on firms due to capital and labor utilization. For the last two decades improvements in logging systems and logging technologies have been less influential in the U.S. Because of low demand for products, increasing operating constraints, and rising input costs, logging businesses have been under financial pressure for more than a decade (Stuart et al. 2010, Pelkki 2012). The ability to find new sources of income and savings may be a key component of business survival and quality of life. However, improvements in safety and health programs may not provide immediate savings, so they are often underappreciated. Nieuwenhuis and Lyons (2002) indicated that financial restrictions were a barrier to improvements in safety levels.

1.3 Worker Characteristics

The personal characteristics of workers involved in accidents are important considerations in accident research and prevention. The age, fitness, and training of the individual workers all may influence the occurrence and severity of accidents (Peters 1991, Slappendel et al. 1993). Surveillance studies often report demographic data of the injured workers with the idea that the data may aid in understanding the relationships among causal factors, the injury, and the person. Typical demographic data include workers' age, work cycle and fatigue, and worker activity. In other industries, such as underground mining, it has been found that demographic factors have been related to injury incidence or type (Margolis 2010).

1.3.1 Age

The age distribution of logging employees has been mentioned as a concern in many analyses (Baker and Greene 2008, Milauskas and Wang 2006, Bolding et al. 2010). Worker demographics point to increased age of the U.S. population in general as well as the logging population (Baker and Greene 2008).

The relationship between injury rate and age has been widely studied and there is mixed evidence about how age relates to injury (Margolis 2010). Younger workers may possess advantages over older workers like increased strength, efficiency, and precision (Ilmarinen 2001). Younger workers may have less experience and training than older workers and this may reduce both their performance and safety in work (Margolis 2010). Older workers may also have age-associated decrements in cognitive ability, fitness, and resumptive ability (Mitchell 1988). Because there is mixed evidence about exactly how age relates to injury, some studies have examined both rate of injury and severity of injury and found that younger workers had a higher rate of injury but employees aged 65 and above suffer more serious job related injuries (Wiatrowski 2005, Mitchell 1988). Margolis (2010) found in underground coal mining that as age increases, miners miss more days of work (more serious) after an accident. The relationship between age and lost-time claims may depend on the type of work injury. Young employees have a higher risk of open-wound injuries, such as cuts and burns while older workers have a higher risk of trauma to bone and ligament injuries, such as fractures and dislocations (Smith 2013).

Mechanization could allow workers to stay on the job longer. Many may continue mechanized logging jobs since there has been little demand for new workers in the last 20 years. Older workers are more likely than younger workers or workers with shorter job tenure to have neck/shoulder complaints due to repetitive stress injuries (RSI) (Axelsson 1995). With aging, the risk for the development of an MSD increases (Holmstrom and Engholm 2003). Margolis (2010) indicated an increased risk of overexertion injuries with age.

There are some logging surveillance studies that address age and injuries (Wolf and Dempsey 1978, West et al. 1996, Driscoll et al. 1995, Husberg et al. 1998). Injury or claims surveillance data often do include the age or experience data for the worker population. Without population data it is difficult to determine if there was any difference in relative risk by age or experience.

1.3.2 Work Cycles and Fatigue

Mechanization has increased the opportunity for long shifts and multi-shift operations. The driving factors for longer work hours are high capital investments in logging equipment (Mitchell et al. 2008). Fatigue and high mental and physical demands can be of concern when working longer shifts (Sullman and Kirk 1998). In New Zealand logging workers work an average of 9.4 hours per day. Machine operators were working longer due to the need for additional hours to perform machine maintenance and repairs (Lilley et al. 2002). About 80% of machine operators reported at least some fatigue at work and 20% reported a high level of fatigue. Smith et al. (1985) found that machine operations typical on southern U.S. logging were less physically stressful than manual or partially manual tasks.

A worker may reduce rest time to accomplish the entire daily household after the long shift. Over the length of the shift rotation, this sleep loss can accumulate and workers may feel overly tired during the last few days of the work schedule (Wednesday and Thursday). Timing of injuries indicates that fatigue was a factor in logging injuries (Bentley et al. 2005, Jarvis 2002, Ashby and Parker 2003). Increased fatigue was also associated with long periods of mentally demanding, repetitive, and sedentary machine operation work (Cummins 1998). Nicholls *et al*. (2004) found that logging equipment operators that rose early exhibited their circadian low with slower reaction times in mid-morning and this was identified as a safety concern.

Mechanization lowered the physical demands (Smith et al. 1985). Less physically fit operators may not be as able to focus on tasks during a long shift as fit ones and small deviations may have substantial effects on performance (Bohlin and Hultaker 2006). In logging truck drivers obesity and life style issues may contribute to fatigue and injury incidence (Mackie and Moore 2009).

Rest time and rest duration influence muscular pain, health problems, fatigue, and working errors, which are main causes of injuries and fatalities (Gallis 2006). Longer breaks allow the mind to relax from the mental pressures of machine operation. Breaks from machine operation can also help reduce illnesses associated with the lack of physical exercise in sedentary mechanized work, but the perception that extended breaks may reduce production limits adoption (Mitchell et al. 2008, Lilley et al. 2002).

1.3.3 Worker Activity

Worker activity is the activity the worker is doing when injury happened. Mechanization has played a major role in both a change in the occupation of logging workers and tasks performed (Laflamme and Cloutier 1988). The chainsaw has been replaced by machines like harvesters, feller-buncher, loaders and processors.

In non-mechanized logging systems felling and delimbing with chainsaw activities were associated with most of the injuries (Wolf and Dempsey 1978, Shaffer and Milburn 1999, Crowe 1986, Longwell and Lynch 1990, Roberts et al. 2005). In mechanized logging operations chainsaws still resulted in most of the injuries, followed by performing equipment maintenance and repair, operating a machine, mounting/dismounting a machine, and walking (Roberts et al. 2005). The most frequently injured workers were equipment operator, followed by deckhand, truck driver, and supervisor which demonstrated the different role of chainsaw operation in mechanized logging. Mechanized systems minimized felling and limbing tasks, but have not eliminated these hazards and injuries. Workers on mechanized logging operations in the South continue to be injured while operating a chainsaw, even on "fully mechanized" operations (Roberts et al. 2005, Shaffer and Milburn 1999).

The effect of mechanization is reflected in the tasks that result in injuries. For cutting processes, Laflamme and Cloutier (1988) indicated that the average individual risk on mechanized sites was almost 3 times lower than on conventional ones. Among equipment operators, machine maintenance or repair accounted for the highest percentage of injuries, followed by operating their machine, operating chainsaw, and mounting/dismounting machinery (Shaffer and Milburn 1999, Roberts et al. 2005).

Operating a machine was one of the least hazardous activities and injuries that occurred during machine operation were a small portion of total injuries, less than 15% in workers compensation reports (Shaffer and Milburn 1999, Roberts et al. 2005, Pine et al. 1994). Equipment operators are largely protected from major traumatic injuries when operating logging machine by engineering controls (Axelsson 1998). Laflamme and Cloutier (1988) indicated mechanization in the forestry sector effectively reduced exposure to accident risk during production activities.

1.3.4 Event or Exposure

The event or exposure describes the manner in which the injury or illness was produced or inflicted by the source of injury or illness. Commonly logging workers' whole bodies are exposed to hazards. In protected cabs, the frequency of many hazards are reduced, but similar hazards are present in mechanized and non-mechanized logging when operators completed other important tasks (e.g. maintenance) (Shaffer and Milburn 1999, Roberts et al. 2005, Pine et al. 1994). It is expected that struck by falling object are reduced in mechanized logging (Shaffer and Milburn 1999, Bell 2002) due to the protection of cabins, although it may be reflected mainly in injury rates rather than injury distribution.

Since machines are present in most types of logging, contact with equipment hazards could be similar. The main increase in hazard would be the opportunity for more ground workers (e.g. fellers, delimbers, buckers, and chasers) to be exposed to machine hazards. However, Shaffer and Milburn (1999) indicated that woods equipment accounted for a higher percentage of injuries in mechanized logging system than non-mechanized logging system. Struck by or run over by equipment and equipment rollovers were two of the three common causes of fatal injury (Jarvis 2002).

1.3.5 Part of Body Affected

The part of body identifies the part of body directly affected by the previously identified nature of injury or illness. Non-mechanized logging had more struck by falling objects injuries than mechanized logging, so there were more head injuries (Brodie and Ibrahim 2010, BLS 2012a). Those hazards resulting from falling logs, limbs, and trees are typical for workers on the ground, manually using a chainsaw to fell or delimb trees or working at the log loading areas (Shaffer and Milburn 1999).

1.4 Review of FRA Safety Alerts by Category

Forest Resources Association (FRA) published safety alerts related to logging and forestry aiming to promote, support, and serve as a catalyst for safe and professional work attitudes, practices, and conditions in timber harvesting and transportation. FRA safety alerts present the accident by examining aspect of the accident steps, using the domino theory (Schuster and Rhodes 1985) and recommendations for preventing similar accidents in the future. The summarized alerts could clearly be identified by the narrative as related to mechanized systems. Mechanized logging refers to felling, delimbing, and bucking trees using logging machines such as feller-bunchers and harvester and the use of grapple skidders rather than cable skidders. Chainsaw felling, limbing, and bucking and cable skidding incidents were excluded from the sample.

The most frequent exposure type in mechanized logging operations was contact with object or equipment (53%), followed by falls/slips/trips (18%) and exposure to harmful substances or environments (13%). Other types of events include transportation incidents (10%) and fires/explosions (6%). Contact with object or equipment injuries were classified as trees/logs falling (33%) and machinery (33%), parts and materials (16%), vehicles (16%) and tools/equipment/instruments (2%).

Falls/slips/trips hazards were associated with mounting/dismounting machines (30%), performing machine maintenance and repair (25%), operating machines (15%), and walking (15%). Another 15% of falls/slips/trips occurred while preparing loaded trucks for travel and removing covers and binders at the mill. Among transportation incidents, 6 out of 11 happened while driving a loaded log truck, 4 involved travel in light trucks with tools and passengers. The event distribution was similar to that described by Roberts *et al*. (2005).

The source of injury or illness identifies the object, substance, bodily motion, or exposure which directly produced or inflicted the previously identified injury or illness. For source of injury 111 of 113 alerts could be categorized. Machinery was the most common source of injury (23%), followed by trees/logs/limbs (persons/plants/animals) (22%) and parts/materials (21%). Vehicles accounted for 19% of all accidents and tools/instruments/equipment for 2%. Structures and surfaces accounted for 7% of all injuries. Other sources of injuries accounted for 6% of all injuries. The distribution was similar to mechanized logging described by Shaffer and Milburn (1999). Roberts et al. (2005) did not show the distributions of source of injuries in mechanized logging.

The nature of injury or illness identifies the principle physical characteristics of the injury or illness. For nature of injuries, 108 of 113 FRA safety alerts could be categorized. Traumatic injuries and disorders which could not be specified accounted for 28% of the 108 alerts and 22% were related to multiple traumatic injuries. Other common categories were burns/corrosion (13%) and cuts/lacerations/puncture (11%). Fractures (7%), strains and sprains (6%), bruises/contusions (6%), amputation (2%) and effects of environmental conditions (2%) were all less than 10% each. Electricity from power line contact (46%) was a common source of burn injuries and 38% of burns occurred with maintenance or repair activities. The remainders of burns were related to warming fires (15%). The low percentage of sprains and strains was unexpected but could be due to a lower likelihood that writers would develop safety alerts for injuries which were not perceived to be serious. Due to high percentages of unspecified traumatic injuries (28%) and multiple traumatic injuries (22%) in FRA safety alerts, the nature of injury was not quite comparable with Roberts *et al.* (2005), but showed evenly distributed nature of injuries.

1.5 Ergonomic Hazards

Mechanization has changed the ergonomic hazards for logging workers. For chainsaw operators and logging laborers ergonomic hazards involved the vibration from chainsaws, repetitive motion, lifting, and bending during varied manual tasks. While many of those hazards are present in mechanized logging, the exposure has shifted to ergonomic hazards involved in machine operation. With increasing mechanization, the logging worker's heavy job has changed into a physically light one. The machine operators complete their work by siting in an ergonomic comfortable cab and moving their hands, arms, and feet (Axelsson 1998). However, due to the long-hours but sedentary work, noise, vibration, repetitive movement of arms and hands (Vik 2004), and high degree of concentration on the job, mechanization could lead to ergonomic hazards such as RSI (Axelsson 1998). Jonsson *et al*. (1983) indicated the forestry equipment operators reported a high prevalence of musculoskeletal symptoms in neck, shoulders, and low back but no difference was found between operators of forwarders, harvesters, and processors in the prevalence and location of symptoms. Wikstrom and Eskilsson (1983) indicated that the level of vibration among forestry machinery operators varied greatly from one type of machine to another, with unloaded forwarders had the highest levels of vibration. Gerasimov and Sokolov (2009) indicated that visibility and work postures were two main factors that influenced the assignment of skidders as relatively uncomfortable working conditions. The best working conditions in terms of ergonomics and occupational safety were provided by harvesters and forwarders.

Musculoskeletal disorders (MSD) are among the most common occupational illnesses in the US (BLS 2012a). MSDs are injuries or pains that affect the muscles, nerves, tendons, and joints (Hagen et al. 1998). MSDs occur when the demands of the job exceed the capabilities of the person doing the job. The main risk factors include high forcefulness of exertion, awkward postures, vibration, fatigue, mechanical pressure, and psychosocial pressure (Axelsson and Ponten 1990, Synwoldt and Gellerstedt 2003).

Much of the research on MSDs in logging has been completed in Northern Europe. In the late 1970's in Sweden most operators surveyed (74%) had complaints of pain caused by machine operation (Kjellstrand 1981). In Norway machine operators were more likely than manual workers to have MSDs (Hagen et al. 1998). Some 50% of Swedish logging machine operators had symptoms of RSI (Cabecas 2007, Axelsson and Ponten 1990). Prevailing average overload syndrome, characterized by complaints and injuries to the neck, arms, and cervical spine, occurred among 50% of logging machine operators, mainly due to one-sided, repetitive movements of arms and hands (Axelsson and Ponten 1990). Complaints of neck and shoulder pain ranged from 27% to 60% of Swedish machine operators depending on age and experience (Axelsson 1995). European surveys suggest that as many as 15% of operators are diagnosed with a MSD and effects on job performance and absenteeism may expand to 25% of operators (Lewark 2005).

A survey showed Southeastern U.S. loggers were clearly exposed to ergonomic risk factors for the development of MSDs (Lynch et al. 2014). In Washington State the logging industry was among the highest claims numbers and rates for carpal tunnel syndrome (Franklin et al. 1991). But in the mid 1980's in Washington, many operations were motor-manual so the cases might be related to either manual work or equipment operation. The rate of MSD in logging in U.S. was less than 5% of the total reported logging injuries (BLS 2012b) and it is possible that MSDs are underreported (Ashby et al. 2001).

Some awkward postures, particularly twisting of the trunk, may increase the risk of back problems (Shan et al. 2013). Operation of controls requires repetitive movements of the hands, arms, and feet and can lead to strain injuries (Axelsson 1995, Jack and Oliver 2008). Addressing ergonomic challenges will involve a comprehensive mix equipment design and selection, training, and organization (Lewark 2005, Synwoldt and Gellerstedt 2003).

The effect of WBV on logging machine operator health is not completely understood but exposure has been related to a number of occupational illnesses including MSDs (Calvo 2009, Jack and Oliver 2008). WBV has a dose-response relationship to low back pain and disorders in forestry machine operators (Tiemessen et al. 2008). WBV may increase fatigue and add to operator discomfort (Rummer 1986).

WBV levels in logging equipment may exceed ISO standards (Neitzel and Yost 2002). Hand-arm and whole body vibration could also be a concern for equipment operators (Neitzel and Yost

2002). In Sweden machine operators reported vibration issues on about 11% of machines (Synwoldt and Gellerstedt 2003). Operators were subject to higher levels of vibration during specific activities and traversing rough terrain. Neck and arm pain increased due to vibration from rough operating conditions, but neck and arm pain among forestry machine operators was not related to WBV exposure (Rehn et al. 2009). Tree felling and processing and machine movement over the terrain did not increase WBV to levels that might produce health risks (Sherwin et al. 2004). The maintenance of logging machinery also involves ergonomic hazards. The ergonomic problems in the work environment could be exacerbated by cold in winter, the necessity of working barehanded, the risk of slipping and falling associated with climbing up to and working on machines, etc. (Vayrynen 1983a).

1.6 Occupational Illnesses

The mental demands of operating some logging machines are quite high (feller buncher and harvester), and most mechanized operations are fast paced. Exposures from longer shifts and psychological stress levels may affect chronic injuries and illnesses (Axelsson 1998, Hagen et al. 1998). An increasing level of psychological demands may lead to increased prevalence of low-back disorders among equipment operators (Hagen et al. 1998). Psychosocial stress may lead by job insecurity, high productivity demands and surges in workload (Mitchell et al. 2008, Kirk et al. 1997). Loggers are also exposed to temperature extremes, job stress, and high productivity demands (Axelsson 1995, Bentley et al. 2005).

Operator noise exposure varied greatly according to the type of machine and the qualities of the operator’s cabin (Neitzel and Yost 2002). Modern machines were likely to have better acoustic treatment and fewer maintenance issues (broken windows, missing doors) that reduced effectiveness. In Sweden machine operators reported noise issues on only about 17% of machines (Synwoldt and Gellerstedt 2003). In Brazil machines in good conditions had noise exposures below the threshold (Seixas and Rummer 1999). In the U.S. noise exposures in the cab of some modern machines exceeded the threshold. Machine operators who routinely used hearing protection had significantly less hearing loss than those who did not (Fonseca 2009). Cant (1977) revealed sound reduction could be obtained simply by providing routine maintenance.

1.7 Engineering controls

Engineering controls available in equipment and tools have been widely adopted. The most obvious being the protection offered in operators’ cabs. Simultaneously programs improved chainsaws (Axelsson 1998). Injury and illness incidence rates have generally declined due to the availability of reduced vibration saws (Axelsson 1995, Mirbod et al. 1992). Longitudinal studies showed little change in the reports of Vibration Induced White Finger (VWF) symptoms among fallers who had only used anti-vibration saws reporting over a 15 year period (51% versus 53%) (Brubaker et al. 1987). More recently Hand-arm Vibration (HAV) from chainsaw still exceeded recommended limits (Calvo 2009). There have been no assessments of HAVs among chainsaw operators in the U.S. Chainsaw noise levels could be reduced but the risk of hearing impairment remains and hearing protection is still an important issue (Axelsson 1998). Kickback hazards were reduced through front-handle guards and chain brakes.

Equipment design and features have improved over time. Mechanized felling machines specifically designed for steeper terrain increased the opportunities for mechanization (Milauskas and Wang 2006, Bell 2002). Other enhancements of operator protection in cabs include glazing standards for thrown object protection (Rummer et al. 2003) and ROPS designs for excavator based machines (Rummer et al. 2003). Modern equipment conforms to OSHA and in some cases ISO standards for operator protection (manufactured after 1994). In one case seatbelt redesign and installation of reminder lights increased the seatbelt use during operation (Sullman 1998).

Equipment redesign may also be effective for some struck by injuries through load securement and support (Struttmann and Scheerer 2001). Unbinding cages are widely used at mill to protect the workers during binding procedures. Additionally, to prevent logs from rolling off during the unbinding procedure, loggers should avoid loading above the standards (Struttmann and Scheerer 2001).

In a survey of Swedish forestry machine operators 15% reported ergonomic shortcomings with the seat and another 7% reported issues with controls (Synwoldt and Gellerstedt 2003). The most frequent (21%) issue was cab access. Multiple machine design parameters in forestry equipment contributed to health issues among machine operators (Grevsten and Sjogren 1996, Attebrant et al. 1997, Eklund et al. 1994). Changes in U.S. equipment design face significant cost issues related to the expense of machine redesign and the economics of new machine purchases.

1.8 PPE

Since feasible engineering controls are lacking for many hazards, use of PPE is important for injury avoidance and minimization. Recently the development of PPE focused on the ventilation of hard hats and better visibility of safety eye wear. Ventilated helmets increased comfort of wearers when using in hot and humid environments, but physiological measures were unchanged (Davis et al. 2001, Holland et al. 2002). Vayrynen (1983b) indicated the low utilization rate for eye protectors was partly explained by design defects: they would frost in winter, they would not have good visibility in rainy days and in the night, and they would cause glare in sunshine. Visors or face shields were a comfortable form of eye protection which could offer protection against splashes and were less likely to mist over than other forms of eye protection such as goggles (Vayrynen 1983b).

Adoption of PPE could be related to an assessment of alleviation of risk relative to the effect on job performance, personal comfort, or the perception that more careful work habits can reduce the need for PPE. Safety clothing added a weight burden to chainsaw operators that affected workload and added to heat stress (Wasterlund 1998). Research has not significantly addressed improvements to cut-resistant leg protection. Workers were less likely to voluntarily wear protective clothing that affected their performance (Cabecas 2007). The increased fatigue from wearing PPE might increase hazard exposure (Wasterlund 1998).

Among Italian motor-manual crews proper use of PPE was a common problem among all the crews observed (Montorselli et al. 2010). Survey or observational data that monitor PPE use among loggers in the U.S. is unavailable. In Pennsylvania only 17% of individuals admitted to trauma centers following logging accidents indicated they were wearing helmets (Johnson et al. 2002). Among Swedish loggers, safety helmets and ear protection were nearly universally adopted in 1980 (Klen and Vayrynen 1984). Helmets, boots, eye protector, and leg protection were the most common equipment responsible for avoiding injury in near misses (Klen and Vayrynen 1984). In New Zealand a substantial reduction in chainsaw injuries was related to the introduction of cut resistant legwear among other measures (Sullman et al. 1999). Seventy-one percent of loggers in Virginia indicated that they used PPE during work (Wightman and Shaffer 2000. Toppila et al. (2005) indicated the rate of adoption of hearing protective devices in forest workers were 97% by the 1990s. A survey of Virginia loggers who attended the sustainable harvesting and research professional program indicated that the most of them would buy chaps and wear PPEs when using chainsaw (Barrett et al. 2012).

1.9 Worker Training

Since additional engineering interventions are limited, hazard recognition and avoidance are primary interventions for many of the more serious and frequent hazards in logging. Off-site training for current logging workers has been offered since the late 1980’s (Clatterbuck and Hopper 1996, Reeb 1996). Formal training may affect hazard awareness, knowledge, and self-reported behavior (Helmkamp et al. 2004, Bell and Grushecky 2006). Wightman and Shaffer (2000) indicated that Virginia’s SHARP logger education and training program resulted in significant improvement in safety practices. When specifically studied the formal safety training programs effected self-reported behavior change and knowledge but had little influence on claims rates (Bell and Grushecky 2006, Neale and Dingus 1996).

In the U.S. formal logging training programs for new logging workers were nearly absent. Most workers develop skills through on-the-job training where workers learn by their mistakes or success. Given the capability of individual firms and trainers, the quality and content could vary considerably. In a small sample of southern logging crews none of the employees had any formal training (Bordas et al. 2001). They observed that logging employees had little understanding of standard job tasks. Even basic requirements like reading the operators manual were not addressed. Supervisors indicated that safety training material available was either difficult to relate to employees or of little utility. Logger have preferred hiring experienced workers over training new workers in part due to the difficulty of training and accommodating new workers (Reisinger et al. 1994).

1.10 Working Conditions

Increased shift length and multiple shifts in logging are responses to supply chain, economic, and environmental issues. Axelsson and Ponten (1990) revealed the organizational control of machine operation was the primary method to reduce ergonomic problems among machine operators. Those organizational controls like rest breaks and job rotation may be effective in reducing MSD’s (Hanse and Winkel 2008). In Sweden work organization changes to address ergonomic issues were difficult to implement and monitor (Synwoldt and Gellerstedt 2003).

Work related stress was another contributor to chronic injuries and illnesses and could result from time pressure and deadlines, productivity pressure, decision making, fatigue, long and monotonous machine operating work (Nieuwenhuis and Lyons 2002). Work stress was related a number of health conditions (Mitchell et al. 2008, Nieuwenhuis and Lyons 2002). Overexertion and fatigue may be related to the increasingly physically demanding tasks in the woods and the landing (Kirk and Sullman 2001). Deckhands in mechanized logging complete various physical tasks like chainsaw operation, machine maintenance, as well as operate equipment. Machine maintenance and repair requires physical effort (Golsse and Rickards 1990) and difficult working conditions. Hazards are greatest for those involved in the physical labor.

1.11 Health Factors

Obesity and life style issues may contribute to fatigue and injury incidence in equipment operators. Obesity can increase susceptibility to heat stress (Mackie and Moore 2009). People who weigh more have more mass, generating heat in their core and causing them to retain more heat (AFOP 2010). In addition, overweight operators tend to have less physically fit muscles and expend more energy during physical activity, creating more heat. Obesity is also a contributing factor to the development of MSDs because excess body weight can increase the burden on the musculoskeletal system (Wearing et al. 2006). The biggest risk for truck drivers may be obesity and associated health concerns (Mackie and Moore 2009).

Dehydration can hasten the onset of muscle fatigue and cause heat stroke (Wasterlund 1998). Among logging workers hydration may be a factor in mental and physical fatigue (Ashby and Parker 2003). Many loggers did not have breakfast but drank large amounts of coffee that caused them to dehydrate and had low energy before lunch time. This increased their risk of work-related injury and illness (Jarvis 2002).

1.12 Conclusion

There are just few examples of injury surveillance which differentiated logging system performance (Shaffer and Milburn 1999, Laflamme and Cloutier 1988, Pilkerton and Wimer 2008, Bell 2002, Roberts et al. 2005). The complexity of lowering injury rates and changing hazards makes it difficult to make precise conclusions about the role of mechanization in logging injuries and illnesses. Operator protection in cabs and the reduction in specific hazard exposures (e.g. chainsaws) should have the most significant effect. Advances in equipment and tool design, accompanied by a more professional workforce would be expected to reduce hazard exposures in both mechanized and non-mechanized systems.

A significant concern in mechanized logging is injuries and illnesses which may be linked to increased work hours, exposure to WBV, and repetitive motion hazards. Fatigue-related injuries are common to both mechanized logging and non-mechanized logging based on previous review and has been resistant to control efforts. Examples of issues to address in this area are design of length of the working shift and job rotation (Axelsson and Ponton 1990). Rest breaks and job rotation may be effective in reducing MSDs (Hanse and Winkel 2008).

Roberts *et al.* (2005) indicated that strain/sprains accounted for the highest percentage of injuries. So strains and sprains may become the most common injuries among mechanized logging workers in future. Since additional engineering interventions and adoption of PPE are limited, new work organization may be more important in reducing injuries. MSDs and chronic injuries and illnesses (e.g. hearing loss) are both difficult for surveillance to detect and to link to specific causes. In this regard it will require more specific surveillance efforts to determine in control measures are implemented and effective.

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Chapter 2: Logging Injury and Illness Rates for the Southern US from Workers Compensation Insurance Data

2.1 Introduction

With an estimated fatality rate of 62.7 per 1,000 workers, it is well documented that logging is one of the most hazardous occupations in the world (Leigh 1987, Fosbroke et al. 1997, Myers et al. 1998, Fischer et al. 2005). Nonfatal injury rates are also high, even though nonfatal injuries rates declined since logging tasks have become increasingly more mechanized (Sygnatur 1998, Bell 2002, Bell and Helmkamp 2003).

Logging injuries are often traumatic and result in disabilities, fatalities, and lost days from work. Injuries and illnesses resulting from exposures and accidents cost the logging industry billions of dollars each year (Pine et al. 1994, Leigh et al. 2004, Roberts et al. 2005). Those injuries and illnesses can impose loss of wages and personal grief for employees and impose significant financial burdens on employers. In West Virginia there were 1371 claims for the period 1996-2001 and the total cost of injuries was over $14 million, over $10,000 per claim and 2.3 million per year (Mujuru et al. 2006). Surveillance data should provide detailed and accurate logging injury and illness rates which may help to develop education based interventions for both state and regionally based logger training programs (Bell and Helmkamp 2003). State-level programs are effective since harvesting techniques, procedures and equipment applications can differ regionally due to different tree species and terrain variation (Bell and Helmkamp 2003).

The inadequacy of injury and illness surveillance data for the logging industry has been noted by the National Academies Review (National Academy 2008) and the National Occupational Research Agenda (NORA) objectives (NIOSH 2008). The Survey of Occupational Injuries and Illnesses (SOII) is the nation's largest occupational injuries and illnesses surveillance system and it provides national statistics for overall injury rates for logging. However the sampling frame for SOII is an issue for logging since over 80% of employers in North American Industry Classification System (NAICS) 1133 have less than 10 employees and would not be included in the sampling frame (BLS 2012). Additionally employers and subcontractors which provide from 30% to 50% of all logging labor are excluded. Only 9 states (AR, LA, ME, MT, OR, SC, VA, WA and WV) sample enough logging or forestry employers to report an annual estimate for NAICS 113 and only 3 states reported estimates for NAICS 1133. The SOII estimates are certainly biased by occupation and firm size and may be biased by regional contribution to the data. Ninety percentage of the SOII respondents interviewed from the state of Washington failed to comply with one or more of the required components through either a disregard for or a misunderstanding of the OSHA recordkeeping regulations (Wuellner and Bonauto 2014).

Logging safety and health specialists have used state and regional workers compensation data as a replacement for, or supplement to, SOII and Census of Fatal Occupational Injuries (CFOI) data. A National Academy of Social Insurance annual report states that workers' compensation insurance (WCI) covered more than 131 million U.S. workers at a total cost of $85 billion to employers in 2007 (NIOSH 2009). The participation threshold is more inclusive than SOII since nearly all logging firms are required to carry workers compensation insurance due to state regulations or contract requirements. Most WCI data analysis has been focused at the state level since monopolistic programs have been able to share data with local researchers. WCI data may identify injury and illness cases that are not captured by the BLS surveys (SOII and CFOI) because those cases are outside the scope or may be cases which are difficult to identify as work related.

Although SOII data indicate a general decline in injury rates, there may be regional differences in trends which could be indicated by an analysis of WCI data. Across the southern U.S., there have been regional analyses of WCI data and 2 studies from Louisiana data. In Louisiana, claims rate declined from 19.98 claims per 100 full-time workers in 1987 to 13.71 claims in 1990 (Pine et al. 1994). From 1991 to 1996 there was no significant linear trend in overall injury rates in Louisiana (Lefort et al. 2003). Roberts and Shaffer (2005) indicated that Total Case Incident Rate (TCIR) for mechanized logging operations in the South fell from 10 in 1996 to 4.9 in 2003.

Coverage of the Western US was limited to data from Colorado (Longwell and Lynch 1990), Washington and Oregon (Pilkerton and Wimer 2008). While most of western logging employment is in Washington and Oregon, logging conditions likely vary across the Great Basin and Rocky Mountains. In Colorado there was no significant difference in injury rates from 1984 to 1987, but there were significantly fewer accidents in 1988 (Longwell and Lynch 1990). In Oregon, the TCIR for mechanized logging operations in 2007 were 60% of the previous 4-year average (2003-2006) and showed a decreasing trend from 2004 to 2007. In the east and northeast

US, only West Virginia claims data were analyzed; The injury rates (16.0 per 100 workers) remained relatively steady from 1995 to 2001 (Bell and Helmkamp 2003). There was no significant decline in total injury rates related to an 8-year safety training intervention (VBSTI) from 1999 to 2007 (Mujuru et al. 2009). Bell (2002) used WCI data to calculate injury rates for the entire WV logging industry from 1995 to 2000 and found that there was a significant increase in the injury rate over this time period. Previously Wolf and Dempsey (1978) summarized claims data in Appalachia from 1971-1974 but did not provide claims rates.

The most recent WCI data indicate that motor-manual, steep terrain logging systems had injury rates about 3 times higher than mechanized systems across the U.S. South and Oregon. International data also reflected regional differences which could be attributed to terrain and working conditions. Klun and Medved (2007) compared fatal accidents occurring in forestry applications in some European countries from 1980 to 2004. Switzerland, Austria and Sweden all had fatality rates (fatalities per million cubic meters) that declined during this period, while rates for Slovenia were stable during this period.

The objective of this study is to develop logging surveillance data from NCCI claims data for the U.S. South. The study compared injury rates to previous WCI claims analysis and contemporary surveillance from SOII and CFOI. I also explored whether state or sub-region analysis could identify factors related to differences in hazard exposure from harvesting systems, terrain, and employment factors.

2.2 Methods

Workers Compensation Insurance (WCI) coverage is a state-mandated insurance program which covers lost wages and medical treatment resulting from an employee's work-related injury or illness. It pays medical expenses resulting from occupational injuries and illnesses and partially replaces workers' lost wages (NIOSH 2009). Workers' compensation claims refer to injuries or illnesses which workers suffered at the work site and were reported to workers compensation insurance providers. The claims data for this study were purchased from the National Council on Compensation Insurance (NCCI) in 2013. NCCI is a U.S. insurance rating and data collection bureau specializing in workers' compensation. NCCI annually collects data covering more than four million workers compensation claims and two million policies. NCCI also produces the Scopes Manual, which details how classification codes are assigned to various kinds of employment.

NCCI supplied data for the logging industry based on eight corresponding codes (2701, 2702, 2705, 2706, 2709, 2719, 2725, and 2727) for twelve states (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN and VA) for 2005 to 2009. Six injury types were included in the classification experience data including fatal, permanent total disability, permanent partial disability, temporary total, temporary partial disability and medical-only claims. Severe claims are the sum of fatal, permanent total disability, and permanent partial disability. I used the developed claims count to calculate injury rates. Developed claims are the estimated ultimate number of claims derived by adjusting the number of incurred claims by development factors.

State employment data were aggregated for the logging industry (the 2002 North American Industry Classification System 1133) from the Quarterly Census of Employment and Wages (QCEW) (BLS 2013). For example, the series identification of ENU01000X051133 corresponding to 01000 is the state code for Alabama, including years from 2002 to 2012; X05 is the code for different types of data: 105 is the code for number of employees for each year, and 505 is for annual pay. NAICS code 1133 is the four digit code for logging. Data for total employment and annual wage were developed for all the states listed for 2005 to 2009.

Annual pay from QCEW was collected from January to December for each year. To compare the data I chose the claims data in the dominant year for the sample of employment. For example, the number of claims in Alabama was from May 2009 to April 2010, so the 2009 annual pay corresponded to the 2009-10 claims.

For three years in the period I was able to relate harvest from Timber Product Output (TPO) data (USDA 2009) to claims information. We collected TPO data from the official website of Southern Research Station (SRS) Forest Inventory and Analysis (FIA) Research Work Unit which collects, analyzes and reports on data pertaining to forest land in the southern region. I chose SRS TPO reports and included all counties for each of the 12 selected states for 2005, 2007 and 2009. Linear interpolations were used for TPO data in 2006 and 2008. The proportion of hardwood saw-log to roundwood volumes was developed and used as an indicator for the relative importance of systems to harvest hardwood logs.

Non-employer participation in forestry and logging (NAICS 113) was used as an indicator for non-participation in workers compensation. The forestry and logging subsector consists of three industry groups: timber tract operations (NAICS 1131), forest nurseries and gathering of forest products (NAICS 1132), and logging (NAICS 1133). I assumed that non-employer data for NAICS 113 was mostly logging. The 2009 annual average employment was 59500 for NAICS 113 and 52500 for NAICS 1133, or about 90% of total employment in NAICS 113 was in NAICS 1133 (logging). The data was collected from the United States Census Bureau. Non-employer statistics (USCB 2014) is an annual series that provides subnational economic data for businesses that have no paid employees and are subject to federal income tax.

Injury claims were considered to have a Poisson distribution (Bell and Grushecky 2006, Mujuru et al. 2009). Poisson regression (SAS v. 9.4 2014) was used to assess injury rate trends from 2005 to 2009 for each of these 12 states. Bartlett's test and Modified Levene's test for equal variances were used to assess homogeneity of injury rate variance between these 12 states. Since the injury rates were measured annually, the measurements for the same state or region were correlated. Thus it was not appropriate to fit a regression model assuming independence. Statistical models for repeated measures were built to assess whether the injury rate trends were the same for the 12 states, divided into five different regions. Coastal Plain: AL, FL, MS, and LA; Mid-Atlantic: NC, SC, and VA; Ouachita Highland: OK, and AR; Interior Highlands: TN and KY; and GA.

I used the attributes of harvest data, physiographic region, presence of hurricane salvage activity, and ratio of non-employers to employees to explore the relationships among general hazard exposure and injury rates. Because “year” was not included as a parameter, correlation of the data could be ignored and the general linear models were appropriate for use to assess whether these attributes had an impact on the injury rate for each state or region. Stepwise regressions were used to select suitable subsets of explanatory variables.

2.3 Results

The denominator for injury rates was estimated by dividing total exposure from NCCI data by the annual wage from QCEW. Figure 2.1 shows the number of total employees (BLS) in the 12 states from 2005 to 2009. There was no record for TN in 2008. Employment declined from about 32000 in 2005 to 25000 in 2009. Oklahoma had the fewest employees and Georgia had the largest number of employees. Ideally NCCI data would have included all logging employees in each state but the number of employees estimated by dividing exposure by average annual wage was considerably lower than QCEW data (Figure 2.2). For example in AL in 2005, the number of employees is 1944 from NCCI and 4918 from BLS. For several states the majority of employees were not covered by systems that report to NCCI, (e.g. self-insured funds) or maybe covered by different codes. The denominator developed from exposure divided by QCEW annual pay was used for the claims rate.

Injury rates were calculated with number of workers’ compensation injury claims in the numerator and number of employees in the denominator, extrapolated to 100 workers per year (Bell and Helmkamp 2003).

$$Injury\ Rate = \frac{number\ of\ injury\ claims}{number\ of\ reported\ employees} \times 100$$

Fatality rates were calculated with number of workers' compensation fatal injury claims in the numerator and estimated number of employees in the denominator, extrapolated to 100,000 workers per year. Since several states had no fatal claims for one or more years an average fatality rate for each state was developed.

Inspection of injury rate showed that the estimate for Georgia was nearly twice that of similar states (Figure 2.3). The discrepancy was likely caused by the upset payroll factor which converted the production units into labor cost. The ratio of manual premium to exposure for Georgia for the whole period shows that premiums were likely adjusted higher to account for the underestimation of exposure or actual payroll. Before 1950, some loggers in US were paid by ton based on delivery to the mill and few payroll records were kept, so NCCI filed "Upset Payroll" to use when actual payroll records were unavailable. Georgia was removed from study of regional claims rate trend but will be analyzed for further analysis state level attributes on claims rates.

Table 2.1 shows all class codes and corresponding descriptions for WCI data from NCCI for the 12 southern states from 2005 to 2009. In addition total payrolls for each code are shown in the table (sum of annual for 2005 to 2009). There are three main class codes 2701, 2702, and 2719: 2701 and 2702 were used in most of the 12 selected states and had the highest total payroll (2702 has the highest total payroll). Separating mechanical from non-mechanical logging is complex since states use a different combination of codes.

Figure 2.4 to Figure 2.7 show the total claims rates by region and SOII recordable injury rate. During the 5-year period, there were 4519 WC claims reported in all regions. Since logging claims rates were considered to have a Poisson distribution, claims rate trends were assessed accordingly for these 11 states (except GA). The model is

$$Injury\ Rate = \beta 0 + \beta 1 State + \beta 2 Year + \beta 3 State * Year$$

The model results are presented in Table 2.2. None of the estimated slopes was statistically significant. The SOII data is included as a reference in the Figures 2.4-2.7. SOII recordable injury rates were lower than most claim rates and SOII appeared to decline during those five years. Nestoriak and Pierce (2009) showed that SOII substantially undercounts both recordable and lost time injury claims.

Bartlett's test and Modified Levene's test were used to determine whether there was a difference in claims rates among those 12 states. The results of means for dependent variable injury rate showed that the P-values of both Levene's HoV test and Bartlett's HoV test were smaller than 0.05, which indicated that the means of claims rates were not equal (Table 2.3). Significant p-value(s) indicated the variances were unequal and the state injury rates were different.

To determine if regional trends were present the following claims rate model was developed (excluding GA):

$$Injury\ Rate = \beta 0 + \beta 1 Region + \beta 2 Year + \beta 3 Year \times Region$$

I assumed that variables from different regions were independent and variables from the same region of different years were correlated. Only region IH had a significant parameter estimate for Region and a significant estimate for slope.

Figure 2.8 showed the average annual fatality rate for each state and CFOI data from 2005 to 2009. Fatal injury rates in most of the states were below CFOI rates for the U.S. for the time period. Oklahoma, Kentucky and Tennessee had higher fatality rates than the other states. CFOI fatality rates from the logging industry (NAICS 1133) remained almost stable at around 90 from 2005 to 2008 and declined to 50 in 2009. Since CFOI is national data, the fatality rate included regions which could have a higher fatal injury rate than the southern U.S. (Scott 2004, Myers and Fosbroke 1994).

To examine the influence of state level attributes on injury rates I developed a regression model on total and severe injury rates (fatality and permanent, disability). The dependent variable was claims rate. The independent variables included the ratio of hardwood saw-log volume to total volume for each state (Phwsaw), physiographic region (Region), presence of hurricane salvage activity (Hurricane) and ratio of number of non-employers to employees (Nonemp). The Historical Hurricane Tracks (HHT 2014) website identified hurricane salvage activities for MS and LA in 2005 and 2006. The claims rate in MS in 2005 was slightly higher than in other years. The severe claims rate in LA and MS in 2005 were much higher than in other years. The model is

$$Injury\ Rate = \beta 0 + \beta 1 Phwsaw + \beta 2 Nonemp + \beta 3 Hurricane + \beta 4 Region$$

The ANOVA tables for these models are presented in Table 2.5. For all claims model, the results of the stepwise regression resulted in a highly significant model ($P< 0.0001$). Five dependent variables were significant, Phwsaw ($P=0.0028$), Region CP ($p < 0.0001$), Region MA ($p <0.0001$), Region OH ($P < 0.0001$), and Region IH ($P = 0.0001$) (Table 2.6). The function of all claims stepwise model is in Table 2.6. $\text{Claims Rate} = 10.53 + 10.60 * \text{Phwsaw} - 5.52 * \text{RegionCP} - 7.41 * \text{RegionMA} - 7.46 * \text{RegionOH} - 8.14 * \text{RegionIH}$.

The ratio of hardwood saw-log to total volume had a positive effect on claims rate. Myers and Fosbroke (1994) indicated regions where the primary type of logging produced hardwood saw-logs had the highest fatality rates compared to other regions.

Figure 2.9 shows the relationship between claims rate and ratio of hardwood saw-log to total volume. The relationship to Phwsaw was related to region IH (TN and KY). So I did another stepwise regression without data in region IH and the results showed RegionCP ($p<0.0001$), RegionMA ($p<0.0001$), and RegionOH ($p<0.0001$) were left in the model and Phwsaw was removed. The model is $Claims\ Rate = 11.024 - 5.479 RegionCP - 6.48 RegionMA - 7.065 RegionOH$ (Table 2.6). TN and KY, which belong to East in Myers and Fosbroke's (1994) research, had much higher ratio of hardwood saw-log than other states (most belong to South, OK belongs to Plains) and had higher claims rate than most of the other states.

Similarly, the p value for fitted function of severe claims full model is less than 0.0001, which means the model was significant and there was a linear association between severe injury rates and the predictors. But only the p value ($P = 0.0004$) for Nonemp was statistically significant. The results of a stepwise regression showed only Nonemp ($p < 0.0001$) remained in the model significant at the 0.05 level. The function of severe claims stepwise model is $Severe\ Claims\ Rate = 378.166 + 176.641 Nonemp$ ($R2 = 0.63$) (Table 2.6).

Figure 2.10 shows the relationship between severe claims rate and ratio of non-employers to all employees for four regions. For this model Nonemp might replace region since the principle difference was present in IH.

2.4 Discussion

For logging injury surveillance this NCCI data does not provide a significant improvement over SOII data. The denominator data in the claims rate is subject to error possibly similar to the issues with GA data (Figure 2.2). For several states the majority of employees were not covered by systems that report to NCCI (e.g. self-insured funds) or maybe covered by different codes.

SOII data was also inadequate to describe injury situations in the Southern U.S. due to variability among states which is not accessible from SOII estimates. NCCI data showed there were differences in claims rate trend among these states. CFOI also lacks details at state level and may not accurately assess injury situations in Southern U.S. Fatal claims rates in most of the 12 states were lower than CFOI rate except OK, KY, and TN. The second issue for CFOI data is it includes regions which could have a higher fatal injury rate than the Southern U.S. Scott (2004) indicated that from 1992-2000 there was a higher percentage of fatalities in the Northeast and the Midwest compared with the South and West regions.

At state level the analysis indicated that claims rates from 2005 to 2009 in 12 southern states were different. At the regional scale both the correlation regression and state level attribute regression indicated claims rates in four regions were different. Hardwood saw-log volume could be an indicator of non-mechanized logging which is more commonly used to harvest hardwood sawtimber in steep terrain. Fatality rates in regions where the primary type of logging was hardwood saw-log were the highest compared with other regions (Myers and Fosbroke 1994). Terrain and factors such as the shape of the trees to be cut may increase the risk for logging injuries in hardwood logging operations (Peters 1991).

Timber salvage operations resulting from hurricane damage require more motor-manual systems than are usually active in normal situations. As a result a large number of less experienced workers operate in a more hazardous environment (Sullman and Kirk 2001). The claims rate in MS in 2005 and 2006 were slightly higher than in other years. Inability to detect differences could be related to timing of salvage activities relative to claims years and small sample sizes.

2.5 Conclusion

SOII and CFOI were inadequate to describe injury situations in the Southern U.S. due to the variability among states. For logging injury surveillance this WCI data does not provide a significant improvement over SOII data due to the uncovered number of employees by systems that report to WCI or maybe covered by different codes.

At state level from 2005 to 2009, claims rate in these 12 Southern states were different. At regional scale the claims rates in four regions were different and Kentucky and Tennessee (Interior Highlands) had significantly different claims rates from other three regions.

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Table 2.1. Class codes, descriptions and payroll from NCCI data for the 12 southern states from 2005-2009.

Class code	Description	States	Total payroll ($/5 Year million)
2701	Log hauling &drivers	AL, AR,GA,KY,LA,MS,OK,SC,TN,VA	111.7
2702	Non mechanized logging	AL,AR,FL,GA,KY,LA,MS,NC,OK,SC,VA	1028.9
2705	Pulpwood Harvesting	GA,LA,MS,NC,TN	50.2
2706	Logging	NC	222.3
2709	Mechanized Logging	AL,GA,NC,OK,SC,TN	208.1
2719	Mechanized logging	AR,KY,LA,MS	696.7
2725	Mechanized logging	VA	51.9
2727	Log hauling	NC	98.7

Table 2.2. Parameter slope estimates and intercept for poisson regression for claims rates in 11 states (except GA). State VA is included in the intercept value and year.

Parameter		DF	Estimate	Standard Error	Pr > ChiSq
Intercept		1	1.8305	0.4412	<.0001
state	AL	1	-0.1408	0.6474	0.8278
state	AR	1	0.038	0.6228	0.9513
state	FL	1	0.2079	0.5997	0.7289
state	KT	1	0.9956	0.5394	0.0649
state	LA	1	-0.175	0.6213	0.7782
state	MS	1	0.288	0.6129	0.6385
state	NC	1	-0.3781	0.7005	0.5893
state	OK	1	-0.9495	0.7895	0.2291
state	SC	1	0.1573	0.6821	0.8176
state	TN	1	0.0958	0.5983	0.8727
year		1	-0.052	0.1369	0.7044
year*state	AL	1	-0.0009	0.201	0.9966
year*state	AR	1	-0.0162	0.1942	0.9337
year*state	FL	1	-0.0224	0.1872	0.9048
year*state	KT	1	-0.1556	0.173	0.3686
year*state	LA	1	0.1008	0.1878	0.5912
year*state	MS	1	-0.1145	0.1968	0.5607
year*state	NC	1	-0.0217	0.2191	0.9213
year*state	OK	1	0.0841	0.2375	0.7232
year*state	SC	1	-0.1138	0.2459	0.6436
year*state	TN	1	0.0489	0.1886	0.7952

Table 2.3. Model statistics for regressions of state and claims rates. Levene's test is for homogeneity of claims rate variance. Bartlett's test is for homogeneity of claims rate variance. The dependent variable for ANOVA is claims rate and independent variable is state.

	Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Levene's Test	State	11	492.1	44.7389	7.37	<.0001
	Error	46	279.4	6.0732		
Bartlett's Test	Source	DF	Chi-Square	Pr>ChiSq		
	State	11	31.9052	0.0008		
F Test for Variance	Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
	Model	11	299.089	27.19	11.54	<.0001
	Error	46	108.388	2.356		
	Corrected Total	57	407.478			

Table 2.4 Parameter estimates and P values for regression of regional trends. Region OH is included in the intercept value and year.

Effect	Region	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept		4.2988	1.1145	7	3.86	0.0062
region	IH	6.7809	1.5778	7	4.3	0.0036
region	CP	2.264	1.365	7	1.66	0.1412
region	MA	1.3409	1.453	7	0.92	0.3868
year		-0.1133	0.2868	38	-0.4	0.695
year*region	IH	-0.8929	0.4121	38	-2.17	0.0366
year*region	CP	-0.226	0.3513	38	-0.64	0.5239
year*region	MA	-0.267	0.3839	38	-0.7	0.4911

Table 2.5. ANOVA tables for all claims and severe claims full regression and stepwise regression.

Analysis of Variance						
Model	**Source**	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr>F**
All claims (Full)	Model	7	275.517	39.360	14.91	<0.0001
	Error	50	131.961	2.639		
	Corrected Total	57	407.478			
All claims (Stepwise)	Model	5	273.436	54.687	21.22	<0.0001
	Error	52	134.042	2.578		
	Corrected Total	57	407.478			
Severe claims (Full)	Model	7	43594842	6227835	14.12	<0.0001
	Error	50	22056901	441138		
	Corrected Total	57	65651743			
Severe claims (Stepwise)	Model	1	41681553	41681553	97.38	<0.0001
	Error	56	23970190	428039		
	Corrected Total	57	65651743			

Table 2.6. Parameter estimates from stepwise selection for all claims and severe claims.

Model	Variable	Parameter Estimate	Standard Error	F Value	Pr > F
All Claims	Intercept	10.5325	0.73489	205.41	<.0001
(Stepwise)	Phwsw	10.5955	3.37562	9.85	0.0028
	CP	-5.5168	0.80286	47.22	<.0001
	MA	-7.4054	0.88685	69.73	<.0001
	OH	-7.4557	0.88815	70.47	<.0001
	IH	-8.139	1.93719	17.65	0.0001
All Claims without Region IH	Intercept	11.024	0.59173	347.08	<.0001
(Stepwise)	CP	-5.4792	0.66157	68.59	<.0001
	MA	-6.4804	0.68934	88.38	<.0001
	OH	-7.0651	0.72472	95.04	<.0001
Severe Claims (Stepwise)	Intercept	378.166	98.757	14.66	0.0003
	Nonemp	176.641	17.9004	97.38	<.0001

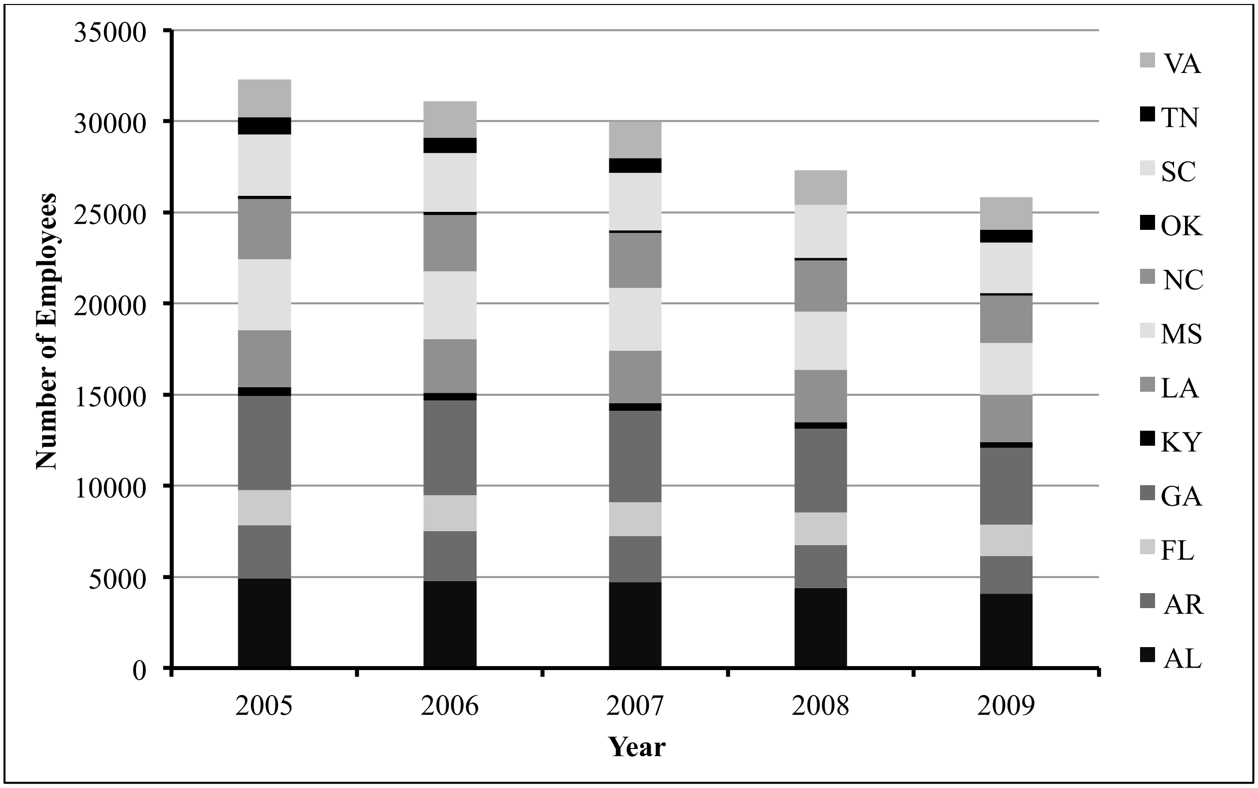

Figure 2.1. Number of total employees from BLS for the 12 states logging industry (NAICS 1133), 2005-2009.

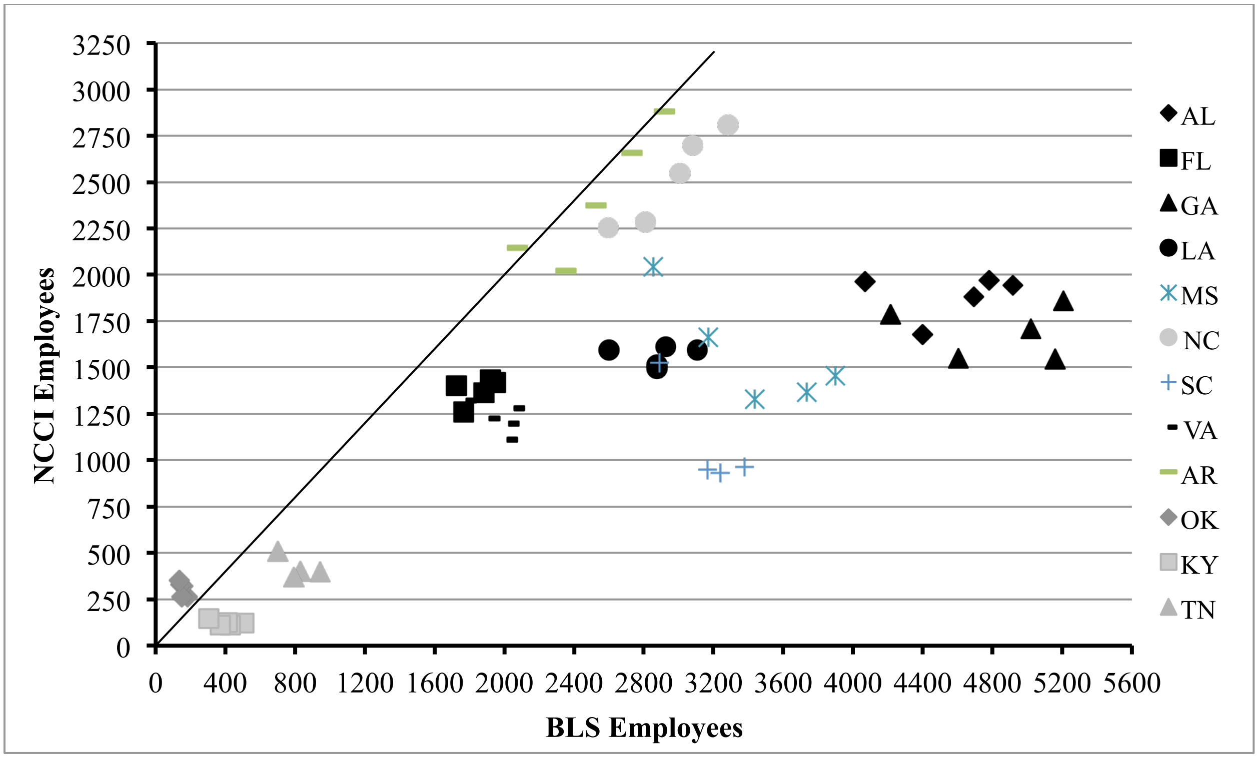

Figure 2.2. Comparison of employment estimates from NCCI (exposure/QCEW annual wage) to BLS employment. Data points are annual estimates for the states in the region. The line is for ratio of 1.

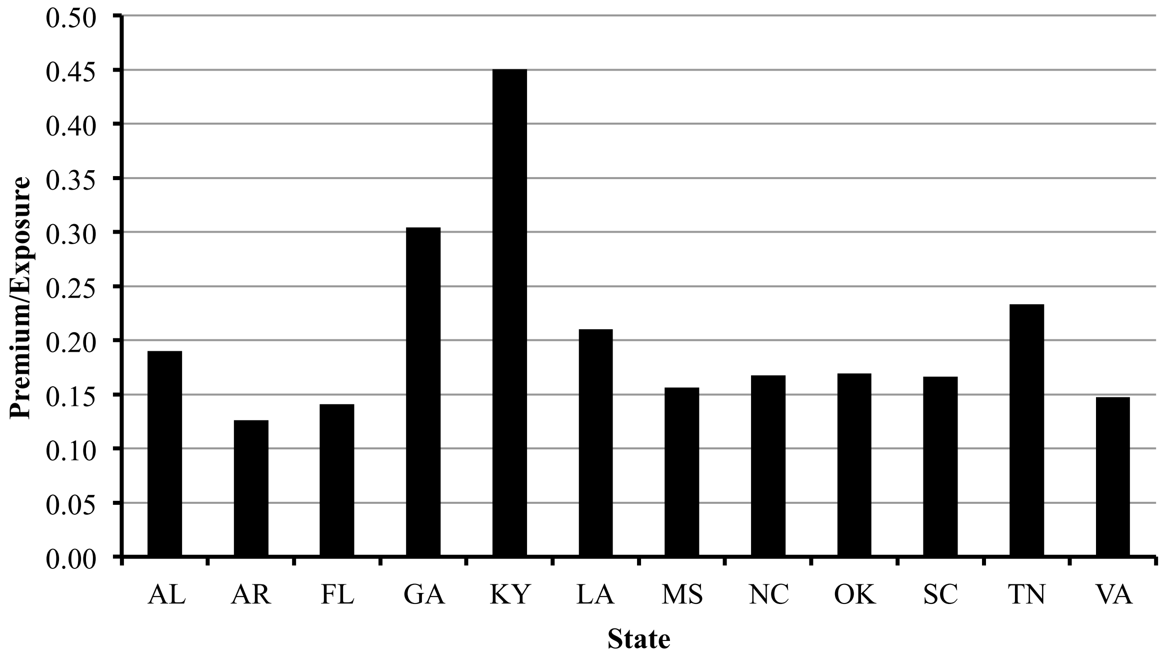

Figure 2.3. Ratio of manual premium to exposure for the whole period.

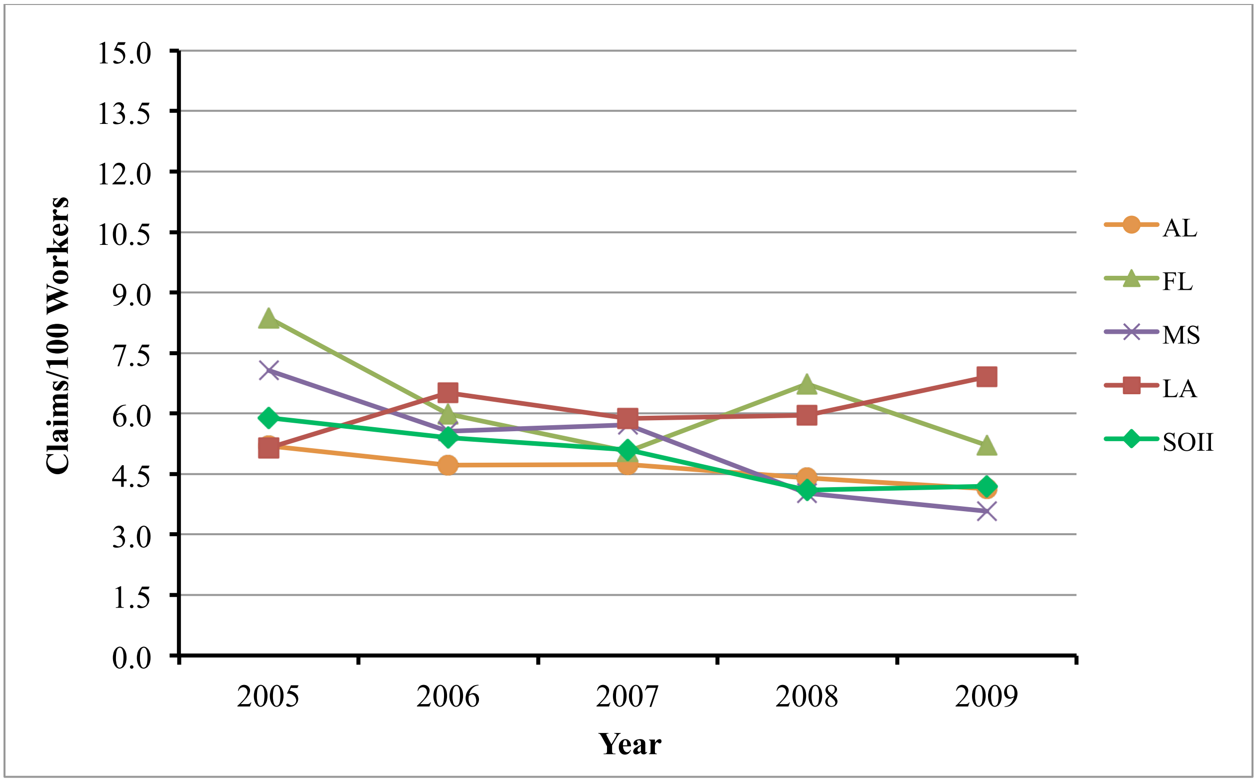

Figure 2.4. Claims rate of logging codes in the Coastal Plain (Region CP) and SOII injury rate (NAICS 1133), 2005-2009.

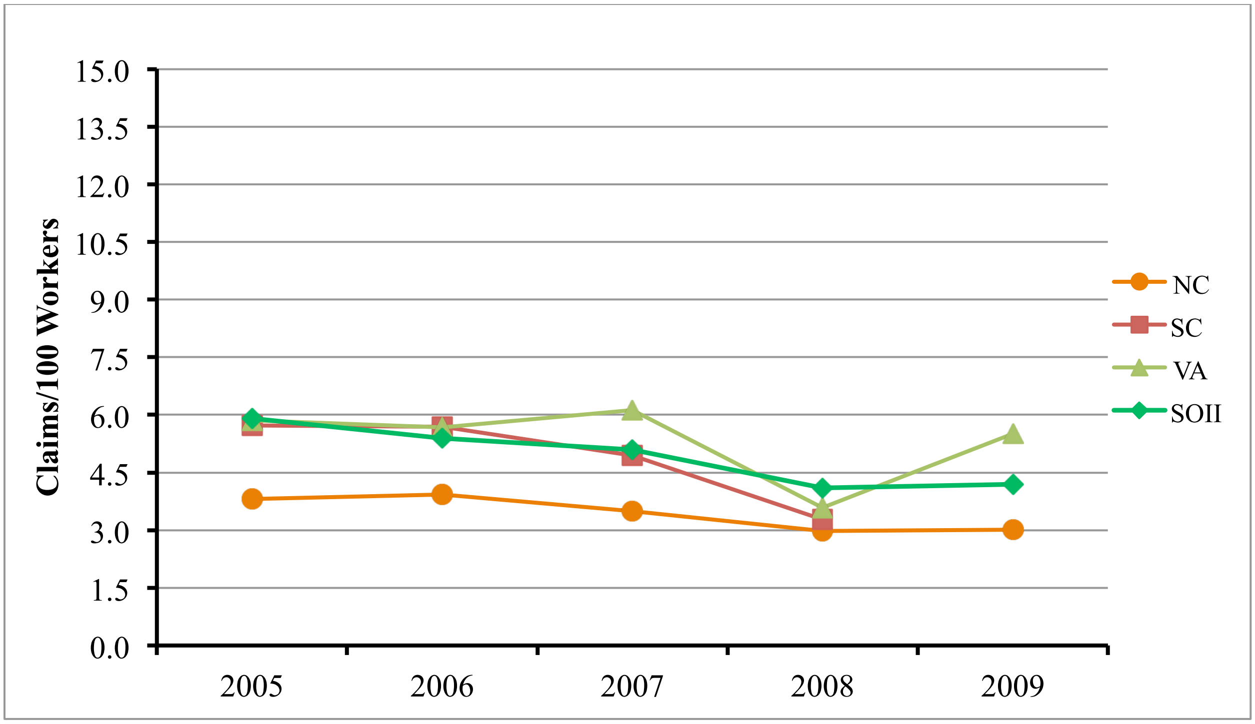

Figure 2.5. Claims rate of logging codes in the Mid Atlantic (Region MA) and SOII injury rate (NAICS 1133), 2005-2009.

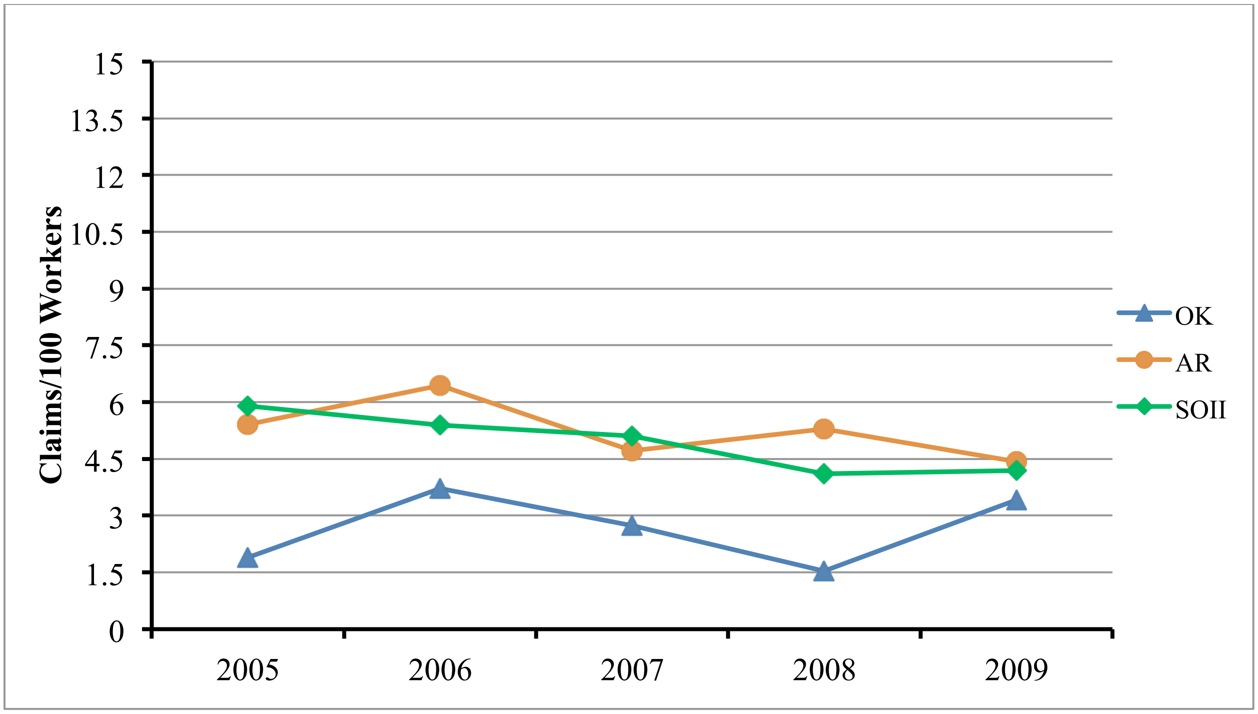

Figure 2.6. Claims rate of logging codes in the Ouachita Highland (Region OH) and SOII injury rate (NAICS 1133), 2005-2009.

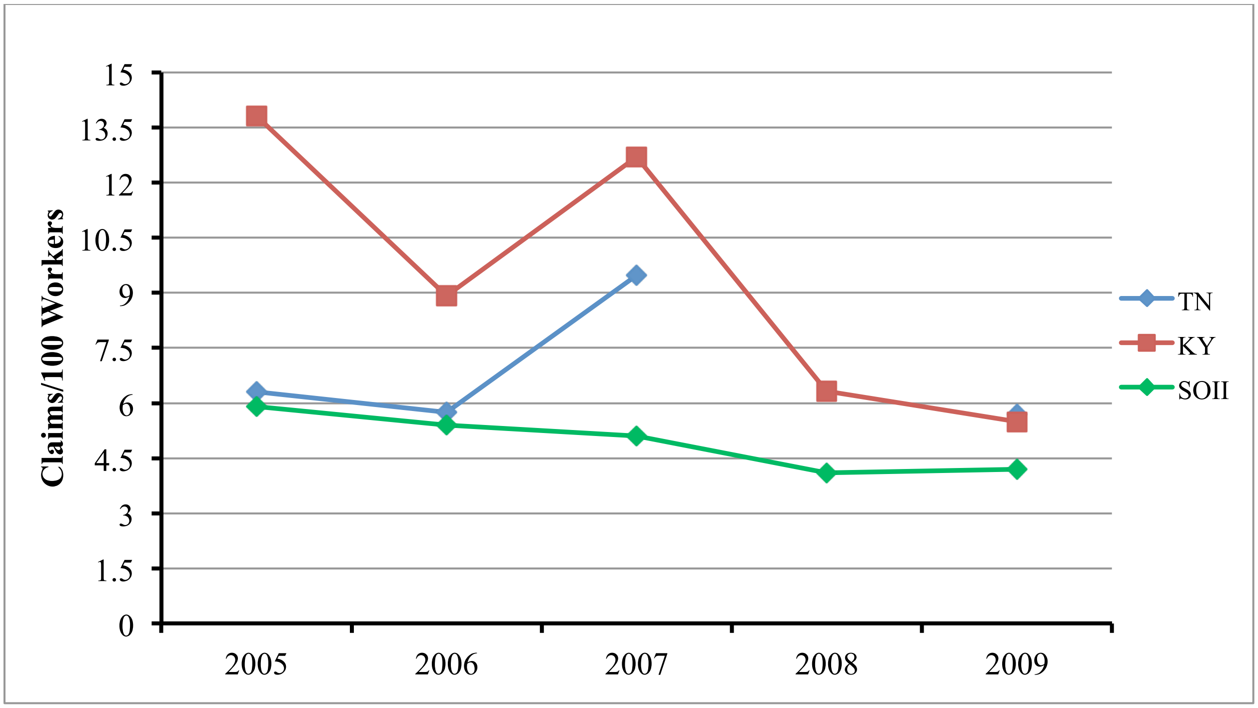

Figure 2.7. Claims rate of logging codes in the Interior Highlands (Region IH) and SOII injury rate (NAICS 1133), 2005-2009.

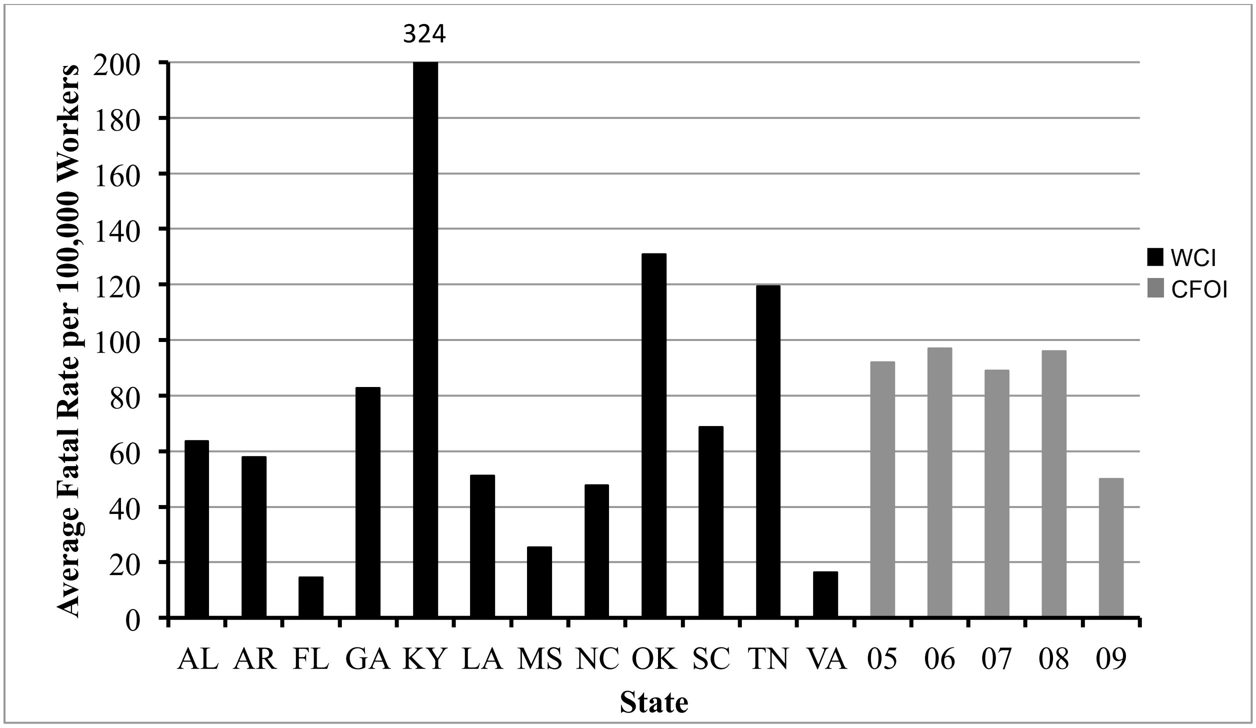

Figure 2.8. Average annual fatal claims rates for the 12 states logging codes and CFOI data from 2005-2009 for NAICS 1133.

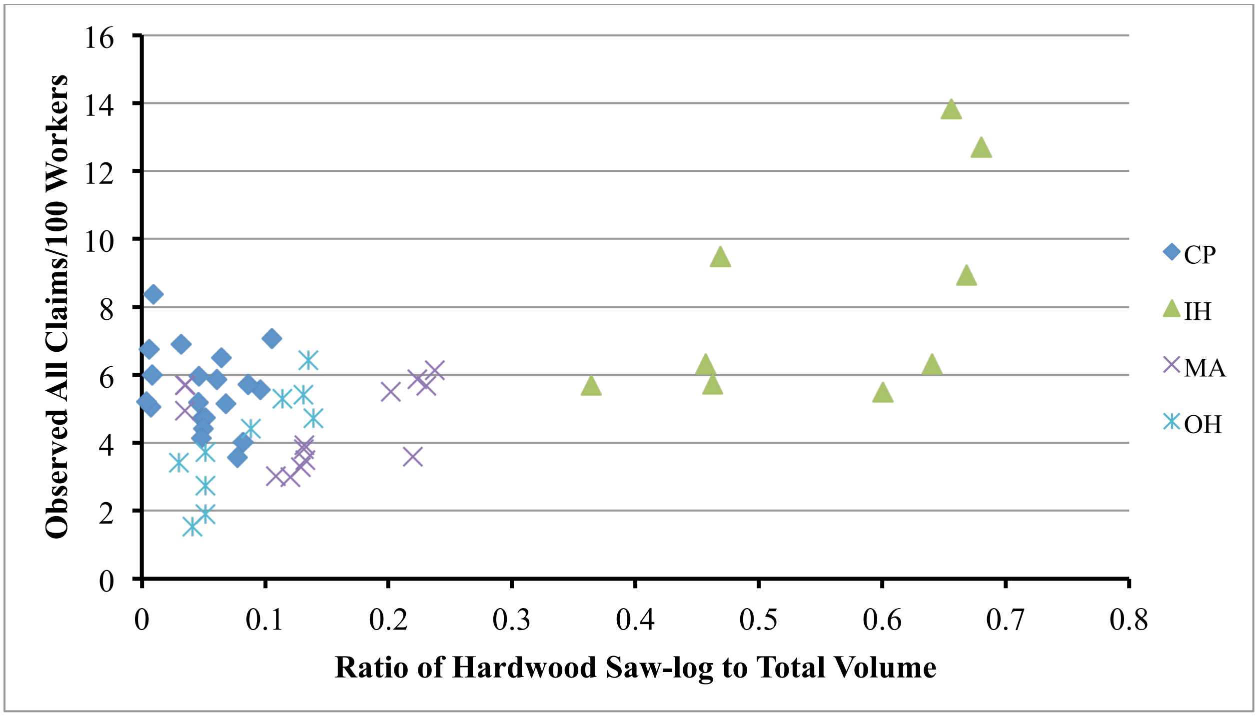

Figure 2.9. Relationship between observed claims rate and ratio of hardwood saw-log to total volume in four regions.

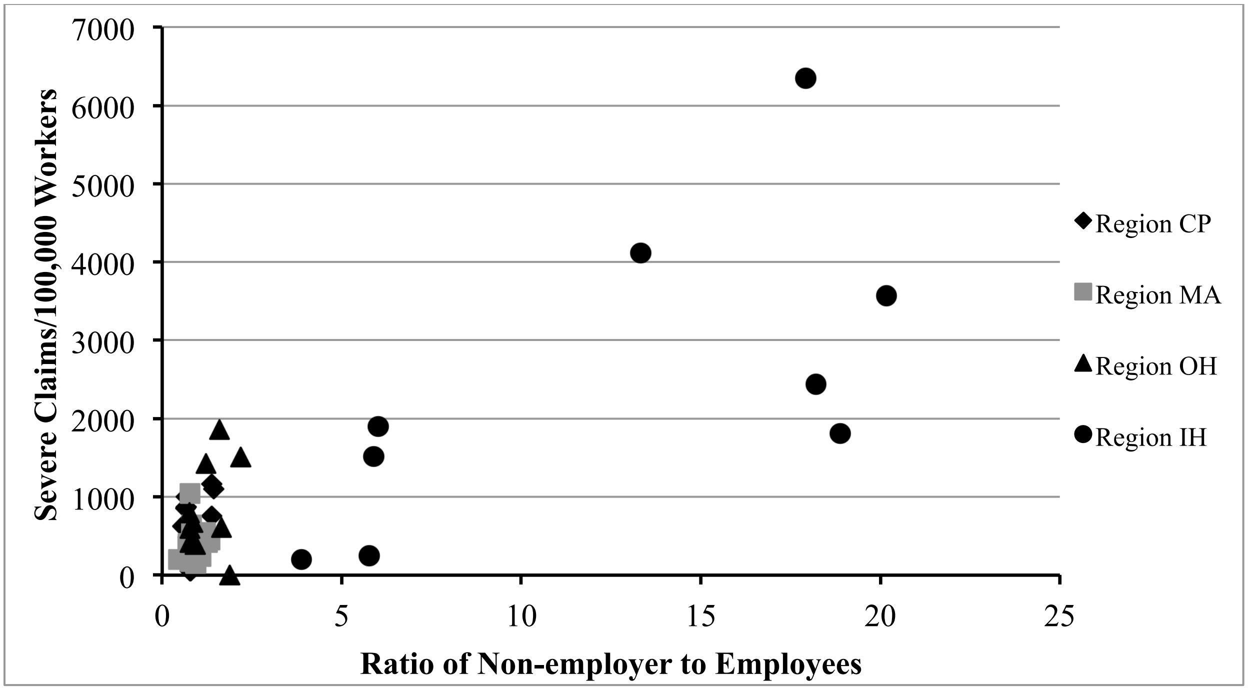

Figure 2.10. Relationship between ratio of non-employer to employee and severe claims rates.

Appendix A

FRA safety alert categories coded by event, source of injury, and Nature of injury.

Alert Number	Event	Source of injury	Nature
05-S-9	2	8	10
00-S-2	2	8	10
02-S-13	2	8	10
02-S-19	2	8	10
03-S-7	2	8	10
08-S-14	2	8	10
10-S-10	2	8	10
00-S-10	2	8	10
02-S-18	2	8	18
04-S-9	2	8	123
01-S-21	2	8	132
07-S-2	3	4	15
10-S-11	3	9	15
08-S-3	3	9	15
14-S-2	3	9	15
06-S-3	3	9	15
03-S-8	3	4	132
02-S-15	3	3	
13-S-12	4	5	10
12-S-17	4	8	10
11-S-7	4	9	17
07-S-1	4	3	18
12-S-10	4	4	18
08-S-10	4	4	18
02-S-8	4	4	18
01-S-3	4	6	18
01-S-17	4	6	18
01-S-1	4	6	18
01-S-26	4	6	18
04-S-5	4	6	111
12-S-16	4	3	123
02-S-9	4	5	123
02-S-6	4	6	123
06-S-14	4	6	123
02-S-4	4	4	132
04-S-4	4	3	143
11-S-10	4	6	143
03-S-17	4		
09-S-14	5	4	10
06-S-18	5	3	15

Alert Number	Event	Source of injury	Nature
08-S-13	5	3	15
12-S-11	5	3	15
08-S-15	5	4	15
06-S-16	5	4	15
01-S-16	5	4	15
01-S-6	5	4	15
01-S-14	5	5	15
12-S-5	5	9	15
14-S-4	5	4	18
06-S-1	5	5	18
02-S-7	5	5	19
04-S-1	5	4	132
07-S-7	5	4	132
05-S-2	6	3	10
08-S-6	6	3	10
09-S-6	6	3	10
12-S-9	6	3	10
07-S-4	6	3	10
09-S-2	6	3	10
13-S-11	6	3	10
03-S-13	6	4	10
07-S-14	6	4	10
01-S-11	6	5	10
04-S-8	6	5	10
12-S-18	6	5	10
01-S-13	6	5	10
06-S-5	6	5	10
00-S-3	6	5	10
00-S-11	6	8	10
02-S-17	6	8	10
05-S-6	6	8	10
13-S-4	6	8	10
12-S-3	6	3	18
01-S-5	6	3	18
12-S-2	6	3	18
00-S-7	6	3	18
10-S-6	6	3	18
01-S-24	6	4	18
12-S-7	6	4	18
12-S-4	6	5	18
13-S-10	6	5	18
05-S-10	6	5	18
01-S-10	6	8	18
06-S-12	6	8	18
10-S-2	6	9	18

Alert Number	Event	Source of injury	Nature
02-S-1	6	5	19
01-S-23	6	5	19
10-S-9	6	3	111
04-S-11	6	5	111
07-S-15	6	5	111
09-S-1	6	5	111
09-S-3	6	5	111
01-S-22	6	8	111
14-S-3	6	8	111
08-S-7	6	3	123
00-S-5	6	5	123
07-S-5	6	3	131
06-S-6	6	3	131
10-S-3	6	3	132
11-S-8	6	3	132
08-S-8	6	4	132
11-S-2	6	4	132
12-S-14	6	4	132
05-S-7	6	7	132
04-S-6	6	7	132
03-S-3	6	3	143
12-S-1	6	4	143
07-S-8	6	5	143
11-S-15	6	5	143
06-S-15	6	8	143
11-S-4	6	4	
01-S-28	6	5	
05-S-3	6		

Appendix B

FRA safety alerts statistics and code description by event, source of injury, and nature of injury.

Code	Event	Amount	Proportion
2	Transportation Incidents	11	0.10
3	Fires and explosions	7	0.06
4	Falls, slips, trips	20	0.18
5	Exposure to harmful substances or environments	15	0.13
6	Contact with object or equipment	60	0.53

Code	Source of Injury	Amount	Proportion
1	Chemicals and Chemical Products	0	0.00
2	Containers, Furniture, and Fixtures	0	0.00
3	Machinery	26	0.23
4	Parts and Materials	23	0.21
5	Persons, Plants, Animals, and Minerals	24	0.22
6	Structures and Surfaces	8	0.07
7	Tools, Instruments, and Equipment	2	0.02
8	Vehicles	21	0.19
9	Other Sources	7	0.06

Code	Nature of Injury	Amount	Proportion
10	Traumatic injuries and disorders	30	0.28
111	Fractures	8	0.07
123	Strains and sprains	7	0.06
131	Amputations (open wounds)	2	0.02
132	Cuts/lacerations/puncture (open wounds)	12	0.11
143	Bruises, contusions (surface wounds and bruises)	7	0.06
15	Burns and corrosions	14	0.13
17	Effects of environmental conditions	1	0.01
18	Multiple traumatic injuries and disorders	24	0.22
19	Other	3	0.03