PhD Proposal:

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The compositional, structural, and functional succession of beetle communities in habitat mosaics created by differing fire regimes in the southern coastal forests of Western Australia.

ABSTRACT

- To inventory the speciose beetle fauna of the landscapes of the Southern forests, probably 20% of biodiversity.
- To compare different beetle communities found in wildfire and mosaic fire regimes.
- To assess different sampling methods for collecting beetle taxa.
- To determine fire impacts on entire biodiversity by the simultaneous monitoring of changes in beetle taxonomic diversity, structural diversity and functional diversity.
- To recommend fire management guidelines to maximize regional biodiversity of floor beetles (ground and litter) in Southern forests.

BACKGROUND

- Arthropods makeup more than 80% of Earth's 12 million living species (Stork 1999).
- Biodiversity of invertebrates essential to "healthy" ecosystem function.
- Biodiversity not well defined (Franklin *et al.* 1981, Noss 1990).
- Past fire impact studies did not monitor all 3 components of biodiversity.
- Determining impacts on entire biodiversity requires the simultaneous monitoring of all 3 components.
- Hierarchy theory provides a systematic framework for comparing the appropriate spatial (& temporal) scales of these impacts.
- A recent review provides a systematic protocol for selecting the most useful bio-indicator taxa for monitoring biodiversity impacts.

LITERATURE REVIEW

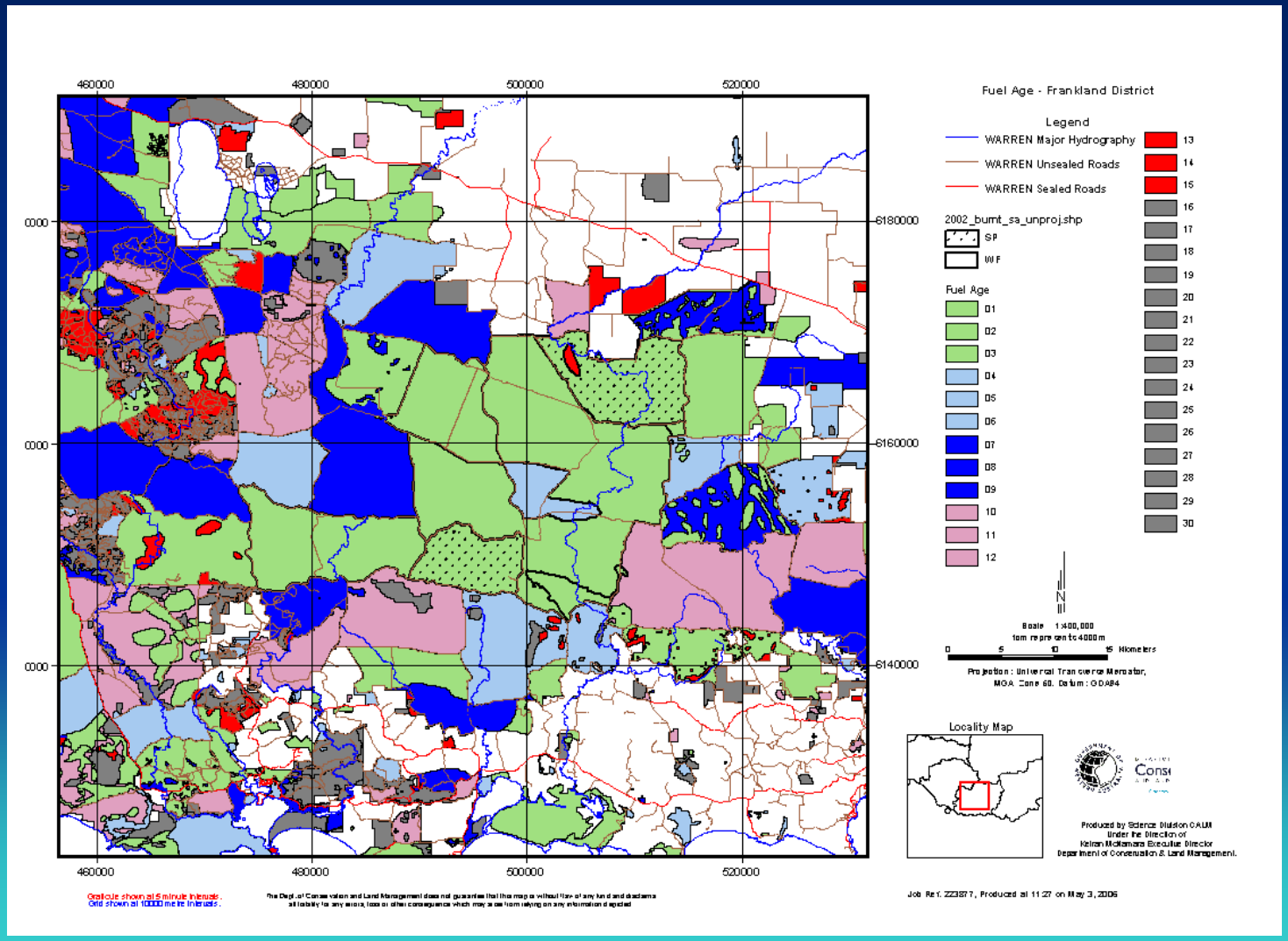
- PVH & IA recently wrote chapter in SW fire book which reviewed invert fire research in SW to 2003.
- PVH worked as a TO for 25 years in CALM on fire research.
- SW ecosystems have been highly fire prone for at least the last 15 million years.
- Changed fire regimes since European settlement of less frequency and hotter fires.
- Different landscapes have different fire regimes.
- Each SW invertebrate taxa is favoured by different post fire habitats.
- Large intense wildfires reduce habitat diversity.

March 2003 Wildfire

Photo courtesy Ted Middleton, Walpole

2003 Wildfire Size and Fuel Age (at May 2006)

Map courtesy Tom Hamilton, Bushfire CRC



Wildfire Crown Damage
after 19 months, Oct 2005

Small Grained Mosaic Fire
after 1 month, April 2006

HYPOTHESIS & OBJECTIVES

- H_1: The “small grain mosaic” fire regime maximizes the taxonomic, structural and functional components of biodiversity of the beetle floor communities in the southern forests.
- O1) Inventory the regional floor beetle fauna, including short range endemic species (paper 1).
- O2) Test the objectivity of methods for monitoring disturbance impacts on the 3 components of beetle biodiversity (papers 2a, 2b, 3, 4 & 5).
- O3) Describe the biodiversity responses of ground and litter beetle communities to long-term disturbance by the wildfire and mosaic fire regimes (papers 6, 7 & 8?).
- O4) Provide recommendations and guidelines in the use of managed fire to maximize future invertebrate biodiversity (papers 6, 7 & 8?).

RESEARCH METHOD

- Past fire impact studies monitored different micro-habitats and lacked balanced pre-fire/post-fire sampling designs.

In this study:

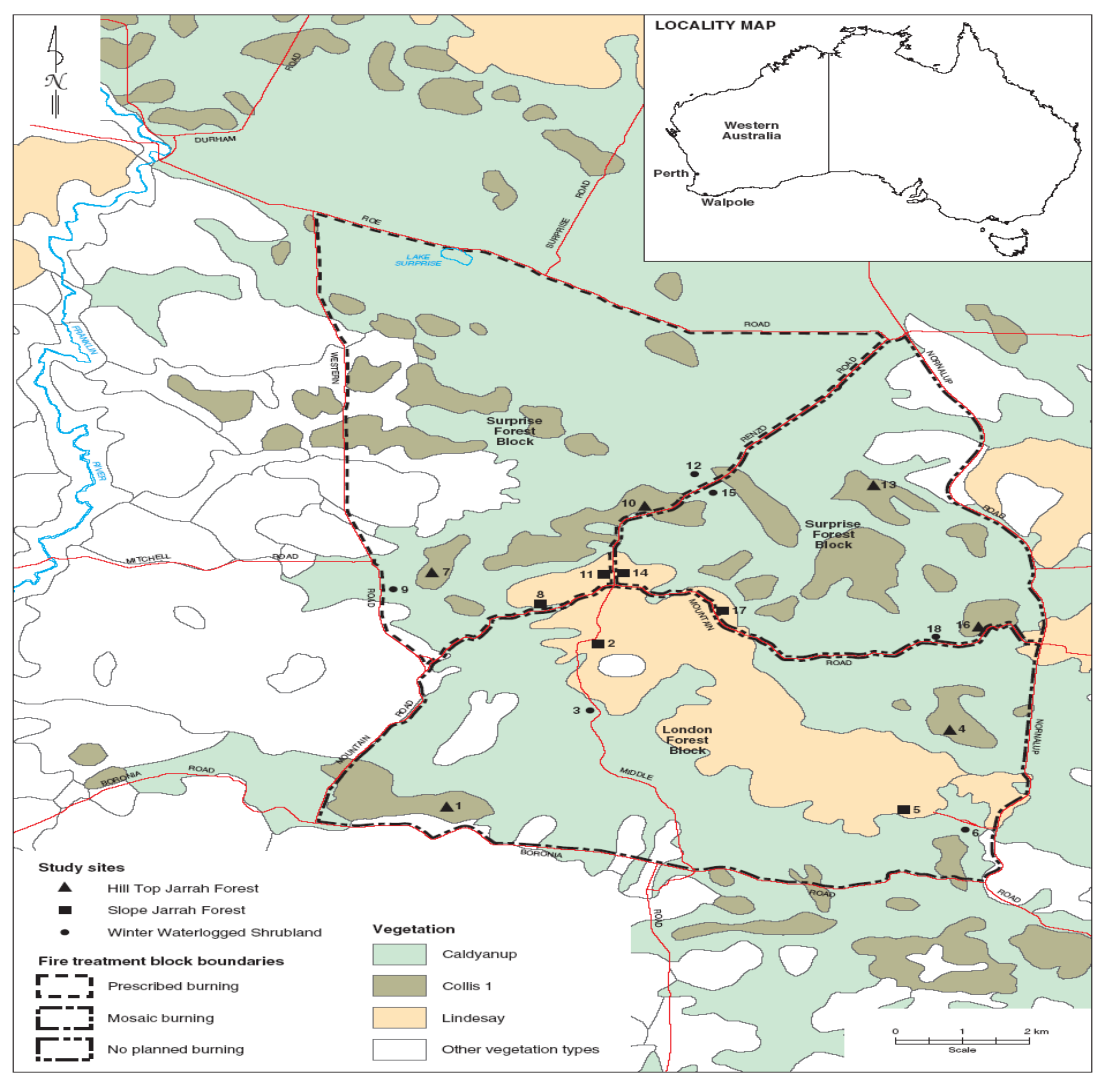
- Temporal Design: balanced pre & post fire sampling in each season.
- Spatial Design: 18 sites (3 “patch” regimes x 3 landforms x 2 sites) and 6 sites (3 “past” regimes x Collis landform x 2 sites).
- Habitat Structure: monitor litter attributes, plant floristics & structure.
- Invertebrate Sampling: pitfalls compared to litter collection.
- Data Analysis: for all 3 biodiversity components.

Study Landscapes

25 Km NE of Walpole, 10 Km E of Mt Frankland

Site Design

Map courtesy Holly Smith, CALM



METHODS: Sampling Design

	Landforms			
Fire Regime (previous burn)	**Collis:** **- hilltop jarrah / marri forest**	**Lindesay:** **- slope jarrah / sheoak forest**	**Caldyanup:** **- winter waterlogged shrublands**	**Future Fire Dates**
Surprise East: **No Planned Burns (Mar. 2003)**	Sites 13 & 16. Pitfall transect (10/site). Pitfall spacing (32/site). Sampled 3 monthly.	Sites 14 & 17. Pitfall transect (10/site). Sampled 3 monthly.	Sites 15 & 18. Pitfall transect (10/site). Pitfall spacing (32/site). Sampled 3 monthly.	No prescribed fires. Wildfires extinguished, if possible.
Surprise West: Prescribe Burns (Mar. 2003)	Sites 7 & 10. Pitfall transect (10/site). Litter transect (10/site = 2 bulked). Sampled 3 monthly.	Sites 8 & 11. Pitfall transect (10/site). Sampled 3 monthly.	Sites 9 & 12. Pitfall transect (10/site). Litter transect (10/site = 2 bulked). Sampled 3 monthly.	Spring 2009.
London: Mosaic Burns (Sept. 2002)	Sites 1 & 4. Pitfall transect (10/site). Litter transect (10/site = 2 bulked). Sampled 3 monthly.	Sites 2 & 5. Pitfall transect (10/site). Litter transect (10/site = 2 bulked). Sampled 3 monthly.	Sites 3 & 6. Pitfall transect (10/site). Litter transect (10/site = 2 bulked). Sampled 3 monthly.	March 2006 & Autumn 2009.

METHODS: Pitfall Sampling

- Spacing trial to determine extent of autocorrelation for pitfalls at 4 sites.
- Pitfall transects at 18 sites to determine fire “patchiness” impacts on beetle assemblages.
- Pitfall transects at 6 forest sites to determine past fire regime impacts on beetle assemblages.

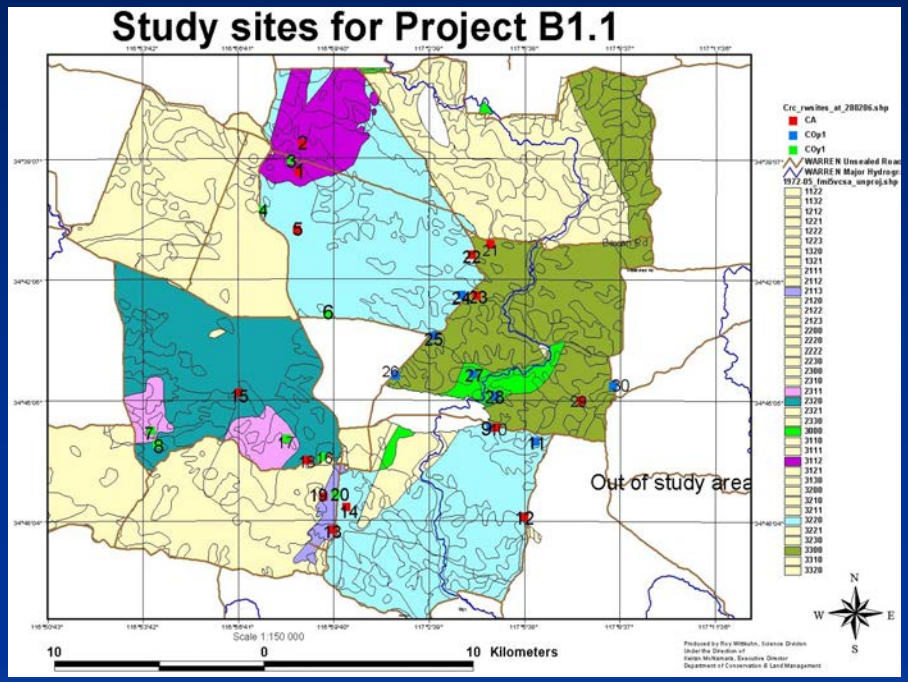
METHODS: Spacing Trial

- 4 sites (13, 16, 15, 18).
- 128 pitfalls sampled 3 monthly.
- 32 pitfalls/site x 1 fire regime x 2 landforms x 2 sites.
- 32 pitfalls/site = 2 x 4 pitfalls x 4 spacing distances (1m, 5m, 20m, 80m).
- Sampled 3 monthly from Dec 04 to Feb 07.

METHODS: Pitfall Transects

- 18 Sites = 3 “patchiness” regimes x 3 landforms x 2 sites.
- 10 pitfalls/ site at 10m spacing.
- 180 pitfalls sampled 3 monthly to spring 2010.

METHODS: Pitfall Transects



- 6 Sites = 3 past wildfire regimes x 1 Collis landform x 2 sites (7 & 17; 8 & 16; 27 & 28).
- 10 pitfalls/ site at 10m spacing.
- 60 pitfalls sampled 3 monthly to spring 2010.
- Wittkuhn & McCaw (2006) Fig. 3.

Pitfall Trap

ETHICAL ISSUES

- Destructive sampling essential to establish regional specimen reference collection.
- Pitfall preservative low toxicity and biodegradable (Ethylene glycol, Chemical Data Sheet 2005).
- Rapid euthanasia (approx. 3 mins.).
- Shallow preservative minimizes by-catch.

METHODS: Litter Sampling

- Comparing the beetle compositions of litter and pitfall samples.
- 0.1 m^2 quadrat, 5 m radius from each of the 10 pitfalls per site.
- Microhabitat variables (litter depth, % cover of litter, live plants, bare soil, woody debris, rock and moss).
- 16 Tullgrens = 2 samples (5 quadrats bulked)/site x 2 fire regimes x 2 landforms x 2 sites, 3 monthly.

METHODS: Swamp Litter

- Site 3, Caldyanup landform.
- 4 swamp sites (3, 6, 9, 12)
- Wildfire sites (9, 12).
- Mosaic sites (3, 6).
- Sampled 3 monthly from Dec 2004.

METHODS: Forest litter

- Site 4, Collis landform.
- 8 forest sites:
- Mosaic sites (1,4).
- Wildfire short (7,17).
- not Wildfire medium (8,WFM10,16).
- Wildfire long (27, 28).
- Sampled 3 monthly from Dec 2004 & Feb 2007.

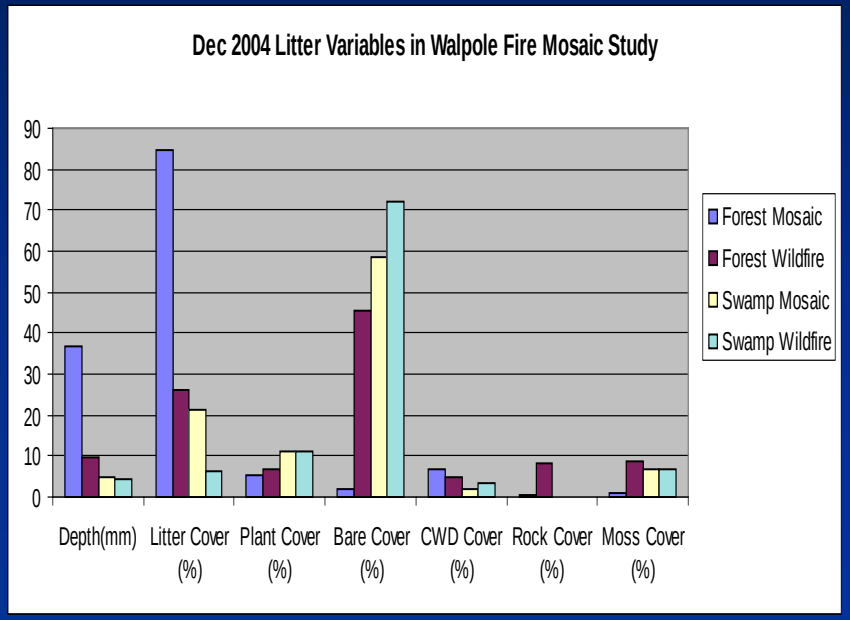
RESULTS: How did habitat recover?

Litter Sampled in Dec 2004.

- Site 10 wildfire forest 20 months after fire. Large ashbeds, many legumes, litter shallow and patchy. Epicormic tree crowns.

- Site 4 mosaic forest 27 months after fire. Rapid litter recovery due to “healthy” tree crowns.

RESULTS: Wildfire impact on ground habitat?



- Mosaic forest litter 3 times deeper.
- Mosaic forest & swamp 3 times more litter cover.
- Wildfire forest 20 times more bare soil.
- Wildfire forest 9 times more moss.

RESULTS & ANALYSES

(completion Dec. 2011)

- **Paper 1: Australian and Study Beetle Fauna:**
  rarefaction analysis, species and family concordance Mantel analysis.
- **Paper 2a: Pitfall Spacing and Pseudoreplication:**
  spatial autocorrelation using mantel test (Lichstein *et al.* 2002, Legendre 1993).
- **Paper 2b: Litter and Pitfall Beetle Fauna:**
  species accumulation and rarefaction analysis, concordance analysis of morphospecies and determined species, ANOVA of α, β, γ richness, MDS and mantel test of species composition, multiple regression of β richness with litter variables.
- **Paper 3: Fire, Taxonomic Diversity & Morphospecies Methods:**
  species accumulation and rarefaction analysis, spatial autocorrelation analysis, multiple regression of α & β richness with site variables and fire age , ANOVA of α, β, γ richness , MDS ordination of common and scarce species composition by site.
- **Paper 4: Fire, Structural Diversity & Biomass Measurement:**
  analyses of species biomass composition as for BC1 taxonomic diversity.
- **Paper 5: Fire, Functional Diversity & Trophic Definition:**
  analyses of trophic biomass composition as for BC1 taxonomic diversity.
- **Paper 6: Beetle Biodiversity & Fire Regimes:**
  mantel test of MDS ordinations of taxonomic, structural and functional composition.
- **Paper 7: Scientific Lag: Defining Biodiversity:**
  review of biodiversity definitions and resultant analytical theory.
- **Paper 8: Beetle Surrogates of Local Biodiversity:**
  mantel test of large sized beetles, scarce and common beetle species and families as surrogates of beetle biodiversity.

RESULTS: BC1 Taxonomic Diversity (paper 3)

- Sample taxa, Biodiversity Component 1 (BC1).
- Sort to morphospecies (msp).
- Digitized images & reference collection
- Coded by msp number in database and identified to order and family, with later determination by taxonomists.
- Test for spatial autocorrelation between nearby sites (Lichstein *et al. 2002,* Legendre 1993).
- Concordance analysis of Mspp and determined species, accumulation and rarefaction curves, ANOVA analyses of α and β richness, regression with site & habitat variables, MDS analyses of common beetle abundance and scarce beetle presence/absence.

Analysis & Data Diary

- A total of 205 pit and litter samples sorted from April 05 to Oct 06.

- Sites 1 & 4 (Mosaic Forest) – 65 litter samples, 32 pitfall samples = 97 samples.
- Sites 3 & 6 (Mosaic Swamp) – a few samples.
- Sites 7 & 10 (Wildfire Forest) – 65 litter samples, 30 pitfall samples = 95 samples.
- Sites 9 & 12 (Wildfire Swamp) – a few samples.

BC1: Taxonomic Diversity
How many morphospecies, Dec06.

Taxa	Msp Richness	Relative Richness (%)
Flatworms (Platyhelminthes)	Mean samplle alpha?	0.5?
Snails (Gastropods)		0.5?
Earthworms (Oligochaeta)		1.9?
Velvetworms (Onychophora)		0.5
Centipedes (Chilopoda)		1.9
Landshrimp (Amphipoda)		0.5
Slaters (Isopoda)		1.9
Pseudoscorpionida		0.5
Mites (Acarina)		**8.9**
Harvestmen (Opilionida)		0.9
Spiders (Araneae)		**9.4**
Springtails (Collembola)		**25.6**
Cockroaches (Blattodea)		0.9
Earwigs (Dermaptera)		0.5
Grasshoppers & Crickets (Orthoptera)		0.9
Bugs (Hemiptera)		3.4
Thrips (Thysanoptera)		1.5
Beetles (Coleoptera)	**191 (42)**	**39.5 (20.7)**
Flies (Diptera)		**8.4**
Moths & Butterflies (Lepidoptera)		**4.4**
Ants, Wasps & Bees (Hymenoptera)		**5.4**
Unknown		**0.5**
γ Richness	**483 (203)**	**100**

BC1: Taxonomic Diversity Fire Regime Richness:

- Total study richness for all arthropods was 264 Mspp at Oct 2005 now 483 Mspp at Oct 2006.

Forest beetle Mspp April 2005 to Oct 2006 was:

- Mosaic forest (2 sites x 6 dates) is 135 Mspp.
- Wildfire forest (2 sites x 6 dates) is 67 Mspp.

BC1: Taxonomic Diversity Unique species richness (β)

- Mosaic forest has 108 “unique” beetle Mspp (61.7 %).
- Wildfire forest has 40 “unique” beetle Mspp (22.5%).
- At both regimes have 27 “common” beetle Mspp (15.4%).

RESULTS: Structural Diversity

(paper 4)

- Measure average biomass of individuals of each msp.
- Correlate alternative biomass measurements (e.g. body size or volume versus dry weight regression function)
- Analyse using rarefaction curves, ANOVA and MDS of common and scarce beetle msp relative biomass at each site.

BC 2 & 3: Structural & Functional Diversity: The size and jobs of Mspp?

Larval Trophic Guild	Wildfire biomass (mm^3)	Mosaic biomass (mm^3)	No-burn biomass (mm^3)	γ Richness
Non-feeding stage (e.g. eggs)	0	0	?	? Mspp
Various guilds	5.3	47.5	?	
Detritivore	285.3	1083.2	?	
Fungivores	2.3	4.9	?	
Omnivores	6.5	19.9	?	
Herbivores	236.6	739.6	?	
Predators	2344.9 (73.6%)	421.5 (16.4%)	?	
Unknown	302.9	252.4	?	
Gross Study Production	3186.9	2568.9	?	

RESULTS: Functional Diversity

(paper 5)

- List larval & adult trophic/functional guilds for each msp.
- Compare alternative methods for categorizing msp trophic guilds.
- Analyse using rarefaction curves, ANOVA and MDS of relative biomass of trophic guilds at each site.

RESULTS: Linking Components

- Link fire impacts on beetle taxonomic composition with changes in structural productivity and changes in relative functions at each site.
- Mantel test of all 3 MDS ordinations of taxonomic, structural and functional composition of beetle assemblages.

SIGNIFICANCE

- This protocol is designed to link changes in all 3 components of biodiversity, by monitoring and analysis of disturbance impacts on arthropod communities.
- This “Walpole” protocol allows the standard monitoring and analysis of regional faunas, such as collected by local volunteer organizations (e.g. Walpole Wilderness Collection).
- The protocol also allows assessment of beetle taxa as surrogates of all arthropod taxa in southern forests.
- This protocol also allows the recommendation of guidelines for the adaptive fire management of arthropod biodiversity in southern forests.

The End
(for now)