Department of Social Sciences
Faculty of Humanities

People, Fire, Forest and Water in Wungong:

The Landscape Ecology of a West Australian Water Catchment

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature:………………………………………….

1st. June 2010

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Dedication

I dedicate this work to my beloved wife, Yvonne, for her patience, over many years, with my bushfire obsession. I'm not a pyromaniac, honest.

I also dedicate it to my fire-fighting friends in the Volunteer Bushfire Brigades, the Forest Products Commission, and the Fire Management Branch of the Department of Environment and Conservation. They are the ones who actually have to 'put the wet stuff on the red stuff'. It is hot, gritty, smoky work.

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I also thank Dr. Ian Colquhoun, and his employer, Alcoa of Australia, for funding a small generator, and the laptop computer on which this thesis was written. I am slightly less enthusiastic about their mining rehabilitation in the catchment. I still bear the scars from giant prickle bushes. Perhaps Alcoa can plead unwise advice from an employee of the former Forests Department.

Finally, I thank all officers of the West Australian Department of Environment and Conservation for their help with various permits and permissions, especially Mr. Greg Standing of Jarrahdale. The DEC librarian at Como, Ms. Deborah Hardie, was unfailingly helpful. Dr. Ian Abbott, of the West Australian Department of Environment and Conservation, kindly read, and commented on, some of my musings. He also contributed some data.

Abstract

Bushfire is, in terms of human lives lost, property destroyed, and damage to natural systems, by far the most urgent environmental problem in Australia. This thesis tries to answer a number of questions about bushfire behaviour, history, effects, and management, in the Wungong Catchment of Western Australia. It does so by an overtly cross-disciplinary approach, involving a mixture of the three main streams of human knowledge, namely the humanities, natural science, and social science.

First, I offer a literature review of several hundred books and papers drawn from the three main streams of knowledge mentioned above. The review includes some discussion of 'bushfire epistemology', a currently vague and neglected matter.

The concept of 'place' is important to humans, so I then give a straightforward geographical description of Wungong Catchment, with some mention of the history of bushfire. To describe the vegetation, I use inductive statistics, and a method developed by me from the ideas of Delaunay (1929) and Dirichlet (1850). Given that there are hundreds of plant species within the catchment, I use a landscape approach, and only sketch the main tree species, and two iconic plants, the *balga* and the *djiridji*, both of which are important to the original custodians of the catchment, the *Nyoongar* people. There is discussion of other people's research into the effect of bushfire on seed banks, and the flowering intervals of some plants of the *jarrah* forest.

To see if Western Australia is anomalous, or fits into the worldwide pattern of humans using fire as a landscape management tool, I then examine some records of bushfire in other lands, including Africa, Madagascar, India, and Europe. The thesis then looks at the history of fire in the *jarrah* forest of Western Australia, based on observations by early European explorers and settlers from 1826 onward, the views of various foresters, and some opinions of current *Nyoongar* Elders.

Using a mixture of natural science, applied mathematics, and archaeology, I give the results of cleaning the stems of those ancient plants called grasstrees, or *balga*

(*Xanthorrhoea* spp.). These carry the marks of former bushfires, stretching back to 1750. They confirm historical reports of frequent fire in the *jarrah* forest, at 2-4 year intervals, and a recent decline in fire frequency. This contradicts the view, held by some, that European arrival increased the frequency of fire.

As support for the *balga* findings, I present a simple mathematical model of self-organization in bushfire mosaics. It shows how lengthy bushfire exclusion can lead to disastrous situations, in which large areas of landscape become flammable and unstable. It shows how frequent, patchy burning can maintain a stable bushfire mosaic, with mild, beneficial fires. In the next chapter, I offer mathematical suggestions on how current unstable mosaics can be restabilized, by careful reintroduction of such burning.

In dry, south-western Australia, water supply is an important topic, and a better understanding of the hydrological effects of bushfire may help with both bushfire and water management. I draw upon the natural science of forest hydrology, and the effects of fire in catchments. The evidence comes not only from Australia, but also from the United States, and South Africa.

Turning to social science, I introduce Professor Peter Checkland's 'Soft Systems Methodology', and suggest how it could be applied in resolving complicated conflict about bushfire management. I finish in legal style, with a summing up, and a verdict on the use of bushfire as a land management tool in Wungong Catchment, and possibly in other flammable landscapes.

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Chapter 1

Mudpies, Hypotheses, and Structure

AN INTRODUCTION TO THE THESIS

All the genuine, deep delight of life is in showing people the mud-pies you have made; and life is at its best when we confidingly recommend our mud-pies to each other's sympathetic consideration.
J.M. Thorburn, Art and the Unconscious, 1925.

Preamble

Although my background lies largely in natural science, this thesis is not entirely scientific, but cross-disciplinary, calling on natural science, social science, and the humanities, in an attempt to understand landscape fire behaviour, history, and ecology, in a place called Wungong Catchment, in south-western Australia. The common Australian (and African) term 'bushfire' is used throughout this thesis to mean fire in quasi-natural landscapes, as opposed to domestic, agricultural, or industrial fires. In North America the term 'wildland fire' is often used. The term 'jungle fire' has been used in India.

Bushfire has both quantitative, and qualitative aspects, and our knowledge of it can be enhanced by both the hard-edged, experimental approach of science, and the softer, more speculative approach of the humanities. Bushfire affects both nature and human society.

In such a complex mix, there is a need for clarity. I am an ecologist, and this thesis involves ecology, yet I intensely dislike the ugly, obscure language that is found in some papers on ecology. An eminent authority on plain language, Sir Ernest Gowers, once gave the classic example of a forty-one word paragraph, from a refereed and published ecological paper, which seems to say that animals move about more than plants, and, after moving, are no longer in the same place (Gowers 1973).

Obscurity is often a sign of having nothing useful to say. I believe that I have something useful to say, so I have tried to keep my sentences clear, and hope readers will forgive any lapses which have escaped my notice, or are, perhaps, beyond my ability to notice. This does not mean that I will always avoid the use of unusual words. English is a rich language, and we should use its vocabulary to the full extent. As George Orwell suggested in his classic book 'Nineteen-Eighty Four', limiting our vocabulary can lead to limitations on our thoughts (Orwell 1949).

I have tried not only to be clear, but also to inject a little life into my writing. In a refreshing paper, in a leading journal of ecology, a Danish biologist, Kaj Sand-Jensen (2007), has called for a more lively approach to scientific communication. Amongst a tongue-in-cheek 'Top-10 list of recommendations for writing consistently boring publications' the author suggests lack of focus, lack of personality, and a lack of humour, combined with numerous trivial citations.

I believe this idea can be extended to all scholarly literature. As well as having a serious purpose, scholarly mud-pies should be fun both to write and to read. I have enjoyed writing this one, and hope the reader, even if not amused, will not be baffled, bored, or dismayed. I have followed the good advice of Kaj Sand-Jensen, and been frugal with references in this chapter. Plenty are given in the literature review in the next chapter.

The Place Studied

Wungong Catchment lies in the *jarrah* forest, in the south-west of Western Australia. The word *jarrah* comes from the language of the *Nyoongar* people, the traditional owners of that forest, and *Wungong* was their name for the main creek which feeds the catchment (*Nyoongar* words are italicised throughout this thesis, as are all words from languages other than English). We are talking about a tall forest of eucalyptus trees (*Eucalyptus marginata*), which shed, every summer, a blizzard of leaves, bark, twigs, and seed capsules. In summer weather, these are highly flammable, and will carry a spreading ground fire, in pure *jarrah* forest, every three to four years. Where there is also a mixture of the trees *marri* (*Corymbia calophylla*) or *coondli* (*Allocasuarina* spp.) the ground litter will carry a spreading fire every two years.

Defining the Thesis

Using Wungong Catchment as an illustration, the thesis itself (*sensu stricto* the proposition) is that Aboriginal people had, and in some parts of Australia still have, a more successful style of managing bushfire, and associated ecosystems, than do present Australian governments and their authorities, both state and federal.

Cross-disciplinary evidence will be presented to support the view that the *Nyoongar* people of south-western Australia, deliberately or accidentally, worked successfully with an inherent self-organizing tendency of bushfire to create stable, diverse vegetation mosaics. These diverse vegetation mosaics satisfied *Nyoongar* needs for a variety of both plant and animal food (Meagher 1973, Hallam 1975) and must have helped to shape the present ecology of the *jarrah* forest. The stability of the mosaics offered protection from vast and dangerous bushfires, such as those seen in recent times in Australia, and in other fire prone lands, such as California.

It is my contention that recent, and present, Australian governments, whether by intent, ignorance, or misinformation, work against that self-organizing tendency, thereby creating unstable bushfire mosaics, severe fires, loss of life and property, and simplified vegetation mosaics. Folly in government is not new. It has been with us at least since the time when the assembled wise heads of Troy chose to pull the wooden horse within the walls, despite the warnings of Cassandra, and her quite rational attempt to set fire to it (Tuchman 1984). Fire is not always bad. Setting fire to things may sometimes be the most rational option, to avoid a great deal of subsequent trouble.

Australian Aboriginal people have been referred to as 'peripatetic pyromaniacs' (Meggitt 1962). Throughout Australia, they have long set fire to things to protect themselves from potentially severe bushfires; to make access easier; to promote the growth, flowering and fruiting of plants (Gott 1999); and so to maximise the yield of animal protein.

There is a contrary view that Aborigines did not use bushfire at the landscape scale, in a deliberate way (Horton 1982, 2000), but this is at variance with the extensive historical evidence, and the opinions of most current investigators, and the Aboriginal people themselves (Rose 1995, 1996, 1997). This matter will be discussed in more detail in following chapters.

It will be argued, through the example of Wungong Catchment, that deliberate burning, in a stable, controlled way, is the best way to protect the *jarrah* forest of Western Australia, and the water catchments in that forest, from future severe bushfires. Evidence will be presented to support the claim that such a bushfire management strategy would protect water supplies; conserve forest biota; and protect human life and property.

As already mentioned, some of the evidence I will present in support of this claim is from the humanities, some from the social sciences, and some from the natural sciences, without assuming that any one of these is, somehow, a superior form of knowledge. It has been suggested that this is the inevitable future of research as we grapple with problems involving both society and nature (Lélé and Norgaard 2005).

Little difficulty is foreseen in various natural sciences working together, but there can be problems when natural and social sciences try co-operating. Some may see economics as the most likely link between nature and society, being concerned with society's use of natural resources, but 'soft systems' studies can make a strong claim too (Vickers 1983, Checkland and Scholes 1999). The 'soft systems' approach recognizes that logic is useful, but that humans do not always behave in a logical way.

In this thesis, some evidence will come from mathematics, and some people may claim that this is a science. My personal view is that pure mathematics is a branch of logic, which is a branch of philosophy, which is a humanity. There is a lengthy discussion of the distinction between the philosophy of mathematics and its practice, in Honderich (1995). However we may classify it, it is one of our most reliable forms of logical reasoning, and is much applied in the sciences. At the same time, if a false initial assumption is made, perfectly logical reasoning will lead to a false conclusion. The reliability, and pitfalls, of models, mathematical or otherwise, will be discussed later.

Defining the Hypotheses

The thesis has four major hypotheses (*sensu stricto* sub-propositions). These are:

1) Before Europeans arrived in Western Australia, and for some decades after, *Nyoongar* people managed the *jarrah* forest landscape by working with a self-organizing tendency of bushfire, so creating a diverse, stable vegetation mosaic, with a finer grain than that which currently exists, and milder bushfires than those which currently occur.

2) *Nyoongar* constructive use of bushfire in the *jarrah* forest was disrupted by European settlement, leading to an unstable, less diverse, and coarser grained bushfire mosaic, with fiercer bushfires at longer intervals.

3) In the Wungong Catchment, a return to something like *Nyoongar* traditional burning, using the advantages of current machinery, communications, and weather forecasting, would avoid the threat posed by fierce fires in an unstable, coarse-grained mosaic, and the water pollution caused by ash, silt, and putrefying dead animals. It would also protect human lives, and nearby settlements, from uncontrollable bushfires.

4) Restoration of a semblance of traditional *Nyoongar* mild mosaic burning in Wungong Catchment would be a useful framework for a rich, cross-disciplinary research program into water catchment management, forest ecology, and the protection of human life and property in the whole of southern Australia, and could provide a template for fire management, in water catchments, in other fire-prone lands. Importantly, the research program should include enquiry into political influence on fire management, which is determined by the mind-sets of both politicians and voters.

The Importance of History

The thesis looks back in time, to pre-European human presence in the *jarrah* forest, including Wungong Catchment, and moves forward to the present day, when there is public controversy over the past and future management of the *jarrah* forest, including the water catchments therein.

I believe that history is an essential part of ecology at the landscape scale. We cannot make sense of landscape without the dimension of time. Simon Schama has written a few poetic, eloquent words on this. 'The sum of our pasts, generation laid over generation, like the slow mold of the seasons, forms the compost of our future. We live off it.' (Schama 1995).

Landscape Ecology

Although, in the title, I use the term 'landscape ecology', I could equally well use the term 'human ecology', or even 'human geography'. All are cross-disciplinary attempts at understanding human interactions with place, and human interventions, over time, in the landscape. It is hard to see where one discipline ends, and another begins, and this, in my opinion, reflects the reality of knowledge. I leave the problem of classifying knowledge into neat packages to academic administrators.

Later in the thesis, in a literature review (Chapter 2 Dodging Disciplines), the metaphor of a 'knowledge swamp' will be introduced. I will try to drive piles into the swamp, and build a creaking causeway over it, wandering, and branching at times, along different paths of knowledge. Some may dislike such uncertainty, and seek disciplinary tidiness, absolute certainty, and concrete foundations. In my view, the creaking in the causeway, often historical, or rhetorical, or even poetic, adds to its interest and charm. As long as we recognise that some parts are creaky, these parts can add useful support, and give adventurous access to parts of the knowledge swamp which might, otherwise, be inaccessible.

This is because, in my view, human knowledge actually advances through a rich mixture of chance and planning, intent and accident, certainty and doubt, order and chaos. That is the road to creative thinking. We should not dull our thinking with the fantasy of absolute certainty and infallible logic. A clear warning comes from mathematics.

In the nineteenth century, it was realised, by some imaginative mathematicians, that Euclid's geometry was not as logically perfect as previously thought (Boyer 1968). We must be cautious about what seem to be axioms, or unchallengeable truths, even when a consensus supports them. History has many examples of situations where a minority was right, and the majority wrong. At the same time, we should be careful to distinguish, if we can, between speculation and reason, and use each in its appropriate circumstances.

Wungong Catchment and Water

With a growing human population, and model-based predictions of drier weather in south-western Australia, water supply is an obvious matter of concern (Water Authority 1995). We should remember that models have a well known element of uncertainty, due to errors of both commission and omission. Some assumptions may be wrong, and there may be omission of essential facts, unknown to the modeller.

However, whether long term predictions of catastrophically drier, hotter weather come true or not, water supply is still a vital matter for the people of Western Australia. At the same time, surface water flow is a useful and decisive way of dividing landscapes to enable local case studies.

In the United States of America, the visionary hydrologist and geologist John Wesley Powell (b.1834) proposed that the western part of North America should be settled water catchment by water catchment, so working with 'nature's intelligence'. He saw water catchments as natural units, where lasting, democratic human communities could arise, sharing water in a responsible way (Worster 2001, 2006).

Unfortunately, he was brushed aside by the bustling engineers and politicians of the day, who saw the future in an energy-intensive system of massive dams and pipelines, pumping water into growing cities, where growing numbers of voters, they assumed, would confirm their choice. An eventual limit to the volume of water available was either not considered, or perhaps was swept under the political carpet.

This thesis adopts the notion that catchments, and sub-catchments, are the basic ecosystems of the *jarrah* forest landscape (Lotspeich 1980). Energy from the sun, and water from rainfall, flow into, and through Wungong Catchment, and its sub-catchments. By means of sunshine, atmospheric circulation, soil formation and development, and drainage, it is energy and water that determine the abundance, diversity, distribution, and survival of plants, animals, and other life forms, such as fungi and soil bacteria.

Human interventions, for instance through logging, mining, water removal or impoundment, and through both the lighting and suppression of bushfires, may change these flows of energy and water, and hence the balance of the biota which depend upon them. We can manage natural landscapes best by working with 'nature's intelligence', shown as a tendency to organise itself, with minimal human intervention. Managing landscape on a catchment basis helps with this.

Thesis Structure

It is difficult to divide a creaking causeway into discrete units, but it must be done, and signposts must be erected. These will make it understandable to, and useable by, others. The thesis is divided into eleven chapters, and below I give outlines of the following ten chapters and their contents:

Chapter 2: Dodging Disciplines
A Literature Review

This chapter is a cross-disciplinary literature review. I could equally well call it bushfire epistemology. Any thesis will include elements of epistemology, usually covertly, within the literature review. This thesis overtly addresses bushfire epistemology, and calls upon the views of several philosophers. I found these views helpful, and hope that the reader will too.

In the belief that disciplinary boundaries may be more of a hindrance than a help in understanding the complexities of bushfire, I try to divide the literature into three streams of knowledge, namely humanities, social science, and natural science. The attempt is not entirely successful, due to the intertwining of knowledge. Drawing on the ideas of an expert on the Middle Ages, and two well known philosophers, I imagine a network of connecting paths along, and between, these three main streams, which flow into the same lake, or swamp. Causeways rest on piles driven into the swamp. I discuss the need for a clear epistemology to underpin bushfire management policy. I do not claim to have established one, but hope that I have contributed some useful ideas, which others can pursue.

Chapter 3: About Wungong Catchment
A Matter of Place

This chapter gives the size and location of the catchment, and describes some aspects of the geology, landform, drainage, climate, vegetation, and animals, native or otherwise. For example, kangaroos are present, but so are introduced feral pigs. There was extensive logging from 1872 to recent times. Wungong Catchment is not a pristine wilderness.

I walked the catchment, and give some descriptive statistics on the vegetation, including two iconic species, the *balga* (*Xanthorrhea preissii*) and the *djiridji* (*Macrozamia riedlii*). Both these were, and still are, of special significance to *Nyoongar* people. Both plants have an intimate relationship with fire. The effects of past logging on tree size and spacing are also described, as both these link to fire and hydrology.

I explain the method used to estimate plant densities. It is based on the geometry of triangular tessellation (Delaunay 1929), and polygonal tessellation (Dirichlet 1850). It gives estimates of the numbers of trees, and the iconic *balga* and *djiridji*.

Chapter 4: The Other Side of the Hill
Bushfire in Foreign Lands

This chapter visits other fire-prone lands. There is an old military idea that ‘time spent in reconnaissance is seldom wasted’. To understand bushfire, and its management, in the *jarrah* forest of Wungong Catchment, it is valuable to reconnoitre elsewhere. Australia has notoriously flammable vegetation, but so do other lands. India, Africa, Madagascar, the Americas, the Middle East, and even

Europe, have their fire history, and fire problems. Given local variations, there is, nevertheless, much in common.

Chapter 5: Bushfire, Flogging, Measles and Foresters
A Brief History of Bushfire in the *Jarrah* Forest.

Historical evidence is presented showing that *Nyoongar* people used bushfire as a land management tool. Similar evidence exists for Aborigines in other parts of Australia.

Following a lead from Dr. Sylvia Hallam, I examined correspondence from the 1840s, on the subjects of bushfire and *Nyoongar* tradition. The implications of this correspondence are discussed, and the full texts of the letters are given in Appendix A. *Nyoongars* were discouraged from burning, firstly by a law in 1846, which threatened flogging and imprisonment. Secondly, two major measles epidemics greatly reduced their numbers, and caused such despair that many traditional ways were abandoned.

For most of the twentieth century, professional foresters managed fire in the *jarrah* forest. The history of this management is examined, including criticism, in the last few decades of the twentieth century, by environmental advocates. The reasons for, and effects of, a decline in the use of fire as a forest management tool are discussed.

Chapter 6: Better to Believe the Balga
Some Archaeology

Over the past decade or more, I have developed a technique of reconstructing past bushfire frequency from marks on old *balga* (*Xanthorrhoea spp*.) grasstree stems. Work has been done in the *jarrah* (*Eucalyptus marginata*) forest, the *tuart* (*Eucalyptus gomphocephala*) forest, and the *Banksia* woodland just north of Perth. As previously discussed, disciplinary boundaries can be elastic, but I believe that the *balga* work is, essentially, archaeology.

The validity of the method has been questioned by an environmental advocate, and by workers in another vegetation type, the *kwongan* heath, several hundred kilometres north of Perth. They extend their criticism to the *jarrah* forest. This chapter discusses both the method and the controversy.

The results of investigating old bushfire marks on *balga* in the Wungong Catchment, the adjoining Monadnocks Conservation Park, and elsewhere in the *jarrah* forest, are presented.

Chapter 7: Does God Play Dice?
Self-Organization in Bushfire Mosaics

As the main mathematical contribution to the thesis, this chapter presents an original bushfire mosaic model, based on Graph Theory and the Four Colour Theorem. This demonstrates the existence of a self-organizing tendency in bushfire mosaics, and suggests that we may do better to work with that tendency, rather than against it, or blindly. A specific model of Wungong Catchment is developed, and the effects of some potential bushfire management scenarios are tested.

Chapter 8: Violins and Bidi Burning
Restoring Lost Mosaics

It is not easy to restore stable, fine-grained fire to a landscape which has, through lack of active management, become unstable and coarse-grained. In this chapter I suggest that some geometry derived from mathematical Knot Theory can help. This follows Giambattista Vico's philosophical view that analysis followed by synthesis, or restoration, can enrich our understanding more fully than analysis alone (*verum et ipsum factum convertuuntur*).

Chapter 9: Fire, Forests and Water
The Relevance of Bushfire to Perth's Water Supply

The current prime purpose of the Wungong Catchment is to supply water to the Perth metropolitan area. Water flow can be affected by varying rainfall, but other influences are soil type, and evapo-transpiration by plants, especially large forest trees. Bushfire, by changing soil and vegetation, can also indirectly affect water flow. I present, and discuss, research findings by foresters and hydrologists on these matters.

Chapter 10: All the World's a Stage
A Soft Systems Approach to Bushfire

In this chapter I discuss the application, to bushfire management, of Soft Systems Methodology. An early contributor to this methodology was Geoffrey Vickers, who had served as an infantry officer in the First World War. That experience gave him a strong interest in the mathematical aspects of organization, but also made him clearly recognize that mathematical approaches alone are insufficient, and human factors must also be considered. His ideas have been developed, in the last half of the twentieth century, by Professor Peter Checkland, who has offered clear and useful ideas on how to tackle complex systems involving people, with their differing, often conflicting, sometimes seemingly illogical, viewpoints (*weltanschauungen*).

Checkland's method was developed in the United Kingdom, for application in industries and government departments. I adapt his systematic approach to include situations, such as that of Australian bushfire management, where there may be political controversy, and lobbying by pressure groups with differing views. Those holding differing views on bushfire management may find it hard to understand the logic of others.

Recklessly piling metaphor upon metaphor, I compare bushfire management to a theatrical stage performance. I use a quote from Shakespeare's play, 'As You Like It', as a metaphor for the sort of play which may take place upon that stage, and the possible interactions between playwrights, audience, actors, and directors, representing researchers and planners, the public, public servants, and politicians.

Chapter 11: Summing Up and Verdict
Some of the evidence

Evidence is rarely, if ever, complete, but I sum up the evidence available from the previous chapters, and conclude that a stable, self-organizing bushfire mosaic, based on frequent mild burning, could, and should be reintroduced into Wungong Catchment, as an act of ecological reconstruction, social safety, and economic sobriety. It would save money, conserve the forest, protect water supply, and make life safer for nearby human communities, and those working in the catchment, or those using it for recreation.

It would also be a real and lasting gesture of apology and reconciliation to the oldest custodians of the catchment, the *Nyoongar* people of Western Australia. They were probably driven out of the catchment in the last half of the nineteenth century, firstly by two major measles epidemics, then by logging.

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Chapter 2

Dodging Disciplines

A LITERATURE REVIEW

The discipline of colleges and universities is in general contrived, not for the benefit of the students, but for the interest, or more properly speaking, for the ease of the masters.

Adam Smith, 'Wealth of Nations' (1776).

Preamble

To improve my understanding of bushfire in Wungong Catchment, I read in a range of academic disciplines, including philosophy. Mention of philosophy can cause a glazing of the eyes, including mine. As the eminent American geographer Carl O. Sauer said, it has 'a numbing effect on those who are not philosophers' (Williams 1987). Perhaps that is why the term 'literature review' is preferred for what is, in truth, an exercise in epistemology. This is a literature review, but it is more than that. It is an exercise in the epistemology of bushfire, that is to say, what we know about bushfire, how we know it, and how reliable our knowledge is.

Clearly bushfire knowledge is cross-disciplinary. For example, it includes such diverse disciplines as physics, chemistry, history, economics, politics, and even psychology. It has a complex, and little discussed, epistemology, and we should not shy away from that fact. We will have a richer discussion if we openly embrace it.

Initially, I hoped to organise this review by disciplines. But how do we define a discipline? University and college structure is often based on the perceptions of administrators, on how disciplines may be defined, and grouped together, but this is not a straightforward matter.

Many people recognize the humanities, the natural sciences, and the social sciences as the three main streams of human knowledge, and thus as the basic grouping of disciplines, but not all agree. Some group the social sciences with the humanities, perhaps because some disciplines have a foot in both streams. Although I thought, at first, that I could structure my reading by disciplines, neatly allocated to the three main streams of human thought, I soon found that it was not so easy. I suspect that Adam Smith understood that, when he noted the conflict between what is convenient to the masters (or administrators), and what is intellectual reality to the students. He was commenting on epistemology.

I have read some geography (e.g. Barrett and Ford 1987). Geography is relevant to bushfire, and one would expect it to pose a puzzle in any discipline sorting exercise, since there is a claim that the unique quality of geography is that it is cross-disciplinary, so filling the voids between other disciplines (Kirkpatrick 2007). Geographers study both nature and society, using both quantitative and qualitative methods. It has been recently suggested that geographers should return to the basic concept of 'place' (Maude 2009), and this appeals to me. It agrees with the older views of the US National Council for Geographic Education and the Association of American Geographers (Anon. 1984). Their guidelines for geographic education state that 'All places have characteristics that give them meaning and character and distinguish them from other places on earth.' In describing places, the humanities, and both kinds of science, have something to offer.

Together with place, time is vital to human understanding. History, like geography, can fill voids, or straddle streams, whichever metaphor appeals. A librarian might have difficulty shelving a book about the history of science, or the history of mathematics. With present day computer searching on keywords, this will be a trivial problem to a potential borrower, but rather more perplexing to the librarian, or to those intent on defining disciplines.

The humanity called history is one of the oldest of human intellectual exercises, and seems to permeate all others. Every discipline has its history, and the history of fire in the landscape is of fundamental importance in understanding the interactions between humans and fire. I suspect that no constructive intellectual activity about bushfire, or anything else, would be possible without some memory of past events.

This thesis also involves ecology, which is another interesting case, highly relevant to bushfire. Some biologists, and possibly librarians, may prefer to view ecology as a narrowly scientific branch of biology, using only 'hard data' and quantitative methods. Yet it can be well argued that ecology is a cross-disciplinary endeavour (Weber 1999), like geography, and closely related to it. Perhaps ecology is part of geography, or vice versa. This is especially true of landscape ecology and human ecology. Studying these matters is impossible without considering past human activities and impacts, and that necessarily involves reading history, and, in some cases, the use of related techniques, such as those of archaeology, and palaeontology.

The Most Significant Sources

As in any literature review, to discuss all my reading in detail would take more time than I, and probably my readers, have available. I am also wary of producing a linear 'laundry list', when the knowledge relevant to bushfire forms such a rich web. What I have done in this chapter, therefore, is to identify, and review, what I see as my most significant sources. Sometimes I found these first, and they led me to lesser works. On other occasions I started with a number of lesser works, and these led me back to a major one. Searching on keywords had me running up and down the library stairs, as I visited diverse sections on history, biology, philosophy, politics, Aboriginal matters, and so on.

Within such a complex web, I have kept in mind the general architecture of my reading, within the three main streams of knowledge. At times it was difficult to tell where one ended, and another began, but that is the reality of knowledge. I had to start somewhere, so where better than with the humanities? Through the work of a novelist, I stumbled across a useful medieval metaphor. Perhaps they were wiser in the Middle Ages than we are now.

A Medieval Metaphor

England has produced a number of excellent detective-story writers. We may recall Agatha Christie, with her dapper Hercule Poirot. Dorothy L. Sayers wrote such stories too, with her detective being the deceptively diffident, yet steely-minded, Lord Peter Wimsey (Sayers 1931, 1993)**.**

Just as Lord Peter had more than one side to his personality, so did Dorothy L. Sayers. She presumably wrote detective novels for fun, and to earn a living, but she was also an early champion of women's rights, and one of the first women to graduate from Oxford University. She was an expert on the Middle Ages (Sayers 1937, 1949)**.**

Soon after the Second World War, she delivered a talk at Oxford University in which she suggested that the education system had lost the tools of learning (Sayers 1947). As a remedy, she suggested a return to the medieval *trivium* (From the Latin for 'three ways'). This was a first year syllabus common to the great medieval universities in Europe, in which students had to acquire three skills, before proceeding further (Russell 1998, Joseph 2002). The skills were logic (clear thought), grammar (clear expression), and rhetoric (the ability to mount an ordered and persuasive argument).

These three skills are still important, for example in writing a thesis, and are highly interactive. In medieval times, students sat their *viva voce* examination for the *trivium* seated on a three legged stool, or *tripos*. This was to remind them that if one leg was wobbly, they would fall.

Accepting the wisdom of Dorothy Sayers' insight, here I have extended the idea of three complementary skills into an imaginary landscape of bushfire knowledge, in which a maze of tracks runs beside, and between, three complementary streams of knowledge. The streams run into a swamp (Figure 2.01). The literature led me along the tracks. Some tracks

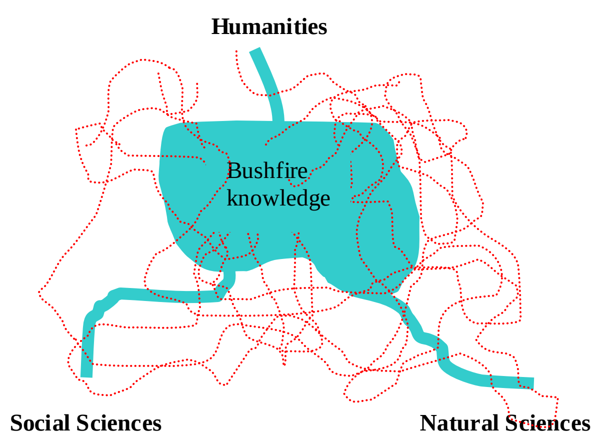

Figure 2.01: An imaginary landscape in which three streams of knowledge (blue) flow into the swamp of bushfire knowledge, with access by a tangle of tracks and causeways (red).

stayed close to a particular stream, but others wandered a great deal, and were the richer for it. To understand bushfire behaviour, ecology, and management, we need to wander the tracks, and wade in all three streams, without assuming that any is 'better' than the others. Each has its merits, and merges with the other two into holistic bushfire knowledge.

We may venture out into the swamp, by means of creaking causeways. Avoiding the dangerous assumption of certainty, these causeways rest on piles driven into the swamp, as suggested by the philosophers Popper (1959) and Lakatos (1970), both noted for their ideas on epistemology. This cautious, philosophical view of knowledge is discussed more fully later in this chapter. It is a good antidote to scientific *hubris*.

Putting the Wet Stuff on the Red Stuff

By now, the reader will not be surprised to find that this thesis is openly cross-disciplinary, bounding over the academic boundaries between geography, history, ecology, botany, archaeology, hydrology, and mathematics. Yet there is still another kind of knowledge, less formally recognised, but relevant to this thesis. This informal knowledge is a practical understanding of Australian bushfire behaviour, which seems to be confined to those who have actually fought against bushfires, or at least attended some, and seen fire-fighters in action. Australian volunteer bushfire fighters commonly refer to this shibboleth as 'putting the wet stuff on the red stuff'. Some good examples of Australian bushfire theory which is backed by practical experience are Cheney *et al.* (2001), and Hodgson (1968).

Some Australian academics write about the ecology and behaviour of bushfire, publish papers and reports upon it, and even offer advice on how to manage it. They may have something to offer on theory, but are often without any apparent practical experience of bushfire fighting, and hence have no grasp of sensory realities, such as radiant heat, smoke density and colour, and the sound of a bushfire, which can range from a friendly crackling, to an earth-shaking roar, depending mainly on fuel quantity and disposition.

I am wary of academic claims about bushfire management which seem sometimes to be devoid of this practical understanding. For example, the advice 'don't fight fire with fire' (Whelan 2002) is, from my own practical experience of the benefits of preventative fire, at complete odds with reality. In Australia, apart from complete removal of native vegetation, the deliberate use of fire to reduce fuel loads is the only proven way to avoid deadly conflagrations. Firefighters know this intuitively, through their sensory experience. This sensory understanding of Australian bushfire has a close parallel in flying. Student pilots would be likely to mistrust a flying instructor who had never been off the ground. Sensory awareness is a vital part of the epistemology of Australian bushfire management, even if there are, as yet, no academic publications on its role in understanding bushfire.

Political Influence on Bushfire Information

Although I have regarded government reports as generally reliable, I have also considered the possibility of political influence. For example, a report on the Victorian bushfires of 2003 was written by a public service bureaucrat, and two academics (Esplin *et al*. 2003). It was severely criticised, in a memorandum by a leading barrister, A.J. Myers QC. He expressed 'grave misgivings about the manner in which the report is written' (Myers 2004).

The barrister's memorandum observed that the lead author, Bruce Esplin, was Emergency Services Commissioner for Victoria during those fires, so 'was not, and did not appear to be, independent in relation to the matters inquired into.' Further, while the qualifications of the two academics were described in the report, 'any reference to skills and experience in relation to forestry management and fire prevention or suppression' were 'notably absent'. This supports the views expressed above, of the need for practical experience in bushfire fighting.

The above government report (Esplin *et al.* 2003) dismissed the idea of Aboriginal burning as a model for current, and future fire management. The authors said '…we do not know enough about traditional burning in southern Australia to be able to re-create an Aboriginal burning regime'. Travelling more widely along the paths and causeways of bushfire knowledge, this thesis may help to fill that gap in their understanding.

Thinking about Thinking

I have introduced the vital topic of bushfire epistemology above, and mentioned two philosophers, Popper and Lakatos, who contributed to our understanding of knowledge. Another philosopher, Robin Collingwood (1945), put forth the view that 'A scientist who has never philosophized about his science can never be more than a second-hand, imitative, journeyman scientist.'

If the books and papers of a literature review are regarded as 'epistles', then it is important to discuss how they fit together, and the relative importance and reliability of the three streams of knowledge, in this case with regard to bushfire. So my next objective was to improve my understanding of these matters.

In the past I avoided philosophy. This avoidance was, perhaps, due to laziness, or perhaps philosophy seemed, at that time, to be remote from my undergraduate concerns with DNA, or tussles with differential equations. Yet time has cured that error on my part. Understanding what we know, and how we know it, and how reliable it is, seems to me now to be of central importance. We need to think about what, and how, we think. Our understanding of bushfire will remain disjointed, and fragmentary, until we come to grips with bushfire epistemology, which is, at present, poorly developed (Pyne 2006).

For example, there is plenty of bushfire history, but we may wonder whether it is a legitimate source of information on bushfire in the past, or hopelessly subjective. Some say that natural science is the only reliable approach to bushfire knowledge, but ecology may not be what some biologists believe it to be. Those from a different background may argue that ecology unavoidably involves both nature and society (Cassirer 1944, Duvigneaud 1980). We humans cannot be simply objective spectators. We are part of the subject matter of ecology, whether we realize it or not. Given the blatant impact, on both nature and society, of recent large bushfires in Australia, a study of the ecology of Australian bushfire cannot be based on natural science alone. As a well loved philosopher put it, long ago (Bacon 1605), 'in this theatre of man's life, it is reserved only for God and angels to be lookers on'.

Simon Blackburn's 'Oxford Dictionary of Philosophy' (2005) was a great help to me in grasping broad ideas in philosophy, which are relevant to bushfire. It is internally cross-referenced, so showing linkage between those ideas. It also gives some external references, from which one can branch out into the vast philosophical literature. It was a valuable springboard, to which I returned repeatedly. Another, more detailed, source for basic philosophical concepts was 'The Oxford Companion to Philosophy' (Honderich 1995).

From Simon Blackburn's dictionary, I made first acquaintance with Neurath's Boat. I found this a more comfortable framework, for bushfire knowledge, than the *hubris* of 'foundationalism', as exemplified, in mathematics, by Euclid's Postulates. Otto Neurath proposed that knowledge is like a boat. Every part can be repaired, as long as the sailors retain, at any time, enough planks to stand on. Neurath's work (Nemeth and Stadler 1996) led me to explore the work of three more recent philosophers; Karl Popper (1959, 1963), Imre Lakatos (1970, 1973) and Paul Feyerabend (1993). The first two disagreed with Neurath, but Feyerabend was more sympathetic.

An even more recent philosopher provided a sarcastic counterpoint. David Stove attacked the work of Popper, Lakatos, and Feyerabend as irrational, and wrote a discourse 'Against the Idols of the Age' (Stove 1982, 1999). Whilst extreme, David Stove's rhetoric was refreshingly blunt, even if his logic was a little askew. Nevertheless, he set a good example by challenging the philosophical 'establishment'. Without such intelligent challenges, right or wrong, philosophy might fossilize. Stove's writing shows that philosophy need not be 'numbing', but can stimulate and enrich the mind, even on the matter of bushfire, which some may regard as academically pedestrian.

Popper's suggestion that science consists only of that body of knowledge which can be framed as falsifiable hypotheses is well-known now, but was probably startling when first stated in the nineteen-thirties. He proposed that all else is pseudo-science, which carries, for me at least, the suggestion of second-class knowledge. Being not fluent in German, I did not read his original '*Logik der Forschung'* (1934), but parts of a translation, 'The Logic of Scientific Discovery' (1959).

Popper was, doubtless, a leading thinker on a range of topics, but, with regard to bushfire, I found his ideas a little too prescriptive and inflexible for my purpose. Bushfire research is more complicated. I found myself in some sympathy with Paul Feyerabend (1993), who was a self-proclaimed intellectual anarchist. Popper's ideas do not seem to apply to all knowledge.

For example, historians can only surmise what happened in the past from fragmentary evidence. How can strictly falsifiable hypotheses be formed, and experiments carried out? The actors are dead, and the places changed. There is no chance of randomisation, replication, or experimental control. Nor can history be repeated. I suspect that Karl Popper would have classified history, therefore, as a pseudo-science, and unreliable for those trying to understand bushfire. I doubt if historians would agree.

I found at least one recognized philosopher who did not. In the book 'The Idea of History'**,** Robin Collingwood (1946) claimed that history is a science, using that word in the sense of a reasoned body of mostly reliable knowledge. Historians ask questions, and carefully examine evidence, which may yield an answer. Yet, due to its own peculiarities, history cannot use the same methods as, say, physics. This does not make history generally inferior to natural sciences, such as physics, or to the social sciences.

History is inferior to physics in finding out facts about magnetism, and inferior to biology in finding out about the structure of DNA. Yet history is superior to both those natural sciences in finding out, say, about the medieval system of education, or the reasons for past use of deliberate bushfire by hunter-gatherers. With regard to bushfire management and ecology, the last mentioned finding is more directly relevant than the structure of DNA, or an understanding of magnetism.

Looking for Consilience

Yet some natural scientists still seem convinced that theirs is the dominant path to knowledge. An eminent biologist (Wilson 1998), presumably writing from a biologist's view of the world, has suggested that the 'crumbling structure of the liberal arts' can be renewed by forging stronger links to natural science. At the same time, borrowing the word 'consilience' from a nineteenth century English polymath (Whewell 1840, Fisch 1991), the same biologist, Edward O. Wilson, wrote that 'A balanced perspective cannot be acquired by studying disciplines in pieces but through pursuit of the consilience among them'.

The meaning of 'consilience' is, literally, a 'jumping together' (Honderich 1995, Trumble and Stevenson 2002). It seems close, in meaning, to the word 'corroboration', but perhaps a little richer. William Whewell's biographer, Menachem Fisch (1991), called it an 'explanatory surprise', and wrote 'That rules springing from remote and unconnected quarters should thus leap to the same point, can only arise from that being the point where truth resides.'

Wilson's message is rather mixed. He suggests that we need a cross-disciplinary approach, yet that the methods of natural science must dominate and replace the methods of the 'crumbling' liberal arts. I disagree, because I doubt if this is possible, and I doubt if the liberal arts are entirely in decay.

Avoiding Physics Envy

Natural sciences are sometimes presented as more reliable, because they are more quantitative, and use applied mathematics more than do the humanities. Some may believe that the only reliable approach to bushfire understanding is through natural science, using statistical induction, or other kinds of mathematics. Yet an astute essay called 'Humanities and Science' (Thomas 1983) warned that the humanities should avoid ‘physics envy’. This matter was taken further in another essay called ‘Ecology and Physics Envy: A Hard Look at the Hard Sciences’ (TeHennepe 1991), where it was suggested that ecologists, also, should avoid imitating ‘hard scientists’.

The richness of the humanities may be due to academic seniority. They have had longer to mature and compost, and in places, admittedly, to crumble. As a matter of historical sequence, I suspect that the earliest human intellectual efforts were art, story telling, and music. These would have enhanced the development of language (Pinker 2008). This, combined with writing, led to literature. Once humans started to reflect upon these forms of mental play, philosophy appeared, followed by natural science, then, much more recently, social science.

I emphasize that this is only my speculation on the historical relationship between the humanities and the sciences. Helpful as the philosophical literature was on other ideas, I found little comfort on this particular matter. Yet it is important to a deep understanding of bushfire. In my opinion, discarding the humanities as imprecise and ‘anecdotal’ will lead to an impoverished understanding. Natural science is essential, but, by itself, insufficient. Acquiring a new, and undoubtedly useful, tool is no reason to throw out all your old ones, and the toolbox.

The Importance of Language

Some suggest that, within the natural sciences, language skills are at a low ebb (Gowers 1973, Sand-Jensen 2007). Poor language skills can lead to muddled thinking. For example, simplistically assuming that bushfire is the same at all times, and all places, to all plants and animals, and to all people, is careless use of language, and can lead to seriously wrong conclusions. I am much in sympathy with the American geographer, Carl O. Sauer, who used colloquial language, or ‘despecialized speech’, because it enabled cross-disciplinary discussion (Williams 1987). Such discussion is essential to an improved bushfire understanding.

Some of our thinking is pictorial, but much of it is in language. In the introductory chapter, I mentioned Sir Ernest Gowers' excellent little book, 'More Plain Words' (1973). I read it long ago, but revisited it before starting this thesis, and found it as astringent the second time around. Gowers, too, regarded careless use of language as a serious issue.

I have already mentioned an unusual, and enjoyable, paper (Sand-Jensen 2007) which urges scientists, and probably other kinds of scholar, to be more lively in their writing. At a deeper, and even funnier level, I read of the physicist Alan Sokal's little hoax at the expense of pretentious, obscure language. Sokal submitted, to a well known post-modernist journal, a deliberate piece of nonsense, dressed up in impressive mathematical and philosophical language (Sokal 1996). It was accepted. With a French colleague, Jean Bricmont, he then wrote a book (Sokal and Bricmont 1998), explaining what he had done. He was careful not to dismiss all post-modernism, but he certainly gave some well known post-modernist writers a roasting. The theme has been extended by others in a book of essays called 'A House Built on Sand' (Koertge 1998).

Unfortunately, such obscurity is not confined to post-modernism. For example, although post-modernism has yet to make much impact in the area of bushfire ecology, we may wonder how a 'three-dimensional semi-strong hybrid multi-dimensional scaling (SSH MDS) ordination based on floristic composition' (Burrows and Wardell-Johnson 2003) can help managers to understand the impact of bushfire on vegetation.

Words can certainly make you weary. When this happened, I found stimulation in 'The Devil's Dictionary', by Ambrose Bierce (1911). Ambrose, a delightful cynic, disappeared in Mexico before the First World War. He recognized the connection between clear language, and clear thought. As a sample of his interesting views, we may note his deep definition of 'logic' as 'The art of thinking and reasoning in strict accordance with the limitations and incapacities of the human misunderstanding.' I wonder how he would have viewed current Australian bushfire knowledge, or rather the 'received wisdom' used in arriving at some political decisions on bushfire.

Landscape, People, and Politics

From experience as a bushfire fighter and researcher, I have some practical knowledge of bushfire and its effects. I have put the 'wet stuff on the red stuff' many times, and I see this as valuable in writing about bushfire. But my practical knowledge of bushfire might be 'hard science', or 'pseudo-science', or something else altogether. My perspective may be distorted. I might have only a part view, and be ignorant of other perspectives. I felt that wider reading might help.

Bushfire is a landscape phenomenon, so I plunged into the basic concept of landscape, starting with Simon Schama's impressive tome, 'Landscape and Memory' (1995). This book is good evidence that natural science is, by no means, the only path to useful knowledge. The book is well organized into four parts, separately discussing the three main physical landscape components of wood, water, and rock, then bringing them together in the final part.

Schama ranges across art, mythology, history, psychology, and the sciences. He even briefly touches on the role of 'regular fire-clearances by its Ahwahneechee Indian occupants' in maintaining the open, flower-strewn floor of Yosemite valley, despite the assumptions of some early European visitors that this was a 'pristine Eden'.

Schama examines the historical roots of environmentalism, and its links to politics. Some may prefer these roots to remain unexamined, since there are embarrassing historical connections to Nazi philosophy and politics. There can be little doubt that some core Nazi intentions were quite evil, yet they were sometimes camouflaged by appeals to a love of nature. The protection of forests was overseen by no less a personage than Reichsforstminister Hermann Göring.

This matter is of relevance to this thesis, since environmental advocacy, including that on forest policy, has played a significant role in recent West Australian politics, and may affect political decisions on bushfire management. We must examine the interactions between environmentalism, politics, and bushfire from more than one perspective.

As a purely hypothetical example, we may consider someone who is engaged in illegal activity in the catchment. This might be horseriding, firewood gathering, or even growing *marijuana* (*Cannabis sativa*). They will be opposed to burning, or any other forestry activities which may interfere with their illegal activity. Yet they cannot openly argue their case in the public arena. They may, therefore, ally themselves with environmental advocates, who oppose burning, thinning, and logging for quite different reasons. As the Arabs succinctly put it, 'the enemy of my enemy is my friend'. In his Devil's Dictionary, Ambrose Bierce (1911) defined the verb to 'dissemble' as 'to put a clean shirt upon the character.' We must listen, respectfully, to the views of those who oppose deliberate use of fire as a landscape management tool, provided those views are presented respectfully. At the same time, we should look very hard at those wearing carefully laundered shirts.

Landscape Ecology

There is a fairly recent branch of ecology known as 'landscape ecology', which is relevant to bushfire, and appears to present landscape study in the form of a natural science. However, even the pioneers of the subject have to agree that history, a humanity, is an essential precursor to any understanding of landscape (Naveh and Lieberman 1994, Forman 1995, Burel and Baudry 2003).

Others have suggested that a cultural understanding of landscape is essential to proper landscape management. They define landscape as 'the interaction of people and place' (Groth and Bressi 1997). Landscape ecology has been overtly applied in studying Aboriginal bushfire management in northern Australia (Bowman *et al.* 2004). Other writers have not called their work landscape ecology, yet it seems to be such in all but name.

For example, Cary *et al.* (2003) have published a collection of essays on bushfire. Some are interesting, and show some depth of thought (e.g. Wasson 2003, Krebs 2003). Others would, I suspect, be of interest to Kaj Sand-Jensen (2007). The central theme is that of bushfire in the landscape, and its effects. Some government inquiries have produced documents on bushfire which address the same theme. One of these is 'A Nation Charred: Inquiry into the Recent Australian Bushfires' (Commonwealth of Australia 2003).

The mingling of history with landscape ecology, or other topics, results in some borderline cases, yet where the word 'history' appears in the title, I have usually regarded it as such. In other cases the historical nature of the work becomes clear in the body of the writing. Information on past Aboriginal use of fire is mainly classed as history, even though it clearly links to both ecology and anthropology.

Aboriginal Use of Fire

One of the earliest historical accounts of *Nyoongar* use of fire in south-western Australia was by Scott Nind. He was a surgeon with the first British party to land, in 1826, at King George's Sound, now known as Albany. Nind published his observations in the Journal of the Royal Geographical Society, London (Nind 1831), and my attention was first drawn to him by Dr. Sylvia Hallam's seminal work on Aboriginal use of fire in south-western Australia (Hallam 1975).

Nind told how *Nyoongars* used bushfire widely, in the summer months, to flush out game, and establish claim to a particular piece of land. His observations were corroborated by his commanding officer, Captain Collett Barker, whose handwritten journals were only deciphered more recently (Mulvaney and Green 1992).

Dr. Neville Green has also drawn on Nind's observations in his books (Green 1979, 1984) and a chapter in 'A New History of Western Australia' (Green 1981). For Western Australia Berndt and Berndt (1980) gave much useful information on the 'Aborigines of the West'.

In particular, Sylvia Hallam's book 'Fire and Hearth' (1975) was a rich source of information on the historical, and cultural, use of fire by the *Nyoongar* people of the south-west corner of Australia. Her more recent works 'The history of Aboriginal firing' (1985) and 'Peopled Landscapes in Southwestern Australia in the early 1800s: Aboriginal Burning Off in the Light of Western Australian Historical Documents' (2002) were also helpful.

Some Personal Observations by Settlers

Other, older observations on bushfire in the south-west were by Edith Hassell (1936), and Jesse Hammond (1933). In the 1880s, Edith Hassell went, as a bride from England, to join her husband at a remote sheep station near Jerramungup. She took an interest in the local *Nyoongar* people, who seemed to have survived the well-documented measles epidemics of 1860 and 1883/4 (Hasluck 1942, Cumpston 1927, Cliff *et al.* 1993, Ward 2000c). Edith described the ceremonial importance of fire to *Nyoongar* people, and its traditional use to renew grasses. She noted the careful way in which *Nyoongar* people timed fires to avoid harm to young birds. Her observations were published as an academic paper, with the help of an American anthropologist (Hassell 1936)**,** and in book form by a descendant (Hassell 1975).

In the last half of the nineteenth century, Jesse Hammond grew up on a farm between Perth and Bunbury, and spent time in the company of *Nyoongar* stockmen, until they were decimated by the measles epidemics of 1860 and 1883/4 (Cliff *et al.* 1993). According to Hammond (1933), the latter was a crushing blow, and many *Nyoongar* people subsequently abandoned traditional hunting and gathering, and even their language. He describes their use of deliberate fire, early in the season, to protect their huts, and berry patches (probably native cranberry, *Astroloma* spp.), against later hot, summer fires.

The decline of the *Nyoongar* population after the two measles epidemics was noted by Daisy Bates, in her book 'The Passing of the Aborigines' (1938). Bates was a journalist, and was not averse to a marketable story, but her comments on disease and despair among Aboriginal people in the south-west are valuable, since they mesh well with the comments of Millett (1872), Cumpston (1927), Hammond (1933), Hasluck (1942), and

Cliff *et al.* (1993). I have summarized elsewhere (Ward 1998a, 2000c) the probable interaction between disease epidemics and the decline of burning by *Nyoongar* people.

Bushfires in other Lands

I extended my reading on bushfire to places other than south-western Australia. These other places included other parts of Australia, and further afield in Africa, Madagascar, Asia, the Americas, and Europe. This wider search is discussed in detail in Chapter 4 (The Other Side of the Hill), but here I give an initial scan through the literature.

Key references in this wider search were books by Stephen J. Pyne, of Arizona State University (1982, 1991, 1997, 2001a, 2001b, 2006). These emphasize the world-wide historical aspects of fire, but also comment on its ecology, philosophy, and even its political implications. It would be difficult to disentangle these four. We may note that there is remarkable consilience between accounts of the ecology, history, philosophy, and politics of landscape fire from different parts of the world.

Professor Pyne's books led me to the fascinating debate on forest fire in the pages of the venerable journal 'Indian Forester', dating back more than a hundred years (e.g. Slym 1876, Shebbeare 1928). The relevance of fire to forests in both India and Burma was discussed, including a detour to Java (Slym and Hill 1881). The trail led from India to Western Australia, where the views of Sir David Hutchins on official bushfire policy (Hutchins 1916) were influential among early professional foresters. Eventually it was noticed that Australian summers, and vegetation, are rather unlike those of northern Europe. The summers are hotter, and drier, and the vegetation much more flammable. European notions on fire can be misleading if applied in other lands and climates.

Sir David was a politically appointed consultant, and he recommended a younger colleague, Charles Lane-Poole as the first West Australian Conservator of Forests. Although politically appointed, Lane-Poole clashed with local politicians over bushfire, and left for Canberra, where he helped found a forestry school (Ward 2000a). Politics and bushfire have a long association in Australia.

We may compare the situation in colonial India and Burma, where villagers had very different ideas on fire from some European-trained 'scientific' foresters, with that in Western Australia, where similarly European-trained foresters, such as Charles Lane-Poole, and Stephen Kessell, were in conflict with locally born field staff and residents (Ward 2000a). This conflict is more fully discussed in Chapter 5 (Bushfire, Flogging, Measles and Foresters).

The Political Ecology of Bushfire

The political ecology of fire is thoroughly discussed by Christian Kull, in two papers (Kull 2002a, Kull 2002b) and a book (Kull 2006) titled 'Isle of Fire: The Political Ecology of Landscape Burning in Madagascar'. He went to Madagascar for his doctoral field-work, and investigated the history of the use of landscape fire by the Malagasy people, and their historical and political interactions with French colonial rulers, and, since independence, with their own government. The consilience between the history and politics of fire in Madagascar, Australia, and India is remarkable. In Madagascar attempts were made, and are still being made, to criminalize, suppress, discredit, or otherwise sideline, traditional burning methods. The Malagasy villagers were, and still are, unimpressed and unrepentant.

Christian Kull certainly explores a maze of tracks around the swamp of political ecology, drawing on humanities, natural science, and social science. He emphasises the rift between academic 'received wisdom' on fire ecology, used by the French colonial rulers, and later by the independent government of Madagascar, and the 'folk-ecology' of Malagasy villagers. Often the villagers had, and still have, practical reasons for burning that are unknown to, or rejected by, some academics, clinging to their own version of 'science'. Fuller discussion is given in Chapter 4 (The Other Side of the Hill).

Looking for Patterns, Self-Organization, and Spontaneous Order

Pattern is integral to landscape, and pure mathematics can be regarded as an abstract search for patterns, whether spatial or numerical. Paul Erdös (1913-1998) was a fine example of a pure mathematician. He was the most prolific mathematician of the twentieth century, and his biography (Hoffman 1998) reveals a monk-like character, traipsing around the universities of the world, offering to 'preach' to the students. His biographer describes him as a 'machine for converting coffee beans into theorems'.

With a colleague, Erdös published a paper which showed that a pattern emerges when random points are joined by random connections (Erdös and Renyi 1959). There is an inevitable sudden formation of 'giant patches', and this seminal paper has inspired some heavy-duty pure mathematics (Bollobas 1985). Although Professor Bollobas is difficult, for me, to follow, the basic idea of small patches joining to form 'giant patches' is quite clear. It will be applied, in Chapter 7 (Does God Play Dice?), to model the way in which small patches of forest fuel can, under long fire exclusion, join to form large patches. In hot, windy weather, fire can spread uncontrollably through these large, connected patches. In this sense, there is predictable spatial self-organization in fire. Given the opportunity, it will always try to simplify a mosaic.

One aspect of self-organization has been called 'Self Organized Criticality' (Bak *et al.* 1989, Bak 1996), and has already been extended to a study of self-organizing behaviour in forest fires (Malamud *et al.* 1998). One of the earliest papers on spontaneous order, by the Australian scientist Robert May (1976), appeared in the journal 'Nature', with the modest title 'Simple mathematical models with very complicated dynamics'.

An interesting bridge between mathematics and history is Carl Boyer's 'A History of Mathematics' (1968). Unfortunately, it does not include many developments in the last half of the twentieth century. Some of these more recent areas of mathematics, such as Graph Theory, Map Colouring, and Knot Theory are relevant to bushfire, and are introduced in Chapter 7 ('Does God Play Dice'), and Chapter 8 (Violins and Bidi Burning). For information on these I had to seek out books such as Robin Wilson's 'Introduction to Graph Theory' (1979) and 'Four Colors Suffice' (2003), and several books on Knot Theory (Livingston 1993, Welsh 1993, Adams 1994). Of the Knot

Theory books, that by Adams was the most useful to a non-expert. It is clear, and shines with personality and enthusiasm. Kaj Sand-Jensen (2007) would approve.

Society and Soft Systems Analysis

Bushfire can severely affect human society, so humans in flammable areas need to manage it, in order to avoid, or at least minimize, damage and death. Debates on bushfire management can become very complex, with social, legal, economic, political, ecological, and emotional elements. A similar complexity exists in debate on the management of business corporations, government departments, or other human organizations, where careful logic may be undone by emotion, or bluster.

Sir Geoffrey Vickers (1983) recognized the importance of human factors in organization and planning. Perhaps, as a veteran of the First World War, he had been confronted by the lack of effective planning evident in Flanders, and the fact that human qualities, such as intelligence, loyalty, and determination, can be crucial to the success, or failure of any plan. Before his death, he discussed his ideas with a younger academic, Peter Checkland.

Professor Peter Checkland has, over the last half of the twentieth century, grappled with this problem, and has found some answers. Working mainly with business and government, he has developed a 'Soft Systems Methodology' (SSM) which tries to integrate all the elements mentioned above (Checkland 1972, 1981, Checkland and Scholes 1999). He emphasizes the importance of understanding the different world views (*weltanschauungen*) that people carry in their heads. He also emphasizes that his models are never finished, but are expected to evolve as more information becomes available, or circumstances change, or people change their outlook. In this, he seems to lean, philosophically, toward Neurath's Boat, rather than Euclid's foundations.

Although I do not know him personally, from his writing, Peter Checkland seems to be a careful thinker, not given to wild claims. I believe his flexible, and practical, ideas are potentially useful in bushfire management, and I discuss them, in more detail, in Chapter 10 (All the World's a Stage).

Bushfire and Water

This thesis is about the management of bushfire in a water catchment, so I drew upon the natural science of hydrology. There is clear evidence that severe bushfires can pollute streams and dams with ash and silt (Water Corporation of Western Australia 2008). We might also consider infection from the rotting corpses of the many animals which are usually killed by major bushfires.

The hydrology of the *jarrah* forest, including Wungong Catchment, is well covered in a number of publications by the earlier Water Authority of Western Australia (1987, 1995), the current Water Corporation (2005a, 2005b), and the Water and Rivers Commission of Western Australia (1997). In addition, there is information on the severe effects on water catchments of the Canberra bushfires in 2003 (Wasson *et al.* 2003).

Two interesting contributions come from Frank Batini, a professional forester, with long experience of the *jarrah* forest and its hydrology. The first (Batini *et al.* 1980) examines the effects on water yield of land use changes in the Wungong Catchment. The second (Batini 2007) discusses what government can do to address the recent drying trend of catchments, including Wungong, in the northern *jarrah* forest. Some options include logging and more frequent, deliberate burning, both of which would reduce water loss by evapo-transpiration. Frank Batini discusses the political sensitivity of these options, and the likely consequences if they are not implemented.

I found useful papers on the effects of forest growth, thinning, and logging on water catchments. Some of these papers come from Australia, some from the USA, and some from South Africa. A review from the USA (Bosch and Hewlett 1982), described the first formal experiment in a catchment in Colorado, in 1909. A more recent paper (Douglass 1983), estimated the vast amount of water which would be released into rivers if all the mature timber in the eastern United States were harvested. A comparison with the flow of the Mississippi River is startling, and highlights the major importance of evapo-transpiration by trees, whether in the very large Mississippi basin, or in a small catchment in south-western Australia.

In a paired catchment study in South Africa (Smith and Scott 1992), pines and eucalypts were planted in four formerly treeless areas. As the trees grew, all areas showed a reduction in streamflow, with eucalypts having a more marked effect than pines. In a number of studies in south-western Australia, removal or thinning of *jarrah* forest increased streamflow (Batini *et al.* 1980, Greenwood *et al.* 1985, Schofield *et al.* 1989, Stoneman 1993, Ruprecht and Stoneman 1993, Stoneman *et al.* 1996).

Also in South Africa, it has been noted that some of the best yielding catchments are grassy (Scott 1993). This can be compared with reports from early explorers in southern Australia, who saw Aborigines burning along creeks and around wells, and noted that grass was stimulated by fire (Leichhardt 1847, Gregory and Gregory 1884, Hallam 1975). In Chapter 9 (Fire, Forest and Water) I speculate on the effect that burning by Aborigines may have had on water quantity and quality.

Des Eaux et des Forêts

I have already discussed the connection between bushfire and water, but there is, of course, a history of the connection between forests and water. This close connection has long been recognized in France, with its famous '*École Nationale des Eaux et des Forêts'* at Nancy, and a government department with a similar name. One writer has used the history of forests and water to trace the growth of hydrology as a branch of natural science (Andréassian 2004), starting with the work of eighteenth century French naturalists in Mauritius.

Some Ideas on Bushfire and Native Plants

In my walking within the Wungong Catchment I saw few flowering *balga*. This is commonly the case in long unburnt areas. The probable cause of this was discovered over thirty years ago. Gill and Ingwerson (1976) found that ethylene gas was needed to provoke flowering, in plants of the same genus, in eastern Australia. Ethylene occurs in bushfire smoke, but also in vehicle fumes. More recently, the connection between fire and flowering was studied by Ward and Lamont (2000b), who found that, in the *jarrah* forest, abundant flowering occurred only after bushfire, and was more likely in taller *balga*, than in short ones. This contradicted an earlier study (Lamont and Downes 1979), which, due to unawareness of this height difference in flowering, concluded that pre-settlement fire intervals were around eighty years, based on flowering intervals. However, the earlier study (Lamont and Downes 1979) did provide some useful information on annual growth rates in *balga*.

A central issue in the debate over bushfire frequency in the *jarrah* forest is the effect of fire on the *jarrah* tree itself. This matter is discussed in some detail in Chapter 6 (Better to Believe the Balga). Some early experts (Stoate and Helms 1938) commented on how resistant *jarrah* is to frequent fire, due to its ability to coppice from lignotubers. The same authors wrote that 3-4 year fires were the general rule up to the 1920s.

Another important issue is that of seed bank dynamics. A long term study in *jarrah* forest showed that nearly all shrub species in that forest flower within 3-4 years after a bushfire (Burrows and Wardell-Johnson 2008). We may consider this to be a remarkable piece of consilience with other evidence on past fire frequency in the *jarrah* forest, especially since those few plants that need longer intervals occur in obvious fire refuges, such as moist creek banks or rock piles. The authors, however, reason that, to be conservative, the inter-fire interval should be doubled to 6-8 years between fires, in order to allow seed banks to build up. This would make sense if effective seed banks do build up monotonically in the long absence of fire, but that may not be true. Due to predation and decay, they may decline. Pierre Duhem's thesis of contingent hypotheses may apply. We don't always know what we don't know. I offer a few possible contingent hypotheses in Chapter 7 (Does God Play Dice?). Burrows and Wardell-Johnson do acknowledge our poor understanding of seed-bank dynamics, and accept that very mild, frequent fires can, in fact, leave many unburnt patches.

The Relevance of the Humanities

I have drawn the literature relevant to bushfire in Wungong Catchment from three main streams of knowledge, but these are connected by a maze of tracks. There is much literature on bushfire from both the social and natural sciences, but the most interesting source of information was, for me, the humanities. The network of tracks around that stream is older, and richer. I conclude that the humanities are at least as necessary as the sciences to our understanding of bushfire. I suspect fundamentally more so, since they provide the operational matrix (toolbox?), without which bushfire science could not exist. Neither natural, nor social science, can exist without language, or history.

History, philosophy, and literature are all rich quarries of ideas, on which the sciences can draw for those 'bold hypotheses' recommended by Karl Popper. David Hume was aware of the richness of history. An historian himself (Hume 1778), he recognized the importance of the humanities as a source for the sciences. He wrote that 'History is not only a valuable part of knowledge, but opens the door to many parts, and affords materials to most of the sciences.'

Scientists are People

Psychologists stress the difference between 'seeing' and 'perceiving'. Another aspect of our different approaches to knowledge lies in our own personalities, and how our minds translate what we see. Even scientists have differing personalities, and may perceive science in different ways. In his book 'Pluto's Republic' [*sic*], Sir Peter Medawar (1982) put it this way:

'Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers and compulsive tidiersup; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics.'

If Peter Medawar was right, then it is small wonder that such varied people will often dodge back and forth between science and the humanities. Generally they will seek certainty from sciences, and inspiration from the humanities, but it can happen either way, and both are needed. Only a very dull, pseudo-scientist could work entirely with grinding linear logic. I even doubt if our minds would allow us to do it for long, without an outbreak of civil war between the cerebral hemispheres (Sperry 1961).

Applying Peter Medawar's insight to my own reading, I suspect that I am not enthusiastic about collecting, classifying, or tidying up. I am not the world's greatest taxonomist. Nor am I a mystic, in fact I shun mysticism. However, I do enjoy art, and, like Hercule Poirot and Lord Peter Wimsey, I do like to solve mysteries. I am not averse to a bit of exploration, either.

Conclusion

In writing this thesis, I have dodged between a wide range of disciplines, and wandered from humanities, to social science, to natural science, and back again. I have drawn upon at least 500 sources, including at least 200 books, and the rest refereed journal papers, newspaper and government reports, and a few press releases. There may be some double counting, since in some places I have referred to a chapter, in other places to the book from whence it came. I have assumed that all papers published in the proceedings of meetings, and all book chapters, have been refereed, and so are reliable.

I do not offer this information on the extent of my reading as a boast, but as some indication of the size of the relevant literature. There remain hundreds of publications which I still need to read. My personal bushfire epistemology is in its infancy.

On reflection, I must be a little cautious in assuming that all my sources are reliable. I have assumed that official reports, coming from august bodies such as the Water Corporation of Western Australia, or the West Australian Department of Conservation and Land Management, are correct. However, with overt political appointments to senior positions in the current Australian State Public Services, we must always be alert to the filtering effect of political correctness, often more by omission than by commission. Public servants, especially politically appointed ones, need always to attend to their career paths and pensions. As lawyers and judges well know, half the truth can be very misleading.

Also, even respected, refereed journals have been known to accept some papers that are incorrect, and reject some that are correct. There is an early example. In the 1890s, the 'father of biometrics', Karl Pearson, submitted a paper to the Royal Society in London, involving the then novel combination of mathematics and biology (Walker 1958). It was rejected, with one referee remarking that 'the author should decide if he wants to write a paper about mathematics, or about biology, and not confuse the two disciplines.' Later, Pearson was, himself, suspected of obstructing the papers of a younger rival, Ronald Fisher. Nevertheless, the referee system is the least worst system we have. Its most pernicious aspect is the formation of social cliques, which promote their own views, and try to stifle those of others.

This is not unknown in the literature on landscape fire. An early paper, by me, on the technique of reconstructing bushfire history from *balga* stems (see Chapter 6, Better to Believe the *Balga*) was rejected by a scientific journal. Both referees (anonymous) objected to my mention of history, as if they believed it was irrelevant, or an inferior kind of knowledge. In modified form, the paper was later accepted by another journal (Ward *et al.* 2001a). That is one reason why I have emphasized that the humanities, especially history, have an important place in bushfire knowledge. In assessing the refereed literature, I have tried to peer into the social matrix in which it sits, and the academic rivalries lurking therein. *Weltanschauung* is everywhere.

Although I have emphasized the importance of plain English, some academic readers may object to my colloquial style. Once again, I must draw upon the eloquence of the late Professor Carl O. Sauer (1889-1975), who described himself as a 'peasant' and a 'cranky old backwoodsman'. Perhaps my background as a forest workman in the 1960s and 1970s has made me see the world in a similar way. I do not intend to change now.

I will give the last word on book learning to my sceptical friend, Ambrose Bierce (1911). He defined 'erudition' as 'dust shaken out of a book into an empty skull.' I think all scholars, whether in the sciences or the humanities, should bear that in mind, even if they find it annoying.

-oOo-

Chapter 3

About Wungong Catchment

A MATTER OF PLACE

'All places have characteristics that give them meaning and character and distinguish them from other places on earth.'

Guidelines for Geographic Education, National Council for Geographic Education and the Association of American Geographers (1984).

Preamble

A highway leads from Perth, the capital of Western Australia, to Albany, a major port on the south coast. It runs through a mixture of farmland and forest. On the way, it passes along the east side of Wungong Brook, and its catchment.

According to some, for much of its way, it follows an old *Nyoongar* footpath, or *bidi* (Moore 1884, Nannup 1996). Before European settlers arrived, these footpaths criss-crossed south-western Australia, and were of great importance, both for travel, and as boundaries between different clan areas (Hammond 1933, Hallam 1975). There may have been songs connected with them, by which young people memorised detailed landscape information, including sources of food and water.

In his book, 'Song Lines', set in northern Australia, Bruce Chatwin (1997) vividly described the connection there between songs, footpaths, landscapes, and long human occupation. Current Aboriginal art often includes cryptic maps of 'country', showing footpath networks and water points. It would be fascinating to know if there were, or still are, *Nyoongar* songs related to Wungong Brook, its tributaries, and former footpaths within the catchment area. They would be a vivid link with the past, and would enhance our understanding of past human connection with this landscape. Perhaps 'singing', or painting, the landscape would help *Nyoongar* people regain their sense of place in their present social turmoil. One *Nyoongar* narrator has made a good start, by recording old tales of how the south-west landscape was formed. The stories involve the *wagyl*, or giant rainbow serpent, who formed the creeks and lakes (Nannup 1996). Presumably the *wagyl* made Wungong Brook.

Those of us whose ancestors came from north-western Europe must never assume that the human history of south-western Australia started in 1826, with the first British military outpost at Albany; or 1829, with the founding of Perth; or perhaps from the arrival of our own families. If we make that error, we may be seriously wrong in our interpretation of the landscape too, for, as previously discussed, human history and landscape are intimately mixed (Naveh and Lieberman 1994, Burel and Baudry 2003). Misreading the Wungong landscape could lead to foolish decisions on bushfire, forest, and water management, and resultant harm to both nature and human society.

In the past, the earliest human intervention in the catchment must have come from *Nyoongar*, or possibly other Aboriginal people, who seem to have been present, in south-western Australia, for tens of thousands of years (Pearce and Barbetti 1981, Berndt 1980). The *Nyoongar* name for the creek, *Wungong*, is still used. I have been unable to find its meaning, but it surely has one, which might enrich our understanding.

Since they survived for so long, as hunters and gatherers in this area, they must have had a good understanding of the plants and animals, some of which were essential food (Meagher 1973). Relying on creeks, pools, wells and springs, they must also have had a direct and vivid understanding of changes in water quantity or quality, for any reason. There is strong evidence that they had a good understanding of bushfire and its effects, and used it deliberately as a land management tool for their own benefit in hunting and gathering (Hallam 1975, 1985, 2002, Green 1981, 1984, Mulvaney and Green 1992, Abbott 2003). It seems likely, therefore, that they would have been well aware of any effects of fire on streamflow.

General Features of Wungong Catchment

Wungong Catchment is mainly forested and hilly, in places downright steep. The predominant vegetation is *jarrah* (*Eucalyptus marginata*) forest, up to thirty metres high, although this is mixed with similar height *marri* trees (*Corymbia calophylla*) on the mid to lower slopes. The deeply fissured bark of the *yarri* tree (*Eucalyptus patens*) can be seen occasionally along creek banks. There are also groves of *coondli* (*Allocasuarina fraserana*) and *boolkarla* (*Banksia grandis*). Other common large plants of this forest include *balga* (*Xanthorrhoea preissii* - up to six metres high) and *djiridji* (*Macrozamia riedlii* - up to two metres high). Most of these plants are now missing from that part of the catchment (about 20%) which has been strip-mined for bauxite over the past few decades, but the mining company (Alcoa World Alumina Australia) is interested in restoring them (www.alcoa.com.au). There are hundreds of smaller plant species, all with interesting connections to bushfire, but this thesis, using a broad landscape approach, must confine itself to the above, and a few other, major species.

Facts, Figures, and Maps

Starting with a map (Figure 3.01), we see the catchment in relation to the city of Perth. To the south-west of the catchment is the small settlement of Jarrahdale (population 950 at 2006). To the north, but unlabelled, is a slightly larger township called Bedfordale (population 1,830), a suburb of Armadale.

Figure 3.01: Wungong Catchment in relation to Perth, Western Australia. (By kind permission of the Water Corporation of Western Australia).

A small dam was built on the Wungong Creek in 1925, and then, as Perth grew, the dam wall was raised, to give a 60 gigalitre capacity in 1979.

As Figure 3.02 shows, the land tenure within the catchment is complex. The water within the catchment is managed by the Water Corporation of Western Australia, but the state forest, and its biota, are managed by the Department of Environment and Conservation (DEC).

Both state government departments have had name changes, and shifts in political philosophy, over the past few decades.

DEC is a successor to the former Forests Department (FD), and the Department of Conservation and Land Management (CALM). Both FD and CALM were actively involved in forest harvesting, but DEC is not, that role being filled by the newly created Forest Products Commission (FPC).

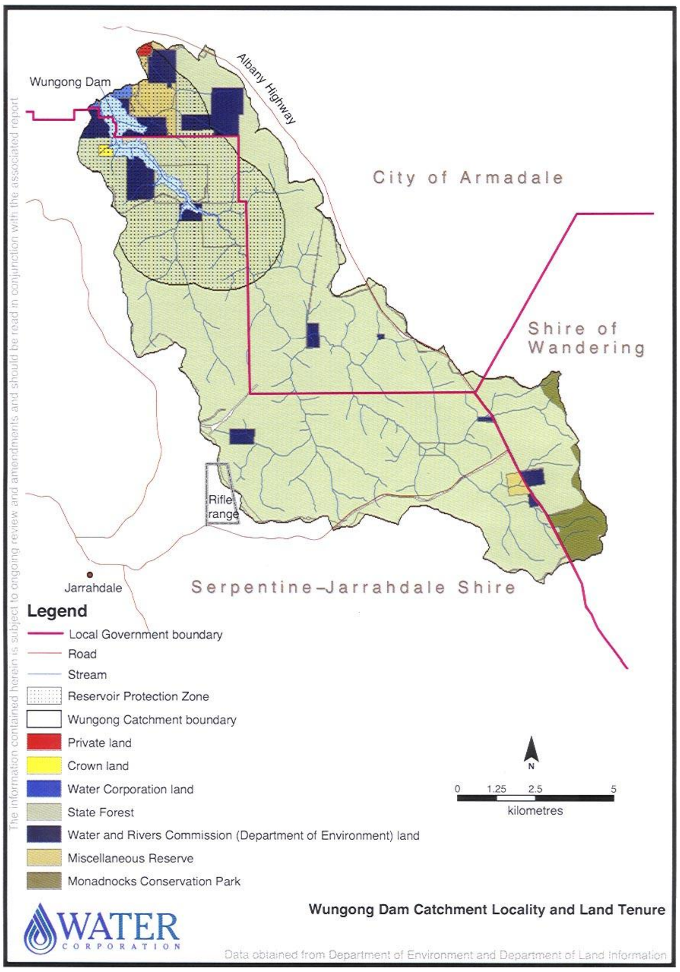

Figure 3.02: Land tenure in Wungong Catchment (by kind permission of the Water Corporation of Western Australia).

The Water Corporation, in response to concerns about declining rainfall in the south-west, and the growth of Perth, is now exploring options such as water recycling, and seawater desalination. The Water Corporation is also considering the hydrological benefits of thinning and burning the forest, so seeking security in a diversity of options. However, all the above options have been subject to political, and ideological, controversy.

In addition to the state government, three local government authorities have some jurisdiction over different parts of the catchment. The north-east part falls under the City of Armadale, the south-west part under the Serpentine-Jarrahdale Shire, and a small portion in the south-east falls within the Shire of Wandering. Some of this last portion is also part of the Monadnocks Conservation Park, managed by the Department of Environment and Conservation.

I am unaware of any current management conflict between these various authorities, but clearly there is potential for such conflict as situations change, and in particular over the management of bushfire. Although their aims overlap, the Water Corporation's central focus is on water, and that of the Department of Environment and Conservation on nature conservation, including bushfire management. Local governments have a complex portfolio, with a central focus on community welfare, but allied interests in bushfire management and nature conservation. Like any form of government, they are prone to lobbying by external pressure groups, but also to infiltration by those pursuing some particular view of the world. I bring the matter of *weltanschauung* into discussion of the use of Soft Systems Methodology (Chapter 10: All the World's a Stage).

Any State Government bushfire policy which had conflicting effects upon water, fire management, nature conservation, and community welfare, would clearly be likely to lead to conflict between the various authorities. The State Government, through a little foresight, has a role to play in avoiding such a situation. At the end of this thesis (Chapter 11: Summing Up and Verdict) I make further comments on this issue, and make some suggestions for avoiding it.

Creeks and Bushfire

The Wungong Brook flows roughly south-east to north-west, and is fed by a rich network of creeks, up to at least fifth order, all of which flow for at least part of the year, when the winter rain recharges the catchment. The drainage shows a rectangular pattern, due to the underlying geology (Churchward and Batini 1975).

A sample of a thousand random points, taken some time ago over the whole *jarrah* forest (Ward and Van Didden 1997) suggested that few places are more than a kilometre from a creek (Figure 3.03). More precisely, over 90% of the *jarrah* forest is within 500 metres of a creek. Since

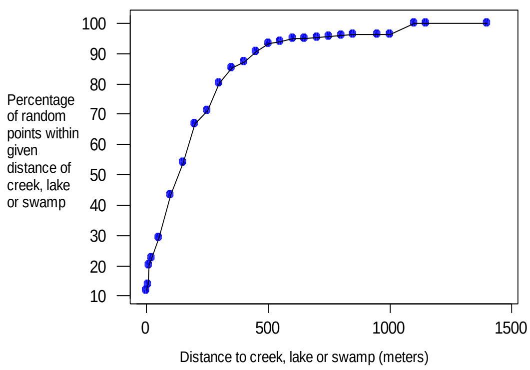

Figure 3.03: Distance from a creek in the *jarrah* forest.

Nyoongar people often travelled along creeks (Berndt and Berndt 1980), the banks of these creeks would have been likely ignition points.

It is probable, therefore, that fire frequency varied little, in general terms, throughout the *jarrah* forest, although there would have been many small local variations. A fire lit along a creek bank, on a summer morning, moving at a conservative kilometre an hour, would easily spread to the top of a nearby ridge by nightfall, provided there was enough fuel (at least 2-4 year old) to carry fire. The damp or shady banks closest to the creek, or midslope rock patches, or gravelly ridges, would have created variation within the landscape matrix, by acting as fire breaks, so sheltering rare (i.e. fire sensitive) plant species. Diversity of fire behaviour would lead to a diversity of habitat, and a diversity of plants. The idea that the richly diverse vegetation of south-western Australia has been shaped by Aboriginal fire was proposed some time ago (Gardner 1957).

Landform and Soil

The creeks have formed valleys by cutting down through the ancient lateritic crust, which remains on the ridges and low hills. These incised valleys contain richer, moister soils than the ridges. In the north of Wungong Catchment, just below the dam wall, the valley is very steep, with slopes of up to 30 degrees.

In the south-east corner of the catchment, where Wungong Catchment overlaps Monadnocks Conservation Park, there are a few prominent granite monadnocks, ranging up to 500 metres above sea level. These stand out, obviously, above the surrounding lateritic hills, which are generally at least 200 metres lower. It seems likely that such monadnocks would have been well known landmarks for *Nyoongar* people. I cannot speak for everybody, but these massive rocks have a soothing psychological effect on me, and were probably of spiritual significance. *Nyoongar* people may have burnt around the monadnocks for spiritual reasons, as is still done around rocks and cliffs in northern Australia (Rose 1996).

The soil pattern has been described in detail by Churchward and Batini (1975), who divided the landscape into crests, slopes and valley floors. Broadly, they described the crests and gentler slopes as gravelly sand over laterite duricrust, underlain by acid, kaolinite clay, with a basement of country rock. The duricrust contains pockets of bauxite, and has been strip mined, in 20% of the catchment, for alumina production. Such mining involves complete removal of the forest, with mixed success in rehabilitation. It has been suggested that this removal of the duricrust increases rain infiltration, and so may decrease flow into the dam (personal communication from Frank Batini).

The lower, steeper slopes are described as colluvial earths and podzols, with some gravel. The valley bottoms, often swampy, are described as alluvial, with some silt. Field checks in the current study confirmed these observations.

The Climate

In the south-west corner of Western Australia rainfall comes from the Indian and Southern Oceans, so generally decreases from west to east, and south to north. Clouds coming in from the Indian Ocean are lifted by the Darling Scarp, which runs north to south, a few tens of kilometres inland. This creates a strip of higher rainfall along the western side of the Darling Scarp, and reaching inland for about ten kilometres. Wungong Catchment lies in this strip, between the 1000 mm and the 1200 mm rainfall isohyets. In the north-west corner of the catchment, around the dam wall, the average annual rainfall is over 1300 mm. The wettest months are June and July (200-300 mm in each month), and the driest January and February (less than 20 mm in each month). The period May to September is cool and wet, October changeable; and the period November to March warm and dry, at times hot and windy. April is also changeable. The bulk of rainfall falls in June, July, and August, with occasional summer thunder storms.

We may compare these periods with the *Nyoongar* seasons. Reportedly, they divided the year into six seasons, each of about two months. These seasons were given by an early settler (Moore 1884, cited by Hallam 1975) as *jilba* (August and September), *gambarang* (October and November), *birok* (December and January), *burnuro* (February and March), *wanyarang* or *geran* (April and May), and *maggoro* (June and July). However, as Sylvia Hallam (1975) warns, we must be alert to the possibility of misunderstandings arising when a newcomer was dealing with a different language and culture. For example, a current *Nyoongar* man says that *jilba* means ‘underground’, and may refer to the roots and tubers available at that time (personal communication from Mr. Noel Nannup).

Animals in the Catchment

A comprehensive report, as part of the Wungong Catchment research project (Water Corporation of Western Australia 2005a), gives information on the animals believed to be in the catchment. The vertebrate information is based on a report by Ninox Wildlife Consulting (2003), and the stream invertebrate information mainly on a report by Bunn (1986).

The first of the above reports describes a rich fauna of at least 210 native vertebrate animals. The most numerous of these are 123 bird species. Emus (*Dromaius novohollandiae*), are described as rare, nor did I see any in my own wanderings in the catchment. The report does mention introduced mammals, including feral pigs and cats, and I saw both these, the former being quite common. From the presence of piglets, feral pigs are clearly breeding in the catchment. Their diggings were noticeable in deep, long unburnt *coondli* litter, possibly in search of fungi.

Some of the native species are regarded as ‘rare, threatened or vulnerable’. These include three small mammals, the *chuditch* (*Dasyurus geoffroii*), *quokka* (*Setonix brachyurus*) and *numbat* (*Myrmecobius fasciatus*), one small python (*Morelia spilota imbricata*), and several birds, including two kinds of cockatoo, Carnaby’s (*Calyptorhycus latirostris*) and Baudin’s (*Calyptorhyncus baudinii*). Another ten species of native vertebrate are regarded as ‘vulnerable’.

There is no report on the land invertebrates of Wungong Catchment, although they are, most likely, those typical of the *jarrah* forest in general. They include the *jarrah* leaf miner (*Perthida glyphopa*), which can be a problem in the forest, by stripping the *jarrah* of its leaf canopy, so inhibiting photosynthesis. There is some evidence, from old herbarium specimens of *jarrah*, and other eucalypt species, that this insect has noticeably increased since frequent burning declined, in some places, in the late nineteenth century (Abbott *et al.* 1999). Without jumping to rash conclusions on causation, there are further historical comments on this in Chapter 5 (Bushfire, Flogging, Measles and Foresters).

Since Wungong is a water catchment, insects living in, and near, creeks are of particular interest. Relying on Bunn (1986), the Water Corporation (2005a) concluded that these are regionally endemic, and there is only a low species richness of such insects in the catchment. Maintenance of thirty metre buffer strips along creeks should ensure that forest operations, such as thinning and burning, will have minimal effects on aquatic insect populations. If such operations increased soil moisture and streamflow, then aquatic insects would benefit, although increased mosquitoes and midges would not be of benefit to vertebrates, including humans. In ecology, there are always swings and roundabouts.

Nearby Human Settlements

The map in Figure 3.01 above shows the small township of Jarrahdale, a few kilometres to the south-west of the catchment. Jarrahdale is an old sawmilling town, the mill operating there from 1872 to the closing years of the twentieth century. There are many old residents in Jarrahdale, but since the mill closed, some houses have been bought by urban retirees, or 'life changers'. Such people are emotionally attached to natural surroundings, but, in some cases, have little practical experience of the bush. Some are seriously unaware of the dangers of bushfire, for example allowing long unburnt native vegetation close to their house, perhaps on the grounds that they are conserving biodiversity. Many houses in the town are wooden, so highly prone to burn from ember showers should a major fire ever emerge from the catchment on an easterly, or north-easterly, wind. Due to a wildfire, or a fierce fire in logging trash, the whole settlement of Jarrahdale burnt down in 1895, but was rebuilt. The local authority is very active in Jarrahdale, trying to raise awareness of the danger, and prepare for it (personal communication from the Emergency Services Department, Serpentine-Jarrahdale Shire.)

Not shown on the map in Figure 3.01, but just north of the dam wall, lies Bedfordale. It is, by West Australian standards, an old settlement, but has recently undergone rapid growth, since it is within commuting distance of the major employment, and shopping, centres of Armadale, and Perth. Most newer houses in Bedfordale are built of brick, but with timber roof construction. They could still burn if there were intense ember showers from a major bushfire in the catchment. As in Jarrahdale, some residents are from an urban background, and not yet fully aware of the fact that what is green and tranquil bush or forest in winter, can become a terrifying wall of flame in summer. Even if aware of bushfire danger, they may lack the practical knowledge to defend themselves against it. Perhaps to reduce water use, some favour flammable native plants around their houses. These sometimes include clumps of *balga*, with massive, highly flammable dead thatch, accumulated over decades of fire exclusion. As in Jarrahdale, local government is doing its best to raise bushfire awareness, and is, reportedly, having great success (personal communication from Brian Watkins, Chief Bushfire Control Officer, City of Armadale).

Balga and *Nyoongar*

In their traditional way of life, fire was of central importance to *Nyoongar* people, both for practical and spiritual reasons (Hallam 1975). There was a close association between their use of fire, and the *balga*.

An early European settler in Western Australia (Chauncy 1878, cited by Hallam 1975) described how *Nyoongar* people made fire. He said: ‘The natives use the stem of the grasstree to produce fire by friction. This is done by rapidly twirling between the hands one piece of stick in a little hole bitten out of another piece… a little dry grass or the dry fuzzy material of the withered seed head of the grass-tree laid in the hole … soon smokes and ignites.’

I was once shown, by a *Nyoongar* Elder, how to make fire in this way. He has since passed away, and, in respect for *Nyoongar* tradition, I will refer to him indirectly (personal communication from Trevor Walley’s late uncle). Making fire this way is quicker and easier than I had imagined, taking only a few minutes. Yet it can only be done if there are *balga* flower spikes available, and these are only abundant for a few years after a bushfire has been through an area (Ward and Lamont 2000b, Lamont *et al.* 2004). Smoke is an important stimulus for *balga* flowering

(Gill and Ingwerson 1976). *Balga* do occasionally flower without bushfire smoke, but often this occurs close to roads or driveways, where we may suspect that vehicle fumes have a role to play.

Apart from its practical use, *balga* is also connected with bushfire in *Nyoongar* mythology. In far off times, *balga* gave plenty of fire to *karak*, the Red Tailed Cockatoo (*Calyptorhynchus banksii*), which shows, as its English name suggests, a brilliant flash of scarlet as it takes flight. The small green *mowan*, or Twenty-Eight parrots (*Barnardius zonarius*), were annoyed, because *balga* only gave them enough fire for the male to have a tiny red patch just above his beak. The female got none. Hence the *mowan* still attack *balga*, biting the needles off short, sometimes causing death (McNee 1997).

Figure 3.04: *Balga* grasstree dead and fallen over, apparently due to long unburnt thatch.

There are other tales of *balga* in connection with *wagyl*, the great rainbow serpent (personal communication from Mr. Noel Nannup). Some *Nyoongar* people say that their traditional *boodja*, or country, is defined by the presence of *balga*, in a triangle from Geraldton to Augusta to Esperance.

Balga occupied, and still occupy, a significant place in *Nyoongar* perception of the world. It is important that we conserve these distinctive icons of the landscape. Millions can still be found in Wungong Catchment (see later survey data), but under recent long fire exclusion they rarely flower, and few young ones are apparent. Old ones are falling over and breaking, as seen in Figure 3.04. These stem breakages are due to heavy thatch, and blatant decay of the old leaf bases (Ward 2000a). *Balga* are peculiar in that they cannot shed their leaves. Only fire can remove them, and recycle the nutrients held within them.

Triangular Tesselation – A Survey Method

There are difficulties in estimating the number of plants in an area, due to complex variation in pattern (Pielou 1974, 1977). A common method is to count within quadrats, or circular plots (Lowdermilk 1927). Others have suggested that densities can be derived from distances between 'nearest neighbours' (Cottam and Curtis 1949, 1956). Yet there are problems with both these methods. For example, clustering can lead to gross errors (Greig-Smith 1964).

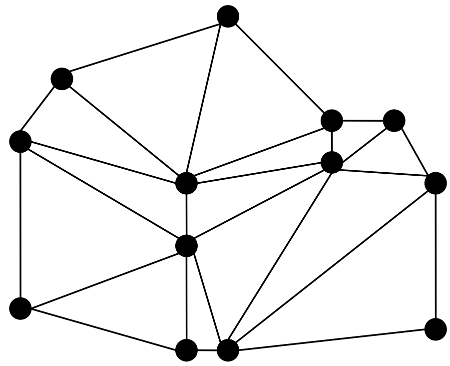

Figure 3.05: A typical Delaunay triangulation for trees, represented by black dots.

There is a radically different approach (Ward 1991), which is easier, faster, ad therefore cheaper to do in the field. Drawing on earlier mathematical work by Dirichlet (1850) and Delaunay (1929), this approach recognizes that, since the angles of a triangle formed by three plants sum to 180 degrees, the area of that triangle can be regarded as containing half a plant. The area can be calculated using Heron's Formula upon the lengths of the three sides. Doubling the area of a triangle formed by three plants gives the mean area occupied by one plant. Regarding an area of forest as a Delaunay triangular tessellation (Figure 3.05), defined by trees, or other plants of interest, gives us a reliable estimate of plant density. Simulation trials show that the method is more accurate than quadrat or circular plot counts, because it is unaffected by variation in plant pattern, such as clustering, interspersed with large bare areas (Ward 1991).

Survey Results for *Balga*

A survey of *balga* grasstrees in Wungong Catchment was made using the triangular tesselation method. Based on observations at 125 points, this survey suggested that the median density of *balga,* where present, is about 457 per hectare (95% confidence interval from 357 to 641). However, *balga* were completely absent from 15.3% of the sample sites, so we can estimate that about 5 million are present in the catchment of 12,845 hectares. They occur from ridge top to creek bank. From casual observation, I expected there would be a greater density of *balga* on the lower slopes than on the ridges, but there was no statistical difference. My casual impression was biased by the greater size of those lower in the landscape.

The absence of *balga* from some apparently suitable sites is due to a policy of deliberate extermination carried out by the former Forests Department of Western Australia (Conservator of Forests 1920-1930). Due to their high flammability, hundreds of *balga* were removed, in some places, as a fire hazard. At that time, the Forests Department had a policy of fire exclusion from high grade *jarrah* forest, with the exception of five chain breaks (about 100 metres) around the perimeter of forest blocks. In theory, frequent (2-4 year) strategic burning of these breaks would protect the rest of the forest. As litter fuel and scrub built up within the blocks, burning the breaks became impossible, due to fires escaping (Wallace 1966). *Balga* were a major factor in these escapes, due to their notorious tendency to create ember showers, even in relatively mild weather in spring and autumn. On extreme days in summer, it is impossible to light a *balga* without setting fire to the surrounding ground litter, and hence to the bush in general.

It may be relevant to point out that, over ninety years ago, on November 15th, 1919, an informal experiment was carried out, by a member of the Royal Society of W.A. A party of members went on a botanical excursion to Greenmount, near Perth. They saw many wonders of nature, including a hillside of flowering grasstrees, which must have been burnt in the previous fire season. However, the expedition was not entirely a success, for 'The latter part of the excursion was devoted to the extinguishing of a bush fire, the result of the investigation on the part of one of the members into the relative inflammability of *Xanthorrhoea preissii* and *X. reflexa*.' (Personal communication from Graeme Rundle). The fact that the fire was extinguished, presumably by hand, is interesting. A bushfire in the heavy fuel near Greenmount now would call for fire trucks, helicopters, and water bombers.

Balga and Bushfire Archaeology

An important feature of this thesis, described in Chapter 6 (Better to Believe the *Balga*) is the estimation of past fire dates, and intervals, from marks on old *balga* stems. This relatively new technique (Ward 1996) is usually called fire history, but a case can be made for calling it fire archaeology. I would argue that history is information on the past, from human records, written, spoken, or pictorial. Archaeology relies on careful interpretation of inarticulate objects, such as old buildings, bones, or pottery. *Balga* are living, yet cannot speak or write. The part of them that informs us of past fires is the dead part of the leaf-base mantle. Others may disagree with my definition of 'archaeology'. This shows that crossing disciplinary boundaries is hard to avoid, because such boundaries are, as noted before, often vague, and controversial. Argument over the matter can be intellectually trivial, often more to do with academic empire building than with a search for the truth.

Based on evidence which will be presented in Chapter 5 (Bushfire, Flogging, Measles and Foresters), and Chapter 6 (Better to Believe the Balga), *Nyoongar* people traditionally burnt the *jarrah* forest every 2-4 years, which is as often as it will just carry a spreading fire. This practice was maintained, by European settlers, roughly up to the First World War, but now typical *jarrah* forest carries litter of more than ten years, and in some places, several decades old. In Wungong Catchment, current litter ages range up to more than seventy years in one part, Chandler Block, where fire has been deliberately excluded, for study purposes, since 1937. The mature *balga* in that block are rotting, and I was unable to find any seedlings. I am unaware of any formal research into this matter by the Department of Environment and Conservation. It would obviously be valuable.

Djiridji and *Byoo*

Similar to *balga*, the zamia (*Macrozamia riedlii*), or *djiridji*, has a very old connection with bushfire, and intimate significance for *Nyoongar* people. Although potentially poisonous, the red fruit (*byoo*) were an important food, especially for large gatherings (Moore 1884). These fruit only appear once in a bushfire cycle, the second autumn after the plant has been burnt. They were harvested, and buried in pits, near running water, to leach out the toxin. This method was widely known in Australia, with a similar report from Queensland (Beaton 1982).

Apart from their importance as a food source, *djiridji* harbour *cyanobacteria* (*Nostoc*) in their coralloid roots (Halliday and Pate 1976). These respond to burning by vigorously fixing nitrogen for three to four years after bushfire, then subsiding until the next fire (Grove *et al.* 1980). Interestingly, a common associate of *djiridji* is Prickly Moses (*Acacia pulchella*), and this fixes nitrogen for the same period after bushfire (Hansen *et al.* 1988). Other plants, including *jarrah* itself, must benefit from the nitrogen fixed by *djiridji,* and legumes such as Prickly Moses.

Survey Results for *Djiridji*

Using the triangular tesselation method, *djiridji* gave a median density, where present, of about 357 per hectare (95% confidence interval from 263 to 612). This was not statistically different from the *balga* density estimate, suggesting that, where present with *balga*, the two species are in approximately equal numbers. This is not surprising, since they are common associates in the *jarrah* forest. Havel (1975) gave them as associates not only in the *jarrah* forest, but throughout the south-west corner of Australia from Kalbarri to Albany.

In Wungong Catchment, however, *djiridji* were absent from a greater percentage of sites (38.7%) than were *balga* (15.3%), so the estimated population of *djiridji* in Wungong Catchment is only about 2.8 million, just over half that of *balga*.

Figure 3.06: Dead *djiridji* in long unburnt area with heavy litter.

At long unburnt sites, with heavy litter, *djiridji* were commonly nearly buried by twigs and dead leaves. They were typically bedraggled, discoloured, or dead (Figure 3.06). Many must have died, and vanished without trace under the heavy litter. The red *byoo* nuts are hard to find, and in present circumstances *Nyoongar* women would be

Figure 3.07: *Djiridji* burnt one year previously

unable to collect enough for a feast. Lack of *byoo* must be a factor in the absence of emus, which eat them. This is a matter that needs examination, before we lose this interesting plant species, and the emus.

For several years after burning, *djiridji* produce more fronds than they had before (Figure 3.07). These fronds are noticeably larger, and greener, than the fronds on long unburnt *djiridji*. This change must be connected with the increased fixation of nitrogen (Halliday and Pate 1976), and other nutrients from ash (Hatch 1960). Any farmer, or gardener, seeing the present sickly colour, crumpled leaves, and stunted size, of long unburnt *djiridji*, would immediately diagnose nutrient deficiency. That diagnosis would be supported by analysis of the leaves (Halliday and Pate 1976).

Some argue that the *djiridji* deaths are due to the cinnamon fungus (*Phytophthora cinnamomi)*, which is present in the catchment, and to which *djiridji* are susceptible. However, other plants are also susceptible to cinnamon fungus, especially *boolkarla*. It was noted that *djiridji* were dying in areas in which these other plants, including *boolkarla*, were healthy. Figure 3.08 shows a discoloured and crumpled *djiridji* seedling next to a healthy *boolkarla* seedling.

Figure 3.08: Discoloured and crumpled *djiridji* seedling (left) with healthy *boolkarla* seedling.

On randomly selected plants, at thirteen sites within, or close to, Wungong Catchment, *djiridji* fronds were counted. A sample of 31 plants was taken at each site, and the median frond counts compared. Recently burnt plants had significantly more fronds than long unburnt plants (Mood's Median Test $p<.05$).

Figure 3.09 shows a pattern of rapid frond increase for the first four years after fire, followed by a rapid decrease as fronds die. A LOWESS function is fitted (Cleveland 1979). In long unburnt areas the number of fronds stabilized at a median of four or five, but these were usually small, discoloured, and distorted. A larger sample, and better coverage of sites and fuel ages, is needed to confirm, dismiss, or extend the matter.

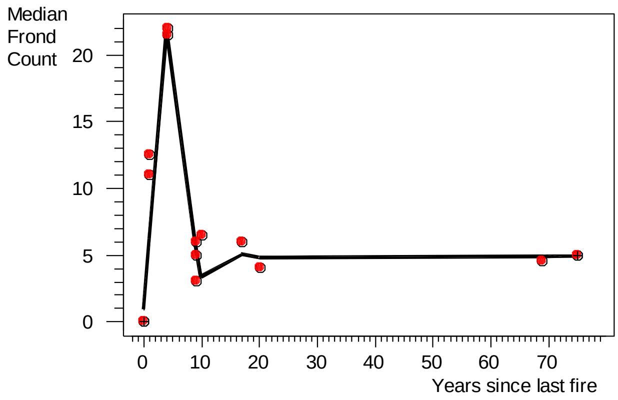

Figure 3.09: Median counts of *djiridji* fronds following fire.

Trees in the Wungong Catchment

Although *jarrah* is the most common tree in Wungong Catchment, there are also many red gum, or *marri* (*Corymbia calophylla*), which grow to a considerable height and girth, and, like *jarrah*, have a life span of several centuries. Generally they were left by the loggers, because *marri* timber is full of gum pockets. For this reason, the *marri* in Wungong Catchment are now the biggest trees, and must have a considerable transpirational pull on the water table.

Other, smaller trees are *coondli* (*Allocasuarina* spp.) and *boolkarla* (*Banksia grandis*). These tend to grow in groves, and, if left unburnt for long periods, create a thick litter layer which smothers most other plants, including *balga, djiridji, marri* and *jarrah*.

Survey Results for Trees

Using the triangular tessellation method (Ward 1991), the presence and density of trees were estimated. Trees (defined as single stemmed, woody plants five metres high or more) were present at all sample sites, with a median density of 566 per hectare (95% confidence limits from 441 to 656). Scaling up by the unmined catchment area gives an estimate of over seven million trees in Wungong Catchment.

Estimating the proportions of the four main species (*jarrah, marri, coondli* and *boolkarla*) gives 38%, 28%, 16% and 13% respectively. The remaining 5% consisted of the much rarer species *yarri* (*Eucalyptus patens*) (4%) and the commonly named 'snottygobble'[1] (*Persoonia elliptica* and *Persoonia longifolia*) (1%). Given the large size of the sample (n=329) we can have a fair degree of confidence in these point estimates. For example, we can be 95% confident that the proportion of *jarrah*, the commonest tree in the catchment, is between 33% and 43%. For other species the confidence intervals are more precise, down to between 2% and 4% for *yarri*, and between 0% and 2% for 'snottygobble'.

The rarity of 'snottygobble' is a matter for concern. Other workers have suggested that it was more common in the past, and that fire is an important factor in its life cycle, with better germination on recently burnt ground (Abbott and Van Heurck 1988). Also, due to the decline of emus to ingest the fruit, seed dispersal must have been affected. The fruit were food for *Nyoongar* people, so I suspect that they cared for the tree in the way they knew best – with fire.

The interaction between emus, 'snottygobble' fruit, and fire, is triangular. Fire releases nutrients, which enable 'snottygobble' to set fruit, so providing food for emus. Passing through the gut of an emu helps dispersal, and possibly germination. The seeds germinate better after fire. This is constructive and informed speculation, and could be the basis of some worthwhile research by the Department of Environment and Conservation, or Alcoa, or a university.

The matter of long distance seed dispersal by emus has been examined in New South Wales, where emus travelling over 13 km/day were reported (McGrath and Bass 1999). These authors also reported that emus seemed commonly to ingest charcoal. The authors gave no opinion on whether this was accidental, or had some digestive function. If the latter, then fire must be important to emus for that reason.

[1] I do not know the *Nyoongar* name for this tree. Possibly 'snottygobble' is a corruption.

At the same time, the authors attributed a decline in the emu population partly to ‘back burning’, that is to say deliberately controlled burning by humans to reduce fuel levels.

Fire intensity, and frequency, must be key factors. If, due to long fire exclusion, fires are fierce, and scrub dense, then emus trying to escape a ‘backburn’ would be unable to run, and would be caught by the flames. More frequent, milder ‘back burning’, would keep scrub thin, and would allow them to escape. In open country, emus are very fast runners, so could escape most fires, and predators, such as dingoes (*Canis dingo*), which were formerly present in the *jarrah* forest (Abbott 2008).

Old Tree Stumps

Logging in Wungong Catchment started with the establishment of a mill at Jarrahdale in 1872, and continued until 1997. A legacy of this logging is found in the remaining stumps of former very large trees. Sometimes only a circle of coppice saplings, around a charcoal filled crater, shows where the root system is still alive (Figure 3.10).

These stumps are mostly *jarrah*, but loggers also prized the rarer *yarri*, which grew close to the creeks. Old photographs of *jarrah* forest show very large trees, with stem diameters of over two metres, and heights over fifty metres (Dell *et al.* 1989, Water Corporation 2005a). Early written descriptions of the *jarrah* forest suggest that, up to the 1920s, the trees were generally much bigger than now, and more widely spaced (Dell *et al.* 1989).

Figure 3.10: A circle of coppice resprouts around a charcoal filled crater.

Survey Results for Tree Stumps

Using the triangular tessellation method (Ward 1991), a survey of these old stumps showed that they were only present at about a half (51%) of the sample points visited. We may reason that in some areas, where fierce fires occurred, perhaps to dispose of logging trash, patches of stumps were burnt away.

The median stump diameter was 80 cms, with a range from 25 cms up to 2.2 metres. The median diameter of current *jarrah* was 18 cms, with a range from 4 cms up to 2.2 metres. There is a significant statistical difference between these two estimates (P<.001).

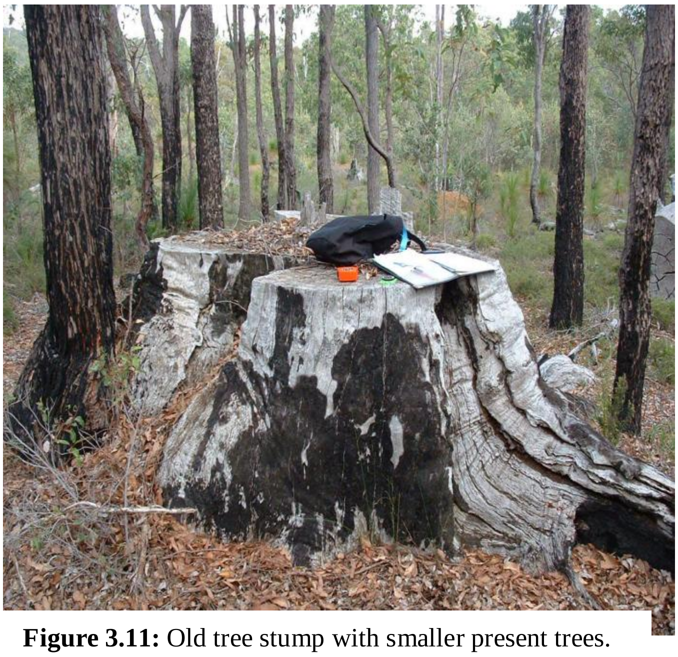

Figure 3.11: Old tree stump with smaller present trees.

Where stumps were found, they were blatantly bigger, and the distances between them greater, than the distances between current, much smaller *jarrah* trees (Figure 3.11). It has been suggested that smaller stumps may have rotted and disappeared sooner than large ones. However, for economic reasons, sawmillers would not have harvested small trees if big ones were available. In addition, old photographs invariably show only large trees being harvested.

The estimated median density of the former large trees, at sites where they could be found, was 84 per hectare. We can be 95% confident that the true median lies between 69 and 100. Scaling by the catchment area, and remembering that stumps were only found at about half the sites, we can estimate that about 600,000 stumps remain in Wungong Catchment. Given the great age of some (400 years or more?), they are a potentially valuable resource for future studies, including possible investigation of past rainfall, and fire frequency. The Department of Environment and Conservation would do well to conserve them, by avoiding fierce fires in the catchment, and raking around stumps before mild burns.

The estimated median distance between old stumps was 14 metres, compared with only 5 metres between current trees. By Mood's Median Test, the probability of this occurring by chance, were there no real difference, is less than one in a thousand. The maximum distance observed between two adjacent old stumps was 55 metres, but between two adjacent current trees the maximum distance found was only 24 metres.

It seems that the current *jarrah* forest in Wungong Catchment consists of much smaller trees, at much closer spacing, than it did before logging started in 1872. This has likely implications for evapo-transpiration and creek flow, which will be discussed in Chapter 9 (Fire, Forest and Water).

Conclusions

There can be pleasure in walking through Wungong Catchment, but there can be pain and injury too. One can fall down old quarries, and into creeks. Walking is particularly unpleasant in areas previously logged, and still littered with trash. It is tiring constantly to step over dead logs and branches. It is similarly tiring to walk in areas supposedly rehabilitated from bauxite mining by planting large prickle bushes, and using a bulldozer to form steep contour banks, full of jagged rock fragments. These areas may look green from a satellite image, or even from the window of a tourist bus, but close examination shows that few of them bear any close resemblance to the surrounding native forest. Although there are places, such as the monadnocks in the south-east corner, which have spiritually soothing characteristics, Wungong is not entirely a romantic paradise.

In the face of likely long past occupation, hunting, and gathering by *Nyoongar* people; known past logging, farming, and quarrying by settlers; recent large scale bauxite mining, mounding, and replanting; the presence of introduced cinnamon fungus, or '*jarrah* dieback' (*Phytophthora cinnamomi*) and feral pigs; firewood gathering; plus recreation, both legal and illegal, in the catchment, it is not a pristine wilderness.

Yet there is still much worth protecting, and restoring, for the benefit of both nature and society, entwined as they are. I will, later, present evidence to suggest that deliberate and skilful use of bushfire has an important role to play in that protection and restoration.

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Chapter 4

The Other Side of the Hill

BUSHFIRE IN FOREIGN LANDS

All the business of war, and indeed all the business of life, is to endeavour to find out what you don't know by what you do; that's what I called 'guessing what was at the other side of the hill'.
The Duke of Wellington, 1885

Preamble

Even if known by different names, bushfire is not confined to Australia. Africa has a long record of deliberate burning by humans, for a range of very practical reasons. In India and Burma, there was a long struggle between European foresters, and villagers who burnt the jungle. There is a vast literature on fire in North America. Even Europe has a record of deliberate burning of forests and bramble patches, for purposes such as clearing, grazing, and growing crops.

In a previous chapter, I suggested that my literature search was like a landscape, with a muddled maze of interconnected paths, surrounding three main streams of knowledge, flowing into a central swamp. This chapter looks to the hinterland of that landscape. Succeeding chapters will spiral inward, crossing many tangled paths of knowledge, first to the *jarrah* forest, then converging on Wungong Catchment itself.

In this chapter, I will not try to cover fire everywhere, because much of that has already been ably done by others. Information in this chapter will focus on a few places, which seem to have relevance to bushfire in Australia, and in particular bushfire in Wungong Catchment. In the final chapters of the thesis, I will discuss, and recommend, a fire management style for that catchment.

My proposals may be politically controversial. Information in this chapter will help the reader to determine if my proposals on bushfire are anomalous on the world scene, or are part of a much larger geographical, historical, and even political picture. I am looking for corroboration, or consilience.

Burning in Africa

Rather than following the Iron Duke's advice and guessing what's on the other side of the hill, Australian ecologists could learn much by studying bushfire on the other side of the Indian Ocean, where Southern Africa has similar climate, soils and vegetation, and some astute ecologists. It also has a similar human history, with indigenous (*Khoikhoi*, *Khoisan* and *!Kung*) people burning for thousands of years before being replaced by *Bantu* migrants moving south, and, a little later, by European migrants moving north from the Cape of Good Hope.

Burning in the 1600s

For example, Parkington (1977) studied the reports of early European travellers in South Africa, and found a description of the *Soaqua* people of the Olifant's River Valley. In the dry summers, they congregated around the lower reaches of the river, for access to fresh water, but in winter, with rainfall, they spread out inland, and gathered plant food. Parkington said that 'Taking advantage of the dry condition of the *veld* and anticipating the plant growth of the wet season, the *Soaqua* burned the grass along the banks of the river in the late summer of 1661, and presumably in other years too.' This sounds remarkably like early descriptions of *Nyoongar* burning and seasonal movement along rivers in south-western Australia (Hallam 1975).

Burning Around Bulawayo

In an excellent article on south and central Africa, Oliver West (1971), former Chief of Botany and Ecology to the then Rhodesian (now Zimbabwean) government, gives references to observations on fire and humans by early European explorers and hunters, and fire's role in stimulating grass growth, at the expense of woody shrubs and trees. He found that excluding fire and grazing led to loss of grass, and encroachment by shrubs and trees. Long standing human use of fire seems to have been a major factor in maintaining large areas of grassy savannah in Africa.

Oliver West quoted a personal communication from a colleague (Kennan 1971) who described traditional burning by the *Ndebele* tribe, around their capital, Bulawayo. The surrounding grassy savanna was divided into three sectors, and one sector was burnt each year, so giving a three year cycle. This was done to stimulate fresh grass for the cattle, by removing tree litter, for the *Ndebele* believe that tree leaves poison grass. Only in the past few decades has the reality of toxic warfare between plants (allelopathy) been demonstrated in other parts of the world (Muller *et al.* 1968).

Bushmen Burning

Further south, describing an African journey in 1811, the hunter W.F. Burchell (1822, in Hall 1984) noted that Bushmen burnt old grass in order to attract game to the fresh green shoots. He described such regrowth as like a ‘field of wheat’. Where there had been no burning, the green growth was smothered by old grass.

Referring to Bushman use of fire in the early twentieth century, Schapera (1930) observed that, in the Okavango area (now part of Botswana), the *veld* was normally burnt at the end of the dry season, in order to promote the growth of roots and bulbs in the coming rainy season. The Bushmen also used fire for hunting, the men spreading around the fire in a semi-circle and driving the game towards other hunters lying in wait. In south-western Australia, *Nyoongar* people also used this hunting method. It was described in the 1840s by a missionary priest, Dom Rosendo Salvado (1977).

Schapera noted that the new grass springing up soon after a fire attracted game into the area. In Africa there is a well known sequence of grazing, with zebra and wildebeest coming in first, followed later by antelope. Australian Aboriginal hunters were, and still are, well aware of the attractions of fresh grass to kangaroos (Mitchell 1848, Hallam 1975, Murphy and Bowman 2007).

Even more recently than Schapera, Marshall (1976) working in Africa amongst *!Kung* Bushmen, said that *veld* fires were common, and were caused by Bushmen, trying to attract game to the post-fire green shoots. He also described how fires ran ‘raging before the winds', until a wind shift blew them back on themselves. He reported being surrounded by as many as 'eight fires at a time'.

In south-western Australia, the technique of using predictable wind changes (for example the daily summer change from land to sea breeze) to make a fire burn back on itself was still known, in the first half of the twentieth century, to *Yamatji* people in *kwongan* heath land near Geraldton (personal communications from Stan Gratte of Dongara, and *Yamatji* Elder Albert McNamara). It was also well known to some European grazier families with coastal leases between Bunbury and Fremantle (personal communication from Elaine Marchetti of Waroona). Up to the early 1960s, they would light a fire at ten in the morning, in March, on a south-easterly wind, then leave it to its own devices, knowing it would safely self-extinguish when the wind backed around to a south-westerly sea-breeze in the afternoon. In current heavy fuels, such a procedure could be disastrous.

Burning by the Bantu

The term *Bantu* simply means 'people', and is used by the cattle and goat grazing people of southern and central Africa to describe themselves. The *Bantu* graziers, who have replaced the Bushmen over most of southern Africa, still use fire for hunting; to stimulate grass for their cattle; and to get rid of ticks, which climb up tall grass stems to drop onto passing beasts and humans. By use of fire these graziers maintain a grassy savannah, or savannah woodland, where otherwise would be dense thorn scrub.

Marwick (1940) noted that the *Swazi* people (who are *Bantu*) have a detailed vocabulary to describe different stages of grass growth in relation to fire. Recently burnt grass is known as *mshakwindla*, and areas conserved from burning for feeding cattle while the new grass grows are called *sikotsa sokuhlala ubusika*. The general name for unburnt ground is *umlale*, and for recently burnt areas *lilunga*. This special vocabulary suggests that landscape fire has long been important in *Swazi* culture.

A similar observation has been made for the *Nyoongar* people of south-western

Australia, who called unburnt country *bokyt*; unburnt country which needed to be burnt *narrik*; and recently burnt country *nappal*, or *yanbart*. There were special words for the different types of grass which sprang up after fire, such as *kundyl* and *booboo* (Moore 1885, Hallam 1975). I doubt if the *Nyoongar* language would contain such detailed terms if landscape fire, and its effects, were of little practical interest to *Nyoongar* people.

Mosaic Burning in Kruger National Park

In Africa, there has been work on mosaic burning (Brockett *et al* 2001), and on the deliberate use of bushfire in Kruger National Park (Brynyard 1971). Evidence for patch burning in East African savanna has been examined (Gillson 2004), and the issue of deliberate burning for fuel reduction is obviously very much alive in that part of the world (Trollope and Trollope 2004).

Kruger National Park is of particular interest. It is South Africa's oldest game reserve, and in 2001 a fierce bushfire swept through it. Large animals, such as elephant, rhinoceros, and warthog were killed, but the fire also killed twenty-three humans (South African National Parks 2001). Of these most were women, gathering thatch grass. We need to understand the historical causes of the severity of this fire.

Originally called the Sabi River Reserve, the area of Kruger National Park must have been subject to the frequent landscape fires of *Bantu* herdsmen for centuries, and hunter-gatherer burning long before that (Parkington 1977, Hall 1984, Govender 2003). The first warden, appointed in 1940, was Colonel Stevenson-Hamilton, who favoured frequent burning to renew grass (Brynyard 1971). He knew that grazing animals tended to avoid long grass, which can give cover to predators such as lion and leopard. He also knew, like the *Bantu* herdsmen, that long grass harbours ticks, which can debilitate both grazing animals and their predators.

His views were contradicted, in 1946, by his successor, Colonel J.A.B. Sandenburgh, who opposed deliberate burning. As a result, much of the game moved into neighbouring areas, where villagers still burnt grass regularly. Being outside the legal protection of the park, the animals were slaughtered in large numbers. According to Brynyard (1971), the exclusion of fire from the park led to an encroachment of woody thorn bush, which was still going on at the time he wrote.

Apart from immediate effects on game, the unburnt grass and thorn bush provided fuel for fierce fires. In the spring of 1954, over five thousand square kilometres burnt, killing many animals. This fire provoked some thought.

Navashni Govender (2003) has outlined the history of attempts at fire management in Kruger National Park. Following the massive 1954 fire, from 1957 to 1980, there was a return to burning blocks of about 4000 hectares, in spring, on a three year cycle. From 1981 to 1991 some variation was introduced in fire frequency and season, in the belief that this was more ecologically sound. But in 1993, academic ecologists decided that only lightning fires were 'natural', and all other fires should be suppressed. Lightning fires were to be allowed to run, even being helped, by park rangers, over artificial barriers, such as roads. The result was an outbreak of massive fires in 1996, after a late wet season had led to heavy fuel accumulation. Some of these fires were due to lightning, but others were blamed on refugees from Mozambique and Zimbabwe. They were possibly trying to clear thick thornbush, to make walking easier. The lethal fire of 2001 has already been mentioned. After that, Kruger National Park adopted a much more flexible fire policy, with greater reliance on the local knowledge of managers and rangers.

This is very similar to the policy advocated for the forests of south-western Australia by Conservator Stephen Kessell in 1929 (Ward 2000a). He emphasized the importance of local knowledge, and local capacity to decide when to burn, and to act promptly. Kessell was responding to the reality of increasingly fierce fires under attempted fire exclusion for the previous decade (Ward 2000a). Whether he said so, or not, he also clearly acknowledged the role that knowledgeable humans have long played in determining fire frequency, and so in altering the intensity of fires.

Flames in Madagascar

Not far from Africa is Madagascar, which was a French colony from 1895 to 1960. Although Madagascar is not generally well known, Christian Kull has amply addressed the history and political ecology of fire in that island (Kull 2000a, 2000b, 2004).

Despite a history of traditional burning in France (Pyne 1997, Ribet 1998), the French colonial forestry officials, and botanists, were opposed to fire, considering it entirely destructive. They had political and economic influence, because of the commercial value of timber. Other French officials, for example agricultural advisers, were more sympathetic to the villagers, understanding the benefits of fire in maintaining grassland for cattle, destroying ticks, and in repelling, or killing, locusts. Nevertheless, the use of fire was made a criminal offence.

The Malagasy villagers resented government interference in their traditional use of fire, and resented the comparison of their traditional burning with what they regarded as real crimes, such as theft or murder, so conflict was inevitable. Burning was not only for practical purposes, but played a recreational and cultural role. The conflict over fire continued after independence in 1960, because the new government adopted the 'received wisdom' from France, that fire is 'bad'. Fire lends itself well to clandestine use, so, despite the power of the state, the villagers burnt, and still burn, with a great strategic advantage. Sympathetic officials sometimes turn a blind eye.

Christian Kull notes that the 'received wisdom' on fire was firstly based on outmoded ideas from the natural science version of ecology, including the 'Vegetation Climax Theory' (Clements 1936), and later on the ideas of the 'conservation boom' of the 1980s and 1990s, when 'biodiversity' became the 'holy grail'. He suggests that the livelihoods and cultural beliefs of the villagers took second place to scientism.

More recent work in ecology suggests that many ecological outcomes are possible from human intervention in the landscape, and that there is no entirely predictable equilibrium state. Both predictable order, and unpredictable chaos, exist within ecosystems, and landscape is a ‘nature-society hybrid’ (Zimmerer 2000). Christian Kull argues that landscape is, therefore, subject to human political negotiation. We should not presuppose that a particular outcome, such as tall, closed forest, is ‘best’, is achievable, and is not negotiable. I suspect that diversity in the landscape offers the best habitat for a diversity of plants and animals.

My own view is that we should, in ecology, always beware of mechanistic science, and be alert to the possibility that our assumptions may be wrong, or insufficient. According to the physicist Pierre Duhem (1906), and the philosopher Willard Quine (1953), extra hypotheses may subtly hide in the background, until recognized and brought into play. Such extra hypotheses may not be scientific, but, as previously argued, historical, philosophical, economic, or political. ‘Scientism’ often ignores these rich ‘Duhemian webs’, so giving an impoverished version of the world and its ecology, including the landscape ecology of fire.

Christian Kull emphasises the extreme complexity of fire, and says that, in order to resolve land use conflicts, we need to consider not only scientific evidence, but also history, power relations, economics, the ‘ideological baggage of the groups in question’, and how they interact. He might well be talking about the debate over bushfire in Australia (Pyne 1991, 2001b)

Du Feu en France

With its generally temperate climate, Europe is not an obviously fire prone region, although there have been severe summer fires in recent times in southern France, Greece, and Sardinia (Rackham 2003). It has been pointed out, however (Pyne 1997), that fire has a long history in Europe, as elsewhere, and has played a role in shaping landscape.

This view is supported by research into the traditional use of fire in rural France (Ribet 1998), where some official correspondence from the eighteenth century makes it plain that shepherds in the Pyrenees and the *Massif Central* used landscape fire as a tool for making country accessible to stock, to promote grass growth, and to enable crops such as rye and oats. Such fire use may date back to the Bronze Age.

For example, in 1731, in a memoir to the *Intendant d'Auvergne* (Ribet 1998), a public servant wrote *'les bergers font usage de metter le feu aux bruyères et dans le temps où la sécheresse les rend les plus combustibles… Le prétexte de ces boutefeux est que les bestiaux à laine et à corne y trouvent mieux à paître.*' [Shepherds make a practice of setting fire to the brambles at the time when the dryness makes them most combustible… The pretext for these bonfires is that sheep and cattle find better grazing there.]

In the same year, another correspondent wrote from Aurillac (Ribet 1998) that '*lorsqu'on met le feu aux bruyères, il y vient l'année d'après une herbe tendre, et la bruyère même qui repousse, fait que les bestiaux paissent dans ces lieux la avantageusement pendant deux ou trois ans.*' [When the brambles are burnt, there is lush grass the year after, also the new bramble sprouts, giving the beasts better grazing in those places for two or three years.]

Yet another wrote (1731) from Riom, in the *Puy de Dome*, disputing the views of an official who opposed burning. He said *'l'auteur de ce mémoire se trompe assurément quand il dit qu'il est inutile de brûler les bruyères. Il y a une bonne partie de la province qui n'aurait presque point de récolte si on se départait de cet usage, et après qu'on a semé une premiere année en seigle et une autre en avoine, la même terre produit pendant plusieurs années un pacage excellent et ce n'est pas qu'après que les bruyères ont surmonté qu'on recommence a brûler et à ouvrir la terre.*' [The author of this memoir is definitely mistaken when he says that it is useless to burn the brambles. Many people in the province have almost no other source of harvest if they abandoned this method, and after they have sown, in the first year, rye, and the next year, oats, the same soil produces for several years an excellent grazing, and it is not until the brambles have overrun it again that they start burning and clearing.]

Like the Malagasy people, those French villagers who have long used fire for constructive purposes, have never accepted its criminalization by the State. According to Ribet (1998) they are currently resisting recent attempts, by middle class ‘conservationists’ from large cities, at politically enforced fire exclusion. Such city people like to walk in the landscape created by the fires of past villagers, but do not want their aesthetic sensitivity offended by any blackened ground. Beauty is, of course, in the eye of the beholder. Australian Aborigines describe unburnt bush as ‘dirty’, and recently burnt bush as ‘cleaned up’. David Hume (1757) said that ‘Beauty is no quality in things themselves. It exists merely in the mind which contemplates them.’ (Partington 1996).

Burning in the Raj

Apart from Africa and Madagascar, another rich source of information is to the north of the Indian Ocean, where traditional burning was common in India and Burma before British and German foresters tried to prohibit, and criminalize it, in the nineteenth century, on ‘scientific’ grounds. This attempt at fire exclusion created ill-will among the villagers, and was, both in India and Burma, a factor in leading to discontent, and the formation of effective, grass roots independence movements (Bryant 1996).

The reasons why Indian and Burmese villagers burnt their forests and jungles were mainly to promote grass for cattle (*coomrie*), and to create clearings for gardens (*toung-ya*) respectively (Pyne 1997). This jarred with the British, and originally German, concepts of ‘scientific’ forestry, which aimed to produce the maximum yield of straight saw-logs. Fire made some timber unsuitable for the saw-mill, although some of the shrewder foresters realized that fire was an integral part of the Indian and Burmese forest systems, and probably had been for thousands of years. Some of these foresters (Slym 1876, H.S. 1896, Carr 1904, Greswell 1926, Shebbeare 1928, 1930, Milroy 1930) expressed doubts about the long term survival of *teak* (*Tectona grandis*), *chil* (*Pinus longifolia*) and *sal* (*Shorea robusta*) forests if fire were excluded. Although fire scars spoiled some logs, they argued that, without fire, there would be, in the long term, no logs at all.

Forester M. J. Slym presented his ideas on the benefits of fire in *teak* forest to a forestry conference in Rangoon in 1875, but he was told by the President that his talk could not appear in the published proceedings. Furthermore, no reason for this could be mentioned. Presumably Slym's views clashed too much with the 'received wisdom' on fire. Slym was, soon after, demoted, but it is unclear if this was a direct result of his heresy. Perhaps it was a warning shot across his bows.

One forester, who enthusiastically embraced the official, 'scientific' view of his superiors on fire, was David Hutchins, who enjoyed rapid promotion, and subsequently visited Australia to share the benefits of his wisdom on fire with the humble colonials. He was informed of traditional *Nyoongar* burning, but chose to dismiss it, presumably as 'unscientific'. Ignoring local Australian knowledge, and the views of some of his fellow foresters in India and Burma, he advocated fire exclusion from eucalypt forests (Hutchins 1916). The results of this attempted fire exclusion will be examined in Chapter 5 (Bushfire, Flogging, Measles and Foresters).

A decade before Hutchins visited Australia, one brave soul, identified only as 'H. S.', wrote to the Indian Forester (1896), questioning the merits of fire exclusion from *teak* forest in Burma. He described how *teak* seeds needed the removal of leaf litter by fire in order to germinate. He considered that regeneration of *teak*, over large areas, was impossible without the help of fire.

'H.S.' (1896) also described the fires in Burma, where the best *teak* forests were burnt over every year. For those who did not know Burma, he explained that such fires were completely different from the 'huge forest fires of America'. Burmese fires were confined to the ground, and advanced slowly through a few inches of dry leaves, with flames usually 'not more than a foot high', such that a 'pony will step over them'. He said that these fires could burn for weeks, and 'travel from one end of Burma to the other'. There are descriptions of fires in south-western Australia, up to the 1920s, which closely resemble this Burmese description (e.g. Wallace 1966). They trickled along all summer, through a few inches of leaf litter, flaring occasionally where a patch of grass or shrub had been missed by previous fires.

In Burma, in the earliest years of the twentieth century, Forester S. Carr (1904) seems to have become exasperated at the official doctrine of fire exclusion. He remarked that those most vocal about fire exclusion were those who had least practical experience of the matter. He asked why, if fire exclusion was beneficial, did *teak* grow faster in the parts of the forest that were regularly burnt?

Nevertheless, in 1906 the authoritarian 'scientific' belief in fire exclusion was still dominant in the Indian Forest Service, even though the longstanding traditional use of fire by Indian villagers was clearly recognised. Some European foresters simply thought they knew better, and perhaps they did, if maximisation of short term timber harvesting was the sole aim, without regard to long term forest regeneration, or human safety, or the welfare of the local inhabitants. The mental baggage, or *weltanschauungen,* of both the senior forest officials, and the villagers, need to be understood.

The Deputy Conservator of Coimbatore, C.E.C. Fischer (1906), wrote that: 'From time immemorial the people of India living in and near forests have been in the habit of burning them whenever they wished and moreover have not thought it in any way incumbent on them to prevent burning or refrain from any act which might cause fire, the burning being generally beneficial from their standpoint. Forests are burnt to obtain new grass, to facilitate the collection of fruit, honey, roots etc.; to facilitate *shikar* [hunting] and even to render passage through the jungle easier and less dangerous ...

Fires being almost entirely due to man are preventible ... we must therefore teach them by the force of example as well as by precept assisted by deterrent punishment meted out to detected incendiarists.'

Fischer's views are disturbingly similar to those expressed by some European settlers, in an official correspondence on *Nyoongar* burning in south-western Australia in 1846. While well aware of traditional *Nyoongar* use of fire, and the benefits, in 1846 they passed a law prescribing flogging and detention for those caught lighting fires (Ward 1998). We may also compare this with the criminalization of fire in Madagascar, under French colonial rule (Kull 2004).

Even a decade after Hutchins visited Australia, an observant forester called E. A. Greswell (1926) noted that *chil* forests in India needed fire in order to regenerate. He traced the history of burning in these forests back to the time of Aryan invasions 2,000 years ago. From records kept from about 1900, he judged that the traditional fire frequency was about every three to four years. It will be seen, later in this thesis, that this is an intriguing cross-match with the traditional *Nyoongar* fire frequency in the *jarrah* forest, and also with the minimum number of colours needed to colour a map so that no two adjacent patches are the same colour (Chapter 7: Does God Play Dice?).

From Greswell's article, the life history of *chil* appears to be similar to that of *jarrah*. It has great coppicing powers, and despite being repeatedly cut back by fires, eventually forms a root strong enough to throw up a dynamic shoot which grows very fast, so saving it from the next fire. He also noted that the firing incidence corresponded roughly to the incidence of *chil* seed years, and had an interesting insight into the sometimes blinkered perceptions of Europeans in an alien environment.

Referring to the fire exclusion imposed by the British foresters, and their German advisers, he finished his article by saying that: 'We talk glibly about following nature and forget that the nature we are visualising may be an [*sic*] European nature inherited from our training and not an Indian nature. We naturally regard fire and grazing as destructive agencies. We, therefore, intuitively welcome the proof provided by the few cases in which they are so and by inductive reasoning arrive at general conclusions which may be incorrect if not dangerous.'

David Hume (1748), who warned against the perils of induction (reasoning from particular to general), would have agreed with him. Advances in statistics and probability in the twentieth century (e.g. Fisher 1944) have made induction a little safer, but deduction (reasoning from general to particular) is still the safest logical path (Joseph 2002).

Flaming Phrygana

There is a dismissive French quip about foreigners who speak French '*comme un mouton Grec*' (like a Greek sheep). Despite linguistic differences, or even rivalries, southern France and Greece have similar vegetation, and have much in common on fire. The Greek word *phrygana* (φρυγανα) means a low heath, similar to the *garrigue* of southern France, although even drier. Many of our domestic herbs, such as thyme, sage, and rosemary come from this heath. I know, from direct experience in Cyprus, that walking through such plants, on a hot day, creates a wonderful herbal odour. This is due to volatile oils (terpenes) in their leaves. These essential oils are highly flammable, and fires occur easily in summer, when the oils vaporize. In Australia, terpenes occur in many plants, including the genus *Eucalyptus*. Not only do they readily burn, but they can inhibit seed germination in other plants (Salisbury and Ross 1969).

The Roman poet Virgil, in his version of the Greek saga, the Aeneid, described 'scattered fires, set by the shepherds in the woods, when the wind is right' (Naveh 1973). Confirming this, a more recent paper on fire in Greece attributed much burning to shepherds, seeking fresh grazing by burning a mosaic of small patches (Liacos 1973). The same author attributed the widespread occurrence of the *maquis* and *garrigue* heaths to past burning by humans.

Some automatically regard the past replacement of tall forest by heath as 'bad', but Liacos reported higher nitrogen content in the burnt soils, and better quality forage. The survival of the shepherds probably depended on their burning for forage. Greek farmers also burnt stubble, so supplying ash as a fertiliser for wheat seedlings, and avoiding seedling chlorosis. Stubble burning reduced weeds and insects.

In recent times, Stephen Pyne, in his book 'Vestal Fire' (1997) has given detailed discussion of fire in southern Europe. He suggests that recent fierce fires in Greece, and elsewhere around the Mediterranean, are partly due to a change in land use, from traditional farming, to holiday villas for wealthy city dwellers. The farmers cared for the land more intensively, for example scavenging firewood, and collecting pine needles for animal bedding. The city people now allow dense vegetation to flourish, and litter to build up, then wonder why it burns, and threatens their houses (Pyne 2001). A highly readable essay on fire around the Mediterranean suggests a long association between humans, fire, and vegetation there, and supports Stephen Pyne's views on the reason for recent large fires (Rackham 2003). In this essay, Oliver Rackham also touches on fire in Israel.

Fire in Israel

It seems the heath vegetation in Israel (*batha*) has a similar fire history, perhaps even older than that of Greece. This was suggested by a distinguished Israeli ecologist, Zev Naveh (1973), who speculated that paleolithic hunter-gatherers, 50,000 years ago, used fire deliberately to drive game and stimulate a richer plant growth.

One effect of fire was to create more edge habitats ('ecotones'), favourable to grasses, bulbs, and herbs. Zev Naveh, in true cross-disciplinary style, called upon the Bible and the Talmud for evidence of the common occurrence, and ecology, of fire in the past. According to Zev Naveh there are at least thirty mentions of fire and its effects in the Bible. Fifteen different species are mentioned, and fire in connection with forest is mentioned six times.

Naveh also recorded the hostile use of fire as a weapon, by Arab herdsmen, probably for over a thousand years, and an awareness of the fertilizing properties of ashes, and the benefits of removing thorny bushes, which can tear the udders of goats and cattle.

After a fire, tree seedlings can appear amongst the geophytes, grasses and herbs. They will, if allowed to grow, often shift the *garrigue* type into the taller *maquis* type, shading out the other plants. According to Naveh, this can occur within 3-5 years. Subsequent failure of grass and herb germination, and geophyte flowering, may not be due solely to shading. Naveh suggests a role for toxic chemicals, contained in shrub and tree litter, which are destroyed by burning. After a few years these chemicals (terpenes) can reappear, and may inhibit germination. We should remember, from Africa, the *Ndebele* belief that leaves from trees are toxic to grass. Allelopathy has been demonstrated in a number of plants, including Californian chaparral (Muller *et al.* 1968).

Californian Chaparral

Much has been said on landscape fire in North America in general, (Pyne 1982, 2004, Williams 2003), and it is pointless to regurgitate it here. This section concentrates on fire in California, which has similar climate and vegetation to Western Australia.

With their climate, vegetation, and steep slopes, Californians were involved early in fire debates. Marvin Dodge (1972), a Californian forest ranger, published, in a prestigious journal, an article on the problem of forest fuel accumulation. He quoted William E. Towell, of the American Forestry Association, who suggested that efficiency in putting fires out might, in fact, prove to be a problem, as unburnt fuels accumulated, and fire hazard increased. From recent reports of Californian fires it seems he was right.

Richard Minnich, using satellite photographs, has contrasted the fine-grained fire mosaic in Mexican Baja California, with the obviously coarser mosaic north of the border, where US fire fighters have long tried to suppress fires quickly. This has resulted in chaparral fuel accumulation, and some uncontrollable fires when the Santa Ana wind blows (Minnich and Chou 1996, Minnich 2001).

As in Australia, this view of fire hazard and history is disputed by some. One paper claims that the difference in Californian fire mosaics is due to differing climate north and south of the US/Mexico border (Keeley and Fotheringham 2001). By examining the satellite image (Minnich and Chou 1996) for themselves, readers may form their own opinions. However, having carefully inspected the satellite image, I am unconvinced by the climatic argument. I doubt if climate respects political borders quite so neatly.

The debate between Minnich and Keeley in California is, nevertheless, an example of the way in which vigorous dialectic (medieval '*disputatio*') can help us reach the truth, sometimes by seeing 'contingent hypotheses' (Duhem 1906). With a colleague (Minnich and Chou 1996), Minnich has proposed that the vegetation of southern California was, in the past, a fine grained mosaic of different fuel ages and vegetation types. For example, grass would have prevailed where burning by Native Americans was frequent, with patches, or clumps, of shrubs, such as chaparral, elsewhere (see nested mosaic model in Chapter 7, 'Does God Play Dice?'). There is evidence (Jackson and Castillo 1995) that California, before the arrival of Spanish Franciscan missionaries in the 1700s, had a large indigenous population, possibly up to half a million. This population was greatly reduced by disease and violence, dropping to only 19,000 in 1900.

Minnich (1987) suggested that large fires, such as those of recent times, were rare, or non-existent, before 1900, when southern California had a finer grained mosaic of different burn ages. Quoting Pyne (1982) he suggested that over zealous fire suppression by US authorities, since the 1920s, has led to a coarse mosaic of heavy fuel, and extensive areas of chaparral, which burn uncontrollably when the dry Santa Ana wind blows. Keeley (2002) took the contrary view that large fires have always occurred in southern California, and nothing can be done to prevent them. He offered an account of a large fire (~ 125,000 hectares or more) in 1889. Goforth and Minnich (2007) contended that newspaper reports of the fire size and ferocity were exaggerated. Relying on such records as property ownership and insurance claims, they estimated that the 1889 fire was much smaller, possibly only a fraction of the size claimed. Keeley and Zedler (2009) gave further evidence to support the claim that the 1889 fire was as big as previously claimed, and offered ingenious arguments against the value of fuel mosaics, involving the use of cellular models of fire spread. They pointed to low lightning frequency in California, and suggested that the present growth in human population has led to more ignitions. However, most of California's current population lives in large coastal cities, and I doubt if many have either the inclination, or the opportunity, to set fires. The former Native American population, living in hutted villages, had both the opportunity and the motive.

An earlier paper (Keeley 2002) acknowledged the likely role of the previous native population in causing ignitions and so changing vegetation, and conceded that a ‘substantial fraction of the landscape was converted from shrubs to grass by native American burning.’ Yet, in contradiction, he later maintained that there was no fire induced vegetation mosaic in pre-European settlement California (Keeley and Zedler 2009).

We could trace this long and involved argument much further, but there is a different, and historically deeper perspective, which may shed light on the dispute. Before Europeans arrived, Native Americans were present in southern California for at least 13,000 years. Like Australian aborigines, they were greatly reduced in numbers by disease and violence, firstly from Spanish settlers, then Mexican rulers, then United States citizens. Two scholars, one of them of Native American descent (Jackson and Castillo 1995), give an Indian population of several hundred thousand in the 1700s, reducing to only 19,000 by 1900. Given that hunter-gatherers, in areas of flammable vegetation, have long made deliberate use of landscape fire, it is reasonable to conclude that, before European arrival, hundreds of deliberate, or accidental, fires were lit each year. There are reports of indigenous *Chumash* people using landscape fire to promote grassland, including food and medicine plants, and for hunting, in particular of rabbits, which would have been difficult to catch in dense, prickly chaparral. There is ethnobotanical evidence that landscape fire was used by *Chumash* to promote food and medicine plants (Timbrook 2007). It would be very unusual if the formerly numerous indigenous people of southern California did not use landscape fire as a tool to hunt, and modify vegetation into a mosaic to suit their needs.

Before quitting North America, we should consider the views of an experienced US fire chief on the social aspects of fire.

Social Aspects of Bushfire in the USA

In a talk to the Australian Fire Authorities Council, in Perth, Western Australia (Williams 2004), Jerry Williams, Director of Fire and Aviation Management for the United States Forest Service, set out his thoughts on the fire problem in the USA.

His emphasis was on the policy needed to address the social aspects of fire management, as well as the operational side. He suggested that good policy on fire would lie somewhere between the two extremes of complete freedom of individual human judgement, and a set of 'rule books' giving precise directions. He pointed out, correctly, that the first extreme would lead, at times, to catastrophe, and the second would never be achievable, given the complexity of the subject.

After giving a list of disastrous fires in California since 1961, Jerry Williams pointed out that the worst losses from these fires occurred where prescribed burning had been withheld, as a matter of political policy. The reasons for this policy were given as visual quality, species conservation, and water catchment values. They resulted in the accumulation of heavy fuel loads, in which fires became uncontrollable, despite California's annual $3 billion fire fighting budget. He suggested that there may even be a tendency for fire-fighting services to encourage the political tendency to foster a fire suppression approach, in preference to that of prevention. Ever bigger budgets lie in that direction. Yet wildfires 'simply outrun' the reliance on more and better equipment, and, in the real world, visual quality, species conservation, and water catchments suffer.

In closing, Dr. Williams called for a better understanding of fire's dynamic role in conserving natural systems, rather than the false view that such systems can be maintained in a static way, by attempted fire exclusion. The dynamic viewpoint would benefit both nature and society. It might be relevant to a recent British fire dispute, which has ecological, social, and economic aspects, of relevance to the Australian bushfire debate.

British Toffs and Twitchers

The idea of landscape fires in cold, foggy Britain may be surprising, but there is a long history. William Camden (1551-1623) an English antiquarian, commented on the traditional use of fire by Devon country folk in the sixteenth century (Camden 1722).

The English naturalist Gilbert White (1788), in his letters to Thomas Pennant, described large heath fires in Hampshire, which country folk lit to stimulate grass for their cattle. This was despite a statute passed in the reign of William and Mary, which threatened 'whipping and confinement in the house of correction' for those burning 'grig, ling, heath and furze, goss or fern…'. More recently, there have been significant fires on heaths in the north of England (Wainwright 2008, Kirby 2008).

In Britain there has been much debate, some acrimonious, on the effects of fire on heather, in particular in association with the economically important activity of grouse shooting. Such shooting is expensive, and landowners are often wealthy gentry or aristocrats. We may, loosely, call the grouse moor owners 'toffs', although they are not all aristocrats. I believe one of their number made his fortune out of renovating plebeian public-houses in southern England.

The nuances of the British class system may elude those from other nations, but environmental issues in Britain sometimes have an element of centuries of historical class conflict, for example fox hunting, and rambling along traditional footpaths across private land. I suspect that the dispute over grouse shooting and heather burning has an element of that historical 'mental baggage' (Kull 2004), but, as the self-made public house renovator shows, simplistic assumptions can be misleading.

The Moorland Association represents the interests of the landowners, 'toffs' or not, who claim to own and manage over 700,000 (over 283,000 hectares) of the estimated 800,000 acres (over 323,000 hectares) of heather in England and Wales (Gillibrand 2004).

Early criticism of the management of moorland for grouse came from the Royal Society for the Protection of Birds. A common name for a bird-watcher in England, especially the more earnest ones, is ‘twitcher’. The ‘twitchers’ objected to gamekeepers shooting hawks, to protect the grouse. This brought the ‘twitchers’ into conflict with the ‘toffs’.

In addition to shooting hawks, or robbing their nests, gamekeepers have also long burned the heather in strips, as soon as it reached the top of their gumboots. This ‘*muir* burning’ became an allied bone of contention, with claims that it was ecologically harmful. In fact, heather depends on fire for regeneration, and grouse depend on young heather for food. Perhaps the ghosts of Pierre Duhem and Willard Quine stalk the *muir*.

An early book, by a knowledgeable landowner (Lovat 1911), mentioned how fire was important in reducing ticks and worm parasites which could adversely affect grouse health and fecundity. His work was quoted in a later book (Kozlowski and Ahlgren 1974), where the authors added that parasites on mammals are also reduced by burning. I have already noted the use of fire in Africa and Madagascar to reduce ticks. I can find no research in Australia on this benefit of fire, yet it might well be relevant. Kangaroos, and other Australian native animals, are commonly infested with ticks. In Britain, the importance of fire to grouse has other aspects.

Grouse feed on the young, nutritious tips of heather, so as heather grows taller, the grouse can no longer reach their food. At the same time, grouse need taller heather for shelter from predators such as hawks, so it is important that heather burning leaves patches of older, unburnt heather. This is achieved by burning in strips up the hillsides. If, however, this deliberate burning is neglected, or prevented by poorly informed legislation, an eventual fierce fire will, as at Fylingdales in northern England, burn all the heather in the area, so leaving no refuge, or food, for the grouse.

Taking a cross-disciplinary viewpoint, such fierce heather fires are not entirely bad. The fierce fire at Fylingdales in 2003 burned deep into the soil and peat, and revealed prehistoric archaeology, in the form of carved stones, which may be 3,000 years old (Wainwright 2008). Presumably the peat concealing them has built up over that period. This suggests, to me, that the recent fire may have burnt deeper than any for the last 3,000 years.

From a long-term, balanced view, it has been pointed out that long past burning may have destroyed the habitat for elk and reindeer in Scotland, but other species, including grouse and hares, have thrived. Not only do grouse benefit from suitable fire frequency and pattern, but red deer are attracted to the better grazing on burnt ground for up to three years after fire (Miller and Watson 1993).

Ecosystems are complex, and, due to the chaotic and unpredictable nature of some events, there can be diverse outcomes from a disturbance such as fire. Whether those outcomes are 'good' or 'bad' depends on your ethical, economic, or perhaps disciplinary point of view (*weltanschauung*). Outcomes are subject to political judgement and negotiation, as Christian Kull has rightly pointed out. We might also consider that the branch of philosophy known as aesthetics enters into landscape choice, and remember that humans hold very diverse ideas on beauty.

From about the 1980s to the present, the dialectic over '*muir* burning' and raptor control has continued, mainly between landowners on one side, and the above mentioned two conservationist bodies, English Nature, and the Royal Society for the Protection of Birds, on the other. English Nature lobbied successfully for political prevention of burning, or at least the imposition of such onerous bureaucratic conditions that landowners would find it very difficult to burn. There was also a linked campaign by the Royal Society for the Protection of Birds, against the shooting of raptors by gamekeepers.

The landowners, with their incomes at stake, responded vigorously (Gillibrand 2004), countering the claims of English Nature, with evidence from an economist (McGilvray 2001), who quantified the importance of grouse shooting to the Scottish economy, and from natural scientists (e.g. Picozzi 1968, Gimingham *et al.* 1981, Hudson *et al.* 1992, Hudson *et al.* 1995, Hudson and Newborn 1995), who found that burning in a mild, patchy manner had benefits for both grouse and heather. Another source claims that raptor control is not only beneficial to grouse, but to other birds (Countryside Alliance 2008).

The political outcome was a reversal of the burning regulations, and the decision on when, where, and how to burn returned to the local control of landowners and their game keepers. It seems to me that, in their own economic interests, such people will tend to use fire responsibly. A whole layer of costly bureaucracy was dismantled, and I doubt if the bureaucrats were pleased. English Nature had its legal and financial wings clipped, and was renamed 'Natural England'. The aims of this organization can be found at (www.naturalengland.org.uk/about/default.htm).

Although the 'toffs' seem to be the present winners, the battle continues in the news media (Carrell 2008), with emotional appeals to conserve raptors. Some articles draw on information from the RSPB. In contradiction, heather burning and grouse management in England are strongly supported by another conservation body, which aims to promote sound moorland management. This conservation body points to the loss of 23% of heather moorland in Scotland between the 1940s and 1980s (Heather Trust 2004).

One possible outcome is that, if moorland owners cannot manage grouse and heather as long experience tells them to, they will convert the land to other uses, such as sheep grazing, or tree plantations. Landscape is, indeed, a highly negotiable matter.

Conclusions

This brief tour of fire effects, conflicts, and research in a number of lands suggests to me a common thread, relevant to fire in the *jarrah* forest, and Wungong Catchment.

This was a widespread recognition, by humans, long ago, that fire can be both friend and foe. No doubt, during the Great Ice Age, about eleven thousand years ago, human survival away from the equator depended on domestic fire for warmth. Even near the equator, the use of cooking fires must be of great antiquity, and landscape fire was used for hunting, and encouraging the regrowth of fresh grass and herbs.

Herding probably developed from the hunter's observation that animals were attracted to, and could be easily found, where grass had grown as a result of burning. As people adopted agriculture, it was found that ash and charcoal were of benefit to grassy crops such as oats and rye, and flame and smoke could help to reduce, or repel, pests such as locusts and ticks. It has been suggested that most of our current important cereal crops arose from the domestication of fire-adapted grasses in the Middle East (Naveh 1973).

Nyoongar people, in south-western Australia, faced the same problems of living off the land, and protecting themselves from the dangers of uncontrollable fire, as humans in other lands. We should not be surprised if we find that they used landscape fire in similar ways.

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Chapter 5

Bushfire, Flogging, Measles and Foresters

A BRIEF HISTORY OF BUSHFIRE IN THE JARRAH FOREST

'There would be practically no difficulty in stopping bush-fires, but no great advantage would accrue from the attempt – sooner or later fires will come, and the advantages gained by bush-fires more than counterbalance the disadvantages. In fact, such conflagrations are frequently advisable. Leave the forest unburnt for a few years, allow the shrubs to flourish, fallen trees to thicken on the ground, with dead leaves impregnated with turpentine, to accumulate and the destruction of the aged Jarrah, the many young plants and seeds will be completed. Allow the fires as a rule to take their course – if possible every 2 or 3 years.'

Joseph Strelly Harris, Inspector of Timber Forests, comments in a report to the Governor of Western Australia by the Surveyor General (Fraser 1882)

Preamble

Joseph Strelly Harris was the son of a medical practitioner. The family migrated from England in the early days of the Swan River Colony. Joseph was not a qualified forester or botanist, but he was an experienced bushman. He was the first to drive sheep from Albany to Perth, in the 1830s, when the present Albany Highway was an old *Nyoongar* track (*bidi*) through the *jarrah* and *marri* forest. On this route, he would have walked through, or near, the Wungong Catchment. He also regularly carried the mail between King George Sound and Perth in the 1830s (Harris 1978), and probably spent much time in the company of *Nyoongar* people. His descendants form part of the present *Nyoongar* community in Perth (personal communication from Mr. Norm Harris in 1996).

He was the joint discoverer, with the then Colonial Botanist, James Drummond, of the poison plants (*Gastrolobium* and *Oxylobium species*) which killed many sheep in the early days of settlement. His discovery has led to some interesting research. These plants germinate best after fire (Cochrane *et al*. 2002), and there is also an interaction with at least one small marsupial, the *woylie* (*Bettongia penicillata*), which digs intensely for truffles after fire, and so spreads their spores in its faeces (Lamont *et al*. 1985). These truffles are ectomycorrhizal, greatly improving the growth of some native plants, for example *marri* and Heart Leaf Poison (*Gastrolobium bilobum*). The fungal spores will not germinate unless they pass through a digestive tract. Fire, truffles, and *woylies* seem to form a mutually supportive triangle.

Joseph Harris held responsible posts as a magistrate at Williams, Toodyay and the Vasse between 1840 and 1861 (Statham 1979). During that period the first Bushfire Ordinance of 1847 was enacted, which was specifically aimed at criminalizing and curtailing traditional burning by *Nyoongar* people (Ward 1998a). The history of this attempt at bushfire prohibition will be examined in more detail later. In 1883 Joseph was appointed as the Inspector of Timber Forests for Western Australia.

Note also his comment, in the above quote, that there would be no difficulty in stopping bush fires. Obviously fires in his time could be stopped with hand tools, green branches, or wet bags. There were no bulldozers, fire-trucks, or helicopters then, and this was true up to the 1920s (Brockway 1923). Forest workers were commonly sent, alone, on a bicycle, with an axe tied to the cross-bar, to tackle bushfires (personal communication from Frank McKinnell in 2003, based on information from old foresters Neville Percival and Jack Thompson). Those bushfires must have been very much milder than present day ones

On arrival, the lone fire-fighter would use his axe to cut a red gum (*marri)* sapling as a beater (Brockway 1923). *Marri* are better for this purpose than *jarrah*, having larger, juicier leaves. Early settlers most likely learnt this simple fact from *Nyoongar* people, who used 'green branches' to beat out mild fires (Stokes 1846). Its importance and relevance might not occur to those without actual bushfire experience. However, beating out fires with green branches would be unthinkable today. Today's raging summer bushfires, in 10 or 20 year old fuel, cannot be stopped, even with water bombers, bulldozers, fire trucks, hundreds of fire fighters, and the Salvation Army to serve breakfast. The cost of suppressing a big bushfire now runs into tens of millions of dollars.

In a recent bushfire at Pickering Brook, a few kilometres from Wungong Catchment, an estimated 1.6 million mature *jarrah* trees were killed by the ferocity of the flames (Burrows 2005), exactly as predicted by Joseph Strelly Harris in 1882. Parts of the area had not been burnt for twenty years, and flames were 10-20 metres high. In the hottest places, fifty percent of trees were killed, some being over 200 years old. One man on a bicycle would inevitably have perished. Logic suggests that the 200 year old trees which died had never before been subjected to such a fierce fire.

When Bushfires Became Fiercer

We can even determine the time when bushfires became much fiercer, and less manageable. It was after two early Conservators of Forests, trained in Europe, tried to exclude fire from the forest in order to produce more saw logs. The Annual Reports of the former Forests Department of Western Australia make interesting reading.

In the report to parliament for 1924 (Forests Department of WA), the then Conservator of Forests, Stephen Kessell, noted that 'protection' (i.e. attempted fire exclusion), actually made fires more difficult to fight. He said: 'In previous years the method employed to extinguish fires was direct beating with bushes, and great success attended such efforts. In the season under review, however, the conditions were more difficult, due to the increased inflammability of the bush, through protection, the exceptionally dry summer, and the strong easterly winds experienced. During the first two months of November and December, the old method was employed, and direct beating found again successful. As the season progressed, however, the conditions became more difficult (owing to the increased inflammability of the bush) and many fires, after having been beaten down and swept in the old way, were found to break out again.'

Oddly, in the same year he published, in Western Australia, a paper (Kessel 1924), which he had previously published in the USA (Kessel 1923). In it, he described the 'damage' done by 'creeping fires in the forest'. This damage was, of course, relevant to sawmilling, rather than to nature conservation. The term 'creeping fires' is reminiscent of the description of traditional fires in Burmese teak forest.

Only mild fires of 500 Kw/m or less (flame <1m) can be controlled by beating, and in *jarrah-marri* forest these are the result of light ground fuels, accumulated over only a few years. Clearly this was the general situation before 1924. Eight years earlier, the visiting forest consultant, Sir David Hutchins (1916), said that: ‘The *jarrah* forest, like most of the *Eucalypt* forests, is liable to be burnt every two to three years.’ Kessell, and his predecessor Charles Lane-Poole, were the first to attempt large scale fire exclusion, with dangerous results, as Kessell later admitted.

Early Observations on Bushfire in South-Western Australia

These observations have been well summarised and discussed by Hallam (1975, 1985, 2002) and Abbott (2003). Although both draw on historical observations of bushfire, Sylvia Hallam is more inclined to the humanities approach, and Ian Abbott more toward natural science and statistics. Nevertheless, the picture painted by each is very similar. Both found frequent and widespread burning by *Nyoongars*, with a common interval around 2-4 years between fires. Most burning was in summer (December to February), although some occurred in spring and autumn.

Nyoongars and Settlers

As further consilience, present day *Nyoongar* people confirm the picture painted by both Sylvia Hallam and Ian Abbott (Eades 1999, Kelly 1998). *Nyoongar* Elders also mention frequent fire, and the prevalence of summer burning. Aiden Eades (*op. cit.*), Chair of the South West Commission of Elders, wrote to the then Minister for the Environment, stressing the importance of regular burning. He wrote that ‘The importance of regular burning (usually every 3-4 years) was stressed by our fathers and grandfathers from an early age.’ He also wrote that traditional burning generates new growth, reduces fire hazards, and attracts native animals into the burnt area to feed on the new growth. Some present descendants of early European settlers endorse this.

James Muir lives at Manjimup, a small timber town, two hundred kilometres south of Wungong Catchment, as the crow flies. He is the grandson of Thomas Muir, who was guided to that area by *Nyoongar* hunters in 1855, because they knew he wanted grassy country for his sheep. In a letter to the West Australian Minister for the Environment, James Muir gave his opinion that the timber areas of Western Australia were, over a long period of time, subjected to 'a summer/autumn burn every 3-4 years or as often as it would burn. Fires were lit by Aborigines or lightning.' James Muir described how this kept the forest understorey low, and prevented big fires developing, through the mosaic effect of burnt and unburnt areas. He said this style of fire management 'was carried on by the early settlers after the demise of Aborigines in the beginning of this century.' (Muir 1999). James Muir's opinions agree with those of an earlier member of his family, Andrew Muir, who wrote that the Warren country, near Manjimup, 'will burn every three or four years.'(Muir 1894).

Appendix D gives a statement from Frank Thompson (1975), who settled in the southern *jarrah* forest before the First World War. He too, said that fire intervals of three to four years were used by 'the natives when they were in the country.' He described how grass grew well after fire, and animals such as kangaroos and wallabies had plenty to live on. Excluding fire led to thicket growth, and 'kangaroos gradually shifted out'. Frank Thompson also described how small mammals were able to run through gaps in the flames, provided fires were mild.

Dwellingup is another small timber town, in *jarrah* forest, within fifty kilometres of Wungong Catchment. Yarloop is a saw-mill settlement about a further twenty-five kilometres south. Soon after a notoriously severe bushfire at Dwellingup, an old inhabitant of Yarloop (Riegert 1961) wrote to the editor of the West Australian newspaper, pointing out that: 'Original white settlers of many years ago told me that the natives used to patch burn the bush wherever there was enough litter to burn. The primary reason for this was to make feed for kangaroos etc. It also kept down insect and other pests without affecting bird life, making a clean bush with healthy rejuvenation and very little damage.' In *jarrah* and *marri* forest there is generally enough litter to burn at 2-4 years after the last bushfire.

A Contrary View

Writing in eastern Australia, Horton (1982, 1994, 2000) takes a contrary view. As far as I can understand his writing, he believes that Aborigines did not use fire to manage landscape, and the bush did not burn frequently before Europeans arrived. For example, he states that there was ‘no extensive and systematic use of fire by Aborigines’. This can be compared with the many sources of evidence which say that Aborigines did, and still do, use fire extensively and systematically. As a single counter example, a team including Aboriginal people (Russell-Smith *et al.* 1997) has said that burning by Aborigines in the Northern Territory was, and is, applied ‘systematically and purposefully’ across the landscape. Horton also states that ‘no Australian plants or animals are adapted to fire’. Again, there is clear evidence that many are. Another single counter example should suffice, for example the need for smoke to germinate West Australian seeds (Dixon *et al.* 1995).

From my other reading, I can only conclude that David Horton must be unaware of the considerable evidence of deliberate burning by Aborigines, from south-western Australia, and also from south-eastern Australia (Ryan *et al.* 1995). He also seems oblivious to the real danger, to both nature and society, which arises when fire is deliberately excluded for long periods, from highly flammable vegetation.

His opinions on bushfire have been strongly refuted by Hallam (1985), yet still seem to be accepted by some. Horton compares his work to Martin Luther’s ninety-five theses, pinned to the door of the castle church at Wittenberg in 1517. I have been unable to discover any evidence of a widespread ‘reformation’ in bushfire beliefs since his book was published. We may remember that Luther was a great advocate of faith and revelation, and called logic ‘the Devil’s whore’ (Blackburn 2005). David Horton is certainly entitled to his views on fire, but should not be surprised if they are challenged on logical grounds.

An Historian Gives an Opinion

Geoffrey Blainey (1975), discussing the wider Australian picture, gives clear historical evidence supporting the deliberate use of bushfire by Aborigines in other parts of Australia. They managed the landscape to their advantage. Earlier, Rhys Jones (1969) had suggested the term ‘fire-stick farming’, probably taking the term from the observations of Edward Micklethwaite Curr, an early settler in Victoria, who mentioned the ‘firestick’, and noted that the ‘blackfellows’ were ‘constantly setting fire to the grass and trees, both accidentally, and systematically for hunting purposes.’ Edward Curr concluded that ‘almost every part of New Holland was swept over by a fierce fire, on an average, once in every five years.’ (Curr 1883, Blainey 1975, Ryan *et al.* 1995).

Early European Observers in South-West Australia

In south-west Australia, early observers of the *Nyoongar* use of bushfire included George Fletcher Moore (1884), Edith Hassell (1936,1975), Isaac Scott Nind (1831), Alexander Collie (1834), James Backhouse (1843), and Captain Collet Barker (Mulvaney and Green 1992), after whom the town of Mount Barker is named.

In his diary, George Fletcher Moore (1884) mentioned the common occurrence of bushfire in the 1830s, and blamed much of it on the *Nyoongar* habit of carrying fire, both for warmth, and to avoid the labour of kindling it afresh. They seemed unconcerned about starting bushfires. They would discard a piece of burning bark, seemingly in a haphazard way, when the day became warmer. The bark would fall, ‘perhaps into a thick bush, or among high grass. A breeze comes, the smouldering embers are blown into a flame, and the whole country is shortly in a blaze.’

Two Royal Navy surgeons, Isaac Scott Nind and Alexander Collie, took a great interest in the *Nyoongar* way of life. They were stationed at King George’s Sound, now known as Albany, on the south coast of Western Australia. Isaac Nind left in 1829, publishing his observations in London, in 1831. Amongst a great deal more information on *Nyoongar* burning (Hallam 1975, Green 1979, 1984), he observed that summer was the time when most bushfires occurred. Nind recorded that ‘It is at this season that they procure the greatest abundance of game. It is done by setting fire to the underwood and grass, which, being dry, is rapidly burnt.'

Nind's successor, Alexander Collie, noted the same thing in a newspaper article in the Perth Gazette in 1834, writing that 'In December, but more particularly in January and February, the natives burn large tracts of country to catch wallabee, or bush kangaroo.'

A recent statistical summary of early bushfire observations (Abbott 2003) supports the view that summer was the main time for *Nyoongar* burning. One can only burn safely in summer if the fuels are low, due to frequent burning. To try summer burning in current fifteen or twenty year old fuel would be definitely disastrous. In *jarrah* forest, bushfire in litter fuel accumulated over as little as five or more years can be uncontrollable, and a danger to humans, in extreme summer conditions (based on my own experience, and personal communication from Greg Standing, fire manager with the West Australian Department of Environment and Conservation).

This should not surprise us. Some time ago, a rule of thumb connecting fuel quantity and bushfire intensity was suggested by an experienced forester and fire manager (Hodgson 1968). He suggested that, in Australian eucalypt forests, doubling the quantity of fuel, doubles the fire rate of spread. Since fire intensity is related to the product of fuel quantity and rate of spread, doubling the fuel quantity should quadruple the fire intensity. If this is true, then if three year old *jarrah* litter will produce an intensity of about 500 kw/metre (personal communication, Phil Cheney, CSIRO), then six year old litter will produce about 2000 kw/metre, which can be uncontrollable.

James Backhouse, visiting Perth in the early summer of 1837, noted that 'The Natives are now setting fire to the scrub, in various places, to facilitate their hunting, and to afford young herbage to the Kangaroos ... In some places, between Perth and Guildford, the Zamias are very fine, their trunks, which are always blackened by fire, being six to eight feet in circumference, and as much in height, and surmounted by fine crests, of stiff, pinnate, palm-like leaves, four feet long or more.' (Backhouse 1843).

If, as some claim, there was little or no bushfire in earlier days, it is hard to see why the zamias (*djiridji*) would have trunks 'always blackened by fire'. Backhouse also described the streets of Perth, writing 'The streets are of sand, mixed with charcoal, from the repeated burning of the scrub, which formerly covered the ground, on which the town stands ...'. Before visiting Perth, Backhouse had been in Tasmania and South Australia. In both places he observed the effects of frequent burning by the Aborigines.

A Botanist's View on Bushfire and Native Plants

An early, and acute, observer of the south-west vegetation was the West Australian Colonial Botanist, James Drummond (Statham 1979). He corresponded with Sir William Jackson Hooker, at Kew Gardens in London. Sir William was having trouble getting Australian plants to flower, so Drummond sent him some advice in a letter. Drummond advised cutting the plants to the ground, and adding some ash to the soil. This would mimic 'the triennial or quaternal burnings they undergo in their native land'. He added that 'some of our plants never flower in perfection but the season after the ground is burned over…' (Drummond 1844, personal communication from Dr. Lachie McCaw, West Australian Department of Environment and Conservation).

James Drummond was a trained botanist. We may wonder why would he suggest a general fire frequency of three to four years if it was not so, or if this was only true for a small part of the country. Why were most West Australian plants at their best soon after fire, but after a few years became 'ragged'? Drummond could 'never remember to have seen Australian plants in a good state after the second or third years'.

Drummond also noted, in his journal (Drummond 1844), that bushfire seemed necessary to provoke flowering in Trigger Plants (*Stylidium* spp.), and he connected this with nutrient supply. He wrote: 'In our journey to the south I gathered a most beautiful *Stylidium* in flower. For several years I have known the plant by its leaves, but I could never get it to flower. From a careful examination of the plant in various situations I have come to the conclusion that this species never flowers in perfection but the second year after the ground has been burned over. The leaves which are uncommonly beautiful became after the second year hard and rigid and apparently incapable of supplying the necessary nutrition to enable the plant to bring its flowers and seeds to maturity. I have named this species *Stylidium elegans*.'

A Soldier with a Farming Background

An early, and active, explorer of south-western Australia was Lieutenant Henry Bunbury, of the 21st Fusiliers. He was stationed in the Swan River Colony in the 1830s, and the present port of Bunbury is named after him. The Bunbury family were, and I believe still are, landowners and farmers in England, so Henry's interest in soils is not surprising. He intended, at one stage, to settle in Western Australia, but then moved on to a successful career, including a post as Governor of New Zealand.

His journals were published by a descendant (Bunbury and Morell 1930), and contain interesting comments on bushfire. For example, in 1837 (cited by Hallam 1975) he wrote that: 'It cannot be denied that Western Australia, as far as it is known, is generally of a rather sandy, barren nature, partly owing to the constant dryness and clearness of the atmosphere and climate and to the periodical extensive bush fires which, by destroying every two to three years the dead leaves, plants, sticks, fallen timber etc. prevent most effectually the accumulation of any decayed vegetable deposit… being the last month of summer … the Natives have burnt with fire much of the country…'.

From his comments, it seems that Bunbury, due to his European background, believed that humus was essential for healthy plant growth. Unknown to him, an 'invisible elephant' was hiding nearby. We now know that in some tropical, and sub-tropical soils, humus is highly fugitive. In moist soils, it decays rapidly, and in dry soils it blows away, carrying nutrients with it. In such circumstances, its role as a substrate for beneficial micro-organisms, and store for moisture and nutrients, can be efficiently filled by charcoal. There is a considerable literature on the virtues of 'biochar' (Lehmann and Joseph 2009). It can play the same role as humus in storing nutrients and water, and providing habitat for beneficial microbes. It breaks down much more slowly than humus. Those still applying European ideas to Australian natural systems need, perhaps, a ‘paradigm shift’ (Kuhn 1962), but old beliefs die hard.

A Travelling Vicar

Although one would expect early settlers in Western Australia to be young, the Right Reverend John Wollaston was a middle-aged English vicar, who migrated to Western Australia. He travelled widely, on horseback, in the south-west. The view from a horse’s back is much better than that through the windscreen of a car. From his journals (Wollaston 1975), he seems never to have become fully reconciled to the harsh Australian bush, when compared with the moister, greener English countryside.

In 1842 he described how *Nyoongar* fires near Bunbury ‘filled the sky with smoke’. He was reminded of the scene Abraham witnessed on looking toward Sodom and Gomorrah after their overthrow; ‘for I beheld and lo the smoke of the country went up as the smoke of a furnace…’. He also wrote ‘the fires occur every summer and for the time, destroy hundreds of acres of vegetation’.

Despite his English background, he had no doubt about the cause of, and reason for, most of the bushfires. He wrote: ‘The bush fires (which this year have been most extensive) are caused by the natives, either accidentally or intentionally. If the latter, it is for the purpose of driving the animals and reptiles into one spot, or the margin of some river or swamp, where they become an easy prey. The burnt ground, too, sends up in the rainy season a sweeter crop of grass which attracts the kangaroo.’

Natives Burning Again

A search in the Battye Library, in Perth, has revealed interesting letters on the topic of *Nyoongar* fire in south-western Australia (Colonial Secretary’s Records 1846). The early British settlers at York, about 75 km. north-east of Wungong Catchment, had suffered losses of crops and grazing, due to bushfires, some caused by the settlers themselves, others of *Nyoongar* origin. The settlers complained to the Governor, Andrew Clarke, asking for action to prevent bushfires.

Having only just been appointed, the Governor wrote to his magistrates, and other senior public servants, for advice. Being handwritten, some words, on microfilm, were hard to decipher. I present the full text, as far as I could decipher it, as Appendix A. This full presentation is important, so there can be no question of my misinterpreting, or selectively quoting to support a particular point of view. In this chapter, I give a brief outline of the correspondence.

The first letter was from the Governor to all 'Residents and Protectors of Natives'. In it, the Governor stated the fire problem at York, and asked for advice on how he might, even if unable to stop the *Nyoongars* burning, at least make the fires less frequent. Clearly the Governor was unaware of the likely outcome if fires were less frequent, and fuel built up. Some of those replying tried to warn him.

Revett Henry Bland, Protector of Natives at York, was the first to reply. He blamed the settlers themselves for some of the fires, but pointed out that it was *Nyoongar* custom to burn in summer, and that this burning had a number of benefits. He could find no evidence of malicious intent.

A well known Waterloo veteran, Captain Richard Goldsmith Meares (Deacon 1948), was the Resident Magistrate at York. He put pen to paper, clearly noting the clash between *Nyoongar* and settler land use, in particular with regard to bushfire. He mentioned that the *Nyoongars* depended on burning to obtain food, but he was in favour of criminalizing the use of fire, at least that by *Nyoongars*. He proposed a carrot and stick approach. *Nyoongars* burning would be imprisoned, and those refraining would be rewarded with bushels of wheat.

On the same day, Charles Symmons, Protector of Natives in the Swan Valley, wrote a balanced letter. He clearly had an interest in *Nyoongar* ways, and remarked that burning was, for them, 'one of their most ancient and cherished privileges'. He pointed out that, although most fires were lit by *Nyoongars*, settlers were responsible for some too, and the law should be applied regardless of race. He also suggested that *Nyoongars* should be allowed to burn in autumn (March onward), as long as they kept away from settlers' houses. He proposed a reward of flour for compliance.

Another Waterloo veteran, Lieutenant-Colonel John Molloy, wrote from the Vasse District, where he was a Resident Magistrate. He was the leader of a party which had settled on the south-west tip of Australia, at Augusta, in 1830, but found the giant *karri* (*Eucalyptus diversicolor*) forest too difficult to clear. In 1839 they moved northwards, therefore, to the more open, grassy country around the present town of Busselton. We may remember, from previous observations in Africa and Madagascar, that grassland is often a sign of frequent fire (West 1971, Kull 2004).

John Molloy's wife, Georgiana, spent much time in the bush with *Nyoongar* guides, collecting seeds to send to James Mangles in London (Hasluck 1966). She was familiar with bushfire, and her husband clearly was too. It seems unlikely that bushfires were rare or non-existent in that south-west corner. In fact, John Molloy considered them 'necessary' and 'salubrious', and had little confidence that the *Nyoongars* would desist entirely. He proposed gifts of flour, and a '*corrobory*' (traditional dance) as incentives to reduce burning.

To the west of the Wungong Catchment lies the Murray District, where Francis Corbett Singleton was the Resident Magistrate in 1846. Writing from his 10,000 acre farm at the junction of the Murray and Dandalup Rivers, Singleton mentions the importance of burning to the *Nyoongars* in obtaining food, and tells us that the most successful fires for killing animals ('in extraordinary numbers') were those impelled by a strong wind.

The use of fast moving fire by Aborigines to kill large numbers of small animals has been noted in more modern times, in northern Australia, where traditional burning is still practised (Haynes *et al.* 1991). Aborigines in Arnhem Land still burn light fuels under strong wind conditions when they wish to avoid damage to tree crowns, flowers, or fruits. The flattened flames and fast moving fires do little damage overhead, because the wind carries the heat away horizontally. A slow moving bushfire in the same fuel, in still conditions, may reach, and scorch, the tree crowns.

Where prescribed burning is now done by government agencies, or land owners, in southern Australia, it is, by choice, in still conditions, and crown scorch is common. This results in almost immediate leaf fall, so creating a fuel carpet again. This will sometimes carry another fire within a year, or even again within the same fire season. We settlers have much to learn about bushfire, especially the 'fast and flat' variety.

Interestingly, Singleton wrote that half the country to the west of the Darling Range (i.e. the coastal plain west of Wungong Catchment) was burnt each year, so that any one place would burn every second year. This suggests that native grasses were an important fuel component. Apart from *coondli,* or sheoak (*Allocasuarina* spp.) groves, and some patches of *marri*, which will burn mildly every two years, most pure *jarrah* forest will carry a fire only every three to four years. As mentioned above, it will carry fire more often if it is burnt too hot, or in still conditions, so leading to substantial leaf fall immediately after the fire.

The land at the junction of the Murray and Dandalup Rivers was described, in 1834, as a rich grassy plain of about 4,000 acres (Richards 1978). It is now fenced grazing land, carrying exotic grasses, which are not deliberately burnt by the farmers. The paddocks will, however, carry a very fast moving fire on a windy summer's day if lit by lightning, vandalism, or accidental ignition, for example by a faulty exhaust pipe.

At Bunbury, on the coast, south-west of Wungong Catchment, the relationship between settlers and *Nyoongar* seems to have been relatively amicable, so malicious burning to harm the settlers was unlikely. Besides, George Eliot, the Resident Magistrate there, like Molloy at the Vasse, regarded fire as a benefit rather than an evil. One of his proposals was that settlers should themselves burn a fire break around their properties, so making themselves 'perfectly secure'. This is further evidence that fires then were much milder than now, when fires can easily jump even wide fire breaks.

Eliot mentioned the benefits of fire, such as better grass growth, and the removal of insects and reptiles. He seems to have had a co-operative arrangement with the local *Nyoongars*, who would notify him when they intended to burn near settlers' buildings.

George Eliot's mention of better feed for stock after bushfire is of ecological significance. A number of other writers have addressed the same theme. For example, the letter above by Revett Henry Bland from York mentions 'the feed is always better where the dead grass has been previously burnt off'. Burning to encourage fresh grass is a world-wide phenomenon, as discussed in Chapter 4 (The Other Side of the Hill - Bushfire in Foreign Lands).

Burning for grass was noted by other settlers in Western Australia. In 1843 Elizabeth Brown wrote, in a letter to her father in England, 'I do not know that any steps have been taken to prevent the Natives from setting fire to the bush, but so long as they do it will injure the appearance of the country by denuding the trees of foliage. Mount Matilda in February last presented the appearance of a most beautiful illumination for several successive evenings, much to Mr. Brown's satisfaction, not for the attractive appearance alone but for the ensuring a much more luxuriant crop of grass, and this is I suppose in general why the Natives are allowed to pursue their custom.' (Cowan 1977).

Captain John Scully was, in 1846, Resident Magistrate at Toodyay, a small town about 90 kilometres north-east of Wungong Catchment. His letter was brief, perhaps because he was preoccupied with personal affairs. He returned to Ireland in the following January (Erickson 1988). He could find no evidence of malicious intent in *Nyoongar* use of fire in his district. Again, this corroborates the idea that such use of bushfire was traditional, and not a response to European settlement. Rather illogically, the letter continues to suggest fines and imprisonment as suitable punishment for lighting bushfires.

By November 1846, Captain Meares at York was becoming impatient at the lack of government action. He sent another letter, asking what steps were being taken. The

Nyoongars had already started their traditional burning. Meares again makes it plain that most bushfires at that time were caused by 'the Natives'. A month later, George Fletcher Moore, by then Colonial Secretary, sent a letter to the Advocate General, asking for legislative action.

Criminalizing Bushfire

Even in those days, the wheels of government turned slowly. The outcome, ten months later, was 'An Ordinance to diminish the Dangers resulting from Bush Fires', passed by the Legislative Council on the 2nd. September 1847, on the authority of Frederick Chidley Irwin, by then the Governor and Commander-in-Chief. The advice of those with some understanding of the social and ecological importance of bushfire to the *Nyoongars* was ignored, in favour of the farming interests of the settlers. No doubt this was also to the liking of the governor, who needed to be seen as someone who took strong action.

In this ordinance anyone setting fire to grass, stubble, shrub, or other natural vegetation between the first day of September and the first day of the following April, could be fined up to fifty pounds. If such person were an Aboriginal Native or a boy under the age of sixteen, then they were to be flogged, receiving any number of lashes not exceeding fifty. The right of appeal extended only to those fined ten pounds or more.

Locking Them Up

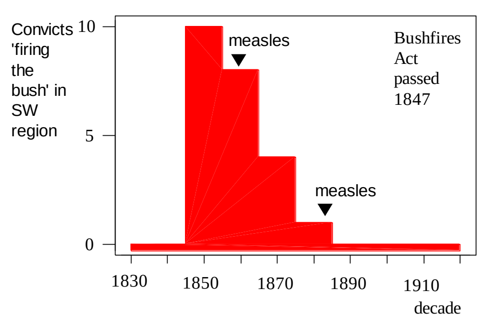

Figure 6.01: Aboriginal prisoners from south-western Australia on Rottnest Island for 'Firing the Bush'

Rottnest Island, off the West Australian coast, was used as a prison for Aborigines from the 1830s to the 1930s. Records of committals have been published (Green and Moon 1997), and Figure 6.01 shows the trend in committals from the south-west, specifically for 'firing the bush'. The measles epidemics of 1860/61 and 1883/4 are also shown.

The Effect of Measles

The First Fleet of British ships to arrive in Australia in 1788 took more than 300 days to make the voyage. By the 1850s clipper ships such as the 'James Baines' and 'Marco Polo' were doing the journey in 60 days, and the introduction of steam ships at about the same time led to further reductions in the voyage time (Cliff *et al.* 1993).

In the early years of European settlement, Western Australia was free of measles, due to the quarantine provided by the long voyage from England. At Fremantle, in 1843, Surgeon Dinely wrote 'Measles, small pox, typhus, or puerperal fevers, or any of those dire diseases to which the Mother Country is subject are here unknown.' (Cumpston 1927). Those who were carrying the virus when they embarked in England, had either died or recovered, and were no longer infectious, by the time they reached Australia (Cliff *et al.* 1993). Faster ships, however, enabled the virus to break through. By 1850 measles outbreaks had occurred in Victoria and New South Wales. Tasmania followed in 1854, Queensland in 1857, South Australia in 1859 and Western Australia in 1860 (Cumpston 1927, Cliff *et al*. 1993).

Measles first arrived in Western Australia in the 1850s, but was successfully quarantined at Fremantle. In 1860, however, the virus arrived in the port of Albany, and spread among the local population, especially amongst the native *Nyoongar* people, who had no resistance. It then spread up the Albany Highway towards Perth, visiting towns such as Mount Barker, Kojonup, Williams, Beverley, and York.

A contemporary observer, the Anglican vicar's wife at York, wrote in her diary that 'Measles were brought into Western Australia, in 1860, from a ship that entered King George's Sound and landed one person ill with the disorder. It spread widely and rapidly, assuming a very virulent character, more especially among the natives, of whom so many died that both they and the colonists in alluding to the visitation spoke of it in terms that would have been almost applicable to a time of pestilence. A lady of our acquaintance told me that on getting up one morning, she found a native woman who had been suffering from measles lying dead outside the house… she presumed that the poor creature must have found herself abandoned by the other natives, in terror of the infectious nature of the disease.'(Millett, 1872).

Nyoongar Decline Increases Kangaroos

Although exact figures are, for obvious reasons, unavailable, by 1870 the *Nyoongar* population had declined noticeably, due to measles, other diseases, and violence (Neville 1948, Radcliffe-Brown 1930, Green 1979). As a result of decreased hunting pressure, the kangaroo population seems to have increased. The Colonial Secretary, the Honourable F. Barlee, introduced a bill in the West Australian parliament, to repeal the need for a licence to shoot kangaroos. In the first reading, he was reported as saying that 'Kangaroos and other wild animals had increased so greatly, that their destruction was absolutely necessary. The natives were not numerous enough to consume them, and besides they now lived more on flour etc. which they procured from the European population, than on the kangaroo and other animals.' (Barlee 1870).

Mr. Monger and Mr. Shenton disagreed with Mr. Barlee, saying that the *Nyoongars* still relied on kangaroo meat. Mr. Monger said that 'The natives to the eastward of York live upon kangaroo, and it would be a great hardship to them if a license was given to have them destroyed'. Mr. Shenton said that 'Between Perth and Toodyay a number of natives live on kangaroo.' Mr. Barlee replied that 'The kangaroos had increased so much while the natives had so decreased that their [kangaroos presumably] destruction was necessary as they ate up the natural grasses from sheep and cattle.' However, Barlee agreed not to pass the bill if it would 'injure the natives' (West Australian Hansard 1870).

More Measles

A second measles epidemic broke out in the winter of 1883, and continued into 1884. Governor Broome wrote to the Secretary of State in London (Broome 1884). 'I regret to inform you that the disease of Measles has for some time prevailed in this Colony… The last occasion on which Measles was prevalent here was in the year 1861, when it caused great havoc among the Aboriginal population, and also severely affected the

Europeans… Some, though not very many, of the Aboriginal natives, have succumbed to the disease at Esperance Bay, in the neighborhood of Albany, and elsewhere… But the native population have not yet been seriously affected as a whole, and certainly it has caused no devastation among them comparable to that which took place when it was epidemic twenty-two years ago. It must be recollected, it is true, that the natives are now much fewer in number; but there are still many in the more Northern Districts, and it is here that I fear grave results.'

Broome's opinion on the relative mildness of the 1883/4 epidemic in the south-west does not match with other reports. One European observer (Hammond 1933) wrote that 'The measles epidemic of the early 'eighties affected the natives of the South-West and East very much. They died off in great numbers; and the nature of those that were left was altered; they lost all interest in bush life; they did not care what the others did or where they went and they were never the same people again. They dropped their own tongue and used the white man's language; they drifted away from all laws, ceremonies and customs. When their old chief Winjan died in 1884, it was the end of the real Aboriginal of the South-West'.

The Colonial Surgeon (Waylen 1883) reported that '…the general death rate was higher than it has been for some years… One or two circumstances have led to this result, chief amongst which may be mentioned an epidemic of measles which, up to the close of the year, had invaded all the Districts of the Colony, and was then spreading. It is 22 years since the last visitation of this malady, so that what in most parts of the world is looked upon as one of the diseases of childhood, became in this Colony one of adult life, frequently assuming a very severe form, characterised by intense fever, delirium, and bronchial complications.'

There is a probable link between measles virulence and conditions of poor nutrition, overcrowding, and intensive exposure (Morley 1969, in Cliff *et al.* 1993). These are exactly the conditions which *Nyoongars* would have experienced at that time, as they were driven off their own country, and forced to share with other groups.

In his next report (Waylen 1884), the Colonial Surgeon noted that 'By the end of the year measles had visited every district, with more or less severity, and but few families escaped; it spread amongst the aboriginals, especially about the Murchison and the Gascoyne, where, owing to exposure and want of proper care and nourishment, many died.' Surgeon Waylen did note that the epidemic was less severe in the south-west than the previous one of 1860/61. There were further outbreaks of measles in 1893, 1898, 1908, 1911, 1915, 1921 and 1924 (Cliff *et al.* 1993).

In the same year as Governor Broome's letter to the Colonial Secretary, a report on the treatment of Aboriginal prisoners (Anon. 1884) stated that 'It is a melancholy fact that throughout Australia the Aboriginal Race is fast disappearing… In what may be termed the Home District of this Colony, which is bounded on the North by the Murchison River, on the East by a line parallel to the coast and from 60 to 100 miles from it, and on the South and West by the sea, a great part of which has been occupied nearly fifty years, the fact that the aborigines are fast disappearing is apparent on all sides; and it is a mournful truth that, whatever is done, it appears to be an impossibility to avert this downward course.'

Despair and Depression

Although the measles epidemics killed many *Nyoongars* directly, comments by two Europeans at, or closer to, that time suggest that there was an ensuing effect of deep despair and depression on the survivors (Hammond 1937, Bates 1938). Such despair would lead to self-destructive behaviour such as alcoholism, collapse of family structure, lethal brawling, and a decline in libido and reproduction. Thus the *Nyoongar* population probably continued to decline for several decades after the epidemics, as older people died and there were few young ones to take their place. Combined with land dispossession and the breakdown of traditional values, introduced disease seems to have caused deep despair, depression, and even mental derangement amongst *Nyoongar* people. Some went into a catatonic state (Bates 1938). To desert their *boodja*, or traditional country, was the ultimate disaster. A probable major cause of the desertion was the unavailability of various traditional foods connected with those who had died.

Such totemic plants or animals could not be eaten for some months after the death, and with many deaths, so many foods became unavailable that their *boodja* could no longer support them.

By the turn of the century, Daisy Bates found only a handful of *Nyoongar* living in traditional style in the Swan Valley, or elsewhere in the south-west. She learnt the phrase '*Jangga meenya bomunggur*' (the smell of the white man is killing us) (Bates 1938). The sharp decline of indigenous populations from diseases introduced by European colonists was not confined to Western Australia. In New South Wales '… half the Aborigines between the Hawkesbury and Botany Bay died from smallpox during April and May 1789…' (Butlin 1983).

It was not only Australian Aborigines who suffered. There were lethal epidemics in both North and South America, New Zealand, and Pacific Islands such as Fiji, Tahiti, Samoa and the Cook Islands (Cliff *et al*. 1993). For example, nearly four centuries ago, in North America, '… in some places where the Indians dyed of the Plague some fourteene yeares agoe, is much underwood, as in the mid way betwixt Wessaguscus and Plimouth, because it hath not been burned.' (William Wood, Massachusetts, 1639, in Budiansky 1995). We may speculate on 'Plague' being, in fact, the serious adult form of measles, to which most Europeans were immune. Had it been bubonic plague, the Europeans would have died too.

There is a strong case for considering disease, and the ensuing depression and self destruction, to be the major cause of decline in indigenous people following colonisation, far exceeding direct violence by firearms (Grenfell Price 1964). Such a population decline would surely have affected traditional burning and hunting in the *jarrah* forest, and this would be true of Wungong Catchment. Even in areas presently untouched by bauxite mining, we should not assume that the vegetation there is exactly as it was before Europeans arrived. As the above quote from Massachusetts shows, human activities affect landscape, and the withdrawal of such activities, due sometimes to human depopulation by disease, can also have an effect.

A New Bride in the Bush

Yet *Nyoongars* and their burning persisted in some places, more remote from disease, police and flogging. At Jerramungup, near the south coast of Western Australia, traditional burning lasted at least until the 1880s.

At that time Ethel Hassell arrived at her husband's sheep station, as a new bride from England. She found the local *Nyoongar* people interesting, and wrote notes on them, some of which were published with the help of an American ethnologist (Hassell 1936), and others by a descendant (Hassell 1975). She described an annual dance by *Nyoongar* people, before they dispersed to light widespread fires. She also mentioned the dense smoke which enveloped the station in the summer bushfire season, and the prominent role of women and girls in the burning (Hassell 1975). The bushfires were carefully timed to avoid harm to nesting birds, and continued until rain put them out.

Recent Long-Burning Bushfires

Some recent, unrestrained, and hence long-burning bushfires, near the south coast of Western Australia, are reported by McCaw and Hanstrum (2003). They describe a bushfire which started in December 1953 and continued until put out by rain in March 1954. It travelled about 70 kilometres. Another such bushfire, in the following summer, travelled more than 40 kilometres before being put out by rain. Even more recently, they describe a fire which started in a National Park in December 1990, and burnt through to March 1991, when it was put out by rain. It covered about 120,000 hectares. News media reporting of bushfires tends to concentrate on those in which human lives or property are threatened. Very large, and long lasting, bushfires, in remote areas, are often unreported, so the general public are often unaware of them.

Foresters and Bushfire

Disturbance of the vegetation in Wungong Catchment has come, in the past, from forestry activities such as thinning and logging, and these have altered the fire characteristics of the *jarrah* forest. For example, given the same weather conditions, areas of dry logging trash will obviously carry a much more intense ground fire than unlogged forest.

From 1916 to 1984 the Forests Department was responsible for bushfire control in the State Forests and woodlands of the south-west, including the *jarrah* and *marri* forest in the Wungong Catchment. In improving our historical perspective, it is worth exploring the attitudes and statements of various foresters, and other government officials involved with forests.

In the early days of British settlement in Western Australia, there was little government control over logging. Private enterprise ran amok. Government permits were issued, but there was no regulation of the amount cut, nor was any official thought given to regeneration of forest after cutting. Logging trash was either deliberately burnt, or would have been burnt by bushfires of other origin. It was considered unwise to leave logs stacked in the bush, since they would inevitably burn (Stoate and Helms 1938).

The forest was regarded as inexhaustible, and clearing it was regarded as laudable development. This was not a unique situation in British colonial history. The historian Richard Grove has described a similar short-sighted exploitation of the Indian and Burmese teak forests until the far-sighted Lord Dalhousie created the Indian Forest Service in 1860 (Grove 1995).

The Baron Speaks Out

One of the first to show concern about the management of West Australian forests was the botanist, Baron Ferdinand von Mueller, who recommended that there should be some 'Initiatory measures suggested for establishing forest administration in West Australia' (von Mueller 1879). The then Surveyor-General of Western Australia, Malcolm Fraser, included von Mueller's report in one of his own to the then Governor, Sir William Robinson (Fraser 1882).

In his 1879 report, Baron von Mueller, writing of south-west forests in general, remarked that fires occurred, yet seemed not to harm the vegetation. He wrote that West Australian forest fires ‘are not so excessively destructive as in the eastern colonies, nor do they as there leave in ghastly deadness vast numbers of standing trees, after the burning element has swept through the woods.’ He described the ‘woods’ of Western Australia as ‘charming at all times, no lifeless trees disfiguring the landscape, all fresh and ever verdant with *Zamias*, *Xanthorrhoeas*, and *Kingias* remaining unimpaired by the scorching flames.’ Nevertheless, ‘the bushy vegetation and underwood, and all kinds of herbaceous plants, are at least periodically apt to be annihilated in the woody country, when the bush ignites…’

As previously mentioned, there is clear evidence that the main season for *Nyoongar* burning was in summer (December-February) (Hallam 1975, Ward 1998a, Abbott 2003), the season known to *Nyoongar* people as ‘*biroc*’ or ‘*peeruck*’ (Moore 1884 in Hallam 1975). In today’s fuel loads, after intervals since the last fire of ten, twenty, or thirty years, bushfires are generally uncontrollable in summer. They usually leave a site blackened and devastated, with no immediate sign of either plant or animal life. Many centenarian trees are killed (Burrows 2005). How can bushfires in 1879 have been ‘not so excessively destructive’, leaving the woods ‘charming at all times, no lifeless trees disfiguring the landscape, all fresh and ever verdant’?

In addition to topography and climate, a major difference between east and west Australia, in 1879, was that in the east, the country was more densely settled by Europeans, and Aboriginal burning had largely been abolished. In the west, although the *Nyoongar* people had greatly declined, European settlement was still sparse, and bushfires were still widespread in non-farming areas, and largely unrestrained. Even if there were fewer ignitions by humans, lightning would still have caused many bushfires (McCaw and Hanstrum 2003), and fires in light fuel were free to trickle on for months, with few barriers, and no attempts at suppression.

We may recall the term ‘creeping fires’, used by a later Conservator of Forests (Kessell 1924). Harris (1879) suggested that fires in his time travelled about three miles (5 km) per day, or less. Even taking a conservative rate of one kilometre a day, in unlimited fuel, and the hundred days of West Australian summer, a bushfire could have traveled over a hundred kilometres, changing direction with the wind, and, at times, burning on a very broad front, so burning a very large area. We should consider, of course, that fuel was, in 1879, still disconnected by regular burning in most places. In patchy, disconnected fuel, even bushfires caused by lightning would, sooner or later, have run into an area where they could not burn.

Inspectors and Conservators

The first Inspector General of Timber Forests was Joseph Strelly Harris, whose views on bushfire have already been given. He died in 1889. Six years later, in 1895, a small Woods and Forest Department was set up, headed by John Ednie-Brown as Inspector General of Forests. Ednie-Brown was a horticulturalist, not a trained forester, but he clearly had a keen interest in trees. A few years before his sudden death in 1899 he produced an illustrated report on West Australian forests (Ednie-Brown 1896). Unfortunately, this contains nothing about bushfire. It is reasonable to assume that absence of comment means that bushfire, while it must have occurred, was not seen as a major problem at that time.

Ednie-Brown was succeeded by his Chief Clerk, Charles Gough Richardson, who, under various titles, compiled the Annual Reports from 1899 to 1915. Richardson had no forestry training either, but his reports are clearly written, and show some understanding of the native forests. He was born in Dublin in 1865, and was educated by a private tutor and in Germany (Battye 1912). He came to Western Australia in 1887, not long after the serious measles and diphtheria outbreaks of 1883/4 (Broome 1884, Cumpston 1927).

The first mention of fire in the Woods and Forests Department Annual Reports, is in 1910, when Richardson wrote ‘Forest fires have been prevalent ever since the earliest days of settlement, when it used to be the custom of the blacks to set fire to the bush to facilitate hunting. Now settlers keep up the practice in order to improve the grazing, and the fact that the selectors throughout our timber areas have an actual incentive to fire the forest renders the work of fire protection doubly difficult.'

Like von Mueller, Richardson noted that although bushfires were 'prevalent' in south-west forests in those days, they were not a major problem. He said 'In this state the forest fires are not so exceedingly destructive as in other parts of the world, nor do they, as there, destroy vast numbers of standing trees.' (Richardson 1910)

A Consultant Comes

In 1914, the government of Western Australia invited an eminent British forestry consultant to visit, and report on the state of the forests. Sir David E. Hutchins was highly regarded in his day, having graduated from the famous *École Nationale des Eaux et des Forêts* at Nancy, in France. He had experience in India and South Africa. In both places he had done his best to eradicate burning and grazing in forests by the native people, seeing it as primitive, and not to be tolerated in 'scientifically managed' forests (Pyne 1991, 1997).

The *École Nationale des Eaux et des Forêts* (now known as *École Nationale Génie Rurale des Eaux et des Forêts*, or ENGREF) is an interesting establishment, established in 1824. Students were encouraged to regard themselves as an elite corps of forest officers. Cadets wore cloaks, carried swords, and did parade ground drill. French nationals received a commission in the army on graduation. The Indian Forest Service, established by the British in the 1860s, trained some of its early officers, including Hutchins, at Nancy, since Britain had no forestry school at the time. Perhaps as a reaction against incendiarism of aristocrats' forests during the French Revolution of 1789, cadets at Nancy were taught that fire was the enemy of foresters. They carried this message to India, and eventually to Western Australia (Pyne 1991).

Hutchins travelled briefly around the south-west of the state in 1914, wrote his report in New Zealand in 1915, and it was published in Perth a year later (Hutchins 1916). The style is authoritarian, almost military. He recommended a quasi-military Forests Department, headed by a professional forester. In line with his South African experience he proposed that Forest Rangers should be ‘armed soldiers of the state’. He recommended as Conservator a promising young man called Charles E. Lane-Poole, who had served under him in South Africa, and was a fellow graduate of Nancy.

From today’s perspective some of Hutchins’ recommendations are quite bizarre. For example, he regarded the native *jarrah* forest as unproductive, and recommended that it be underplanted with exotic pine trees, so giving both softwood and hardwood from the same forest. True to his Nancy training, Hutchinson declared fire to be anathema, and believed that the shady pine trees would help to keep fire out of the forest.

Possibly they would in northern France, but anyone who has seen a pine tree explode in flames on an Australian summer day would be very wary of spreading them throughout the *jarrah* forest. Fortunately, pines are reluctant to grow in the gravelly upland *jarrah* forest, due to the poverty of the soil. Some miserable, stunted pine patches resulting from Hutchins’ advice can still be found.

He proposed widespread grazing by pigs, cattle and deer in the *jarrah* forest, and the introduction of pheasants to provide shooting for tourists from England. As a shooting man, Hutchins was surprisingly unaware of the regular burning done on English and Scottish estates to increase grouse populations (Hudson and Newborn 1995).

The depth of Hutchins’ understanding of south-western Australian forests and climate may be judged by his statement that ‘Owing to the absence of the hot winds of Eastern Australia and the comparatively light nature of the undergrowth in the forests of Western Australia, fire protection is easier there than in other fertile parts of the Australian continent. The Karri forest in its natural condition does not burn, nor does the drier inland forest.’

Anyone familiar with the hot easterly winds of summer in south-western Australia will conclude that Hutchins was unfamiliar with local conditions. The 'light nature' of the undergrowth that he saw in the *jarrah* forest was due to it being burnt every three years or so. Referring to that time, two professional foresters (Harris and Wallace 1959) said that 'It should be remembered that there was virtually no forest area at that time which carried more than 5 years' leaf litter and the greater part varied from 1 to 3 years. It appeared that virgin forest did not accumulate litter to any marked extent and subsequent accumulations of litter and scrub in protected compartments [i.e. protected from bushfire] could not have been envisaged.'

The fire exclusion which he advocated eventually led to dense undergrowth, with dead litter loads of over 30 tonnes per hectare, even excluding logging debris. A summer fire in such fuel cannot be suppressed by any human means, only by heavy rain, or by running into an area of reduced fuel. Further, anyone who, like the writer, has seen flames fifty metres up in *karri* (*Eucalyptus diversicolor*) crowns will be rather interested to learn that *karri* will not burn. I suspect that Hutchins had never actually 'put the wet stuff on the red stuff'.

Hutchins had clearly been informed of the traditional burning activities of the Aborigines. He wrote 'From an unknown period the Australian forest has been subject to the fires of the Blacks, fires lit for the purpose of providing food and hunting-grounds for the game… The general use of fire by the Australian mainland blacks has, I believe, never been questioned.'(Hutchins 1916). Yet he believed that European 'science' could do better. It was simply a matter of 'organisation'.

In fact he was very naive about ecology (Ward 1996), which was not taught in the universities of his day. Apart from pine planting, he had other ideas, such as planting oak trees throughout the *jarrah* forest, supplying acorns for large herds of pigs; and the introduction of deer, and the aforementioned pheasants and partridges, to provide shooting for wealthy English tourists. He described the *karri* forest as 'cut and come again', and proposed logging in the Stirling Range National Park. Luckily, the ideas of government consultants are not always implemented. Sir David ended his days in New Zealand, but not before advising the government there to import elephants to help in logging. Nevertheless, Hutchins' general opposition to fire, and naïve 'scientific' epistemology were shared by his protégé, Charles Lane-Poole.

The Man From Nancy

Charles Lane-Poole was only 31 years old when Hutchins recommended him as the first professional Conservator of Forests for Western Australia. Charles came from a talented family. His brother became an admiral, and founded the Australian naval academy at Jervis Bay. His father, Stanley Lane-Poole, was Professor of Arabic at Trinity College in Dublin. Charles was educated at St Columba's College, and gained a place by competitive examination at the French forestry school at Nancy (Nairn and Serle 1986).

Lane-Poole had never been to Australia before, and had no first hand knowledge of Australian bushfire hazard, behaviour and effects. His views on fire may well have been influenced by Hutchins, who was his mentor in South Africa, and by lectures given by the French chemist Professor Henry, of Nancy, who believed that forest humus had the power to fix free nitrogen from the air. Henry was wrong, humus cannot itself fix nitrogen, and it creates more acid conditions which can immobilise nutrients, and mobilise toxic amounts of metals, such as copper, aluminium, and manganese. Nitrogen fixation occurs through bacteria and cyanobacteria which live in the soil, and are generally favoured in the first few years after fire by the more alkaline conditions due to cations in ash (Kozlowski and Ahlgren 1974, Grove *et al.* 1980).

Professor Henry's 'scientific' finding was enthusiastically embraced by the Indian Forest Service, under the aegis of the three successive German Inspectors-General, Dietrich Brandis, Wilhelm Schlich, and Berthold Ribbentrop. Their enthusiasm for humus led to their belief that fire should be banished from Indian and Burmese forests.

Richard Grove (1995) refers to the Indian historian Guha (1983), who attributed to Brandis 'many of the foundations of a 'scientific' ideology used to conceal straightforward consideration of the imperial need for raw-material resources.' Since

Indian villagers were not ‘scientific’, their views on fire were brushed aside (Slym 1876, Slym and Hill 1881, Shebbeare 1928). Both Hutchins and Lane-Poole had a similarly dismissive view of indigenous Australian fire knowledge and practice.

In sharp contrast to von Mueller’s comments of 1879, and Richardson’s comments in 1910, Lane-Poole’s first Annual Report to Parliament in 1916 mentions ‘serious forest fires’ and makes the comment ‘Annually a great part of the forests is swept away by fires and vast quantities of young and old timber are destroyed.’

His European education had not prepared him for the realities of the West Australian summer, when fires can occur quite frequently by lightning, quite apart from those caused by humans. There was no capacity to suppress fires in remote parts of the forest in those days, when horses and bicycles were the main means of transport. There are descriptions of fires trickling through the *jarrah* forest for months, flaring up in hot spells. For example, ‘… it is not unreasonable to assume that the forest was completely burnt through every 2-4 years. Even as late as 1925 the writer was able to observe three fires of this nature in unmanaged virgin forest east of Jarrahdale. These fires were alight in December and continued to burn until the following March.’ (Wallace 1966).

In the summer of 1916/17 Lane-Poole had some respite from fire, due to above average rain in the winter and spring of 1916, and also possibly due to the absence on military duty of most young men. During this first year he seems to have learned a few facts about scrub growth and litter accumulation in eucalypt forests. He realised that the ‘light nature’ of the south-western forest undergrowth described by Hutchins was actually due to frequent burning, and that, in the absence of fire, eucalyptus leaf litter, dead sticks and seed capsules tend to accumulate, and undergrowth to thicken. In the 1917 report he warned ‘If next summer happens to be a normally dry one, however, the added collection of dead leaves and twigs and the increased size of the undergrowth are likely to cause serious fires.’

Due to World War I, any mention of fire and weather was censored from the 1918 Annual Report for fear of giving aid to the enemy. After the war, in 1919, we learn that 'As predicted in the report for 1917 the summer of 1918-1919 proved a destructive one from a fire point of view …'. It seems likely that some locally-born Australians tackled Lane-Poole about his views on bushfire, as he mentioned that 'There are a few residents in the country who insist that fires do good to the forest …'.

People who lived and worked in the bush knew then, as they do now, that for a few winters following a bushfire, there is a spectacular burst of green growth and flowering, due to the effect of heat and smoke on seeds and buds, the release of nutrients in ash, and increased nitrogen fixation by soil bacteria (Kozlowski and Ahlgren 1974).

By 1919 Lane-Poole had No. 1 State Forest (*tuart (Eucalyptus gomphocephala)* at Ludlow) 'under protection' from bushfire. He proposed legislation to exclude bushfire from all state forest, but the clause was struck out at the political level, probably by Sir James Mitchell, then Premier and Minister for Lands. Sir James, and his close political ally, Hal Colebatch, had, in April 1919, toppled the Lefroy government which opposed forest clearing for soldier settlement, and Mitchell became premier in May 1919. He and Colebatch were, at that time, about to initiate the ill-starred 'Group Settler Scheme', under which migrants would be encouraged to settle on forest blocks, clear them, and presumably burn the debris (Nairn and Serle 1986).

The Annual Report for 1920 contains no mention of bushfire, which is odd in view of Lane-Poole's vehement views. He probably realised that his job was in peril, and wished to avoid clashing again with the politician who had struck out his bushfire exclusion clause in the previous year.

In the Annual Report for 1921 Lane-Poole seems agitated and repetitive. He returns to the theme of bushfire. Referring to the forest in general, he said 'The general condition of the forests is decidedly bad … Seventy-five years of practically uncontrolled cutting and entirely uncontrolled burning have reduced this national asset to such a condition that only a negligible quantity of sound, young trees is growing to the acre on the portion which has been cut over.' (Lane-Poole 1921).

He had clearly had further arguments with locally born staff, on the role of bushfire. It seems that locals had pointed out to him that bushfire is needed for plentiful eucalypt germination, for he testily remarked that 'The general belief current in the timber areas that fires cause a good germination of trees of the eucalypt family [*sic*] through the mere roasting of the seeds is erroneous, as the seed falls, as a general rule, after the fire season is over.'

Lane-Poole was partly right, but he ignored the effect of bushfire in opening the capsules to release the seed; the possible effect of smoke on seed while still on the tree; and the effect of seed falling into a nutrient enriched ash bed, free of seed-rotting mould spores. He was aware that ash may inhibit the movement of ants, so preventing seed theft before germination. He was unaware of the benefits of charcoal (Lehmann and Joseph 2009).

It seems that Lane-Poole knew the 1921 report was his swan song, and he took a Parthian shot at the body politic which had frustrated him. 'The afforestation policy of the State, once embarked upon, should be as little as possible liable to be disturbed by political changes or moulded by political pressure.' He resigned shortly after, and took up a position with the Commonwealth Government. His subsequent career was distinguished, including the founding of an Australian Forestry School in Canberra.

Oxford to the Rescue

Following Charles Lane-Poole, the next Conservator of Forests was a very young man of 24 years, educated in forestry at Adelaide and Oxford Universities. Initially, he continued Lane-Poole's bushfire exclusion theme.

Perhaps due to his Oxford education, Stephen Kessell was, however, observant, and willing to consider contradictory information. He noted that in an area which had not been burnt for 20 years ' … the density and height of the undergrowth is less than on an adjoining plot which is burnt practically every year. A large percentage of the *jarrah* is forked low down for some unknown reason…'.

This was, of course, directly contrary to the rigid Nancy doctrine that fire impoverishes soil, based on the faulty findings of Professor Henry. We now know that bushfire can, on some soils, raise soil pH, and so enhance soil bacterial activity and nutrient availability (Kozlowski and Ahlgren 1974, Ellis 1994). A good local example of this is the enhanced growth of *djiridji*, or zamias (*Macrozamia riedlii*) after bushfire, due to increased nitrogen fixation by cyanobacteria (*Nostoc*) in the roots. *Djiridji* can fix up to 35 kg. of nitrogen per hectare during the first 5 to 7 years after a fire (Grove *et al.* 1980). *Djiridji* are still common in the *jarrah* forest, although many now look sick and discoloured. Due to long fire exclusion, few are now producing cones and fruit (Chapter 3: About Wungong Catchment).

Kessell was more flexible in his attitude to bushfire than his predecessor. He recognized that total bushfire suppression was impossible, due to the slow decay rate of dead leaves, twigs, bark and logging debris, in a seasonally dry climate. He recommended the disposal of logging debris by spring burning.

In the 1923 Annual Report, following a conference with field staff at Mundaring (Brockway 1923), he made an interesting observation on the bushfire fighting methods of the day. 'Direct beating was the chief method employed in fire fighting, for which healthy young red gums proved the best weapons.' Beating with green branches is only effective on bushfires with an intensity of 500 Kilowatts/metre or less - in other words a bushfire that most people can jump over, or, as in Burma, a forester's pony can step over.

Those with practical experience of beating fires will know that *jarrah* branches are next to useless, since, due to their high terpene content, they burst into flames. Settlers probably learned the use of *marri* branches, or saplings, from the *Nyoongars*, who used 'large green boughs' (the tops of *marri* saplings?) to prevent bushfire entering thickets they wished to conserve (Stokes 1846). As Kessell soon found out, this *Nyoongar* method was only possible where flame heights were low due to an accumulation of only a few years litter. With bushfire exclusion, litter began to pile up, and green boughs proved inadequate.

Annual Reports for 1922, 1923, and 1924 tell us that although only a small area was burnt in the summer of 1922/23, the summer 1923/24 was hot and dry, and, according to Kessell, incendiarism was rampant. Due to protection from bushfire, fuel loads had increased, and there was an ominous change in bushfire behaviour. In the preamble to this chapter, Kessell's remarks on the failure of hand tools to control increasingly fierce fires were given.

We can also detect a change in attitude to bushfire by Kessell, as he allowed his staff to do some deliberate burning, probably on the advice of older, more experienced field staff. He said that 'In order to reduce fire hazards, preliminary burning was carried out around all centres of bush working …'.

His ideas on bushfire protection by deliberate burning were still evolving, but he seems, by this stage, to have accepted that widespread, regular burning was the only solution. Presumably as a result of discussions with experienced field staff, he concluded that 'The solution of the whole question of fire control is bound up with the establishment of resident workmen throughout the forest, each man looking after a defined area which he knows thoroughly, and on which he can choose the best times for carrying out controlled burning.'

This emphasis on an intimate local knowledge of vegetation, terrain, and climate, sounds remarkably close to the traditional burning by *Nyoongar* people before Europeans arrived (Hallam 1975, 1985, 2002, Green 1979, 1981, 1984, Mulvaney and Green 1992), and the burning by early European settlers who were familiar with those traditional methods (personal communications from Jim Muir of Manjimup, and Elaine Marchetti of Waroona). It is also similar, in practice and effects, to the burning done by present day Aborigines in Northern Australia (Stocker 1966, Haynes 1985, Lewis and Ferguson 1988, Rose 1997, Russell-Smith 1997). As mentioned in Chapter 4 (The Other Side of the Hill – Bushfire in Other Lands), even grouse moor owners in Britain have recently seized back the right to local control of management fire. Fire is too dynamic, and potentially dangerous, to be closely managed by a far off, uninformed, and sometimes sluggish, bureaucracy.

Conclusions

If I have rambled far in the history of bushfire and the *jarrah* forest, it is because history is an essential component of bushfire epistemology. The rich complexity of history necessarily involves some rambling along tracks which may, initially, seem irrelevant. Mature reflection can later show high relevance, due to the revelation of 'contingent hypotheses' (Duhem 1906), such as the linkage between measles epidemics, desertion of *Nyoongar* land, and bushfire frequency. I agree with the philosopher Robin G. Collingwood (1945), who wrote that 'I conclude that natural science as a form of thought exists and always has existed in a context of history, and depends on historical thought for its existence. From this I venture to infer that no one can understand natural science without an understanding of history.'

Unsurprisingly, foresters have a long history of association with the *jarrah* forest. Their views, even if not always correct, are worth noting, and must be part of our frame of thinking. More so, the much longer history of *Nyoongar* association with the *jarrah* forest, and bushfire, is essential knowledge for anyone trying to understand, and manage, bushfire in that forest. We should remember the 1920s, when bushfires became noticeably fiercer, and more difficult to control, due to ill-advised attempts at long fire exclusion. This adverse change was acknowledged by one of those responsible for such attempts. The Forests Department began research into bushfire hazard in the 1930s, and into bushfire behaviour in the 1950s (McCaw *et al.* 2003).

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Chapter 6

Better to Believe the Balga

SOME ARCHAEOLOGY

'The historic records from around the world leave no room to doubt that primitive herding and gathering peoples, as well as ancient farmers and herders, for a number of reasons, frequently and intentionally set fire to almost all the vegetation around them that would burn.'

Professor Omer C. Stewart (1963)

Preamble

Balga, or grasstrees (*Xanthorrhoea* spp.), are iconic plants of the south-western corner of Western Australia, and can live for over 400 years (Ward and Van Didden 2003a). As shown in Figure 6.01, they accumulate highly flammable thatch. Even in cool, wet winter weather, the radiant heat is sometimes enough to dry shrubs and litter, and start a ground fire. When they burn in summer, a surrounding ground fire is inevitable, due to burning thatch dropping to the ground. When there is a running ground fire, it is nearly inevitable that other grasstrees will ignite. The exception is when ground fuel is very light, and the grasstree is very tall, but this will lead to tall grasstrees burning less often than shorter ones. We can reconstruct a conservative bushfire history from old fire marks on grasstree stems (Ward 1996, Ward *et al.* 2001a). This archaeological information meshes with the history of Chapter 5 (Bushfire, Flogging, Measles and Foresters), giving a framework within which we can better understand bushfire. Not everybody believes the results of the *balga* method.

Figure 6.01: *Balga* grasstrees burning, in winter, at Karagullen, near Wungong Catchment.

This chapter will describe the method by which past bushfire frequency can be reconstructed. Results from Wungong Catchment will be compared with those from other parts of the *jarrah* forest, and especially with those collected in 2003 from Monadnocks Conservation Park, which is adjacent to Wungong Catchment, and overlaps it. The views of those who dispute the validity of the grasstree technique will be considered.

The *Balga* Method

The stems of *balga* are usually covered with charcoal, formed when the thatch of dead leaves burns. This is not a new situation, as early European settlers commented on it (Millett 1872). Indeed, a common name for the *balga* was 'blackboy'. That name has been banished from academic circles, on the grounds that it is offensive to *Nyoongar* people. The current academically acceptable English name is 'grasstree'.

The charcoal can be cleaned off with a grinder, so exposing cream and brown growth rings on the stems (Ward 1996), which match with internal growth corrugations (Lamont and Downes 1979). The grinding also exposes some bands of dark pigment in the old leaf bases. In the *jarrah* forest, these dark bands occur consistently at points on the stems where fires are known from DEC (Department of Environment and Conservation, formerly Department of Conservation and Land Management, or CALM, or Forests Department) records to have occurred; and where fires were likely to have occurred, since the grasstree flowered at that point. Flowering in grasstrees is commonly caused by smoke (Gill and Ingwerson 1976).

Figure 6.02 shows part of a cleaned stem from a previous study (Ward and Van Didden 1997), with estimated dates, and dark bands. Diagonal faults in the stem can be seen. These are due to the spiral structure of the plant. When it slumps downward, perhaps due to the gum softening in a bushfire, a twisting motion occurs.

Figure 6.02: A cleaned balga stem.

For the stem shown, it is known, from government records, that fires occurred at the site in spring 1984 and summer 1971/2. From their position in relation to fires, and to the internal growth corrugations, the cream growth bands appear to be connected with winter/spring, and the brown with summer/autumn. One cream band, and one brown band, correspond to the annual growth surges described by Lamont and Downes (1979).

As part of an earlier study (Ward and Challinor 1999c), some leafbases were carefully removed, washed in alcohol, and cut into one centimetre pieces measured from the proximal end. The length of leafbase can vary from tree to tree due to burning away by past fires (Drummond 1847). In this case each leafbase gave five pieces. Each year showed the twin band of cream and brown leafbases seen in Figure 6.02, and these were separated, giving a hundred samples for the decade. These samples were analysed by pyrolysis gas chromatography and mass spectrometry to identify the dark pigment (Challinor 1989, 1995, Ward and Challinor 1999c). They were also analysed for zinc, calcium, magnesium, manganese and copper.

In previous work in the *jarrah* forest (Ward and Van Didden 1997), the tops of several recently burnt grasstrees were ground off, revealing dark bands of leafbases where green needles had burnt. Figure 6.03 shows a band of dark leafbases formed by the remains of green needles burnt a few weeks previously. The leaves immediately above the dark band were still live and green at the time of grinding. Leafbase samples were taken immediately above, on, and immediately below the dark band. These were submitted for analysis to identify the dark pigment.

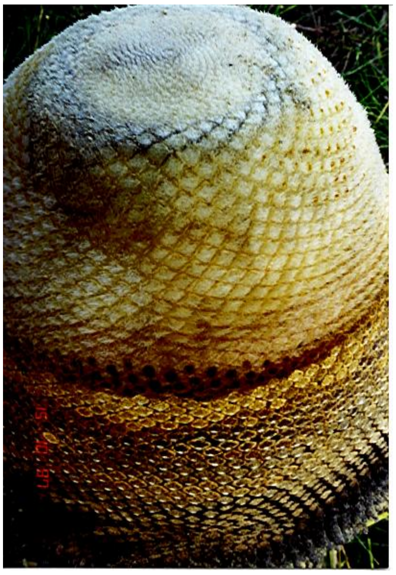


Figure 6.03: Dark band of leafbases formed by a fire a few weeks earlier.

As a further check, the colour difference between the dark and light coloured leafbases was quantified using an industrial ColorTec–PCM colorimeter. This gives scores in the three spectra of the Hunter colour system (Wright 1969), namely black/white, red/green, and blue/yellow.

Chemical and Colour Analysis Results

The analysis by gas chromatography and mass spectrometry (Ward and Challinor 1999c) showed that for the samples taken immediately above, on, and immediately below the dark band in Figure 6.02, the compound lapachol (2-hydroxy-3-(3-methyl-2-butenyl), 1, 4-naphthalenedione) was absent from the leafbase below, present in the dark leafbase, and present as a trace in the leafbase immediately above. The method is well established (Challinor 1989, 1995).

A randomly chosen section of stem, for the decade 1894-1903, was then sampled in detail. There were three external dark bands within the decade, implying three fires.

Close examination suggested that the pigment was in the central vascular bundle of the leaf, so some samples were checked by excising the vascular bundle. When the dark vascular bundle was absent, lapachol was absent, but when the dark vascular bundle was present, lapachol was present. Lapachol was absent in the light coloured vascular bundle. Figure 6.04 shows the presence/absence of lapachol in the vascular bundles of the leafbases.

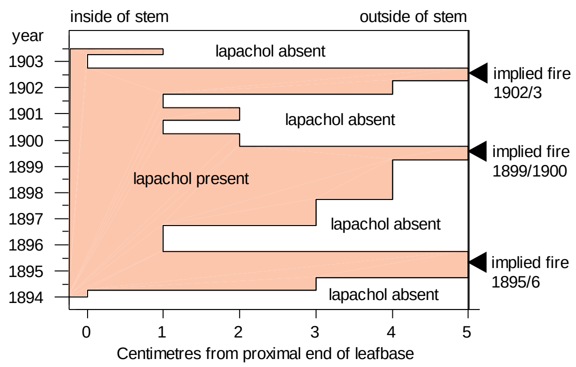


Figure 6.04: Presence/absence of lapachol in vascular bundles.

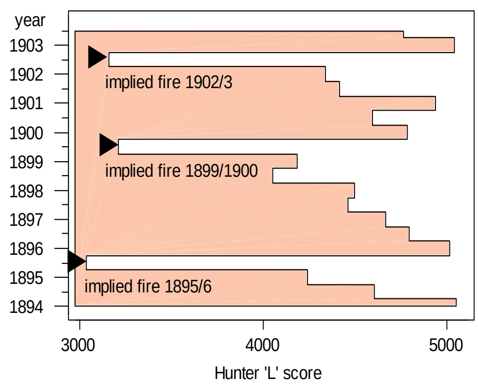


Figure 6.05: Hunter ‘L’ score (black/white) for the outer centimetre of grasstree

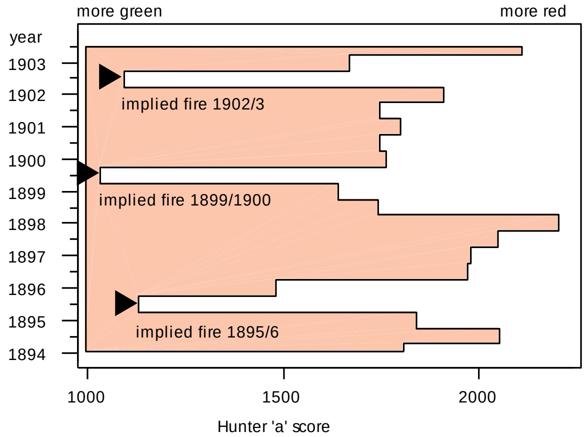


Figure 6.06: Hunter 'a' score (green/red) for the outer centimetre of grasstree leafbase.

Figures 6.05, 6.06 and 6.07 show the colour differences between the leafbases with lapachol, and those without. Although not visibly green to the naked eye, the dark leafbases contain some green pigment. This suggests the presence of chlorophyll, which supports the hypothesis that lapachol is formed when fires kill green leaves.

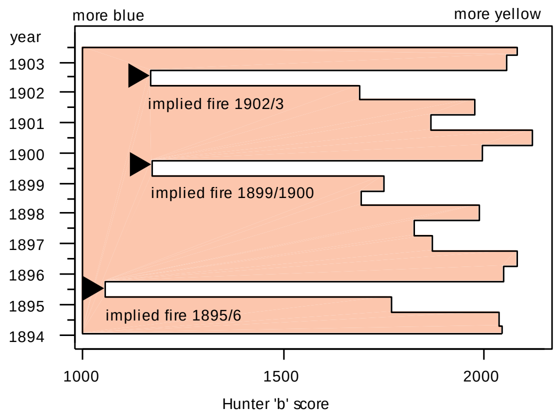


Figure 6.07: Hunter 'b' score (blue/yellow) for the outer centimetre of grasstree leafbase.

Analysis of the stem shown in Figure 6.02 shows, in Figure 6.08, implied fire events and subsequent elevated zinc levels. Zinc is important to mammals, including humans. A deficiency can lead to stunted growth and infertility (Underwood and Somers 1969, Smith *et al*. 1982). Although introduced predators are a likely cause of

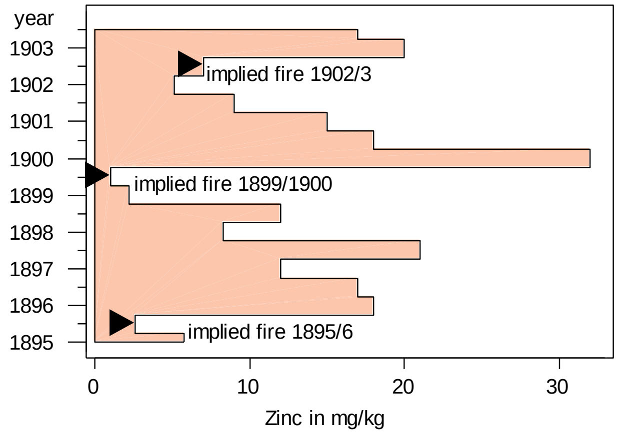


Figure 6.08: Zinc at 4 cm from the proximal end of grasstree leafbases.

declines in native mammals (Abbott 2008), they may not be the only cause. More research into the possible role of zinc in native animal health and fecundity is needed.

Calcium levels showed an association with implied fire events (Figure 6.09). The calcium in wood ash has a well known effect in raising the pH of forest soils, so changing nutrient availability, and the activities of microbes (Fowells and Stephenson 1933, Fuller *et al*. 1955, Ahlgren and Ahlgren 1965, Braathe 1973).

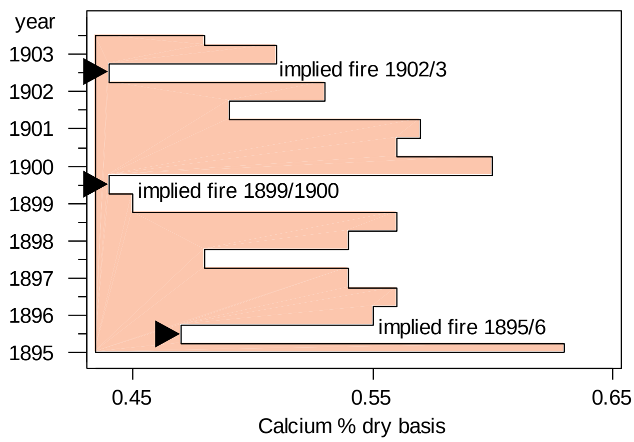


Figure 6.09: Calcium at 1 cm from the proximal end of grasstree leafbases.

Magnesium also showed a rise for several years after implied fire events (Figure 6.10). Magnesium is an essential structural element in chlorophyll (Salisbury and Ross 1969), and is generally more available when soil is more alkaline.

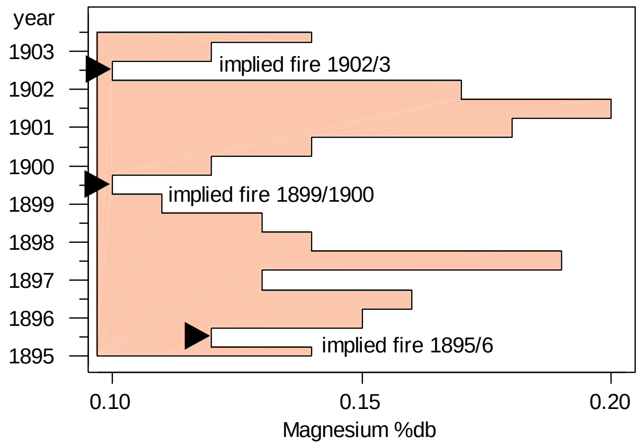


Figure 6.10: Magnesium at 4 cm from the proximal end of grasstree leafbases.

Manganese (Figure 6.11) showed a different pattern in that it was highest in the dark pigmented leaf bases. It is a trace element, and it, too, is believed to have a role in chlorophyll formation (Salisbury and Ross 1969).

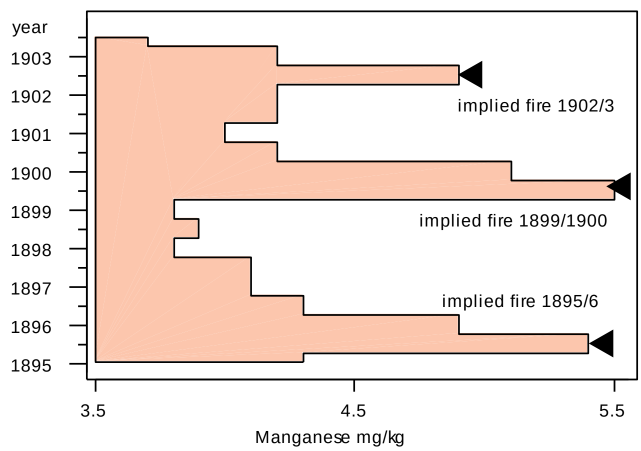


Figure 6.11: Manganese at 1cm from the proximal end of grasstree leafbases.

Like manganese, copper was highest in the dark leafbases. The pattern in Figure 6.12 suggests a fall in available copper over the few years after a fire, followed by a rise. It has been long known that a rise in soil alkalinity can cause copper to become less available to plants (Gartrell 1969). Since that study, it has been found that, in some soils, raising the soil pH can improve the growth of citrus seedlings, due to less copper toxicity (Alva *et al.* 2000). Even more recently, in a ten year trial, an association of low pH and high copper availability was found to decrease bacterial-feeding soil nematodes, and increase hyphal-feeding nematodes (Korthals *et al.* 2009). Without reaching too hasty a conclusion, the relationship between fire, ash, charcoal, soil pH, and possible copper toxicity in long unburnt *jarrah* forest certainly merits further investigation.

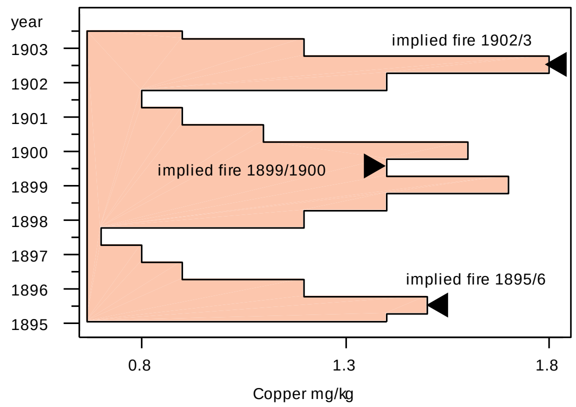


Figure 6.12: Copper at 5 cm from the proximal end of grasstree leafbases.

Conclusions from Historical, Chemical, and Colour Analysis

Given that the dark bands are quantitatively different, both in colour and chemistry, from the rest of the stem: and given that they can be produced by deliberately burning green needles on grasstrees: and given that they match with past known fires, then it seems reasonable to conclude that they are indicators of past fires. The same conclusion was reached by another study, which used a different approach, involving chemistry and histology (Colangelo *et al*. 2002). Microscopic examination of fine sections of *balga* leaf bases showed that the vascular bundles were clogged with dark pigment after burning, but not before.

Bushfire History of the *Jarrah* Forest - Method

More than a decade ago, a total of 159 grasstrees was examined at 50 sites distributed throughout the *jarrah* forest (Ward and Van Didden 1997). Each tree yielded information on at least two decades, some giving a record of over twenty decades. The final data matrix consisted of 1548 records, each record containing fields for the number of fires in that decade, the annual rainfall at that site, site latitude and longitude, vegetation type, distance from creek, etc.

The sites were deliberately spread across the rainfall isohyets, so giving good representation of different rain zones. With regard to vegetation and landform, large grasstrees are commonly found on moist, open sites, low in the landscape. This means that ridges are under represented in the data. This matter will be discussed later. Figures 6.13 and 6.14 show the sample sites in relation to annual rainfall and the *jarrah* forest respectively.

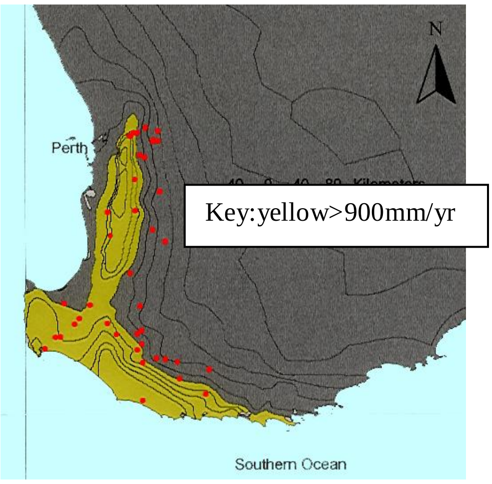


Figure 6.13: Sample sites and rainfall isohyets.

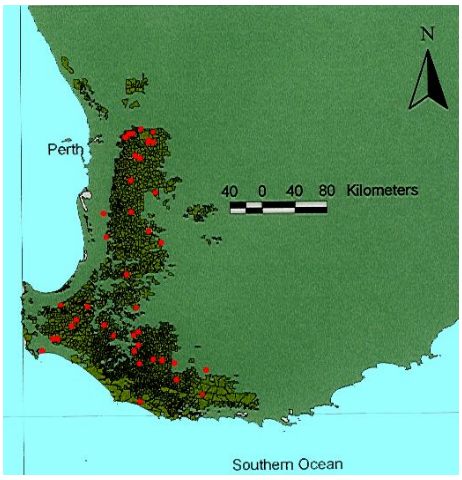


Figure 6.14: Sample sites in *jarrah* forest.

Bushfire History of the Jarrah Forest - Results

The reconstructed fire history of the *jarrah* forest is summarised in Figure 6.15**.** The large standard errors in the earliest decades are caused by the small size of the samples, such old trees being relatively rare. The sudden drop in fire frequency between 1860 and 1870 coincides with the severe measles epidemic which ravaged the *Nyoongar* population in the early 1860s (Richards 1978, Cliff *et al.* 1993).

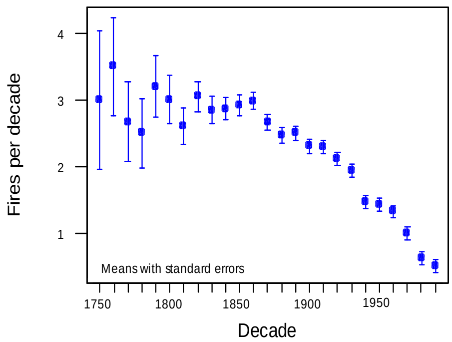


Figure 6.15: Reconstructed *jarrah* forest fire history by decade

On many stems the change in fire frequency is quite abrupt for that period. At some sites the abrupt drop in fire frequency occurred in the 1880s, when a second severe measles epidemic occurred (Hammond 1933, Hasluck 1942). The abrupt drop in fire frequency in the 1940s was probably due to the absence of young men on military service, and also due to an official policy of banning burning on the grounds that fires might provide guidance to Japanese night bombers. The decline in fire frequency in recent decades is due to tighter bureaucratic control; public opposition to burning; and a lack of opportunity and resources to carry it out.

In Figure 6.16 the same data are grouped into eight eras:

1. 1750-1829 – pre-European era, lightning and *Nyoongar* burning
2. 1830-1859 – early settlement era with traditional *Nyoongar* burning still common
3. 1860-1889 – disease epidemic era, with great decline in *Nyoongar* population
4. 1890-1919 – uncontrolled logging era, severe wildfires
5. 1920-1939 – attempted fire exclusion by Forests Department, but severe wildfires
6. 1940-1959 – men absent at World War II, heavy fuel buildup, severe wildfires
7. 1960-1979 – introduction of controlled burning after Dwellingup fire
8. 1980-1997 – strict management plans, public complaints, declining resources etc.

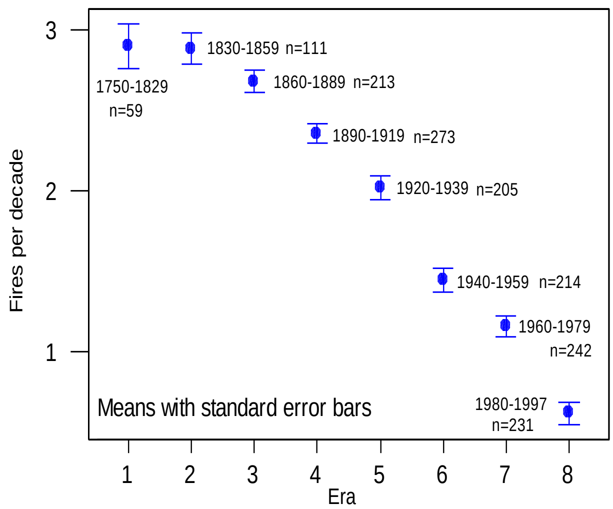


Figure 6.16: Reconstructed fire history for *jarrah* forest by era.

For those with a statistical background, a better understanding of the distribution of the fire frequency variable about the mean may be derived from Figure 6.17 (a-h), which gives eight histograms. As time passes, the distribution of fire frequency changes from leptokurtic and symmetric, to platykurtic and skewed.

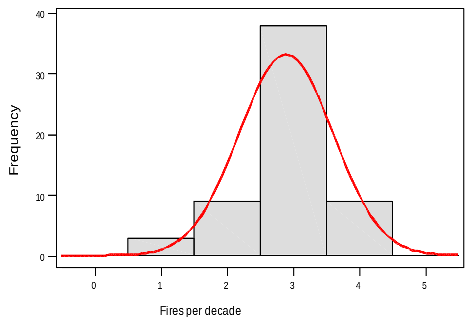


Figure 6.17(a): Era 1750-1829

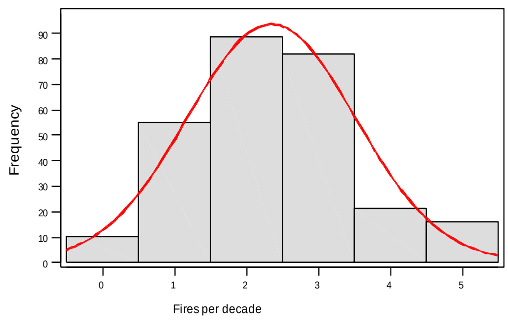


Figure 6.17(b): Era 1830-1859

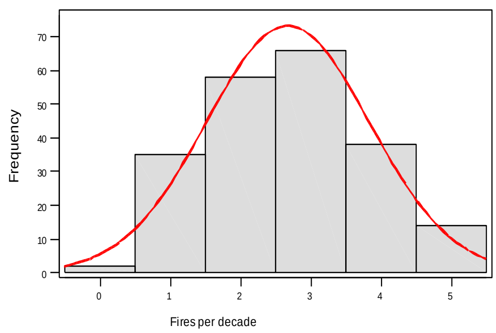


Figure 6.17(c): Era 1860-1889

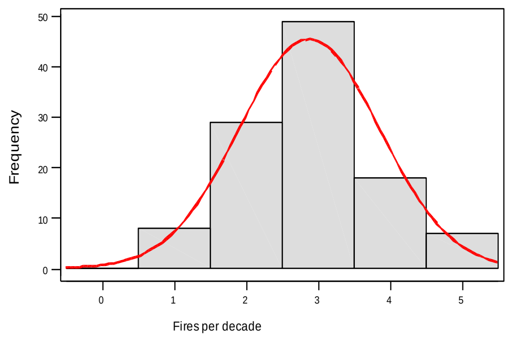


Figure 6.17(d): Era 1890-1919

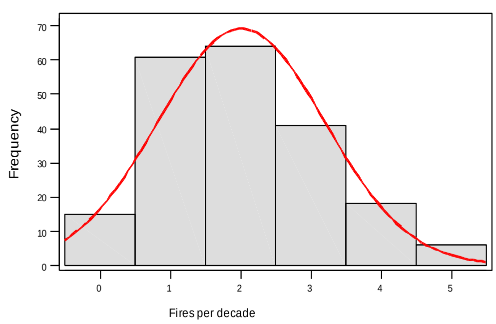


Figure 6.17(e): Era 1920-1939

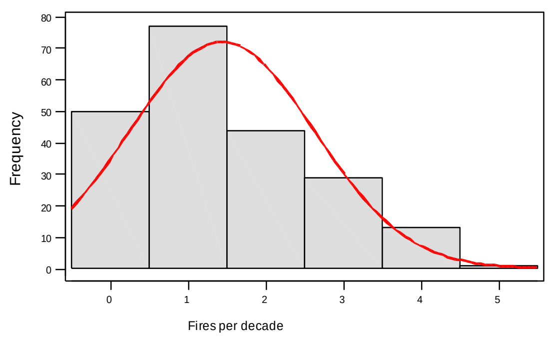


Figure 6.17(f): Era 1940-1959

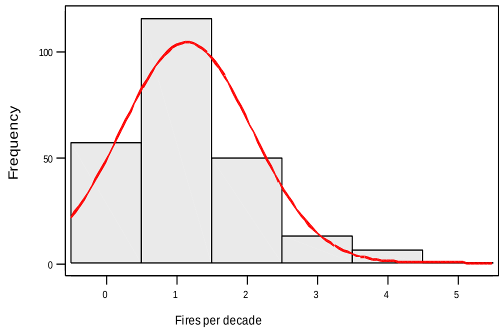


Figure 6.17(g): Era 1960-1979

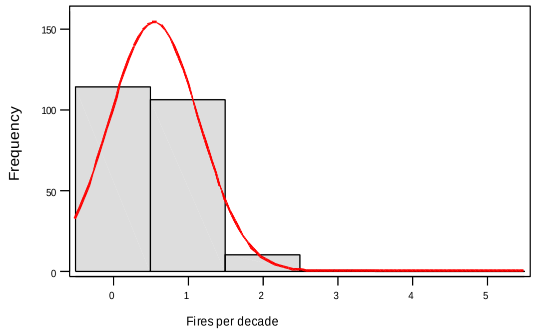
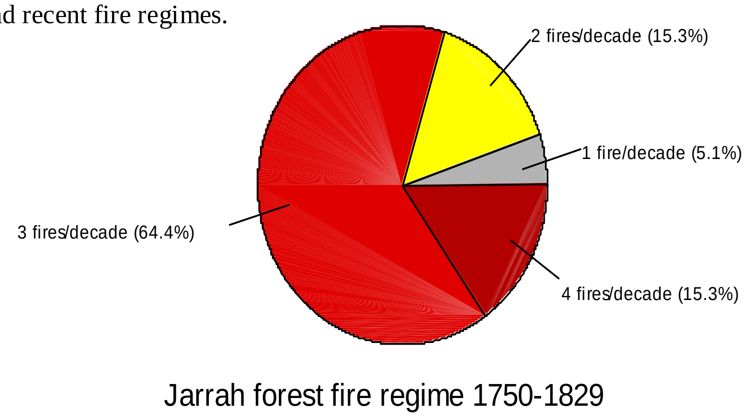
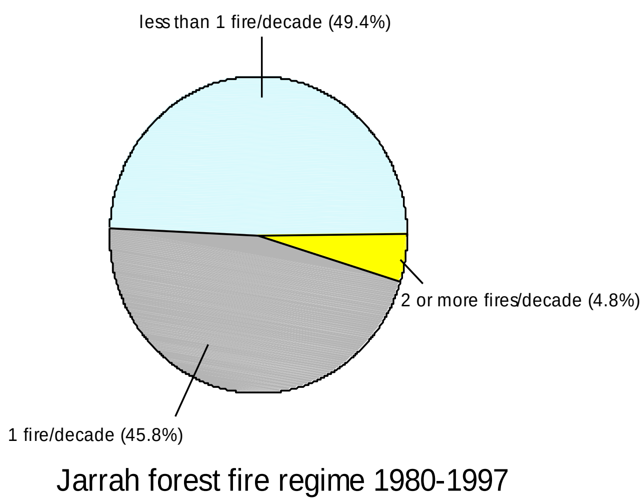


Figure 6.17(h): Era 1980-1997

The data can also be presented as piecharts, and some readers may find this helpful. For example Figure 6.18 compares the reconstructed fire frequency in the pre-European and modern eras.

Figure 6.18: Comparison of reconstructed Aboriginal and recent fire regimes.





Bushfire History of the Jarrah Forest - Discussion

Large grasstrees tend to occur close to water, so the sampling is skewed towards creek banks. Yet analysis of the data shows no relationship between proximity to a water body and fire frequency. However, as pointed out in Chapter 3 (About Wungong Catchment), analysis of the drainage and landform of the *jarrah* forest shows that the forest has such a rich network of creeks that it is difficult to find anywhere that is more than a kilometre from a drainage line, suggesting that fire had potential access to most parts of the landscape, apart from moist, rocky, or bare areas.

This conflicts with the 1839 report by Sir George Grey (1841) of heavy litter in the central *jarrah* forest, east of Harvey (cited by Hallam 1975). It can be seen, in Figure 6.14, that grasstree sampling was sparse in that area, so further sampling might help to resolve the matter. Perhaps *Nyoongars* avoided that area for some reason unknown to us. If the mosaic was coarser there, then Sir George might have chanced on one or more larger unburnt patches.

It is emphasized that the above suggested reasons for general uniformity of fire frequency apply to the *jarrah* forest, where litter accumulates rapidly after a fire. They are not true, for example, in *wandoo* woodland at Dryandra, where the evidence from grasstrees plainly suggests that fires were much more frequent along the (then grassy?) drainage lines (every 2-3 years) than on the bare, rocky ridges (every 15-25 years) where fuel accumulates slowly.

Concern may be expressed about the effect of frequent burning on refugial vegetation along creeks. Under the current fire regime, Department of Environment and Conservation staff usually burn from the ridge top down, because ridges dry first in spring, and burning down the slope gives a slower moving fire. Under this approach, creeks rarely burn until late summer or autumn, when the riparian soil, vegetation and litter are dry right through. This can result in a fierce fire, and complete burn out of the creek bed. Also, where rock outcrops occur on slopes, a mild fire travelling up the slope will leave a ‘fire shadow’, or unburnt patch, on the upper side of the rocks. A fire travelling down the slope will not. Such unburnt patches are potential refuges for fire sensitive plants.

If *Nyoongar* hunters lit close to the creek in early to mid-summer, then the headfire would have travelled up the slope. If the riparian soil and vegetation were still moist, there would have been little, or no backfire, so thickets of intact vegetation would have been left along the creek bed and immediate banks. History tells us that unburnt thickets were the subject of a special hunting technique in spring, in which vegetation was broken down around the perimeter to entangle the animals when they were driven out by fire (Green 1979), and there is a record of *Nyoongar* people deliberately guiding fires away from some places (Stokes 1846, Hallam 1975). These were possibly hunting patches, or perhaps thickets used to grow spear shafts (Kelly 1999), which needed about twelve years to reach useable size.

If *Nyoongar* people burnt as frequently as the evidence presented suggests, then it would be more rational to switch the research spotlight away from the effects of frequent burning, and toward the effects of not burning for long periods. Some interesting work has been done in Tasmania on this, showing that eucalypts decline under long fire exclusion (Ellis 1994), and benefit from ash and charcoal in the soil. The benefits of charcoal in soil are the subject of much current research, mainly with an agricultural, and climate change mitigation, emphasis (Lehmann and Joseph 2009). Forest research tends to confirm the view that most eucalypts are well adapted to frequent fire, and sicken without it (Jurskis 2005). There are many interesting research leads to be followed in the *jarrah* forest, concerning forest health and fire frequency. Amphion Block, near Dwellingup, has not been burnt since 1931, and Chandler Block, in Wungong Catchment, has not been burnt since 1937. Both these are potentially rich research sites.

Oral History of Bushfire Frequency

The findings of the general survey of grasstrees in the *jarrah* forest are supported by an oral history survey carried out by the West Australian Department of Environment and Conservation (personal communication from Dr Ian Abbott, DEC). Between 1997 and 2006, Ian Abbott interviewed 206 people, over 50 years of age, who had spent much of their life working in the bush, for example farming or forestry. Some only gave general comments on bushfire, sometimes with broad estimates of fire intervals. However, 62 of them gave exact intervals for former bushfire frequencies. I have added another 6, who were interviewed by me some years ago, making a sample of 68 people. They overwhelmingly gave 2-5 years as the typical fire interval for *jarrah* forest prior to the Second World War. Their opinions were based either on their own observations, or on what they were told by their parents. Figure 6.19 shows a histogram of their replies.

The longer intervals of 6-10 years were reported by residents of vegetation types other than *jarrah*, for example heath, near the south coast. One individual reported fire intervals of 20-30 years. It is unclear what sort of vegetation he was talking about. Due to the limitations of the graphical software used, the red bar representing this single individual's views is coarse, and appears to represent two people.

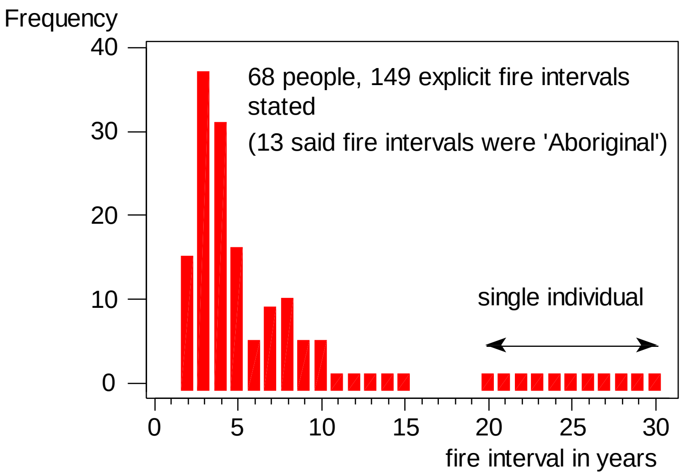


Figure 6.19: Histogram of fire intervals remembered by old bush residents

The *Kwongan* Dispute

The validity of the grasstree method has been questioned by a group of researchers working, at that time, out of Melbourne, with field trips to Western Australia (Enright *et al.* 2005, Miller *et al.* 2007). They did not work in the *jarrah* forest, but in the *kwongan* sandplain heath several hundred kilometres north of Perth.

Their main objections are, firstly, that adjacent grasstrees sometimes show different fire dates; secondly, that fire dates derived from grasstrees in *kwongan* bush do not match well with fire dates derived from satellite photographs over the past thirty years; and thirdly, that some past fire intervals derived from grasstrees are less than the hypothetical minimum sustainable fire interval of about twelve years, derived from their seedbank model, for several *Banksia* species which grow in the *kwongan*. On this basis, they conclude that all fire histories reconstructed from grasstrees (e.g.

Ward 1996, Ward and Van Didden 1997) are unreliable, not only in the *kwongan*, but for all of south-western Australia, including the *jarrah* forest.

The two papers submitted to a journal by these authors (Enright *et al.* 2005, Miller *et al.* 2007) appear, to me, to be flawed. As with all published academic work, both the logic and the data presented therein should be carefully examined by their readers. Nevertheless, both papers were published in a refereed journal, and so must be persuasive to some. I have published a comment on the first (Ward 2006), and a paper (Ward 2009) in answer to the second. In the paper I give informative data which were omitted by Enright and Miller. For the interest of readers, both the comment, and the refereed paper, are given in Appendix C. For copyright reasons, I cannot include the original critiques, but they should be available at any university library, or online.

Appendix D gives some past comments on bushfire, back to 1791. These include some comments (‘folk-ecology’) on bushfire in the *kwongan* (Gillam 2005). Some of the informants come from farming families which have been in the *kwongan* for several generations.

In defending our own research, we are all, by definition, partisan – that is the nature of vigorous, and I hope productive, academic dialectic. Being partisan does not necessarily mean a lack of objectivity, or integrity. It may show quite the opposite, when one is a partisan for the truth. As stated in my paper (Ward 2009), I genuinely hope that the authors who have criticized my work will continue to contribute research on bushfire, so that we may all arrive at the truth.

Readers must make up their own minds on the dispute. However, my own opinion is that the past fire intervals derived from grasstree records for *kwongan* scrub, north of Perth, are valid, as are those from other vegetation types, including the *jarrah* forest, further south. That being the case, I have used the grasstree technique to try to find information on past fire frequency in the *jarrah* forest of Wungong Catchment. I compare the Wungong data with some previously collected grasstree data from the neighbouring Monadnocks Conservation Park, which overlaps, in part, with Wungong Catchment.

Mounting Litter Loads in National Parks

Since 1985, when the Forests Department was replaced by the Department of Conservation and Land Management, a layer of dead leaves, sticks, bark, twigs and branches has mounted up in most National Parks and Reserves, smothering many native plants. In places it is up to 40 tonnes/ha, and the knee-deep piles of sticks make walking difficult. When summer lightning strikes occur, unstoppable fires result, putting the lives of fire crews at risk. In 2009, fierce summer bushfires occurred in heavy fuels in King's Park, Perth; in Yanchep National Park; and in native forest, plantations, and farmland near Bridgetown. The disastrous bushfires in Victoria, in February 2009, must surely be food for thought for most Australians. When over a hundred people die, we must question official policies on fire management. Further severe fires have occurred, most recently in December 2009, at Badgingarra, and Toodyay, in Western Australia.

The former was in *kwongan* bush, in the Moore River National Park. No humans were killed, or houses lost, so it attracted little news media attention, but the broad fire front suggests long previous fire exclusion. The second fire, around the settlement of Toodyay, led to newspaper banner headlines such as 'Bushfire Disaster: 37 homes lost: Four injured: Damage bill in millions' (West Australian December 31st. 2009).

Bushfire in Monadnocks Conservation Park

Close to Wungong Catchment, there was, in 2003, a bushfire in Monadnocks Conservation Park, which attracted little news media attention. Nobody was killed, yet, in area, it was one of the biggest fires in south-western Australia since the Second World War. Some of the fiercest behaviour was in twenty year old unburnt litter on the slopes and

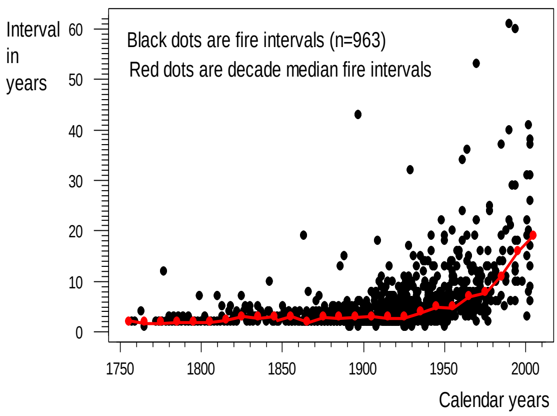


Figure 6.20: Past bushfire intervals in Monadnocks Conservation Park

summit of Mount Cooke, a granite monadnock. Thousands of large, mature trees were killed, large boulders cracked, and no pocket of vegetation among the rocks remained unburnt (Burrows 2005). Following the first rain after the fire, some ephemeral water courses were choked with deep drifts of silt and ash (personal observations by the author).

A few months after the fire, a survey of sixty old grasstree stems was made (Ward and Van Didden 2003a). The stems yielded 963 fire intervals, stretching back to the year 1750. The raw data are given in Appendix B.

Figure 6.20 shows the pattern of fire intervals in Monadnocks Conservation Park since 1750. The general increase in fire intervals is obvious. The implications for fire behaviour should also be obvious. Despite the presence of many fire crews, including professionals and volunteers, the above mentioned bushfire (2003) was uncontrollable, until it ran into an area of light fuel, deliberately burnt a few years before.

Bushfire in Wungong Catchment

As part of this study, some large grasstrees were cleaned in Wungong Catchment. The Water Corporation staff were helpful, but were clearly concerned about me carrying out such a messy activity in the catchment, especially within the hygienic exclusion zone around the dam. One of their concerns was the use of a generator, and the risk of fuel and oil spills. For this reason, I kept grasstree cleaning to a minimum. The grasstrees cleaned showed very similar bushfire histories to those cleaned in a previous study, just over the road in

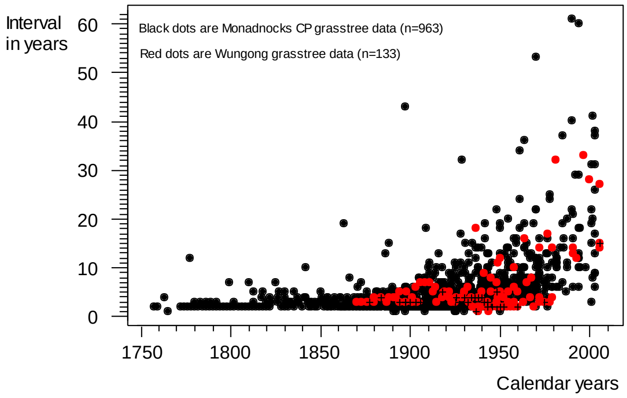


Figure 6.21: Wungong grasstree fire intervals superimposed on Monadnocks Conservation Park data.

Monadnocks Conservation Park (Ward and Van Didden 2003a). As mentioned in Chapter 3 (About Wungong Catchment), the catchment and the park overlap in the south.

Figure 6.21 shows the Monadnocks Conservation Park data, with the Wungong Catchment records superimposed in red, for comparison. In Wungong Catchment I cleaned eleven grasstrees. These were mostly in the southern part of the catchment (positions given in Appendix B), since no large, sound grasstrees were found in the northern part. The cleaned grasstrees showed 133 fire intervals, the oldest fire being in 1867, the most recent in 2006. It will be remembered that logging started in the 1870s. It is plain that, back to then at least, the two fire histories are very similar. Fire intervals have greatly increased over the twentieth century. Nevertheless, there were occasional longer fire intervals, at some places, in the nineteenth and eighteenth centuries. Broadscale, frequent burning did leave some longer unburnt refuges.

General Conclusions

Large samples of old fire marks on *balga* grasstrees show a consistent pattern of increasing fire intervals over the twentieth century, both in Wungong Catchment, and the adjacent Monadnocks Conservation Park. This pattern matches well with grasstree results from other parts of the *jarrah* forest, and other dry forest and woodlands of the south-west, including *tuart* forest, and *banksia* and *wandoo* woodland (Ward 1996, Ward 1998b, Ward 1998c, Ward and Sneeuwjagt 1999a, Ward 2000a, Ward *et al.* 2001a, Ward 2001b, Ward and Van Didden 2002, Ward and Van Didden 2003a, Ward and Van Didden 2003b, Ward *et al.* 2004, Ward 2004).

The pattern of frequent fire, generally at 2-4 year intervals before the First World War, matches with historical accounts, and with information from present day *Nyoongar* Elders, both given in Chapter 5 (Bushfire, Flogging, Measles and Foresters), and Appendix D. It will be shown, in Chapter 7 (Does God Play Dice?), that there is consilience with a mathematical modelling exercise, which shows that a fire mosaic will only remain stable if patches are burnt as often as they will just carry a fire. For *jarrah* forest that fire interval is 2-4 years.

Fire at 2-4 year intervals also makes sense when the life cycles of native plants and animals are considered. The example of *djiridji* health and fruiting has been given

(Chapter 3: About Wungong Catchment). In one extensive study (Burrows and Wardell-Johnson 2008), it was found that only a very small minority (3/639) of native vascular plants need longer than 4 years to flower, and these grow in obvious potential fire refuges, such as moist creek banks, and rocky places. The only way to conserve thousands of such small fire refuges in the *jarrah* forest (Burrows and Abbott 2003) is within a mosaic of broadscale, frequent, mild, patchy burning.

Recent broadscale, fierce fires in long unburnt leaf litter and scrub destroy plant and animal habitat wholesale, and sometimes put human lives and property in danger. From a nature conservation point of view, it is possible to maintain long unburnt refuges in a landscape matrix of frequent fire, but not the reverse mosaic of 'strategic burning', that is to say, frequent burning of small areas within a long unburnt landscape matrix (Gill 2001). The West Australian Forests Department did that experiment in the 1920s, when they tried frequent burning of only narrow (20 metres) breaks in otherwise long unburnt forest. The experiment failed. Due to the vagaries of the weather, trying to burn the narrow breaks led to repeated escapes into the adjacent long unburnt areas, despite efforts at chopping down all the highly flammable grasstrees within the breaks (Forests Department Reports, 1920s).

There is clear consilience between the historical bushfire intervals shown on old grasstrees in the *jarrah* forest, and other, independent sources of information. There can be little doubt, from history alone, that the *jarrah* forest, up to the First World War, was generally burnt as often as it would carry a fire, that is to say every 2-4 years. There was plenty of ignition, both from lightning and humans, and no rural fire brigades to put fires out.

As already emphasized, this does not mean that every square metre burnt that often. In light fuel, fires would obviously have been mild and patchy, with many unburnt refuges passed by, because the litter was too moist, or too shady, or protected by rocks, or by a log that was too damp, at the time, to burn. With such mild fires, even a wind gust could divert a fire around an unburnt patch.

On the subject of former fire frequency in the *jarrah* forest, and its effects, we should consider the views of Dr. T.N. Stoate, who joined the then Forests Department of Western Australia before the First World War. He was Senior

Assistant Conservator of Forests in 1930, Acting Conservator from 1942-1945, and Conservator from 1945-1953. He was a foundation member of the Institute of Foresters of Australia, and President of the Institute from 1941-1945. In 1953 he was awarded a D.Sc. by the University of Western Australia, for his outstanding research into the forests of south-western Australia. After he left the Forests Department, he moved to the USA, where he was a Research Professor at the University of Washington. Most people would accept Dr. Stoate as a forestry expert.


Figure 6.22: Jarrah coppice from a lignotuber, two years after fire.

Just before the Second World War, Stoate produced a report, with another experienced forester called Andy Helms (Stoate and Helms 1938). In it, they said that '*Jarrah* as a species is remarkably resistant to fire, a fact which has aided to support the popular contention that fires are of little consequence and can even be beneficial. Young seedlings and saplings can tolerate complete destruction of the stem above the ground and, in a short time, recover in a surprising manner, thanks to the recuperative coppicing powers of the lignotuber.'


Figure 6.23: Cleaned *balga* in Wungong Catchment. Early fires are at 3 year intervals, recent ones much less frequent. See grasstree No 61, Appendix B.

The lignotuber is a woody growth that forms, below ground, on *jarrah* seedling stems, a few years after germination. It eventually reaches the size of a football, or even bigger. It stores starch, and so enables the seedlings and saplings to survive interruption of photosynthesis, due to having their leaves burnt off. In fact, they coppice vigorously from it (Fig. 6.22). Eventually, one of these coppice shoots assumes a 'dynamic' nature, and grows very fast, over a metre a year. Within three years, its crown is safe from damage by a mild fire running underneath.

Taking a timber production point of view, Stoate and Helms (*op. cit.*) did note that 'Intense fires cause serious malformation in growth'. However, they also said that 'Prior to the successful application of adequate fire protection measures [i.e. in the 1920s], it was unusual for any area of *jarrah* forest to escape periodic burning by at least a light ground fire for more than 3-4 years. Such fires, however light, invariably destroy all seedlings in their first year, but once lignotubers have been developed a large proportion survive by virtue of their ability to coppice.'

The date of Stoate and Helms' report (1938) makes it especially valuable, since both had worked long in the *jarrah* forest before writing it. Having joined the Forests Department before the First World War, Stoate was an eye-witness to the bushfire situation then. Eye-witness evidence is, in the legal system, preferable to hearsay.

The prompt and prolific coppicing of *jarrah* lignotubers after fire is familiar to all West Australian forest workers. In the words of Baron Von Mueller (1879), it makes the forest look 'all fresh and ever verdant'.

Several decades after Dr. Stoate, another Conservator of Forests, Roy Wallace, then President of the Royal Society of Western Australia, wrote that '… it is not unreasonable to assume that the forest was completely burnt through every 2-4 years. Even as late as 1925 the writer was able to observe three fires of this nature in unmanaged virgin forest east of Jarrahdale. These fires were alight in December and continued to burn until the following March.' (Wallace 1966). We should remember that Jarrahdale is not far from Wungong Catchment.

I think we should believe the *balga*. The *balga* data are strong evidence that the *jarrah* forest was, for hundreds of years, and therefore probably for thousands of years, burnt regularly at 2-4 year intervals. Since the *jarrah* forest still exists, it can obviously cope with such a fire regime. This applies to the *jarrah* tree itself, which has clear adaptations to fire, and the associated plants and animals. There are likely effects on soil microbes, *mycorrhizae*, and soil chemistry, and so on plant nutrition. It is well established that smoke has benefits on seed germination, and the flowering of some plants. The charcoal produced by bushfire may play a more important role than has yet been recognized by botanists, and others. This is discussed further in Chapter 7 (Does God Play Dice?).

The research focus needs now to be on the effects of mosaic fire, in some places fierce, in others mild, on the ecology of the *jarrah* forest. These effects, applied to the whole of south-western Australia, have been well discussed by Burrows (2006). He discusses a trial of fine grained mosaic fire, currently under way in the southern *jarrah* forest, with encouraging early results. The next chapter will examine the notion that bushfire has a spatial, self-organizing tendency. If we can understand that tendency, we can work more frugally and intelligently with it, rather than blindly against it. Both nature and human society stand to benefit.

-oOo-

Chapter 7

Does God Play Dice?

SELF-ORGANISATION IN BUSHFIRE MOSAICS

A little fire is quickly trodden out,
Which, being suffered, rivers cannot quench.

William Shakespeare, Henry VI, 1592.

Preamble

Shakespeare was right with regard to the urban fires of his time, which, if allowed to grow, could consume whole streets of wooden houses very rapidly (Jones *et al.* 1984). However, despite a growing interface between urban areas and large areas of natural vegetation (Gardner *et al.* 1987), there are still major differences between the management needed for urban fires and bushfires.

With regard to bushfire in flammable landscapes, the wisdom of ritual rapid attack on all fires is questionable. As discussed in Chapter 4 (The Other Side of the Hill), repeated rapid suppression of small *chaparral* fires in California has been counter-productive, leading to eventual large, uncontrollable bushfires (Minnich and Chou 1996, Minnich 2001). Others in the United States have pointed out that over zealous fire exclusion and suppression, as promoted by the Smokey Bear campaign between the two world wars, has led to fuel accumulation, and large, destructive forest fires over the past few decades (Kleiner 1996). Similar claims have been made in Australia (Hoggett and Hoggett 2004, Council of Australian Governments 2005), and in particular, for the *jarrah* forest (Kessell 1924a, Harris and Wallace 1959, Wallace 1966).

This chapter presents a mathematical enquiry into what may seem to be a paradox to those without direct experience of bushfires. Some may wonder how withholding, or suppressing, bushfire can lead to bigger bushfires. Intuitively, or from practical experience of bushfire-fighting, we may suspect that heavier fuel is one part of the explanation, and fuel connectivity another.

Past bushfires form a landscape mosaic, with the properties of a palimpsest – new fires can obliterate old fire boundaries. Within such a mosaic, bushfires may have some underlying spatial, self-organizing tendency, which can be mathematically modelled.

Four Dead Mathematicians

To tackle the matter of self-organizing bushfire behaviour we must, as so often happens, call on history to shed light on the matter. Few mathematicians can foresee the future uses which may be found for their ideas, but such uses are often found, sometimes hundreds of years later. Some history of mathematics can help us to see things in a better perspective, and understand the ideas we will use. If we are unaware of what happened before we were born, we are but intellectual babies.

I doubt if René Descartes (1596-1650), lying in bed until ten in the morning, in a freezing winter nearly four hundred years ago, could foresee that his combination of

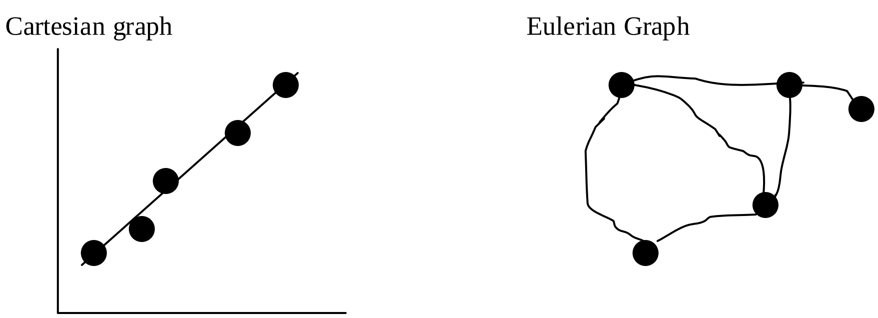


Figure 7.01: Two kinds of graph.

algebra and geometry into the 'Cartesian framework', would prove to be one of the most useful tools for twentieth century science, and other fields such as management (Boyer 1968). This framework is often referred to as a 'graph', and I will use this term where appropriate, being careful to distinguish it from another kind of 'graph' usually credited to the Swiss mathematician, Leonhard Euler (Figure 7.01).

Leonhard Euler (1707-1783) was a mathematical spoilsport. For centuries the good people of Königsberg, then a city in Prussia, had enjoyed both exercise and entertainment by trying to walk a circuit over the city's seven medieval bridges in such a way that they crossed each bridge only once. In 1736 Euler proved that it was impossible. To do so, he used a diagram which represented the bridges as connected points. This simple concept of a set of points, and a set of connections between them, is also, rather confusingly, known to mathematicians as a 'graph', and Euler's idea has given rise to a whole area of intriguing mathematics known as Graph Theory (Wilson 1979).

The third mathematician in our quartet is Francis Guthrie (1831-1899), who was a student at Cambridge in the 1850s, and later a professor at Cape Town University. While still a student, he noted that he could colour a map of the counties of England, using only four colours, in such a way that no two adjoining counties were the same colour. This seemingly innocent discovery led to a mathematical search which has kept mathematicians intrigued, and frequently baffled, up to the present day (Wilson 2003).

After more than a hundred years of effort, a proof of sorts was published (Appel *et al.* 1977), but this very voluminous result arose from using a computer to test every possibility – a proof by exhaustion. An elegant analytic proof, which can be done with paper and pencil, is yet to be found. Current mathematical approaches to the problem use Eulerian graphs to represent the coloured maps, and Figure 7.02 shows how a coloured map is converted to its dual (Eulerian) graph.

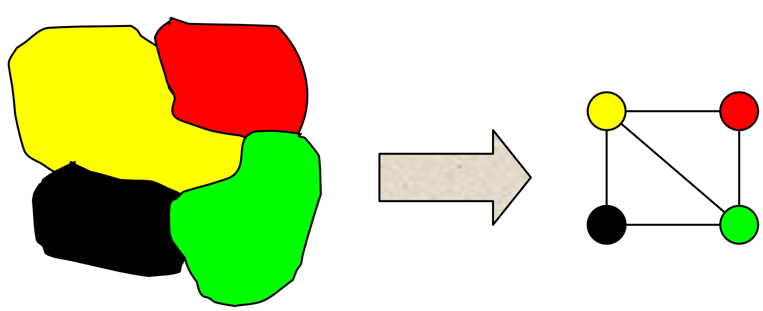


Figure 7.02: A coloured map with its dual graph.

Converting a map to an Eulerian graph has a number of advantages, including simplicity, and abolition of scale. In a map, patches may be of a complicated shape. Also, some may be big, and others small. The graph abolishes patch scale and shape, much in the same way that the stations of the Paris metro, or the London underground, or the New York Subway, can be shown more simply as lines, or loops, of connected dots. Connectivity is of interest to the passenger, but not the actual twists and turns of the track, nor the exact distance between stations.

The relevance of Guthrie's discovery to bushfire is that, depending on configuration, any Eulerian graph can be coloured with two, three, or four colours. Four is the maximum number of colours needed to colour any graph, so that no two neighbours are the same colour. More than four colours may, of course, be used, but are not needed.

Figure 7.03 shows an example of a simple Eulerian graph that needs four colours, although many others, some much bigger, and more complicated, are possible. Figures 7.04 to 7.06 show simple examples of other graphs that need only three, or two colours. The configuration in Figure 7.06 has no circuits, and is known in mathematics as a 'tree' graph. Graph theorists are fond of playful metaphor, and a collection of such graphs is known as a 'forest'.

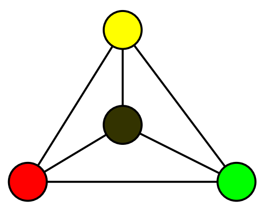


Figure 7.03: Hub with odd number of neighbours (Four colours needed)

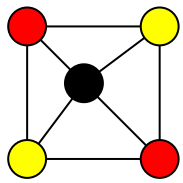


Figure 7.04: Hub with even number of neighbours. (Three colours needed).

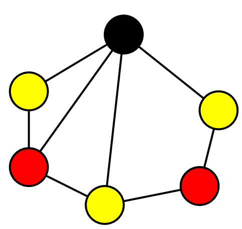


Figure 7.05: No hub, any number of neighbours (Three colours needed).

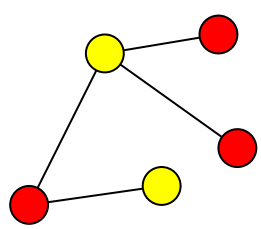


Figure 7.06: No hub, no circuits. (Two colours needed).

However, it can equally well be compared with a branching creek, and a collection of such creeks might constitute a catchment. In Wungong Catchment, creeks are important both for water, and as animal habitat.

The final member of our group of four distinguished mathematicians is Paul Erdös, a Hungarian whose life spanned most of the twentieth century (1913 to 1996). One of the topics he studied was that of random graphs (Eulerian), and the way in which random connections between a random set of points show some predictable behaviour.

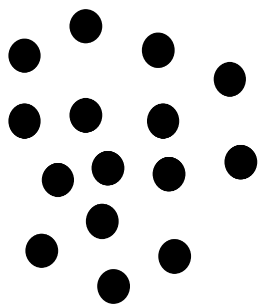


Figure 7.07: A set of 15 random points.

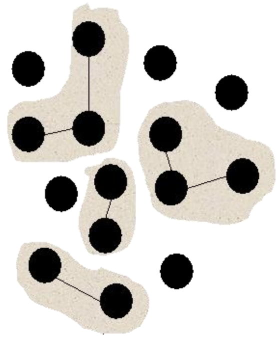


Figure 7.08: A set of 15 random points with 6 random connections. No '*giant patch*' yet.

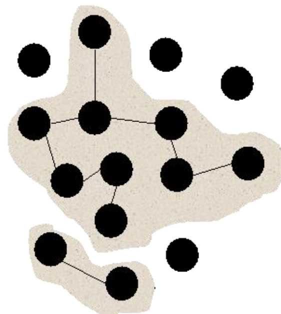


Figure 7.09: A set of 15 random points with 9 random connections. A '*giant patch*' is visible.

With a Hungarian colleague, he published a paper (Erdös and Rényi 1959) which showed how a 'giant patch' suddenly appears at some point, as connections are added. (Figures 7.07 to 7.09). Intuitively, this 'connectivity avalanche' is due to a general tendency for connections to change from those between single points, to those between whole sets of points.

In order to save space, graphs 7.07 to 7.09 show only some of the stages prior to, and after, the formation of a 'giant patch'. We can now use a Cartesian graph (Figure 7.10) to show the result more succinctly, with all connection stages included. It will be seen that, as concluded by Erdös and Rényi, the 'giant patch' forms rapidly after a certain number of connections are made. The critical number of connections will vary with size and configuration of the starting graph.

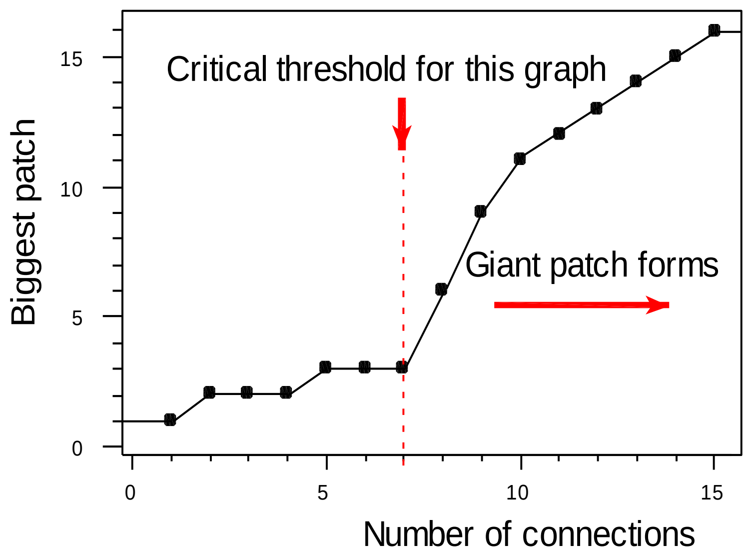


Figure 7.10: Giant patch formation.

In trying to understand why very large, uncontrollable bushfires have occurred in the past few decades in southern Europe, Russia, the USA, and in Australia (Minnich 2001, Hoggett and Hoggett 2004, Pyne 2006), and could occur in the *jarrah* forest around Wungong Catchment, the concept of 'giant patches' is of interest, and may help in explaining extreme bushfire behaviour. Although fuel quantity and connectivity are not the only determinants of bushfire behaviour, they are very important. Without fuel, there can be no bushfire, no matter how extreme the weather. Even with fuel, if it is patchy and disconnected, a bushfire cannot make much progress (Loehle 2004). If fuel is connected into 'giant patches', a bushfire may be unstoppable.

Applying the Ideas to Wungong Catchment

Wungong Catchment can be divided into thirty-six sub-catchments (personal communication from Bishnu Devkota, Water Corporation of Western Australia. As mentioned earlier, sub-catchments can be regarded as ecosystems (Lotspeich 1980). These sub-catchments can then be represented as an Eulerian graph.

It is assumed that, over the past four years, the catchment had been burnt on a sub-catchment basis, with any sub-catchment burnt as soon as it would carry a trickling fire. For simplicity in this demonstration, this minimum fire return period is taken as 3 years, where a year is counted from mid-winter to mid-winter. In other words, ignition can occur any time within the fourth fire season after the previous fire. This is true, in general, for the *jarrah* forest, but obviously local variations will occur, as discussed earlier in this thesis (p.2). A sophistication of the model to cope with nested mosaics is discussed later in this chapter, where patches of different fire return periods can co-exist.

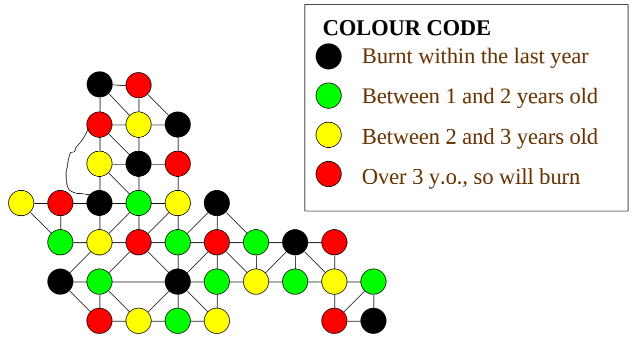


Figure 7.11: Graph of the leaf litter situation if Wungong Catchment had been burnt as a mosaic over the past four years.

Under previous patchy burning, the litter fuel situation might be as shown in Figure 7.11. It will be seen that this forms a four-colour map (Wilson 2003), where no two patches of the same colour are connected. Most patches will not carry a bushfire. Those that will (red) are quarantined by surrounding low litter fuel, so a bushfire could not spread from them along the ground, only by airborne embers. Given the low litter fuel levels, such ember production and transport would be minimal. If it did occur, it could only cause fires in other patches which are themselves quarantined. The occurrence of a large, uncontrollable bushfire would be very unlikely.

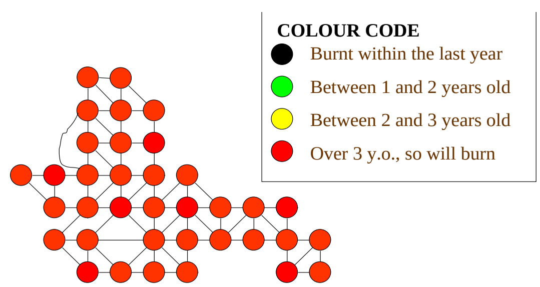


Figure 7.12: The current (2009) litter fuel situation in Wungong Catchment

The bushfire management strategy of deliberate, or 'prescribed' burning, has declined in Australia over the past few decades, due to a combination of economic, political, and social factors (Pyne 1991, 2003, Ward and Sneeuwjagt 1999). This applies to the *jarrah* forest, including Wungong

Catchment. The boundaries of those areas that have been burnt, by the Department of Conservation and Land Management (CALM), or its successor, the Department of Environment and Conservation (DEC), have been determined by historical features, such as forest administrative blocks, and existing roads and tracks, without regard to the hydrological boundaries of catchments and sub-catchments. As a result of a lack of regular burning, the whole catchment now carries enough litter fuel and tall shrubs to carry a fierce summer bushfire. The current sub-catchment, and whole catchment, fuel situation is shown as a graph in Figure 7.12.

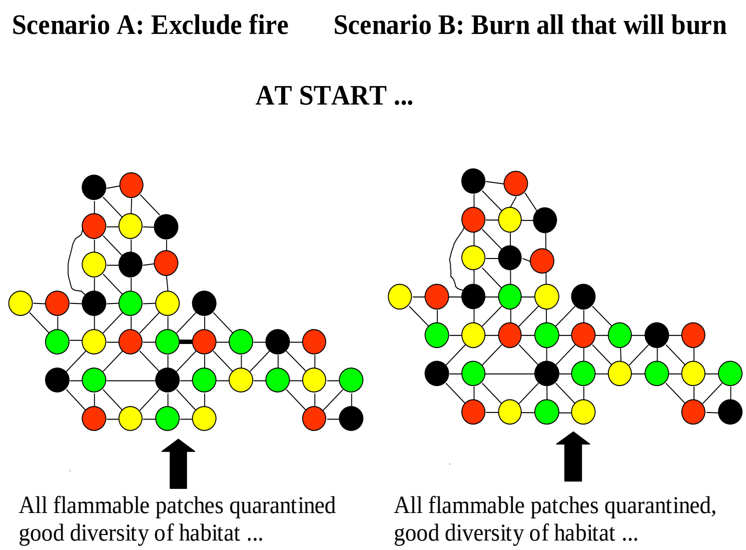
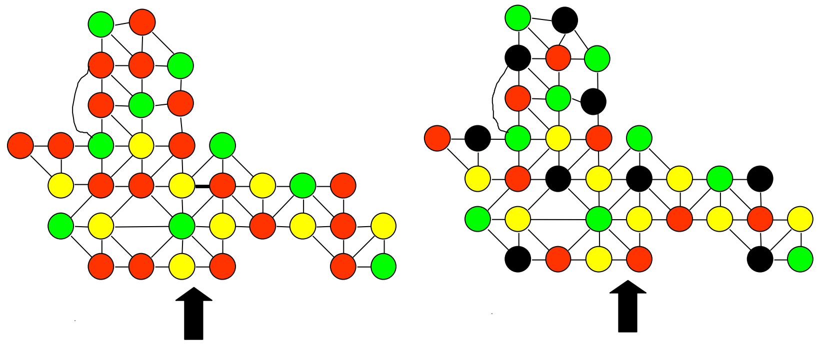


Figure 7.13: Start with two identical mosaics.

To make the effect of regular mosaic burning quite clear, an experiment can be run with the model, comparing the fuel graphs which would occur in Wungong Catchment, under two different bushfire scenarios. Scenario A is to attempt the indefinite exclusion of bushfire; Scenario B to introduce it as often as possible. Upland *jarrah* forest will just carry a mild, patchy bushfire every 3-4 years (Wallace 1966). Figure 7.13 shows one of many possible start mosaics, and Figures 7.14 to 7.17 show the fate of the Wungong Catchment mosaic under each scenario.

Scenario A: Exclude fire **Scenario B: Burn all that will burn**

AFTER 1 YEAR ...



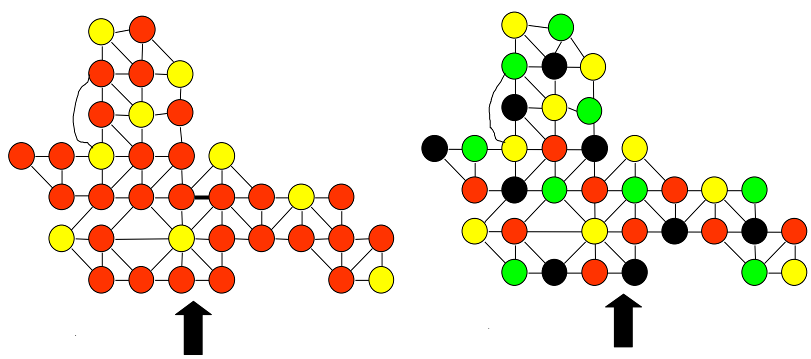
Flammable patches become linked, although of different ages ...

All flammable patches quarantined, good diversity of habitat ...

Figure 7.14: Joining up of flammable patches in Scenario A.

Scenario A: Exclude fire **Scenario B: Burn all that will burn**

AFTER 2 YEARS ...



Giant flammable fuel patch has formed ...

All flammable patches quarantined, still good diversity of habitat ...

Figure 7.15: The unburnt mosaic has become dangerously unstable, the burnt mosaic remains stable.

Scenario A: Exclude fire **Scenario B: Burn all that will burn**

AFTER 3 YEARS…

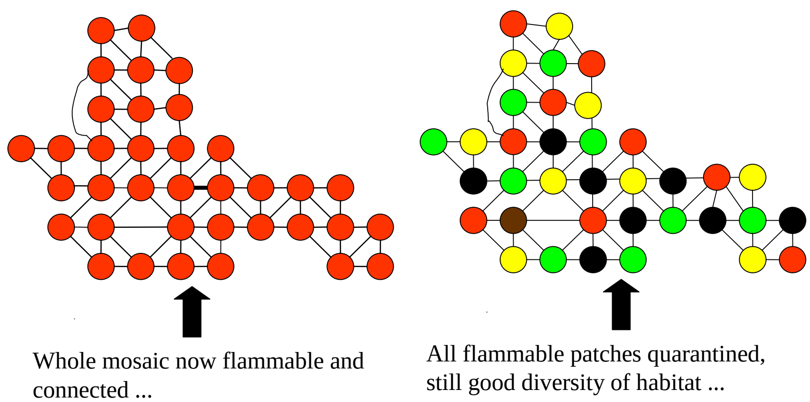


Figure 7.16: An obvious difference in bushfire potential.

Scenario A: Exclude fire **Scenario B: Burn all that will burn**

AFTER 4 YEARS or more...

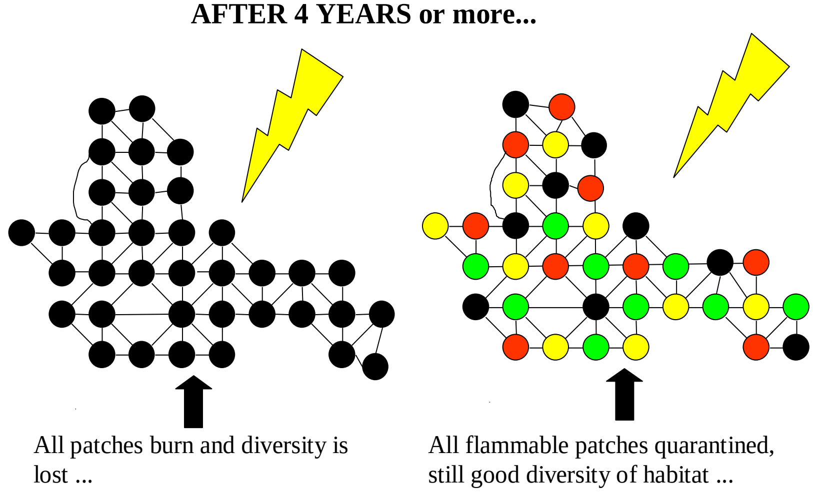


Figure 7.17: After four years (it might be twenty or fifty years), the inevitable happens, due to lightning or arson.

The above modeling exercise only considered the two extreme scenarios. One is attempted total bushfire exclusion, the other burning all that will burn. The outcomes were, respectively, eventual complete loss of vegetation age diversity (i.e. a single aged patch), and maintenance of the 36 patch original mosaic, with a stable mix of four litter fuel ages. Intermediate scenarios have been tested, where a constant number of patches is lit, each year, over four or more years. The results are given in Table 7.01.

No. of patches burnt each year (B)	1	2	3	4	5	6	7	8	9…
Return period for fire (r)	3	3	3	3	3	3	3	3	3…
Final stable number of patches (P)	4	8	12	16	20	24	28	32	36…

Table 7.01: Results of burning a regular number of patches each year.

From Table 7.01 it can be seen that, where **B** is a regular number of patches burnt each year in a mosaic of flammable vegetation, **r** is the minimum return period, in years, for spreading bushfire in that vegetation, and **P** is the final, stable, cyclic number of patches in the mosaic (i.e. **B**, **r** and **P** are all positive integers), such that no two patches of the same age are adjacent, then:

$$\mathbf{P = B(r+1)}$$ **Equation 1** (Modified fromWard 2003)

An important implication of Equation 1 is that more frequent ignitions maintain a finer grained, more diverse mosaic of vegetation ages. Adjacent patches of vegetation will have different structure and species composition. Reducing ignitions, or trying to exclude them indefinitely, can only lead to a coarser grained, less diverse mosaic of vegetation ages, structure, and plant species, and impoverished food and shelter opportunities for animals. In a coarse mosaic, when fire eventually happens, it will be bigger than in a fine mosaic. Due to more accumulated fuel, the fire will also be more intense, more destructive, and more costly to fight.

In addition, given equal numbers of animals to start with, more animals will usually be killed by a single big bushfire, than by a number of smaller fires, since it is self-evident that they will, on average, have further to run in order to escape the flames. Large animals, such as kangaroos and emus, will be hampered in their escape by dense, long unburnt thickets. Humans are similarly vulnerable, and *Nyoongar* people must have been aware of this before European settlement. In a large burnt area, animals, especially slow moving reptiles, will take longer to re-establish, than in a small burnt area. Fine-grained mosaics have a number of ecological, economic, and social advantages over coarse-grained mosaics.

Equation 1 only covers the situation where there is a constant number of ignitions each year. In practice, this will usually be impossible due to rain, or dangerously hot and windy weather, or simply by lack of patches available to burn. A more likely set of scenarios is that the number of ignitions, whether by natural means, such as lightning, or by humans, will vary from year to year within the same area. Multiplication is only a special form of addition, in which the same amount is added on each occasion. For example, **n** multiplied by **m** is the same as **n** added to itself **m** times, or **m** added to itself **n** times.

We may, therefore, modify Equation 1, using summation (**Σ**) rather than multiplication. Where the number of ignitions ($\mathbf{B_i}$) varies from year to year, the final number of patches at year **t** (i.e. $\mathbf{P_t}$) is the sum of the ignitions over the period of (**r + 1)** years, that is:

$$\mathbf{P}_t = \sum_{i=t-r}^{t} \mathbf{B}_i \qquad [t > r, \mathbf{B}_t > 0]$$

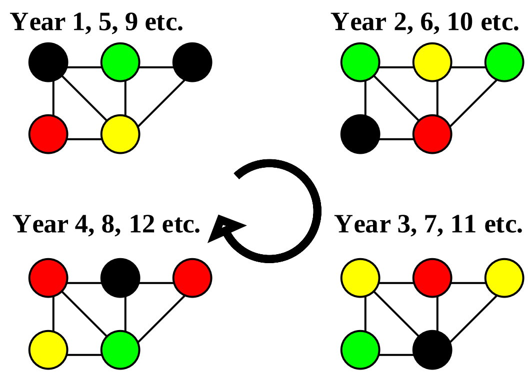
Equation 2 (Modified from Ward 2003)

In the above equation, the condition that $\mathbf{B}_t > 0$ is important, as it specifies that there will be at least one final ignition in the period under examination. Although ‘giant patches’ can, before a fire occurs, include smaller patches of different ages, the eventual bushfire will overwrite the palimpsest, and make them all the same age.

Matrix Representation of a Mosaic:

A more compact way of presenting scenarios of the mosaic burning model is as a matrix, in which the elements are the numbers of patches of each age within the mosaic. Each row is a year (**t**), and there are **r + 1** columns, representing the four stages of a minimum three year return period for bushfire in that mosaic.

For example, the progression through time of a simple coloured graph is shown in Figure 7.18, with its compact matrix representation. From now on, space will be saved by showing only the matrix for various burning scenarios within the 36 patch mosaic of Wungong Catchment.



Year	B	G	Y	R	(Colours black, green, yellow and red)
1, 5, 9 etc.	2	1	1	1	(Burn one red patch)
2, 6, 10 etc.	1	2	1	1	(Burn one red patch)
3, 7, 11 etc.	1	1	2	1	(Burn one red patch)
4, 8, 12 etc.	1	1	1	2	(Burn two red patches, which will cycle the mosaic to its start)

Figure 7.18: A coloured bushfire graph cycling clockwise through time, with its equivalent matrix.

A Selection of Bushfire Management Scenarios:

Using Wungong Catchment as an example, and again assuming that Scenario B (burn all that will burn) has applied previously, we start with the mosaic shown in Figure 7.11, with nine patches of each colour. This starting mosaic is not unique, as there can be different arrangements of the colours, each arrangement still maintaining the quarantine effect.

In Western Australia, bushfire policy is sometimes influenced by political matters. Imagine that, due to political influence, all burning was excluded from Wungong Catchment for a year. Subsequently, due to a change of government, or government policy, maximal burning was resumed. We would see an initial loss of diversity, then cyclic stability restored at a coarser level. Instead of the initial 36 patches, the mosaic would stabilize at only 25 patches. Such a scenario is shown in Table 7.03.

Year	B	G	Y	R	Total	
1	9	9	9	9	36	(Assume that Scenario B has applied previously.)
2	0	9	9	7	25	(No burning, so matrix coarsens)
3	7	0	9	9	25	(Assume all flammable patches burnt from here on.)
4	9	7	0	9	25	
5	9	9	7	0	25	
6	0	9	9	7	25	(Same as year 2, mosaic now 4 stage cyclic and stable, provided maximum burning is maintained.)
↓						
∞						

Table 7.03: Scenario C – excluding fire for a year, then restoring it.

The longer burning is excluded, the coarser the mosaic becomes. Table 7.04 shows the result of a Scenario D, in which fire is excluded for two years, then maximum burning restored. In Tables 7.03 and 7.04 it will be seen that it is not always possible to burn the same number of patches each year.

Year	B	G	Y	R	Total	
1	9	9	9	9	36	(Assume that Scenario B has applied previously.)
2	0	9	9	7	25	(No burning, so matrix coarsens.)
3	0	0	9	2	11	(No burning, so more patches lost.)
4	2	0	0	9	11	(From here on all available patches burnt each year.)
5	9	2	0	0	11	
6	0	9	2	0	11	
7	0	0	9	2	11	(Same as year 3, mosaic now stable, but less diverse)
↓						
∞						

Table 7.04: Scenario D – excluding fire for two years, then restoring it.

Although the final number of patches will eventually be the same for a repeated sum of ignitions over (**r** + 1) years, the disposition and connectivity of those patches will vary, according to choices in burning. Even under maximal burning, there may be years when no patches, or few, are available for burning. In other years, a choice of many patches may be available. Self-organization in bushfire mosaics is more complicated than it may first appear to be.

Table 7.05 shows the potential effect on the Wungong mosaic of excluding bushfire for three or more years.

Year	B	G	Y	R	Total	
1	9	9	9	9	36	(Assume that Scenario B has applied previously.)
2	0	9	9	7	25	(No burning, so matrix coarsens.)
3	0	0	9	2	11	(No burning, so more patches lost.)
4	0	0	0	1	1	(No burning, all patches now connected as one.)
5	1	0	0	0	1	(Single big bushfire, now cyclic single patch.)
↓						
∞						

Table 7.05: Scenario E – excluding fire for three or more years.

Eventually the whole catchment is flammable, and all may burn as a single, uncontrollable bushfire, depending on wind, and fire fighting resources available.

In litter fuel of five or more years accumulation, past field experience shows that a bushfire in the *jarrah* forest can, in the windy conditions, and extreme heat and dryness of some West Australian summer days, be uncontrollable in daylight hours (personal communication from Greg Standing, fire manager with the Department of Environment and Conservation, concerning a bushfire at Karagullen).

Nesting Mosaics

In the above discussion, for simplicity, it has been assumed that a whole mosaic will have the same fire return period of **r** years. However, in the real world this may not be so. Drawing on our own experience, and the ideas of landscape ecology (Naveh and Lieberman 1994, Burel and Baudry 2003), we can imagine a landscape in which there are, say, clumps of shrubs set in a grassy area, or matrix.

Suppose the grass will burn every second year, but the shady clumps of shrubs only every eight years, or more. This situation can be modeled using the Eulerian graph approach (Figure 7.06). As before, black is recently burnt, green between 1 and 2 years old, yellow from 2 to 3 years old, and red over three years old, so capable of carrying fire. Excluding the anomalous blue patch (shady shrubs), the mosaic can be burnt on a four year cycle, or as a four-colour map. The blue patch might burn every second, third or fourth cycle (8-16 years), so acting as a refuge for plants or animals which need longer periods between fires. It might remain unburnt for even more cycles, or never burn. The model can be extended to include many anomalous patches, and even sub-mosaics, within a frequently burnt matrix. If the surrounding matrix patches are not burnt as often as they will carry fire, then, due to increased connectivity, the mosaic will simplify, and the blue patch may be lost.

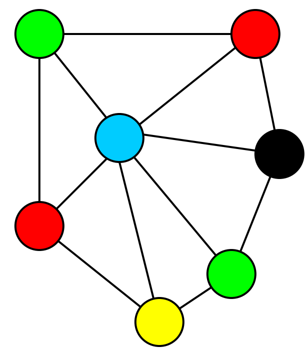


Figure 7.06: Mosaic with one anomalous shady shrub patch.

The concept of nested mosaics is important in trying to understand how plants which require longer than four years to flower, and set seed, could survive in a landscape generally burnt at 2-4 year intervals. In the *jarrah* forest, such plants are a tiny minority. According to one study (Burrows and Wardell-Johnson 2008), only 3 out of 639 species (less than half a percent) fell in this category. They usually occur in moist, shady refuges, but can also occur in areas of low fuel, such as bare, windy ridges, or rock patches. In such situations, burning surrounding patches as often as they will just carry a fire will contribute to the conservation of the less frequently burnt refuges, and hence to the conservation of those few species which need more than four years to flower and set seed. This reasoning may elude those who believe that, because some species need more than four years to flower, then ‘burning’ the landscape at intervals less than that will inevitably lead to extinctions.

For example, it has been suggested that, since most plants in the *jarrah* forest have a juvenile period of 3-4 years, then fire should be excluded for 6-8 years, i.e. twice the juvenile period (Burrows and Wardell-Johnson 2008). The authors admit that this is only a ‘rule of thumb’, but they see it as a precautionary strategy. The Eulerian Graph model above shows that, if such a policy is followed, then small, refuge patches will disappear, due to large, all-consuming fires in 'giant patches'. The mosaic will inevitably coarsen, and post-fire diversity of habitat will be the poorer. Fire sensitive plants may be lost.

Despite their recommendation of 6-8 year forest burning, Burrows and Wardell-Johnson (2008) do cautiously acknowledge that fire sensitive plants could survive under a regime of 'frequent but very low intensity, patchy fires', and that 'there is a paucity of information on seed bank dynamics and seed longevity in fire prone ecosystems.'

'Thought experiments' have a place in ecology, and can lead to useful hypothesis formation and testing. In the *jarrah* forest, logic suggests that effective seed banks do not necessarily build up, monotonically, in the absence of fire. Once a continuous carpet of *jarrah* leaves has formed (within 2-4 years after fire), any subsequent seed will be shed on top of it, interspersed with subsequent leaf falls. When a fire eventually occurs, it will tend to burn most of the seeds suspended in the leaf layer. Only those that fell onto bare soil, in the first few years after the fire, may actually be effective. In addition, the seeds within the litter layer may be more liable, before a fire occurs, to predation by ants, weevils, birds, or small mammals. Prolonged absence of fire may also lead to nutrient lockup, so that flowers may produce apparently sound seed, which is actually sterile. Calcium, which is present in wood ash, may be essential in pollen formation (Salisbury and Ross 1969). Charcoal in the soil may play a larger part in the nutrition, growth, survival, and flowering of native plants than is presently recognized by some botanists (Lehmann and Joseph 2009). The above ideas, although partly speculative, may yield some useful hypotheses for seed bank research. All good research starts with speculation.

I agree with Burrows and Wardell-Johnson (2008) on the current lack of knowledge about the flowering and seeding of native plants, and seed bank dynamics. We should make no management decisions based on assumed seedbank dynamics, until the situation is better resolved by more research. Remembering the Duhem-Quine notion that knowledge forms extensive webs, we should not lightly dismiss evidence from history (Chapter 5: Bushfire, Flogging, Measles and Foresters), and the grasstree record (Chapter 6: Better to Believe the Balga). Both these sources suggest that the *jarrah* forest was burnt, for centuries, and so probably for millennia, on a general 2-4 year cycle. From the Eulerian model, this suggests that such bushfires were patchy, with many refuges remaining unburnt for longer periods. The modeling in this chapter strongly suggests that such refuges can only survive, in the long term, if surrounded by frequently burnt country.

Conclusion

My conclusion is that, with regard to bushfire mosaics, God does not play dice. It has been demonstrated, by mathematical evidence, that palimpsest mosaic formation by successive bushfires is not a random procedure, but that there is an underlying, geometric, self-organizing tendency, due to the predictable formation, under deliberate fire exclusion, of large patches of connected fuel.

The longer fire has been excluded, the heavier, and more extensively connected these fuel patches will be. For the same weather and moisture conditions, a bushfire in heavier fuel will always be more intense than a fire in lighter fuel. Similarly, a bushfire in a mosaic of big patches will always have the potential to spread over a greater area, and have a greater perimeter, than a bushfire in a mosaic of relatively small patches, in which each burnable patch is quarantined due to its neighbours not yet being capable of carrying a fire. Other research, using the different mathematical approach of Percolation Theory (Loehle 2004), showed close consilience. It was concluded that frequent, and patchy, burning of between a quarter, and a half, of any area, will prevent the formation of big fires, with long perimeters.

Fighting an intense bushfire, especially one with a long perimeter, will always be more difficult and expensive than fighting a mild fire, with a short perimeter. In managing anything, it makes more sense to work, where possible, with a natural self-organizing tendency, rather than against it, or in ignorance. Both historical evidence (Chapter 5:

Bushfire, Flogging, Measles and Foresters), and evidence from fire marks on grasstree stems (Chapter 6: Better to Believe the Balga), support the claim that, by luck, or good judgement, *Nyoongar* people found a way to work with the self-organizing characteristics of bushfire. We newcomers need to learn from their example.

For *jarrah* forest, fire exclusion for only a few years, over a large area containing a range of fuel ages, is likely to destabilize a complex, small scale mosaic, leading to a simpler one of flammable 'giant patches'. In extreme summer heat, wind and dryness, these can carry an uncontrollable summer bushfire. The historical evidence is very clear, that such bushfires can cause severe damage to both natural and social systems, and can kill people. Such death and damage, and their causes, have been the subject of a number of Royal Commissions, and other forms of report, in Australia (Stretton 1939, Rodger 1961, Hoggett and Hoggett 2005). All, so far, have concluded that fuel reduction by burning is a central priority.

Wungong Catchment is largely composed of *jarrah* forest, with a range of fuel ages, up to over seventy years. Any area carrying litter older than three years has the potential to support a spreading bushfire. Assuming that we all want to avoid human deaths, loss of property, long term damage to natural systems, and damage to water catchments and their infrastructure, the implications for future bushfire management by the Department of Environment and Conservation, and water catchment management by the West Australian Water Corporation, should be quite plain.

Just as fuel mosaics can be coarsened by fire exclusion, so they can be made finer by deliberate burning of small patches. In long unburnt areas, with heavy fuel, this may not be easy. We cannot sprinkle fire like 'ecological pixie dust' (Pyne 2003). It will need an understanding of bushfire behaviour in relation to shade, drainage, moisture gradients and topography. The next chapter (Chapter 8: Violins and Bidi Burning) will discuss some geometric notions which may help us to scatter 'ecological pixie dust' in a safe, and effective way.

-oOo-

Chapter 8

Violins and Bidi Burning

RESTORING LOST MOSAICS

Verum et ipsum factum convertuntur.

Giovanni Battista Vico 1710, De Italorum Sapientia

Preamble

Giambattista Vico was a humanist. While accepting the value of logic, he opposed its mechanistic use, and understood that there was far more to human intelligence than just analytic logic. His '*verum factum*' principle is difficult to translate exactly into English. There is not always an exact match between languages, nor to the thinking processes behind them. A reasonable attempt is that 'knowing and making are essentially the same'.

Although a native of Naples, we may surmise, from his use of the following metaphor, that he visited the city of Cremona, famous for its violin makers. He noted that if someone pulled a violin apart, they would learn something about violins. However, if they were to reassemble the violin correctly, they would learn much more (Collingwood 1946). Analysis is useful, but synthesis is important too.

A similar idea has been suggested in ecology, where re-creating an ecosystem is much more demanding than destroying one deliberately, or by neglect, or even by pulling it apart in an analytical way. Perhaps because it is more difficult, we may learn more ecology by trying to restore an ecosystem, than by simply pulling it apart, physically or conceptually (Jordan *et al.* 1990).

Bushfire can, with luck, be deliberately excluded from an area of Australian bush which would, without deliberate fire exclusion, be capable of burning every few years. Yet the eventual fierce fire will destroy any age mosaic which was there before. Restoration of that mosaic, or one similar, can only be achieved by deliberate use of fire.

However, to reintroduce regular, patchy burning, similar to that which was used by *Nyoongars* long before Europeans arrived, may be difficult. As mentioned at the end of the previous chapter, fire is not an 'ecological pixie dust', to be sprinkled willy-nilly (Pyne 2003). Nevertheless, I argue that even if a perfect facsimile is not achieved, much may be learnt from the exercise, and the final outcome will be safer, more diverse, and more predictable, than a simplified fire regime, in which 'giant patches' burn fiercely, and dangerously, at usually long, but unpredictable, intervals.

Knot Theory

This chapter starts by examining the relevance to fire mosaics of a branch of mathematics known as 'Knot Theory' (Welsh 1993, Livingston 1993, Adams 1994). Starting more than a hundred years ago, as a bit of intellectual fun, this branch of mathematics has repeatedly produced surprising connections between seemingly different kinds of mathematics, and has also found some surprising applications.

An early proponent of its practical application was the physicist, Lord Kelvin, who thought it might give some insight into the nature of chemical bonds. This stimulated research into the matter, and Knot Theory grew in extent and mathematical status. Kelvin's idea foundered, but more recently Knot Theory has proved useful in exploring the geometry of knots or tangles in DNA strands (Adams 1994).

Some Simple Bushfire Geometry for Small Areas

There is a simple fact of geometry, drawn from Knot Theory, which could help in safely restoring a finer grained mosaic in smaller areas (say a few kilometres across), if that mosaic had been lost, due to a wide-spreading fire. This could apply in national parks and nature reserves, or around human settlements, or along tracks and creeks passing through larger areas, such as Wungong Catchment.

Any number of closed loops, whether they overlap or not, will create a two-colour map on a plane surface, or even on the surface of a sphere. To introduce the idea, Figure 8.01 shows a set of overlapping rectangles, and Figure 8.02 a set of overlapping ellipses. In both figures the resulting mosaic is then coloured in black and green, representing burnt and unburnt. The choice of which set of patches is which colour is arbitrary.

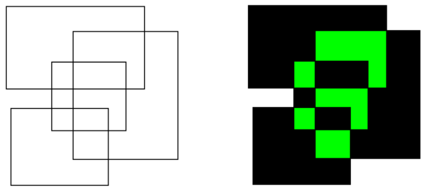


Figure 8.01: Overlapping rectangles form a mosaic.

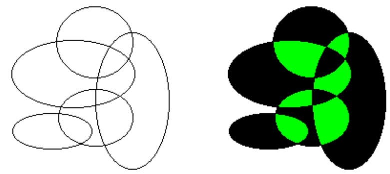


Figure 8.02: Overlapping ellipses form a mosaic.

Intriguingly, provided each loop is closed, the shape does not matter. Random lines can be used, even crossing themselves. Figure 8.03 shows a two-colour mosaic created in this way. We can, of course, use more colours if we wish, and still maintain the condition that no two adjacent patches are the same colour. Figure 8.04 shows such a mosaic, using the four colours of Chapter 7 (Does God Play Dice?).

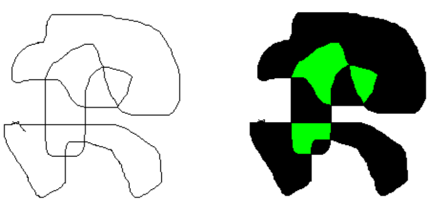


Figure 8.03: Two random loops, one crossing itself.

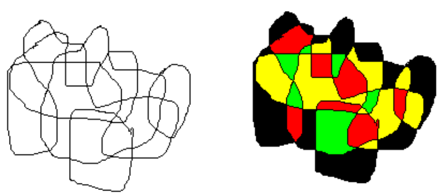


Figure 8.04: A four colour random loop mosaic.

Translating the geometry to a field situation, we could, in a relatively small area, use a rake, garden leaf-blower, brush-cutter, or similar tool, to create a set of random fire breaks. The area could be sub-divided as finely as needed, or as practically possible, or within the constraints of a particular budget. In larger areas, heavier mechanical help, perhaps a tractor with a blade, might be needed. In mild weather, such as the West

Australian winter, breaks could be created by burning, even in heavy surrounding fuel, using drip-torches, or butane-burners.

If fuels are heavy initially, the patches would need burning in mild weather, to avoid spread into adjacent patches. Once sufficient fuel reduction were achieved over the whole area, then fires could be lit, even in summer, without causing major problems. Legal clearance for summer burning would, of course, be needed. Without strong wind to spread embers, each burnable patch would be quarantined by surrounding unburnable patches, and, due to low fuel in the burnable patch, the fire would be mild, regardless of high air temperature and low humidity.

The two-colour mosaic in Figure 8.03 could be burnt at two year intervals, if that were ecologically advisable, and enough fuel accumulated in that time to carry a fire. It could, on the other hand, be burnt in spring and autumn, then left unburnt for several years. In *jarrah-marri* forest, the minimum potential return period for fire is, as previously discussed, in several chapters, generally two to four years.

The four-colour mosaic in Figure 8.04 could be burnt on a four year cycle. If, due to past long fire exclusion, fuels were initially heavy, it would be hard work at first, with a need for vigilance and prompt suppression of fires straying out of their patch. Thoughtful working with natural features, such as topography, drainage, creeks, and rock outcrops, would make the task easier. As fuels became lighter, and the cycle became established, it would become much easier. Only occasional hand-beating of straying fires would be needed, much as described by John Lort Stokes of HMS Beagle (1846), or Forester Brockway at Mundaring (1923).

As explained in Chapter 7 (Does God Play Dice?), if patches were not burnt as soon as they were ready to carry fire, then there would be an eventual, and inevitable, loss of mosaic stability, due to merging of adjacent patches. The eventual fire would result in a coarser mosaic, that is to say, a loss of diversity. In other words, the mosaic would self-organise in response to a decreased ignition frequency (Equations 1 and 2 in Chapter 7).

This increase in patch size and fire intensity would be independent of any potential change in fire behaviour due to change in climate.

Restoring Mosaics in Larger Areas

In large areas, say 10,000 hectares or more, it may be possible to restore mosaics by using the above method, plus knowledge of different drying rates, connected with different vegetation, shade, aspect, soil type, and season.

As an example, in south-western Australia some sedge swamps can burn even in winter, given enough wind. The flames move through the sedges, over the standing water underneath. This prevents deep burning of peat, which occurs with summer and autumn fires, and is a concern to some ecologists (Horwitz *et al.* 2003). At the same time, the water is given a good smoking, which can result in a spectacular germination of some native flowers as the swamp dries out in spring (personal observation at Terry Haddon's farm, at Nannup, and elsewhere). The importance of smoke to seed germination was discovered in South Africa (De Lange and Boucher 1990), and has been found to apply in south-western Australia (Dixon *et al*. 1995).

Ridge tops and north facing slopes in the *jarrah* forest may be dry enough to burn in early spring, valleys and south facing slopes only later, in summer or autumn. By judicious lighting, perhaps by aerial incendiary bombs, large areas could be burnt patchily, and economically.

Burning of such large areas would, however, create relatively coarse mosaics. There would be advantages in creating finer grained mosaics, by hand-burning along creeks and tracks. In Wungong Catchment, small marsupials, known by their *Nyoongar* name of *quokka,* shelter from predators in dense thickets along creeks. At the same time, they need recently burnt vegetation nearby, to provide nutritious and palatable food. A fine grained mosaic of burns would be of advantage to these threatened populations.

Since *quokkas*, and other small to medium mammals, were hunted and eaten by *Nyoongars*, it seems likely that areas along creeks were burnt as a fine grained mosaic. Mention has already been made (Chapter 6, Better to Believe the Balga) of a special technique being used to hunt small to medium animals in thickets (Green 1979). Fire breaks were created by treading, and small patches burnt. The animals got their legs tangled as they fled the fire, and so were easily speared. We may be able to recreate similar patchy habitat, offering both shelter, and fresh shoots for food, by careful burning, without, of course, the accompanying slaughter. At the same time, if such fine mosaics proved favourable to the animals, culling might be necessary from time to time, to prevent overpopulation and habitat degradation.

Bidi Burning

In Chapter 3 (About Wungong Catchment) it was noted that, in earlier days, *Nyoongar* people were great walkers, and had an extensive system of tracks throughout their country, or *boodja* (Hallam 1975). An individual track was called a *bidi*, with the plural form of *bidi-bidi* (personal communication from Koodah Cornwall, a *Nyoongar* employee of the Department of Environment and Conservation). They have been shown as a map (Nannup 1996), and I believe they still have great significance to *Nyoongar* people, since *bidi-bidi* are intimately entwined with their spiritual matters, and land custodianship.

In Chapter 3 (About Wungong Catchment) it was also noted that the same use of tracks to define territory was known in other parts of Australia. It is a distinctive feature of some Aboriginal art. Further, such tracks have been called ‘songlines’ (Chatwin 1997), because there were (and may still be) songs associated with them, which describe the country traversed, so serving as a musical, or poetic, map. The relevance of ‘songlines’ to bushfire management has been suggested by Stephen Pyne (1991).

Without wishing to pry too much into *Nyoongar* matters, it seems likely to me that there were such *bidi-bidi* in and around the well watered country of Wungong Catchment. It has been said that the current bituminized Albany Highway, which runs beside, and through Wungong Catchment, roughly follows a former major *Nyoongar bidi* linking the Swan River with present day Albany (Harris 1978).

Whatever may be the truth on that matter, there are two recreational tracks, in and near Wungong Catchment, maintained by the Department of Environment and Conservation. One is called *Munda Bidi*, after a prominent *Nyoongar* Elder at the time of European settlement. The other is called the *Bibbulman* Track, but this seems to be a misnomer, due to a geographic mistake by a journalist (Bates 1938). The mistake was perpetuated by the former Forests Department, which established the track. Although the track leads to the south coast, at Albany, I believe the *Bibbulman* were a group, or clan, who lived further west, near the present town of Augusta.

Both these recreational tracks offer an opportunity, within the Wungong Catchment, to use the above fine-grained fire mosaic restoration technique. The benefits would be greater security for walkers; protection of overnight huts and wooden bridges; greater diversity of habitat for native plants and animals along the track; better flowering and seed germination, and decreased possibility of the Department of Environment and Conservation facing legal action for injury, or loss of life, due to a major bushfire. An uncontrollable fire in the long-unburnt Mount Cooke area, in 2003 (Burrows 2005), burnt a walkers' hut on the *Bibbulman* Track. Luckily, nobody was in it at the time, but government departments, having a duty of care, should not trust to luck.

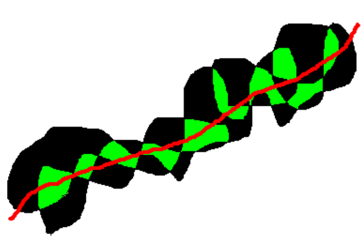


Figure 8.05: A mosaic along a track.

Figure 8.06: A mosaic along a creek.

Creating Mosaics within Mosaics

Bushfire mosaics have a fractal quality, in that each 'burnt' patch can be, in itself, a mosaic of second order burnt and unburnt, due to the presence of rocks, or moist, shady places, different aspects, animal diggings etc. As discussed in Chapter 7 (Does God Play Dice?), this second order mosaic will be most pronounced when fires are frequent and mild, in low fuel. It will disappear when long fire exclusion and heavy fuel loads create large, fierce fires, which coarsen and simplify mosaics.

A good example of such total burnout, due to heavy, connected fuel, was the already mentioned fire at Mt. Cooke, just east of Wungong Catchment (Burrows 2005). There have been others, notably in National Parks, where long fire exclusion has been attempted. Due to a policy of attempted fire exclusion, the bushland in King's Park, Perth, has heavy, connected fuel, and has been damaged by three fierce fires since 1980. Overseas, in 1988, Yellowstone National Park in Wyoming burned fiercely, due to attempted broadscale fire exclusion. In South Africa, Kruger National Park burned fiercely in 2001, for the same reason.

In restoring mosaics, anomalous patches will be found (Burrows and Abbott 2003), which will not carry a fire as often as the surrounding country. They can be safely left unburnt, provided that they are surrounded by a frequently burnt matrix. Fire sensitive plants and animals will benefit. The Department of Environment and Conservation is already attempting ecological mosaic burns in the southern *jarrah* forest (Burrows 2006), and early results are encouraging (personal communication from Dr Neil Burrows). The information is that they are trying to do this using aircraft, and incendiary bombs, and are guided by seasonal moisture gradients. I suspect that hand-burning, by people on the ground, will be needed to achieve a finer grained result in some places along creeks and tracks.

Conclusions

By regular, fine-grained mosaic burning along tracks and creeks, and rather coarser burning elsewhere, the Water Corporation, and DEC, could protect Wungong water catchment from future uncontrollable bushfires. Such burning would definitely benefit two iconic plants, the *balga* (*Xanthorrhoea preissii*) and the *djiridji* (*Macrozamia riedlii*). As explained in Chapter 7 (Does God Play Dice?), the milder nature of the burns would protect fire refuges, in which those few plants that are fire-sensitive can survive. It would also help to protect humans, such as resident catchment rangers, walkers and cyclists on the *Bibbulman* Track and *Munda Bidi*, and the residents of Bedfordale and Jarrahdale.

In southern India, there is a traditional form of art, called *kolam*, which has much in common with the mosaic patterns suggested above (Figure 10.07). It is geometric, being based on lines twining around square matrices of dots, usually in multiples of three (Mall 2007). It is created by women on outside walls, and the footpath near their door, and its purpose is to keep bad spirits out of the house, and allow good ones in. The geometry of '*bidi* burning' might serve a similar purpose. Bushfire can be seen as a good spirit, or a bad one, depending on how we burn. *Nyoongar* people have many spiritual beliefs connected with water, and the next chapter examines, in more detail, how bushfires can be 'good' or 'bad' in water catchments.

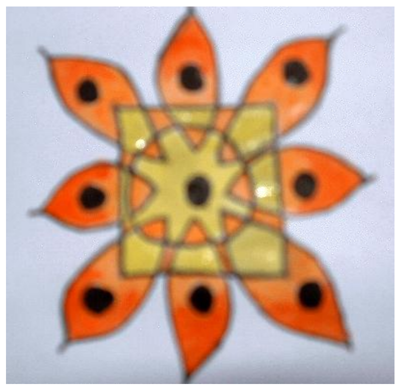


Figure 10.07: Geometric *Kolam.*

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Chapter 9

Fire, Forest and Water

THE RELEVANCE OF BUSHFIRE TO PERTH'S WATER SUPPLY

The knowledge of man is as the waters, some descending from above, and some springing from beneath…

Francis Bacon, The Advancement of Learning (1605)

Preamble

I have read that Freemasons, following ancient Egyptian beliefs, say that knowledge comes from both heaven above and the world beneath (Brown 2009). I suspect that Francis Bacon was a Freemason, or a Rosicrucian. Be that as it may, the Perth metropolitan area certainly gets water from a number of directions. Some from above, some from beneath, and some sideways from the Indian Ocean.

Perth's early water supply was from backyard wells, or the Swan River. In the first half of the twentieth century, dams were built across the creeks leading out of the Darling Scarp. In the second half of the twentieth century, much underground water was discovered, and exploited, on the Swan coastal plain, but there is uncertainty on the wisdom of further exploiting it, for reasons discussed later. Recently, in response to low rainfall over the past quarter century, a desalination plant has been built on the coast, just south of Perth, at Kwinana. This supplies 45 gigalitres a year, or about 17% of Perth's present domestic demand of just over 260 gigalitres/year. Currently (2009) the desalinated water is being stored in Canning Dam, to the north of Wungong Dam. Another desalination plant, further south at Binningup, is expected to yield a similar amount by 2011 (Water Corporation 2005a).

Most of Perth's water supply (56%) comes from underground. A great deal of water is stored in the deep sediments of the coastal plain. The remaining 27% (about 70 gigalitres/year), comes from catchments in the hills just inland from Perth, where rainfall is higher than on the coastal plain, and the geology and topography are suited to dam building. One of these dams is on the headwaters of the Wungong Creek. Water from dams is the cheapest option, but, partly due to a decline in rainfall over the past few decades, and an increasing human population, it represents a declining proportion of the total water supply. Like other water sources, catchments do need management.

Population Growth

At present, Perth has a population of over 1.6 million souls (Australian Bureau of Statistics 2008). Due largely to migration, this is expected to grow to 2.2 million by 2030 (WA Planning Commission 2000). Householders may be encouraged by education, or coerced by price, into using less water. This saving will, most likely, be more than cancelled out by the greater number of households, and an increase in water demands by more industries and services catering for that larger population. The Water Corporation has adopted a policy of promoting a diversity of water sources, including the use of recycled water (Water Corporation 2005).

Climate

Desalination of sea water is a rational response to a growing population, and to the prediction that the southern corner of Western Australia can expect a drier, hotter climate over the coming decades (Indian Ocean Climate Initiative 2002). However, nothing is perfect. Desalination is expensive, and energy hungry. Some oppose the use of fossil fuels for this purpose. The Water Corporation has tried to meet this objection by using wind energy, but there is world wide controversy about the reliability, economics, and aesthetics of wind turbines (e.g. Sawer 2008, Etherington 2009). I do not propose to enter that argument here, only to inform readers that conflict over wind turbines exists, and may influence future decisions on desalination plants.

Other aspects of predicted climate change are that forested catchments may yield less water, due partly to declining rainfall, and that some underground aquifers may dry up, or be polluted by seawater incursion. Again, there is public debate on whether we should draw any water from underground aquifers, given the possibility that this will dry up wetlands, which are important habitat for many native plants and animals. One possibility for increasing water supply is that of thinning forests in catchment areas to increase water yield (Water Corporation 2005a). Another is more frequent burning of catchments, to reduce the thick layer of leaves, sticks, and bark, which logic suggests must currently act as a sponge, intercepting, and retaining, the first rain of winter, so reducing flow into the streams. Reduction of the shrub layer, by more frequent burning, might have a similar effect, due to reduction in evapo-transpiration.

Forests and Water

There is an old perception of a connection between forests and water. Dr. Vazken Andréassian (2004) has traced this perception back at least to Pliny the Elder, in the first century BC. In France, the intimate connection between '*eaux et forêts'* was recognised before the French revolution in 1789, and is still recognised in the famous *École des Eaux et des Forêts* (now more grandiosely known as the *École Nationale du Génie Rural des Eaux et des Forêts*, or ENGREF, see www.agroparistech.fr). Andréassian recognises Bernardin de Saint Pierre (1737-1814) as one of the first to write on the subject in France, based on studies in Mauritius. In his writings, de Saint Pierre claimed that forested areas of Mauritius attracted more rain than open areas.

This claim was disputed, and two schools of thought arose, which Andréassian calls the 'engineers' and the 'foresters'. The sceptical 'engineers' called for hard evidence, but the 'foresters' of the day, wanting to extend their dominion, were more inclined to believe anecdote, and individual case studies. Interestingly, in the present debate over Wungong Catchment, it seems to me that it is the 'engineers and foresters' who tend to base their views on hard data, and the 'environmentalists' who may be swayed by a romantic, or aesthetic, commitment to conserving forests, and gaining political dominion over them. Although I have never heard current 'engineers and foresters' appeal, professionally, to romantic notions, I have heard 'environmentalists' appeal to science. I hope I have already made it plain that I do not think that romantic notions, and aesthetics, should always be ignored, in favour of 'hard data'. A balance is needed.

In any event, the eventual outcome of the debate, in France, and other parts of the world, was various 'paired catchment' studies. This approach is the workhorse of present forest hydrology (Hewlett 1971). In these studies, two similar catchments are initially monitored for comparison, and then a treatment, such as fire, logging, or clearing, is applied to one. The difference in streamflow response is observed and recorded.

Yet there are problems. Most such studies are relatively small, and of short duration, due to practical matters. It is laborious and expensive to manipulate and study even a small catchment, of, say, a few square kilometres, over a few years. Further, although two catchments may be superficially similar, there can be large hidden differences of soil, geology, and hydro-geology, which confuse the results. Also, rainfall and evaporation vary from year to year. What is true in a hot, dry year, may not be true in a cool, wet year, and vice versa. A run of dry, or wet, years may have a lag effect on stream flow for several years after that dry or wet period has ended. There has been a call for larger, longer running catchment trials, to overcome these variations, and to thereby improve understanding and prediction (US National Academy of Sciences 2008). In a useful review of paired catchment studies (Brown *et al.* 2004) it has been pointed out that there are four kinds of experiment. Some involve afforestation, some deforestation, some regrowth, and some forest conversion. They can give different results, for example deforestation is quicker, and can reach equilibrium sooner, than afforestation. Due to the thirst of young regrowth, experiments involving deforestation may initially underestimate the eventual water yield of mature forest.

The Water Corporation of Western Australia proposed, in 2005, that thinning the *jarrah* forest in Wungong Catchment would increase runoff into the dam, and restore something like the widely spaced, mature forest which existed before European settlement and logging (Water Corporation 2005a). Picking our way through the unnecessary confusion caused by political renaming of government departments, we find that this follows the lead of an earlier report by the then Water Authority of Western Australia (1987).

This proposed thinning is opposed by some local environmentalists, who seem to believe that the current stocking of many small trees is the 'natural' state of the forest in the catchment (Schultz 2009). As described in Chapter 3 (About Wungong Catchment), the evidence from old tree stumps, and other historical descriptions and photographs, is that the previous forest had much bigger trees, at much wider spacings.

The Effect of Forest Thinning and Logging on Water Yield

In a review (Bosch and Hewlett 1982), the first paired catchment experiment was identified as that at Wagon Wheel Gap in Colorado, USA, in 1909. So we now have over a century of data gathering and analysis, in different parts of the world. This section will examine results from the USA, South Africa, and Australia, which seem to have similar problems with supplying water for growing urban populations.

Although catchments vary in their responses, there is a general tendency for thinning to increase stream flow. This occurs through a reduction in leaf area, so reducing evapo-transpiration. This increase in stream flow only lasts until the leaf area regrows, which takes various periods, depending on tree species, climate, and soil. As one would logically expect, an increase in forest density, or afforestation of a previously treeless area, consistently decreases stream flow, due to increased evapo-transpiration.

Although the magnitude of runoff changes is difficult to predict for individual catchments, a hydrologist (Douglass 1983) reached the startling conclusion that if all the mature timber in the eastern United States were harvested simultaneously, the extra water yield would equal half the annual flow of the Mississippi River. He quickly pointed out that even if such harvesting were achievable, the disadvantages would outweigh the advantages, but it does vividly illustrate the hydrological potency of changes in forest area, and therefore in evapotranspiration.

The fact that trees are thirsty water users is well demonstrated by a paired catchment study in South Africa, where trees were planted in four widely separated areas which were previously treeless (Smith and Scott 1992). Results varied from place to place, but overall, the growing trees significantly reduced streamflow, with eucalypts doing this sooner than pines. Eucalypts are well known for their thirsty transpiration, which probably keeps them cool (Pryor 1976). A study of water use by alien species in South Africa (Le Maitre *et al.* 2002) named *Acacia* and *Eucalyptus* as significant water users. Another study (Blignant *et al.* 2007) gave an economic analysis of the costs and benefits of increasing water supply by removing such alien species from catchments. It was found that the benefits exceeded the costs.

The thirst of eucalypts is not usually a problem in large parts of Australia, where deep rooted trees can tap into abundant underground water. It is a problem in lands where groundwater is scanty, due to geology, as in most of South Africa (Blignant *et al.* 2007). It can be a problem, for humans in Australia, when scrub and eucalypts thicken up, perhaps due to a decline in fire frequency, and the water table drops to a point where creeks cease to flow and wells dry up. This may be the case in Wungong Catchment, but research continues (Water and Rivers Commission 1997, Water Corporation of WA 2005a).

Water Yield from the *Jarrah* Forest

The issue of water yield from, and evapo-transpiration by, the *jarrah* forest of Western Australia has been studied over the past few decades (e.g. Batini *et al.* 1980, Greenwood *et al.* 1985, Stoneman 1993, Stoneman *et al.* 1996). The general principles determined by earlier work in the United States and South Africa (Bosch and Hewlett 1982) have been found to apply in south-western Australia. Broadly speaking, thinning a forest leads to an increase in water yield as stream flow.

An early paper (Doley 1967) confirmed that *jarrah,* like other eucalypts transpires a great deal of water in summer (Pryor 1976). We may logically expect that removal of some *jarrah* from a catchment will have a noticeable effect on hydrology. This is confirmed by a number of studies.

In a small catchment, south of Wungong, the effects of a two-thirds thinning of *jarrah* forest were tested (Stoneman 1993). Over the following nine years, streamflow, as a percentage of rainfall, increased more than fifteen-fold, from 0.5%, to 7.6%. This was despite there being below average rain during that period. In addition, streamflow duration increased, and the water table rose by 8 metres in a midslope borehole, and by 4 metres in the valley. The study ended, possibly due to lack of funding, but there was no sign of equilibrium, so the author considered further increases to be likely.

Another study (Ruprecht and Stoneman 1993) showed that, in a *jarrah* forest catchment, the effects of thinning on streamflow lasted 12-15 years. The authors cautioned against facile extrapolation, since, as already discussed, apparently similar catchments can vary greatly in response to thinning. Nevertheless, they reached a general conclusion, based on figures from more than twenty catchments (including eight controls) that thinning *jarrah* forest consistently leads to increased streamflow, until the forest canopy is restored by regrowth. They also found that water tables rose after thinning, in one catchment by 15 metres in the valley, and 20-25 metres under the lower slopes, over a period of 13 years. Less rain was needed to start streams flowing in thinned catchments, than in unthinned controls.

While not in the same league as the Mississippi River, these increases in water yield are certainly worth considering in the thirsty Perth region of Western Australia. For Wungong Catchment in particular, the authors (Ruprecht and Stoneman 1993) estimated that forest thinning would increase streamflow from 15% of annual rainfall, to 21%. They cautioned that, after thinning, young regrowth forest may, for a while, reduce streamflow, due to increased evapo-transpiration. There may be ways of avoiding, or at least mitigating this reduction. One possibility is to replace part of the forest by grass patches.

Forest, Grass and Water Yield

A study in the United States suggested that there can be benefits to both water supply and animal habitat, by partly replacing forest or woodland with grasses (Lyons *et al.*

2000). The authors suggested that, in some cases, grassy cover on stream banks may offer hydrological advantages over trees. There can be less erosion, and grass offers better water filtration. In addition, a mixture of riparian grass and clumps of trees would offer a better diversity of both plant and animal habitat. They quote historical evidence that some smaller streams in North America, now fully wooded, formerly had grassy banks, sometimes with clumps of trees. This was possibly due to patch burning by Indians, and grazing by wild animals. Although not mentioned in their paper, beavers (*Castor canadensis*), where present, would also have removed trees along streams, so allowing grass and forbs to grow in cleared patches (Kay 1994).

In South Africa, some of the best yielding catchments have grassy stream banks (Scott 1993). After fire, the grass regrows quickly, and acts as a sediment trap, so reducing, or even eliminating, erosion. One of the commonest grasses in South African catchments is the tussock grass *Themeda triandra*, which is maintained by burning at two to three year intervals. The same species of grass grows in Australia, where it is known as kangaroo grass. Interestingly, it also grows all around the Indian Ocean, including Papua-New Guinea, Indonesia, Malaysia, Thailand, Sri Lanka, India, Pakistan, and East Africa. It has been suggested that this distribution is due to long past human migration and burning (Coupland 1993).

The maintenance of grassy stream banks by mowing, burning, grazing or herbicides may be seen as a disadvantage by present day catchment managers, but there is historical evidence, from both south-eastern and south-western Australia, of grassy riparian areas being maintained, in the early days of European exploration and settlement, by Aboriginal burning.

As an example, the explorer Ludwig Leichhardt, in eastern Australia, reported that 'The natives seem to have burnt the grass systematically along every water-course and around every waterhole in order to have them surrounded with young grass as soon as the rain sets in … Long strips of lately burnt grass were frequently observed, extending for many miles along the creeks' (Leichhardt 1847, quoted in Hallam 1975, p. 75).

Since Aborigines relied, for their very lives, upon creeks, soaks, and wells, they would surely have noticed any differences in water quantity and quality connected with burning, or not burning. It is reasonable to assume that, being present for thousands of years, they made the rational choice.

In south-western Australia there are many mentions of grass associated with wells and creeks (Hallam 1975). For example, in August 1846, 'At the edge of the flat found a native well with good water and a patch of grass around it...' (Gregory and Gregory 1884). Also, Thomas Bannister, on Boxing Day 1831, was near the Williams River, to the south of Wungong Catchment. He recorded in his journal that 'The land on the banks of the river is good dark loam with a considerable quantity of grass to the summit of the hills...' (Burton Jackson 1993). Drawing on local knowledge, the same author states that 'Kangaroo grass was prolific in the Williams River area in the 1800s.'

One of the state government's management aims in Wungong Catchment is to maintain native biodiversity. Where species have been lost, it would be worthwhile to try to re-introduce them. During my foot survey (Chapter 3 About Wungong Catchment) I saw no kangaroo grass, but I have seen it in other parts of the *jarrah* forest, for example near an old railway track in John Forrest National Park, which was regularly burnt until the line was closed in 1961. Since then, the park rangers have burnt it from time to time, trying to get rid of what they think is the invasive weed called 'wild oats' (*Avena fatua)*, to which it has some resemblance. In fact, the burning stimulates the kangaroo grass tussocks.

Kangaroo grass can tolerate a range of soils (Cole and Lunt 2005), but in south-western Australia it tends to grow on sand over clay, lower in the landscape, often on creek banks. It needs burning every 2-4 years to maintain it. There is ample evidence, from both Australia and other countries, that *Themeda triandra* is promoted by burning when dormant, but decreases when

Figure 7.1: Kangaroo grass (*Themeda triandra*).

burnt in the growing season, or not burnt at all (Booysen and Tainton 1984, Lunt 1995). Without fire, it eventually smothers under its own dead thatch. There are patches near my home, in the Canning River valley, only a few kilometres from Wungong Catchment.

As a member of my local Volunteer Bushfire Brigade, I have taken part in deliberate burning of some of these patches. Cured kangaroo grass burns readily, with a loud crackling. I can well imagine that *Nyoongars* would have enjoyed burning it, and would have done so as often as possible. It seems likely to me that this attractive native grass, and others such as wallaby grass (*Danthonia pallida*) and bandicoot grass (*Danthonia bipartita*), may have formerly been present along some creeks in Wungong Catchment, but have disappeared due to lack of regular burning (Paterson 1992).

It would be worthwhile to search the catchment for potential kangaroo grass habitat, and, if such places are found, try to restore them. Apart from its well known attraction for grazing kangaroos, the tussocks give refuge to small mammals. The establishment of patches, or strips, of native grasses along some creeks in Wungong Catchment would provide a satisfying link between native animal conservation, fire as a management tool, decreased erosion, and improved water quality and yield. Efforts at kangaroo grass restoration have already been made in south-eastern Australia (Cole and Lunt 2005).

Effect of Bushfire on Water Yield

As with their studies on trees and water yield, South African workers have offered some clear evidence on fire and water yield. In some South African mountain catchments, it was found that wildfire in eucalypt and pine plantations increased subsequent storm waterflow two or three-fold (Scott 1993). This was accompanied by soil loss. Part of this extra runoff was due to hot fires making soil water-repellent, particularly under eucalypts.

Although Wungong Catchment is not mountainous, it does contain some steep country, eucalypt forest, and soils which are likely to become water-repellent after burning. Catchment management by fire is common in South Africa, and where plantations were deliberately burnt in mild conditions, there was a moderate increase in streamflow under pines (+12%), but not under eucalypts. Other catchments, covered in the native *fynbos* (heath), showed no change in stormflow, even after wildfire, but a moderate increase (+16%) in total annual flow. This was attributed to decreased evapo-transpiration. The author (Scott 1993) emphasized that the effects of fire on streamflow are complicated, involving soil, climate and vegetation. Native grasses, germinating quickly after fire, were mentioned as a benefit, protecting soil from erosion. One of these grasses was *Themeda triandra.*

In Australia there have been several studies of the effects of severe, uncontrolled bushfire on streamflow in Victoria and New South Wales (Brown 1972, Langford 1976, Lane *et al.* 2006). Summarizing the results, we may conclude that, in those parts of Australia, severe bushfire can definitely cause increases in streamflow, and increases of up to ten fold in erosion and sediment load. This effect lasts for up to five years after the fire, although this period may be less where vegetation regrows rapidly. The rate of regrowth depends on the severity of the fire, and, of course, on climate, soil depth, and soil fertility. In one tall Victorian forest type (*Eucalyptus regnans*) the initial increase in streamflow was followed by a decrease, due to increased evapo-transpiration by the regrowing tall forest (Lane *et al*. 2006). Such tall forest regeneration would only occur after a severe fire which killed the mature trees. Mild, regular, deliberate burning would not kill mature trees.

Conclusions

Although *jarrah* is well adapted to fire, fire does act as a thinning agent (Wallace 1966). When fires are mild, only seedlings are killed. Severe fires, in heavy litter, can kill many old veteran trees, which will take centuries to replace. A recent such bushfire, in long unburnt (15-20 years) *jarrah* forest at Mt. Cooke, a few kilometres from Wungong Catchment, had flames 10-20 metres high. It burnt an estimated 5.5 million trees back to a stump, and killed outright an estimated 1.6 million veteran trees. In the hottest areas, 50% of trees were killed, some of them over 200 years old (Burrows 2005). It will obviously take centuries to replace these losses.

Such a holocaust in Wungong Catchment would have a severe effect on hydrology. Immediately after the fire, creek beds would be full of ash and charcoal. The first heavy rain would flash flood, and wash ash into the dam, together with silt and clay from soil erosion. The putrid corpses of any animals killed, but not completely cremated, by the fire would also pollute the streams. Mature forest would be killed, and its gradual regrowth would most probably lead to an eventual, and long lasting, decline in streamflow. There is an obvious risk to both life and property in the nearby settlements of Jarrahdale and Bedfordale, and to the catchment rangers, their families, and homes.

History suggests that all these adverse consequences could be avoided by intelligent and effective bushfire management, including regular reduction of fuel by mild mosaic burning. Native grass restoration along some creek banks may have a constructive part to play, both in hydrology, and nature conservation. Regular burning of such grass patches would help to prevent broad fire fronts developing; would give catchment rangers valuable training; and would enhance their confidence in managing bushfire.

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Chapter 10

All the World's a Stage

A SOFT SYSTEMS APPROACH TO BUSHFIRE

'What we really need are concepts that put nature and people in the same picture. We need an ecological framework that acknowledges the central role played by Homo sapiens.'
Tim Low, The New Nature, 2002.

Preamble

Since the advent of computers, mathematical modeling has become very popular amongst scientists. Using the metaphor proposed in Chapter 2 (Dodging Disciplines), it can be regarded as a way of building causeways over the swamp of proto-knowledge.

Today, the news media may give some people the impression that models are always arcane and mysterious, created by a high priesthood of scientists, supernaturally skilled in mathematics and computing. Yet verbal models have long been used, by non-scientists, to clarify complex matters. For example, in the Bible it is noted that Jesus used parables, which are essentially metaphoric verbal models, and can be very vivid. What could be more striking than the mental picture of a camel trying to pass through the eye of a needle?

In Islam, Sufi mystics have long used metaphors to explain their ideas, and challenge the minds of beginners (Shah 1964). One such is the story of a tiny ant, struggling through the pile of a richly patterned rug. From its viewpoint, the ant cannot see the rich pattern, just a frustrating jungle of coloured fibres. If the ant were lifted to a vantage point well above the rug, it might then see the pattern. Some use the metaphor of an 'invisible elephant' to describe the situation where we cannot see a very large factor in a system.

The eastern metaphorical approach appeared in Europe in the fables of Aesop (Perry 1965) and La Fontaine (Haddad 1984). More recently, a farm and its animals have been used as a metaphor for political chicanery (Orwell 1970). In formal western science, the value of analogues and metaphors as models was skilfully pointed out some decades ago (Leatherdale 1974). Soft Systems Methodology (SSM) uses both pictures and metaphors to explore, and understand, complex problems involving both nature and society (Checkland 1981, Checkland and Scholes 1999).

William Shakespeare, in his play 'As You Like It', made one of the characters say 'All the world's a stage, and all the men and women in it players …' (Shakespeare 1623). Nearly a century before, a renowned Flemish scholar wrote 'Wherever I turn my eyes, I see all things changed, I stand before another stage and I behold a different play, nay, even a different world.' (Erasmus 1529, in Gilmore 1963). Whether we credit Shakespeare or Erasmus, clearly both appreciated the power of a good metaphor. A play is a good metaphor for the world. A theatrical metaphor may be useful in understanding the particular problematical situation surrounding the management of bushfire in Wungong Catchment, and in placing a range of cross-disciplinary information into an organised context. Within such a framework, other models, of different kinds, can be nested.

Holistic Thinking

Holistic thinking is not easy, and perhaps that is why so many people, especially those with scientific training, prefer the analytic, or reductionist approach. Analysis is certainly useful, but unfortunately a pile of petals is not a rose, and a pile of cogs is not a clock. In breaking systems down for study, we can lose essential properties of the whole. In addition to analysis, it is helpful to view a whole system from as many perspectives as possible, without breaking it down. Holism and reductionism are complementary, not mutually exclusive.

One attempt at systematic holistic thinking is General System Theory (von Bertalanffy 1968, 1981, Flood and Carson 1988). However, after a promising start, this seems to have foundered (Checkland and Scholes 1999). The reason may be that the real world is not entirely amenable to logical and explicit 'hard' modeling.

For example, the 'logical positivists' tried, and failed, to make philosophy an entirely symbolic subset of mathematics in the 1930s (Carnap 1939). A contrary view can be argued, that mathematics is a branch of philosophy, in particular that branch of philosophy known as logic. All mathematics is logic, and hence it is philosophy. Not all philosophy is mathematics.

As another example, the 'behaviourist' school of psychology (Skinner 1974) has come under strong attack by 'humanists' (Frick 1971, Rogers 1980, Maslow 1999). It seems there is more to philosophy than just symbolic logic, and more to psychology than just controlled experiments and statistical models ('rats and stats'), useful as those approaches may be for some matters.

To complicate matters still further, in ecology, problems rarely come singly, but as connected webs, in which the seeming solution of one problem may exacerbate another, or create a new one. This is not a new idea. In 1516, Sir Thomas More said that ' … by applying a remedy to one sore, you will provoke another …' (Wasson 2003, in Cary *et al.* 2003). It could be argued, of course, that Sir Thomas was merely making a bald medical statement on contagion. Knowing something of the man and his mind, we may suspect a lurking metaphor.

There are rather obvious cases from industrial and commercial history, where solving an economic problem created, or exacerbated, social and ecological problems. The Industrial Revolution in Britain brought some economic benefits, but social, economic, and ecological evils too. Friedrich Engels (1844) commented on these, in his visit to England as a young man. A native Englishman had already referred to London as the 'great wen' (Cobbett 1830), and the application of a similar economic remedy elsewhere in England, and later in the world, has created many similar urban 'wens', or festering social and ecological ulcers. Current debates about climate vagaries seem to fall in the same category, where social, economic, and ecological interests are sometimes in direct conflict.

Another aspect of holism is that proposed by the French physicist Pierre Duhem (1861-1916) in the early years of the twentieth century, and extended more recently by the philosophers Willard Quine (1908-2000), Imré Lakatos (1922-1974), and Paul Feyerabend (1924-1994). In the sometimes obscure jargon used by philosophers, it has been called 'confirmation holism'.

To recapitulate in very broad terms, this proposes that human knowledge does not occur as isolated facts, but rather as connected webs. This implies that a single hypothesis cannot always be tested in isolation. It is sometimes necessary to consider other, contingent hypotheses. This idea has been called the Duhem Thesis, or the Quine-Duhem Thesis, and is relevant to cross-disciplinary studies such as geography and ecology, where hypotheses are often contingent. The concept creates difficulties for the widely accepted hypothetico-inductive system (Popper 1934, 1959), and this was accepted by that concept's author (Popper 1963).

Popper's approach may only be applicable to a subset of human knowledge, which some may choose to label 'hard science'. Remembering that Wittgenstein (2001) proposed the term 'word games', we should beware of the rhetorical properties of the word 'hard'. Some may interpret this as meaning more difficult, and hence intellectually superior. Yet some 'soft science' may, in fact, be just as difficult, or even more so, as recognized by an eminent natural scientist (Wilson 1998, see inset).

> '*Everyone knows that the social sciences are hypercomplex. They are inherently far more difficult than physics and chemistry, and as a result they, not physics and chemistry, should be called the hard sciences.*'
>
> Edward O. Wilson,
> Consilience, 1998.

Soft Systems Methodology

Soft Systems Methodology (SSM) was developed by Peter Checkland and colleagues, at Lancaster University, in England (Checkland 1972, 1981, Checkland and Scholes 1999), to address complex systems, where 'hard models' may only be partially successful, or may even, when used naively, and in isolation, make the problem worse. As usual, a little history will help to understand this approach better.

In the First World War, a young English officer called Geoffrey Vickers won both the Victoria Cross and the *Croix de Guerre*. As a result of his trench fighting experience in

Flanders, he became very interested in improving organization and planning. After the war, he returned to university, and studied law. At the same time, he pondered the application of mathematics to organisational matters. His work contributed, during the Second World War, to the social science known as Operations Research, in which mathematical methods are used to obtain optimal social results. This has led to current research into network analysis (Hu 1969, Plane and McMillan 1971), which has much in common with the mathematical model of bushfire spread given in Chapter 7 (Does God Play Dice?). Yet Geoffrey Vickers, from his army experience, never forgot the importance of human factors such as loyalty, courage, and commitment (Vickers 1983), and realized that a logically perfect plan can fail if they are ignored. Towards the end of his life, he had contact with Peter Checkland, who further developed his ideas.

The SSM approach has been successfully applied, over the past thirty years, to many situations in industry and the public service. SSM is not necessarily the answer to all problems, but it can help. Peter Checkland compares SSM to the cavalry in nineteenth century European warfare. It lends tone to what might, otherwise, be a 'mere vulgar brawl'.

In SSM, it is recommended that those investigating complex problems first spend twenty minutes or so drawing a 'rich picture' of the situation, as they initially see it. In military terms, this might be called an initial 'appreciation'. Such 'rich pictures' are often child-like cartoons, and can be on scrap paper, since they are only a temporary step. As the study progresses, the 'rich picture' can, and should, be redrawn, a number of times, reflecting a growing understanding of the problem.

The first 'rich picture' is used to identify the elements of the acronym CATWOE, standing for client, actors, transformation required, *weltanschauung*, owners, and environmental constraints.

The meanings of some of these terms may not be immediately clear, so we can use the example of a chocolate factory, drawn from a well known children's book (Dahl 1964). The factory is owned by 'Willie Wonka', and the workers are called 'Oompa-loompas'. The profitability of the factory is determined by the chocolate buying public. Imagine that the public stops buying chocolate, and the factory starts to lose money. A consultant is called in to address the matter, and transform loss into profit. The acronym helps us to identify the six main components of the situation as:

Client – Willy Wonka, the factory owner.

Actors – the Oompa-loompas.

Transformation sought – from loss to profit.

***W**eltanschauung* – the 'world view' or 'mind-set' of each participant.

Owners – the public, who may, or may not, buy chocolate.

Environmental constraints – matters such as funds available, factory size, cocoa bean and sugar supply, etc.

The next step in SSM is to write 'root definitions', or more detailed descriptions, of the six components, and how they may interact. Again, this is only a first attempt, and can be changed later, as things become clearer. The sequence is recursive and adaptive.

The six elements are then used to sketch out a simple framework model, showing how they connect, and suggesting sites for more intensive modelling, perhaps including the 'hard' variety. As in previous stages, this initial framework model can also be re-visited, and changed, as understanding grows. It is drawn informally, avoiding hard boxes and straight arrows, which may create a premature illusion of hard certainty. This style has been vividly referred to as 'fried eggs and string' (Checkland and Scholes 1999). Useful metaphors pop up everywhere.

The above six element approach has been found suitable in industrial situations, but an environmental matter, such as fire management in Wungong Catchment, may sit more comfortably within a slightly modified approach.

Changing the acronym

The authors of SSM recommend that, within the general methodology, individual methods be flexible and adaptive. Different situations may call for different approaches.

With that in mind, we may remember William Shakespeare's metaphor comparing the world with a stage. Can scenery, actors, director, audience etc. be used as metaphors for the elements of the Wungong Catchment situation?

Using the different acronym SAPDATA, we can identify seven main elements involved with fire management in the Wungong Catchment. These are:

Script – the fire management plan.

Author(s) – of the fire management plan, with a certain mind-set.

Play – the implementation of the fire management plan.

Director – the West Australian Government, represented by ministers and senior bureaucrats, with certain mind-sets.

Actors – the public servants or contractors who will implement the fire management plan, and their mind-sets.

Theatre – the Wungong Catchment, with its landscape, vegetation, animals, climate, soils, creeks, human settlements etc.

Audience – the West Australian community, with a great range of mind-sets.

It will be seen that the *weltanschauung* of CATWOE has been rendered as the English term 'mind-set', and is incorporated into the relevant human elements, rather than separated out. Although the word *weltanschauung* is used in philosophy, and is given in the Shorter Oxford English Dictionary (Trumble and Stevenson 2002) as a loan word, it is rather long, and unfamiliar to many. The term 'mind-set' may come more easily to the English speaking tongue, and is only half as long. The next step is to create the root-definitions of these seven elements.

Root Definitions

The **script**, or fire management plan, will be partly based on information from the general published literature on catchments and bushfire, and partly on the more specific findings of cross-disciplinary research carried out in the Wungong Catchment over the past few years, including this thesis.

The **authors** of the fire management plan will be the responsible officers at the Water Corporation, in co-operation with relevant bushfire experts from the Department of Environment and Conservation, and elsewhere. These authors should recognize that they have their own mind-sets, which may be more academic, or more practical, and may vary due to different employment, educational, and cultural backgrounds. Public service career paths will be a significant factor too. Engineers, foresters, and biologists do not necessarily speak the same language, or see problems in the same light.

The fire management **plan** should be practical, and based on a sound appreciation of the social, ecological, and economic implications. Whilst taking account of the differing mind-sets of politicians, public servants, private contractors, and the authors themselves, it should, importantly, be aware of the highly varied mind-sets of the audience, the voters of Western Australia. This means that it should not be unduly influenced by any vociferous minority, with views on fire management which are contrary to the wider public self-interest. The difference between self-interest and folly has been well stated as 'self-interest is whatever conduces to the welfare or advantage of the body being governed; folly is a policy that in these terms is counter-productive.' (Tuchman 1984)

The **director** of the enterprise is the West Australian government, represented by the various ministers for (*inter alia*) water, environment (DEC), and emergency services (FESA). They will consult with their senior public servants, and let them know the government's wishes, in line with what the government deems to be in the public interest. If they misjudge public opinion, they may be publicly embarrassed by adverse media publicity, and possibly removed from office at the next election.

Their political mind-sets may be different from those of the authors, although public servants, especially at senior levels, will need to be politically sensitive, or their career path may be in jeopardy. In the literal theatre, there is always an interesting interplay between the sensitivities of directors and actors, and this may be similar to that between politicians and public servants. A difference is that politicians, as well as directing, often also wish to appear in the spotlight.

The **actors** are the operational public servants, both managers and field staff, who will carry out the requirements of the fire management plan, using their own expertise and judgement. Lesser roles in fire management are played by local residents and recreationists. The occasional arsonist may sometimes play a starring role in the play. We must remember that some actors are intelligent and constructive, but others may have a tendency to squabble, or overact, or try to upstage each other. The present cast of actors has succeeded previous ones. The original principal actors, the *Nyoongar* people, managed fire in the catchment for millennia, their directors being their Elders. They are no longer much visible on stage, but their descendants are, I suspect, watching closely from the wings, as a distinctive, and knowledgeable, section of the audience.

The **theatre** is the Wungong Catchment itself. We may regard the natural landscape and its climate as the stage scenery. The landscape includes the landform, the forest, the animals, and human settlements. The climate has a large influence upon water flow and evaporation, and potential fire ignition by lightning. The scenery has been changed in the past by logging, mining, and dam building. It may be changing now, and into the future. This is similar to the idea of a well-known English pioneer ecologist, who wrote about changes to the 'furniture' (rocks, hollow trees, dead logs etc.) in Wytham Woods, near Oxford University (Elton 1946).

The **audience** is the public of Western Australia, and is the most complicated element of the framework model, since it includes disparate groups, with many mind-sets. Different parts of the audience may be supportive, neutral, or critical of the script and the play. Within the audience, the news media are present, and will spread news about the play. This news may, or may not, be accurate, or favourable. Journalists, editors, and television presenters may all have their own mind-sets. If a director decides to make changes in the play, then the actors will carry them out. Yet the director must consider the feelings, and capabilities, of the actors, and possible audience reaction to such changes. A director who loses audience support may be humiliated, or sacked. At the same time, the situation may be complicated by a minority of hecklers and rowdies in the audience, especially if they are well organised, and work together.

In trying to understand mind-sets, it is worth remembering the legal question '*cui bono?*', or 'to whose benefit?'. Even seemingly irrational, or disruptive, viewpoints or actions may make sense if we understand the sometimes covert benefits which are possible, or are believed to be possible.

Putting it Together

Figure 11.01 shows a 'rich picture' of some potential elements of bushfire management in Wungong Catchment. Building on that 'rich picture', we can now progress to a more sophisticated framework model showing the place of this thesis in the larger scheme of creating, and implementing, a fire management plan for Wungong Catchment. This move to a more sophisticated model is consistent with the recommendations of the originators of SSM. It must be both recursive and progressive, in other words, it is consistent with adaptive management.

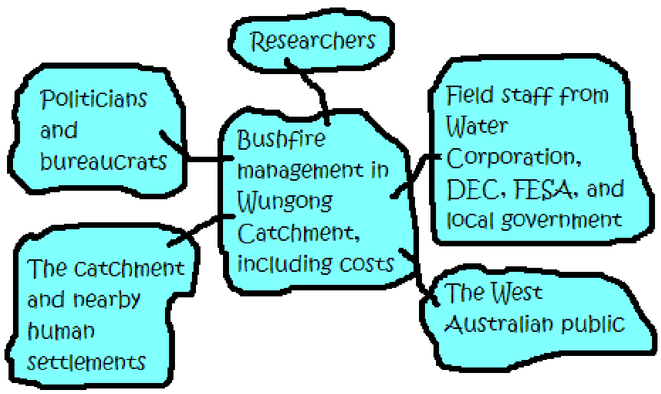

Figure 11.01: A *rich picture*.

The soft systems model in Figure 11.02 offers nesting sites for the natural, and social science of the 'theatre' (Chapter 3: About Wungong Catchment), and for a mathematical model of bushfire mosaics (Chapter 9: Does God Play Dice?). It can also accommodate hydrological information from the Water Corporation, and elsewhere (Chapter 7: Fire, Forest and Water). The 'script' can also draw on the fire history of the catchment, which has been derived from old fire marks on grasstree stems (Chapter 8: Better to Believe the Balga), and historical observations on bushfire in the *jarrah* forest (Chapter 6: Bushfire, Flogging, Measles and Foresters). The risk to the communities of Jarrahdale and Bedfordale can be plainly set out, and the predictable costs of an organized program of prescribed burning can be compared with a *laissez-faire* approach, with occasional disastrous fires, costing millions of dollars to fight. In other words, the humanities, natural sciences, and social sciences all have their roles to play.

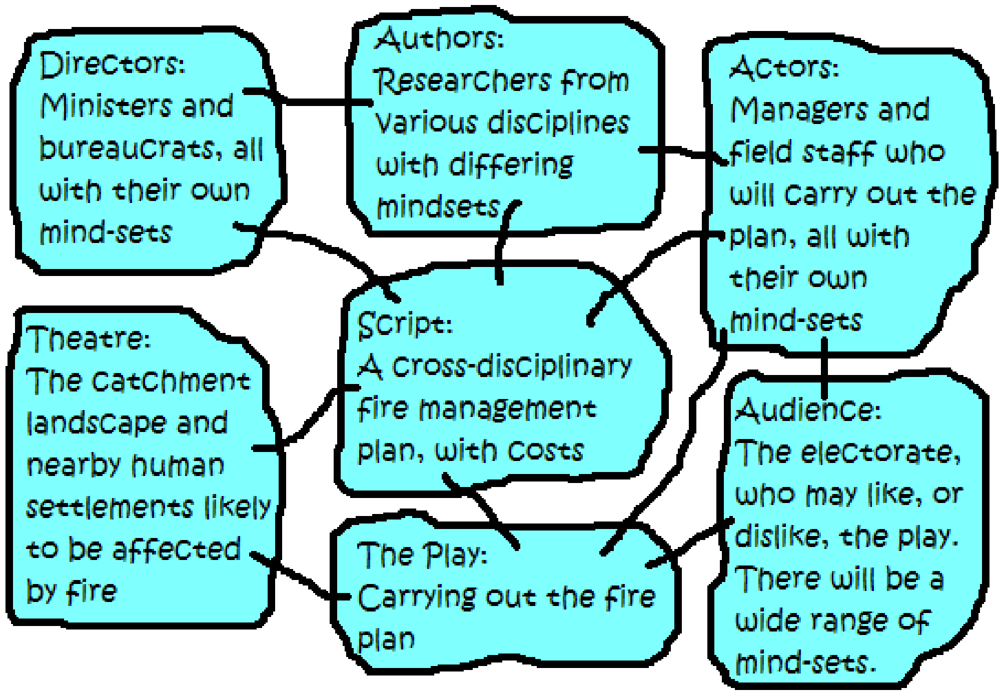

Figure 11.02: A provisional soft systems model for bushfire management in Wungong Catchment.

Conclusions

From his writing, Peter Checkland appears to be a careful and productive thinker. Soft Systems Methodology (1972, 1981) has much to offer, yet may be scorned by some who put all their faith in 'hard science', or by others who doubt its efficacy. Unfortunately, 'hard science' does not have a good track record in solving hyper-complex problems involving both nature, and human society. It may, on its own, be a rather simplistic view of the world. Geoffrey Vickers (1983) understood that. The soft systems approach seems, to me, to offer a richer mental landscape. It can accommodate natural science, and social science, yet it does not suffer from 'physics envy'. Humanities, such as history, are given full recognition, and opportunities occur for identifying consilience between the three streams of human knowledge.

In my view SSM is a valuable research tool, which can broaden and deepen our understanding of the world in general, and bushfire ecology in particular. It overtly recognizes different human mind-sets. In relation to the Wungong Catchment, it can help the Water Corporation of Western Australia to integrate information flowing from a cross-disciplinary research program, potentially subject to political influence, and open to criticisms by the news media, the public, and lobby groups. The simple models offered above can be further developed, in line with Peter Checkland's notion of ongoing adaptation.

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Chapter 11

Summing Up and Verdict

SOME OF THE EVIDENCE

'It is a capital mistake to theorize before you have all the evidence.'
Sir Arthur Conan Doyle, 1888

Preamble

Sir Arthur Conan Doyle's fictional sleuth, Sherlock Holmes, surely knew a thing or two about theorizing from evidence, but the trouble is that rarely, if ever, do we have all the evidence. We must do the best we can with a part, remembering Pierre Duhem's deep idea (1906) that hypotheses come in connected webs, not singly. In examining a single hypothesis, we must remember that its truth, or otherwise, may depend upon other hypotheses in the web, some of which may lie outside our understanding. A little knowledge can be a dangerous thing.

In scientific papers it is common to have a discussion, then a conclusion. However, this is not a scientific paper, but a wide ranging, cross-disciplinary thesis, grounded in humanities. This was discussed in an early chapter, together with the notion that ecology, and in particular landscape ecology, are not wholly scientific disciplines, and should not try to cramp their epistemology entirely into the methods of 'hard science'. They should avoid 'physics envy'.

With that in mind, perhaps jurisprudence has something to offer in improving our grasp of bushfire, its history, and its ecology. As in a court of law, we must carefully consider all the evidence available, recognizing that some may be missing. Apparently hard scientific evidence may be persuasive, but snippets of history may be equally telling, and can be an astringent cross-check on the validity of our thinking. Logic is central, but it may come in different forms. Science does not have a monopoly on logic, and it has been argued, early in the thesis, that mathematical logic, although used by the sciences, is not, in itself, a science, as Karl Popper defined that word. Another philosopher, R.G. Collingwood, has suggested that history has its own version of logic.

Fire of different kinds has clearly been a central factor in human history and evolution. Our ancestors used fire to hunt, keep warm, and for many other purposes. Today, most of us travel by courtesy of fire, harnessed for human benefit, whether under a car bonnet, or within an aircraft engine. It has been suggested that thinking about fire, whether landscape, domestic, or industrial, deserves a more central place in schools and universities (Pyne 2001a). At present, it is very much on the academic fringe.

In this thesis I have tried to show the cross-disciplinary nature of the matter. In this chapter, following legal practice, I sum up the evidence on how we might use fire to manage a water catchment. Finally, I arrive at a verdict, which I hope will be helpful to ecologists, and those responsible for catchment and bushfire management.

In Chapter 1 (Mudpies, Hypotheses, and Structure) I stated the thesis (*sensu stricto* proposition), and its four hypotheses (p.5). In this chapter, I arrive at my own conclusions about the central thesis, and its hypotheses. Readers are invited to arrive at their own conclusions.

The Evidence from Geography and History

In Chapter 3 (About Wungong Catchment) there is a geographical description of the Wungong Catchment, with mentions of its historical use by *Nyoongar* people. It is broad-brush, as one might expect in landscape ecology. Finer, scientific details of hydrology, botany, and zoology, will emerge from the research program currently being conducted by the Water Corporation. A future discussion with *Nyoongar* Elders would be of great value. As an interim botanical observation, it seems that at least two iconic plants, *balga* and *djiridji*, have a strong relationship to bushfire, and to *Nyoongar* traditions.

Due to its inability to shed old leaves, *balga* rots in the prolonged absence of fire. It only flowers abundantly after a fire. *Djiridji* has a clear 3-4 year boost in frond growth and fruit production after bushfire, and declines in the prolonged absence of fire. It fixes nitrogen for only 3-4 years after fire, as do leguminous plants. There is evidence, from anthropology, that both *balga* and *djiridji*, and their interactions with bushfire, were of importance to *Nyoongar* people.

In Chapter 4 (The Other Side of the Hill), historical, and geographical, evidence shows that there is a world-wide pattern of past fire usage by hunter-gatherer ancestors, and by early pastoralists and farmers. Australia is not unique in this respect, although our current climate and vegetation make us one of the more fire prone parts of the world. The chapter introduces some of the present day political and economic conflict over human use of fire, such as the contest between 'toffs' and 'twitchers' in Britain, over who should control the use of fire as a management tool for grouse moors. The conflict over fire in Madagascar is examined, where Malagasy villagers have clashed with the 'received wisdom' of some ecologists and government officials on traditional burning practices. Landscape has long been shaped by humans, and assumptions on what is 'best', and what is 'natural' need to be carefully considered. 'Folk ecology' should not be lightly dismissed.

Chapter 5 (Bushfire, Flogging, Measles and Foresters) takes a close look at the history of bushfire in south-western Australia. It devotes attention to the strong historical evidence of traditional *Nyoongar* burning, at 2-4 year intervals, over most of the *jarrah* forest, at the time of European settlement, in the first half of the nineteenth century. This continued for some decades after that arrival, but was eventually suppressed by a combination of severe legal sanctions, and a decline in the *Nyoongar* population, due to introduced diseases, especially measles.

European settlers, imitating *Nyoongar* burning, freely continued to use frequent fire up to the time of the First World War, but, soon after, professional foresters, acting on inept advice from overseas, tried to suppress fire throughout the *jarrah*, and other, eucalypt forests. Their motive was to protect potential sawlogs from fire damage, but the resulting, unforeseen effect, was to increase the size and intensity of forest fires, and the difficulty of bushfire suppression.

In response to these uncontrollable fires, in the second half of the twentieth century, foresters tried to return to traditional 2-4 year burning, but found the work load too great, so simply doubled the period to 6-8 years, in the belief that this would prevent uncontrollable fires equally well. More recently, two foresters have suggested that 6-8 years is actually an ideal fire interval for *jarrah* forest, because it is double the juvenile period of nearly all the plants in that forest. They acknowledge that this convenient piece of arithmetic is only a 'rule of thumb', with insufficient evidence available on the dynamics of the *jarrah* forest soil seed bank to reach a rigorously scientific conclusion. We may wonder why nearly all the plants of the *jarrah* forest flower within 2-4 years after fire. Some light has already been shed on this by historical records of consistent 2-4 year burning in former days. Chapter 6 (Better to Believe the Balga) gives further, independent, evidence of 2-4 year burning in the *jarrah* forest. The consilience on frequent former burning, at 2-4 year intervals, is very strong.

For the past few decades, the use of deliberate burning as a forest management tool has been a matter of public controversy. Many have joined the debate, coming armed with varying degrees of expertise. Some would like to ban the use of fire in the forest. Others suggest fire intervals of fifty years or more. Others favour a return to something like the traditional burning by *Nyoongar* people, as far as we understand it, taking advantage of present day weather forecasting, communications, and machinery, including aircraft.

The Evidence from Archaeology

Chapter 6 (Better to Believe the *Balga*) describes a technique by which past bushfire frequencies, stretching back over two centuries, can be reconstructed from marks on the stems of old *balga* grasstrees. From its first publication, in 1996, this technique has been disputed by some who believe that, before European settlement, bushfire was rare, or non-existent, in the *jarrah* forest. Repeated surveys on hundreds of *balga*, throughout the *jarrah* forest, stubbornly refuse to comply with that belief. The conflict has appeared in several arenas, including letters to newspaper editors, the scientific literature, and evidence to a parliamentary committee. A recent, refereed paper has shown that some of the arguments against the *balga* technique, even though published in a refereed journal, do not hold water. We must avoid misleading evidence, no matter how apparently respectable its provenance.

The *balga* technique was used in Wungong Catchment, and showed, as in other parts of the *jarrah* forest, that bushfire occurred consistently every 2-4 years before the First World War, and in some places up to the 1930s. This matches well with similar evidence from *balga* in Monadnocks Conservation Park, just the other side of the Albany Highway. It also matches with statements from recognised experts on the *jarrah* forest, based on first-hand observations, from before the First World War up to as recently as the 1930s. It also matches with the views of a sizeable sample of older people, with experience in the bush between the two World Wars.

The Evidence from Mathematics

'Self-organisation' has been a subject of discussion in economics for several hundred years, and, more recently, in natural science. As in any management, there may be advantages in identifying, and working with, any self-organizing tendency which is apparent in bushfire.

Most models of bushfire behaviour use a statistical approach, trying to estimate the frequency of fire at a single, hypothetical point. In Chapter 7 (Does God Play Dice?), a different form of mathematics is used. Graph Theory offers some advantages in modeling the way in which fuel patches connect up in the long absence of fire, and can form dangerously flammable 'giant patches'.

The model can be used to track the progress of fuel accumulation, through time, within an area such Wungong Catchment. Iterations show that the only way to maintain a stable, innocuous, fire mosaic is by frequent burning. Due to the rate of fuel accumulation, this frequency is, for most of the *jarrah* forest landscape, at 2-4 year intervals. Such mild burning would protect relatively small fire refuges, which can remain unburnt for long intervals, and are habitat for that very small minority of *jarrah* forest plants which are sensitive to short fire intervals. The model shows why, if fire is excluded from the broadscale landscape matrix for long intervals, these refuges will be lost in an eventual intense fire, due to lightning, or arson.

Mathematics is again used, in Chapter 8 (Violins and Bidi Burning), to explore ways of restoring the advantages of frequent fire, to an area where those advantages have been lost, through long fire exclusion. Knot Theory, and the Four Colour Map Theorem, give some insights into mosaic formation, structure, and application.

The Evidence from Hydrology

In Chapter 9 (Fire, Forest and Water) evidence is presented of the links between bushfire, and both the quality, and quantity, of streamflow. With a growing population, and suggestions that the climate of south-western Australia may become drier and hotter over the next few decades, questions of water supply are clearly important. Bushfire is an element of the hydrological system, and *Nyoongar* people may have been aware of this, since they not only burnt the bush, but relied on creeks, springs, and wells for their water supply.

Paired catchment studies have a few problems, in that superficially similar catchments may differ greatly in concealed hydro-geology, but such studies both in Australia, and other countries, suggest a general tendency for fire, initially, to reduce leaf area, and so evapo-transpiration. This initial effect may be later reversed by an increase in evapo-transpiration as vegetation regrows. These changes in evapo-transpiration can have a marked affect on stream-flow. It seems probable that frequent, mild fires will have less extreme effects on streamflow than infrequent, intense fires.

In addition to, or in conjunction with, fire frequency, changing the vegetation may affect streamflow. It has been noted that grass patches have a beneficial role to play in catchment hydrology, by reducing evapo-transpiration, and reducing post-fire erosion, so enhancing water quality. Grass tussocks can also be good habitat for some small mammals. Some West Australian native grasses, notably kangaroo grass, need fire every 2-4 years in order to thrive.

Evidence on Charcoal

Anyone who has walked in the *jarrah* forest will have noticed the prevalence of charcoal, on the ground, on fallen logs, and on standing tree stems. *Balga* grasstrees are remarkable for their charcoal coated stems. It would be surprising if charcoal played no part in the *jarrah* forest ecosystem.

Some people, perhaps comparing with temperate forests in Europe or North America, dislike the low level of humus in the *jarrah* forest soils, blaming its absence on too frequent fire. One of these was Lieutenant Henry Bunbury, in the 1830s, who was used to the farming soils of England. Yet recent discoveries concerning 'biochar' suggest that the role of humus in temperate soils can be fulfilled by charcoal in warmer climates. It seems that eucalyptus trees flourish in soil that is low in humus, but high in ash and charcoal. People of European descent can sometimes be culturally deceived in their perceptions of other landscapes. This is probably true for someone of any cultural group, suddenly transplanted to a foreign landscape, shaped by other climates, soils, and past human economic and cultural imperatives.

Evidence on Social and Economic Matters

From the last sentence in the above section, it can be concluded that fire is not just a natural phenomenon, but involves, *inter alia*, social and economic aspects. Some sound evidence on this has come from a visiting US fire chief, Jerry Williams. There is a difference of *weltanschauung* between those who would like to prevent dangerous fires occurring, and those who would prefer, perhaps for budgetary and career reasons, to rely on massive attempts at suppression. This preference for the quasi-military approach to fire management may not be consciously held, but may, nevertheless, be a real factor in the way that professional fire fighting authorities approach bushfire, and present their case for bigger budgets in the political arena.

Avoiding Conflict over Bushfire Management

The state government needs to play a leading role in avoiding potential conflict between state government departments over bushfire policy. Such conflict can only be to the disadvantage of both nature and society. There may be merit in considering a Department of Water and Forests, similar to the French *Departement des Eaux et des Forêts*. South Africa has a similar department. There would be advantages in professional foresters and hydrologists working closely together to achieve the best outcome for the public of Western Australia. Field staff, such as catchment rangers, and forest rangers, given a common badge and uniform, and the right leadership, could work well together, having much in common.

A Verdict on Bushfire Management in Wungong Catchment

In conclusion, I offer a verdict of twelve beliefs about bushfire. These are derived from the evidence offered immediately above, and the fuller discussion within the body of the thesis.

These beliefs do not claim to be a 'gospel', but set out a clear position, which is open to further research and discussion. Following Peter Checkland's thinking, they can be the basis of an adaptive, cross-disciplinary, soft systems model. Humans, their emotions, and their belief systems, need to be included, and beg further research. More research, in both science and the humanities, can enrich the model, and correct any false beliefs.

Belief 1: Humans have deliberately lit bushfires, in the *jarrah* forest of Western Australia, probably for thousands of years.

Belief 2: In south-western Australia, roughly up to the first half of the twentieth century, the general frequency of bushfire, due to a combination of lightning and human activity, was as often as the vegetation and climate would allow. For *jarrah-marri* forest this minimum potential fire interval is every 2-4 years. This does not mean that every square metre was burnt that often.

Belief 3: Due to low fuel levels, such bushfires would have been generally mild and patchy, even in summer, with occasional flaring in patches missed by previous fires. This fire regime would have created a relatively fine-grained, stable, and self-organizing mosaic of patches with a range of vegetation age and structure, and many fire refuges, for both plants and animals. Such a diverse vegetation structure would have offered habitat for, and so conserved, a rich diversity of native plants and animals.

Belief 4: Over the past fifty years, due to lengthening intervals between bushfires, a stable, largely fine-grained, mosaic has been replaced by an unstable, coarse-grained mosaic, offering less diverse habitat for plants and animals. In an unstable mosaic, summer bushfires can become uncontrollable by, and a danger to, human beings and their property. Such bushfires destroy vital fire refuges, and also directly destroy large numbers of native animals, and old, mature trees, which will take centuries to replace. In a water catchment, uncontrollable fires can severely affect water supplies.

Belief 5: Experience in Australian catchments, and those in other fire-prone countries, has shown that fierce bushfires can, due to removal of trees and other vegetation, cause short term flash flooding after the next heavy rain. There can be a longer term decline in regular water yield as vegetation regrows. Mild mosaic burning may mitigate both problems, by frequent, light pruning of the vegetation, and reduction of heavy leaf litter.

Belief 6: Experience in Australia, and elsewhere, has show that flash flooding, soon after fierce bushfires, causes soil erosion, so affecting the quality of stream water by ash and silt pollution. Again, mild mosaic burning may mitigate the problem.

Belief 7: Restoration of fire-loving native grasses along creek banks should be investigated for a number of potential benefits, including less erosion, better water quantity and quality, and enhancement of native animal feeding and shelter opportunities. Maintaining these grass patches, by frequent fire, would be good fire training for catchment rangers, and give them confidence in their fire skills. Many catchment rangers have a keen interest in wildlife, and would find habitat restoration a stimulating challenge. Such work would be attractive to many young *Nyoongar* people, and satisfying employment, in line with their ancestors' practices, would be a social benefit. The human factor must always be considered.

Belief 8: Under current climatic conditions, the best management option for Wungong Catchment, for reasons of ecology, hydrology, fire control, and human safety, is a return to former mild, patchy burning as often as the landscape matrix of the *jarrah* forest will carry a mild bushfire, which is every 2-4 years. Some suggestions have been offered on how this can be safely done, using ideas from geometry.

The suggested approaches, although not yet field tested, are worth such testing. They could have a number of benefits, including training opportunities for fire crews, and the opportunity for Volunteer Bushfire Brigades to charge for their services, so relieving the financial burden on local governments. Fine mosaic burning would improve human safety, especially along recreational walk-tracks, and bicycle-tracks. It would help with nature conservation, and even the aesthetics of the bush, with more wildflowers, and the 'ever verdant' appearance described by Baron Von Mueller in 1879. If there is public opposition to such mosaic burning, then evidence of its benefits could be provided by highly visible demonstration mosaics, established, for example along the recreational tracks and around picnic spots within the catchment.

Belief 9: If, as suggested by some climate models, the climate of south-western Australia becomes inexorably hotter and drier, then the potential for fierce bushfires will increase, water supply will decrease, and the need for pre-emptive fire control by mild, patchy, mosaic burning will be even more urgent.

Belief 10: Regular, mild fires can sequester very large volumes of charcoal in the soil, on its surface, and on the stems of trees and shrubs, so reducing the accumulation of carbon in the atmosphere, if this is, in fact, a problem. There is evidence that charcoal can improve soil fertility and moisture holding capacity, filling the role played by humus in more temperate climates. Regular burning will create more charcoal than fire exclusion.

Belief 11: This thesis has not closely addressed the cost differential between a pre-emptive approach to bushfire management, and the opposite policy of waiting for bushfires to occur, then trying to fight them. Accurate figures are difficult to obtain, are complex, and could be the subject of another whole thesis.

Evidence from an experienced fire manager from the United States suggests that an ounce of prevention is worth a pound of cure. We know that big bushfires can cost tens of millions of dollars to fight. Preliminary reports from the present Royal Commission into the 2009 bushfires in Victoria suggest that the pre-emptive approach, of mild, prescribed fire, although not cheap, would be cheaper than the massive effort needed to fight mega-fires (www.royalcommission.vic.gov.au).

Whilst on money matters, insurance companies may be interested in the potential of frequent, pre-emptive burning to reduce future claims and premiums. State and local governments should choose to brave unpopularity, in some parts of the electorate, in order to avoid the possibility of future class actions over loss of life and property due to preventable mega-fires.

Belief 12: This set of beliefs offers a basis for adaptive bushfire management in Wungong Catchment. It is also a framework for a progressive research program into bushfire management. It is derived from a rational, cross-disciplinary analysis, and addresses ecological, social, and economic aspects. It can probably be extended to the whole *jarrah* forest of south-western Australia. It offers ideas on fire management relevant to other parts of Australia, and other fire-prone lands.

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Appendix A: The full text of nine letters about bushfire, written in 1846

The first letter is from the newly appointed Governor of Western Australia, Colonel Andrew Clarke. The settlers at York had complained that their crops and grazing were being burnt by the *Nyoongars*. Governor Clarke sought advice from his magistrates, and some other senior officials.

Circular 17 February 1846

Residents and Protectors of Natives

Sir

His Excellency the Governor having heard with much regret of the serious damage and loss of property which the settlers, especially in the York District and the past season, have sustained by fires made either or otherwise by the natives, is very desirous of adopting some measure which would, if it did not entirely put a stop to these fires, at all events have the effect of making them less frequent.

With this view His Excellency wishes you to consider the subject and offer such suggestions thereupon as your experience may dictate.

I have the honor to be … (Signature missing on microfilm, but Peter Broun was Secretary at that time.)

Revett Henry Bland, Protector of Natives at York, was the first to reply. He blamed the settlers themselves for some of the fires, but pointed out that it was *Nyoongar* custom to burn in summer, and that this burning had a number of benefits. He could find no evidence of malicious intent.

York March 2nd 1846

Sir

I have the honor to acknowledge receipt of your circular of 17th February on the subject of Bush Fires, and wishing any suggestions with a view to their prevention for the future.

I fear His Excellency will find it a very difficult subject to deal with, and impossible wholly to prevent, it has always been the custom of the Natives to fire the country during the summer season for a variety of purposes, first to assist them in hunting, it also clears the country of underwood, which if not occasionally burnt, would become an impenetrable jungle, infested with snakes and reptiles.

The principal fires in this District that occurred during the earlier part of the present season, originated either from the Settlers themselves, or from the Natives setting fire to hollow trees to dislodge the opossum. December and January being their principal season for hunting them, they have never been accustomed, and are unable in most cases if they wished, to put the fires out, and when the tree falls, the grass ignites and is so extremely dry that the fire will run for many miles, until either a road or some bare spot checks its progress. The principal fire at the Toodyay where three fields of wheat were burnt, originated from a Settler burning a tree near his house.

I consider it an advantage that portions of the country should be burnt every year, provided it is not done till late in the summer, the feed is always better where the dead grass has been previously burnt off.

When I first settled in the District, and got acquainted with the Natives, finding myself much inconvenienced by the bush fires, I commenced the practice of giving them presents of flour and clothing when the first rains set in, provided they had not fired the country during the summer, I found this plan succeed [*sic*] *to a certain extent, and it was followed up by the Government, who through me used to give them presents until two or three years since, when it was discontinued I believe for want of funds.*

I have made every enquiry in the District both personally, and through the Police, as to the origin of the fires this season, and do not think that in any one instance they have originated through any malicious intent, the evil however requires some remedy, as the law at present only applies to cases of burning crops of corn, stacks, buildings etc.

It would be hard to debar the Native the food Providence has placed at his disposal, by preventing the use of Fire, without which he cannot procure it. I have no doubt a great deal may be done by rewarding them with Flour and Clothing, to induce them to give up this practice until later in the season, and by passing an act of Council to punish them, when they can be proved to have done it with a decided intent to injure the Settler, and also to prevent the Settlers themselves from making fires for clearing, or other purposes, until the corn has been all harvested.

I have the Honor to be, Sir,
Your Obedient Servant
R.H. Bland
Protector of Natives

A Waterloo veteran, Captain Richard Goldsmith Meares (Deacon 1948), was the Resident Magistrate at York. He put pen to paper, clearly noting the clash between *Nyoongar* and settler land use, in particular with regard to bushfire. We may admire his firey rhetoric, but not his sentence and paragraph construction. Perhaps his military background had accustomed him more to the sword than the pen.

York, March 3rd 1846

Sir

In reverting to your letter of the 17th. February Inst. wherein His Excellency the Governor expresses a wish that I should consider the subject of the Natives firing the bush and to offer any suggestion which might be adopted to prevent the occurrence – even in part – of the very serious damage sustained in the York District by this practice. It seems necessary to premise in the first instance that when this Territory was taken from the Aborigines and by Act of Parliament they were created British Subjects – 'no equivalent for them having been reserved' – it would appear the intention was that they should still maintain themselves as in their primitive state – if so - they burn for their *food – whereas the existence of our Flocks and Herds depends on what to us is thus annually irretrievably destroyed and the whole district is now groaning under the ruinous spoliation: some impute it to the Squatting Act which has of late caused a new occupation and thus as it were driven them from their second resource – the first being the old settled Districts. Here are three parties, the Government, the Natives, and the Settlers: the Government let to A.B.* [Anybody?] *4000 acres of land for one year having previously paid ten pounds for a license, the next day the whole of these Lands are fired and burned bare by the Natives: the Lambing has commenced, the sheep die, and the farmer is ruined: now it would certainly appear that these lands should be protected by the Government itself – but hitherto the battle has been fought by the new owners against the old ones. The Settlers have adopted a custom of giving at Harvest Time, from each farm, one bushel of wheat to each Tribe 'provided they do not burn the run' as also gleaning of the fields, to both which advantages they are* [reckless or feckless?]*; and on this ground we at present stand.*

Now it strikes me that whatever is done for these people should come through some higher Authority than the owner of each farm – the proprietors might give in their quota in kind to be deposited for distribution in the hands of a proper officer of the Government who I should say were equally bound with the Settlers to pay in a bountiful [mite?]*: all the Tribes have their Chiefs although I believe not very commanding ones but still they might be selected, encouraged, and made very useful in holding control over the rest by investing them with authority to receive from the Government officer and distribute although in the officer's presence and to distinguish them with some mark of favour – if they deserved it – some pains might be taken to educate each Chief in our language so that they might become interpreters and know and understand amongst themselves gradually as the light may break in upon them that we are trying to render them ultimate service and which Time will teach them to appreciate. If we are to keep Flocks it is quite clear that the Lands must be preserved and not fired: and thus the immediate attention of the Natives should be called to the subject, to warn them against solitary confinement and Rottnest* [Note: a penal island off the West Australian coast], *and that for the future, in no one instance will firing the country be overlooked for they laugh at our idea of* *letting a fire escape them if they wish to put it out, and the wheat collected would I should imagine be more than equivalent to what they would otherwise obtain by those burnings and would also come at the very period when they perform their destructive operations being in January and February.*

If I have written my opinions rather freely I beg to assure His Excellency they are the thoughts of an Old Settler who has the prosperity of the Colony most dearly at heart.

I have the Honor to be Sir
Your most obedient Humble Servant
Richard G. Meares
Resident

On the same day, Charles Symmons, Protector of Natives in the Swan Valley, wrote the following balanced letter. He clearly had an interest in *Nyoongar* ways, and remarked that burning was, for them, '*one of their most ancient and cherished privileges'*.

Perth March 3rd. 1846

Sir

I have the honor to acknowledge the receipt of your letter dated the 17th. of February Inst., expressive of His Excellency's wish that I might endeavour to suggest some measures for the putting a stop to the fires kindled in the bush by the Natives, or at least rendering them of less frequent occurrence.

In reply, I must first beg leave to draw His Excellency's attention to the fact that although by far the larger proportion of bush-fires are occasioned by the Natives, yet that many originate in the wilful or careless conduct of the Settlers themselves. The smouldering ashes of a woodcutter's fire – the chance spark from his pipe are all sufficient means of combustion amongst vegetation parched to tinder by the summer heat.

I merely allude to these facts to show the necessity of making some restrictive enactments for the white man as well as for the black.

As regards the Aborigines, I need scarcely point out to His Excellency, that, as in all cases connected with an interference in native habits and feelings – the question of the best means of remedy is one of considerable difficulty.

My knowledge of the Native character renders me extremely sceptical as to the success of any remedial plan for checking one of their most ancient and cherished privileges – but, as in all my transactions with this singular people, I have never been discouraged by the failure of measures which must in the first instance be purely experimental – so, in this case – let some plan of operation be devised – and should it fail – we can only recommence de novo.

I should suggest therefore to His Excellency the practicability of informing the Natives in all the settled Districts of the determination henceforward of the Government to put a stop to their custom of indiscriminately firing the bush, and that on no pretence whatever are they to commence their burning operations before the beginning of the month of March – after which period they may be allowed to do so – the immediate vicinity of the Settlers' homesteads being rigidly excepted. That, provided such regulations be observed on the part of the Natives, the Settlers and the Government combined, should undertake on the 1st. of March of each year to distribute in their several districts through means of the Protectors and the Resident Magistrates, such gratuities of flour as may at once suffice the cupidity of the Natives and convince them of the policy of compliance with our regulations.

I consider this plan as at least worthy of consideration (however much it may be modified or enlarged) it having been found effectual in the neighborhood of some farms in the York District, where the Shepherds confirm that by this gratuity they could calculate with tolerable certainty on the period for the native firing of the bush.

It will be for the Law Officers of the Crown to determine as to the nature and extent of the penalty to be enforced on the infringement of any arrangements of this nature which may be entered on between the Aborigines and the Government.

I must, in conclusion beg to recall to the attention of His Excellency the equal necessity of legislative restriction in the case of the Settlers and their farm laborers.

I have the honor to be Sir, Yr very Obedient Servt
Chas Symmons, Protector of Natives

Another Waterloo veteran, Lieutenant-Colonel John Molloy, wrote from the Vasse District, where he was a Resident Magistrate.

Vasse 17th March 1846

Sir

I have to acknowledge the receipt of the circular of the 17th. Ult. In reference to its contents I must confess my utter inability to offer an opinion as to any effective means of controlling the incendiary propensities of the Natives. Speaking of this district I should say we have not suffered any great inconvenience from Bushfires, the Natives carefully abstaining from their practice until after the harvest is fully accomplished an event to which they look forward with a degree of pleasurable anxiety.

A stern command not to destroy the pasturage with a threat of banishment from the habitations of the Settlers has its effect and so far from Bush fires being generally offensive I believe the opinion prevails in this quarter that they are not only necessary but salubrious.

There are doubtless measures of prevention capable of adoption such as individuals taking the initiative in burning when the country is not in a forward combustible state *and the fires can be easily arrested, perhaps they would require encouragement to effect the formation of a barrier belt around points requiring protection.*

Finally the prospect of Reward by holding out to the Natives the enjoyment of a General Corrobory throughout the district when the distribution of about three pounds of flour to each native on a named day might be offered to them provided a proper degree of abstinence [illegible] *should have been observed this would not as far as I can be permitted to form an estimate be a consideration to the proprietors but of a trifling nature.*

I have the honor to be Sir
Your most Obedt. Servant
J. Molloy
Resd. Magistrate

Francis Corbet Singleton was the Resident Magistrate for the Murray District, which lies to the west of the Wungong Catchment.

Dandalup March 7 1846

Sir

I have the honor to acknowledge the receipt of your circular concerning the damage sustained by the Settlers through the means of Bush Fires; and requesting me to forward for the information of His Excellency such suggestions as might present themselves to my mind.

In reply to the same I would first observe that my experience of the evil alluded to has been confined to this District, which is of a character totally different to that of the Districts eastward of the Range.

In those parts of the Territory a Bush fire will, as has been proved during this season, extend for many miles, not only burning up all vegetation and thereby causing severe damage to the flocks and herds, but utterly destroying the property of several of the Settlers.

In this District it is quite otherwise – the major part of the country to the Westwd [*sic*] *of the range being sandy these districts are only partially burnt, and as a general rule I would remark that the vegetation will only burn once in two years – Further; it appears to be about one half of the sandy land burns over by the fires annually; the graziers are therefore fortunately secure in having the other portion for the sustenance of their flocks and herds. The herbage, unless it has been burnt in the previous summer becomes exceedingly hard, and is usually refused by the stock – The fires are never general and if not intentionally lighted by the Europeans for the purpose mentioned, are kindled by the Natives for the purpose of more effectually securing their game; which is captured in extraordinary numbers where a strong wind impels the flames.*

I think I may with safety say, that since I have resided in this district no damage has occurred from Bush fires where common precaution has been made use of to prevent the calamities supposed to attend a fire of that nature … [A lengthy discussion of domestic fires, smoking, and the law has been omitted] *…To frame a statute forbidding the Natives to fire the bush would I fancy prove abortive; and could such a law be carried out in practice I should conceive it to be an unjust one. The Aborigines look forward to the summer season with the same feelings as Europeans – To both it is the time of harvest – It is then that they gather in by means of these fires their great harvests of game; and altho'* [*sic*] *in many districts they have been bribed (or paid) for not setting fire to the bush, I look upon it as unjust to demand them to abstain from securing their game or their means of subsistence in a manner which they find to be the most effective.*

As well might we compel them to desist from smoking opossums out of trees, on the grounds of such a practice injuring our timber, as to enforce the former rule because our sheep lack feed.

[The last few paragraphs mainly discuss feed for sheep, and have been omitted.]

I have the honor to be Sir
Your obed. Srvt.
Francis Corbet Singleton
Resident

At Bunbury, on the coast, south-west of Wungong Catchment, the relationship between settlers and *Nyoongar* seems to have been amicable, so deliberate burning to harm the settlers was unlikely. Besides, George Eliot, the Resident Magistrate there, like Molloy at the Vasse, regarded fire as a benefit rather than an evil. He offered the following thoughts.

Resident's Office, Bunbury, March 9th 1846

Sir

I beg to acknowledge the receipt of a Circular from your Offce of the 17th Ulto requesting me to offer any suggestion experience may dictate on the subject of the prevention of fires made accidentally or otherwise by the Natives in the Bush.

In answer thereto I beg to state that the only means I am aware of for that purpose would be for the Government to offer a Reward to be given at the commencement of the Rainy Season to the Natives of the districts that have been least burnt. Such a measure would probably partially prevent burning the Country and would also perhaps induce the Natives to stop those fires that come from a distance. At the same time I must observe that in my opinion every Settler ought at the beginning of the dry season to burn a strip of country in the immediate neighbourhood of his homestead by these means he would be perfectly secure from Bush Fires and by merely giving up a day or two's work probably save his property from destruction.

I am not myself at all adverse to the practice of burning the Country inasmuch as it produces better food for the stock and also destroys an enormous number of Reptiles and

Insects which would in a few years were it not for the fires increase to such a degree as to render the country almost uninhabitable.

In this District the Natives if they wish to burn any swamp or piece of country in the Vicinity of dwellings always come first to ask my permission.

I remain Sir,
Your obedt. Servant
George Eliot
Resident

Appendix B: Raw grasstree data from Monadnocks Conservation Park (stems 1-60, showing 963 past fires) and Wungong Catchment (stems 61-71, showing 131 past fires)

Stem 1, jarrah/marri slope: 32°19.384'S, 116°14.333'E
1860,1862,1864,1866,1868,1870,1872,1874,1876,1878,1880,1882,1884,1886,1888, 1890,1892,1894,1896,1898,1900,1902,1904,1906,1908,1910,1912,1914,1925,1937, 1961 (31 fires)
Stem 2, jarrah/sheoak slope: 32°19.447'S, 116°14.299'E
1892,1898,1903,1916,1921,1955 (6 fires)
Stem 3, sheoak slope: 32°19.447'S, 116°14.333'E
1911,1913,1915,1924,1928,1934,1937,1940,1944,1959,1964,1977,1983 (13 fires)
Stem 4, sheoak slope: 32°19.452'S, 116°14.343'E
1900,1910,1917,1970 (4 fires)
Stem 5, jarrah flat: 32°18.409'S, 116°17.571'E
1880,1882,1884,1886,1888,1890,1892,1895,1897,1899,1902,1905,1908,1913,1917, 1928,1934,1944,1955,1969,1977,1987 (22 fires)
Stem 6, jarrah flat: 32°18.426'S, 116°17.558'E
1890,1895,1898,1902,1907,1911,1914,1917,1919,1924,1925,1928,1931,1940,1945, 1955,1968,1988,1994,2002 (20 fires)
Stem 7, jarrah/wandoo slope: 32°21.143'S,32°16.287'E
1867,1871,1874,1877,1880,1883,1886,1889,1892,1895,1897,1900,1904,1909,1912, 1919,1928,1938,1941,1944,1948,1954,1961,1968,1972,1975,1991 (27 fires)
Stem 8, jarrah flat: 32°18.394'S,116°17.574'E
1901,1903,1905,1907,1909,1912,1914,1916,1918,1921,1924,1928,1934,1994 (14 fires)
Stem 9, jarrah flat: 32°18.393'S, 116°17.580'E
1903,1905,1908,1910,1912,1914,1916,1919,1922,1926,1932,1934,1941,1948,1953, 1966,1985,1995 (18 fires)
Stem 10, wandoo/blackbutt/paperbark flat: 32°18.804'S, 116°19.026'E
1922,1924,1925,1933,1937,1938,1941,1948,1985,1991 (10 fires)
Stem 11, wandoo/blackbutt/paperbark flat: 32°18.805'S, 116°19.023'E
1910,1912,1914,1916,1918,1926,1930,1933,1939,1947,1953,1962,1970,1982,2002 (15 fires)
Stem 12,wandoo/blackbutt/paperbark flat: 32°18.806'S, 116°19.021'E
1846,1848,1851,1854,1857,1861,1865,1869,1873,1877,1882,1886,1889,1892,1895, 1899,1902,1911,1916,1923,1927,1933,1943,1961,2002 (25 fires)
Stem 13, wandoo/swamp banksia: 32°20.005'S, 116°19.944'E
1960,1965,1970,1975,1977,1995 (6 fires)
Stem 14, wandoo/swamp banksia: 32°20.006'S, 116°19.948'E
1890,1892,1894,1896,1897,1899,1901,1903,1905,1907,1908,1911,1918,1921,1923, 1925,1926,1928,1938,1945,1958,1970,1984,1994 (24 fires)
Stem 15, wandoo/swamp banksia: 32°20.012'S, 116°19.949'E
1900,1903,1905,1913,1916,1920,1927,1961,1967 (9 fires)

Stem 16, wandoo flat: 32° 20.237'S, 116° 20.227'E
1880,1882,1884,1886,1888,1890,1891,1892,1894,1896,1898,1900,1902,1904,1906, 1908,1910,1912,1914,1916,1918,1920,1922,1924,1926,1928,1931,1935,1940,1943, 1945,1953,1958,1962,1965,1969,1976,1994 (38 fires)
Stem 17, wandoo flat: 32°20.222'S, 116° 20.236'E
1932,1936,1942,1946,1956,1961,1966,1971,1982,1994 (10 fires)
Stem 18, wandoo flat: 32° 20.222'S, 116° 20.246'E
1910,1912,1914,1916,1918,1920,1922,1924,1926,1928,1931,1935,1946,1953,1958, 1965,1994 (17 fires)
Stem 19, jarrah ridge: 32° 22.160'S, 116° 20.455'E
1933,1940,1945,1953,1961,1965,1971,1982,1994,2003 (10 fires)
Stem 20, jarrah ridge: 32° 22.165'S, 116° 20.456'E
1924,1926,1929,1930,1933,1940,1945,1956,1972,1982,1994,2003 (12 fires)
Stem 21, wandoo gully/blackbutt: 32° 22.414'S, 116° 20.498'E
1755,1757,1759,1763,1765,1777,1780,1783,1786,1789,1792,1799,1802,1810,1813, 1817,1820,1822,1826,1830,1832,1842,1844,1863,1866,1873,1886 (too tall for further measurement 5.5 metres) (27 fires)
Stem 22, wandoo gully/blackbutt: 32° 22.419'S, 116° 20.495'E
1911,1913,1915,1917,1919,1921,1923,1925,1927,1929,1932,1935,1937,1939,1942, 1945,1949,1953,1958,1964,1968,1981,1994 (23 fires)
Stem 23, jarrah/marri edge of Sullivan's Rock: 32° 22.556'S, 116° 15.246'E
1876,1881,1885,1890,1892,1895,1900,1907,1912,1918,1923,1942,1948,1970,1991 (15 fires)
Stem 24, jarrah/marri, edge of Sullivan's Rock: 32° 22.527'S, 116° 15.266'E
1831,1834,1837,1841,1844,1847,1851,1854,1857,1861,1864,1867,1870,1873,1876, 1880,1885,1890,1895,1900,1908,1912,1918,1926,1948,1970 (26 fires)
Stem 25, casuarina/grasstree flat: 32° 21.563'S, 116° 14.543'E
1910,1912,1914,1916,1918,1920,1922,1924,1926,1933,1941,1945,1950,1954,1960, 1963,1970 (17 fires)
Stem 26 casuarina/jarrah: 32° 21.850'S, 116° 14.717'E
1913,1916,1919,1922,1925,1928,1931,1935,1937,1941,1945,1952,1956,1960,1970, 2001 (16 fires)
Stem 27 casuarina/jarrah: 32° 21.895S, 116° 14.750'E
1922,1925,1928,1937,1940,1942,1945,1950,1955,1961,1965,1968,1970,1982,2001 (15 fires)
Stem 28 casuarina: 32° 21.897'S, 116° 14.751'E
1850,1852,1854,1856,1858,1860,1862,1864,1866,1868,1870,1872,1874,1876,1878, 1880,1882,1884,1886,1888,1890,1893,1896,1900,1903,1906,1910,1913,1922,1928, 1934,1940,1948,1953,1963,1972,1982,1987 (38 fires)
Stem 29 jarrah/marri: 32° 21.978'S, 116° 14.933'E
1870,1873,1876,1879,1882,1885,1888,1892,1896,1900,1911,1916,1922,1928,1932, 1940,1954,1978,1988 (within 2001 spring burn area, but too tall to ignite at 3.2 metres)(19 fires)
Stem 30 casuarina open patch: 32° 22.091'S, 116° 14.889'E
1890,1893,1896,1899,1902,1905,1908,1911,1915,1919,1922,1925,1928,1932,1935, 1939,1942,1945,1948,1954,1961,1977,1988,1988,1998,2001 (26 fires)

Stem 31 casuarina open patch: 32° 22.089'S, 116° 14.874'E
1890,1893,1896,1899,1902,1905,1908,1911,1915,1919,1921,1924,1927,1930,1934, 1937,1940,1943,1947,1954,1957,1962,1973,1979,2001 (25 fires)
Stem 32 jarrah/marri: 32° 22.258'S, 116° 15.002'E
1881,1884,1890,1895,1900,1904,1911,1915,1919,1924,1938,1944,1953,1978,1985 (15 fires)
Stem 33 jarrah: 32° 22.309'S, 116° 15.046'E
1870,1872,1874,1876,1878,1880,1884,1886,1889,1892,1896,1901,1907,1910,1914, 1916,1926,1942,1958,1970,1986,2001 (22 fires)
Stem 34 jarrah/casuarina: 32° 28.425'S, 116° 20.477'E
1915,1920,1924,1930,1935,1939,1946,1949,1954,1962,1966 (11 fires)
Stem 35 jarrah/casuarina: 32° 28.436'S, 116° 20.484'E
1872,1876,1880,1884,1888,1900,1908,1911,1918,1922,1926,1940,1953,1958,1963 (15 fires)
Stem 36 jarrah: 32° 28.424'S, 116° 20.488'E
1818,1825,1830,1835,1838,1842,1845,1850,1854,1858,1866,1869,1873,1888,1891, 1909,1916,1931,1950 (19 fires)
Stem 37 jarrah: 32° 28.424'S, 116° 20.488'E
1872,1875,1878,1880,1883,1886,1888,1890,1893,1897,1901,1908,1918,1921,1926, 1930,1935,1942,1945,1949,1953,1963,1992 (23 fires)
Stem 38 jarrah/casuarina: 32° 22.291'S, 116° 15.087'E
1808,1810,1812,1814,1816,1818,1820,1823,1826,1828,1830,1833,1835,1838,1840, 1843,1845,1847,1849,1852,1854,1856,1859,1861,1863,1865,1871,1876,1879,1883, 1888,1893,1896,1902,1905,1911,1915,1920,1922,1925,1929,1932,1950,1964 (44 fires)
Stem 39 marri, summit of Mt. Vincent: 32° 21.921'S, 116° 15.254'E
1902,1905,1910,1914,1920,1933,1937,1941,1955,1962,1972 (11 fires)
Stem 40 marri, summit of Mt. Vincent: 32° 21.921'S, 116° 15.257'E
1902,1905,1909,1915,1921,1926,1934,1943,1959 (9 fires)
Stem 41 marri, summit of Mt. Vincent: 32° 21.919'S, 116° 15.264'E
1902,1905,1909,1914,1918,1924,1930,1943,1955,1963,1970 (11 fires)
Stem 42 marri, summit of Mt. Vincent: 32° 21.711'S, 116° 15.187'E
1900,1902,1904,1906,1908,1910,1912,1914,1916,1918,1922,1924,1927,1931,1934, 1938,1943,1948,1955,1964,1970,1976 (22 fires)
Stem 43 marri, summit of Mt. Vincent: 32° 21.712'S, 116° 15.184'E
1932,1935,1938,1944,1951,1954,1964,1970,1976,1982 (10 fires)
Stem 44 marri, summit of Mt. Vincent: 32° 22.116'S, 116° 15.192'E
1907,1911,1928,1964 (4 fires)
Stem 45 marri, summit of Mt. Vincent: 32° 22.112'S, 116° 15.198'E
1891,1897,1902,1907,1912,1916,1920,1935,1955,1967,1974 (11 fires)
Stem 46 marri, summit of Mt. Vincent: 32° 22.159'S, 116° 15.180'E
1897,1905,1915,1923,1937,1950,1964 (7 fires)
Stem 47 marri, summit of Mt. Vincent: 32° 22.160'S, 116° 15.182'E
1922,1931,1944,1949,1950,1965,1973,1979 (8 fires)
Stem 48 marri, summit of Mt. Vincent: 32° 22.145'S, 116° 15.186'E
1890,1895,1897,1905,1914,1920,1930,1935,1942,1948,1955,1963,1976 (13 fires)

Stem 49 marri, summit of Mt. Vincent: 32° 21.964'S, 116° 15.242'E
1925,1928,1931,1935,1941,1950,1954,1960,1971,1979 (10 fires)
Stem 50 marri, summit of Mt. Vincent: 32° 21.970'S, 116° 15.242'E
1941,1944,1950,1952,1960,1968,1979 (7 fires)
Stem 51 jarrah: 32° 22.084'S, 116° 18.517'E
1920,1922,1924,1926 (4 fires)
Stem 52 jarrah: 32° 22.086'S, 116° 18.523'E
1935,1938,1942,1945,1950,1955,1960,1968,1990,2003 (10 fires)
Stem 53 jarrah: 32° 22.070'S, 116° 18.522'E
1908,1910,1912,1914,1916,1918,1920,1922,1924,1926,1928,1930,1932,1934,1936, 1938,1940,1942,1944,1946,1948,1951,1958,1962,1967,1977,2003 (27 fires)
Stem 54 jarrah: 32° 22.065'S, 116° 18.525'E
1950,1952,1955,1960,1964,1969,1973,1977,2003 (9 fires)
Stem 55 jarrah: 32° 23.426'S, 116° 18.879'E
1873,1876,1879,1882,1885,1888,1892,1895,1898,1902,1905,1908,1911,1914,1920, 1925,1930,1934,1940,1945,1950,1958,1966,2003 (24 fires)
Stem 56 jarrah: 32° 23.420'S, 116° 18.885'E
1898,1901,1904,1907,1910,1914,1918,1923,1927,1930,1935,1940,1947,1957,1965, 2003 (16 fires)
Stem 57 wandoo: 32° 23.654'S, 116° 20.354'E
1901,1903,1905,1907,1909,1911,1913,1915,1917,1919,1921,1923,1925,1927,1929, 1934,1938,1940,1946,1950,1955,1963,1972,1986,2003 (25 fires)
Stem 58 wandoo: 32° 23.653'S, 116° 20.348'E
1923,1927,1929,1934,1938,1940,1946,1950,1960,1972,2003 (11 fires)
Stem 59 wandoo/ti-tree: 32° 20.866'S, 116° 20.017'E
1891,1893,1895,1897,1899,1901,1904,1907,1909,1913,1916,1922,1933,1940,1947, 1950,1990 (17 fires)
Stem 60 wandoo/sedges: 32° 20.731'S, 116° 20.294'E
1770,1772,1774,1776,1778,1780,1782,1784,1786,1788,1790,1792,1794,1796,1798, 1800,1802,1804,1806,1808,1813,1818,1822,1827,1830,1833,1837,1850,1854,1897, 1929,1990 (32 fires - very tall 4.15 metres – started missing fires back in 1850s, when over 2 metres high? Sedge fires probably fast moving in strong wind – flattened flames?)

(Wungong Catchment stems from here on. Australian Map Grid used.)

Stem 61 jarrah 0422049, 6423795
1891,1894,1897,1900,1903,1906,1913,1918,1923,1926,1930,1934,1938,1950 (14 fires)
Stem 62 jarrah 422079, 6423752
1874,1877,1880,1884,1887,1891,1894,1897,1903,1906 (10 fires)
Stem 63 jarrah: 0420394, 6424076
1944,1946,1948,1950,1952,1954,1956,1958,1960,1968,1972,1975,1978,1991,2006 (15 fires)
Stem 64 jarrah: 0420402, 6424083
1992,2006 (2 fires)

Stem 65 jarrah: 0420379, 6424003
1934,1936,1938,1940,1943,1945,1950,1955,1960,1963,1967,1969,1972,1975,1979,2006 (16 fires)
Stem 66 jarrah: 0420418, 64243998
1936,1937,1938,1941,1943,1944,1946,1948,1950,1952,1955,1958,1960,1977,1991,2006 (16 fires)
Stem 67 jarrah: 0421997, 6423916
1930,1933,1935,1940,1945,1948,1952,1958,1972,2000 (10 fires)
Stem 68 jarrah: 0422086, 6423755
1867,1870,1873,1876,1880,1884,1888,1892,1898,1901,1908,1914,1919,1937,1945,1949 (16 fires)
Stem 69 jarrah: 0422022, 6423790
1891,1894,1891,1901,1904,1911,1917,1922,1925,1930,1934,1938 (12 fires)
Stem 70 jarrah: 0421993, 6423921
1915,1918,1922,1926,1932,1941,1948,1964,1997 (9 fires)
Stem 71 jarrah: 0421996, 6423879
1922,1925,1929,1932,1936,1940,1943,1948,1958,1965,1979 (11 fires)

Appendix C: Some papers on the grasstree dispute

These have been removed from this electronic copy for copyright reasons. The originals can be found in the journals given in the references.

Appendix D: A Time Sequence (1791-2006) of Comments on Bushfire by Early Visitors and Settlers, and Present Day *Nyoongar* Elders and Farmers.

1791: *'This spot was intersected with several small streams of water, yet the same marks of fire were evident on all the vegetable kingdom…it was evident, as far as we traversed the sides of the hills, that the vegetation had recently undergone the action of fire; the largest of the trees had been burnt, though slightly; every shrub had some of its branches completely charred; and the plants lying close to the ground had not escaped without injury.'*

Commander George Vancouver, near present day Albany, 1791.

Note: The fact that the shrubs were not completely consumed, and the ground plants were still recognisable, shows that this must have been a mild fire, and therefore the time elapsed since the previous fire only a few years. Fierce fires, after long fire exclusion, produce a typical blackened moonscape, with hardly any shrub matter remaining.

1830: *'A large fire made by the natives spread rapidly owing to the dry state of the grass.'*

Mary Friend, Fremantle, 1830 (Noted by Dr. Ian Abbott in 2003)

1831: '*The whole of the country, between the Conical Hills (near Augusta) and Cape Naturaliste, has been burnt*.'

John Dewar and Andrew Smith, 1831.

Note: There were few Europeans in that area in 1831. It was inhabited by *Bibbulman* and *Wardandi Nyoongars*.

1831: '*I walked along a broad belt of good soil for one mile. Fire had recently gone over its surface, and left only enough of wattle shrub to show that this had been the chief production…'*

Alexander Collie, King George's Sound, 1831.

Note: Again, the fact that the wattle bushes were still recognizable as such, is evidence that this was a relatively mild, patchy fire, the sort that occurs in litter a few years old.

1831: '*Thickets* that '…*the natives are in the habit of burning … at intervals of three years' to drive out Tammar and Banded Hare Wallaby*.'

John Gilbert, near Northam (Noted by Dr. Ian Abbott in Gilbert's journals, in Liverpool, England.)

Note: Some quote early observations of dense thickets as evidence of long fire absence. In fact, some shrubs can grow over 2 metres in a few years. Under long fire exclusion the thickets tend to thin out underneath, as shorter shrubs die, and tall ones self-prune.

1834: '*In December, but more particularly in January and February, the natives burn large tracts of country to catch wallabee (sic), or bush kangaroo. For this purpose they generally go in considerable numbers and select a fine and warm day, and, having fired a portion of thick scrub or grass where they know these animals to live, they watch their being driven out by the fire, and either spear them or knock them down with a short and rather slender baton called 'toollila'… The fires when thus lighted generally proceed spreading and consuming everything in their progress, and before the coldness and dew of the night repress their fury or intervening barren spots stop their rage, overrun some square miles of surface'*

Alexander Collie, Albany, 1834.

Note: Night humidity will only suppress a summer fire in light fuel.

1837: '*The streets are of sand, mixed with charcoal, from the repeated burning of the scrub, which formerly covered the ground, on which the town stands...The Natives are now setting fire to the scrub, in various places, to facilitate their hunting, and to afford young herbage to the kangaroos*…'.

James Backhouse, Perth, 1837

1837: '*It cannot be denied that Western Australia, as far as it is known, is generally of a rather sandy, barren nature, partly owing to the constant dryness and clearness of the atmosphere and climate and to the periodical extensive bush fires which, by destroying every two to three years the dead leaves, plants, sticks, fallen timber etc. prevent most effectually the accumulation of any decayed vegetable deposit… being the last month of summer … the Natives have burnt with fire much of the country…'.*

Henry Bunbury, 1837.

Note: A common argument is that *Nyoongars* were burning with hostile intent, and this only occurred after European arrival. There are clear statements that, on the contrary, they were simply following tradition.

1840s: '*In our journey to the south I gathered a most beautiful Stylidium in flower. For several years I have known the plant by its leaves, but I could never get it to flower. From a careful examination of the plant in various situations I have come to the conclusion that this species never flowers in perfection but the second year after the ground has been burned over. The leaves which are uncommonly beautiful became after the second year hard and rigid and apparently incapable of supplying the necessary nutrition to enable the plant to bring its flowers and seeds to maturity. I have named this species Stylidium elegans.*'

James Drummond, Colonial Botanist, 1840s.

Note: Fire exclusion, even for 5 or 6 years, leads to the lockup of nutrients in dead matter, and hence starvation of many native plants. In moister climates, decay recycles nutrients. In dry Australian conditions, fire is needed.

1841: *'The absence of fertility is naturally accounted for in a very dry climate by the summer fires passing over a great portion of the surface of the country, and preventing any accumulation of decayed vegetation.'.*

The Inquirer (newspaper), Perth, 1841.

1842: '*During my excursions in the bush my interest in bushfires has often been aroused … Others ascribe them entirely to the blacks … who light fires all over the place to cook their food but leave them unextinguished. During the hot summer the grass dries out and becomes highly inflammable, and the leaves of the myrtaceous plants, which are full of essential oils, also get very dry. The consequence is that bushfires quickly spread over enormous areas, though without becoming a danger to human beings…*'.

Ludwig Leichhardt, 1842, New South Wales.

Note: The observation that the fires were no danger to human beings is irrebuttable evidence of low fuel levels, due to a fire every few years. Recent fires (2003) in heavy, woody fuels, in long unburnt National Parks in New South Wales, were very fierce and dangerous indeed.

1844: '*When I was a sojourner in England, I never remember to have seen Australian plants in a good state after the second or third years and that, I think, is in a great degree owing to their not being cut down close to the ground when they begin to get ragged; how for the pruning knife and a mixture of wood ashes in the soil would answer as a substitute to the triennial or quaternal burnings they undergo in their native land, I am unable to say, some of our plants never flower in perfection but the season after the ground is burned over…'.*

James Drummond, Swan Valley, 1844.

Note: Drummond was a trained botanist, and traveled widely in south-western Australia. It is hard to see why he would suggest a common fire frequency of three to four years if it was not so, or if this was only true for a small part of the country.

1846: *'I fear His Excellency will find it a very difficult subject to deal with, and impossible wholly to prevent, it has always been the custom of the Natives to fire the country during the summer season…. It would be hard to debar the Native the food Providence has placed at his disposal, by preventing the use of Fire, without which he cannot procure it.'.*

Revett Henry Bland, Protector of Natives, York, 1846.

Note: Bland was one of those who said that there was no malice in *Nyoongar* burning.

1846: '*…I must confess my utter inability to offer an opinion as to any effective means of controlling the incendiary propensities of the Natives. Speaking of this district I should say we have not suffered any great inconvenience from Bush fires, the Natives carefully abstaining from their practice until after the harvest is fully accomplished…'.*

Lt. Col. John Molloy, magistrate and farmer, Vasse.

Note: Again, no evidence of malice.

1846: '*In those parts of the Territory [York District] a Bush fire will, as has been proved in this season, extend for many miles, not only burning up all vegetation and thereby causing severe damage to the flocks and herds… the major part of the country to the Westward of the range being sandy these districts are only partially burnt, and as a general rule I would remark that the vegetation will only burn once in two years –*

Further; it seems to be about one half of the sandy land burns over by the fires annually…The fires are never general and if not intentionally lighted by the Europeans…are kindled by the Natives for the purpose of more effectually securing their game; which is captured in extraordinary numbers where a strong wind impels the fires.'.

Francis Corbett Singleton, magistrate and farmer, Dandalup.

Note: Fast moving, flattened flames, in light fuel, with strong wind, have a very brief flame residence time, cause little damage to trees, and may germinate some seeds better by radiant preheating, or by blowing downward smoke into the ground. Some present botanists, who may have seen few fires, often have no idea of the extreme diversity of fire behaviour (*pyrodiversity?)*, from benign to lethal. Assuming that a particular species is always killed by fire is simplistic, yet is sometimes an assumption of 'mathematical models' of seed production, and animal populations. Current extremely intense fires completely incinerate small animals. *Nyoongars* must have used fire more intelligently than that, or they would have starved to death.

1879: '*In West Australia the forest-fires are not so excessively destructive as in the eastern colonies, nor do they as there leave in ghastly deadness vast numbers of standing trees, after the burning element has swept through the woods; on the other hand the woods of West Australia are charming at all times, no lifeless trees disfiguring the landscape, all fresh and ever verdant with Zamias, Xanthorrhoeas, and Kingias remaining unimpaired by the scorching flames. Nevertheless, the bushy vegetation and underwood, and all kinds of herbaceous plants, are at least periodically apt to be annihilated in the woody country, when the bush ignites…'.*

Baron Von Mueller, botanist.

Note: If the forest was '*all fresh and ever verdant'* despite fires, then the fires were obviously milder, patchier, and therefore more frequent, than today. In the '*eastern colonies'* the Aborigines died from disease, or were driven off, much earlier than in Western Australia.

1880s: ' *… the natives burn large tracts of country each year, to ensure the grass and herbage coming up green and sweet at the first rains, also to drive out the game for hunting purposes. All the young of the birds that nest on the ground were hatched and able to fly, also all the young ground rats were running about, so it was quite time for the* *man carls (bushfires) … in a few days the whole country was on fire and the smoke driving down on the station made life intolerable.'.*

Edith Hassell at Jerramungup.

Note: Edith observed that women and girls did much of the burning, and the term '*man carl'* possibly means '*girls' fire'*.

1882: '*There would be practically no difficulty in stopping bush-fires, but no great advantage would accrue from the attempt – sooner or later fires will come, and the advantages gained by bush-fires more than counterbalance the disadvantages. In fact, such conflagrations are frequently advisable. Leave the forest unburnt for a few years, allow the shrubs to flourish, fallen trees to thicken on the ground, with dead leaves impregnated with turpentine, to accumulate and the destruction of the aged Jarrah, the many young plants and seeds will be completed.*

Allow the fires as a rule to take their course – if possible every 2 or 3 years. If you wish to preserve timber from an overgrown scrub burn the country in lanes, or on each side of a water-course; fires help to split the seed pods and make them more susceptible to the early rains. Fires South and West of Busselton travel at a rate of 3 miles per day, even not so fast.

No doubt fires in the Northern ranges require greater caution… Measures should be adopted to stay native fires on the timber ranges, particularly northwards from Bunbury. Heavy fines inflicted on persons leaving fires burning at their camps, firing the country, except at certain seasons and in certain localities, might tend to reduce the destruction of timber in this way. Permits might be granted, in the months of April and May, to burn strips of scrub between the belts of trees to improve the feed for stock and lessen danger from fire. At the South the timber country might, with advantage, be burnt every four or five years.'

Joseph Strelley Harris, Inspector General of Timber Forests.

Note: Harris was an experienced bushman.

1916: '*The jarrah forest, like most of the Eucalypt forests, is liable to be burnt every two to three years…'.*

Sir David Hutchins, International Forestry Consultant, in a well known report to the West Australian Government.

Note: Hutchins was the first to propose that all bushfire should be excluded from the *jarrah* forest, to enable the growth of undamaged saw logs. Previously, he was involved in planting the Troodos mountains of Cyprus with pine trees, replacing the richly diverse *phrygana* shrubland, which was formerly burnt frequently by shepherds to encourage new growth for the sheep. To protect his pines, Hutchins obtained a ban on burning by shepherds, so causing great hostility to British rule. In the 1950s the pine plantations burnt fiercely, due to military activity in the fight against EOKA terrorism. Nineteen soldiers were killed.

1924: *'In previous years the method employed to extinguish fires was direct beating with bushes, and great success attended such efforts. In the season under review, however, the conditions were more difficult, due to the increased inflammability of the bush, through protection, the exceptionally dry summer, and the strong easterly winds experienced. During the first two months of November and December, the old method was employed, and direct beating found again successful. As the season progressed, however, the conditions became more difficult (owing to the increased inflammability of the bush) and many fires, after having been beaten down and swept in the old way, were found to break out again.'.*

Stephen Kessel, Conservator of Forests, Annual Report to Parliament.

Note: Only mild fires of 500 Kw/m or less (flame <1m) can be controlled by beating. Kessel's comment suggests that this was the general situation before 1924, with light fuels, due to burning every 2-4 years.

1938: '*Jarrah as a species is remarkably resistant to fire, a fact which has aided to support the popular contention that fires are of little consequence and can even be beneficial. Young seedlings and saplings can tolerate complete destruction of the stem above the ground and, in a short time, recover in a surprising manner, thanks to the recuperative coppicing powers of the ligno-tuber.'*

Stoate, T.N. and Helms, A.D. (1938) Stocktaking in the Jarrah Bush, p.137. Forests Department, Perth. (Copy at Forests Department Library, DEC, Como).

Note: Dr. Stoate was an expert on the *jarrah* forest. He was awarded a D.Sc. from the University of Western Australia, for his forest research. He later became a professor of forestry in the USA.

1938: '*Intense fires cause serious malformation in growth'*.

Stoate, T.N. and Helms, A.D. (1938) Stocktaking in the *Jarrah* Bush, p.141. Forests Department, Perth. (Copy at Forests Department Library, DEC, Como).

1938: '*Prior to the successful application of adequate fire protection measures* [i.e 1920s], *it was unusual for any area of jarrah forest to escape periodic burning by at least a light ground fire for more than 3-4 years. Such fires, however light, invariably destroy all seedlings in their first year, but once lignotubers have been developed a large proportion survive by virtue of their ability to coppice.'*.

Stoate, T.N. and Helms, A.D. (1938) Stocktaking in the *Jarrah* Bush. Forests Department, Perth. p.125. (Copy at former Forests Department Library, DEC, Como).

1956: *'Under dense pole stands the scrub growth is low and sparse, and in the leaf litter fires run about quietly, causing little damage to the crowns of the dominants while hastening the death of the dominated members and thus performing a useful thinning. It is obvious that fire has always been a natural phenomenon in the jarrah forest.'*

A.C. Harris (1956) Regeneration of Jarrah (*E. marginata*). Australian Forestry, Volume 20(2), p.54.

Note: Mr. A.C. Harris was West Australian Conservator of Forests in the 1950s and 1960s.

1960s: *'It should be remembered that there was virtually no forest area at that time which carried more than 5 years' leaf litter and the greater part varied from* ***1 to 3*** *years. It appeared that virgin forest did not accumulate litter to any marked extent and subsequent accumulations of litter and scrub in protected compartments could not have been envisaged.'*

Roy Wallace and Alan Harris. Undated, but probably in 1960s. Typed report in Forests Department Library, DEC, Como.

Note: The authors were successive Conservators of Forests.

1961: '*Original white settlers of many years ago told me that the natives used to patch burn the bush wherever there was enough litter to burn. The primary reason for this was* *to make feed for kangaroos etc. It also kept down insect and other pests without affecting bird life, making a clean bush with healthy rejuvenation and very little damage.'*

P.G. Riegert, Yarloop. A letter to the editor of *The West Australian* newspaper, Feb 4 1961.

Note: It is well known to fire-fighters that *jarrah* forest generally accumulates enough litter to burn again after 2-4 years.

1966: '*... it is not unreasonable to assume that the forest was completely burnt through every 2-4 years. Even as late as 1925 the writer was able to observe three fires of this nature in unmanaged virgin forest east of Jarrahdale. These fires were alight in December and continued to burn until the following March.'*

Roy Wallace, President of the Royal Society of WA and Conservator of Forests, 1966.

Note: Recent grasstree cleaning in Monadnocks Conservation Park, east of Jarrahdale, has shown old fire marks at 2-4 year intervals from 1750 up to the 1920s.

1975: '*You see, the Natives …they used to burn the country every three or four years…when it was burnt the grass grew and it was nice and fresh and the possums had something to live on and the kangaroos had something to live on and the wallabies and the tamars and boodie rat ...It didn't burn very fast because it was only grass and a few leaves here and there and it would burn ahead and...sometimes there'd be a little isolated patch of other stuff that wasn't good enough to burn the time before, but as it burnt along perhaps there might be some wallabies or tamars …those animals didn't run away from fire, they'd run up to it and you'd see them hopping along the edge of the fire until they saw a place where the fire wasn't burning very fierce…'*

Mr. Frank Thompson, interviewed in 1975, about his memories of fire near the south coast, before the First World War. Tape held in Battye Library, Perth.

1986: '*That burning was done deliberately is suggested by Threlkeld's reference to a ceremony performed in the mountains near Lake Macquarie in 1826 which involved burning a 'large part of the country' prior to a kangaroo hunt… There is evidence that significant areas were burnt. Thus Dawson 'on ascending a gentle acclivity we saw the*

grass had been burnt as far as the eye could reach… in a few moments [we] discovered numerous footsteps of men and children on the burnt ground.'
Helen Brayshaw, New South Wales, 1986.

1998: I sought information on fire and Aborigines from some old residents of the *kwongan* heath area around Dongara, Eneabba, and the Mount Adams area. Mr. Peter Summers, of Dongara, said he believed that, in the 1920s, there were 'large groups' of Aborigines in the Mount Adams area, and recommended that I contact Mr. Robert Downs, whose father farmed there at that time. Mr. Downs confirmed that, before the Second World War, Aborigines from Mingenew used to go through the Mount Adams area every year, shooting kangaroos, and 'spot burning'. This burning brought up native grasses. He also mentioned feral donkeys in the area, and that they would kill zamias by 'eating the heart out of them'.

Mr. Stan Gratte, of Dongara, remembered Aborigines, he thought called Brockman, hunting and burning in the Mount Adams area in the 1930s. He thought they burnt strips, and any place would have burnt about every 4-5 years.

I also contacted an Aboriginal Elder, Mr. Barry Dodd, of the Bundiyarra Aboriginal Resurce Centre at Geraldton. He confirmed that the Brockman family were involved in kangaroo shooting and burning before the Second World War, in the Mount Adams area.

I was contacted by Shirley Scotter, and Charlie Ellery, of the Irwin Historical Society at Dongara. They had heard that I was interested in Aboriginal use of fire, and confirmed that kangaroo shooters (Brockmans and others) used to go through the Mount Adams area before the Second World War, and burnt frequently, every 4-5 years. They burnt small strips, which ran into previously burnt areas. In Charlie's opinion, recent fires have been less frequent, and so more damaging.

1999: I was contacted by Mr. Michael Kelly, whose family have farmed at Mingenew (*kwongan* heath) since the 1880s. He believes that the Yardanogo (Mount Adams) area was burnt frequently in former days, and has heard descriptions of long thin fires, sometimes with a zig-zag path. These were lit in the morning, on an easterly land breeze, and ran towards the coast, then doubled back with the sea-breeze in the afternoon. He has noted an increase in mistletoe in the *kwongan*, especially on prickleybark trees (*Eucalyptus todtiana*), and believes this is due to infrequent burning. He believes that former mild fires killed the mistletoe early in its life, and so led to the formation of tree hollows, important for wildlife. Under less frequent burning, mistletoe kills the host tree. My own observations in that area confirm that there are many dead trees. It is not immediately clear if they died from the mistletoe parasite, or from fierce, infrequent fires. This matter needs research.

1999: '*The bush was traditionally burnt every 3-4 years.*'
Aidan Eades, Chairman of the South West Commission of Elders, talking of *jarrah* forest, in a letter to the then Minister for the Environment. (Copy at Department of Environment and Conservation, Perth).

1999: '*My grandfather was the first European settler in the district in 1855, and lived here until 1926. My father lived here from 1876-1966. The ecology of the timber areas of Western Australia developed over a long period of time with a summer/autumn burn every 3-4 years or as often as it would burn. Fires were lit by Aborigines or lightning. This system kept the understorey low and prevented big fires developing because of the mosaic of burnt and unburnt areas. This method of burning was carried on by the early settlers after the demise of Aborigines in the beginning of this century.*'
James R. Muir, Manjimup farmer. Letter to Minister for the Environment April 1999.

2005: Some Background on *Kwongan* Fire: This is a response by Mr. Rob Gillam, of Irwin House, Dongara, to some questions sent by David Ward, Retired CALM Research Scientist (Tel: 08 9397 5684), concerning the Yardanogo Nature Reserve, near Mount Adams, not far from Dongara. Mr. Gillam is a farmer, and experienced firefighter with his local volunteer brigade. Yardanogo Nature Reserve is *kwongan* (sand plain heath), and contains some fire sensitive *Banksias*, namely *B. prionotes* and *B. Hookeriana*. An early explorer mentioned 'clumps' of *Banksias* in the area. A survey of old fire marks on grasstree stems at Yardanogo (also known as Mt. Adams) revealed regular 2-3 year burning from 1860 to 1900; regular 3-5 year burning from 1900 to 1939; and irregular burning at much longer intervals since World War 2.

Question 1: How long have you and your family known the general area, in particular Yardanogo Nature Reserve?

Answer: *Our family came to the Irwin area in 1936. Born in 1948, I have my knowledge from mid 1960s, but have always had a strong interest, been involved with fires, and had a strong interest in the anecdotal knowledge and stories.*

Question 2: Do you think CALM (now Department of Environment and Conservation) is managing fire well there?

Answer: *No I believe that they allow the fuel load to build up to too high a level and when we get fires (usually from lightning) they are too big and too hot.*

Question 3: If not, how could they be managed better?

Answer: *Frequent strip or mosaic burning that is carried out in late winter and spring. This then burns cool and does not kill the trees. The actual scrub will always come back even after a hot fire in 2-3 years but the Banksia and Blackbutts*[1] *take many years to grow again after big summer fires.*

Question 4: Others have told me that shooters operated in that area in the 1960s, removing pigs, donkeys, goats and brumbies. Do you know anything about this? Did they camp there? If so, did they camp at any particular place? Did they burn the bush, or individual blackboys for warmth, or signals? Are any of them still around, and might remember where they camped?

[1] Comment by David Ward: Coastal Blackbutt, or Pricklybark, is *Eucalyptus todtiana* – many dead trees of this species, plus *Banksias*, can be seen along the Brand Highway, where recent hot fires, after long fire exclusion, have occurred. Had such fires been the norm in the past, there would no longer be any *Banksia* or Pricklybark. Mistletoe may have a role in these deaths too. Local information from another source, suggests that previous light, frequent fires kept the mistletoe down, but recent long fire exclusion allows it to grow to the point where it kills the host tree.

Answer: *To my knowledge and also a close friend who remembers the 1950s there have never been pigs, goats, or donkeys in the reserve that were in numbers to shoot. There were many (100s) of wild horses, and these used to attract shooters during the 1960s and 70s for pet meat. I don't believe they established camps.*

Question 5: I have also been told that Aboriginal kangaroo shooters (Brockmans from Mingenew) went through the area regularly before Second World War, and burnt to bring up grass. Do you now anything about this? How often did they burn? Was the grass a short annual (*Austrostipa compressa*)? Is this best burnt every year, or every second or third year, or at longer intervals? Did they burn big areas, or a mosaic of strips or patches?

Answer: *Charlie Brockman and then with him his son 'Bobbie' are the Aboriginal shooters who used to roam and look after this country. They had a camp on the Milo Road about 8 miles south east of 'Irwin House' (my home) and from there they used to shoot all the sandplain scrub country from Irwin down as far as Moora. They were excellent horsemen and crack shots using 303s. They always shot over the horses withers, having a small gig made of two sticks tied together which they put over the horses withers then stood next to the horse and shot over the horse resting their rifle in the gig. My friend, who still owns the property where they camped, remembers them coming into camp and then selling the kangaroo skins to a skin buyer. As many as 1700 on one occasion.*

The Brockmans shot during the winter and the spring and always as they went they lit up the scrub that would burn. Under those 'cool burn' conditions the scrub would only burn slowly and generally not burn trees. Because it was cool and the fuel load not excessive it would only burn every 3-4 years maybe 5 in some places. This meant that they always had fresh country to get kangaroos on next year. There was some limited grass that grew, but it only seemed to be there the first year after a fire (The short annual grass you speak of sounds right).

There were NOT [sic] any big summer fires then as the continual mosaic pattern of the Brockmans' burns limited lightning strikes to a small area.

The Brockmans stopped shooting in the late 50s or early 60s and are now both dead. They did not shoot or burn in the summer as it was very hot and water was scarce.

2006: '*Aboriginal people burned off every two to three years* …'
Patrick Hume, *Nyoongar* Elder, talking of paperbark country around Forrestdale Lake, in the book 'Forrestdale: People and Place' by Rod Giblett (2006).

2006: '*This particular area hadn't been burnt for about six years and it was a very intense one. There was all these insects flying out … hundreds of them…The bush must have been full of them because it hadn't been burnt for so long. Six years was a very long time between burns. The bush would have been burnt every few years, every two or three years*:'
Ulla Hunt, member of an early Armadale settler family, talking of a bushfire in 1938, at Forrestdale Lake, in the book 'Forrestdale: People and Place' by Rod Giblett (2006).

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