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South East Queensland Fire and Biodiversity Consortium

Fire Research Newsletter

Edition 1 - January 2014

Contents

1.0 Editorial

Welcome to the first edition of the South East Queensland Fire and Biodiversity Consortium (SEQFBC) *Fire Research Newsletter*. It has been a long time in the making and there are many people to thank for their generous contributions, including the terrific bunch of students currently working on their Honours or PhD projects: Emma, Orpheus, Brett, Philip and Ross. All the best to you this year with your studies, I am sure you will all do very well. I look forward to seeing more students working in the area of fire research in the coming years. I hope our SEQFBC Research Student Scholarship Program ('the Scholarship Program') has helped to increase the profile of fire research in SEQ and the opportunities that exist with our dedicated academics and land managers. Speaking of the Scholarship Program, thanks again to Fireland Consultancy for their generous contribution towards the scholarship and of course, congratulations again to our scholarship recipients, Ross Waldron and Brett Parker (research summaries provided below). We look forward to hearing of your research progress over the course of the year and wish you all the best for the challenge that is Honours! Getting back to thanking contributors, I would like to thank Rebecca, Mark, Guy and Patrick for providing summaries of research papers for inclusion in the newsletter. We're all very busy and I really appreciate the time taken to provide these. Finally, it has again been another huge fire season for the southern states (and it's not over), with the tragic loss of life and property. Our heartfelt thoughts go out to everyone impacted by these fires and we hope that the remainder of the season proves to be uneventful. I am on maternity leave as of today and will return in February 2015. I look forward to seeing you all then and working on a second edition of the SEQFBC Fire Research Newsletter. If you would like to contact one of the students featured in this edition and their email has not been provided please contact Craig (cwelden@seqcatchments.com.au). Enjoy reading and take care.

2.0 Spotlight on a Student

2.1 Emma Burgess (PhD)

Project title: Managing fire for nature conservation in sub-tropical woodlands
Supervisors: Dr Martine Maron[1], Dr Patrick Moss[1] and Mr Murray Haseler[2]
Institution: [1] The Landscape Ecology & Conservation Group, School of Geography, Management & Planning, University of Queensland. [2] Bush Heritage Australia. [3]
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Wildfires and altered fire regimes continue to threaten global biodiversity. This has stimulated much research into the ecological impacts of fire and effective means of burning to maintain biodiversity focused on the broadly accepted paradigm that 'pyrodiversity begets biodiversity'. Much work has been carried out at the alpha diversity level in relation to the fire event. Uncertainty, however, remains about the ecological significance of a heterogeneous fire regime at the beta and gamma diversity level. Controlled burning for biodiversity conservation thus remains a controversial topic.
The main aim of my PhD project is to gain a better understanding of the particular spatial and temporal patterns of fire that maintain or threaten biodiversity by focusing beyond the patch-scale and using birds as a biodiversity surrogate. The study is located in Bush Heritages Carnarvon station reserve, in the Brigalow Belt South Bioregion, Queensland.
These findings will provide an understanding of the operational minimum level of spatial diversity, at appropriate spatial resolution for effective ecological fire management.

2.2 Orpheus Butler (Honours)

Project title: Forest stoichiometry shift in response to vegetation fire in south-east Queensland.
Supervisors: Associate Prof. Chengrong Chen[1] and Dr Tom Lewis[2].
Institution: School of the Environment, Griffith University[1] and Agri -science Queensland, the Department of Agriculture, Fisheries and Forestry[2].

This study is a Griffith University Honours project which commenced in July 2013, under the supervision of Associate Professor Chengrong Chen and Dr Tom Lewis. The aim of the study is to examine the effects of wildfire on the C:N:P stoichiometry of forest ecosystems in south-east Queensland, Australia, with intent to better understand the significance of vegetation fire in regards to biogeochemical nutrient cycling and ecosystem structure and function. C:N:P stoichiometry refers to the balance of the total concentrations of carbon (C), nitrogen (N) and phosphorus (P) in leaves, leaf litter and soil, as expressed by ratios. This study is unique in its investigation into the influence of both wildfire and prescribed burning on the C:N:P stoichiometry of various components of Australian forest ecosystems.

An experimental location has been established at White Rock-Spring Mountain Conservation Estate (WRSMCE), near Ipswich. Other potential experimental locations identified to date include Toohey Forest, near Griffith University's Nathan campus, and Bellthorpe National Park, near Maleny. The WRSMCE experimental location consists of an area that has been affected by fire three times since 1998, most recently by a wildfire in October, 2012, and a nearby area that has remained unaffected by fire since 1998. Samples of leaves of several key plant species, leaf litter and soil have been collected from both of these areas, and will be analysed for total organic C, total N and total P. The concentrations of these elements and their ratios will be compared between the recently burned and long-unburned areas, to ascertain the influence of fire.

2.3 Brett Parker (Honours)

Project title: Remotely sensed burnt area analysis and validation: A procedure to effectively map spatiotemporal patchiness and severity of fire to guide appropriate ecological management.
Supervisors: Dr Sanjeev Srivastava[1] and Dr Tom Lewis[2].
Institution: University of the Sunshine Coast[1] and Agri-science Queensland, the Department of Agriculture, Fisheries and Forestry[2].

My honours research project is focused on remotely sensed fire mapping and the aim is to create a remote sensing/GIS fire mapping procedure useful to land managers who require precise knowledge about various aspects of fire regimes within ecosystems. Landsat satellite imagery will be used as it spans back to 1972. Detection of frequency, intensity, seasonality and patchiness of individual burn scars as well as the “invisible” severity and patchiness mosaic of aggregated burns will be analysed from back to 1972.

The classification of imagery will follow the methods of my prior student research project. However, validation will be conducted via ground truthing using a plant canopy analyser to detect LAI and FCOV integrated into the GeoCBI (a post fire field survey sheet), and remote validation with WV-2 imagery. Once Lsat imagery has been classified and validated it will integrated with the RE vegetation GIS datasets, as a determent of ecological appropriateness for current fire regimes in broad vegetation classes.

I am in the process of selecting study sites that will incorporate as many vegetation communities as possible to understand where the analysis is strong and weak. If anyone has specific study sites or management objective in mind that may work in with this project I am interested to know.

2.4 Philip Stewart (PhD)

Project title: Changing Fire Regimes of Fraser Island, Queensland.
Supervisors: Dr Patrick Moss
Institution: School of Geography, Planning and Environmental Management, University of Queensland**.**

The focus of the study is to identify past, present and future changes in fire regimes on Fraser Island. The impacts of these changes on vegetation population dynamics including changes in temperature and precipitation regimes spatially and temporally. Fire is an important driver in the development of ecosystem evolution, composition, structure and distribution. With carbon dating records of fires dating back 40 thousand years ago, changes in vegetation composition, distribution and abundance in conjunction with changes in precipitation and temperature regimes may be identified. Fires have modified the islands ecosystems creating fire dependency and creating fire disturbance-adapted ecosystems. It is suggested that due to the importance of fire as an ecosystem modifier, plants developed traits to survive fire, such as resprouting post-fire and serotiny of cones and fruit. However such traits are not necessarily only developed through fire as a process of natural selection, other factors may play a role in such trait development within plants. Paleo-records and modern observations show a definitive link between fire and climate (temperature and precipitation), with an increase in fire with increasing temperatures. This has serious implications as in a warmer world there will be an increase in wildfire risk. Of importance is the understanding of the interactions between multiple drivers of fire regimes from the past and present. This is critical for developing fire regime management protocols for Fraser Island and the Great Sandy Region in the future.

2.5 Ross Waldron (Honours)

Project title: Comparing the impacts of wildfire and prescribed burning on woody understorey composition and the reaction of eucalypt regeneration in a dry open forest.
Supervisors: Associate Prof. Neil Tindale [1] and Dr Valerie Debuse[2].
Institution: University of the Sunshine Coast[1] and Agri -science Queensland, the Department of Agriculture, Fisheries and Forestry[2].
Email: mangaross@hotmail.com

Background and aims:
Determining how often to carry out management burns to reduce fuel loads within forests is a balance between managing fire risk while optimising the health, diversity and resilience of forest ecosystems. While frequent low intensity hazard-reduction burns are carried out to reduce fire risk in urban and peri-urban areas in south east Queensland, longer inter-fire intervals are often recommended to maintain the ecological resilience of forests, but which also increase the risk of high intensity wildfires occurring. When wildfires do occur after long periods of fuel accumulation, the effects of single high intensity fires on plant community dynamics are likely to contrast from those caused by frequent lower intensity burns due to the combination of differing intensity and frequency of fire.

Understanding the comparative effects of prescribed burns and occasional wildfires on the resilience and health of forest ecosystems is vital to inform best-practice fire management strategies in south east Queensland. However, pertinent studies relevant to south east Queensland forests are rare, partly because previous fire history is often unknown or is a complex sequence of prescribed burning and wildfires, which can confound pre- and post-wildfire comparisons at a site. The Department of Agriculture, Fisheries and Forestry's (DAFF) long-term fire experiment in Bauple State Forest provides a unique and important opportunity to compare the ecological impacts of highly contrasting fire management strategies. The experiment has a known fire history since 1946 and comprises of a long unburnt area and two frequently burnt treatments (every 1-3 years). Part of the long unburnt treatment was burnt once by a wildfire in 2006 after a 60-yr absence of fire, creating a fourth treatment.

This study aims to quantify the impact of a single high intensity wildfire on woody understorey vegetation composition and compare it to compositional changes in two frequently burnt areas. The project will assess the changes in woody understorey vegetation composition from a pre-wildfire measure in 1993 to post-wildfire measures recorded in 2007 and 2014. The project also aims to compare the post-wildfire changes (2007-2014) in understorey composition in the wildfire treatment with compositional changes in the remaining long unburnt area over the same period. This study will also examine the response of eucalypt regeneration for the prescribed vs arson treatments. These studies are important in native forest research for determining how resilient a native forest is to repeated burning vs arson in terms of future wood production.

These trends will then be compared to compositional changes in understorey vegetation in two frequently burned treatments: (1) an area burned every year since 1952 and (2) an area that has been burned every 3 years (on average) since 1973. This work will build on the recently published study on long-term changes in woody vegetation dynamics at this site that focused on the pre-wildfire period (Lewis and Debuse 2012). The impact of wildfire on height class variations (understorey structure) is likely to be determined separately from this project, unless there is sufficient time within the scope of the honours project.

Methods and Analysis:
The study will be carried out at the DAFF's long-term fire experiment at Bauple State Forest that was established in 1952. The long-term experiment is situated in a dry sclerophyll or open forest that is dominated by spotted gum (*Corymbia citriodora* subsp. *variegata*) with subdominant grey ironbark (*Eucalyptus siderophloia*), white mahogany (*E. acmenoides*), forest red gum (*E. tereticornis*), broad-leaved ironbark (*E. fibrosa*) and pink bloodwood (*C. intermedia*). Dry sclerophyll forests represent the predominant forest type in regional and peri-urban areas of south east Queensland and are associated with relatively high levels of fuel accumulation compared with some other ecosystems. Thus, they are a highly relevant forest to study for improving fire management outcomes in south east Queensland.

Woody understorey vegetation will be assessed within 100 × 1 m belt transects, each of which is located at the northern margin of a 100 x 40 permanent plot. Woody vegetation will be recorded in five transects within the wildfire treatment and six transects within each of the remaining three treatment areas: long unburnt since 1946, annually burnt since 1952 and triennially burnt since 1973 (n = 23). The density and species (or species groups) of woody understory plants (≤ 7.5 m height) will be measured for three height classes: 0 – 1 m, 1 – 3 m and 3 – 7.5 m. Historical measure data will be obtained from DAFF. Analysis of compositional data will be carried out by multivariate analysis techniques using software such as Primer or Canoco, which will be provided by DAFF. Any comparisons of single species between pre- and post-fire periods or among treatments will be carried out using General Linear Models.

Timing:
Field study will occur for three weeks between March and May, yet to be determined, with completion of Honours project analysis from the new data in spring 2014.

3.0 Research Paper Summaries

3.1 Bradstock *et al*. (2012) Summary by Sam Lloyd

Bradstock, R.A., Boer, M.M., Cary, G.J., Price, O.F., Williams, R.J., Barrett, D., Cook, G., Gill, A.M., Hutley, L.B.W., Keith, H., Maier, S.W., Meyer, M., Roxburgh and Russell-Smith, J. (2012). Modelling the potential for prescribed burning to mitigate carbon emissions from wildfires in fire-prone forests of Australia. *International Journal of Wildland Fire* 21, 629 - 639.

Professor Ross Bradstock from the Centre for Environmental Risk Management of Bushfires at the University of Wollongong heads another stellar list of fire ecologists in this paper examining the potential for prescribed burning to mitigate carbon emissions from wildfire using modelling. The authors recognise that the contribution of carbon and greenhouse gases from vegetation fires is substantial and has the potential to rise in the future. Therefore, management strategies that reduce emissions from wildfire may play an important role in mitigating climate change via reduced vegetation burning. One of the most favourable strategies is that fuel is reduced via prescribed burning, which in itself increases carbon emissions, but overtime decreases overall carbon emissions due to the prevention or reduction in the severity of large, intense unplanned wildfire. Research from North America and Europe provides evidence that the mitigation of wildfire via fuel modification is potentially able to substantially reduce carbon emissions. In recent years, there has been increasing discussion in Australia around the land management strategy that prescribed burning can potentially (and possible substantially) reduce carbon emissions from unplanned fires. However, the effectiveness of this strategy largely depends upon the vegetation type (and thereby fuel type and accumulation), environment and fire characteristics and therefore the "*efficacy*" of prescribed burning in reducing unplanned fires. Obviously, long-term reduction in emissions will not occur if emissions from prescribed burning exceed those from unplanned fire. To measure this potential for reduced carbon emissions knowledge of both the efficacy of fuel treatments in combination with emission estimates is required for the ecosystem or vegetation type being studied. Australia contains a range of fire-prone temperate eucalypt forest that burn regularly and therefore offer significant potential to mitigate carbon emissions, however the authors rightly identify that a "*comprehensive assessment is required*" to determine the potential reality of this strategy.

The authors used a "*general conceptual model*" based on the difference between the "*outlay*" and "*savings*" of emissions resulting from differing rates of prescribed burning and decreased wildfire activity, respectively to evaluate the potential for the strategy to be utilised in temperate eucalypt forest. The model was run for a daily time period over a 500 year period for each fuel type (low, moderate and high rate of fine fuel accumulation), with fire weather sampled randomly from the defined distribution in each year and all models runs were repeated 1000 to obtain means and confidence intervals.

The authors found that mean "*inter-fire interval*" (based on an interaction between prescribed and unplanned fire) decreased with increased prescribed fire treatment in all fuel types. However, estimates of mean fire intensity (prescribed plus wildfire combined) declined with increasing prescribed burning in all fuel types. The authors also found that mean fuel consumption by prescribed fires was approximately 40% of that of wildfire Moreover, whilst relative fuel consumption increased with increasing rate of prescribed fire treatment, the range of the increase was relatively small and did not differ substantially between fuel types. Overall, the mean rate of fuel consumption decreased with increasing "*leverage*". The authors define "*leverage*" as "*the area of unplanned fire reduced per unit area of prescribed fire*". Therefore, low leverage indicates relatively low effectiveness of prescribed burning in reducing the percentage area of the landscape burnt per year. At high leverage, fuel consumption was found to decrease with an increase from low to moderate treatment. Whilst at low leverage the rate of fuel consumption increased with prescribed burning.

Overall, the potential for the mitigation of carbon emissions via the use of prescribed burning in south-eastern eucalypt forest was predicted to be limited on this basis of this model. Specifically, high rates of prescribed burning may lead to either no change or a net increase in emissions, relative to no prescribed burning, due to predicted trends in fuel consumption. This is further illustrated by the relatively low leverage of prescribed burning, i.e. prescribed burning in temperate eucalypt forest is not very effective at reducing the area of unplanned fire per unit area of prescribed fire. The authors go onto to discuss how the relatively low rates of leverage reflect a low rate of "encounter" between treated areas and areas subsequently exposed to wildfire. For example, Price and Bradstock (2010) found that only 22.5% of prescribed burn patches were encounted within 5 years by subsequent wildfire in Sydney eucalypt forest. Five years being defined as the time period where maximum reduction in wildfire spread and severity will be achieved.

Whilst prescribed fire is unlikely to mitigate increasing carbon emissions in temperate eucalypt forest, the authors identify that there may be the potential to alter the chemical form or mix of greenhouse gases (i.e. the mix of CO, CO^2, N_2O, CH_4) with environmental benefits. However, the authors also recognise that climate change may increase the frequency and intensity (and therefore fuel consumption) of wildfire in south-eastern Australia thereby further reducing the efficacy of prescribed burning in mitigating carbon emissions. The results described in this study are in contrast to the situation in tropical north Australian savannas. Higher efficacy (i.e. leverage) of prescribed fire in savannas coupled with the huge area of savannas and annual extent of fires may indicate greater potential for prescribed burning to mitigate carbon emissions in these landscapes. Overall, these results support previous simulation models for the western USA, but do not, however, rule out the potential usefulness of prescribed fire to mitigate carbon emissions in the arid woodlands and shrublands of inland Australia.

3.2 Driscoll *et al*. (2010) Summary by Sam Lloyd

Driscoll, D. A., Lindenmayer, D. B, Bennett, A. F., Bode, M., Bradstock, R. A., Cary, G. J., Clarke, M. F., Dexter, N., Fensham, R., Gordon, F., Gill, M., James, S., Kay, G. Keith, D. A., MacGregor, C., Russell-Smith, J., Salt, D., Watson, J. E.M., Williams, R.J. and York, A. (2010). Fire management for biodiversity conservation: Key research questions and our capacity to answer them. *Biological Conservation* 143, 1928 - 1939.

This paper has been authored by some of Australia's most prominent ecologists and fire ecologists and despite being three years old, I believe it is a paper we need to examine when considering the need and capacity for fire research in South East Queensland. Inappropriate fire regimes can substantially alter ecosystem structure and function and increase the risk of localised extinction.

Climate change is predicted to increase the likelihood of wildfire and alter fire regimes and therefore poses both a serious threat and highlights the increased importance of sustainable fire management for biodiversity conservation and sustainable land management. Obviously, we need to know how flora and fauna species respond to current or varying fire regimes in order to adequately plan for sustainable ecological management. The authors identified three areas of knowledge needed to achieve a goal of sustainable ecological fire management: (1) "*a mechanistic understanding of species' responses to fire regimes*"; (2) "*knowledge of how the spatial and temporal arrangement of fire regimes into fire mosaics influences the biota*"; and (3) "*an understanding interactions of fire regimes with other processes that can either modify the response of species to particular fire regimes, or modify the regimes directly*". In this paper the authors review available research with respect to addressing these knowledge requirements and identify several limitations.

A mechanistic understanding of species' responses to fire regimes: The authors acknowledge that despite recognising the importance of monitoring, few species can be monitored at length, this being particularly true for animal species and as such most research and fire management strategies have focussed on plant species and vegetation groups. Commonly, fire management frameworks classify plant species into broad vegetation groups and define upper and lower limits to fire regime components. This narrow focus on fire intervals and particular species may not be the most successful strategy for all plants or animals. The "*plant functional-type approach*" has been recognised as offering greater success with respect to plants and it is predicted that it may be possible to apply it to animal functional groups. However, utilising the functional trait framework to better represent the needs of animals requires further research and understanding that the authors categorise into five key areas: (1) animal life-cycles, movements and habitat resources; (2) the influence of fire regime spatial distribution on availability of limiting resources; (3) development of functional classifications for animals based on life histories, resource use and behaviour; (4) identifying thresholds of fire spatial and temporal patterns that maintain habitat resources and animal populations; and (5) testing and refining predictions as needed.

Knowledge of how the spatial and temporal arrangement of fire regimes into fire mosaics influences the biota: The authors unsurprisingly identify that the influence of the spatial arrangement of fire regimes on species persistence is poorly understood and in order to mitigate localised extinction information is needed about species responses under various fire regimes and at different sites throughout a region. Whilst the use of fire mosaics is often encouraged, this commonly occurs without clear specifications around mosaic size, extent or intensity. Indigenous fire management practices provide evidence that "*fine-grained mosaic of fire ages promotes habitat heterogeneity*" and this may be a beneficial strategy for intact habitats. However, in fragmented landscapes such a strategy may not be as useful if vegetation patches are too small or altered to allow for the necessary variation in fire size and/or interval. The scale of applied fire mosaics is identified as one of the most pressing questions, especially when considering fire management strategies applied at a scale smaller or larger than the scale at which key biological processes operate.

Understanding interactions of fire regimes with other processes that can either modify the response of species to particular fire regimes, or modify the regimes directly: The effect of fire on a particular species and its potential recovery after fire depends on a range of biotic and abiotic factors, including removal of habitat features (e.g. salvage logging after fire), rainfall and herbivory. Three key processes identified as being particularly important are: (1) climate change, (2) invasive grasses, and (3) habitat loss and fragmentation.

To better understand how well fire research can address fire management issues the authors examine four key areas of research: (1) manipulative experiments; (2) natural experiments; (3) longitudinal studies and (4) simulation modelling. Each research method has a range of "*filters and limitations*" that constrain the type and amount of data that can be collated, the most prominent being that "*detailed knowledge can only be obtained for a limited set of species*". The best applications of the four research methods range from looking at the long term and large scale effects of fire regimes using simulation modelling, testing relationships and studying short fire interval questions using manipulative experiments, studying the long term effects of fire severity and extinction risk using longitudinal studies and using natural experiments to study short term effects of severity and patchiness and long term effects of fire regimes. However, three broad knowledge gaps were identified as overlapping across the four research methods, these being: (1) the ability of link species traits to response and fire regime; (2) knowledge of how species are influenced by spatial and temporal fire mosaics and (3) knowledge of how key influences such as weather, predation and habitat fragmentation interact with fire to alter species response to fire. The authors identify that the research that has most influenced management has been the identification of "minimum and maximum fire intervals" for particular species, primarily plants and the use of modelling study the potential outcomes of various management options.

In conclusion, the authors suggest four key areas of required research to better enable informed adaptive fire management planning for biodiversity conservation: (1) a species-level approach to measuring biodiversity responses to fire, thus facilitating an understanding of wildlife responses in particular needed for use in simulation modelling; (2) natural experiences with accurate mapping need to examine long-term, large-scale fire processes with the potential to examine a range severity, spatial and temporal intervals; (3) simulation modelling utilising information from the afore mentioned research methods; and (4) experimental approaching that utilise natural fires to test for fire interactions with other processes. How we can apply these recommendations in SEQ does in large part depend upon available funding for existing researchers and their students, resources available to land managers and importantly highlights the need for land managers and researchers to collaborate on fire ecology research that informs fire management, which also requires that land managers have the capacity (i.e. time and resources) to be involved in such valuable research.

3.3 Daniau *et al*. (2012) Summary by Sam Lloyd

Daniau, A.L., Bartlein, P.J., Harrison, S.P., Prentice, I.C., Brewer, S., Friedlingstein, P., Harrison-Prentice, T.I., Inoue, J., Izumi, K., Marlon, J.R., Mooney, S., Power, M.J., Stevenson, J., Tinner, W., Andric, M., Atanassova, J., Behling, H., Black, M., Blarquez, O., Brown, K.J., Carcaillet, C., Colhoun, E.A., Colombaroli, D., Davis, B.A.S., Costa, D.D., Dodson, J., Dupont, L., Eshetu, Z., Gavin, D.G., Genries, A., Haberle, S., Hallet, D.J., SEQ Fire & Biodiversity CONSORTIUM

Hope, G., Horn, S.P., Kassa, T.G., Katamura, F., Kennedy, L.M., Kershaw, P., Krivonogov, S., Long, C., Magri, D., Marinova, E., McKenzie, G.M., Moreno, P.I., Moss, P., Robinson, G.S., Sasaki, N., Scott, L., Takahara, H., Terwilligar, V., Thevenon, F., Turner, R., Valsecchi, V.G., Vanniere, B., Walsh, M., Williams, N. and Zhang, Y. 2012 Predictability of biomass burning in response to climate change. *Global Biochemical Cycles 26.*

This very interesting and relevant paper examines the relationship between fire, temperature and precipitation using historical charcoal records and modern climatic data to predict likely changes in fire patterns with climate change. Interactions between climate, vegetation and fire regimes are complicated by the influence of direct human intervention (i.e. planned burning) and indirect human activities resulting in habitat fragmentation and fuel reduction. Whilst it is recognised that climate is an important control on biomass burning, the sensitivity of fire to historic changes in temperature and moisture balance has not been documented. Moreover, this information is becoming more valuable as people aspire to study and predict how fire regimes may respond to climate change. The relationship between increased fire and a warming climate is described by the authors as being primarily due to increased fuel loads as a result of increased vegetation growth and a longer fire season supporting fire weather. The authors recognise that most studies are constrained by available temporal data and using sedimentary charcoal records may allow for analysis of fire regimes over centennial timescales. The authors analyse sedimentary charcoal records (i.e. biomass burning) over the past 21,000 years (including an analysis of modern data between 1996 and 2008) to examine patterns of fire regimes and regional climate changes.

The authors found a general pattern of increase in biomass burning with increasing temperatures in both the northern and southern hemispheres. However, this relationship was not found to be linear, with the increase in fire per unit increase in temperature greater in warmer climatic conditions than in cooler temperatures. Moreover, moisture plays an important role, where by under relatively dry conditions an increase in precipitation (less evaporation) is associated with increased fire and under relatively moist conditions an increase in precipitation (less evaporation) is associated with a decrease in fire, with intermediate moisture levels resulting in the greatest fire. Importantly, the authors also found a similar pattern between fire, temperature and moisture when looking at monthly data between 1996 and 2008, indicating climate change and global warming will likely provide for increased global fire, especially in regions predicted to experience increased drought. In regions where fuel is not currently a limiting factor and precipitation is predicted to increase (e.g. high northern latitudes) fire is expected to decrease. However, model simulations suggest that the predicted increases in precipitation are unlikely to offset temperature associated increases in fire. Overall, the results suggest that temperature is likely to be the "*dominant driver*" of fire with respect to climate change. The authors also recognise that whilst some studies suggest that modern land management and landscape fragmentation may have been associated with a twentieth century decrease in global fire incidence, a large number of studies have found an increase in fires in the last two decades and these increases have been linked to increasing global temperatures. These results further indicate fire incidence and hazard will increase with increasing global temperatures and supporting the need for effective and cooperative landscape scale fire management.

3.4 Gibbons *et al*. (2012) Summary by Sam Lloyd

Gibbons, P., van Bommel, L., Gill, A. M., Cary, G. J., Driscoll, D. A., Bradstock, R. A., Knight, E., Moritz, M. A., Stephens, S. L. and Lindanmayer, D. B. (2012) Land Management Practices Associated with House Loss in Wildfires. *PLOS one* (7) 1.

This freely accessible and very practical paper examines the relationship between house loss, fuel characteristics and vegetation features as related to different fuel management treatments. The paper looks at the effectiveness of some current management regimes and proposes a series of recommendations, as identified from research arising from the tragic Black Saturday bushfires. Specifically, the authors predicted that "*modifying several fuels could theoretically reduce house loss by 76% - 97%*", this in turn reducing loss of life.

Houses destroyed during wildfire are due to: (1) exposure to flames in adjacent fuels; (2) radiant heat from nearby fuels (typically less than 40m); and (3) airbourne embers and firebrands from nearby and distant fuel (typically <10km). However, wildfires are very difficult to study and so the importance of these different fuels and effectiveness of different treatments is relatively unknown. The authors identify that current fuel reduction activities are commonly broad-scale and at a distance (mean distance of 8.5km from houses in this study) from peri urban communities. Moreover, evidence that such fuel reduction activities mitigate impacts on peri urban communities are limited.

In this study the authors sampled 499 houses to quantify the effects of different fuel types on house loss. At each house they recorded 24 potential variables representing the key aspects of fire behaviour (i.e. weather, terrain and fuel) that may help explain house loss. Predictions for each fuel variable were made with the Forest Fire Danger Index (FFDI) held at 100 (this being the value for FFDI above which 64% of houses have been destroyed in Australian wildfires).

A logistical regression model with eight significant explanatory variables was used to predict house loss. The model indicated that the most significant fuel variables leading to a greater proportion of house loss were: (1) where there was a higher percent cover of trees and shrubs within 40m of dwellings; (2) where trees and shrubs within 40m of dwellings were dominated by remnant native vegetation rather than planted; (3) where there were more buildings within 40m; (4) where groups of trees or shrubs were clustered together in the upwind direction; (5) where the upwind distance from houses to prescribed conducted within 5years was distant rather than close; and (6) where dwellings were closer to public forested land (i.e. less private land) in the upwind direction. An alternative model also indicated that houses were at a similar risk when they occurred close to either national parks or state forest.

Unsurprisingly, the authors found that weather had a strong effect with more houses lost at higher temperature and wind speed and lower relative humidity. None of the variables representing terrain were significant in the selected model.

The fitted logistic model also indicated that reducing fuel could substantially reduce the number of houses destroyed during severe wildfires. Specifically, the authors found that minimising key fuels at every house could potentially reduce the percent house loss from the observed value of 35% to a predicted mean of 4.6% (+/- 1.9% standard error mean). This equates to a reduction in house loss of 76% - 97% (with a 95% confidence interval). However, the amount of fuel reduction required to achieve this also equates to serious vegetation loss and therefore, requires consideration of other ecological consequences. The authors predicted that reducing native vegetation within 40m around houses from 90% cover to 5% cover reduced the likelihood of house loss by 43%. Therefore, every 10% reduction in remnant native vegetation cover within 40m of houses reduces the likelihood of house loss by approximately 5%. Moreover, 38% fewer houses were destroyed if surrounded by primarily planted vegetation, rather than remnant native vegetation. However, given many people move to peri urban areas to be "closer to the bush" and have more vegetation around them this is not necessarily going to be a management recommendation well received by all landowners. It does, however, present people with indisputable facts and once provided with the information people can consider their options and the consequences and ideally work with their local Rural Fire Brigade and organisations like the SEQFBC to plan options to reduce their risk.

In terms of distance to areas of prescribed burning and public forested areas, the authors found that (1) 14% fewer houses were lost if located 200m from public forest, rather than 10m; (2) 26% fewer houses were lost if 2km from public forest; and (3) on average 15% fewer houses were lost if prescribed burning within 5years was undertaken 0.5km upwind from houses (the nearest distance between houses and prescribed burning), rather than 8.5km upwind from houses (the average distance between houses and prescribed burning). Importantly, the authors found that the proximity to houses of prescribed burning was more important than the total percentage of the landscape that is prescribe-burnt.

Overall, the authors found that modifying key fuels within close proximity (<40m) of houses could substantially reduce house loss during wildfires in extreme weather conditions. This also extends to a reduction in loss of life as many deaths occur when people shelter in a house that is exposed to flames and subsequently ignites (69% of lives lost during the 2009 wildfires examined in this study were in houses). The authors suggest that their results support a move from broad-scale fuel reduction management actions to intensive hazard reduction activities closer to properties. Issues of concern with the application of these recommendations are recognised by the authors, including the reality that maximum fuel reduction activities are unlikely to be possible at every at risk property due to funding/resourcing, access and other environmental and logistical reasons.

Whilst issues of resourcing and the reality of substantial fuel reduction in close proximity to houses is a serious consideration for public land managers, this paper also highlights the opportunities that exist for those of us working with private landowners and the community. Private landowners are able to examine options for modifying fuel within close proximity to their home, without necessarily compromising the ecological and asthetic values for which they purchased the property. As the paper shows, planted native vegetation does not pose the same level of risk and provides opportunities for landholders to reduce high risk vegetation in place of planted vegetation. The SEQFBC will be taking the findings from this paper into consideration with the current review of the manual for the Fire Management Planning Workshops for private landholders. Landholders are also encouraged to refer to the document “Landscaping for Bushfire”, published by the Victorian Country Fire Authority (www.cfa.vic.gov.au).

3.5 Heckbert *et al*. (2012) Summary by Rebecca Laws

Heckbert, S., Russell-Smith, J., Reeson, A., Davies, J., James G. and Meyer C. (2012) Spatially explicit benefit-cost analysis of fire management for greenhouse gas abatement. *Austral Ecology* (37) 724 - 732.

This paper does the maths to determine the financial scope for prescribed burning to acquire carbon offset credits in Northern Australia. Three different estimates of how much carbon can be sequestered through prescribed burning early in the year in savannah habitats (25%, 34%, 48%) based on other studies are explored. The price of fire management is estimated from the WALFA project plus additional project costs gave them a cost of $12.83/tonne. Carbon abatement through fire management was found to be financially viable for 51 million hectares of tropical savannah. However, the paper lacks the detail of the finer scale vegetation types and land topography which are likely to impact on regional viability. The paper strongly argues that there would be extensive benefits for remote indigenous communities not only financially but also for enhancing their cultural heritage through expanding cultural burning practices. However the paper doesn’t give in in-depth analysis of the differences between an ideal indigenous cultural fire regime and a regime that would be ideal for carbon sequestration.

3.6 Kelly *et al*. (2012) Summary by Mark Panter

Kelly, L. T., Nimmo, D. G., Spence-Bailey, L. M., Taylor, R.S., Watson, S.J., Clarke, M. F. and Bennett, A.F. (2012) Managing fire mosaics for small mammal conservation: a landscape perspective. *Journal of Applied Ecology* 49, 412 - 421.

The maintenance of 'fire mosaics' comprising spatially heterogeneous patches of differing fire history is a common management objective. However, the specific characteristics of fire mosaics most likely to enhance the conservation of fauna in particular ecosystems is still poorly understood.

This paper describes a broad-scale, whole-of-landscape study of the spatial and temporal properties of fire-prone landscapes that influence the distribution of small mammals in the semi-arid Murray Mallee region of Australia. This differs from previous research which has largely been conducted at a site level, thus preventing direct comparison and understanding of how combinations of spatial features influence fauna.

Small mammals were surveyed within 28 landscapes (each 12.6 km2) representing a range of fire histories, and different fire mosaics, across an area of 104 000 km2. In what is believed to be a first, generalised linear mixed models were used to examine the relative influence of fire mosaic landscape properties on the capture rate of individual species and the species richness of native small mammals. The five landscape properties investigated included the influence of the proportional extent of fire age-classes, the diversity of fire age-classes, the extent of the dominant vegetation type, rainfall history and biogeographic context.

The study resulted in 1265 captures of seven mammal species. Three of the four most commonly encountered species were positively associated with the spatial extent of fire age classes. In particular, older vegetation and vegetation of a suitable seral stage post fire was found to provide important habitat for native small mammals. However, overall, rainfall and biogeographic factors were found to be the dominant influences. Rainfall recorded 6 months prior to trapping was found to exert a substantial influence on the species richness of small native mammals. Higher annual rainfalls and rainfalls above the long-term average were both positively associated with species richness. Biogeographic factors were also influential across the study area. Three of the four most commonly encountered species were positively associated with the northern, more arid, landscapes. This may be attributed to environmental gradients associated with a study conducted at a whole-of-landscape scale. Practitioners of patch mosaic burning for biodiversity conservation need to consider both the ecosystem characteristics and the requirements of any priority species. This study has identified the retention of older vegetation and vegetation of a suitable seral stage as a key requirement for retention of small native mammals.

It has also highlighted some of the opportunities and constraints associated with a whole-of- landscape approach to the study of fire mosaics and their influence on small mammal distribution. In particular, practitioners and land managers should be cognisant of biogeographic influences and rainfall variation when developing proposals for mosaic burns.

3.7 Lewis *et al*. (2012) Summary by Guy Morgan

Lewis, T, Reif, M, Prendergast, E & Tran, C (2012) The effect of long-term repeated burning and fire exclusion on above- and below-ground Blackbutt (*Eucalyptus pilularis*) forest vegetation assemblages. *Austral Ecology* 37, 767 – 778.

Undertaken in Peachester State Forest on the border of the Sunshine Coast and Moreton Bay Regions, SEQ, this study investigates the influences of three fire treatments on *Eucalyptus pilularis* forests (Regional Ecosystem 12.9-10.14) understorey species (<7.5m) and the related vegetation characteristics. The three experimental fire treatment areas consisted of long un-burnt (since 1969), biennial and quadrennial burns (since 1971-1972). Experimental fire treatment areas ranged from 1.3 – 2 ha and considered to be typically low intensity (<2500kW m^{-1}) patchy burns. 17 biennial and eight quadrennial burns were undertaken since the early 70's in the months from June to September.
Soil composition varied across the sites, but aspect and slope were similar (north facing and ~10° respectively). The two sampling sites were categorised as north and south (2.8km apart) consisting of six sampling plots (0.08 ha) with three subplots (6x1m) in each plot.
The specific aim of the study was to answer the following research questions:

1. How do standing vegetation composition, structure and richness and soil-stored species composition and richness vary between frequently burnt areas (biennial and quadrennial prescribed burning) and areas that have not been burnt for 40 years? More specifically, do frequently burnt areas have a lower density of tall woody understorey plants and a higher density of short-lived herbaceous species?
2. Does the density of resprouting species, obligate seed-regenerating species and short-lived species with transient seed banks in the standing and soil-stored vegetation vary among the three fire regimes studied, and do heat and smoke treatments influence seed.

Key results and key discussion points are provided below. A variety of results showed significant differences between treatment, site and treatment by site.

(1) Standing vegetation richness, density and composition: No significant differences were detected for species richness between treatments for standing vegetation <3m in height. The discussion nominated species replacement being the cause and suggested that differing fire treatments are important for species diversity / composition. Rainforest tree and shrub species were identified as the replacement species across the unburnt areas and the quadrennial burn sites resulted in an intermediate mix of species. Biennial burns showed a prevalence of herbaceous taxa, resprouting shrubs and bracken fern.

Native species density was higher in the burnt areas for vegetation 0-1m and 1-3m in height. This was attributed to higher numbers of resprouting species. Resprouter density (>3m) was higher in the quadrennial burn treatment, attributed to temporal growth opportunities. There were no resprouter species (3m – 7.5m) in the biennially burnt sites.

Grass species richness was higher in burnt areas, with density responding inconsistently across sites. Southern sites showed higher density in burnt areas (both treatments) whilst the northern site carried higher densities in the quadrennial burn sites. The authors note that frequent fire regimes aimed at reducing fuel loads result in a more flammable understorey, increasing the probability of fire, but suggest that an understorey of grasses could be desirable in reducing crown fires.

Obligate seeder species (<3m) richness and density did not differ between treatments.
Standing vegetation composition was affected by treatments (contributing to 36.3% of variation), but site influences showed the greatest influence (63.7%).

(2) Soil stored vegetation richness and composition: Soil species composition was affected by the various burn treatments and the authors note that for certain plant groups soil stored vegetation may provide insights where effects are not evident in standing vegetation.

Soil forb density was lower in the quadrennial burn treatment compared to unburnt and biennial treatments and grass density was lower in the biennial treatment, whereas, fern density was highest in the biennial treatments. Soil tree and tall shrub richness was highest in the unburnt treatment, with no difference between burn treatments. Obligate seeder richness was lower in the biennial treatments with no difference in other treatments. Suggesting that less frequent burning favours soil stored obligate seeder species. *E.pilularis* was common in all soil samples, but many other species from the standing vegetation were absent or uncommon in the soil (e.g. *Imperata cylindrical* and *Themeda triandra* respectively). *Dodonaea triquetra* was common in the burnt areas in both standing vegetation and soils samples.

Separate soil heating (heated to 80°c for 15min) and smoke treatments (1x1m sealed tent exposed for 30min, using *E. pilularis* forest litter) un-expectantly, produced no significant results and this was withdrawn from further analysis. The discussion highlighted a number of possible causes such as: burn condition replication anomalies, the potential for a combined treatment of heat and smoke producing results and a possible relationship in Blackbutt forests with canopy reduction by fire and gap driven canopy tree recruitment triggered by resource availability (e.g. light) as opposed to heat or smoke. Treatment effects were significant (contributing to 41.4% of differences), but again, site effects had the greatest influence (59.6%) on soil stored vegetation.

3.8 Liu *et al*. (2013) Summary by Sam Lloyd

Liu, X., Chen, C.R., Wang, W.J., Hughes, J.M., Lewis, T., Hou, E.Q. and Shen, J. (2013) Soil environmental factors rather than denitrification gene abundance control N20 fluxes in a wet schlerophyll forest with different burning frequency. *Soil Biology and Biochemistry* 57, 292 – 300.

The production of nitrous oxide (by anaerobic denitrification) is an essential process with regards to the global nitrogen cycle, which in turn has a substantial impact on climate change. This influence on climate change has resulted in increasing interest in recent years. Fire is a crucial driver of ecosystem processes and has an important role to play in nutrient/nitrogen cycling, however, the mechanisms involved are largely unclear. In this study, the authors use a 35 year old repeated burning trial to examine the impact of different fire regimes on nitrous oxide (N2O) flux, inorganic nitrogen, dissolved organic carbon, pH, electrical conductivity, moisture, denitrification gene abundance and their interactions. The data set comprised three treatments (no burning, 2 yearly burning and 4 yearly burning) and soil samples were collected in January and April 2011. The analysis found that more frequent fire (2 yearly) significantly reduced soil N2O fluxes, availability of carbon and nitrogen substrates and moisture, but increased soil pH and electrical conductivity compared with the other two treatments. N_2O emissions were controlled by soil environmental factors rather than denitrification gene abundance.

3.9 Williams *et al*. (2012) Summary by Patrick Moss

Williams, P.R., Parsons, M., Jensen, R., and Tran, C. 2012 Mechanisms of rainforest persistence and recruitment in frequently burnt wet tropical eucalypt forests. *Austral Ecology* 37, 268-273.

It has long been assumed that absence of fire over decadal and centennial scale in wet tropical eucalypt forest, and in general wet sclerophyll forests across eastern Australia, corresponds (particularly during the European settlement period) to the development and expansion of dense rainforest into these ecotones. This pertinent and interesting paper examines the mechanisms and processes associated with this, particularly examining rainforest plants ability to survive frequent fires and form a seed source for this expansion. The authors used 14 years of data collected from 13 plots positioned across the eucalypt –rainforest ecotone of the Wet Tropics of north-eastern Australia to examine rainforest seedling recruitment and post-fire regenerative capacity. The study found that the recruitment of new rainforest plants within the ecotone was most abundant in the initial year after the fire and if this post-fire pulse of recruitment is left undisturbed, subsequent germination of additional rainforest species can be facilitated. This finding is in contrast to previous theories of rainforest recruitment, which is thought to be delayed until several years of fire absence. The authors propose that the removal of grass cover is critical to abundant rainforest recruitment, whether temporarily in the immediate post-fire environment or once a developing rainforest mid-strata shades out grasses. Another important finding of this study was the ability of tropical rainforest species to persist under frequent fire regimes through resprouting. However the mode of resprouting is significantly different from eucalypts, with rainforest taxa resprouting through ground-level coppicing, while eucalypts resprout through the canopy (i.e. epicormic shoots). This is the crucial factor that results in regular fire maintaining an open structure in wet tropical eucalypt forest through the inability of rainforest plants to maintain their heights when fires fully scorch their crowns and in contrast to eucalypt species ability to maintain height through epicormic shoots.