Gnangara Sustainability Strategy

An across-government initiative

Groundwater - Biodiversity - Land use

THE IMPACTS OF *PHYTOPHTHORA CINNAMOMI* ON FLORA AND TERRESTRIAL FAUNA ON THE GNANGARA MOUND

Marnie L. Swinburn, Leonie E. Valentine, David A. Mickle and Tracy L. Sonneman

Department of Environment and Conservation

December 2009

Department of Environment and Conservation

Government of Western Australia

Water Corporation

CSIRO

Forest Products Commission Western Australia

The Impacts of *Phytophthora cinnamomi* on Flora and Terrestrial Fauna on the Gnangara Mound

Draft Report to the Department of Environment and Conservation and the Gnangara Sustainability Strategy

Marnie L. Swinburn, Leonie E. Valentine, David A. Mickle and Tracy L. Sonneman
Gnangara Sustainability Strategy
Department of Environment and Conservation

Government of Western Australia
Department of Environment and Conservation

Gnangara Sustainability Strategy Taskforce
Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.gnangara.water.wa.gov.au

December 2009

Gnangara Sustainability Strategy

This document has been commissioned/produced as part of the Gnangara Sustainability Strategy (GSS). The GSS is a State Government initiative which aims to provide a framework for a whole of government approach to address land use and water planning issues associated with the Gnangara groundwater system. For more information go to www.gnangara.water.wa.gov.au

Acknowledgements
The Department of Environment and Conservation – Gnangara Sustainability Strategy would like to thank the following for their contribution to this publication: Dr Barbara Wilson, Alice Reaveley, Dr Kristen Bleby, Katrina Zeehandelaar, Dr Rob Davis and the numerous volunteers who assisted in the field.

Contents

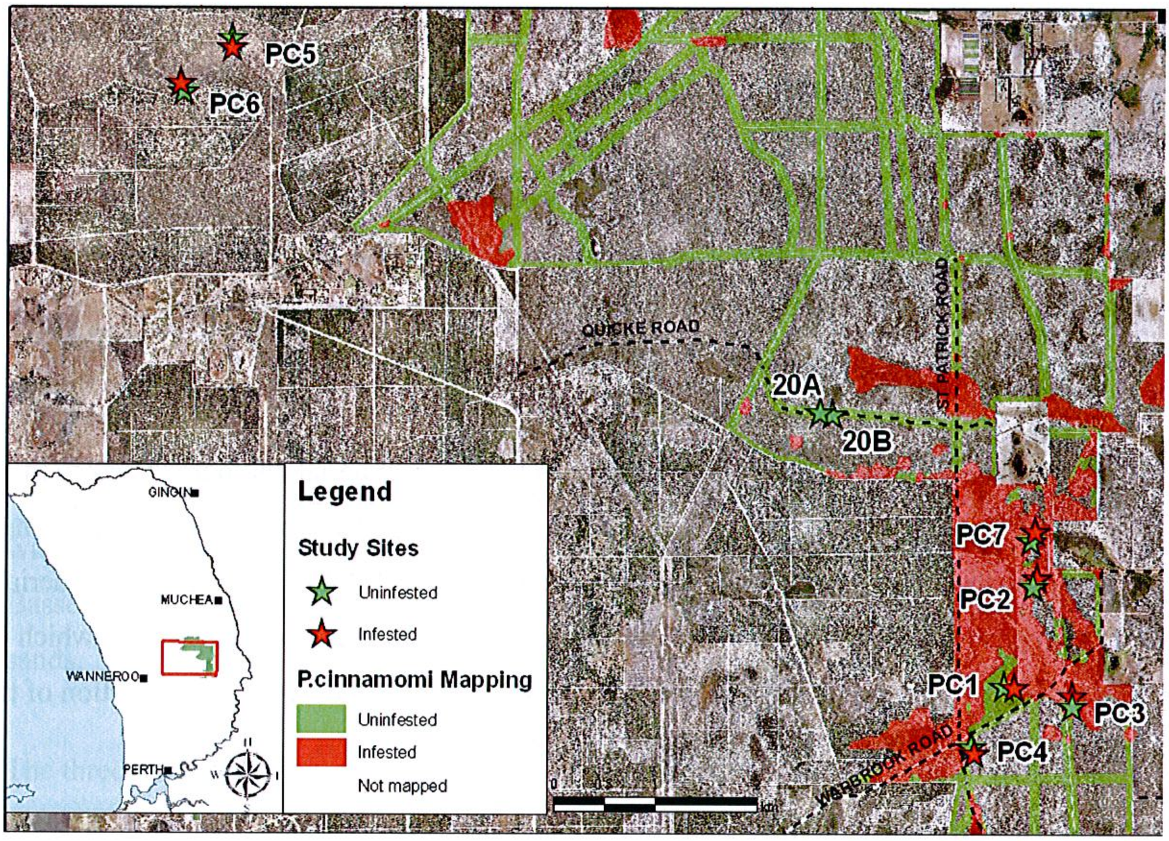


Figure 1. Seven paired infested and uninfested avifauna sites (PC1-7) and two GSS general fauna survey sites (20A and 20B) with *Phytophthora* dieback mapping in Gnangara-Moore River State Forest Melaleuca block and the proposed Melaleuca Nature Reserve. Inset: Study sites in relation to the GSS study area.

Floristic survey

A total of twenty-one 10x10m floristic quadrats were established at the seven paired *P. cinnamomi* infested and uninfested sites. Three floristic quadrats were surveyed at each paired site, one quadrat in the uninfested 1ha site, one within a buffer of the infection front between uninfested and infested areas (transition), and one within the infested 1ha site (Figure 2 and 3). The quadrat corners were fixed using galvanised fence droppers and centre point coordinates (±10m accuracy) were collected using a GPS unit. At the centre point, canopy cover was measured using a Lemnon spherical densiometer, which calculated an approximate percentage live canopy cover value. The vegetation structure and cover were recorded using Keighery (1994). The crown cover is estimated to as close to 5 % as per the National Vegetation Inventory System. Up to three dominant species were recorded as part of each layer and any more that three dominants were classed as mixed. Vegetation condition was recorded using the Keighery (1994) Vegetation Condition Scale.

Vascular plants were recorded during two months in spring 2008 following the methods outlined in Keighery (1994). The presence of all vascular plants located within the 10x10m quadrat was recorded and a specimen was collected for identification (Appendix 1). Species identification was completed by a botanist with assistance from the Western Australian Herbarium. A detailed examination of floristic diversity patterns within the GSS study area will be the focus of a separate report (Mickle *et al.* in prep).

Statistical Analysis

Estimates of species richness at each site were determined using all plant species that were able to be differentiated as different taxa within each site (Appendix 1). Plant species richness and percentage live canopy cover (sqrt-arcsine transformed) were both analysed using two-way ANOVA (SPSS, version 17) to examine the impact of *P. cinnamomi* status (uninfected, transition and infected), using the site location as a blocking factor. Pair-wise post hoc analyses were carried out using Tukey's honestly significant difference (HSD) test to examine within-factor differences among *P. cinnamomi* status.

For community analyses, taxa that could not be distinctly identified between sites were excluded from analysis (Appendix 1). The composition of species was examined among infection status (uninfested, transition and infested) using permutation-based non-parametric MANOVA (preMANOVA; Anderson 2001) with PC-ORD (version 5.0; McCune and Mefford 1999). Non-metric multidimensional scaling (NMDS, Kruskal 1964), using a rank-tranformed Sorensen distance measure, was used to graphically depict the site assemblage relationships of plant taxa using PC-ORD. Where 3-dimension ordinations were deemed more appropriate (determined using scree plots and Monte Carlo tests), the two axes that represent the highest proportion of variance in the ordination are displayed. Plant species that were correlated with the NMS axes ($r^2 > 0.2$) are graphically depicted on the ordination.

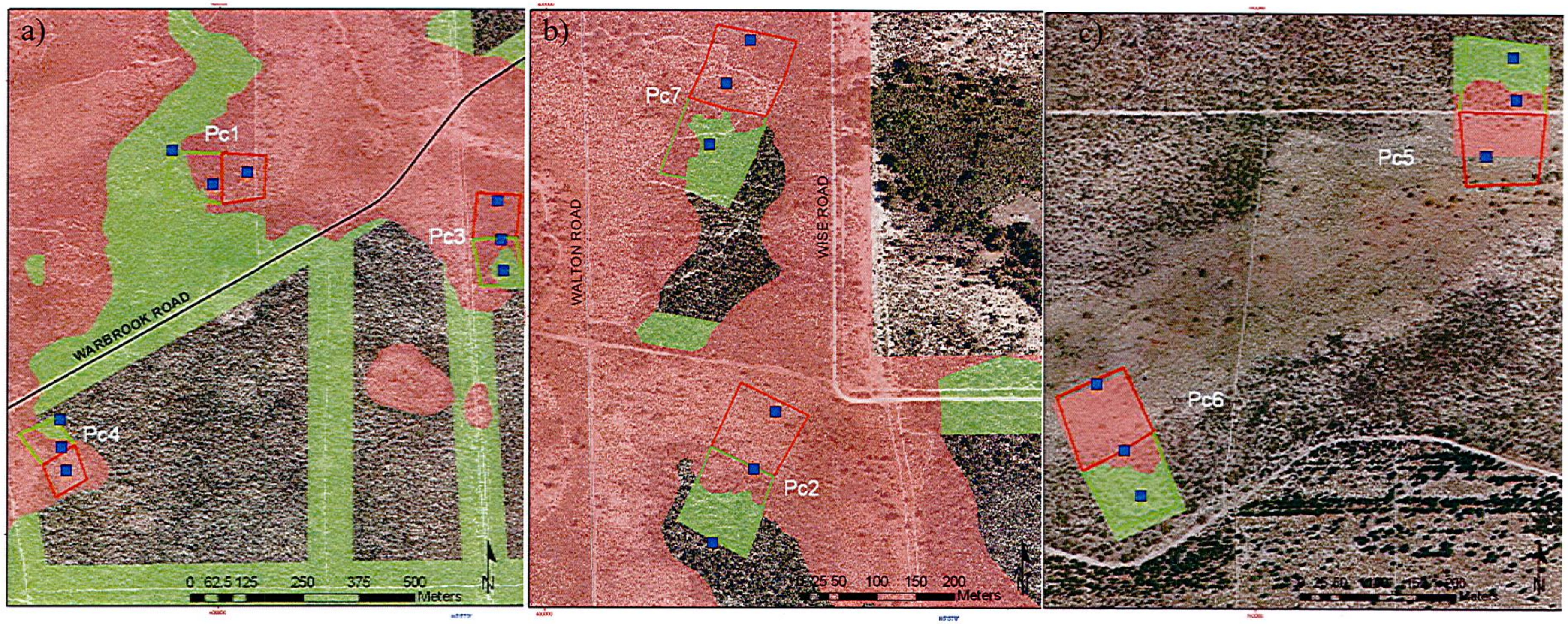


Figure 2: Floristic quadrats (■) located within 1 ha infested (red quadrats) and uninfested (green quadrats) avifauna sites with *P. cinnamomi* dieback interpretation (background red is infested vegetation; background green is uninfested vegetation, clear is unmapped) by Forest Management Branch (DEC) ; a) sites Pc1, Pc3 & Pc4 adjacent to Warbrook Road in the Melaleuca forest block in Gnangara-Moore River State Forest; b) sites Pc2 in Melaleuca forest block & Pc7 in the proposed Melaleuca Nature Reserve; and c) sites Pc5 and Pc6 in Melaleuca forest block

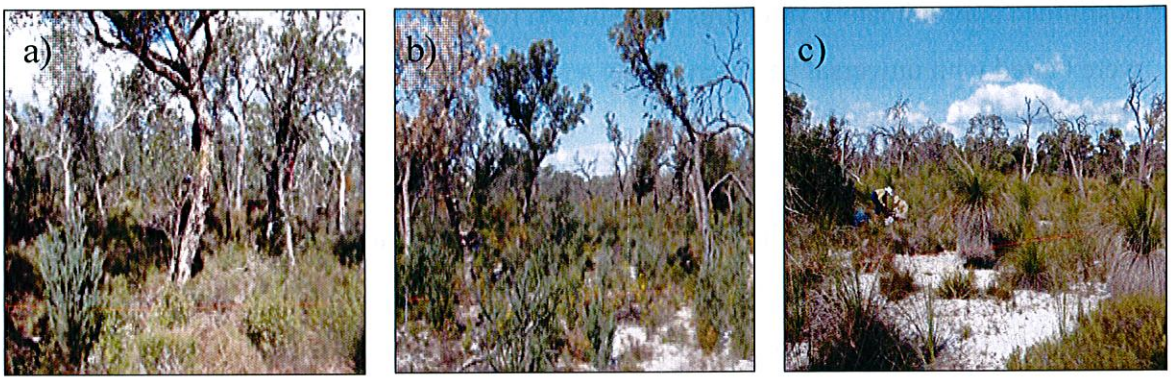


Figure 3: Floristic site Pc7 in: a) uninfested woodland with healthy *Eucalyptus todtiana* and *Banksia* spp.; b) transition zone of the disease front with a fresh *Banksia* death at left of photo and older death at the right; and c) infested woodland with disease front and *Banksia* spp. deaths in background (Photos: D. Mickle).

Ground-dwelling vertebrate fauna survey

Fauna survey

For logistical reasons, only five paired dieback infested and uninfested sites (n=10) were surveyed for ground-dwelling vertebrate using an array of pit-fall traps (20 L buckets), funnel traps and aluminium box traps (Elliots) in late March 2009. An additional paired site from the GSS general fauna survey in an extensive dieback-free area was also surveyed to provide a comparison to previous vertebrate trapping events (Valentine *et al.* 2009) and to compare larger uninfested patch sizes (Figure1). These two sites act as the 'control'. In addition to the ground-dwelling vertebrate fauna survey, a concurrent survey assessing the invertebrate assemblages was conducted using the pit-fall trap arrays at the same sites. The results from the terrestrial invertebrate component are reported in Zeehandelaar (2009).

A total of 12 sites were surveyed using pitfall trap arrays located within 2 metres of the floristic quadrats within *P. cinnamomi* uninfested and infested vegetation. Ten pitfall traps were located in a Y shape, with three pits placed along each arm radiating out from a central pit at approximately 7 metre intervals. One funnel trap was installed one metre past the last bucket on each arm. The pitfall and funnel traps were connected with 30 cm high aluminium fly wire drift fence extended out one metre past the end of each funnel trap.

Each arm measured approximately 25 metres long (Appendix 2). Five elliott traps were positioned approximately 10 metres apart in two rows either side of the trapping array and were baited with universal bait comprising a mixture of peanut paste, rolled oats and tinned sardines.

Sites were open for 5 nights in autumn 2009. While open, all traps were checked once per day in the early morning. Captured animals were identified, processed and released onsite. Measurements taken included: weight (g), snout-vent length (mm), total length (mm) for reptiles; and, weight (g), head length (mm), short pes length (mm), gender, and presence of pouch young for mammals. Mammals were ear notched for recapture purposes, whilst reptiles were marked with a non-toxic permanent marker pen under the throat. Amphibians were not marked. Taxonomic nomenclature, including common names, followed the Western Australian Museum taxonomic checklist (2009).

Habitat Assessment

The pre-existing 10x10m floristic quadrats located within the uninfested and infested avifauna sites were used to estimate percentage cover of ten common species identified during the floristic surveys (*Xanthorrhoes presssi, Xanthorrea brunonis, Lyginia barbata, Eremaeae pauciflora, Alexgeorgia nitens, Desmocladus flexuosus, Stirlingia latifolia, Astroloma xerophyllum* and *Adenanthos cygnorum*). Where there were was difficulty in differentiating between similarly related taxa these were grouped (eg. *Xanthorrhoea preissii - X. brunonis and Lyginia imberbis -L. barbata* and *Desmocladus flexuosus-D. fascicularis*).

Within each of the floristic quadrats, three randomised 1 m^2 quadrats were established to examine microhabitat attributes. Attributes assessed included vegetation structure and ground substrate composition. To provide an index of vegetation complexity within a 2 m height range, vegetation contact (both live and dead) was recorded (for height classes 0-20cm, 20-40cm, 40-60cm, 60-80cm, 80-100cm, 100-150cm, 150-200cm) using a graduated pole, placed at the point in the centre of the quadrat. Ground cover within the $1m^2$ quadrat was estimated as a percentage of vegetation (live and dead), soil (bare ground) and litter (including leaf and woody debris) to a total combined cover of 100%. Litter depth (cm) was measured using a ruler that was pressed through the litter (where relevant) until it touched a firm soil surface.

Thermal Microhabitat data

Temperature data was collected using four iButton thermologgers (Thermochron, Dallas Semiconductor/Maxim) located at various strata levels of the vegetation and exposures to the sun within each infested and uninfested paired site. In total 40 thermologgers in 10 sites collected microhabitat data over four trapping days during late March 2009. Thermologgers within gauze cloth were placed i) ontop of the litter layer under a shrub (litter-shade), ii) ontop of the litter layer in full sun (litter-sun), iii) within the cover of a shrub, approximately 60cm above the ground (vegetation-shade) and iv) on the outside of a shrub approximately 60cm above the ground (vegetation-sun). Average daily temperatures (minimum, maximum, mean, range and co-efficient of variation) over a 24 hour period were calculated and represented graphically for strata level (leaf litter and vegetation).

Statistical Analysis

For the purposes of statistical analyses, we excluded the two 'control' sites, and only conducted statistical tests on the five paired *P. cinnamomi* infested and uninfested sites ($n = 10$). To examine the impact of *P. cinnamomi* we compared a number of variables (reptile abundance, reptile species richness and the abundance of dominant individual species, and the percentage estimates of live vegetation cover, dead vegetation cover, soil cover and leaf litter cover, a measurement of litter depth and data collected on understorey structure (touch pole data)) between uninfested and infested sites using a paired t-test (SPSS, version 17.0). The counts for touch pole height classes 80-100cm, 100-150cm and 150-200cm were excluded from analyses due to limited data.

The composition of reptile species was examined between *P. cinnamomi* infested and uninfested sites using perMANOVA (see floristic analysis section above for more detail). Non-metric multidimensional scaling (NMDS, described above) using a rank-transformed Sorensen distance measure, was used to graphically depict the site assemblage relationships of reptile species using PC-ORD. In addition, Indicator Species Analyses on the reptile assemblage was conducted using the methods of Dufrene and Legende (1997) in PC-ORD (version 5.0).

To examine the impact of time since last fire, a univariate ANOVA comparing fire age (old versus young) was also carried out on a number of variables (reptile abundance, reptile species richness and the abundance of dominant individual species, and the percentage estimates of live vegetation cover, dead vegetation cover, soil cover and leaf litter cover, a measurement of litter depth and data collected on understorey structure (touch pole data)) between old and young sites (SPSS, version 17.0). For the purposes of this exploratory analysis, sites were assumed to be independent. In addition, the composition of reptile species was examined between young and old fire age sites using perMANOVA (method described above).

Habitat variables for each site were correlated with reptile species richness and abundance, abundance data for dominant species and year since last fire (recorded in years since last burn or YSLB) using Pearson correlation coefficient (SPSS, version 17.0). For all univariate analyses, abundance data for individual species were square-root transformed and percentage ground cover values were arcsine transformed to satisfy Levene's test of homogeneity and variance. For community analyses, the abundance data of species was log (n+1) transformed.

A three-way ANOVA (SPSS 2008, version 17.0) of thermal microhabitat data tested the interactions between *P. cinnamomi* status (infested/uninfested), strata location (leaf litter/vegetation) and exposure to the sun (sun/shade) for five average daily temperature variables (minimum, maximum, mean, range, and coefficient of variation).

Results

Floristic Survey

Species richness and canopy cover

Richness of plant taxa within each 10 x 10 m quadrat varied substantially, with a maximum of 71 taxa (recorded from an uninfested site) and a minimum of 34 taxa (recorded from an infested site). There was a significant difference in mean plant species richness among sites with different infection status (ANOVA: $F_{2,12} = 17.349, p < 0.001$), and among site locations (ANOVA: $F_{6,12} = 5.941, p < 0.01$). Infested sites had lower plant species richness than uninfested sites ($p < 0.001$) and transition sites ($p = 0.01$). However, there was no difference in plant species richness between uninfested and transition sites ($p > 0.05$), and mean plant species richness was fairly similar between uninfested and transition (Figure 4). Species richness also varied among site location, with sites located in group 4 typically containing the highest species richness, and those in location 2, 3 and 7 the lowest species richness.

The percentage live canopy cover also varied among infection status (ANOVA: $F_{2,12} = 7.650, p < 0.01$; Figure 4). The uninfested sites had significantly higher amount of canopy cover than the infested ($p < 0.01$). Although there was no significant difference between the average amount of canopy cover in the uninfested and transition sites, there was a trend for canopy cover to be higher in the uninfested sites ($p = 0.06$). The amount of canopy cover in transition sites was not significantly different to uninfested sites (Figure 4).

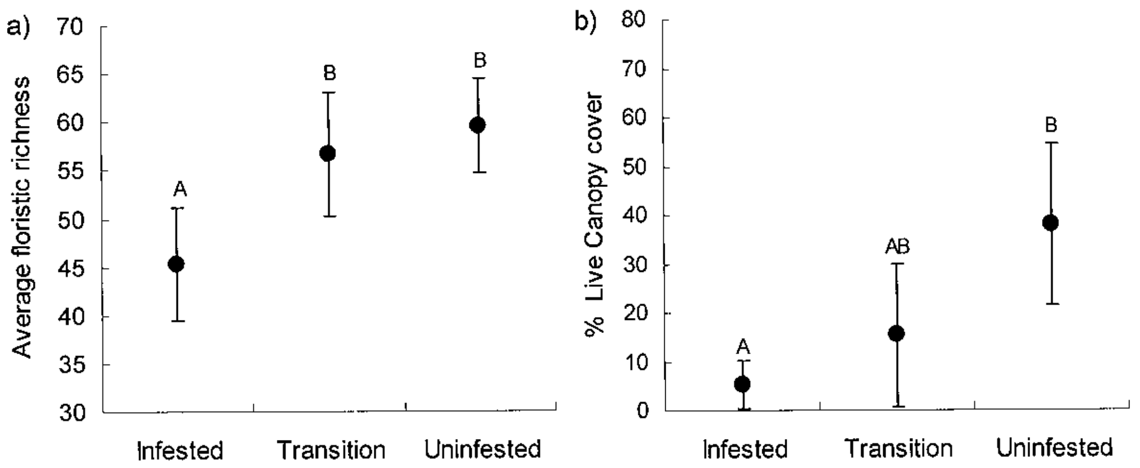


Figure 4: Differences in mean (± 95% CI) a) plant species richness and b) percentage live canopy cover in *P. cinnamomi* infested, transition and uninfested floristic quadrats. Letters above error bars indicate pair-wise significant difference between means from Tukey HSD post-hoc tests.

Community Analysis

Of the 223 plant taxa that were examined, 162 taxa were differentiated between sites and were included in community analyses. There was a significant difference in community structure between *P. cinnamomi* status (perMANOVA: $F_{2,18} = 2.030$, $p < 0.01$). Pair-wise comparisons indicated that the infested sites contained a different community composition compared to the uninfested ($p < 0.01$) and transition ($p < 0.05$) sites. The transition sites were not different to the uninfested ($p > 0.05$).

NMDS ordination found a stable 3-dimensional solution representing 84 % variance (stress = 0.125), with axes one and two representing 73 % of the community variation (Figure 5). The infested sites clearly grouped away from the uninfested or transition sites (Figure 5a). The majority of species were positively correlated with the uninfested or transition sites. For example, *Banksia attenuata, B. menziesii, Constephium pendulum, Drosera menziesii, Hibbertia hypericoides*, *Petrophile linearis* were all associated with sites that were uninfested or transitional. Few species were correlated with the infested sites, however *Melaleuca seriata, Stylidium* sp. Kalbarri and X*anthorrhoea brunonis* and *X. preissii* were associated with some of the infested sites (Figure 5b).

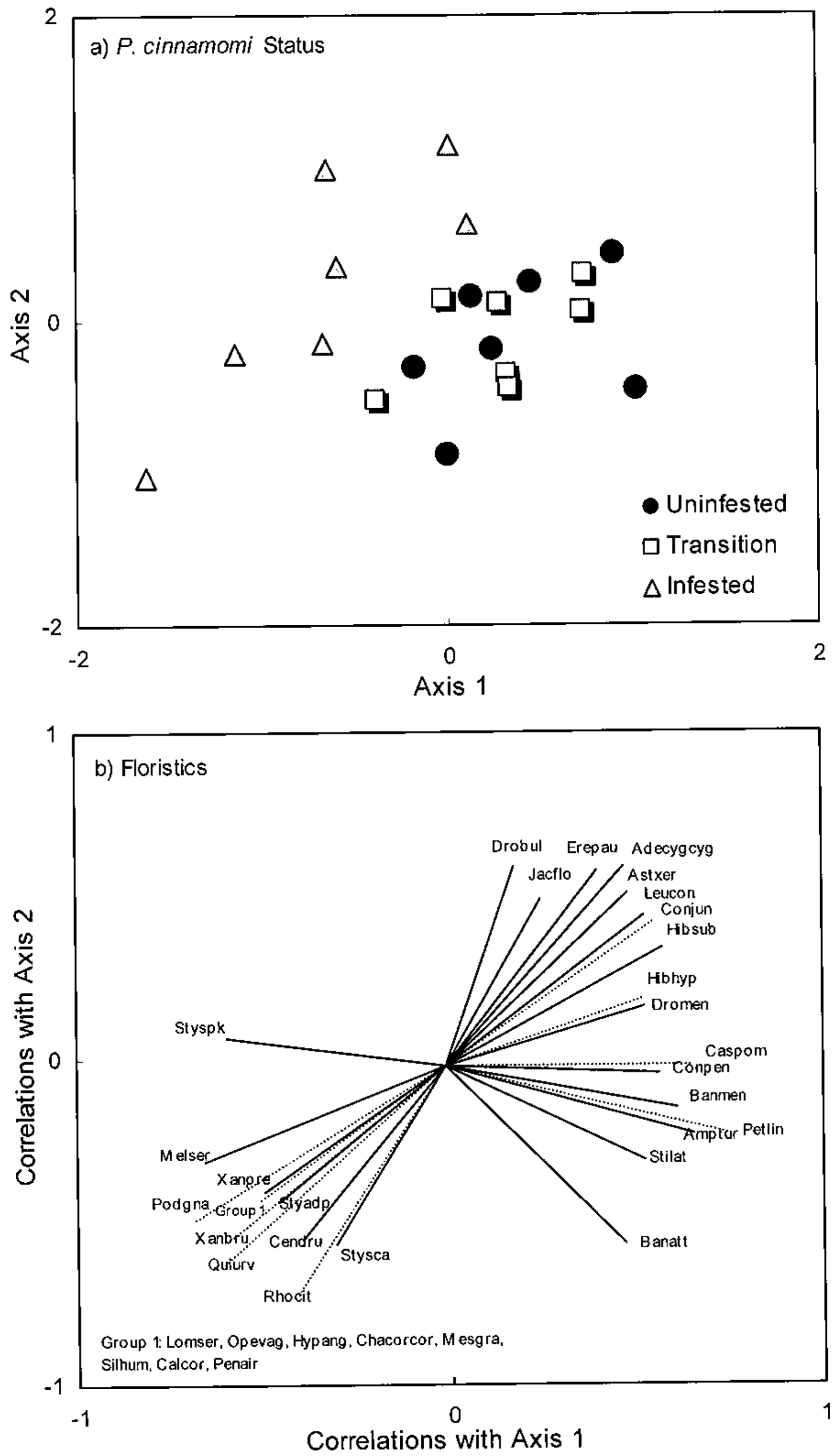


Figure 5: a) NMDS ordination (Sorensen distance measure) of plant assemblages (n = 162 species) in 21 floristic quadrats coded by *P. cinnamomi* status. The ordination is in three dimensions (stress = 0.125), with axis 1 and 2 plotted (r^2 = 0.463 and 0.267 respectively). b) Correlations of plant species (r^2 > 0.2) with NMDS ordination. Species codes are explained in Appendix 1.

Species of Interest

Two plant species of interest were identified during this project; *Leucopogon aff polymorphus* and *Calectasia* sp. Pinjar (C. Tauss 557). *Leucopogon aff polymorphus* requires a formal description and identification as although it was very similar to *L. polymorphus*, it had hairy ovaries. This distinguishing characteristic of the specimen makes it a species of interest and two specimens were lodged with the Western Australian Herbarium (specimen numbers currently unavailable). *Leucopogon aff polymorphus* was found in two floristic quadrats, in both uninfested and infested Banksia woodland.

Calectasia sp. Pinjar (C. Tauss 557), a priority one species, was known from one collection record in the Western Australian Herbarium at the time of this study and from a 2007 survey of a new population in Melaleuca Park (Swinburn and Hoskins 2009). The species was collected from three floristic quadrats during this project, one uninfested and two infested and extends the known extent of the population. Two specimens were lodged with the Western Australian Herbarium (WAH specimen numbers 08008140 and 08008132).

Ground-dwelling vertebrate fauna survey

The survey effort across the 12 fauna study sites yielded 20 fauna species over 780 pitfall and funnel trap nights. Two mammal species, one frog species and 17 reptile species were captured during this trapping program (See Appendix 3 for a complete species list). Of the 17 reptile species, 15 species were observed in the paired infested and uninfested sites and included in analyses. One native mammal, *Tarsipes rostratus* (Tarsipedidae), one introduced mammal, *Mus musculus* (Muridae), and one frog species, *Heleioporus eyreii* (Limnodynastidae) were recorded. The reptile families represented include: Pygopodidae (1 species), Diplodactylidae (1 species), Agamidae (2 genera, 2 species), Scincidae (7 genera, 11 species) and Elapidae (2 genera, 2 species). Eight individuals of the priority one species *Neelaps calonotos* were captured between three sites, with seven recorded from sites infested with *P. cinnamomi.* Pitfall and funnel traps were equally successful in capturing this species of burrowing snake.

Total species richness and abundance for reptiles, mammals and frogs varied among sites (Figure 6), with minimum and maximums occurring in both infested and uninfested sites

(Appendix 4). *Rankinia adelaidensis* and *Lerista elegans* were the most abundant reptile species, followed by *Cryptoblepharus buchananii,* and were found at 100%, 92% and 58% of sites respectively, and were examined independently. In addition, we also examined the abundance of the two mammal species captured, *Tarsipes rostratus* and *Mus musculus*, and the frog *Helioporous eyrei.*

Fauna trends with P. cinnamomi status and fire age

Fauna and *P. cinnamomi* status

There was no significant difference in the overall abundance of reptiles and species richness of reptiles between *P. cinnamomi* status sites (Table 1; Figure 6). In addition, no significant differences in abundance were detected for any individual species between *P. cinnamomi* infested and uninfested sites, with the exception of *Cryptoblepharus buchananii* (Table 1). *C. buchananii*, a small mostly-arboreal skink, was observed in higher abundances in the uninfested sites (Table 1; Figure 7). *Rankinia adelaidensis* showed a trend ($p < 0.1$) towards higher abundances in the infested sites (Figure 7), and the abundance of *Lerista elegans* was higher in the uninfested sites, though this was not significant. Mean abundances of the mammal and frog fauna were not significantly different between infested and uninfested sites (Table 1; Figure 7), although there was a slight trend towards higher abundances of *Mus musculus* in the infested sites.

A permutation-based nonparametric MANOVA on the community composition of 15 species of reptiles between the paired *P. cinnamomi* infested and uninfested sites indicated that the reptile assemblage showed a trend towards being influenced by *P. cinnamomi* status ($p = 0.064$), however, no useful NMDS graphical solution was found. Indicator species analysis on the 15 species of reptiles identified that only *C. buchananii* showed a trend towards being an indicator species of uninfested sites ($p = 0.0512$).

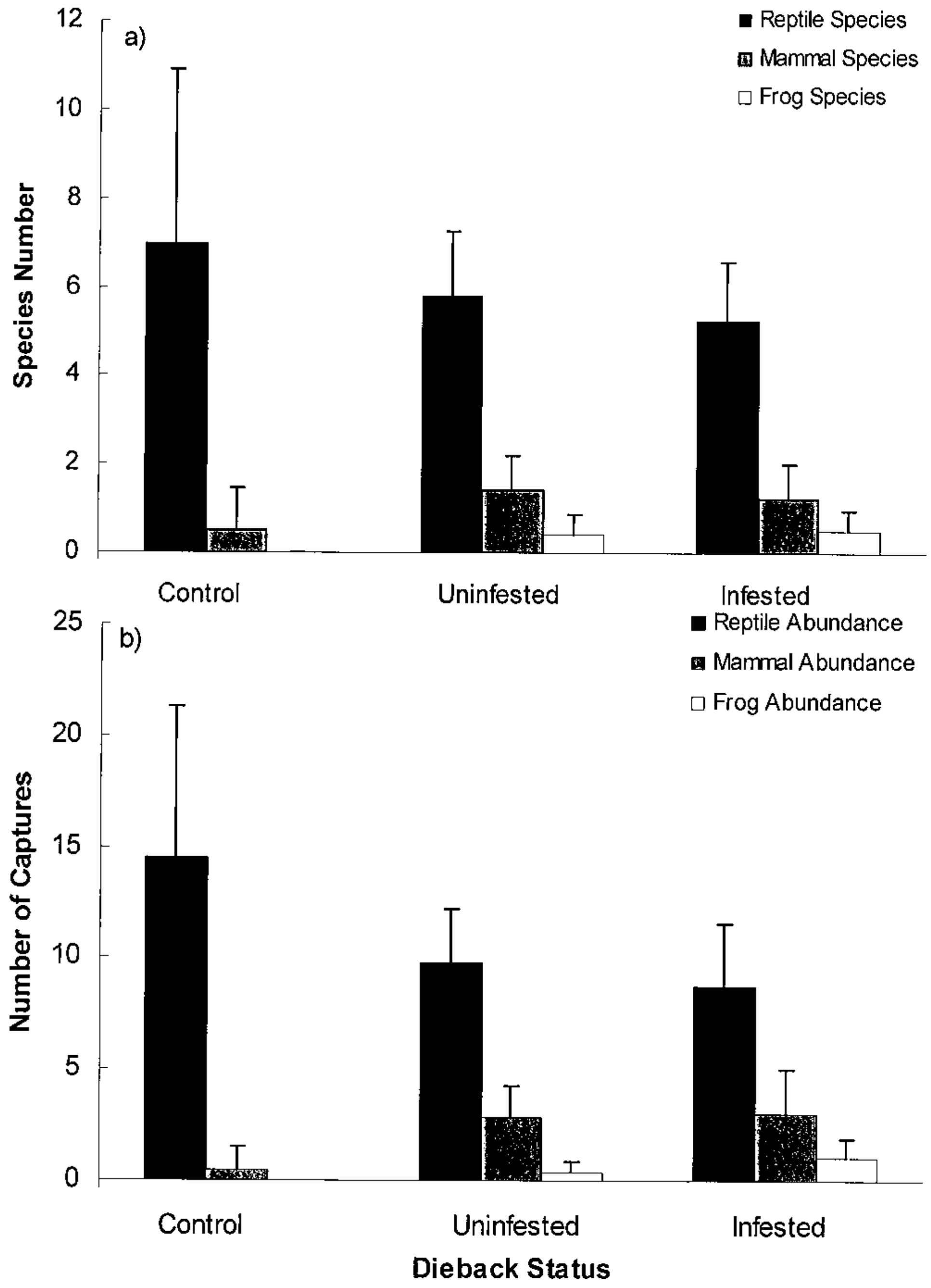


Figure 6: Fauna assemblages in three site categories depicted as a) species richness and b) abundance for reptiles (black bars), mammals (grey bars) and frogs (white bars) (n=12). Error bars in graph indicate 95% confidence intervals.

Table 1: Paired t-test T-values for *P. cinnamomi* status (n=10) and ANOVA F-values for Fire Age (n=10) influencing reptile abundance, species richness, individual species abundances (square-root transformed) and habitat variables (ground cover percentage estimates were Arcsine-transformed). Asterisks indicate p values ($p \leq 0.1$^, $p \leq 0.05$* and $p \leq 0.01$**).

	P. cinnamomi **Status**	**Fire Age** $_{df=1,8}$
Reptile species richness	-0.55	2.48
Reptile abundance	-1.00	4.51^
Cryptoblepharus buchananii	**3.76***	0.49
Rankinia adelaidensis	-1.47	3.77^
Lerista elegans	1.60	0.00
Tarsipes rostratus	1.01	2.30
Mus musculus	-1.11	0.04
Helioporous eyrei	-1.33	0.30
Touch pole counts		
0 -20 cm	-0.35	1.51
20 - 40 cm	**3.58***	1.22
40 - 60 cm	1.26	1.67
60 - 80 cm	0.95	0.80
80 - 100 cm	-	-
100 - 150 cm	-	-
150 - 200 cm	-	-
Litter cover	**3.13***	0.59
Soil cover	-2.798*	2.62
Live vegetation cover	-0.10	**12.44****
Dead vegetation cover	-1.71	0.37
Litter depth	**4.76****	0.24

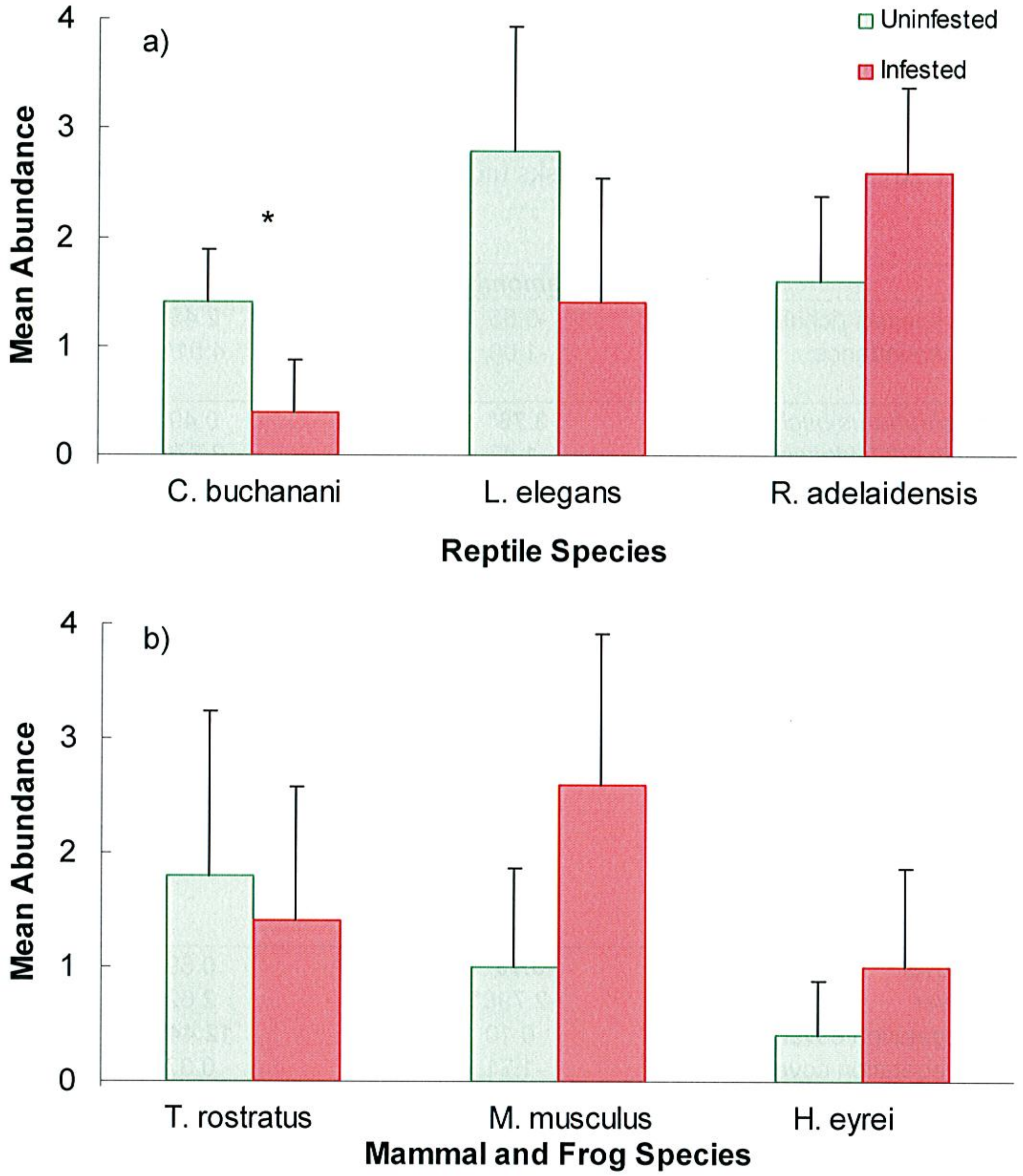


Figure 7: Trends of mean abundance for a) reptiles (*Cryptoblepharus buchananii, Lerista elegans* and *Rankinia adelaidensis*) and b) mammals and frog species (*Tarsipes rostratus, Mus musculus* and *Helioporous eyrei*) in uninfested and infested sites. Error bars in graph indicate 95% confidence intervals, asterisk indicates significant p value ($p \leq 0.05$*) for paired t-test (n=10).

Fauna and fire age

The number of reptile species did not significantly differ between fire age categories (Table 1), although there was a trend ($p < 0.1$) for higher reptile abundance in the older fire age categories (Table 1; Figure 8). Reptile species richness and the abundance of *Lerista elegans* was also slightly higher in the older fire age categories, although these results were not significant (Table 1; Figure 8). Only the small terrestrial dragon *Rankinia adelaidensis* had a trend for higher abundances in the younger fire age sites.

A permutation-based nonparametric MANOVA on the community composition of 15 species of reptiles indicated that species assemblage was potentially influenced by fire age ($p = 0.054$), however, no useful NMDS graphical solution was found.

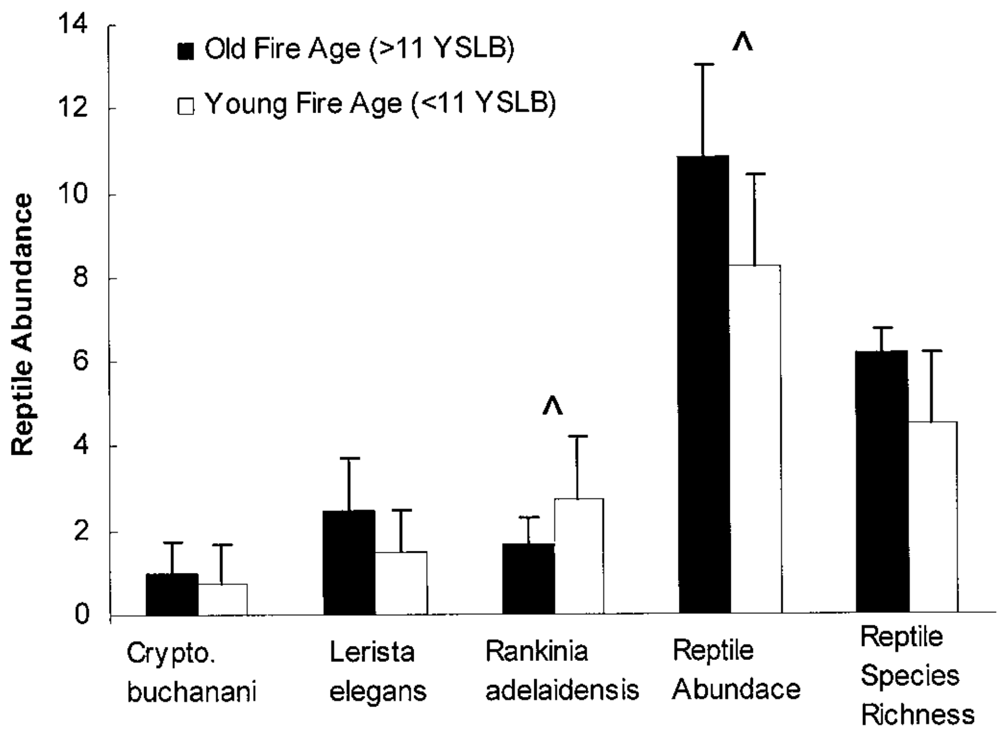


Figure 8: Reptile abundance and fire age (old versus young). Old >11 years since last burn, young <11 years since last burn. Error bars represent 95% confidence intervals,^ indicates ANOVA f-values with $p < 0.1$ (n=10).

P. cinnamomi and fire effects on habitat parameters

The status of *P. cinnamomi* (infested and uninfested) at sites influenced a number of habitat parameters (Table 1). The uninfested sites displayed a higher number of touch pole counts at 20-40cm, and greater amounts of litter depth and litter cover compared to infested sites. In contrast, the amount of soil cover was greatest in infested sites (Table 1; Figure 9).

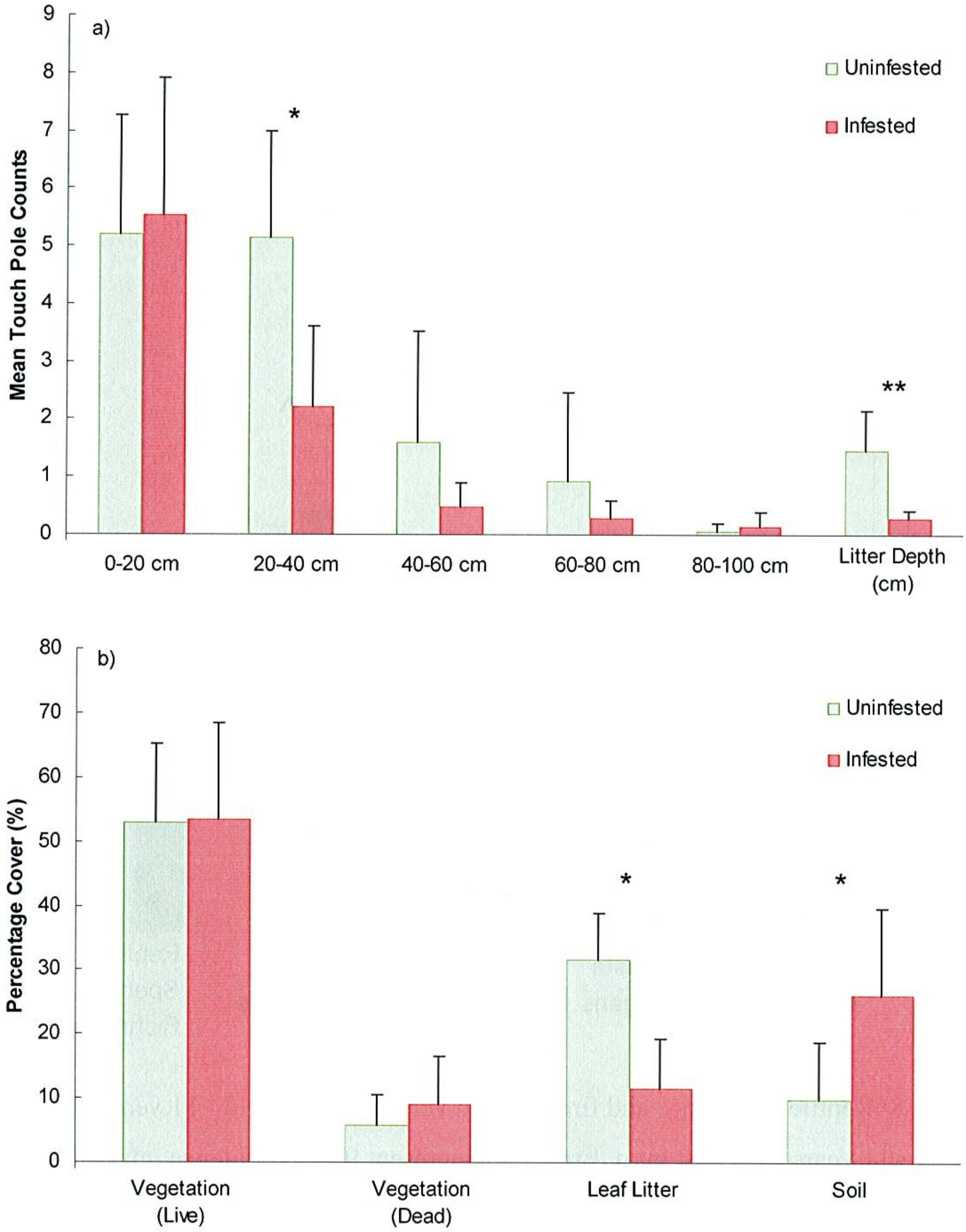


Figure 9: Influence of *P. cinnamomi* status on a) vegetation structure and litter depth and b) ground cover. (n=10). Error bars indicate 95% confidence intervals; asterisks indicate *p* values ($p \leq 0.1$^, $p \leq 0.05$* and $p \leq 0.01$**) from paired t-tests (n=10).

Live vegetation cover was significantly influenced by fire age (Table 1; Figure 10), with more vegetation cover in the older fire age sites. In addition, live vegetation cover was strongly, positively correlated with the year-since-last fire (Table 2).

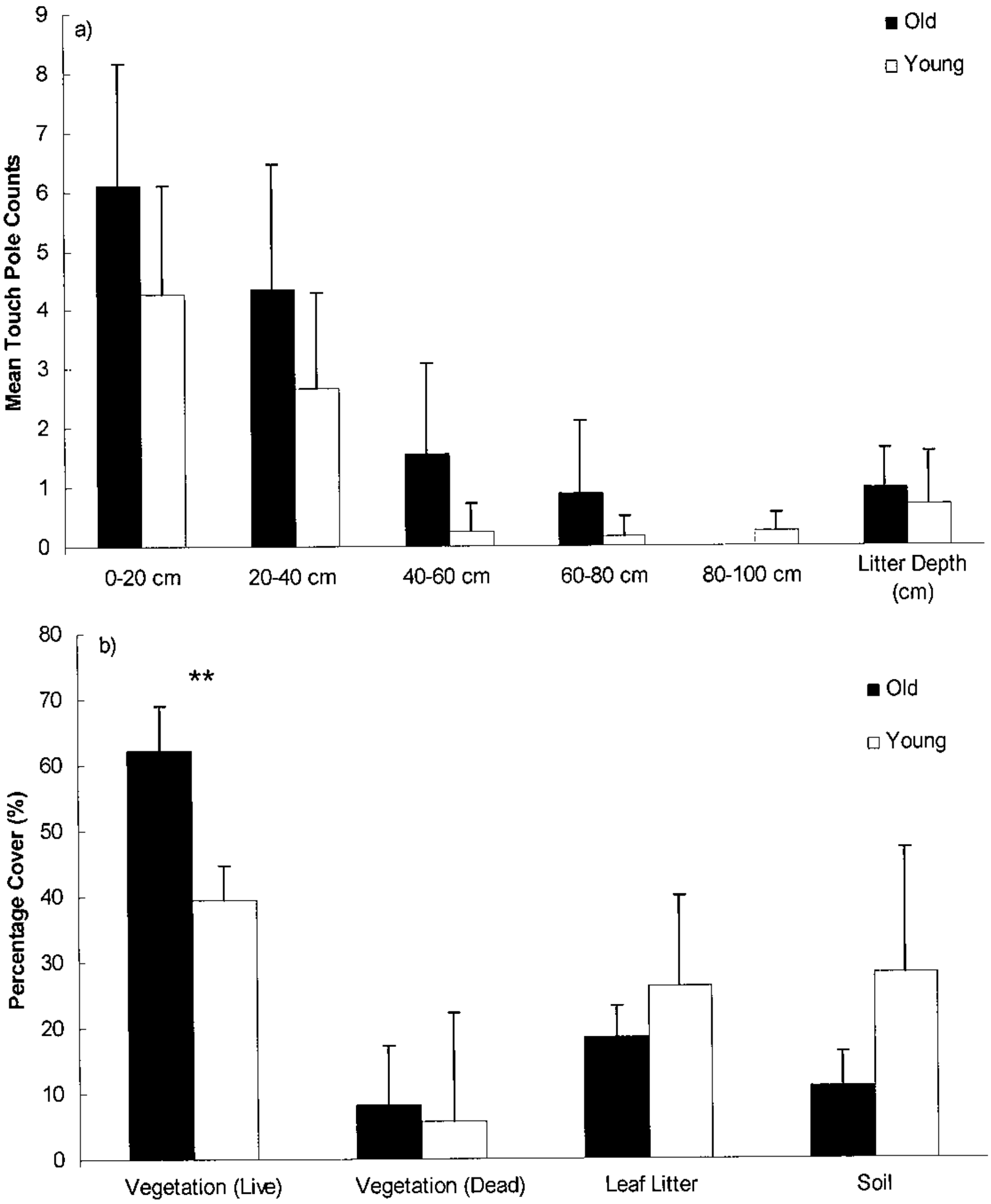


Figure 10: Influence of fire age (old versus young) on a) vegetation structure and litter depth and b) ground cover. Old >11 years since last burn; young <11 years since last burn. Error bars indicate 95% confidence intervals; asterisks indicate ANOVA F-values where $p \leq 0.01$** (n=10).

Fauna and habitat parameters

Reptile abundance showed a strong positive correlation with live vegetation ($r = 0.878$, $p = 0.001$), and a trend ($p > 0.1$) for a negative correlation with percentage soil cover. Reptile species richness was not significantly correlated with any habitat parameter but displayed a positive trend with live vegetation and the number of touches at 20 - 40 cm.

The abundance of both *C. buchananii* and *L. elegans* was positively correlated with litter cover (Table 2), and *L. elegans* abundance was also positively correlated with the number of touches at the 20-40cm interval (Table 2). In addition, the abundance of *L. elegans* showed a positive trend with litter depth (r =0.624, p =0.054) and negative trend with percentage soil cover (Pearson's r = -0.562, p = 0.091). The abundance of *R. adelaidensis* had a positive association with percentage soil cover and a trend for a negative association with touches at 0-20 cm and live vegetation (Table 2).

M. musculus displayed a positive correlation with soil cover (r = 0.646, p = 0.037) and negative correlation with vegetation at 20-40 cm (r = -0.663, p = 0.037). Positive trends were observed for dead vegetation cover and negative trends for litter cover (Table 2). *H. eyrei* exhibits a negative correlation with leaf litter cover (Table 2) but positive trend with live vegetation.

Table 2: Pearson correlations (r) of reptile abundance, species richness, individual species abundances and year since last burn (YSLB) with habitat variables at each site (n=10).

	C. buchanani	*L.elegans*	*R. adelaidensis*	*M. musculus*	*H. eyrei*	*T. rostratus*	YSLB
YSLB	-0.191	0.027	-0.627^	0.393	0.081	0.200	
Litter cover	**0.723***	**0.741***	-0.133	-0.626^	**-0.664***	0.245	-0.265
Soil cover	-0.471	-0.562^	**0.865****	**0.646***	-0.041	-0.121	-0.522
Live vegetation cover	-0.237	0.027	-0.616^	-0.204	0.563^	0.191	**0.735***
Dead vegetation cover	-0.053	-0.3	-0.01	0.58^	-0.036	-0.09	0.316
Litter depth	0.557	0.624^	-0.545	-0.519	-0.371	-0.076	0.205
Touch pole counts							
0 -20 cm	-0.152	-0.394	-0.591^	0.049	0.348	-0.42	0.427
20 - 40 cm	0.309	**0.837****	-0.384	**-0.663***	-0.241	0.466	0.329
40 - 60 cm	-0.223	0.203	0.114	-0.218	-0.296	0.436	0.323
60 - 80 cm	-0.306	0.065	0.228	-0.05	-0.346	0.274	0.212

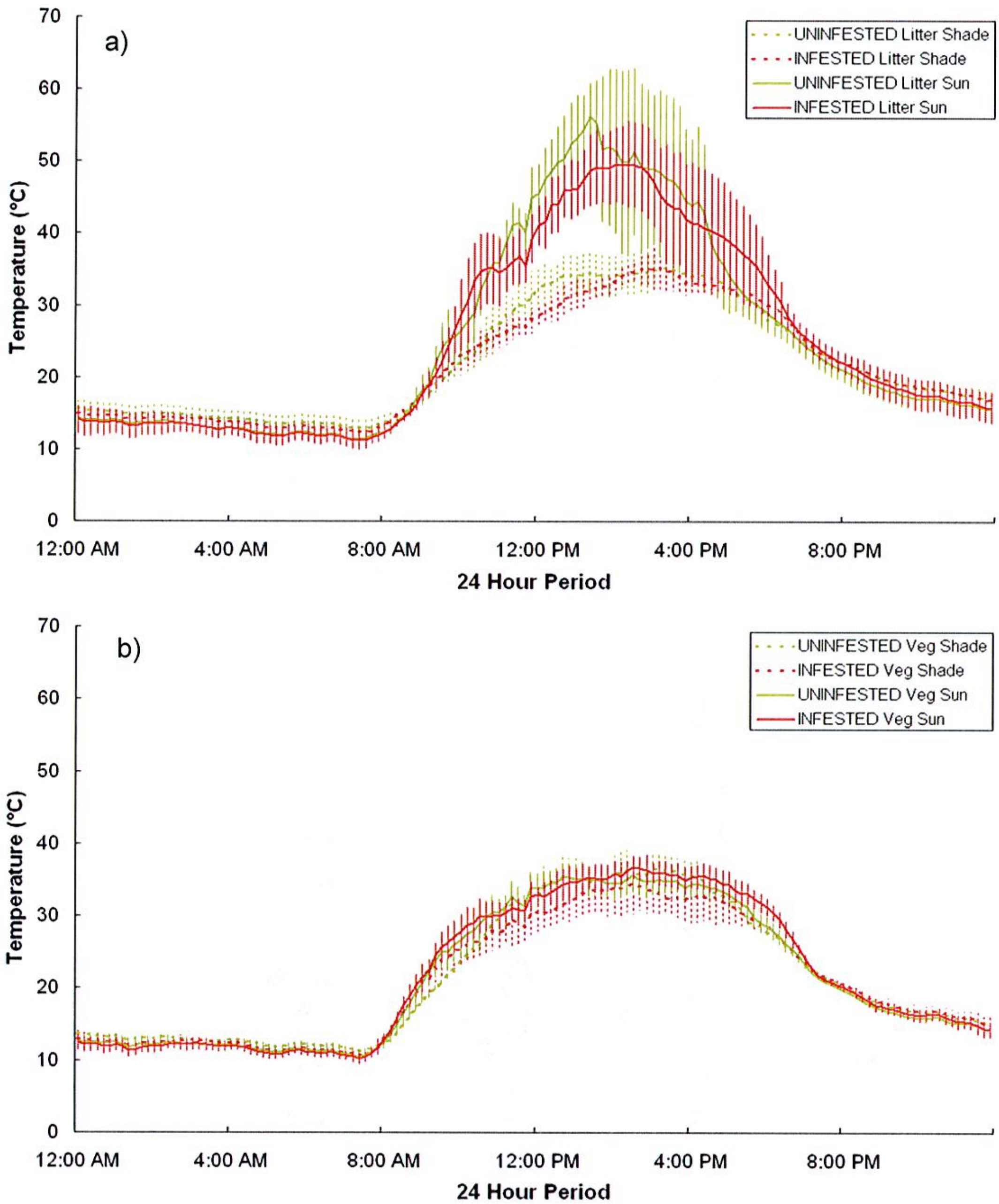


Figure 12: Mean daily temperatures (degrees Celsius) across sites for a) leaf litter and b) vegetation. Error bars in graph indicate 95% confidence intervals.

Temperature means displayed over a 24 hour period indicate there is less variation between infested/uninfested sites and sun exposures in the vegetation strata compared to leaf litter (Figure 12). Vegetation appears to buffer thermal extremes whereas higher temperature variation is experienced in leaf litter.

Discussion

Comparisons of plant species richness and live canopy cover show that the pattern of structural and floristic change in vegetation habitats may occur at different time scales. It appears that the canopy cover, composed primarily of highly-susceptible *Banksia* species, exhibits declines at the infection front before plant species richness is affected. Shearer *et al.* 2007 found species richness was lower in old infested Banksia woodland than that at the infection front and adjacent uninfested vegetation. Subsequent declines in plant species richness as the disease progresses may be attributed to either the direct impact of the pathogen removing susceptible species (the pathogen directly infects the understorey plant species and continues to spread via root to root contact) or in tandem with loss of canopy structure and thus changes to growing conditions for some plants (Shearer *et al.* 2007). For example the collapse of the canopy caused by *P. cinnamomi* infection leads to a change in growing conditions for understorey species (e.g. increased exposure to solar radiation, increased soil temperature, increased soil moisture evaporation/reduced soil moisture, reduced soil cover). These new growing conditions may not be beneficial to some understorey species, and so they decline or disappear from an infested area, leading to reduced species richness.

Floristics and vegetation structure in habitats where *P. cinnamomi* has been introduced show changes over time (Shearer and Dillon 1995) and the suitability of these habitats for fauna will vary depending on the range of microhabitats present and the microhabitat requirements of particular species of fauna. This study found that *P. cinnamomi* influenced several habitat variables which were subsequently correlated with specific faunal species.

P. cinnamomi infestation negatively influenced leaf litter depth, litter cover and vegetation structure at 20-40cm, and these habitat parameters were correlated with both *Lerista elegans* and *Cryptoblepharus buchananii* abundances. *C. buchananii* abundance was higher in uninfested sites, as was *L. elegans* abundance although to a lesser degree. These species therefore appeared to be negatively impacted by *P. cinnamomi* infestation of their habitat.

Species that appeared to benefit from *P. cinnamomi* infestation were *Mus musculus* and *Rankinia adelaidensis*. Both were positively correlated with increasing percentage soil cover estimates and in the case of *M. musculus*, was negatively correlated with vegetation structure at 20-40cm level. Both soil cover and vegetation at 20-40cm was influenced by *P. cinnamomi* infestation. *R. adelaidensis* was also influenced by young fuels ages. The thermal requirements of *R. adelaidensis* may influence this habitat preference, with the dragon species preferring more open environments provided by infested habitats or those of young fuel ages.

Very little is known about the habitat requirements of the priority three snake species, *Neelaps calonotos*. The species is listed by DEC as one known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. While it is locally abundant in *Banksia* sandplain habitat on the Swan Coastal Plain (Storr *et al.* 2002) additional surveys and further evaluation of the species' conservation status by the DEC is required. The survey outlined in Valentine *et al.* (2009) captured the majority of *N. calonotos* in old fuel ages (>16 YSLB). In this study all were found in sites aged at 11-12 YSLB and were predominantly in infested sites. Captures were clustered in two sites and, interestingly, three individuals were captured together in the one funnel trap. The dominant vegetation of the two infested sites where *N. calonotos* was captured also differed from the remaining fauna survey sites. These two sites were composed of high densities of either X*anthorrhoea preissii* or *Adenanthos cygnorum*, which contributed greatly to vegetation structure of the understorey. These sites could be a starting point to build upon ecological data for this species.

Overall, many trends were identified from the vertebrate fauna survey. However, in order to fully explore these trends, additional trapping data would be required. Many variables displayed a trend towards either *P. cinnamomi* infested or uninfested sites. Only five nights of trapping data were collected, limiting the power to detect differences between *P. cinnamomi* infested and uninfested sites. Valentine *et al.* (unpublished data), used species accumulation curves, to determine that eight to 14 nights trapping in uninfested areas across spring and autumn was optimal for the northern Swan Coastal Plain. It is likely that additional trap nights would have provided the power to identify significant changes in patterns of faunal assemblages between infested and uninfested sites.

The location of study sites may also influence the optimal trap nights required to reach species asymptotes. Most uninfested sites were isolated pockets amongst infested areas, and thus isolated from large areas of uninfested areas. In some regards they represent islands in a matrix of potentially unsuitable habitat. Faunal assemblages may therefore be influenced by the lack of a healthy faunal community to act as a reservoir for dispersal and have potentially already undergone modifications in species diversity and abundance.

Fire age and YSLB were shown to influences species abundances and habitat parameters, despite this study not being designed to asses the impact of fire. Fire has also been shown to influence the survival and dispersal of the *P. cinnamomi* pathogen in the south coast of Western Australia and to compound the pressure upon post-fire establishment of plant species (Moore 2005). The differing fire ages may therefore introduce the confounding factor of varied seedling establishment in infested sites and thus variable species richness and structure into our investigation of the impact of *P. cinnamomi* in *Banksia* woodland.

Topographical variability between and among sites may also have introduced unfavorable biases into this study. The sites were initially selected to carry out an avifauna survey, and were not selected for fine-scale fauna and flora analysis. Uninfested 1ha sites were generally located higher in the landscape at the top of a sand ridge or on the upslope, whilst infested sites were often located in depressions at the base of slopes in water gaining areas. This is an artifact of the spread of *P. cinnamomi* along water gradients. Often the only areas uninfested within the larger infested area were located at the top of sand hills. The vegetation often reflected these differences with *X. preissii* and *X. brunonis* among others, dominating infested areas but providing little cover in uninfested. Topography, like differing fire ages, may therefore have confounded the investigation into *P. cinnamomi* impacts.

P. cinnamomi status did not play a large role in influencing thermal microhabitats at our sites. Minimum and maximum temperatures were higher in uninfested sites than infested sites. This may be due to the composition of the vegetation in infested sites. Often 1-2m tall *Adenanthos* or *Xanthorrhoea* were dominant and provided a large degree of shading from the sun, and a denser mid strata level than in uninfested sites where these species contributed less cover than in infested sites.

Recommendations for further investigations

- Flora surveys in spring and autumn increase the likelihood of plants carrying fruiting bodies or flowers which are often essential for plant identification. Therefore floristic surveys should ideally be conducted over two seasons (spring and autumn) to allow proper identification of plants to species level.
- *P. cinnamomi*-uninfested and -infested sites should be located within the same topographical location to ensure flora and fauna composition is influenced by disease status rather than topography
- Location of uninfested sites should be situated in larger areas of uninfested *Banksia* woodland to reduce the likely pressures experienced within small isolated pockets.
- Fire also needs to be controlled for within the experimental design
- A minimum of eight trap nights (preferably 14 trap nights) are recommended in the northern Swan Coastal Plain (Valentine unpublished data) when trapping vertebrate fauna

References

Abbott I. (2006) Mammalian faunal collapse in Western Australia, 1875 - 1925: the hypothesised role of epizootic disease and a conceptual model of its origin, introduction, transmission, and spread. *Australian Zoologist* **33**, 530 - 61.

Beard J. S. (1984) Biogeography of the Kwongan. In: *Kwongan. Plant life of the Sandplain* (eds J. S. Pate and J. S. Beard) pp. 1-26. University of Western Australia Press., Nedlands, WA.

Beard J. S., Chapman A. R. & Gioia P. (2000) Species richness and endemism in the Western Australia flora. *Journal of Biogeography* **27**, 1257-68.

Churchward H. M. & McArthur W. M. (1980) Landforms and soils of the Darling System, Western Australia. In: *The atlas of natural resources, Darling System, Western Australia* pp. 25-33. Department of Conservation and Environment, Western Australia.

Cresswell I. D. & Bridgewater P. B. (1985) Dune vegetation of the Swan Coastal Plain, Western Australia. *Journal of the Royal Society of Western Australia* **67**, 137-48.

Davidson W. A. (1995) Hydrogeology and groundwater resources of the Perth Region. Bulletin 142, Geological Survey of Western Australia, Perth, Western Australia.

Davis R. A. (2009) Impact of fire and *Phytophthora* dieback on birds in the Gnangara Sustainability Strategy. An unpublished report prepared by the University of Western Australia and Department of Environment and Conservation for the Gnangara Sustainability Strategy, Perth.

DEC. (2009) Nature Conservation Service Swan Region Plan 2009 – 2014 (Draft March 2009). Department of Environment and Conservation, Government of Western Australia, Perth, Western Australia.

DOW. (2008) Gnangara groundwater areas - Water Management Plan (draft for public comment). Department of Water, Perth WA.

Garavanta C. A. M., Wooller R. D. & Richardson K. C. (2000) Movement patterns of honey possums, *Tarsipes rostratus*, in the Fitzgerald River National Park, Western Australia. *Wildlife Research* **27**, 179-83.

Garkaklis M. J., Wilson B. A., Calver M. C. & Hardy G. E. S. J. (2004) *Habitat alteration caused by an introduced plant disease, Phytophthora cinnamomi: a significant threat to the conservation of Australian forest fauna.* Royal Zoological Society of New South Wales, Mosman, NSW.

Heddle E. M., Loneragan D. W. & Havel J. J. (1980) Vegetation complexes of the Darling System, Western Australia. In: *Atlas of natural resources, Darling System, Western Australia* pp. 37-72. Department of Conservation and Environment, Perth, Western Australia.

Hill T. C. J., Tippett J. T. & Shearer B. L. (1994) Invasion of Bassendean Dune Banksia woodland by *Phytophthora cinnamomi. Australian Journal of Botany* **42**, 725-38.

Hopper S. D. & Gioia P. (2004) The southwest Australian floristic region: Evolution and conservation of a global hot spot of biodiversity. *Annual Review of Ecology, Evolution, and Systematics* **35**, 623-50.

Keighery B. J. (1994) Bushland plant survey: A guide to plant community survey for the community. Wildflower Society of WA (Inc.), Nedlands, Western Australia.

Kruskal J. B. (1964) Nonmetric multidimensional scaling: a numerical method. *Psychmetrika* **29**, 115-29.

McCune B. & Mefford M. J. (1999) *Multivariate analysis of ecological data, Version 5.* MjM Software Design, Gleneden Beach, Oregon.

Mickle D. A., Valentine L. E. & Kuehs J. M. (in prep) Patterns of floristic diversity in the Gnangara Sustainability Strategy study area. Unpublished report prepared for the Department of Environment and Conservation and the Gnangara Sustainability Strategy, Perth, Australia.

Mitchell D., Williams K. & Desmond A. (2003) Swan Coastal Plain 2 (SWA 2- Swan Coastal Plain Sub-region). In: *A biodiversity audit of Western Australia's 53 Biogeographical subregions in 2002* (eds J. E. May and N. L. McKenzie) pp. 606-23. Department on Conservation and Land Management, Perth, WA.

Mittermeier R. A., Robles-Gil P., Hoffmann M., Pilgram J. D., Brooks T. M., Mittermeier C. G., Lamoreux J. L. & Fonseca G. (2004) *Hotspots revisited: Earth's Biologically Richest and Most Endangered Ecoregions.* Cemex, Mexico City.

Moore N. A. (2005) Role of fire on *Phytophthora cinnamomi* in the Stirling Range National Park, Western Australia. Murdoch University Honours Thesis, Perth.

Newell G. R. (1997) The abundance of ground-dwelling invertebrates in a Victorian forest affected by dieback (*Phytophthora cinnamomi*) disease. *Australian Journal of Ecology.* **22**, 206-17.

Nichols O. G. & Bamford M. J. (1985) Reptile and frog utilisation of rehabilitated bauxite minesites and dieback-affected sites in Western Australia's jarrah *Eucalyptus marginata* forest. *Biological Conservation* **34**, 227-49.

Nichols O. G. & Watkins D. (1984) Bird utilisation of rehabilitated bauxite minesites in Western Australia. *Biological Conservation* **30**, 109-31.

Pez M. & Swinburn M. (2009) *Phytophthora* dieback interpretation report of Melaleuca block and the proposed Melaleuca Nature Reserve. A report for the Gnangara Sustainability Strategy. WA Department of Environment and Conservation, Perth, Western Australia.

Semeniuk C. A., Semeniuk V., Cresswell I. D. & Marchant N. G. (1990) Wetlands of the Darling System, southwestern Australia: a descriptive classification using pattern and form. *Journal of the Royal Society of Western Australia* **72**, 109-21.

Shearer B. L., Crane C. E., Barrett S. & Cochrane A. (2007) *Phytophthora cinnamomi* invasion, a major threatening process to conservation of flora diversity in the South-west Botanical Province of Western Australia. *Australian Journal of Botany* **55**, 225-38.

Shearer B. L. & Dillon M. (1995) Susceptibility of plant species in *Eucalyptus marginata* forest to infection by *Phytophthora cinnamomi*. *Australian Journal of Botany* **43**, 113-4.

Storr G. M., Smith L. A. & Johnstone R. E. (2002) *Snakes of Western Australia.* Western Australian Museum.

Swinburn M. & Hoskins M. (2009) Field survey of threatened flora and threatened ecological communities for the Gnangara Sustainability Strategy. Unpublished report prepared by the Department of Environment and Conservation for the Gnangara Sustainability Strategy. Perth.

Valentine L. E., Wilson B. A., Reaveley A., Huang N., Johnson B. & Brown P. H. (2009) Patterns of ground-dwelling vertebrate biodiversity in the Gnangara Sustainability Strategy study area. Unpublished report prepared by Department of Environment and Conservation for the Gnangara Sustainability Strategy, Perth.

Western Australian Museum. (2009) Checklist of the Terrestrial Vertebrate Fauna of Western Australia (October 2009), URL: http://www.museum.wa.gov.au/collections/natscience/vertebrates/VertebrateChecklist.asp. Western Australian Museum, Perth.

Wills R. T. (1992) The ecological impact of *Phytophthora cinnamomi* in the Stirling Range National Park, Western Australia. *Australian Journal of Ecology* **17**, 145-59.

Wills R. T. & Keighery G. (1994) Ecological impact of plant disease on plant communities. *Journal of the Royal Society of Western Australia* **77**, 127-31.

Wilson B. A., Newell G., Laidlaw W. S. & Friend G. R. (1994) Impact of plant diseases on faunal communities. *Journal of the Royal Society of Western Australia* **77**, 139-43.

Wooller R. D., Richardson K. C., Garavanta C. A. M., Saffer V. M. & Bryant K. A. (2000) Opportunistic breeding in the polyandrous honey possum, *Tarsipes rostratus. Australian Journal of Zoology* **48**.

Yesertener C. (2007) Assessment of the declining groundwater levels in the Gnangara groundwater mound, Western Australia. In: *Hydrogeological Record Series HG14.* Department of Water, Perth WA.

Zeehandelaar K. (2009) Are vertebrates limited by the availability of invertebrates in dieback affected Banksia woodlands? (Honours thesis). University of Western Australia, Perth, Western Australia.

Appendix 1: Floristic results of 10x10m quadrat assessments

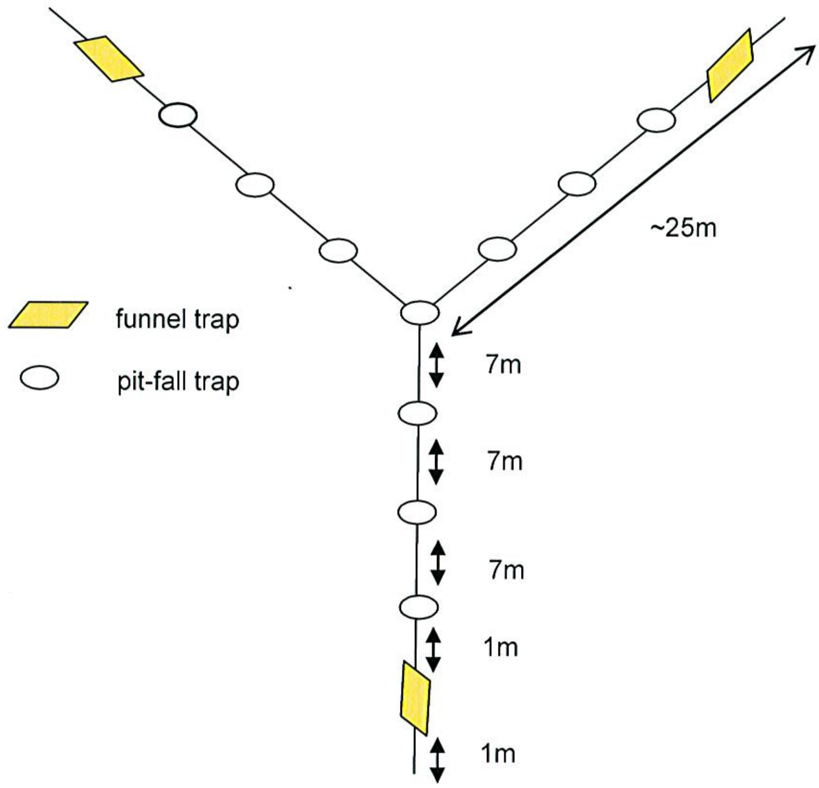
? Indicates unconfirmed plant identification
* Indicates plant taxa used in NMDS analysis
† Indicates taxa were combined under the same code for NMDS analysis

Species Code	Species Site	PC1A	PC1B	PC1C	PC2A	PC2B	PC2C	PC3A	PC3B	PC3C	PC4A	PC4B	PC4C	PC5A	PC5B	PC5C	PC6A	PC6B	PC6C	PC7A	PC7B	PC7C
? BCON	*? Burchardia congesta*																			+		
? DBRA	*? Disa bracteata*												+									
* ACABAR	*Acacia barbinervis*																	+				
* ACAHUE	*Acacia huegelii*	+	+		+			+		+											+	
* ACAPULGLA	*Acacia pulchella var. glaberrima*							+			+	+	+	+	+	+	+	+		+	+	
* ACASES	*Acacia sessilis*					+							+					+		+	+	
* ADECYGCYG	*Adenanthos cygnorum subsp. cygnorum*	+		+	+			+			+	+	+							+	+	+
* ADEOBO	*Adenanthos obovatus*						+	+	+													
AIRSP	*Aira sp*														+		+	+				
* ALENIT	*Alexgeorgea nitens*	+	+	+		+	+		+	+	+	+	+				+	+			+	+
* ALLHUM	*Allocasuarina humilis*				+	+														+		
* AMPTUR	*Amphipogon turbinatus*	+	+		+	+					+	+	+		+		+	+		+	+	
* ANDHET	*Andersonia heterophylla*		+		+						+	+		+				+			+	
* ANDLEHLEH	*Andersonia lehmanniana subsp. lehmanniana*					+		+														
* ANIHUMHUM	*Anigozanthos humilis subsp. humilis*	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+		+	
* ANIMAN	*Anigozanthos manglesii*																				+	
* ARCCAL	*Arctotheca calendula*								+													
* ARNPRE	*Arnocrinum preissii*	+												+				+				
* ASTXER	*Astroloma xerophyllum*	+	+	+	+	+	+	+			+	+	+								+	
* AUSOCC	*Austrodanthonia occidentalis*															+						
AUSSP	*Austrodanthonia sp*					+				+							+	+				
* AUSCOM	*Austrostipa compressa*		+											+	+	+						
* BANATT	*Banksia attenuata*	+	+		+	+		+	+		+	+		+	+		+	+	+	+	+	
* BANILI	*Banksia ilicifolia*	+					+	+	+	+												+
* BANMEN	*Banksia menziesii*	+	+		+			+				+		+			+			+	+	
* BEAELE	*Beaufortia elegans*	+	+	+	+	+							+	+		+		+			+	
* BORPUR	*Boronia purdieana*										+	+										
*† BORRAM	*Boronia ramosa*										+	+	+									
*† BORRAM	*Boronia ramosa subsp. anethifolia*																				+	
* BOSERI	*Bossiaea eriocarpa*	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+
* BRIMAX	*Briza maxima*	+	+							+					+		+			+		
* BURCON	*Burchardia congesta*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
* CALFLAFLA	*Caladenia flava subsp. flava*	+				+		+			+	+	+				+	+		+		
* CALCOR	*Calandrinia corrigioloides*																		+			
* CALNAR	*Calectasia narragara*				+															+		
* CALSPP	*Calectasia sp Pinjar*			+							+		+									
CALSP	*Calothamnus sp*														+							
* CALANG	*Calytrix angulata*													+								
* CALFLA	*Calytrix flavescens*	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+		+	+	
* CALSAP	*Calytrix sapphirina*										+	+	+					+				
CAL	*Calytrix sp*				+																	
CARSP	*Carpobrotus sp*					+					+	+				+	+	+	+			
* CASGLA	*Cassytha glabella*			+								+		+								
* CASPOM	*Cassytha pomiformis*		+		+	+														+	+	
CASSP	*Cassytha sp*	+											+		+			+				
* CENDRU	*Centrolepis drummondiana*	+								+	+				+		+		+			
* CENINC	*Centrolepis inconspicua*																+	+				
* CENPIL	*Centrolepis pilosa*														+							
* CERGLO	*Cerastium glomeratum*																+					
* CHACORCOR	*Chamaescilla corymbosa subsp. corymbosa*																		+			
* CHOMIC	*Chordifex microcodon*		+	+								+										
CHO	*Chordifex microcodon*																				+	
* COMCAL	*Comesperma calymega*																	+				
* CONMIN	*Conostephium minus*	+	+					+	+					+			+	+				
* CONPEN	*Conostephium pendulum*	+	+			+		+	+			+								+	+	
CONSP	*Conostephium sp*																+	+				
* CONACUACU	*Conostylis aculeata subsp. aculeata*											+	+							+		
CONACUCYG	*Conostylis aculeata subsp. cygnorum*																			+		
* CONJUN	*Conostylis juncea*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+
* CONTERPLA	*Conostylis teretifolia subsp. planescens*											+										
* CRACOL	*Crassula colorata*			+		+	+				+	+	+		+	+	+	+	+			
CRA	*Crassula sp*		+																			
* CROKIN	*Cronina kingiana*										+											
* DAMLIN	*Dampiera linearis*	+		+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+
* DASBRO	*Dasypogon bromeliifolius*	+					+	+	+	+	+	+	+	+		+			+	+	+	+
* DAVTRI	*Daviesia triflora*		+								+	+						+			+	

Species Code	Species	PC1A	PC1B	PC1C	PC2A	PC2B	PC2C	PC3A	PC3B	PC3C	PC4A	PC4B	PC4C	PC5A	PC5B	PC5C	PC6A	PC6B	PC6C	PC7A	PC7B	PC7C
* DESFLE	*Desmocladus flexuosus*	+			+	+								+	+	+				+		+
DIUSP	*Diuris sp*																	+				
* DROBUL	*Drosera bulbosa*		+	+	+																	+
* DROERY	*Drosera erythrorhiza*	+				+	+	+	+	+	+	+	+		+		+			+		
*† DROMAC	*Drosera macrantha*								+	+						+						
*† DROMAC	*Drosera macrantha subsp. macrantha*							+														
*† DROMEN	*Drosera menziesii*	+	+	+	+		+		+			+	+	+	+			+				
*† DROMEN	*Drosera menziesii subsp. menziesii*										+										+	
*† DROMEN	*Drosera menziesii subsp. penicillaris*					+		+									+					
* DROPAL	*Drosera pallida*				+						+									+		
* DROPAR	*Drosera parvula*						+				+	+		+				+				
* EHRCAL	*Ehrharta calycina*			+		+																+
* ELYBRU	*Elythranthera brunonis*																+					
EPA	*Epacrid White*	+																				
EPASEE	*Epacridaceae seedling*															+						
*† EREPAU	*Eremaea pauciflora*																				+	
*† EREPAU	*Eremaea pauciflora subsp. pauciflora*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+		+
ERESP	*Eremaea sp*							+														
* EUCTOD	*Eucalyptus todtiana*				+								+							+		
EUP	*Euphorbia*																		+			
FLA	*Flatweed*									+												
* GASCAP	*Gastrolobium capitatum*			+							+				+	+					+	
* GLACAR	*Gladiolus caryophyllaceus*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
GOM? T	*Gompholobium ? tomentosum*		+		+	+																
* GOMCON	*Gompholobium confertum*							+	+													
* GOMTOM	*Gompholobium tomentosum*			+				+		+	+		+		+	+		+		+	+	
GOM	*Gompholobium tomentosum*	+																				
* GONPIT	*Gonocarpus pithyoides*				+			+			+	+	+	+								
GOOSP	*Goodeniaceae sp*																		+			
HAE	*Haemodorum sp*									+												
* HAESPT	*Haemodorum spicatum*	+															+	+				
* HEMGLA	*Hemiandra glabra*	+																				
* HEMLIN	*Hemiandra linearis*		+																			
* HENTUR	*Hensmania turbinata*	+			+				+		+			+				+			+	
* HIBAUR	*Hibbertia aurea*																	+				
* HIBHUE	*Hibbertia huegelii*		+								+	+		+			+					
* HIBHYP	*Hibbertia hypericoides*	+		+	+	+					+									+	+	
HIBSP	*Hibbertia sp*													+								
* HIBSPG	*Hibbertia sp Gnangara*	+	+			+					+	+	+	+			+	+			+	
* HIBSUB	*Hibbertia subvaginata*	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+		+	+	+
* HOVPUN	*Hovea pungens*	+	+	+																		
* HOVTRI	*Hovea trisperma*				+		+	+												+		
* HYPANG	*Hypocalymma angustifolium*																		+			
* HYPROB	*Hypocalymma robustum*	+	+					+	+	+	+	+					+					
* HYPGLA	*Hypochaeris glabra*		+		+	+	+	+	+		+	+	+	+	+	+	+	+	+	+		+
HYPSP	*Hypochaeris sp*																		+			
* HYPEXS	*Hypolaena exsulca*						+			+					+							
* ISOMAR	*Isolepis marginata*				+	+		+			+	+			+	+	+	+	+	+		+
ISO	*Isolepis sp*						+						+									
* ISOCUN	*Isotropis cuneifolia*				+	+																
* JACFLO	*Jacksonia floribunda*	+	+	+		+	+	+	+		+	+	+		+			+			+	+
* JACFUR	*Jacksonia furcellata*							+													+	
* LAGHUE	*Lagenophora huegelii*																			+		
*† LAXRAM	*Laxmannia ramosa*													+								
*† LAXRAM	*Laxmannia ramosa subsp. ramosa*			+															+			+
LAXSP	*Laxmannia sp*															+						
* LAXSQU	*Laxmannia squarrosa*		+	+	+						+		+	+				+			+	
* LECFLO	*Lechenaultia floribunda*	+							+				+									
LEPSP	*Lepidosperma sp*				+																	
* LEPFIM	*Leporella fimbriata*																			+		
* LEPEMP	*Leptomeria empetriformis*											+										
* LEPSPI	*Leptospermum spinescens*										+											
* LEUAFF	*Leucopogon aff polymorphus*						+				+											
* LEUCON	*Leucopogon conostephioides*	+	+	+	+			+	+	+	+	+	+	+	+			+		+	+	+
* LEUPOL	*Leucopogon polymorphus*							+	+	+			+			+						
* LEUPRO	*Leucopogon propinquus*												+									
LEUSP	*Leucopogon sp*																		+			
LEUSP	*Leucopogon sp seedling*																		+			
* LEUSQU	*Leucopogon squarrosus*													+				+				
* LEVSTI	*Levenhookia stipitata*													+	+							
LOB? T	*Lobelia ? tenuior*													+	+							
LOM? P	*Lomandra ? purpurea*	+						+														
* LOMCAE	*Lomandra caespitosa*		+		+		+				+	+	+		+							+
LOM	*Lomandra caespitosa*			+																		
* LOMHER	*Lomandra hermaphrodita*					+								+	+					+		
* LOMPRE	*Lomandra preissii*													+								
* LOMSER	*Lomandra sericea*	+													+	+			+			
LOMSP	*Lomandra sp*	+		+				+		+		+	+			+	+					
* LOMSUA	*Lomandra suaveolens*																	+				

Species Code	Species Site	PC1A	PC1B	PC1C	PC2A	PC2B	PC2C	PC3A	PC3B	PC3C	PC4A	PC4B	PC4C	PC5A	PC5B	PC5C	PC6A	PC6B	PC6C	PC7A	PC7B	PC7C
* LYGBAR	*Lyginia barbata*																			+		+
* LYGIMB	*Lyginia imberbis*			+			+			+	+	+	+	+	+	+	+	+		+		
LYG	*Lyginia imberbis*	+	+		+			+	+												+	+
LYG	*Lyginia sp*					+																
* LYSCIL	*Lysinema ciliatum*											+	+									
* MACFRA	*Macrozamia fraseri*				+												+			+		
MEL? S	*Melaleuca ? seriata*		+																			
* MELSER	*Melaleuca seriata*								+	+						+			+			
* MELTRI	*Melaleuca trichophylla*										+	+			+		+	+				
* MESGRA	*Mesomelaena graciliceps*																		+			
*† MILTEN	*Millotia tenuifolia*																		+			
*† MILTEN	*Millotia tenuifolia var. tenuifolia*		+																			
MYRSP	*Myrtaceae sp*																	+				
MYRSP	*Myrtaceae sp seedling*	+																	+			
* NUYFLO	*Nuytsia floribunda*	+		+	+						+		+		+		+		+	+		+
* OPEVAG	*Opercularia vaginata*																		+			
* PATOCC	*Patersonia occidentalis*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+
PATSP	*Patersonia sp*										+											
* PENAIR	*Pentaschistis airoides*	+				+	+		+					+	+	+	+	+	+			+
* PERSAC	*Persoonia saccata*														+					+	+	
* PETLIN	*Petrophile linearis*	+	+		+	+		+	+		+	+	+	+	+		+	+		+	+	
* PHISPI	*Philotheca spicata*	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	
* PHLCIL	*Phlebocarya ciliata*	+		+	+		+	+	+	+	+									+		+
* PHYPAR	*Phyllangium paradoxum*			+						+	+	+		+			+		+			
PHYSP	*Phyllangium sp*	+	+										+		+	+		+				
* PITPUL	*Pithocarpa pulchella*		+		+	+		+	+													
POASP	*Poaceae sp*											+	+									
POASP	*Poaceae sp Glabrous*																		+			
POASP	*Poaceae sp Hairy ligule*			+	+		+															
POASP	*Poaceae sp Hairy sheath*												+							+		
* PODANG	*Podotheca angustifolia*		+	+	+					+		+										+
* PODCHR	*Podotheca chrysantha*														+							
* PODGNA	*Podotheca gnaphalioides*														+	+			+			
* PORERI	*Poranthera ericoides*										+	+	+								+	
* PRAPAR	*Prasophyllum parvifolium*	+																				
* PTEAFF	*Pterostylis aff nana*							+														
* PTEBAR	*Pterostylis barbata*	+																				
* PTESAN	*Pterostylis sanguinea*																+			+		
PTESP	*Pterostylis sp*		+																			
* PYRNIG	*Pyrorchis nigricans*																	+	+	+		
* QUIURV	*Quinetia urvillei*														+	+	+		+			
* REGINO	*Regelia inops*											+	+									
* RHOCIT	*Rhodanthe citrina*	+				+				+	+	+		+	+	+	+	+	+			
* SCAREPREP	*Scaevola repens var. repens*																			+		
* SCHCUR	*Schoenus curvifolius*	+	+	+	+		+	+	+				+	+		+		+				+
SCH	*Schoenus curvifolius*					+				+	+	+			+						+	
* SCHINV	*Scholtzia involucrata*	+	+		+	+	+	+			+	+		+	+		+	+			+	
* SILHUM	*Siloxerus humifusus*																		+			
* STILAT	*Stirlingia latifolia*		+		+						+	+		+	+		+	+		+	+	
* STYADP	*Stylidium adpressum*													+					+			
* STYAND	*Stylidium androsaceum*															+						
* STYARA	*Stylidium araeophyllum*				+		+			+			+	+	+	+			+		+	+
STY	*Stylidium bunched*										+											
* STYCRO	*Stylidium crossacephalum*					+							+		+					+		
*† STYDIU	*Stylidium diuroides*		+	+	+	+					+	+	+				+	+			+	
*† STYDIU	*Stylidium diuroides subsp. diuroides*													+								
STY	*Stylidium Large*							+														
* STYREP	*Stylidium repens*	+	+	+	+	+		+	+	+	+	+	+		+	+	+	+	+	+	+	
* STYRIG	*Stylidium rigidulum*		+								+		+	+	+		+					
* STYSCA	*Stylidium scariosum*	+															+		+			
* STYSCH	*Stylidium schoenoides*	+		+				+														
* STYSPK	*Stylidium sp Kalbarri*						+	+		+	+	+				+			+			+
* THECAM	*Thelymitra campanulata*	+	+					+						+								
THY? A	*Thysanotus ? arbuscula*											+										
* THYARB	*Thysanotus arbuscula*							+	+													
THY	*Thysanotus sp*								+													
* THYSPT	*Thysanotus sp Twining*														+							
* TRAPIL	*Trachymene pilosa*	+	+			+	+	+	+	+	+			+	+		+	+	+	+		+
TRISP	*Tricoryne sp*							+		+												
* TRITEN	*Tricoryne tenella*															+						
* URSANT	*Ursinia anthemoides*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
* VERNIT	*Verticordia nitens*	+	+		+					+	+	+						+	+		+	
WAHSP	*Wahlenbergia sp*		+					+		+	+	+				+	+		+			
WAI	*Waitzia sp*																	+				
* WAISUA	*Waitzia suaveolens*		+				+				+		+									+
* XANBRU	*Xanthorrhoea brunonis*	+				+	+		+	+					+	+	+		+			
* XANPRE	*Xanthorrhoea preissii*	+	+			+	+							+	+	+	+		+			+
* XANHUE	*Xanthosia huegelii*		+	+		+	+			+	+	+	+	+	+		+	+	+			
	Total Taxa	67	61	43	55	52	41	57	42	44	71	67	60	55	61	46	57	63	49	55	51	34

Appendix 2: Fauna survey pit-fall trap design layout



Appendix 3: Species captured during fauna survey March 2009

Class	Family	Species
Amphibia	Limnodynastidae	*Heleioporus eyreii*
Reptilia	Pygopodidae	*Pletholax gracilis gracilis*
	Diplodactylidae	*Strophurus spinigerus spinigerus*
	Agamidae	*Pogona minor minor*
	Agamidae	*Rankinia adelaidensis*
	Scincidae	*Acritoscincus trilineatum*
	Scincidae	*Cryptoblepharus buchananii*
	Scincidae	*Ctenotus australis*
	Scincidae	*Ctenotus fallens*
	Scincidae	*Lerista elegans*
	Scincidae	*Lerista praepedita*
	Scincidae	*Menetia greyii*
	Scincidae	*Morethia lineoocellata*
	Scincidae	*Morethia obscura*
	Scincidae	*Tiliqua occipitis*
	Scincidae	*Tiliqua rugosa rugosa*
	Elapidae	*Neelaps calonotos*
	Elapidae	*Parasuta gouldii*
Mammalia	Muridae	*Mus musculus*
	Tarsipedidae	*Tarsipes rostratus*

Appendix 4: Fauna species richness and abundance by site

Yellow highlight indicates highest species richness or abundance, while red indicates lowest richness or abundance.

Site	Reptile Species	Reptile Abundance	Frog Species	Frog Abundance	Mammal Species	Mammal Abundance	**Spp. Richness**	**Spp. Abundance**
20A	9	18	0	0	0	0	**9**	[illegible]
20B	5	11	0	0	1	1	**6**	**12**
PC1A	7	12	1	1	1	4	**9**	**17**
PC1C	7	15	1	1	2	6	**10**	[illegible]
PC2A	7	11	1	1	0	0	**8**	**12**
PC2C	6	9	1	2	1	3	**8**	**14**
PC3A	6	11	0	0	2	3	**8**	[illegible]
PC3C	6	7	0	0	0	0	**6**	[illegible]
PC4A	3	5	0	0	2	3	**5**	**8**
PC4C	3	8	0	0	2	4	**5**	[illegible]
PC7A	6	10	0	0	2	4	**8**	[illegible]
PC7C	6	11	1	2	2	5	**9**	**18**

Group	Reptile Species	Reptile Abundance	Frog Species	Frog Abundance	Mammal Species	Mammal Abundance	**Spp. Richness**	**Spp. Abundance**
20	10	29	0	0	1	1	11	**30**
PC1	11	27	1	2	2	10	14	[illegible]
PC2	9	20	1	3	1	3	11	**26**
PC3	10	18	0	0	2	3	12	**21**
PC4	4	13	0	0	2	7	6	[illegible]
PC7	7	21	1	2	2	9	10	**32**