

J. W. Gottstein Memorial Trust Fund

The National Educational Trust of the Australian Forest Products Industries



BURNING AMBITION – TERTIARY EDUCATION OPPORTUNITIES FOR BUSHFIRE PROFESSIONALS

TINA BELL

2012 GOTTSTEIN FELLOWSHIP REPORT

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JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships and Awards – each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.
2. Seminars – the information gained by Fellows is often best disseminated by seminars as well as through the written reports.
3. Wood Science Courses – at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.
4. Study Tours – industry group study tours are arranged periodically and have been well supported.

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Executive summary

Formal tertiary education relating to fire lacks presence in Australian universities despite bushfires being a critical part of the landscape and culture. In contrast, fire education in the United States (US) features more widely in the tertiary curriculum than in Australia. I undertook a study tour of several states on the west coast of the US in October–November 2012 to gain insight into curriculum and teacher and student perspectives. I used this information to compare tertiary-level fire education on offer in the two countries and in Canada to provide an insight into what principles, practices or curricula may be adopted to improve tertiary education of fire professionals in Australia.

I interviewed 20 fire educators, 30 postgraduate students and 116 undergraduate students from universities in California, Colorado and Arizona. Half of the universities visited are strongly research-focused and the other half provide tertiary education and training for a range of professions including Foresters, Wildland Firefighters, Natural Resource Managers and Soil Scientists. Similarly, there were two clear groups of students – those that were pursuing careers in forestry, wildland firefighting or land management and those that wanted research-based careers, whether in academia or with State or Federal governments.

Undergraduate and postgraduate courses (equivalent to subjects or units of study) were classified as being 'fire-specific' if the word 'fire' was in the title of the course or 'fire-related' if the word 'fire' was in the course description. Courses available from the universities visited ranged from two or more fire-related topics to six or more fire-specific topics. The universities involved in provision of professional tertiary education and training had the greatest number of fire-specific courses on offer. Research-focused universities offered fewer fire-specific courses but had a number of fire-related courses. Most of the relevant courses consisted of traditional lectures, field experience and practical work but some were discussion-based or featured a seminar series given by fire professionals. The latter format was very popular with students and was a particular feature of research-focused universities.

In Australia, there is no State or Federal requirements for a specific level of tertiary education for fire professionals and the number and type of courses on offer at universities reflect this. However, there are many vocational institutes and industry management schemes that deliver relevant training and education. Tertiary education in Australia should therefore aim to create a strong foundation for students that want to become professionals associated with fire and land management agencies or want to be involved in fire-related research or policy.

The two recommendations coming from this research are a call for: (1) an appraisal of tertiary education and multi-agency training on offer for fire professionals in Australia, and (2) the development of a fire-related curriculum for land managers and firefighters combining tertiary education and other fora.

1. Background

A recent web-based survey revealed that few universities in Australia offer courses (equivalent to subjects or units of study) to undergraduate students about bushfires, neither fire behaviour, plant and animal ecology associated with fires, fire management and policy or social aspects of bushfires (Bell unpublished, see below). This is surprising as Australia is a fire-prone continent and the devastating fires in Victoria in 2009 and in New South Wales in 2013 have shown us that bushfires continue to claim lives and destroy property. In comparison, there are many universities in the United States (US) with a range of fire-related courses and degrees that major in fire science (Kobziar *et al.* 2009). This raises the question of whether we are doing enough in Australia to educate our next generation of fire professionals – including our future forest, land and resource managers, researchers and policy makers.

Two of the key recommendations made by the Royal Commission into the 2009 Victorian bushfires were to improve bushfire education and training in Australian universities (see Box 1). It was clear from these recommendations that we need to better educate researchers and managers alike. One of the most effective ways of doing this is to improve the range and quality of teaching available at our universities.

Box 1. Education-related recommendations made by the Royal Commission into the 2009 Victorian bushfires (Victorian Royal Commission 2010).

Recommendation 55: “...development of education and training options to improve understanding of bushfire risk management in building and planning regimes by helping [develop] a suitable tertiary institution design and implement a course on bushfire planning and design in Victoria.”

Recommendation 65: “...to promote continuing research and scholarship in related disciplines [physical, biological and social sciences].”

In addition, two training-related recommendations were made by the Senate Committee on Agriculture and Related Industries (see Box 2) after an enquiry into the incidence and severity of bushfires across Australia (Commonwealth of Australia 2009). These recommendations called for development and support of a national accreditation course for bushfire training. It is not inconceivable that there would be a place for tertiary education in the development and delivery of such a course as certain universities in the US already have a strong role in federal accreditation for forestry and land management (see Section 1.2). Comments within the Report advocate both tertiary education and hands-on training is needed for fire professionals and that the numbers of new recruits and skilled people currently working in land or fire management agencies are declining.

More locally, a recent review of education and training in agriculture, forestry and fisheries in New South Wales (New South Wales Government 2013) made recommendations to the Federal government for increased funding and benefits for PhD scholarships as a means to encourage students into tertiary-level research (see Box 3). In the same report, two recommendations were made to the Forestry Industry in relation to tertiary education (see Box 3). Although a similar enquiry undertaken in Victoria did not include forestry in the definition of agriculture used (Parliament of Victoria, Education and Training Committee 2012), a number of recommendations were made by the Minister for Higher Education and Skills about attracting students into agricultural research by supporting more Commonwealth-funded places, improving the structure of tertiary level agricultural courses and promoting agriculture as a career. From these and other reviews, the tertiary education sector in which

education of fire professionals may have a place clearly needs attention at both a State and Federal government level.

Box 2. Training-related recommendations made by the Federal Government in 2009 after an enquiry into the incidence and severity of bushfires across Australia (Commonwealth of Australia 2009).

Recommendation 10: “The Commonwealth assist the states with bushfire training for land managers and volunteers by co-ordinating curriculum development and delivery of a national bushfire accreditation course, to be delivered by the relevant state agencies.”

Recommendation 11: “The Commonwealth organise the co-operation of state land management and fire agencies to provide the practical training aspect of the curriculum as part of a national bushfire accreditation course.”

Apart from these and other recommendations and reviews, researchers and academics themselves have recognised the need for better education of fire professionals in land management agencies, universities and technical colleges. A long overdue call has been made with the following statement “Books and other teaching materials must be written and prepared, lecturers must be employed, teaches must be brought up to speed with current knowledge, curricula must be changed, policies and guidelines for practices must be revised and implemented, and staff must be trained and educated.” (Adams and Attiwill 2011). While Fisher *et al.* (2005) lamented the lack of soil science being in the repertoire of recent graduate Foresters in the US, they echoed a far reaching sentiment: “We do not need more education; we need better education.”

Box 3. Tertiary education-related recommendations made in the Review into Agricultural Education and Training in New South Wales Report to the Federal Government (New South Wales Government 2013).

Government Recommendation 25: “The NSW Government, through the Standing Council on Primary Industries, raises the following matters with the Federal Government:

- a. Greater provision of top-up scholarships by Research and Development Corporations, to the maximum allowable under the taxation rules
- b. An increase in the maximum allowance for top-ups under the tax-free provisions for research scholarships and
- c. The need to restore competitive and respectable stipends for postgraduate scholars under the Australian Postgraduate Award and Australian Research Council schemes, including annual increments and superannuation entitlements.”

Industry recommendation 10: “The forest industry comes together to review its needs for courses in universities to ensure continued availability of higher education in forestry.”

Industry recommendation 12: “Rural Research and Development Corporations and other research funders commit to a minimum of 5 years funding for post-doctoral scholars with an obligatory 3-year review to establish prospects.”

A study tour of several tertiary institutes in the US provided valuable insight into fire management training and education opportunities available. The curriculum on offer at each institute was compared to what is available in comparably-sized Australian institutes. Students and teachers were asked about their views of the type and quality of tertiary education available for fire managers and researchers and the opportunities this provides for employment prospects and advanced training. By understanding what fire education opportunities and innovations are possible, we can benefit the wider community with better instruction of our current fire professionals and prepare the upcoming generation.

1.1. Fire training and education in Australia

A web-based survey of universities in Australia revealed relatively low numbers of ‘fire-specific’ (the word ‘fire’ appears in the title of the course) undergraduate and postgraduate courses compared to offerings in the US (Table 1). While ‘fire-related’ courses (the word ‘fire’ appears in the course description) are available in all but four of the Australian universities surveyed, the relevant degrees are constantly being revised such that there is little permanence. It is evident that there is considerable room for improvement at all levels of learning and education, particularly for training our future fire professionals in Australia.

Tertiary-level forestry education is similarly restricted with few universities providing forestry-specific courses and a small number of forestry students graduating each year (de Fégely 2010; Pratley *et al.* 2010). A decline in the forestry industry in recent years has been caused by market pressures, environmental concerns, government policies and compliance requirements (New South Wales Government 2013). As such, the current level of training and education for forestry has been judged to be adequate to meet current and emerging needs in NSW (New South Wales Government 2013). Most forestry training is provided by Technical and Further Education institutions in NSW and an undergraduate degree is only offered at Southern Cross University. Forestry training and education in other states in Australia are similarly limited.

Table 1. State distribution of Australian universities offering courses with ‘fire-specific’ and ‘fire-related’ content. The course content from 25 Australian universities was examined. Courses on offer may be at the undergraduate (e.g. Bachelor) or postgraduate (e.g. Masters or PhD) degree level. Data for the United States is from Kobziar *et al.* (2009) and represents 22 universities.

State	Fire-specific courses	Fire-related courses	Alternative delivery courses
Australian Capital Territory	3	0	1
New South Wales	6	11	9
Northern Territory	1	0	1
Queensland	2	1	0
South Australia	1	1	0
Tasmania	0	1	0
Victoria	5	4	1
Western Australia	0	8	0
Total (Australia)	8	23	12
Total (United States)	72	–	29

The Australasian Fire and Emergency Authorities Council (AFAC) are in the process of consolidating their training and accreditation in the fire and emergency industries (a

‘Professionalisation Scheme’). An Industry Capability Development Strategy has recently been developed to improve and promote professionalism. Already on offer are:

1. Development programs in leadership and management
2. Licensed training courses such as basic wildfire awareness training for people with supporting roles on the fireground and provision of the underpinning knowledge of the Australasian Inter-service Incident Management System (AIIMS)
3. Industry training support including fire simulation training
4. A range of resources and support products

This array of education and training primarily services the fire and emergency industry and should be viewed as being complementary to what might be offered at a tertiary level.

1.2. Fire training and education in the United States and Canada

Fire education in the US is generally associated with land-grant universities and technical community colleges specialising in forestry and/or range management (Kobziar *et al.* 2009). There is generally a land-grant university or college in each state and these institutes are federally-funded. Most land-grant universities are public but there are several that are privately run.

The introduction of the GS-0401 series of training in 2004 required a person already in or intending to seek federal employment as a ‘Fire Professional’ to complete a Bachelor degree or at least 24 credits of courses that would be required as part of a degree in forestry, fire, natural resources or a closely related field (<http://www.ifpm.nifc.gov/>). The aim of the Interagency Fire Program Management Qualification Standards and Guide (IFMP Standard) was to establish minimum qualifications for fire managers and administrators required to make fire management decisions. It was largely a ‘corrective action’ in response to catastrophic fires in 1994. This requirement saw an increase in fire-specific courses being offered and whole new undergraduate degrees were developed in some instances. The advent of on-line and distance courses also improved the fire educational reach of many universities (e.g. University of Idaho: <http://www.uidaho.edu/cnr/certificateprograms/401series>; Oregon State University: <http://ecampus.oregonstate.edu/onlinedegrees/ifpm/>).

The original intent of this project was to include several universities in Canada but time and funding constraints prevented this travel component. Nevertheless, some information can be included about education of fire professionals in Canada as a means of comparison with Australia and the US. For example, one of the strategic objectives listed in the National Canadian Wildland Fire Strategy (Canadian Council of Forest Ministers 2005) includes tertiary training of personnel (see Box 4). The Federal government is responsible for fire management in the national parks, where a greater emphasis is placed on the use of prescribed fire. The responsibility for forest and fire management for remaining land rests with each of the 13 autonomous provinces and territories. Four provinces with large fire management organisations – British Columbia, Alberta, Ontario and Quebec – generally account for about 80% of total expenditure in Canada.

Wildland firefighters in Canada require SP-100 training which qualifies candidates to apply for entry level positions as a Category 1 or Category 2 Fire Fighter. The training for the SP-100 is approximately 60% field work and 40% theory and can be completed in 40 hours.

Box 4. A key education-related strategic objective listed in the Canadian Wildland Fire Strategy (Canadian Council of Forest Ministers 2005).

“Maintain an economically efficient and world-class wildland fire preparedness and response capability through long-term replacement of deteriorating equipment and infrastructure, implement Canadian training standards, and recruit and train personnel at universities and community colleges.”

1.3. Approach taken

Fire education at a tertiary level is likely to vary widely in scope, intention and audience so I attempted to capture this variation from the point of view of both the educator and the student. The main investigation activities included:

1. In-depth interviews with academics responsible for delivering fire-related courses (see Appendix 1)
2. Group and one-on-one interviews with undergraduate and postgraduate students taking fire-related courses

Topics explored with the first group included course content, mode of delivery and learning outcomes against a backdrop of training needs for forestry, land management and fire industries, and with the second group included motivation for study and potential career paths for graduate students. Prior to interviews I generally gave a seminar (to a departmental audience) or lecture (to a student cohort) describing broad fire patterns and ecological and social outcomes in Australia (titled: *Forest fires in south-eastern Australia*; see Appendix 2). In many cases, I had the chance to explain the motivation for my investigation to the intended interview audience and to answer any preliminary questions they had.

Only a certain amount and type of information can be gained from working with people through email and other media. Making personal contact allowed me to interact directly with fire educators to understand their course content and motivation. This was matched with the ability to gain student perspectives of fire-related courses and the information gathered was immediate, accurate and candid. The original intention was for students to complete surveys including a range of questions relating to their studies but human ethics requirements from multiple institutions made this research method untenable. During informal individual and group interviews, the students and educators were made aware of how their verbal responses would be used and were given the chance to refrain from participating if they were not entirely comfortable with the task. No participants were personally identified.

The first component of this research required identification of professional fire educators and their relevant tertiary institutes. Given time and logistical constraints, tertiary institutes located on the west coast of the US and Canada were targeted. The universities that were visited are presented in Table 2.

Unfortunately, Prof John Innes and Assoc Prof David Tindall from the Faculty of Forestry at the University of British Columbia in Canada were not available at the proposed time of my visit. This Faculty specialises in all aspects of education of forestry professionals and, at the time, offered several relevant undergraduate courses: *Forest Fire Science and Management*, *Advances in Forest Fire Science and Management*, *Social Research Methods for Studying Forestry and Conservation Problems*. Similarly, Prof Penelope Morgan in the College of Natural Resources at the University of Idaho was not available. This College also offers forestry and natural resource management degrees and specialises in distance education. On-line courses on offer include: *Fire Ecology and Management*, *Global Fire Ecology and*

Management, Fire Ecology, Fire and Fuel Modelling, Fire Behaviour, Remote Sensing of Fire and GIS Application in Fire Ecology and Management. To replace these two opportunities, the University of Arizona and Northern Arizona University were chosen instead (Table 2). Other suitable universities would have been Washington State University, Oregon State University, University of Oregon and the University of Nevada but the scope and timing of the project was necessarily limited.

Table 2. Tertiary institutes in the United States visited in 2012 for this study.

University	Dates visited
Humboldt State University – Arcata, California	1–5 October
University of California Berkeley – Berkeley, California	7–11 October
University of California Santa Barbara – Santa Barbara, California	12 October
California Polytechnic State University – San Luis Obispo, California	14–18 October
University of Colorado Boulder – Boulder, Colorado	18–24 October
Colorado State University – Fort Collins, Denver	24–27 October
Northern Arizona University – Flagstaff, Arizona	27 October–2 November
University of Arizona – Tucson, Arizona	2–8 November

1.4. Travel logistics

My travel to the US was mainly supported by the Gottstein Trust with award of a prestigious Gottstein Fellowship to collect data for a project titled “Burning ambition – tertiary education opportunities for bushfire professionals” (\$5250). I was also supported by the Bushfire Cooperative Research Centre (CRC; \$2500) and the Faculty of Agriculture and Environment (\$2500). Contact with educators for potential visits was made via email or Skype in early August 2012 and organisation of my travel continued for the next eight weeks.

2. Tertiary institutes visited

2.1. Humboldt State University, Department of Forestry and Wildland Resources

2.1.1. The university and department

Humboldt State University (HSU) is the most northerly campus of the 23 school Californian State University (CSU) system. It was established in 1913 as a Teachers College and renamed the Humboldt State College in 1935. After several additional name changes, it became the California State University Humboldt in 1974. This university is one of the smallest in the CSU system with about 8000 students, most of whom are undergraduates. The University offers 44 Bachelor degrees, 21 Masters degrees and various teaching qualifications (<http://www.humboldt.edu/programs>). Students doing Masters degrees do coursework and independent research, the balance of which depends on the particular course they are doing. There are no PhD students but they may be affiliated with the University through their supervisors (advisers). The University is divided into three colleges:

1. College of Arts, Humanities and Social Sciences
2. College of Natural Resources and Sciences
3. College of Professional Studies

The catchment area for students at HSU is California with 50% of students from southern California. It was made very clear during student interviews that the idea of working in the

forests in northern California is appealing and is very much an attraction for studying at HSU. It is well known that graduate students from HSU are readily employed in forestry and land management agencies and this is one of the main drawcards for many of the undergraduate students. A relatively high number of students at HSU are international (10–15%) but this proportion is small (1–2%) in the College of Natural Resources and Sciences.

The Department of Forestry and Wildland Resources consist of 24 Faculty academics and lecturers, all of whom are involved in teaching, and numerous other researchers (i.e. Postdoctoral Fellows), Adjunct Faculty and Associates. Academic staff members from other faculties are also involved in teaching about fire but at a higher conceptual level such as fire being described as “a driver of global-scale changes in vegetation and climate and in landscape-scale ecology”. Humboldt State University is one of the few universities with a fire laboratory equipped for measuring aspects of fire behaviour (Fig. 1A). The fire science program teaches modern techniques for managing wildfire and an advanced training program is offered for state and US Forest Service employees and similar professionals.

2.1.2. Courses offered

In the Forestry program, students taking an undergraduate degree in Forestry choose one of five options. These include specialisations in:

1. Forest Operations
2. Forest Resource Conservation
3. Wildland Fire Management
4. Forest Hydrology
5. Forest Soils

All of these options allow the student to qualify as a ‘Forester’ in Federal employment. The fourth specialisation allows the student to qualify as both a ‘Forester’ and a ‘Hydrologist’ and the fifth specialisation allows the student to qualify as both a ‘Forester’ and a ‘Soil Scientist’. The first four specialisations allow the student to become accredited by the Society of American Foresters (but not the fifth option).

The Wildland Fire Management option has students taking fire-specific courses in their third and fourth years of study. These include: *Fire Management Capstone*, *Fire Ecology*, *Wildland Fire Behaviour* and *Wildland Fuels Management*. All forestry students are required to take a second year-level course called *Introduction to Wildland Fire*. A postgraduate level Masters in Science (MS) course is also described.

Introduction to Wildland Fire (second or sophomore year)

“This core course provides a history and development of fire policy, a basic introduction to fire behaviour and an overview of fire use in wildland management and conservation.”

Wildland Fuels Management (third or junior year)

“This course is designed to provide a substantive overview of the field of wildland fire science and management. To meet this objective, the course covers the elements of fire behaviour, fire and fuels management, and the historical development of the field. Implications of fire suppression and climate change are addressed.”



Fig. 1. Facilities available for fire education at the tertiary institutes visited. (A) The fire laboratory at Humboldt State University, (B) the 'fire column' used at the California Polytechnic State University, (C) the 'fire box' used at Colorado State University, and (D) student field trip for Northern Arizona University.

Fire Ecology (third or junior year)

“This course is designed to provide students with a firm understanding of fire ecology as it relates to ecosystem and fire management. Each student learns about fire as a disturbance, its importance to ecosystems, and how fire affects plants and animals. Additionally, the students explore fire as an evolutionary force, adaptations of plants to fire, fire regime types, fire history methods, and how fire influences plant populations, communities and successional processes.”

Wildland Fire Behaviour (also called ***Fire Behaviour and Use***; third or junior year)

“This course is designed to provide students with a thorough understanding about fire behaviour and use across a variety of ecosystems. Each student learns about the fundamental principles that pertain to fire behaviour, fuel properties, and wildland fire use. The ultimate goal of this course is to provide students with information and tools that will better prepare them for positions related to wildland fire suppression and use in different capacities. However, this course is not intended to teach students how to ‘fight’ fires.”

Fire Management Capstone (fourth or senior year)

This course requires completion of a small group-based project resulting in production of a thesis. The group of students ideally contain a mix of interests such as one studying forest operations teamed up with a wildfire student and an environmental/conservation student. Suitable projects are proposed, generally in the form of a management scenario for a particular area, and input is gained from each group member.

Advanced Wildland Fuels Management (postgraduate level)

“Advanced Wildland Fuels Management is a graduate-level course dealing with growing issues in contemporary and future management of natural resources. Despite the paradigm shift away from fire suppression, steps to erase or manage decades of changes in fuels in wildlands are difficult and usually experimental. Recent fires have threatened resource values (e.g. timber, wildlife habitat, biodiversity, water quality) as well as human health and safety. This course deals specifically with managing wildland fuels in forests and rangelands, with case studies from California and the south-eastern US. This course is designed to give students an advanced understanding of fuel dynamics, management strategies and the challenges facing fuel managers. Students utilise the evolving literature on the topic coupled with field visits and use of models to evaluate treatment effects on fire behaviour, fuel consumption and smoke production.”

Students have access to the college forest, the Schatz Demonstration Tree Farm, the Arcata Community Forest, public and private forest lands and various production centres. Students interact with professional forest managers and researchers in the classroom and in the field.

2.1.3. Educator perspectives

The points that were raised through one-on-one interviews with four fire educators at HSU (see Appendix 1) are listed below. The comments made are grouped into topic areas and are not specifically attributed to any one person.

History of fire education at HSU

- Teaching related to fire has been done at HSU for about 60 years. Initially the only course taught was about fire suppression and this was delivered to wildland firefighters prior to the summer fire season. Associated with the development and delivery of this topic was well-known forest and fire researchers, Emeritus Professor James Agee, Prof Harold H Biswell and Harold Weaver.

- Fire ecology was introduced into the curriculum as the focus in the professional world shifted from fire suppression to fire management.
- When forest production in California was at its highest in the late 1970s, there were about 700 students in the Forestry degree. Over the last decade, demand for wood, primarily for housing, has dropped and student numbers have dropped concomitantly. There are about 250 students currently enrolled in the Forestry degree, 55 of whom are specialising in Wildland Fire Management.
- There was an increase in student interest and enrolment in fire-specific topics as fire management replaced suppression activities. It is thought that teaching related to fire at HSU really became popular through the promotion by and reputation of Prof Morgan Varner.
- The introduction of the professional training requirement (GS-0401 Fire Management Specialist) that fire professionals need a university degree has shaped the current undergraduate and graduate offerings at HSU.

Fire-specific courses

- The *Fire Ecology* course encompasses, among other topics, community ecology and population dynamics of plants and animals, evolutionary influences of fire and plant flammability, and fuels management and climate change. It is a core course for Forestry students specialising in Wildland Fire Management and is often taken as an elective course by student studying Wildlife Management and by MS students.
- The *Wildland Fire Behaviour* course involves fire weather, fuel characteristics (e.g. types, moisture dynamics, time-lag classes), prescribed fire and adaptive management.
- The output of the *Fire Management Capstone* course is a group-based thesis. For the project component, the Course Coordinator tries to include individuals from a range of specialisation groups (i.e. hydrologist, forest operations, fire management and conservation).

The student cohort

- Community colleges are considered to primarily be for vocational and technical training but they do provide a mechanism for students to gain entry into university.
- The CSU system attracts high school graduates (usually top 25% of students) and students transferring from community colleges; the University of California system generally attracts the top 10% of high school graduates.
- Other universities that students could go to for fire-specific education would be the University of California Berkeley and the California Polytechnic State University. It was suggested that HSU is often preferred by students as it is easier to gain admission in terms of lower entrance requirements and tuition fees are cheaper.
- Humboldt State University attracts a particular type of person (i.e. someone wanting to get into the forestry industry or to work in forests or with natural resources), and this group differs from the student cohort at the University of California Berkeley and the California Polytechnic State University.
- Humboldt State University is marketed as a residential campus with 2500 bed spaces. It is the largest residential campus in the CSU system.

Barriers to education

- Educators try to encourage cross-faculty classes but is difficult as there is not often a common base-line of skills. This is a universal problem, not just associated with forestry and fire education.
- All staff at HSU have high teaching loads but are still expected to do research and gain competitive research funding.
- The fire-specific courses on offer always need to be reviewed to keep the balance between 'training' and 'education'.
- Unfortunately, across the entire university, one third of freshmen students do not come back after their first semester.
- There is a constant requirement to attract new students. A recent initiative by HSU is to develop a program with a sister University in Xi'an, China. It is expected that exchange students complete their first and final years in the US, and two years in China. There will obviously be language barriers but this is yet to be addressed in the College of Natural Resources and Sciences.

2.1.4. Student perspectives

A total of 12 undergraduate and postgraduate students were interviewed in small groups over a three-day period. All students were enthusiastic and very forthcoming with their views and most were very clear on their intended careers. Some students had come straight from college to university and others had already spent time in the workforce as a Fire Professional or in another profession, sometimes quite unrelated.

Employment opportunities and motivation to study

- It was clear that students felt that once they have a Bachelor of Science (BS) degree they have excellent opportunities for being employed by State or Federal agencies (estimations of up to 100% employment rate). However, the private forestry sector offers few opportunities due to considerable regulations and a very small demand for local timber.
- A MS degree offers the opportunity to undertake research but the main pathway for employment is still via the Federal system. Graduates with either a BS or MS have an equally high rate of employment (i.e. one degree is not viewed as being superior to the other).
- Student A had a very clear impression of where he wants to be in the near future and he feels that he will get there by improving his understanding of fuels and the implication of fires. The focus of his study is firmly focussed on gaining a better understanding of fire management.
- Student B was not as committed to fire management and preferred a broader educational base. He was planning to do a double major (i.e. two specialisations) and would even contemplate further study involving research before entering the workplace.
- Student C was not clear on intended employment goals but was keen to get fireground training over summer as well as completing a BS.
- Student E was aiming to work for the National Parks or a state or federal Forest Service.

- Student H was nearing the end of his degree and was facing a decision about what to do next. He expected to look for work with the US Forest Service or Bureau of Land Management and Fire Service but expressed frustration with the mechanics of the government system as he had been involved with it in the past. This was mainly related to the sense of 'an old boy's club' for managers in conflict with the need for a university degree. In their opinion, experience on the fireground far outweighed tertiary learning. Regardless, student H was planning to enter the government system and do what he could to cause change via management. He presented very mature and admirable long-term goals.
- Student I wanted to increase her knowledge in fire so was taking several fire-specific courses. This student aimed to find work as an Ecologist in a state or federal agency and, working towards this goal, already had three summers of field research experience and had been successful in gaining a small research grant from the Forest Service.
- Student J had worked with the US Forest Service for the last four summers on fuels crews in Colorado. This student had a definite objective to work towards managing fireground crews but still required another 8 years of experience to be suitably qualified. This student would also like to become part of the Hot Shots crew but this would require just as much experience.
- Student K was pursuing a degree from an interest in fire rather than for a career option as he has military experience that would allow him to be hired in a wide range of positions.
- Student L is a postgraduate student. This student did an undergraduate degree at HSU then worked in the University of California system as a Technician. She saw the MS as a way to move her career ahead and aims to work in the State government system or private enterprise. It is not a primary objective to work as a fire professional but she was interested in the field.

Entry pathways

- Student C had done three courses at a local community college while working on gaining 'residency' in California. A student needs to be able to prove that he/she has lived in California for a period of 12 months before they can get a reduction in tuition rates at a local university. The transfer of credit points from community college to HSU was viewed as being relatively easy.
- Student D reiterated that the cost of tuition at HSU compared to community college was a crucial factor in deciding the pathway for entry to university.
- Student E completed 2.5 years at a Junior College in southern California before transferring to HSU. The attraction of this entry pathway for him was that he was able to stay close to home while gaining his basic education.
- Student F had three years of technical training and experience as a Botanist in the National Parks Service but wanted to get back into more serious research. The strategy to do this was to get a suitable undergraduate degree combining topics of interest and experience and then consider postgraduate studies.
- Student I was from a different faculty and had little experience with fire but wanted to combine this field with interests in plant community ecology.

Competing universities

- For the majority of students interviewed, HSU was the preferred option for study because of the following features:

1. A well-recognised Forestry degree
 2. Located in the forest/natural environment
 3. Offers a strong community atmosphere
 4. Considered to be a resource-rich university
- Universities in Oregon and Washington offer Forestry degrees but tuition is more expensive if students are from out-of-state.
 - The University of California Berkeley was viewed as offering research- and policy-based education and would not be useful for practical forestry or fire training. This university was viewed as being an option for gaining MS or PhD degrees.
 - Study at HSU offers the opportunity to gain a 'Red Card' (or Interagency Qualification Card) certification for Wildland Fire Suppression. This allows the student to become a trainee wildland firefighter which, with experience and an appropriate university degree, can lead to a professional position with a number of state or federal agencies (e.g. US Forest Service, Bureau of Land Management).
 - Applications for entry to university may have been made to a number of universities but it was the positive response gained from HSU that swayed at least one of the students to study there.
 - A strong choice for studying at Cal Poly was that they have their own fire crew which guarantees experience on the fireground. This is not an option at HSU due to insurance implications.

Other opportunities and considerations

- Humboldt State University has a recognised chapter for the Student Association for Fire Ecologists (SAFE). It has only recently been revived and current activity was around fund raising for travel to the Association for Fire Ecology (AFE) conference in Oregon in December 2012. There are currently 15–18 students in the HSU SAFE group and 8–10 students come to each meeting. The broader SAFE community was established in 2000 by a group of graduate students at the University of California, Davis who shared a strong interest in fire ecology and related issues (<http://fireecology.org/safe/current-safe-chapters/>).
- Three students interviewed had undertaken student exchange abroad (e.g. Australia, University of Newcastle).
- Student B commented on class sizes and how they varied from course to course (i.e. 5–50 students). This was in no way a critical statement but more reflective on the popularity of different areas of study.
- A number of students interviewed thought that it would be a good idea if an introductory course about wildland fire was mandatory for all postgraduate students working in the general field of biology. They also recommended the value of the weekly Departmental Seminar Series in which experts in fire management and research present their work.

2.2. University of California Berkeley, Department of Environmental Science, Policy, and Management

2.2.1. The university and department

University of California Berkeley

The University of California was established in 1868 and its flagship campus was established in Berkeley in San Francisco. The University of California Berkeley (UC Berkeley) is a public research university and occupies nearly 500 ha on the eastern side of San Francisco Bay. There are 130 academic departments and more than 80 interdisciplinary research units with approximately 1600 full-time and 500 part-time Faculty staff. There are approximately 350 undergraduate and postgraduate degrees covering a wide range of disciplines. The latest census (2012) counted 35 899 students, including 25 774 undergraduates and 10 125 students undertaking graduate degrees. The greatest proportion of students is from California with 10% from out-of-state and 10% international students. About one third of the first year students transfer into UC Berkeley from other universities, the remainder are direct applicants. Approximately 12% of funding comes from the state with greater proportions from contracts and grants (32%) and tuition fees (27%). The University of California Berkeley is a highly ranked university (e.g. US National Research Council Rankings, Times Higher Education World Reputation Rankings, US News and World Report) and has a very good reputation for both education and research.

The Department of Environmental Science, Policy, and Management (ESPM) in the College of Natural Resources at UC Berkeley was formed in 1993 and is the largest department in the College. It comprises three divisions:

1. Ecosystems Sciences
2. Organisms and Environment
3. Society and Environment

There are currently 76 Faculty academics, nine Adjunct academics and 24 Emeritus Professors in the Department. Topics of research in ESPM include climate change-related sciences, conservation biology, insect biology and human relationships to the environment. It offers five undergraduate majors including Conservation and Resource Studies, Environmental Sciences, Forestry and Natural Resources, Molecular Environmental Biology and Society and Environment. The Center for Forestry sits within ESPM (<http://ucanr.edu/sites/cff/>). Career opportunities for graduating students include employment in government and non-government organisations, medical and other professions, the private sector including consultancies and graduate education.

University of California Santa Barbara

Due to Prof Max Moritz's connection with the University of California Santa Barbara (UC Santa Barbara), I had an unexpected opportunity to interview two additional Faculty academics (see Appendix 1). A description of the University and the relevant department and the responses of the academics are included.

The University of California Santa Barbara is a public research university and one of the 10 campuses in the University of California system. The main campus is located near Goleta, 13 km from Santa Barbara. The University of California Santa Barbara joined the University of California system in 1944 and is the third oldest general-education campus. There are 1050 Faculty staff and approximately 18 000 undergraduate students. The proportion of undergraduate students from the local catchment area is small (5%), with the majority of students coming from other parts of California. Only 6% of students are from out-of-state or are international.

The Biology Department and the Bren School of Environmental Science and Management at UC Santa Barbara are both associated with fire education. The Biology Department is responsible for both undergraduate and postgraduate teaching and offers 10 different majors and more than 200 courses. It consists of two departments:

1. Department of Ecology, Evolution and Marine Biology (EEMB)
2. Department of Molecular, Cellular and Developmental Biology

The EEMB has 35 Faculty academics and 23 researchers and Emeritus Professors. There are approximately 70 MS and PhD students. The Bren School has 20 full-time Faculty academics and approximately 20 Adjunct or Affiliated Faculty staff and researchers. The School is responsible for postgraduate teaching and offers a two-year professional Master of Environmental Science and Management program and a PhD program in Environmental Science and Management. Currently there are about 160 Masters and 45 PhD students.

2.2.2. Courses offered at UC Berkeley

There is no fire-specific undergraduate course on offer at UC Berkeley but students enrolled in courses with Forestry, Resource Management or Conservation and Resource Studies majors or the inter-college Environmental Sciences major can complete a series of units related to fire ecology and fire behaviour.

Wildland Fire Science (undergraduate level)

“The historic, current, and future role of wildland fire is a major management and political issue. Tremendous resources, and sometimes life, are lost each year to wildfire. Concerns over issues such as forest health and sustainability have also highlighted the importance of understanding the role of fire in ecosystems. To understand the interaction of fire and ecosystems the following topics are covered in this course: fire ecology including the effects of fire on plants and soils, fire history and dendrochronology, wildland fuels, fire behaviour, fire behaviour modelling, fire management, prescribed fire, and fire problems in the urban/wildland intermix. The class participates in prescribed fires during the semester, weather permitting.”

Fire, Insects, and Diseases in Wildland Ecosystems (undergraduate level)

“This course provides insights into the importance of fire, insects and diseases through lectures, discussion sessions and field trips. In addition, there are discussions how humans are affecting wildland ecosystems through both direct (e.g. forest management) and indirect (e.g. travel, air pollution, commerce) actions that change the roles of these agents.”

Fire Ecology Seminar Series (undergraduate and postgraduate level)

“This graduate seminar focuses on the role of fire as an ecological factor in historic, prehistoric, and current contexts in forest and rangeland systems. Activities include weekly readings, student led group discussions and possible observation of or participation in prescribed burns, weather and resources permitting.”

Current Research in Wildland Fire Science (undergraduate and postgraduate level)

“The goal of the this lecture and discussion series is to bring distinguished members of the fire science community from across the country to UC Berkeley, in order to promote discussion and awareness about the most recent research, policy, and management in the field. Weekly readings and presentations by distinguished guest lecturers are followed by discussion. Faculty and persons outside of UC Berkeley are also encouraged to attend the seminar series.”

2.2.3. Educator perspectives

Unfortunately, Prof Scott Stephens was away while I was visiting UC Berkeley but I did interact with researchers and postgraduate students in his group. Dr Max Moritz is a Professor at UC Berkeley and I met him in Santa Barbara where he is now involved in extension education as a Cooperative Extension Specialist in Wildland Fire. The points that were raised during one-on-one interviews with three fire educators from UC Berkeley and UC Santa Barbara are listed below. The comments made are loosely grouped into topic areas and are not specifically attributed to any one person.

Funding sources for postgraduate student research

- Most of the funding for fire research in the US, including support for graduate students, comes from the Joint Fire Sciences Program. Funding is awarded annually through a rigorous peer-review process and successful research projects are selected according to the needs of fire and fuel managers. Other federal research programs that fund fire research include those in the US Forest Service, Forest and Rangeland Research Stations, US Geological Survey and the National Fire Plan.
- To develop a new research focus through the Strategic Environmental Research Initiative of UC Santa Barbara, the topic of wildfire and climate change has recently been targeted to receive funding to form new collaborative partnerships in the faculty and elsewhere to help address this large-scale environmental challenge. The topic will also be integrated into the MS and PhD curricula and activities within the wider university and public communities.

The student cohort

- Of the 30 PhD students that have been through the PhD program associated with the Department of Environmental Science, Policy and Management, 27 students had from 6 months to 5 years of practical fire experience. Only three came straight from university with no prior fire experience.
- A proven method of 'recruiting' postgraduate students is to offer an internship over the student non-contact summer period. This position may or may not be paid and generally provides researchers with field support for on-going projects. This is a strategy that has been used in the Stephens research group with a high degree of success.

Fire-related courses

- Fire ecology, fire behaviour and fire management are not taught as fire-specific courses at UC Santa Barbara as the student cohort is too small (see above). However, there are two fire-related courses on offer (*Ecology and Management of Californian Ecosystems* and *Restoration Ecology*) and there are several postgraduate students pursuing research about wildfire.
- Teaching related to fire ecology in the undergraduate courses include the use of fire by Native Americans as a management tool in grasslands, the effect of fire interval and fire management in chaparral, fire in coastal sage scrub and Sierra conifer forest, and changing fire frequencies in Hawaii.
- Fire managers meet the students while they are on field trips and they talk to them about aspects of fire in different plant communities. There is no fire behaviour or fire modelling taught.
- In the *Restoration Ecology* course, the students learn how fire can be used as a tool for restoration using a part of the campus (coastal sage brush) that was burnt recently as a practical demonstration. This course also discusses fire return interval in relation

to human values, unwanted use of fire in ecosystems and fire as a 'new' element in ecosystems where it does not normally occur (e.g. salt marsh as a result of urban development).

- Teaching resources at UC Berkeley include:
 1. Blodgett Forest consisting of managed and unmanaged mixed conifer forest, oak forest, and brushland
 2. Baker Forest and the UC Forestry Camp located in the middle of Plumas National Forest consisting of old growth mixed conifer forest with cutover secondary growth forest
 3. Whitaker's Forest adjacent to Kings Canyon National Park consists of giant sequoia/mixed conifer forest and stands of second-growth redwood
 4. Russell Research Station located in the coastal hills of Contra Costa County which has been used for wildland and forestry research and teaching since 1961

Barriers to education

- Fire ecology has been an incredibly important issue in western US for the last 50–60 years and there has been scientific debate among researchers for just as long. As in any field of research there are always going to be opposing views. In the case described, the importance of fire in the environment has caused a local divide among experts – those that have the view that fire has far more importance than other ecological forces and those that think that fire is one of many factors in shaping plant and animal communities.
- It can be said that the same conflict has arisen in Australia. From an education perspective, varying scientific beliefs will undoubtedly influence teaching and may become exacerbated in the following generations of researchers and managers.

2.2.4. Student perspectives

While visiting UC Berkeley I had the opportunity to take a class of eight undergraduate and postgraduate students as part of the *Fire Ecology Seminar Series* (see above). I gave a presentation about fire ecology in south-eastern Australia and followed up with a discussion with seven of these students. In addition, I interviewed four postgraduate students. It was interesting to note that several of the undergraduate students interviewed had no fireground experience, and little other familiarity with fire outside of their academic studies. This is likely to be very much the same for postgraduate students in Australia.

Employment opportunities and motivation to study

- Student A was completing a Conservation Resource degree with a major in Fire Science. This student went straight from high school to university and has no field or work experience. This student hopes to find a position in the National Parks Service or Cal Fire.
- Student B is doing an undergraduate degree in Environmental Sciences. He works for the Forestry Service but is on a leave of absence to continue his studies. He has taken this path as he realises that to progress his career in the industry he needs more than just firefighting experience. This student is interested in pursuing MS and PhD qualifications.
- Student C is doing an MS in Range Management and did Environmental Science as an undergraduate at the University of California Santa Cruz. Since completing a

degree, this student has been an intern student in the National Parks Service for several years and was been waiting for a suitable position to become available. This has not happened so the decision was made to do a higher degree to become more competitive in the workforce. This student may continue on to a PhD. Prior to doing the current study, this student had no experience in fire ecology or fire behaviour.

- Student D went from high school straight to university. His interest in fire came from talking to relatives associated with the fire industry and a general interest in climate change. This student's major is in another faculty but he elected to enrol in the *Fire Ecology Seminar Series* out of interest.
- Student G, a postgraduate student, has a background in fire but in the context of the east coast where the fire return interval is 200 years or more. This student did not take any fire classes as an undergraduate as her interests were in water. This unit is being taken out of interest.
- Student H was nearing completion of his PhD. Prior to this he did a MS at UC Santa Barbara in Geography. Again, this student had little experience or knowledge of fire but took appropriate classes in the early stages of his candidature that were on offer at UC Berkeley. Post-PhD, this student hopes to find employment in the Federal government (e.g. US Geological Survey, Environmental Protection Agency, NASA) or as a consultant in the private industry.
- Student I is half-way through a PhD and expects to take five years to complete. The first year and a half was devoted to taking classes and to study for the qualifying exam.

Entry pathways

- Students A, D, E and F went straight from high school to UC Berkeley after successful applications to study. All students are local and did not have to complete residency to qualify for reduced tuition rates.
- Students B, C and G had work experience (paid and volunteer) prior to their current studies.
- Student G completed a MS (on a fire-related topic) at the California Polytechnic State University then worked for the Nature Conservancy for several years before deciding to do further studies at UC Berkeley. Within the first week of the taking up the position with the Nature Conservancy she was required to do fire weather predictions. In the first year of her postgraduate studies she was able to take several fire courses on offer.
- Student I came to UC Berkeley to do paid field work that is regularly advertised through the web-site of the Stephens research group. After completing an internship, she applied to do postgraduate degree. This student had gained a BS and a MS at different institutes.

Competing universities

- The University of California Berkeley is very well known in the forestry industry and has a very good reputation for graduating students with a strong background in forestry and research.
- The reputation of the professors was a significant reason for students enrolling in a particular course or applying for a MS or PhD.
- The general response to the question of why choose UC Berkeley over other universities was that the programs available in Environmental Science, including fire

ecology, were excellent. One of the highlights was the opportunity to learn about and discuss relevant research, particularly through the seminar series.

Other opportunities and considerations

- A former student (and current staff member) conveyed that he originally became interested in studying fire after completing an 8-week intern program over summer through his undergraduate degree at UC Berkeley. He found the course to be very practical and hands-on. A summer 'camp' was a requirement for all Forestry students and consisted of 1 hour of class work in the morning and the remainder of the day was spent in the field taking measurements. The main project was to devise a fire management plan for a 40 ha plot in which the students had been working. He took additional courses in fire and, although starting out on another pathway, forestry became his minor course. He gained further experience as a field technician for one of the researchers in the group at Berkeley.

2.3. California Polytechnic State University, Department of Natural Resources Management and Environmental Sciences

2.3.1. The university and department

The California Polytechnic State University (Cal Poly) is a public university located in San Luis Obispo, California. It was founded in 1901 as a vocational high school and is currently one of only two polytechnic universities in the CSU system. Cal Poly is the second largest land-holding public university in California. It has land associated with the San Luis Creek Ranches adjacent to the campus, the Western Ranches close to the campus and the Swanton Pacific Ranch and Valencia Property in Santa Cruz County. Cal Poly has six colleges and offers 147 Bachelor degrees and 49 Masters degrees. The university is primarily devoted to the instruction of technical arts and applied sciences. There are approximately 1250 full- and part-time Faculty staff with 18 880 enrolled students (2013 census). The main student catchment areas are the San Francisco Bay and Los Angeles (52%), with 8% of students from the local area; 10% of students are from out-of-state and only 0.5% are international. Approximately 4000 freshmen students are enrolled each year and there are about 800 students transferring from other universities and community colleges.

The Department of Natural Resources Management and Environmental Sciences in the College of Agriculture, Food and Environmental Sciences is responsible for fire education at Cal Poly. The Department offers four undergraduate majors:

1. Environmental Earth Sciences
2. Environmental Management and Protection
3. Forestry and Natural Resources
4. Environmental Soil Science

There is also an MS program in Forestry Sciences comprising course work and research and including studies in fire ecology and ecosystem management of oak woodland, chaparral and Sierra forest. Undergraduate and MS students that complete the Forestry and Natural Resources major are qualified to seek employment as a forester, environmental manager, natural resource manager, park administrator, park ranger, resource planner, watershed manager, hydrologist, fire and fuel manager and in many other related environmental areas. There are approximately 3750 students currently enrolled with the majority at the undergraduate level.

2.3.2. Courses offered

In the Forestry and Natural Resources major there is a range of 'concentrations' including:

1. Wildland Fire and Fuels Management
2. Forest and Environmental Practices
3. Urban Forestry
4. Natural Resources Recreation
5. Environmental Planning and Assessment
6. Watershed Management and Hydrology

The Wildland Fire and Fuels Management concentration has four core courses and students can choose from 17 elective courses which cover a wide range of topics. Students that have elected to do other concentrations and majors can also select fire-specific courses as electives. All students in their senior (fourth) year of study are required to complete a project under faculty supervision. Projects are described as being typical of problems which graduates must solve in their fields of employment and their results are presented in a formal report. The 'concentrations' and courses on offer are very similar to those HSU.

The Forestry and Natural Resources program is accredited by the Society of American Foresters and the US Office of Personnel Management recognises employment as a forester with the Federal Government upon graduation. Transfer students can gain credit for course done through any other University of California campus, the Californian Regional Fire Academy, and other fire technology or emergency medical technician courses.

Wildland Fire Control (second or sophomore year)

"This course covers topics of fire control techniques used for various wildland fuels. It includes elementary fire physics, fuels, weather, fire behaviour, tactics and fire suppression techniques, fire line construction and safety, 'mop-up', air operations and fire organisation. Completion of this course meets the basic wildland firefighter certification requirements for the USDA Forest Service and partially meets the requirements for Firefighter I certification for the California Department of Forestry and Fire Protection."

Wildland Fire Management (third or junior year)

"This course describes wildland fuels, fire weather and fire danger ratings in chaparral, grassland and forested areas. Advanced modelling of surface and crown fire behaviour is demonstrated and applied. Fire management strategies and implications, policies and objectives of fire management organisations are introduced and discussed."

Internship in Forest and Natural Resources (third or junior year)

"Selected students spend up to 12 weeks (180–200 hours) with an approved firm or agency engaged in forest or natural resources management. Students learn to apply and develop their managerial skills and abilities."

Wildland-Urban Interface Fire Protection (third or junior year)

"This course introduces biophysical and socioeconomic issues affecting wildland fire management in urbanised landscapes. Topics investigated include fire risk assessment, fire prevention and mitigation, fire preparedness, during-fire response, and post-fire recovery actions by public- and private-sector agencies and residents."

Fire Ecology (third or junior year)

“This course covers the effects of wildland fires on shrub, woodland and forest environments and includes aspects of fuels, plants, soil, water, wildlife and air. There is a strong emphasis on forest and shrub ecosystems in the western US.”

Fire and Society (third or junior year)

“The pre-historical and historical record of human use of and attitude toward fire are introduced in this course. The mythology and religion of fire including traditional, cultural and ethnic variations are described and their influences on modern US institutions involved in managing fire are discussed.”

Technology of Wildland Fire Management (third or junior year)

“A range of models and technologies to solve complex land management problems are presented along with historic, current and future perspectives of wildland fire in California. On the basis of this understanding, the role of fire in sustainability and ecosystem health is discussed. The assumptions and limitations of fire behaviour and suppression models are examined.”

2.3.3. Educator perspectives

I was fortunate to have the opportunity to interview two academics (see Appendix 1), including the Departmental Head, to gain their views on fire education in the US. I also spent a day touring the surrounding area looking at fire scars of various ages in a number of vegetation types and to get a feel for the educational resource available for hands-on teaching in fire ecology and management. The comments made during one-on-one interviews are loosely grouped into topic areas and are not specifically attributed to any one person.

Education potential

- The State Department of Forestry and Fire Protection (Cal Fire) is responsible for management and fire protection of privately-owned land in California. The Department also provides a range of emergency services in 36 (of 58) counties across the State through contracts with local governments. The Cal Fire Academy, along with programs run by the Office of the State Fire Marshall and the State Fire Training Agency, provides training education and certification programs for the California Fire Service.
- The potential for fire professionals to be promoted depends on the manner in which they entered the workforce. For example, while a relevant degree is required for the National Parks and Forest Services (GS-0401 accreditation), this is not necessarily the case for fire professionals working in Cal Fire.
- The desire to work for one agency or another also depends on salary. For example, the Bureau of Land Management pays much better than the Forest Service and Cal Fire offers the highest wages.
- Students entering the workforce as a fire professional may have a competitive advantage initially if they went through the Cal Fire Academy but later in their career they will realise that a degree is essential regardless of how much experience they may have gained.
- The value of on-line courses was discussed as an emerging method of teaching, particularly for courses with aspects for firefighting accreditation. This would not replace face-to-face teaching and one form of teaching would not be an electronic

version of the other. On-line course would have to be carefully crafted to give two very different audiences their own unique experiences yet achieve learning outcomes.

- A student demonstration of the 'fire column' showed not only the hands-on way in which fire behaviour is taught at Cal Poly but also the enthusiasm that is shown by the educators (Fig. 1B). Students have access to the Swanton Pacific Ranch in Santa Cruz County on the northern Central Coast of California. The property is composed of redwood forest, coastal grassland and riverine ecosystems. Forest stands of predominantly second growth Redwood and Douglas-fir are managed for commercial production. Recent field studies for the Wildland-Urban Interface Fire Protection have been held at the Eagle Ranch, south-west of Atascadero.

Barriers to education

- There is no PhD program at Cal Poly but academics can be an Associate Supervisor for a PhD student based at another university.
- Allowing students in General Education to enrol in fire-specific courses in their sophomore and junior years boosts enrolment numbers and allows the course to keep running for students that take courses as part of their fire concentration.

2.3.4. Student perspectives

Student interviews were held as part of scheduled undergraduate classes that I attended or presented a lecture. The student responses were not as detailed as the small groups interviewed at other universities but I could note general patterns and perceptions from the student cohort. As is common in a large group, several individuals tended to dominate the discussion but I attempted to encourage whole group participation with a show of hands for certain questions. The size of the two student groups interviewed were 21 (Student Group 1) and 30 (Student Group 2) individuals and both were second (sophomore) General Education year courses. I also had the opportunity to interview two MS students.

Employment opportunities and motivation to study

- The range of majors in Student Group 1 was wide and included: Forestry and Natural Resources, Biology, Botany, Chemistry, Earth Science, Agriculture, Dairy Science, Computer Science, Kinesiology and Theatre.
- The motivation for study ranged from general interest, and from several students having fathers who were firefighters,
- Potential employment opportunities for those students taking the course as part of the fire concentration included: Cal Fire, National Parks or Forest Services, Fire Safe Councils, Hotshot or Hand crew member, entry into the Wildland Firefighter Apprenticeship Program.
- Temporary summer employment in a Hotshot Crew allows participation in the management of all phases of fire suppression activities including initial and extended attack, fire line construction, hose lay construction, fire operations and mop-up and responsibility for the operation and maintenance of specialised tools or equipment. Temporary employment in a Hand Crew allows participation in prescribed burning duties such as assisting with fire dispatch through operation of radios and telephones to exchange information for fire weather and other forest suppression activities.
- Several students were keen to become a City (or Municipal) Firefighter. Entry to this employment is apparently very competitive so to do this they were planning to get

experience in the US Forests Service and already had or were planning to get Emergency Medical Technician training certification.

- Student A was a former undergraduate at Cal Poly and completed in 2004. He gained work but then had the opportunity to do a MS. Few undergraduate students were interested in continuing on with a MS but several would “maybe do one later”.

Entry pathways

- Many of the students in Student Group 1 were already in the workforce and were studying part-time and still working or, less commonly, had taken a leave of absence for full-time study. These students had come from the US Forest Service, Cal Fire and a residential tree care company.
- Student A was a former undergraduate at Cal Poly and completed in 2004. He joined the workforce but was encouraged by his employer to do a MS.
- Student B was an undergraduate in the 1970s and had always intended to do a MS but never had the time to do it. Once he retired he could fulfil his dream and draw on his vast experience of working in the fire industry.

Competing universities

- Cal Poly was a popular choice for students concerned with becoming a career firefighter as this university is certified by the Federal Wildland Fire Service Association.
- The location of the campus was an attraction for some students (i.e. beach culture and local mild climate).
- The University of California Berkeley was not a popular alternative choice as it is very research focused and tuition is too expensive. The courses on offer were too limited and were no what many students were interested in.
- The Forestry and Natural Resources degree at Cal Poly was viewed to be ‘well rounded’ compared to degrees offered at other universities.

2.4. University of Colorado Boulder, Department of Geography

2.4.1. The university and department

The University of Colorado Boulder (UC Boulder) is a public research university located in the Rocky Mountains region. It was established in 1877 and has become the flagship campus representing the four universities in the University of Colorado System. It offers approximately 3400 courses in 150 fields of study spread across 78 degree programs at the Bachelor level, 56 at the Masters level and 53 at the PhD level. In 2013, there were more than 24 500 undergraduate and 5000 postgraduate students. Arts and Sciences is the biggest discipline capturing nearly 70% of student enrolments. There are approximately 3800 Faculty academics with a similar number of Adjunct Fellows, Emeritus Professors and researchers. The University of Colorado Boulder is not a land-grant university and was awarded more than \$380 million in sponsored research funding in 2012.

The Geography Department sits within the College of Arts and Sciences and is responsible for fire-related teaching and research at UC Boulder. The Department broadly covers all aspects of physical geography (climatology, geomorphology, biogeography, arctic and alpine systems, hydrology, global change), social geography (population, political, urban, social and cultural geography; human dimensions of environmental change; natural resources; conservation behaviour) and geographic information science (GIS, cartography, remote

sensing). There are 23 Faculty academics, 15 Adjunct, Emeritus Professors and researchers and approximately 80 postgraduate students in the Department.

2.4.2. Courses offered

There are no fire-specific undergraduate or postgraduate courses on offer at UC Boulder but there are several fire-related courses described below. In addition, there are opportunities for Internships and Honours projects that investigate aspects of fire ecology and management. MS and PhD students attend a scheduled seminar series.

Environmental Systems 1 – Climate and Vegetation (first or freshman year)

“This course introduces the atmospheric environment of the Earth including elements and controls of climate and their implications for hydrology, vegetation, and soils. The distribution of physical features across the surface of the Earth and interactions between humans and their environment are emphasised, especially those leading to global change on the decade to century time scale.”

Environment and Culture (second or sophomore year)

“This course examines nature-culture interactions and the effects of development and resource use on environmental quality, as well as practical efforts to manage and protect the environment.”

Environments and Peoples (fourth or senior year)

“This course studies the interaction of people and the environment, including human adaptation and modification of environments, cultural interpretation and construction of landscapes, and natural resources and land management.”

Seminar Series – Comparative Environmental Studies (postgraduate level)

“The literature and presentations selected in this seminar series is used to critically examine cross-cultural experience with adjustments to natural hazards and political management of resource exploitation.”

Seminar Series – Impacts on Forest Dynamics and Disturbance Regimes in the Rocky Mountain Region (postgraduate level)

“In this seminar series both fine- and coarse-scale patterns of tree mortality and their consequences for ecological communities, disturbance regimes and selected ecosystem processes are explored. The focus is on the Colorado Rocky Mountains but literature derived from studies conducted elsewhere is also used. The approach is multi-scale from individual tree mortality responses to landscape and regional-scale responses of tree populations and disturbance regimes to broadscale climate variability. The literature included will be diverse ranging from ecophysiology to dendroecology to climate science, and the goal will be to integrate this diverse literature by focusing on key issues and questions.”

2.4.3. Educator perspectives

I talked with Faculty academics and in the Department of Geography (see Appendix 1) about current fire research and supervision of postgraduate students. We touched on the need for empirical ecological research but also social research and education, particularly in light of recent fires in Colorado.

- Education and research relating to wildfire is extremely important in Colorado. The last big fires in Colorado were in 2002 (>4000 ha) and the most recent ones were in June–July 2012. The largest fire in the local area – the ‘Hyde Park fire’ – was located

just west of Fort Collins. It burnt almost 88 000 acres (35 600 ha). The most important fires were called the 'Waldo Canyon fires' which burnt nearly 17 000 acres (7000 ha) and devastating communities around Colorado Springs, the second largest city in the State. Pike National Forest was burnt. Approximately 35 000 residents were forced to evacuate, houses were looted and displaced bears were a threat. There were 1534 firefighters on the ground and 165 National Guard troops were mobilised to maintain order. <http://www.thefiscaltimes.com/Articles/2012/07/02/Colorado-Fires-Charred-Communities-Still-on-Alert.aspx#page1>

- Fires in 2010 that were close to Boulder were not extensive in size but resulted in significant loss of homes. Many studies have shown that fuel treatments such as tree thinning in an area 200 ft (60 m) from buildings made little difference to saving them. More important is the removal of fuel close to the building such as removing flammable debris and cutting grass. Even the most basic knowledge such as replacing timber or shingle roofs or closing windows when houses are evacuated is not being used for building protection.
- Unfortunately, despite this knowledge, the research and management money is still going into fuel treatment and there are many ongoing debates around who should pay for it.
- Current research includes: (i) Spruce beetle and wildfire interactions under varying climate in the Colorado Rockies; (ii) WildFIRE PYRE: Feedbacks and consequences of altered fire regimes in the face of climate and land-use change in Tasmania, New Zealand and the Western US; (iii) Wildfire regime shifts in Southern South America from tree-ring reconstructed fire history networks: climatic controls, land use and ecological feedbacks. Current PhD and MS students are involved in research in all of these projects.
- The second project has exchange internships for undergraduate students associated with it (<http://wildfirepire.org/education/courses>).
- Wildfire research in Colorado has really been driven by a few researchers with diverse backgrounds and viewpoints – a hydrologist, a historian, an economist and a fire statistician.
- It is often stated that the length of the fire season has increased and there is now “an unprecedented amount of wildfire in the landscape”. This declaration has been strongly debated, once using data relating to fuel accumulation (or lack of) and fire suppression but now using data relating to climate change. A series of recent papers outlining correlations among fire activity and climate variability have renewed the debate.

2.4.4. Student perspectives

The focus of my investigation at UC Boulder was on postgraduate students (MS and PhD) as there was no opportunity to interview any undergraduate students (mainly because there was no Forestry or Natural Resource Management degree and no fire-specific courses offered). I had face-to-face interviews with nine postgraduate students and, from their responses, I found similar themes of limited experience with wildfire or the fireground as an undergraduate and the outstanding reputation of Faculty academic staff being an impetus for further study. The backgrounds of students interviewed ranged from undergraduate degrees in Evolutionary Biology, Ecology and Geography.

Employment opportunities

- Three students expressed their interest in becoming tertiary-level educators. They did not necessarily want to teach courses devoted to fire science – but rather to teach aspects of Geography, Resource Management, Ecology, Forestry and Biology in relation to fire. Two of the students wanted to remain in the university system as Postdoctoral Fellows to continue fire-related research. This viewpoint was not encountered at any other university visited and probably reflects the very academic nature of their research advisors. One student will probably take on a full-time teaching position at a community college and a second wants to teach in a small private university with her greatest focus being on teaching, not research.
- One student was expecting to find an international postdoctoral position investigating disturbance history using a range of tools.
- The remainder of the students aspired to research-based positions in State or Federal government agencies. Unlike student interviewees from other universities, only one of the students at UC Boulder had previously worked in a State or Federal government agency for an appreciable amount of time.
- PhD students are relied on for some of the undergraduate teaching at UC Boulder. Current teaching duties include delivering lectures in an introductory course called *Climate and Vegetation* (a General Education class) which has a strong fire component (e.g. plant adaptations to fire, fire in the tropics). One PhD student helps with undergraduate teaching by demonstrating for Introductory Geography (approximately 120 students) and Biogeography (20–30 students).
- A strongly held view by one student is that what is taught in the class is too conceptual and much different to gaining experience by being around fires. However, some of the abstract (e.g. related to fire behaviour) is necessary, it cannot be ignored or taught any other way.

Motivation to study

- The majority of students admitted that they had little wildfire experience prior to beginning their postgraduate studies but several had since gained on-ground fire training (e.g. Red Card accreditation and Basic Wildland Fire certification), had worked in fires crews or has gained management experience through casual employment (e.g. with the local County Council) during the course of their current degree.
- For a number of students, their motivation to study wildfire came from graduate classes given by a fire researcher at UC Boulder or another university. As described by students from UC Berkeley, it was also common for an initial interest in wildfire to come from being a field assistant as an undergraduate student.
- For one student, his first interest in fire came from when he was a field assistant as an undergraduate student working on a project investigating the influence of fire cycles on bird populations. There were no fire-specific courses available during the BS studies of this student and the closest he came to studying fire was a course in Forest Ecology.
- For a second student, an interest in fire developed during her undergraduate degree in Environmental Science with a field trip to the Biscuit fire. Here the student group talked to fire managers and gained a greater awareness of the science and policy of fire.
- For a third student, the attraction of working at UC Boulder came from doing a project at a nearby research station and later securing paid work there. This work was based

on animal disease and the student eventually wanted to return to research on trees. Her choice of studying at UC Boulder was also determined by the quality and reputation of the Faculty academic staff.

- One student was highly motivated to study but was time-limited and PhD studies obviously conflicts with other needs.
- Friends who had worked in Hot Shot and Hand Crews provoked further interest in fire management and this familiarity has helped several students in their PhD studies and teaching.

Competing universities

- For all of the students interviewed, the choice to study at UC Boulder was determined by the quality and reputation of the Faculty academic staff in general. Studying at UC Boulder provided an opportunity for students to commence (regardless of level of fire experience) or to continue research in an area of interest and to work with a high profile fire researcher. Because of this, all students expressed a high degree of passion for their research and strong loyalty to their advisors.
- The location of the university and the surrounding natural environment was also an attraction. The University of Colorado Boulder was chosen by one student because it offered high quality ecology and education programs and was close to family.
- For several students, their undergraduate studies were completed in eastern US and were taught that “forests never burn”. Only with exposure to other forest systems in western US has this ‘myth’ been dispelled.

Other considerations

- Although one student admitted to having limited experience on the fireground, through the work done in the field, this student felt that he had developed a good relationship with fire managers and has gained some insight to fire from friends who were on fire crews.
- One student was a visiting PhD candidate fulfilling the requirement to spend some of her candidature outside Europe. She has spent 9 months at UC Boulder previously and had returned for a further 3 months. While in the US she has been investigating beetle outbreaks in the northern Rockies but this research will not go into her final thesis. Instead, it is destined for a manuscript. Her background includes BS and MS degrees and now a PhD in Forestry, all completed at the same university.
- According to the Italian Ministry of Education, University and Research (2012), the number of tertiary institutions offering undergraduate and postgraduate degrees in forestry (listed as ‘Science of Forestry’ or ‘Science of Forestry and the Environment’) was: BS – 17; MS – 14 and PhD – 14. At the undergraduate level, there are no courses that can be described as being fire-specific but fire-related course such as Forest Ecology will make reference to the ecological effects of fire. At the MS level, eight of 14 institutions offer courses with explicit reference to fire (e.g. *Fire Ecology and Post-fire Restoration*; *Prevention and Recovery of Forests after Fires*; *Forest Management Planning and Fire Prevention*). Again, courses on offer may be fire-related (e.g. *Natural Disturbances*; *Forest Landscape Management*).

2.5. Colorado State University, Warner College of Natural Resources

2.5.1. The university and department

Colorado State University (CSU) was established in 1870 as the Colorado Agricultural College as a land-grant institution. In 1935, the College became the Colorado State College of Agriculture and Mechanic Arts, and in 1957 was given its current name. Colorado State University has eight colleges and 55 academic departments with about 1600 full- and part-time Faculty academics. Bachelor degrees are offered in 65 areas of study, with 55 Masters degrees, 40 PhD degrees and a professional degree in Veterinary Medicine. In 2013, there was about 22 500 undergraduate students, 3800 graduate students and 550 veterinary students. Approximately 75% of students are from Colorado, 21% are from out-of-state and 4% are international students.

The Department of Forest and Rangeland Stewardship in the Warner College of Natural Resources has five academic departments:

1. Ecosystem Science and Sustainability
2. Fish, Wildlife and Conservation Biology
3. Forest and Rangeland Stewardship
4. Geosciences
5. Human Dimensions of Natural Resources

The Department offers undergraduate and postgraduate programs in a wide variety of disciplines in Forestry, Natural Resources Management and Rangeland Ecology. There are 20 part- and full-time Faculty academics, 300 undergraduate students and approximately 80 Masters and PhD students in the Department. There are three majors on offer at CSU:

1. Forestry
2. Natural Resources Management
3. Rangeland Ecology

Within these majors there are seven 'concentrations' including:

1. Conservation and Management
2. Forest Biology
3. Forest Management
4. Forest Fire Science
5. Forestry Business
6. Range and Forest Management
7. Restoration Ecology

An additional offering from the Department is an online degree in Fire and Emergency Services Administration (<http://www.online.colostate.edu/degrees/fire-services/>). This degree is tailored for career firefighters and first responders who want to develop their careers and prepare for promotion. Most students in the program should have at least five years of work experience and typical students are currently employed as career or volunteer firefighters, paramedics, emergency managers, prevention and code compliance trainers and wildland firefighters. The academics interviewed had little contact with teaching or administration of this degree.

2.5.2. Courses offered

The concentrations including Forest Biology, Forestry Management and Forest Fire Science are accredited by the Society of American Foresters. In 2012, approximately half of the students were doing a Forest Fire Science concentration and 45% were doing Forest Management. The remaining concentrations attracted far fewer students. Fire-specific courses include:

Fire Effects and Adaptations (third or junior year)

“Fire is an important component of ecosystems worldwide. In this course, the concept of the fire regime, plant and animal adaptations to fire regimes, fire history methods, and community and ecosystem responses to fire are introduced and current issues in fire management are discussed.”

Wildfire Behaviour and Management (fourth or senior year)

“In this course, the chemical, physical and ecological aspects related to wildland fires are explored and the basics of fire management and policy are investigated. The class is divided into four parts: (i) combustion and behaviour of wildland fires, (ii) measurement and assessment of the fuel complex, (iii) introduction to fire ecology, and (iv) fire management. In the first two parts of the class, factors that influence fire behaviour are discussed and basic fuels and meteorological measurements used in wildland fire are covered. In the fire ecology section, the ecological effects of wildland fires on plants, wildlife, air and water are investigated. In the management section, current fire and fuels management strategies are described and the connection between fire management and ecology is highlighted.”

Advanced Wildland Fire Management (fourth or senior year); also called ***Forest Fire Meteorology and Behaviour*** (postgraduate level)

“In these two courses, the fundamental concepts related to the physical and chemical concepts governing fire behaviour are explored and these processes are connected with management and the ecological effects of wildfires. Although much work has been done to scientifically understand fire over the last 500 or more years, the complexity of the phenomena we know as fire has created difficulties in our ability to advance further understanding. The lack of progress has resulted in several scientists suggesting that we need to move away from traditional approaches which have used the methods of ecologists and foresters to ones which are more fundamentally based on concepts related to the physical and chemical mechanisms which underpin wildland fires.”

Fire Economics and Policy (fourth or senior year)

“Fire economics and policy are rapidly evolving in response to an increase in the presence of fire as a major topic in the natural resources field. This course includes current policies, economic theory and quantitatively based methods and relies heavily on microeconomics including both consumer theory as a foundation for valuation and on production theory and the production function for development of the operating models and for policy interpretation.”

Fire Ecology (postgraduate level)

“Fire is a fundamental ecological process in terrestrial ecosystems around the world, affecting individual organisms, populations, communities and ecosystems. The effects of fire vary immensely over time and space, depending on conditions of weather, topography, fuels and species. Plants, animals and microbes exhibit an amazing variety of adaptations that allow them to survive – even thrive – in the presence of fire. In this course, several fundamental questions about the role of fire in ecosystems around the world are examined in depth. Some of the key themes of the course include: scale, spatial and temporal

heterogeneity, evolutionary context, interacting effects and influences, methodology, limits of our knowledge and human influences on 'natural' fire processes."

Current Research in Fire Ecology (undergraduate and postgraduate level)

"This course covers current topics in the field of fire ecology and provides opportunities for students to interact with scientists and managers. There are bi-weekly presentations by prominent fire ecology, fire science and fire management researchers. The topics for discussion include interactions of climate change and fire, interactions between bark beetles and fire, Burned Area Emergency Response treatments and effectiveness, challenges to modelling fire behaviour and wildland fire management."

2.5.3. Educator perspectives

I had the opportunity to interview three Faculty academics (see Appendix 1), all of whom are involved in teaching. Their responses are loosely grouped into topic areas and are not specifically attributed to any one person.

Education potential

- There was considerable discussion around certification of fire education courses, not only for accreditation in forestry and fire management but also in areas such as ecology and biology.
- One of the main stimuli for such certification is that the Federal government has a history of hiring people with no formal training to do ecological monitoring and research.
- It has been proposed by the Education Committee of the Association for Fire Ecologists (AFE) that there are different levels of expertise that can be accredited such as a professional (or senior) ecologist and technical (or junior) ecologist for monitoring pre- and post-fire burning. A way in which the different levels of expertise can be recognised has been trialled by this group.
- The first round of fire ecology 'certification' was held in 2011 – six people applied, five were accepted and one person is on probation. Course such as those on offer at CSU could be used as part of the certification process. If successful, it would be a good way to advocate for more courses to be provided and appealing for more teaching staff.
- The College hosts STARFire – a spatial fire planning system that allows planners and managers to evaluate the risks of wildland fire while restoring and maintaining resilient landscapes (<http://warnercnr.colostate.edu/research-and-outreach/departmental-research/starfire>). It is also the home for the Colorado Forest Restoration Institute – a group that aims to act as a bridging organisation among researchers, land managers and communities to advance the knowledge and practice of forest restoration and wildfire hazard reduction in the central Rocky Mountain region (<http://coloradoforestrestoration.org/>).
- There is a very strong 'fire lab' called the Western Forest Fire Research Center. The centre promotes interdisciplinary solutions to fire management problems in Colorado including fuel management, ecosystem restoration, suppression and rehabilitation. Many of the students interviewed were supervised by the Faculty academics associated with this centre and therefore have access to educational and training facilities (see Fig. 1C; <http://warnercnr.colostate.edu/research-and-outreach/centers-and-institutes/westfire>).

Funding sources for postgraduate student research

- The main funding body for wildfire science, the Joint Fire Science Program (JFSP), awards up to \$200 000 to postgraduate students as part of the Graduate Research Innovation Award. This is a very good incentive for research students but it is highly competitive with only five to six grants awarded each year. The main focus is not to fund PhD projects but to value-add to them and enhance what was already planned. This scheme has been modelled on the National Science Foundation Dissertation Improvement Grant. The JSFP also funds travel grants for postgraduate students which are administered through AFE.

The student cohort

- At CSU there is considerable flexibility in undergraduate degrees, at least until the third year of study. Students are encouraged to take courses that are non-traditional for credit or as non-credit to pursue outside interests.
- As I found in California, many students transfer from community colleges to university. There are also a relatively high number of students that transfer within CSU to the Natural Resource Management degree. There are fewer students that transfer into Forestry.
- To teach Fire Science there has to be basic instruction about concepts such as fire behaviour and fuel physics but then students also have to learn about value systems ('good fire, bad fire') as well. It is increasingly important to make students aware of the social and political aspects of fire.
- The Fire and Emergency Services Administration degree is fairly self-contained and there is little teaching interaction with Faculty academics. It is advertised along with undergraduate degrees but there is little academic take up given the applied scope of the degree. A similar 'wildland-urban interface' training tract is being planned.

The National Fire Plan (2000) identified four main areas for planned funding:

1. Strategic targeted suppression
2. Fuel reduction
3. Restoration of fire into fire-adapted systems
4. Social capacity

Despite this, the majority of funding is still directed towards fire suppression.

- One academic was familiar with the on-line teaching modules available for fire in the Northern Territory and was enquiring if a similar teaching aid was being developed for southern Australia.

2.5.4. Student perspectives

I was fortunate to be able to interview small groups of undergraduate and postgraduate students over the course of several days. I spoke to a total of 18 undergraduate students and three postgraduate students. The majority of the students had a clear idea of what they were studying and why they were doing it. The students were very focussed and dedicated.

Employment opportunities and motivation to study

- Student A is doing a Structural Fire major through a different college but has joined the Department for non-credit courses in Emergency Management training and is

taking an introductory fire course as an elective. Once this student has completed his studies he is planning to become a firefighter for a few years then will use his degree in another way.

- Student B is interested in wildland fire and will probably not do any further studies once his degree is completed. He aims to be an Engine Captain but is completing his degree 'just in case'.
- Student C is doing a concentration in Fire Science and once he has completed his degree and gained few years of ecologically-based field experience, he will return to do postgraduate study in watershed management. He has a very clear idea of his future career direction.
- Student D is doing a concentration in Fire Science but plans on becoming a firefighter for a few years before applying for more permanent employment in fire management and planning.
- Student E is a Business student doing a MBA but had the opportunity to do a postgraduate course in another faculty. This is a common practice as a certain number of credit points can be gained from other faculties and departments.
- Student F is doing a BS in Wildlife Management concentration through the Department of Biology but a fire-specific course was interesting from a management perspective. She plans to go straight to a MS after her undergraduate degree and then find employment in Federal government or embarking on a PhD.
- Student G is doing a concentration in Forest management but admitted that if he had taken a fire-specific course earlier in his degree he probably would have changed his concentration.
- Student H is doing a concentration in Fire Science but has had no fireground experience. In this case, he has more than 200 hours of professional training in the army and will probably return to this profession after his degree. Student I also has a military background and is doing a BS in Wildlife Management but has no clear idea of a future career.
- Several students were doing fire-specific courses as part of Forestry or Natural Resource Management majors. These students would be looking for work with the State or Federal government or with some form of land trust.
- Student J is a MS student that had gained more than 10 years of field experience before coming back to do further studies. This student realised that if he wanted to pursue a research career then he would need additional skills. He did get 30 credit points on the basis of his prior experience.
- Student K is a MS student with a background in Forestry. This student had extensive field work experience in the National Parks Service but this did not include experience of the fireground. Regardless, he was responsible for investigating the impacts of fire management when he was in the Federal government sector.
- Student L did her undergraduate degree at CSU and was following up with a MS. She was from another Department but was participating in postgraduate classes from interest. Her career ambition is to either teach at a smaller university or to become a researcher in the State or National Forest Service.

Entry pathways

- The majority of the students interviewed applied for the degrees they wanted and were accepted for study. There was only one internal transfer but that was from a

similar degree. One student had no clear idea of what he wanted to study so began doing a degree in Arts then transferred to Science and then to Forestry based on “an interest in fire and working outdoors”.

- None of the students interviewed transferred to CSU from community college but several had left their previous employment to study.
- One postgraduate ‘followed’ a Faculty academic from a different university to work with the same advisor.

Competing universities

- As with other land-grant universities, one of the major attractions for study at CSU was that certain courses are accredited for the forestry and fire industries. The Natural Resource Management degree was an important attraction for several students.
- Some students had even enrolled at other universities but were not satisfied with the degree offerings and therefore transferred to CSU.
- The local natural attractions (e.g. snowboarding and forests) attracted several students to CSU for their degrees as well as being the ‘local’ university for several others.
- Several students applied for entry into the Municipal Firefighter Academy but it was very competitive and entry requirements were high. Fire Science at CSU was a second choice.

Other opportunities and considerations

- Student loans are an important consideration for future studies. Tuition and board at a residential college costs approximately \$18 000 per annum and degrees are typically 3–4 years duration. After graduating, these loans need to be paid off and students need to gain experience in areas they want to pursue.
- There is an active chapter of SAFE at CSU (<http://warnercnr.colostate.edu/student-association-for-fire-ecology>). This group holds informal discussions in the ‘CSU Fire Lab’ and invites guest speakers for lectures and discussions.
- One feature of the local SAFE group is that they have some unique contacts for organising fire training exchange and an opportunity for students to attain their Red Card. Such an exercise was organised in 2011 for burning on some property owned by the Nature Conservancy. Five students applied to the University for funding for travel, food and accommodation and the Nature Conservancy, and local land managers organised for loan of the gear required. There were plans to do this the following year with a cohort of 10 students.
- On-line learning opportunities were thought to be useful but could not replace hands-on experience or ‘classroom’ teaching.

2.6. Northern Arizona University, School of Forestry

2.6.1. The university and department

The Northern Arizona University was established in 1899 as a public school. It was originally called the Northern Arizona Normal School and from 1925 to 1929 the school was known as the Arizona State Teachers College. It was also called the Arizona State College but since 1966 it has been the Northern Arizona University (Drickamer and Runge 2011). The main campus is located in Flagstaff but it has 36 satellite campuses across the state. Across the

University there are 87 undergraduate degree programs, 58 postgraduate degree programs and 68 on-line degree programs. There are 19 320 students enrolled at the main campus in Flagstaff (2013 census) and another 7000 students at other campuses or on-line. This cohort is served by 2590 part- and full-time Faculty academics and approximately 3500 support staff within seven colleges. The majority of students come from within Arizona (71%) and 3% of students are international.

The School of Forestry is within the College of Engineering, Forestry, and Natural Sciences. The forestry program was created in 1958 and members of the School were located in the Blome Building. In 1960, the School moved to the northern part of the campus and two years later, the Forest Service constructed an office and laboratory facility close by (Drickamer and Runge 2011). A stronger alliance was formed with land and fire agencies when the Forest Service (both State and Federal) commissioned construction of the Southwest Forest Science Complex for joint office and laboratory facilities. There are 28 Faculty academics working in the broad areas of ecology, sustainability and forest science. The campus is located near the largest contiguous area of Ponderosa Pine forest; there is a School Forest (the NAU Centennial Forest) of approximately 19 000 ha of forest woodland and rangeland; and is only 130 km from the Grand Canyon National Park, all of which provide important teaching resources.

2.6.2. Courses offered

Students can do a BS in Forestry, a Master of Forestry (coursework only) and MS and PhD research degrees. The Forestry degree is nationally accredited by the Society of American Foresters. The first two years are devoted to general education including introductory forestry courses, biology, chemistry, mathematics, economics, public speaking and English. The third and fourth years specialise in directed coursework, internships and individual and group projects. For fire-specific training, students can do the GS-0401 Series Certificate in Fire Ecology and Management. This qualification provides a strong background to students and working fire professionals that are interested in studying fire or working in natural resources on fire management and general land management issues. This certificate may be completed concurrently with a degree program or as a stand-alone certificate.

Introduction to Wildland Fire (second/third or sophomore/junior year)

"This course provides an introduction to the science of wildland fire, the role of fire in forested ecosystems and wildland fire management."

Fire Monitoring and Modelling (third or junior year)

"This course introduces key fire monitoring protocols used by federal land management agencies along with several different types of models used to predict fire effects and fire behaviour."

Fuel Treatments and Modelling (third or junior year)

"In this course, the history of fire management in the US is described. There is discussion of fuel treatments available – their success and ecological effects. Students learn about how fuel models are used as a way to evaluate which fuel treatment is most appropriate in a given stand."

Fire Ecology for Professionals (fourth or senior year)

"Wildland fire is a disturbance force with important ecological and social implications in most of the world's ecosystems. This course integrates ecological and cultural aspects of wildland fire, providing an ecological foundation for fire managers and professionals."

Fire Ecology and Management (fourth or senior year)

“This course examines the ecological and cultural aspects of wildland fire, including fire regimes, fire effects, and the principles, techniques and challenges in present-day wildland fire management.”

2.6.3. Educator perspectives

I had the opportunity to interview two of the two Faculty academic staff responsible for teaching fire-specific courses (see Appendix 1). In addition, I interviewed the Course Coordinator responsible for the certificate for professional fire training. The points that were raised during one-on-one interviews are loosely grouped into topic areas and are not specifically attributed to any one person.

The student cohort

- Northern Arizona University provides basic and mid-level Wildland Firefighting certification (e.g. up to Firefighter II, Types I and II) but any higher certification needs considerable on-ground and managerial experience.
- Teaching at NAU includes a mix of training through classroom work for core and elective courses and assessment and practical work during seasonal placements with on-going evaluation by supervisors.
- Throughout the university degree or certificate, a ‘taskbook’ is compiled with evidence of all of the incidents attended during practical work and what was done coursework. Experience is viewed as being paramount in the fire industry.

Education potential

- Research interests of the Faculty academics interviewed include:
 1. Effects of fire severity on the overstorey composition and structure
 2. Understorey vegetation and fuels and post-fire rehabilitation
 3. Understanding the long-term patterns of fire regimes and how fire regimes are regulated by climatic patterns
 4. Relationships among vegetation structure, composition and diversity and disturbance regime (e.g. fire, livestock grazing, timber harvest)
 5. Application of field experiments and simulation models to develop and test practical management strategies for conserving forest ecosystems

All of these topics have the potential for postgraduate research.

- The Burned Area Emergency Response (BAER) program is administered through the National Interagency Fire Center. The aim of the program is to provide ‘first aid’ after wildfire to protect life, property and water quality and to prevent ecosystems from further damage after the fire is out.
- The objectives of the BAER program are to:
 1. Determine if an emergency condition exists after the fire
 2. Alleviate emergency conditions to help stabilise soil, control water, sediment and debris movement, prevent impairment of ecosystems, mitigate significant threats to health and safety
 3. Monitor the implementation and effectiveness of emergency treatments

- This program has strong links with Faculty academics and researchers at NAU so there is the potential for undergraduate studentships and postgraduate research projects. One student interviewed mentioned gaining field experience as part of this program.

Other considerations

- One Faculty academic described the Southwest Fire Science Consortium (SFSC) as she is the Principal Investigator and together with a Coordinator, is an integral part of the organisation of research, workshops and field trips.
- The consortium is a way in which local managers, fire scientists and policy makers can interact and share information. The goal of the SFSC is to provide and communicate the best science to make management decisions and for scientists to be researching topics that are important for managers. The SFSC is purported to be the only regional organisation of this type and it crosses discipline, agency, administrative and state boundaries.
- The JFSP supports the SFSC by funding two to three workshops or field trips annually and for smaller travel grants for individuals. There is also funding to develop on-line material such as working papers or 'Wildfire Lessons Learned' stories and for hosting webinars (<http://swfireconsortium.org/>).

2.6.4. Student perspectives

I had the opportunity to present a lecture to a group of students taking the *Introduction to Wildland Fire* course. There were 20 students in attendance, five of whom were doing the Certificate in Fire Ecology and Management. I also had the chance to interview three postgraduate students, attend a scheduled SAFE meeting and to join a very informative student field trip to the 2010 Schultz Fire Burn Area (see Fig. 1D).

Employment opportunities and motivation to study

- Students A and B both have considerable practical fire experience (structural or seasonal Hand crew) but they want to get a degree to make a difference to their career progression. Student A became interested in fire as an intern in the Forest Service.
- Students C and D transferred internally from Engineering. One student is interested in post-fire recovery of plant and animal communities and the other was influenced by having family in firefighting. Student C sees himself either going into the airforce or emergency management training after completing a tertiary degree.
- Student E has no experience in fire but still wants to be a wildland firefighter.
- Students F, G and H are studying journalism, information technology and archaeology, respectively, and were taking an introductory wildland fire course out of interest and to gain final credit points.
- Student I was deciding between specialising in structural firefighting or wildland firefighting so was taking the course to help decide where his interests lay.
- Student J is a postgraduate in the early stages of research. This student's research project has only a small fire component (land management-based) and she did not take any fire-specific units as an undergraduate or during her MS and was taking a postgraduate course to learn more about fire ecology. This course is a student-led discussion of relevant papers. I attended such a class and the students were

discussing the effect of fire and feral animals on native animals, including those in Australia.

- Student K is a mature age student doing a MS. He had been a wildland firefighter since 1994 and had remained in the profession despite not having any tertiary qualification. Prior to starting a MS he did a BS degree in Interdisciplinary Studies.
- Student L is a postgraduate student nearing completion of a MS. His experience included the retail and restaurant industry and an undergraduate degree in Business and Marketing. He is applying previous knowledge gained in the type of research he is doing but it has little scope for wildfire.

Entry pathways

- Student D enrolled in Forestry “on the spur of the moment” as it meant that he did not need to relocate. He plans to transfer to another campus of NAU once he has decided what degree he wants to do.
- One student was a career firefighter but had left this profession. He decided to pursue tertiary education by beginning in community college. This pathway will allow him to stay in the area of fuel management and have some sort of leadership role.
- Student L gained a considerable number of credit points towards his MS degree from a quite unrelated undergraduate degree.

Competing universities

- Student J chose to do a PhD at NAU as she had worked with Forest Services in Arizona and had developed a good relationship with local land managers. She chose a university in Arizona despite doing her BS and MS degrees through universities in California.

Other opportunities and considerations

- Northern Arizona University has a very active SAFE group and I was invited to attend a scheduled meeting. At this meeting there was information exchange about upcoming jobs on Fire Crews and distribution of promotional t-shirts and hats. As a highlight of the meeting, a workshop on ‘How to write a resume’ and a description of the governmental ‘Pathways Initiative’ had been organised. The latter is a scheme to inform students and recent graduates about programs for internships, jobs for recent graduates, and applications for Presidential Management Fellows with the Federal government. Unlike SAFE groups in California, only two students were attending the AFE conference in Oregon in December so there were no overt fundraising activities planned.

2.7. University of Arizona, School of Natural Resources

2.7.1. The university and department

The University of Arizona (UA) is a public land-grant university which was founded in 1885. It is located in central Tucson and is said to be the oldest continually maintained green space in Arizona. There are approximately 38 000 enrolled students undertaking Bachelor, Masters, PhD and professional degrees across 334 fields of study (2013 census). The main catchment for students studying at UA is Arizona (72%), with a considerably smaller proportion from California (10%) and from out-of-state (12%). International students comprise approximately 6% of the total enrolment at UA.

The School of Natural Resources is within the College of Agriculture and Life Sciences. The College was founded in 1889 and delivers the land-grant component of the University. It

administers a variety of programs at ten regional agricultural centres and delivers extension activities to Federal, State and County governments and agencies. The College provides career pathways into a wide range of areas including: agribusiness, government, public service agencies, retail and service industries, conservation and environmental organisations, farming and ranching, research extension and education. There are 40 Faculty academics, 18 Adjunct and Emeritus staff and 24 researchers in the College.

The School of Natural Resources hosts the Institute of the Environment, a group which facilitates cross-faculty collaborations (e.g. Schools of Engineering, Social Sciences, Agriculture and Architecture) to research a variety of environmental challenges. Fire-related teaching and research is also offered through the Laboratory of Tree-ring Research (LTRR). This is another example of cross-faculty collaboration with joint appointment of Faculty academics from a range of Schools and Departments (e.g. School of Natural Resources, Anthropology, Geosciences).

2.7.2. Courses offered

Both fire-specific and fire-related courses are described here (previously only fire-specific course have been listed) as the Faculty academics interviewed have a strong role in delivery of the fire-related courses. The fire-related courses proved to be seminal in the decision to pursue fire-related research for many of the students interviewed. A selection of the courses described is required for the Graduate Certificate in Dendrochronology which is offered by the LTRR to UA and non-UA graduates and non-degree seeking professionals.

Introduction to Wildland Fire (third or junior year)

“This course provides students with a broad, balanced understanding of fire as a biophysical process. Fire is explored from many perspectives, including physics, ecology, biogeography, management, policy and economics. The course strives to make the study of fire interesting and relevant in the contemporary world by examining how such factors as climate change, invasive species and land use influence how fire interacts with the landscape, and how human activities affect fire as an Earth system process. A range of fire management strategies are examined including fire suppression, prescribed fire, wildland fire use and landscape restoration ecology. The course provides a global perspective on fire, with primary emphasis on ecosystems of western North America. This course is a requirement for all students doing a Watershed or Rangeland Management degree.”

Fire Ecology Seminar (undergraduate and postgraduate level)

“Fire ecology is the study of role that fire plays in ecosystem function and structure. Fire is a keystone process in grasslands, shrublands, savannahs and many forested systems. Recent anthropogenic changes – such as the spread of invasive species – are changing the fire regimes of many ecosystems, including the Sonoran Desert. In the southwest, recent large fires may be pushing ecosystems past their ‘tipping points’ into new configurations. These and other topics are studied in a student-led seminar format, reading and discussing papers in classic and current literature. Students in this seminar obtain a broad, informed view of the roles that fire plays in a variety of ecosystems in a changing world.”

Wildland Fire Management (postgraduate level)

“This course covers the following topics: principles of fire behaviour in forest, range and other vegetation types; interrelationships of fuels, weather and topography; pyrolysis and combustion processes; effects of fire; fuels inventory; prevention, detection and control techniques; fire danger rating and fire behaviour modelling. A research paper on a specific fire issue or problem in the professional discipline area of each student is required.”

Climate Change Adaptation: Perspectives at the Nexus of Science, Society and Resource Management (postgraduate level)

“In this course, the actions required to reduce vulnerabilities or increase resilience to the potential impacts of climate change are examined. Each of the class sessions is designed to include thought-provoking presentations by practitioners, land managers and researchers to combine state-of-the-art science and theory with on-the-ground realities. While the general focus is on impacts and responses in the arid southwest (e.g. water, fire, species, ecosystems), the tools, philosophies and frameworks for action and incorporating adaptation planning at the local-, regional-, national- and international-scale are investigated.”

Ecology of Savannas, Shrublands and Woodlands (postgraduate level)

“Ecosystems comprised of co-occurring herbaceous and woody plants form a continuum between grasslands with little woody vegetation and forests with nearly complete coverage of woody plants. These systems are variously referred to as savannas, shrublands, parklands and woodlands and represent a substantial portion of the terrestrial biosphere. This course examines how woody and herbaceous life forms in such systems interact; how their interactions are influenced by climate, soils and disturbances such as herbivory and fire; and how changes in the relative abundance of grasses, shrubs and trees affect ecosystem processes and wildlife habitat. The concepts and principles covered in this class are broadly applicable to the conservation and progressive management of dryland ecosystems characterised by dynamic mixtures of herbaceous and woody vegetation.”

Introduction to Dendrochronology (undergraduate and postgraduate level)

“In this course students learn the scientific basis, techniques and applications of dendrochronology. The biological basis of tree-ring research and the central principles of dendrochronology are studied. The students learn about applications of dendrochronology in different disciplines via lectures and discussions with leading dendrochronologists at the LTRR. During intensive, weekly laboratory sessions and a weekend field trip students learn the practical skills of specimen collection, preparation, observation, and the most important method and principle of dendrochronology – cross-dating. At the end of the course, students should be able to collect tree-ring samples, prepare and date the samples and build a local chronology. Students will be able to evaluate dendrochronological analyses, and interpret their own data for specific research issues.”

Teaching resources include the Santa Rita Experimental Range, a 21 ha property south of Tucson in Pima County, Arizona. It lies at the foot of the north-western edge of the Santa Rita Mountains and is characterised by long, gently sloping alluvial fans and small areas of steep, stony foothills and a few isolated buttes. The property is the longest continuously active rangeland research facility and is one of the oldest biological field stations in the US. The Walnut Gulch Experimental Watershed (15 000 ha) surrounds the city of Tombstone in southern Arizona. The watershed was established in the 1950s to study floods and the impact of soil and water conservation on runoff. Historical records indicate that most of the Walnut Gulch Experimental Watershed was grassland approximately 100 years ago but the lower two-thirds of the watershed are now dominated by shrubs.

2.7.3. Educator perspectives

I had the opportunity to interview four Faculty academics involved in fire education (see Appendix 1). Each educator provided a unique perspective as their involvement in teaching as their research interests were so broad. Only one of the interviewees was directly involved in delivery of fire-specific courses but the others delivered fire-related courses and have research interests in which fire is an important component. The comments made are listed

below and arranged into several common themes and are not specifically attributed to any one person.

The student cohort

- In 2012, the distribution of undergraduate majors was estimated to be 90% in Natural Resource, 5% in Ecology and Evolutionary Biology and 5% in Geography.
- Regional forest and fire agencies often have close collaborations with local universities and rely on them for a pool of students for seasonal fieldwork. As has been the case with many of the undergraduate and postgraduate students interviewed at other universities, a strong interest in fire research has come from seasonal work with a local or regional agency.

Education potential

- Fire-related research interests of the Faculty academics interviewed include:
 1. Fire regimes, disturbance interactions and fire-climate relationships
 2. Restoration ecology
 3. Climate change adaptation, climate variability and drought
 4. Decision support and the effective delivery of science to decision makers

These broad areas of research are available to postgraduate students for study.

- Arizona University offers degrees in Range Management and Watershed Management but not a degree that will certify students for working in forestry or fire agencies. Instead, potential forestry and fire professionals come to AU for research-based degrees such as MS or PhD. Postgraduates tend to look for employment in State or Federal land management agencies, non-government organisations or to pursue a career as an academic.
- If postgraduates pursue a career in State or Federal land management agencies they may be involved in 'place-based' science as local monitoring technicians or in regional units as regional flora, fauna or fire managers. From a research perspective, graduates could be employed by the Forest Service in a role similar to CSIRO scientists in Australia.
- The National Advance Fire and Resource Institute is based in Tucson, Arizona. It is described as being a national centre for training of interagency wildland fire professionals (<http://www.nafri.gov/index.htm>). This Institute serves the practical needs of fire and land management.
- Fire professionals already in agencies can also go to university to become further qualified. Another route is via a community college or through a fire training academy.
- It was estimated that fewer than half of the Fuel Management Officers in Arizona have a tertiary degree.
- One lecture I attended for the course *Introduction to Wildland Fire* was about techniques and tools for fire suppression. It was delivered jointly by the District Forester and Assistant Fire Manager from the Arizona State Forestry Division. One presenter was a recent graduate from UA. The information provided was very practical with basic theory (e.g. fire triangle, ignition sources), duties on the fire line (e.g. hand crew, dozer driver, smoke jumpers) and a description of personal protective gear worn.

Fire research and policy in the US

- Science-based land management has only really been in existence since 1970 when National Environmental Policy Act was created. As a consequence of the Act, land managers with PhD qualifications are being employed. Similarly, as a result of the Fish and Wildlife Services Act, 'research' has shifted from simply monitoring plants and animals to 'adaptive management', a process for which knowledge of the biology and ecology of organisms is needed. The situation has arisen that there are people in agencies that do not have the research experience required, for example, for dealing with the consequences of climate change.
- Fire policy in the US is in a 'tangle' as it is still largely suppression-based. Fire is a natural process and will also change according to climate change. This needs to be accounted for in policy and practices.
- There are very few examples of fires that can be left to burn naturally – the single most complicating factor is patterns of land use.

2.7.4. Student perspectives

At AU I had the opportunity to interview nine postgraduate students in two group sessions over a two-day period. There was a more-or-less equal division of students who had completed the undergraduate degree (BS) at AU and were now continuing on with postgraduate degrees with those students that had come from other universities. The majority of students had no direct fireground experience but all had become interested in studying fire through previous employment or undergraduate internships, or, in two cases, personal experience of fire on family properties.

Employment opportunities and motivation to study

- Student A has spent eight years studying at AU beginning with a BS in Geology. The first time wildfire really came to the attention of this student was through large fires with extensive loss of property in 2000 and 2001. Unfortunately, property belonging to the family was damaged and this made an obvious impression. Practical experience has come from being a field assistant with the BAER team. This led to a move to another state to work in offices of the Forest Service working on aspects of fire history. After several years, this student decided that more academic training in the form of postgraduate studies was needed as she was not 'qualified' for research work required of her.
- Student B described the range of flexible courses on offer as an undergraduate student. The example used was a course called Landscape Disturbance Ecology that was developed after the Horseshoe Fires in 2011. It was a Tier 2 course so attracted fewer credit points than a planned Tier 1 course. It consisted of four meetings to discuss the fire with a field day at the burnt sites. Eight students took up the offer.
- Student C did an undergraduate degree in Anthropology at AU and is now doing a PhD. As an undergraduate, this student could do a course in tree-ring analysis and enjoyed it so much that it became a minor field of study.
- Student E had no formal educational background in fire ecology prior to starting a MS at AU. However, on the basis of an undergraduate degree with biology and ecology he gained considerable field experience in post-fire ecology and dendrochronology in another state. He came to AU with a specific project to research for his degree.

- Student H is an out-of-state postgraduate student. This student had gained experience field experience working in the National Parks Service and the Peace Corps as an environmental volunteer.
- Student I did an undergraduate degree at UA and is now doing PhD. Field experience includes seasonal firefighting and research experience was gained as a Research Assistant for a Faculty academic.
- Many of the postgraduate students were continuing with their studies because of their positive experience during summer internships or field camps. If the student was already interested in pursuing a research career, these placements often consolidated the idea that the student wanted to work on some aspect of fire.

Entry pathways

- Student C had worked in another state but came specifically to AU to work in the Tree-Ring Research Laboratory.
- Student G did an undergraduate degree in Geography at AU and while doing an introductory course about dendrochronology gained an interest in wildland fire.

Competing universities

- Students overwhelmingly chose AU for postgraduate studies based on the reputation of Faculty academics and the world-class facilities for dendrochronology.
- Students described a very collaborative research environment among students and Faculty academics and suggested that there would be few other universities that could claim to achieve this.
- According to student perspectives, AU has a reputation for teaching both applied and fundamental science.

Other considerations

- Students appreciate the chance to take courses outside their intended field of study. For example, Student F described completing a MS in Canada which allowed access to a 'continuous' Department of Biology in which course were on offer from four different universities.

3. Discussion

Through the course of my visit to eight universities in California, Colorado and Arizona, I interviewed 20 fire educators, 30 postgraduate students and 116 undergraduate students in group and face-to-face interviews. A number of themes related to employment opportunities, motivation to study, entry pathways and university choice emerged for undergraduates and postgraduates. These themes were generally reinforced when fire educators were consulted. There were two clear groups of students – those that had their sights set on careers in forestry, wildland firefighting and land management and those that wanted to pursue research-based careers, whether in academia or with State or Federal government agencies. Within each of these groups there was a range of fire experience from career wildland firefighters with 10+ years of fireground experience to little-to-no familiarity with fire at all.

Student loans were an important consideration for current undergraduate students and any future tertiary studies they may undertake (e.g. MS and PhD). Tuition and board at a residential college costs approximately \$18 000 per annum and degrees are typically 3–4 years duration. After graduating, these loans need to be paid off regardless of whether students are working in the area they want to pursue as a career.

3.1. A career in wildland firefighting

Half of the universities visited cater for tertiary education and professional training and development of wildland firefighters – HSU, Cal Poly, CSU and NAU. These universities all have a strong emphasis on forestry and natural resource management. In each of these universities there are at least six fire-specific courses on offer at undergraduate and postgraduate level. At HSU, all students doing the Forestry degree are required to take an introductory fire course regardless of whether they are doing a fire major. Interestingly, Forestry students at this university suggested that all biology graduates should be required to take this course. At Cal Poly, CSU and NAU, students from other Faculties are encouraged to do fire-specific courses for course credit.

Students doing a Forestry degree at HSU, Cal Poly, CSU and NAU gain accreditation as a 'Forester' in Federal employment. A similar accreditation is not yet offered in 'Wildland Firefighting' but the fire concentration or specialisation in BS Forestry degrees from these universities all satisfy the education component of the federal requirements for GS-0401 training (Red Card; for example see <http://nau.edu/CEFNS/Forestry/Degrees/Certificates/Fire-Ecology-Management/>). In addition, students have the opportunity to accrue at least some of the practical experience required for this certification during their undergraduate degree by working on fire crews during the summer season.

The universities listed above all have close links with local State and Federal forest and fire management agencies and students are regularly used to populate seasonal fire crews. This arrangement is most formally organised at Cal Poly with organisation of their own fire crew to provide support to the local area in exchange for fireground experience for students to obtain their Red Card. There was a similar arrangement at HSU but insurance costs and liabilities have made it impossible to sustain. Students at CSU were taking the initiative and using local contacts to organise group-based fireground experience to gain their Red Card. Electronic and more traditional paper notice boards are used to advertise openings for seasonal fire crews at these universities (e.g. see <http://nres.calpoly.edu/news.ldml>).

Professional training for firefighting is also supplied by other non-tertiary institutes such as the National Advance Fire and Resource Institute in Arizona and the Municipal Firefighter Academy in Colorado. A degree in Fire and Emergency Services Administration is administered through CSU but does not involve Faculty academics. Almost all municipal fire departments require a high school diploma or equivalent. Some require college-level credits while others require the completion of a fire fighting training program from an educational institution that teaches fire protection/fire control and/or paramedic skills. A number of areas award preference points in the hiring process to those who have earned college credits. Some of the students interviewed were deciding between a career in municipal firefighting and wildfire fighting (which requires GS-0401 accreditation) and were taking a variety of fire-specific courses to inform their decision.

Many of the mature-age students interviewed were doing a BS or a MS for career progression in the fire industry. Some individuals had taken an absence-of-leave from their current position and a smaller number were being sponsored by their employees. Apart from fulfilling their GS-0401 training requirements, these students were seeking progression beyond management on the fireground to more senior managerial roles. One student valiantly saw this as a means to have an effect on the bureaucratic structure "from the inside".

3.2. A career in research

The other universities visited – UC Berkeley, UC Santa Barbara, UC Boulder and UA were more academically-based and, although fire-specific courses were on offer, they were not geared towards professional forestry or wildland firefighting accreditation. The extreme case was witnessed at UC Boulder where there is a large research group in the Geography Department with strong research interests in fire (and good research links to Australia), but only fire-related courses are offered by the College, the most relevant of which are limited to postgraduates (e.g. 'Seminar Series'). Regardless, the focus on fire education was clearly evident. A similar situation was found at UC Santa Barbara. This 'level' of fire education is similar to what is on offer in many tertiary institutes in Australia – a strong research component but little structured learning in formal lectures and classes (Table 1). The University of California Berkeley and UA offered at least three fire-specific courses and correspond to the 'upper level' of formal tertiary fire education available at only a few universities in Australia (e.g. University of Melbourne, University of Western Sydney). Of course this is no reflection on the quality and quantity of informal fire education on offer to research students at tertiary institutes across Australia.

There were many instances when students admitted to enrolling in a fire-specific course out of interest or because they had little experience or knowledge of fire and were undertaking a research project involving fire. This pattern was more prevalent with students at UC Berkeley, UC Boulder and UA but also apparent for students at HSU, CSU, NAU and Cal Poly. At NAU and Cal Poly, students from other faculties were encouraged (and rewarded with credit points) to take fire-specific courses. 'An interest in fire' is likely to be the same motivation that we find in students in Australia. At UC Berkeley and UC Boulder, several students claimed that their interest in studying fire at a postgraduate level initially came from attending a relevant seminar series. In these cases, the reputation of the adviser was of considerable importance. In at least two cases, students who did a fire-specific or fire-related course as an undergraduate went on to change the focus of their degree.

A proven method of 'recruiting' postgraduate students is to offer an internship over the student non-contact summer period. This position may or may not be paid and generally provides researchers with field support for on-going projects (see Box 5 for an example). This is a strategy that has been used in the research groups by the fire educators interviewed with a high degree of success. For example, one student came to UC Berkeley to do paid field work and, after completing the internship, this student applied to do a postgraduate degree. The pattern was found to be common for research-based universities such as UC Berkeley, UC Santa Barbara and UC Boulder.

Undergraduate students at Cal Poly and NAU and postgraduate students at UC Boulder were particularly keen to explore the possibilities for summer exchange to work with forest, land management and fire agencies in Australia. The desire for exchange to work with university academics or researchers was not as great. Faculty academics were also very interested in pursuing a scheme to facilitate student exchange.

The International Association of Wildland Fire (IAWF) currently act as a broker for student exchange, internships and scholarships (see an example posting in Box 6). The IAWF is a professional organisation that promotes better understanding of fire and provides a worldwide link with people interested in fire and fire management. Communication is achieved with publications such as a magazine devoted to fire (*Wildfire*), a peer-reviewed journal (*International Journal of Wildland Fire*), regular and periodic conferences and summits (e.g. The Fire Behaviour and Fuels Conference, Human Dimensions of Wildland Fire), webinars, and an email list-server (FIRENET).

Box 5. An example of an advertisement for summer internships (from <http://cnr.berkeley.edu/stephens-lab/>).

The Fire Science Lab hires full and part time undergraduate technicians, field assistants, and graduate researchers during the academic year and field seasons (summer). Students and graduates with an interest or background in fire, forestry, ecology or a related field are encouraged to apply.

Closing date: 1 April 2013 or until filled

Pay range: \$10–\$14 per hour

Housing: will be provided at research site(s)

Length of positions: employment period is from 8 to 16 consecutive weeks between May and September 2013

More information: see specific positions listed or contact project manager for specific project(s).

Qualifications: work experience or coursework including field exercises covering the following:

- Ability to work in a multi-agency, diverse environment, in a manner consistent with safe forestry practices.
- Ability to learn basic vegetation identification, measurement techniques, including use of tree measurement tools.
- Ability to learn safe power tool operation and maintenance.
- Use of spreadsheet applications; ability to use or learn to use hand-held data recorders, radios and other field equipment
- Safe operation and care of manual transmission vehicles.
- Willingness to learn new skills.
- Coursework or experience in forestry, natural resources management, forest ecology or related field is desired but not required.
- Outdoor savvy – familiarity with navigation by map and compass, basic first aid training.
- These positions are 90%+ field work. Field Research Assistants will be exposed to hot dry or unpredictable weather, rough terrain, insects, high elevations and other environmental conditions; must be capable of sustained physical work under these conditions.
- Approved personal safety equipment may be required by differing projects.

Box 6. An example of the communication mechanisms of scholarships and internships (from <http://nres.calpoly.edu/news.ldml>).

Posted by IAWF Thursday 30 January 2014

“In an effort to continue to promote the scholarly pursuits and graduate level training within the global wildland fire community, in 2014 the International Association of Wildland Fire (IAWF) will again be awarding two graduate-level scholarships, each valued at \$3,000USD to IAWF members who are Master of Science (MSc) or Doctoral (PhD) students studying wildland fire or wildland fire related topics. We encourage applications from students studying any aspect of wildland fire, be it from the perspective of physical, ecological or social science to less traditional subject areas as well. We are looking, through this scholarship, to recognize and support any type of research relevant to the global wildland fire community.”

3.3. The 'pool' of forestry and fire professionals

It has been estimated that there are approximately 14 000 permanently employed wildland firefighters in the US including Hot Shot crews, Smoke jumpers, Fire Prevention Technicians, Type I crews and other firefighters (Bracmort 2013). This figure does not include seasonal Type II crews or administrators and support personnel. In Canada, determining the number of people employed in the fire sector is somewhat harder to establish. The Canadian Wildland Fire Strategy (Canadian Council of Forest Ministers 2005) states that the forest industry directly employs more than 376 000 people, many of whom would be involved in fire management in some way. It is equally difficult to determine numbers of bushfire firefighters, administrators and support crews in Australia. To provide some level of indication, the number of people employed in forestry, logging and wood manufacturing was 75 800 in 2010 (ABARES 2011). In addition, the Australasian Fire and Emergency Authorities Council represents a workforce of over 250 000 emergency management professionals including volunteers and career staff (<http://www.afac.com.au/about>), but not all of these people will be directly involved in fire management. The number of academics and researchers that could claim to be working in fire-related areas in Australia, Canada and the US and could claim to be 'fire professionals' is unknown and probably more dependent on funding opportunities and the scattered and sporadic nature of planned and unplanned fires than on the supply of tertiary-trained people.

Along with an inability to determine definite numbers of fire professionals in Australia, Canada and the US, it is difficult to determine if the demands by fire and land management agencies in the US for suitably trained and qualified wildland firefighters are being met adequately. There are mitigating circumstances around establishing this including reliance of operations on state and federal funding availability and annual budget justification, changing requirements for firefighters in 'normal' and 'extreme' fire years, and increased environmental, training and safety legislation. Kobziar *et al.* (2009) recognises that the duties of US fire professionals have become more complex because of changes in fuel load due to historical fire management strategies, increased fire in the landscape due to climate change and the increasing risk associated with an expanded wildland-urban interface. It may be that agencies are simply 'making ends meet' with the human resources they have. This situation applies equally for Canada and Australia.

Kobziar *et al.* (2009) recognised that the most important way to improve tertiary education opportunities for fire professionals is to establish a mechanism for universities, agencies and other relevant bodies to discuss and plan education requirements for fire professionals and the ways in which to achieve what is needed. In addition, there needs to be cooperation between tertiary education providers and agencies to identify career paths to ensure that future fire professionals achieve the education, training and experience needed. These are both excellent suggestions for the current situation in the US where a tertiary degree is required to comply with GS-0401 accreditation training. Perhaps more relevant in Australia and Canada, where accreditation does not require tertiary-level education but is more reliant on certification through training is the suggestion for multi-agency collaboration to provide: (1) input into course development, (2) university access to training courses, and (3) access for students to experience real fire situations.

3.4. Recommendations from this and other projects

As a background to this report, a number of important recommendations made by State and Federal government enquiries in Australia were listed (see Boxes 1–3). While they are not likely to have an immediate or even a direct effect on professional training or tertiary education in fire they have a more general capacity to:

- maintain or increase tertiary education in forestry and fire,
- encourage postgraduate studies into fire research by improving the financial situation of students, and
- encourage postgraduate studies into fire research by increasing post-doctoral opportunities through job security.

It is clear that there is no single professional or governmental body in Australia that can or should be expected to drive these reforms. For example, land and fire management agencies are state-based and would only be concerned with training and educational needs within their borders; professional forestry or fire agencies are practically-orientated and technical training and industry accreditation is likely to feature more prominently than tertiary education. Unless it becomes a national requirement for fire professionals to hold a tertiary degree as in the US, an investment of time and money into relevant higher education will be limited. Instead, the attention of improving and consolidating tertiary fire education might reasonably fall to the educators themselves.

An excellent example of an educator-driven reaction comes from a recent project tasked to develop a National Soil Science Curriculum (Field *et al.* 2012). A consortium of five universities was involved in developing a set of recommendations for teaching soil science effectively and to produce university graduates with qualities including knowledge, skills and capabilities needed to enter the workforce. A wide range of stakeholders (current students, graduates, other academics, employers and professional bodies) were consulted in the course of the two-year project. In total, 12 recommendations were made for development of a comprehensive curriculum in soil science (see Box 7). Many of these recommendations would make an excellent starting point for development of a common curriculum in tertiary fire education.

There are two recommendations that I can offer from my experiences during this travel.

The first is to do a formal review of the depth and breadth of tertiary-level education related to fire theory and practice that is available in Australia. A parallel review of the training on offer to fire professions in each of the states would also be warranted. Once this type of information was collated, areas of collaboration between agencies and universities could be more easily identified and confidently progressed.

Stemming from the tertiary education review, a second recommendation would be to determine the level of need for a 'common' curriculum in tertiary fire courses –and if decided that it is needed – what such a curriculum might involve. Do our next generation of fire professionals need a general knowledge of operational, theoretical, environmental and social aspects of fire management or is the pathway involving training and 'on-the-job learning' as we tend to use currently good enough?

4. Conclusions

1. Universities visited in the US were either strongly research-focused or provided tertiary education/training for a range of land-based professions.
2. There were two distinct groups of students – those pursuing careers in wildland firefighting and land management and those wanting research-based careers.
3. Students from other Faculties or Departments were encouraged to take fire courses if they were interested.
4. Courses available ranged from six or more fire-specific topics to two or more fire-related topics. The universities involved in provision of professional tertiary education and training had the greater number of fire-specific courses on offer.

5. In the US there is a Federal requirement for a specific level of tertiary education for fire and land managers. The number and type of fire-specific courses on offer from each university reflected this.
6. A review of training and tertiary education opportunities available to fire professionals in Australia is justified and could be the catalyst for collaboration and consolidation of future offerings.

Box 7. Selected recommendations from the National Soil Science Curriculum (Field *et al.* 2012). Square brackets indicate the author's minor modification to wording.

Recommendation 2: 'The contribution of professionals in industry represents an opportunity for further demonstrating [the relevance of research], practical application and provision of real-life scenarios to enable problem-based learning.'

Recommendation 3: 'Ensure engagement with activities that address the core body of knowledge required by industry and the application of scientific rigour to analytical techniques and meaningful interpretation of results.'

Recommendation 4: 'Involve industry through a variety of appropriate methods, including placement of students, guest lectures, mentoring, suggestions and support for projects, and curriculum advice.'

Recommendation 5: 'Utilise enquiry-based learning wherever possible to engage students in critical thinking and problem-solving and help them make connections between concepts in different contexts and systems and minimise rote learning.'

Recommendation 6: 'Engage the students in authentic group activities and problem solving to enhance understanding and develop teamwork and communication skills.'

Recommendation 7: 'Utilise practical laboratory and field activities, particularly field trips, wherever possible to enable the practical application of concepts, and for the students to engage with their teachers and peers.'

Recommendation 8: 'Provide assessments that allow students to demonstrate conceptual understanding as developed by a variety of means.'

Recommendation 9: 'Units of study should progressively build students' writing skills in a range of authentic contexts involving different audiences.'

Recommendation 10: 'Provide opportunities for students to have formative input into how the course is delivered thereby enabling changes to be made as required.'

Recommendation 11: 'Sustain and further develop project outcomes by ensuring continuation of the engagement of national and international organisations, professional bodies and other stakeholders in educational activities.'

5. Acknowledgements

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Appendix 1. Details of professional fire educators visited during this study and their relevant tertiary institutes.

University	Educators	Relevant courses	Speciality
<i>Humboldt State University</i> Department of Forestry and Wildland Resources	Dr Jeffrey Kane Emeritus Prof John Stuart Assoc Prof Morgan Varner Dr Rosemary Sherriff (Geography Department)	<ul style="list-style-type: none"> • <i>Advanced Wildland Fuels Management</i> • <i>Fire Ecology</i> • <i>Fire Management Capstone</i> • <i>Introduction to Wildland Fire</i> • <i>Wildland Fire Behaviour/Fire Behaviour and Use</i> • <i>Wildland Fuels Management</i> 	Undergraduate degree in Forestry Distance education
<i>University of California Berkeley</i> Department of Environmental Science, Policy and Management	Assoc Prof Max Moritz Prof Scott Stephens*	<ul style="list-style-type: none"> • <i>Current Research in Wildland Fire Science</i> • <i>Fire Ecology Seminar Series</i> • <i>Fire, Insects, and Diseases in Wildland Ecosystems</i> • <i>Wildland Fire Science</i> 	Forestry and fire Postgraduate research opportunities
<i>University of California Santa Barbara</i> Department of Ecology, Evolution and Marine Biology	Emeritus Prof Bruce Mahall Prof Carla D'Antonio	<ul style="list-style-type: none"> • <i>Ecology and Management of Californian Ecosystems</i> • <i>Restoration Ecology</i> 	Biological sciences Environmental science and management
<i>California Polytechnic State University</i> Department of Natural Resources Management and Environmental Sciences	Dr Chris Dicus Dr Douglas Piirto	<ul style="list-style-type: none"> • <i>Wildland Fire Control</i> • <i>Fire Ecology</i> • <i>Fire and Society</i> • <i>Technology of Wildland Fire Management</i> • <i>Wildland Fire Management</i> • <i>Wildland-Urban Interface Fire Protection</i> 	Professional fire training for forestry, fire and land managers
<i>University of Colorado Boulder</i> Department of Geography	Dr Alan Tepley Dr Holly Barnard* Prof Tom Veblen	<ul style="list-style-type: none"> • No fire-specific course on offer 	Geography and fire Postgraduate research opportunities

* indicates no availability during visit

Appendix 1. (cont.)

University	Educators	Relevant courses	Speciality
Colorado State University Warner College of Natural Resources Department of Forest and Rangeland Stewardship	Dr Chad Hoffman Prof Doug Rideout* Dr Monique Rocca Prof Skip Smith* Prof Tony Cheng	<ul style="list-style-type: none"> • <i>Advanced Wildland Fire Management</i> • <i>Current Research in Fire Ecology</i> • <i>Fire Ecology</i> • <i>Fire Economics and Policy</i> • <i>Fire Effects and Adaptations</i> • <i>Forest Fire Meteorology and Behaviour</i> • <i>Wildland Fire Behaviour and Management</i> 	Forestry and fire Undergraduate degree in Forestry majoring in Forest Fire Science
Northern Arizona University School of Forestry	Dr Andrea Thode Prof Peter Fulé Dr Molly Hunter* Prof Wally Covington*	<ul style="list-style-type: none"> • <i>Fire Ecology and Management</i> • <i>Fire Ecology for Professionals</i> • <i>Fire Monitoring and Modelling</i> • <i>Fuel Treatments and Modelling</i> • <i>Introduction to Wildland Fire</i> 	Forestry and fire Postgraduate research opportunities Professional certification in fire
University of Arizona School of Natural Resources Institute of the Environment Laboratory of Tree-ring Research	Prof Steven Archer Assoc Prof Don Falk Dr Gregg Garfin Prof Tom Swetnam	<ul style="list-style-type: none"> • <i>Climate Change Adaptation: Perspectives at the Nexus of Science, Society and Resource Management</i> • <i>Ecology of Savannas, Shrublands and Woodlands</i> • <i>Fire Ecology Seminar</i> • <i>Introduction to Dendrochronology</i> • <i>Introduction to Wildland Fire</i> • <i>Wildland Fire Management</i> 	Postgraduate research opportunities Certificate of Dendrochronology

* indicates no availability during visit

Appendix 2.

Forest fires in south-eastern Australia

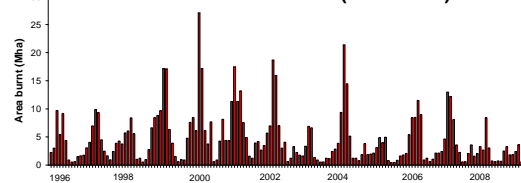
Dr Tina Bell

FACULTY OF AGRICULTURE
& ENVIRONMENT



Australia is a fire-prone country

Area burnt in Australia (1996-2009)



Modified from Giglio *et al.* (2010) *Biogeosciences* 7, 1171-1186

Data sets compiled from four sensors (ATSR, VIRS, Terra MODIS, MODIS) using three methodologies (500 m map, local regression and regression tree)

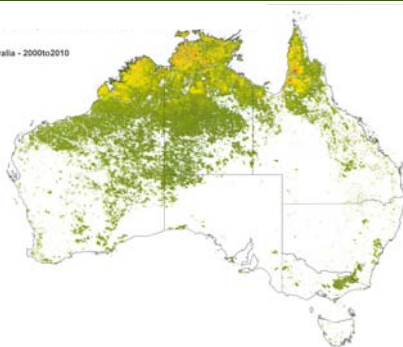
2

Fire frequency 2000-2010

Legend

Fire Frequency Australia - 2000to2010

Years Burnt
 Burnt One Year
 Burnt Two Years
 Burnt Three Years
 Burnt Four Years
 Burnt Five Years
 Burnt Six Years
 Burnt Seven Years
 Burnt Eight Years
 Burnt Nine Years
 Burnt Ten Years
 Burnt Eleven Years



3

MODIS satellite map 10 day period in Jan 2012



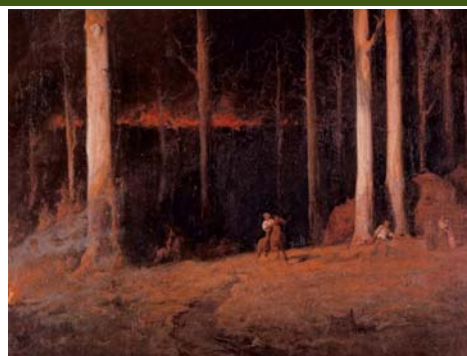
4

Bushfires in Victoria, Black Thursday 1851



5

Gippsland, Sunday Night, February 20th 1898 John Longstaff



6



Major fires in south-eastern Australia

Year	Location	Area burnt (ha)
1993-94	Sydney/Blue Mountains/North coast NSW	>800,000
1995	Southeast Queensland	333,000
1997-98	Hunter/Blue Mountains/Shoalhaven, NSW	>500,000
1997-98	Caledonia River, Gippsland, Victoria	32,000
2001-02	Greater Sydney, NSW	744,000
2002	Stanthorpe/Toowoomba, Queensland	40,000
2002-03	Eastern Highlands, Victoria	1.1 million
2002-03	Brindabella Ranges/Canberra, ACT/NSW	>157,000
2002-03	NSW east coast including greater Sydney	1.46 million
2002-03	Arthur-Pieman, Tasmania	100,000
2005	Eyre Peninsula, SA	145,000
2006-07	Eastern Highlands, Victoria	1.05 million
2009	Central Highlands, Victoria	450,000

7



Not all fires are the same...



8



Prescribed fire in south-eastern Australia



9



Black Saturday fires, Victoria 2009



10



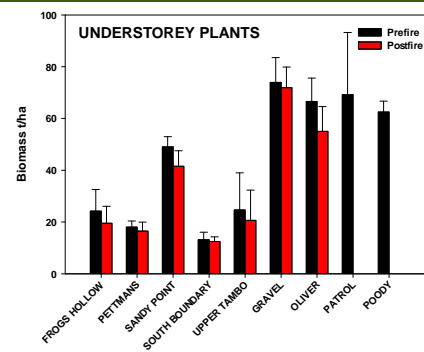
The aftermath can be different...



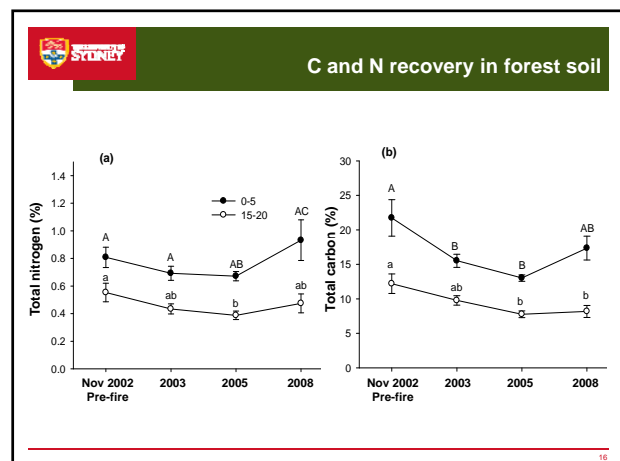
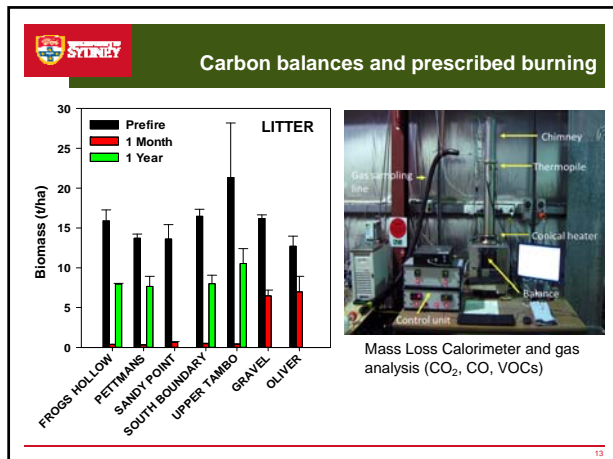
11



Carbon balances and prescribed burning



12





Evidence of past fires



19



Snowgum (*Eucalyptus pauciflora*)



20



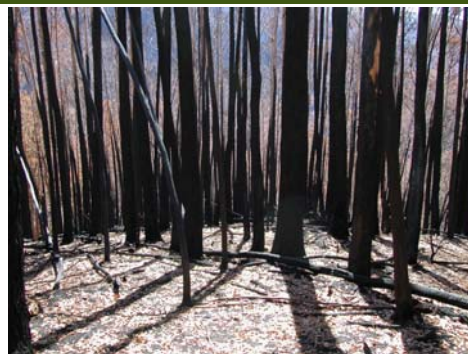
Resprouting from an underground lignotuber



21



Fire-sensitive *Eucalyptus delegatensis*



22



Mass germination of fire-sensitive species



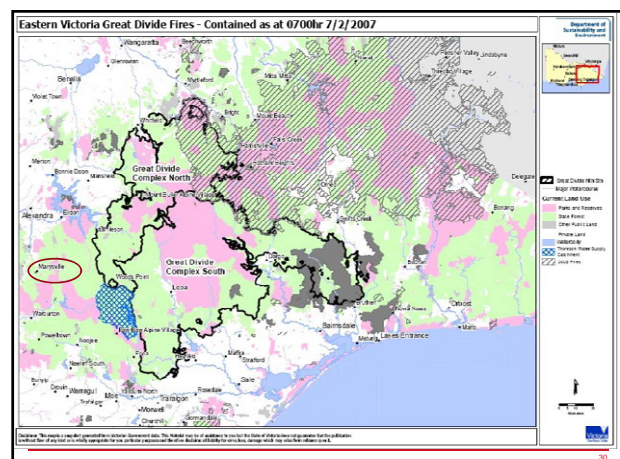
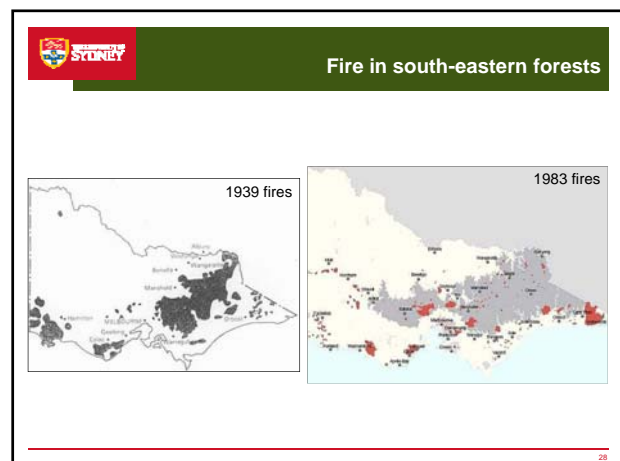
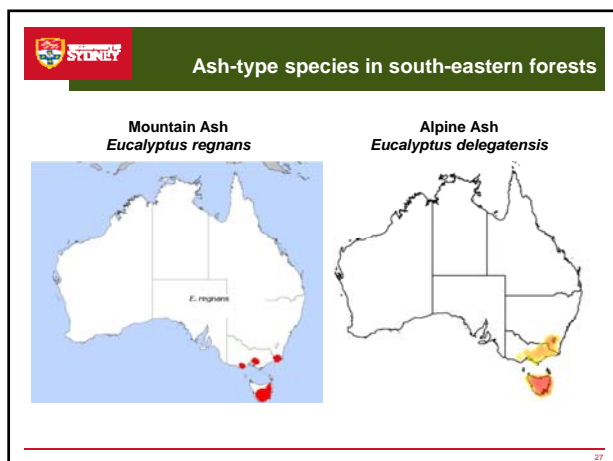
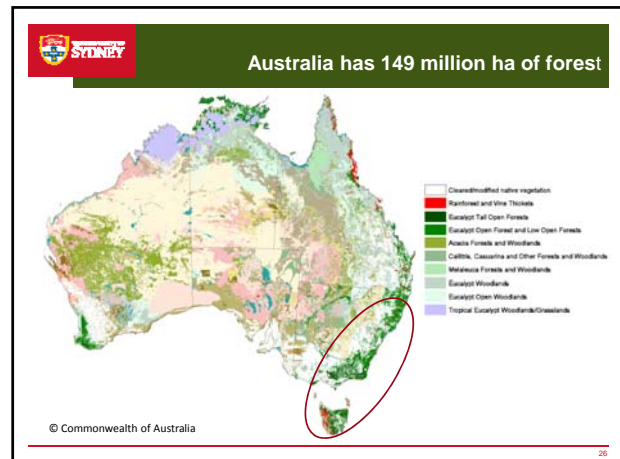
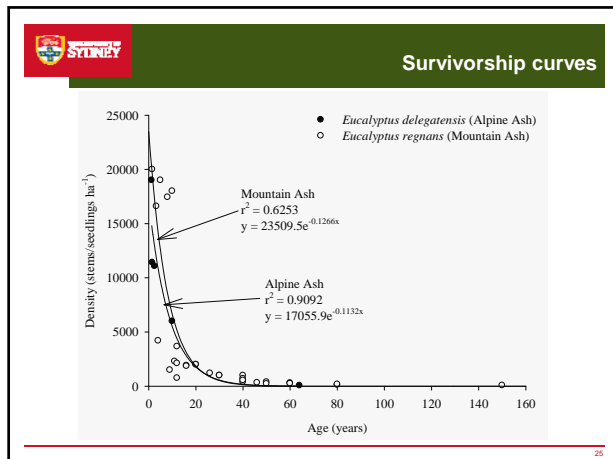
23



Mass germination of fire-sensitive species

Year	<i>Eucalyptus delegatensis</i> (Alpine Ash)		<i>Acacia obliquinervia</i> (Hickory Wattle)
	Overstorey (stems ha ⁻¹)	Seedlings (stems ha ⁻¹)	Seedlings (stems ha ⁻¹)
2005	70 ± 4 (36-143)	12 033 ± 613 (0-58 000)	317 868 ± 6 470 (169 000-542 000)

24





A recovery program was needed

In 2004/05

- › Aerial re-seeding of 3314 ha of Mountain Ash and Alpine Ash forest
- › Hand planting of 183 500 seedlings
- › Salvage logging and site preparation
- › \$5.8 million spent on rehabilitation

In 2009/10

- › Aerial re-seeding of 4500 ha of Mountain Ash and Alpine Ash forest
- › 3500 kg of seed distributed during 250 hours flying time



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Forest catchments in south-eastern Australia

- › Half of the catchments from which SE Australian cities draw water are *E. regnans* forest
- › Half classified as Mixed-species Open Forest (containing specimens of *E. obliqua*, *E. radiata*, *E. dives*, *E. viminalis*, *E. rubida*, *E. globulus*, *E. mannifera*, *E. macrorhyncha*, *E. baxteri*)



32



Forest catchments in south-eastern Australia

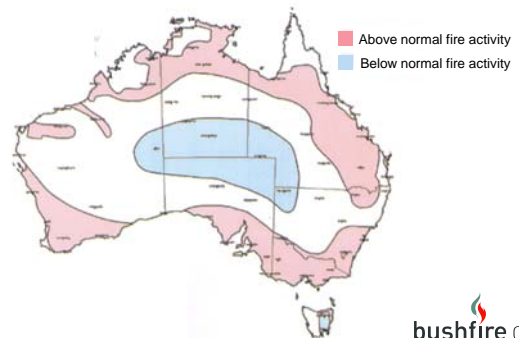
- › Water yield is strongly linked to water use by vegetation – 5% change in water use may result in a 20% reduction in streamflow
- › 3 years after crown fires trees are still bearing epicormic branches and juvenile foliage
- › Structure is changing over time – many small branches distributed evenly along trunk in 2010 to fewer and larger branches in 2012



33



Seasonal outlook 2009-2010

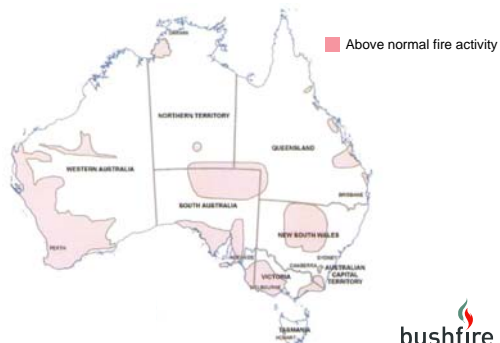


bushfire CRC

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Seasonal outlook 2010-2011

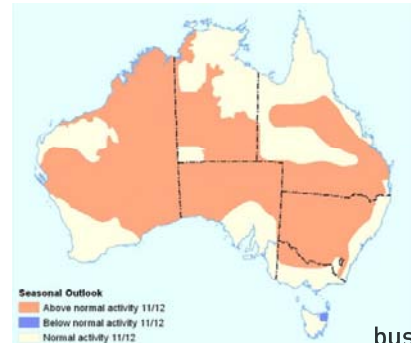


bushfire CRC

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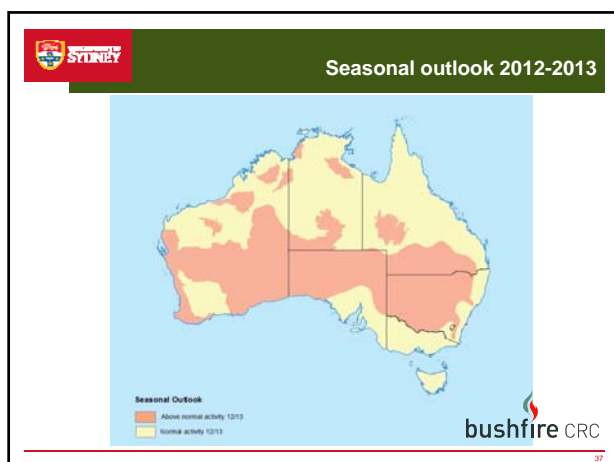


Seasonal outlook 2011-2012



bushfire CRC

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Current fire research in FA&E

- › Smoke composition and the effect of smoke on vegetation
- › Forest carbon balance and formation of black carbon
- › Post-fire tree water use and impacts on water catchments
- › Interaction of fire with:
 - woody weeds
 - *Acacia* and other legumes