Department of Parks and Wildlife

The Fauna of Boonanarring Nature Reserve.

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Introduction and Background

Boonanarring Nature Reserve is unique reserve with an ecotone of 10 vegetation types from the Swan region, home to many native species. Managed by the Swan Coastal District of Department of Parks and Wildlife, this ‘C’ class reserve is the most north-eastern reserve of the district’s tenure, situated 15km north of Gingin, covering 9250ha. This reserve is listed in the Forest Management Plan as part of the Comprehensive, Adequate and Representative reserve system (CAR) for forests in Western Australia (Conservation Commission of Western Australia 2013). Situated on the Dandaragan plateau with a mix of soil types, Boonanarring Nature Reserve contains 573 different flora, 13% of which are recorded as special interest (Figure 2). Two threatened ecological communities reside within the reserve including *Banskia attenuta – B. menziesii* and *Banksia ilicifolia* woodlands. Several faunal species within the reserve are listed as of importance, *Morelia imbricata spilota* (carpet python) and *Simoselaps calonotos* (western black striped snake) (Burbidge *et al.* 1996). Boonanarring Nature Reserve was last surveyed in 1986 for fauna and vegetation by the then Department of Conservation and Land Management staff. Apart from the 1986 survey (Burbidge *et al.* 1996) and some broad scale vegetation mapping conducted by Beard (1979), no other surveys have been conducted in the nature reserve. To determine the current fauna species list for the reserve, fauna surveys were carried out in 2012.

Prescribed burning, fencing, predator and weed control are some of the management actions carried out by land managers. Appropriate use of these actions can only occur when managers are well informed. Fire management by the Department of Parks and Wildlife aims to provide ‘an ecologically appropriate temporal and spatial mosaic of vegetation and habitat established across a range of different seral stages, at both landscape and local scales’. A main aim of prescribed burning is also asset protection to ensure large wildfire do not occur and destroy human property (Department of Parks and Wildlife 2014b). To achieve this mosaic prescribed burning is ideally carried out. Other management issues are maintaining the condition of the Dandaragan Plateau including the threatened ecological communities, *Phytophthora cinnamomi* ‘dieback’, mining activities (including vegetation clearing), declared and rare flora and fauna, reducing the distribution or density of weed species and feral predators (Department of Parks and Wildlife 2014a; b). Currently no feral predator or weed control occur in this reserve, this report may aid the use of these controls in the future. Prescribed burning occurs in Boonanarring Nature Reserve but has not included biological diversity and conservation of native species within it planning so far.

The purpose of this report it to detail the fauna within Boonanarring reserve and identify management issues or actions that are required. More specifically the aims are;

- Assess the current faunal diversity and abundance in 2012,
- compare the species richness and abundance of faunal groups between the earlier 1986 and the current 2012 faunal surveys (26 years apart),
- the fire history of the reserve is known and there is a possibility of assessing the relationships between the fire history and the faunal groups, the practicality of the fire regimes and their impact on the faunal groups,
- and lastly, determining the presences of introduced predators such as the feral cat (*Felis catus*) and fox (*Vulpes vulpes*) will inform the land managers about the predation threats to native fauna and the need for feral animal control (primarily using 1080 baiting).

Methods

Location and vegetation

Boonanarring Nature Reserve is located in north-east of the Swan Coastal Plain, north of the GinGin town site (Figure 1). The reserve is a mix of vegetation types including banksia (*Bankia grandis*, *Banksia attenuata* and *Banksia menziesii*), *Eucalyptus marginata* (jarrah), *Eucalyptus calophylla* (marri) and *Eucalyptus wandoo* (wandoo) woodlands verging on the Dandaragan Plateau (Figure 2). This reserve is one of kind on the Swan Coastal Plain, with no other reserves containing its floral diversity. It has a Mediterranean climate of wet winters and dry, hot summers (Burbidge *et al.* 1996; Sonneman 2012).

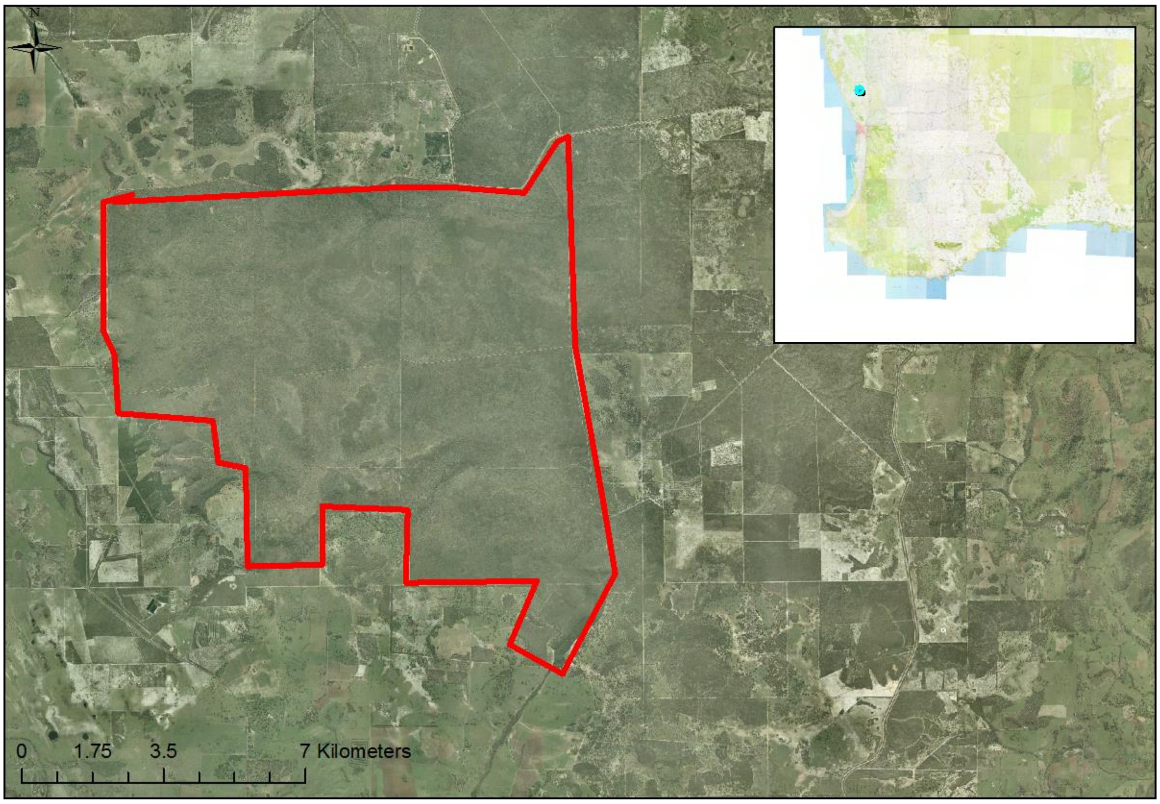


Figure 1: Location of Boonanarring Nature Reserve on the Swan Coastal Plain, Western Australia.

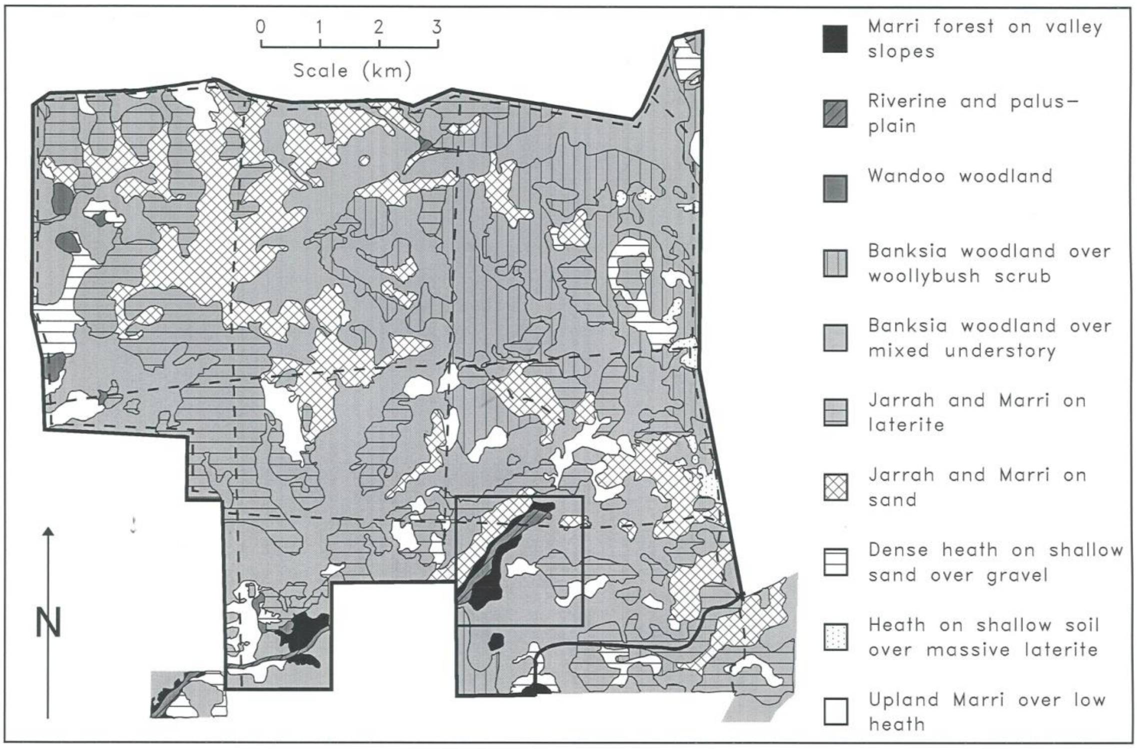


Figure 2: Vegetation map of Boonanarring Nature Reserve, from (Burbidge *et al.* 1996).

Fire history of Boonanarring Nature Reserve

The reserve contains a centrally located Fire Exclusion Reference Area (FERA, since 2006) with a total area of 845 hectares (Figure 3). At present 78% of the reserve has a fuel age of less than ten 'Years Since Last Burn' (YSLB) with 99% of this recent fire history due to prescribed burns. Two prescribed burns were planned for spring 2012 and autumn 2013 in which an additional 417 hectares to the area of young fuel age. These burns did not go ahead but future prescribed burns are planned. Burbidge et al. (1996) recognised fire as a major management problem and were concerned for the persistence of small mammals if frequent fire continued to be introduced to the reserve (Sonneman 2012). Fire ages of the fauna survey sites are listed in Table 1, a large number of the sites have an unknown fire history.

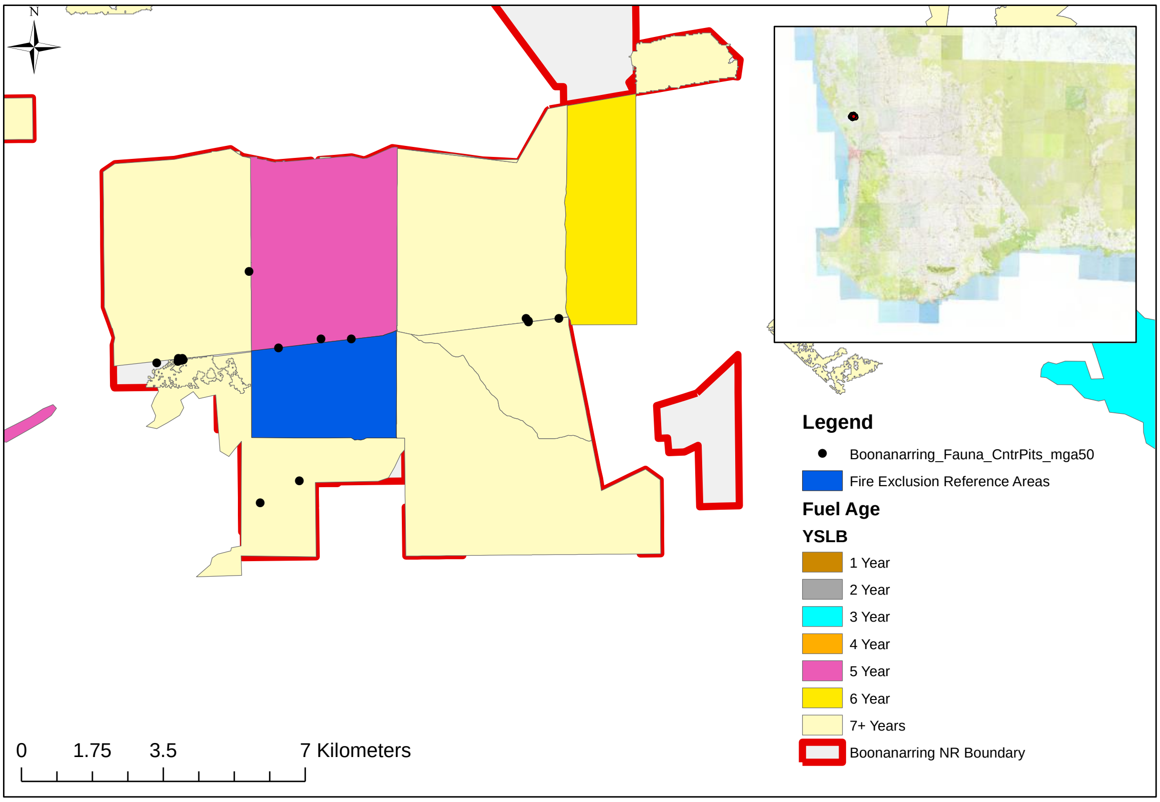


Figure 3: Fire history of Boonanarring Nature Reserve, Western Australia. The black dots highlight the fauna trapping sites, the dark blue indicates a Fire Exclusion Reference (since 2006) and site each area is numbered and coloured to indicate the fuel age (map produced in 2014).

Table 1: Fire history and description of each site from the 2012 surveys at Boonanarring Nature Reserve. AB indicates that the site had associated grid of PVC traps.

Site number	Fire age (years)	Vegetation type
1	14	*E. calophylla* over heath
2 and AB2	14	Banksia woodland
3 and AB 3	14	*E. wandoo* woodlands
4	3	*E. marginata* and *E. calophylla*
5 and AB5	5	Banksia woodlands
6	8	*E. marginata* and *E. calophylla*
7	14 (FERA)	*E. marginata* and *E. calophylla*
8	14 (FERA)	Heathlands
9	8	Heathlands
10	14	Breakaway- low vegetation
11	14	Unusual tall heath on slope with eucalypts.

There is a planned burn for Boonanaring in Autumn 2014 that will include sites 2 and 3 (Figure 4). There is a potential to research the influence of fire and prescribed burns on the fauna of Boonanarring.

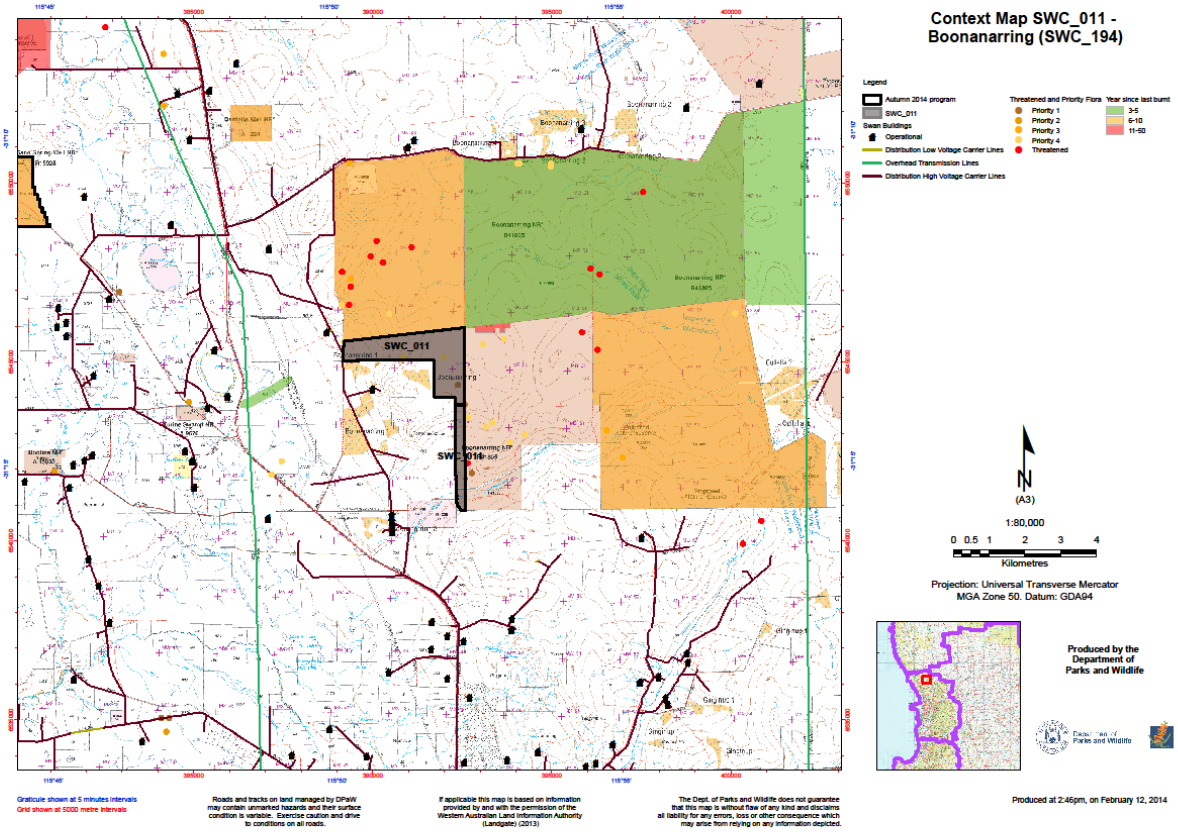


Figure 4 Locality of planned prescribed burn for Autumn 2014 in Boonanarring Nature Reserve.

Experimental design

To determine the changes in faunal assemblages from 1986 to 2012, sites in the autumn 2012 were located in similar positions as the 1986 surveys. However, for the spring 2012 surveys additional sites were located in different vegetation types and/or fuel age in an attempt to survey as many different environments as possible. The trap efforts for each year are detailed in Table 2. Opportunistic observations were included for both survey years. In 2012 observations were made at the time of trapping and in 1986 observations were made in the months of February, July and August.

Table 2: Trap nights and survey effort of the 2012 and 1986 surveys of Boonanarring Nature Reserve.

	Trap nights in 2012		Trap nights in 1986
Survey method	Autumn	Spring	
Pitfall traps	480	880	0
Funnel traps	288	0	0
PVC traps	0	144	300
Cage traps (at site)	72	0	0
Cage trap transect	636	60	0
Elliott traps (at site)	180	60	300
Total trap nights	1464	1024	600
Motion sensing cameras (No of cameras)	7	6	0
Bat detectors (No of detectors)	2	0	0
Sand pads (No of pads)	17	17	0
Bird surveys (No of surveys)	2	1	Opportunistic
Spotlighting (No of nights-2012/ hours of effort-1986)	2	1	5
Mistnetting for bats (Hours of effort)	0	0	9.5
Funnel traps for fish (Hours of effort)	0	0	8
Systematic searches	2 searches	0	Unknown

2012 survey

A mixture of trap methods and active searches were implemented during two survey periods in 2012- 15th-23rd April (Sonneman 2012) and 15th to the 22nd of November. This included pitfall, cage, Elliot and funnel traps (Figure 5) in combination with camera traps, SM2 (bat detector), sand pads, bird surveys and opportunistic searches (details in Table 2).

Terrestrial Fauna

a. Pitfall and Elliot traps

In 2012 surveys occurred in both autumn and spring. Autumn surveys monitored six pit fall sites and in spring an additional five sites were surveyed. In autumn each pitfall site had 10 buckets connected by drift fence in a Y formation with two funnel traps at the end of each arm, and two cage traps and five Elliott traps distributed within approximately 30m of the pitfall buckets (Figure 5). In spring the same set up was used; however, funnel, elliot and cage traps were excluded from the sites. Three additional sites (AB 2, 3 and 5) were set up of only PVC pit fall traps in the spring survey with a total of six PVC traps (60cm deep) per site as it was suspected that *Pseudomys albocinereus* could jump out of the 20L buckets. To the east of site five in spring one site solely of cage traps was set-up in a grid formation of three rows of five traps. All pitfall and funnel traps were opened for eight nights and Elliot and cage traps were open for six nights (with the exception of the spring survey, cage and Elliot traps were open for four nights, due to a lack of captures). All captures were marked with a colour marker under the chin.

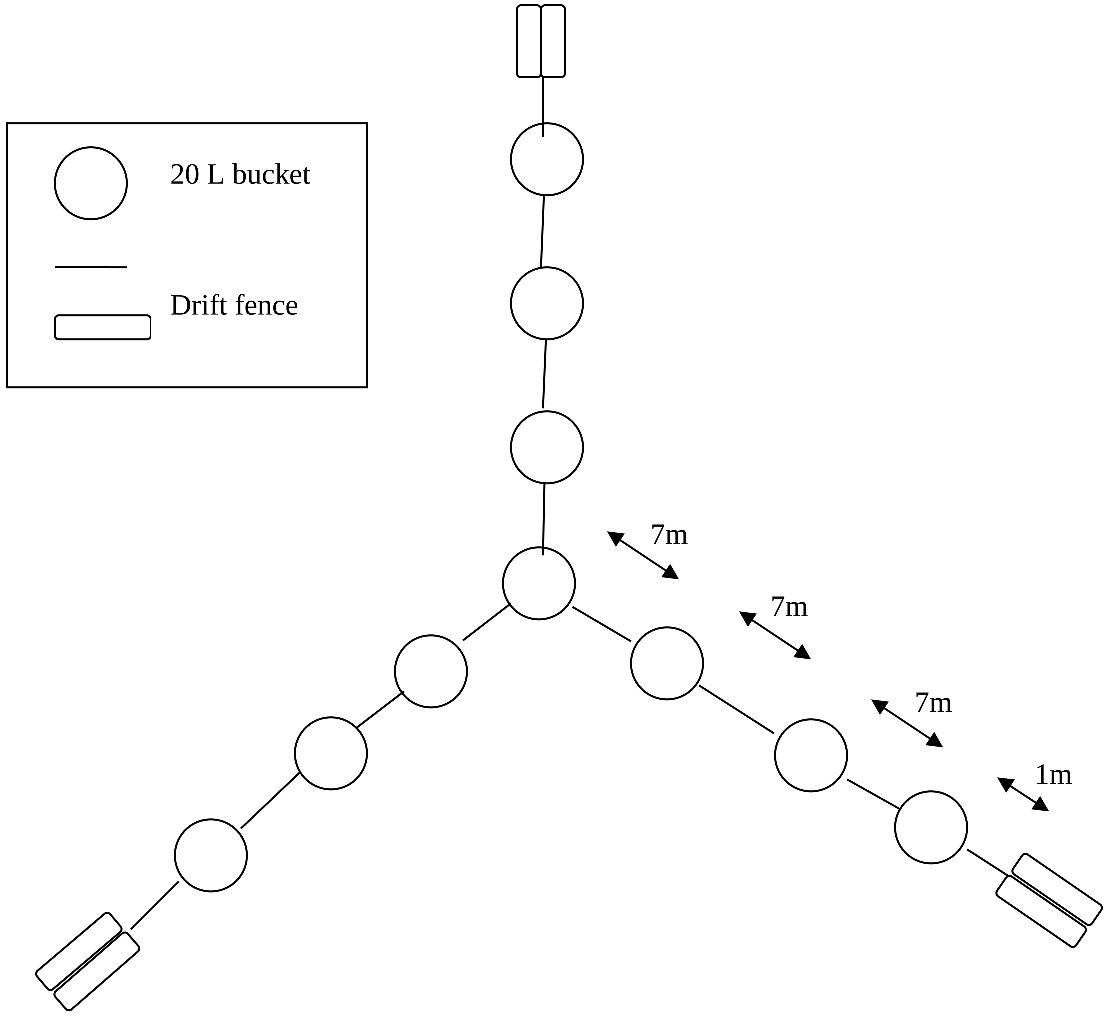


Figure 5: Trap design for the pitfall sites in autumn and spring 2012 (no funnel traps were used in spring 2012).

a. Cage traps

A cage trap transect was also employed. In autumn a transect of 106 cages throughout the reserve were opened (Figure 6). In spring the 15 cage traps were opened along the creek line specially aimed at capturing *Hydromys chrysogaster* (water rats), *Rattus fuscipes* (bush rats) and *Isoodon obesulus* (bandicoots) (Figure 6). The number of cage traps employed dropped from autumn to spring due to a lack of captures in autumn 2012. Cage trap transects were open for six nights for the autumn 2012 survey and 4 nights for the spring 2012 survey. All cage traps were approximately 30-50 metres off internal tracks and baited with universal bait.

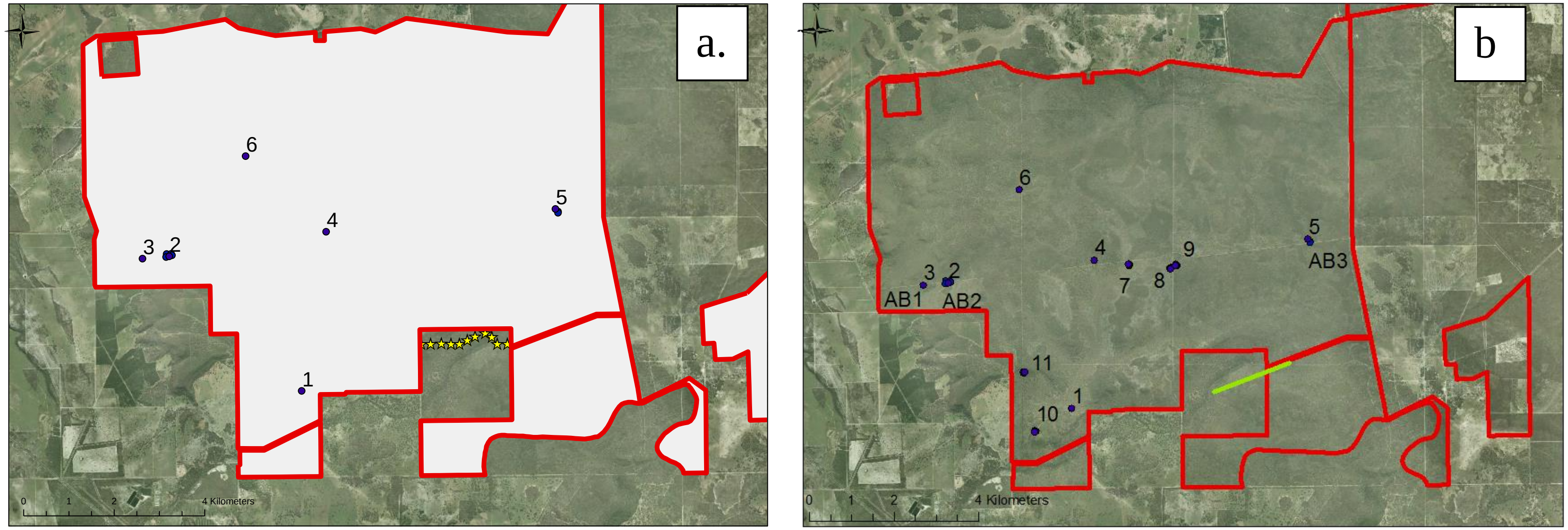


Figure 6: Location of pitfall sites (design desribed above; numbered) and cage trap transects (transects; yellow stars-a; green line; b) in Boonanarring Nature Reserve, autumn (a) and spring (b) 2012.

c. Passive surveying effort

A total of 17 sand pads were established for both surveys in 2012, approximately every 500m along the main tracks; however as existing sand was utilised to form the pads, the distance between pads varied with the changing substrate. Of the 17 sand pads, seven and six in autumn and spring respectively had camera traps running for four consecutive nights. Sand pads in spring 2012 were not in the identical locations to autumn 2012 as the earlier surveys were not marked using a GPS and could not be located.

Two SM2 bat detectors were also set out for four nights in autumn 2012. No bat detectors were used in the spring survey.

Spotlighting was also employed for two nights (17^{th} and 18^{th}) with a cumulative 43 km covered using at least one spotlight (from the vehicle) in the autumn survey. One night of spotlighting occurred for the spring 2012 survey, on the 16^{th} of November, 2012.

Opportunistic surveys were conducted by six or seven people for 20-30 mins at three locations between the 17^{th} and 18^{th} April, 2012. This involved raking leaf litter, turning over rocks and looking under bark. Any opportunistic sightings were also recorded throughout the survey effort. No opportunistic searches occurred during the spring survey.

d. Avian fauna

Two bird surveys were conducted at dusk on the 21^{st} April, 2012 by Geoff Barrett (Department staff). Each involved walking for 20 minutes and identifying species by their call in an area covering one to three hectares. Opportunistic sightings and calls were also recorded throughout the survey, as for terrestrial fauna. In the spring 2012 survey one bird survey on the 20^{th} of November occurred at site ten and 11 by Tracy Sonneman and Karen Bettink (Department staff) and the following volunteers Norman, May Anne Cluise, Cailtin and Nick.

1986 survey

Seven sites (2ha area) were systematically searched and underwent live-capture trapping from the 17^{th} to the 23^{rd} of March 1986 for amphibians, birds, reptiles and mammals (Table 2). Live capture trapping occurred in sites one to four and seven using pitfall traps and at sites five and six Elliot traps. Trapping set up differed between the sites using both Elliot and pit fall traps (sites one to four had three lines of pitfall traps, sites five and six has three lines of Elliot traps and site seven had two lines of pit fall traps). All captures were marked with a colour marker under the chin. Trap nights equated to 600 nights. Five hours of spotlighting occurred (Burbidge *et al.* 1996).

Analysis

Faunal differences between autumn and spring surveys in 2012

Data from the autumn and spring surveys in 2012 was collected from 20L bucket pitfalls, PVC tubes pitfalls (spring only) and funnel trap data (autumn 2012 only). Mammal and reptile abundance and species richness and, individual species' abundances were standardised to ten trap nights per site. Individual species were only analysed individually if their captures were above 20 individuals. A one-way ANOVA determined the relationship between the survey (independent variable) and the faunal measures (dependent variables) (Statsoft 2007). Amphibians were not analysed due to low captures.

Differences in the trap types in the spring 2012 survey

One-way ANOVAs determined if there was a statistical difference in the faunal captures (mammal and reptile abundance and species richness and, individual species' abundances; independent variable) from the two different types of pitfall traps (20L buckets and PVC tubes; dependent variable) used in spring 2012 (Statsoft 2007). Mammal and reptile abundance and species richness and, individual species' abundances were again standardised to ten trap nights to account for the difference in the number of trap nights.

Faunal differences in the 1986 and 2012 surveys

Abundance data for 1986 was only available for mammals captured. Reptiles and amphibians captured were only noted as absent or present at each site in 1986. Mammal abundance included pitfall, funnel and Elliot trapping data but not cage and PVC pit fall trapping data from 2012 and 1986. Data for the species richness faunal variables (mammals, reptiles and amphibians) included all the different trapping methods, opportunistic and systematic sampling, pitfall, PVC funnel, Elliot and cage trapping, spotlighting and motion sensing cameras used in 2012 and 1986. As the trap efforts differed between the years the faunal measures were standardised to ten trap nights. Dependent variables were mammal abundance, reptile, mammal and amphibian species richness and individual mammal species' abundances (only species that were caught in enough numbers for analysis). The independent variable was the year (1986 or 2012). A one-way ANOVA determined whether the dependant fauna variables had changed over the years (Statsoft 2007).

Seasonality can influence the abundance and species richness of fauna caught (Bamford 1986; Bury and Corn 1987; Jenkins *et al.* 2003; Lamckert *et al.* 2006; Moseby and Read. 2001; Wardell-Johnson and Grant 1983). A direct comparison of 1986 and 2012 may be influenced the season in which the survey was completed. The 1986 surveys occurred in March and the autumn 2012 surveys occurred in April. A comparison of fauna from those two surveys might be a better indication of whether the fauna has changed from 1986 to 2012, as the spring 2012 survey was completed in November when reptiles are most active and captures/sightings may have been higher. A one-way ANOVAs of only autumn 2012 data and 1986 data compared a change in the mammal abundance, mammal, reptile and amphibian species richness and individual mammal abundances (Statsoft 2007).

Individual species capture data.

Four species, *T. rostratus*, *M. musculus*, *P. albocinereus* and *S. grisoventer*'s capture data including capture numbers, sex ratio and body weights were compiled for closer examination. Weight data for 2012 data included mean, standard deviation and range for each species; weight data for 1986 was the weight range for each species.

Assess the fire regimes and the possible impact of fire management

Multiple regressions determined if there was any relationship between mammal and reptile abundance and species richness and, individual species' abundances; independent variable and the year since last burn (Statsoft 2007).

Predator estimates

Activity of *V. vulpes* and *F. catus* was estimated from the 17 sand pads over 5 nights from the autumn 2012 survey. Firstly, the activity of each predator species was summed (i.e. tracks seen were added for each day the sand pads were checked). These values were standardised by the number of sand pads and averaged for an average daily index of activity for both *V. vulpes* and *F. catus*.

Results

Captures in 2012

During autumn and spring there were 1464 and 1144 trap nights respectively, totalling 3142 total trap nights for 2012. Two amphibian species, *Mytobatrachus gouldii* and *Limnodynastes dorsalis* were captured in 2012 by pitfall traps (Table 7). No further amphibian species were seen by other methods (Table 9). Seven mammal species were captured during the pitfall, Elliot and cage trapping including two introduced species, *M. musculus* and *Rattus rattus* and five native species, *P. albocinereus*, *S. griseoventer*, *S. granulipes*, *Sminthopsis* sp. and *T. rostratus* (Table 7). Five mammal species were identified from the sand pads, *M. musculus*, macropods *(Macropus fuliginosus/Macropus irma)*, *Felis catus*, *Vulpes vulpes* and an unidentified mammal (Table 9). Twenty eight reptilian species from a range of families were captured in 2012 from pitfall trapping, four Gekkonidae, four Pygopods, two Agamidae, thirteen Scinidae and three elapids (Table 7). A further unidentifiable elapid and lizard and a *Lialis burtonis* were opportunistically noted or recorded from the sand pads (Table 9).

Bird surveys in 2012 revealed 16 bird species in autumn and 7 in spring (Table 8). One other bird species, an unidentified owl was seen during spotlighting in spring 2012 (Table 9).

Bat calls were recorded; however, they are yet to be identified.

Comparison of surveys in 2012

Mammal and reptile species richness, reptile abundance and *Mus musculus* abundance were significantly different between the autumn and spring 2012 surveys (Table 3 and Figure 7). There were more mammal and reptile species in spring than the autumn surveys, as well as more reptile captures (Figure 7a, b and c). More *M. musculus* were captured in autumn than spring (Figure 7d). Mammal abundance and abundances of the individual mammal and reptile species did not differ between the two 2012 surveys (Table 3 and Figure 7).

Table 3: Relationships between mammal abundance, mammal and reptile species richness, amphibian species richness and individual mammal species' abundance and the season of trapping in 2012 (autumn and spring) using a one way ANOVA (F and P values in bold are significant).

Dependant variable	*F* and *P* values
Mammal abundance	2.74, 0.11
Mammal species richness	**12.33, 0.003**
Reptile abundance	**24.48, >0.00**
Reptile species richness	**8.484, 0.011**
Mus musculus abundance	**10.05, 0.006**
Pseudomys albocinereus abundance	2.13, 0.16
Sminthopsis griseoventer abundance	1.86, 0.19
Tarsipes rostratus abundance	4.01, 0.06
Ctenophorus adelaidensis	0.72, 0.40
Ctenotus fallens abundance	6.22, .0.02
Lerista elegans abundance	4.69, 0.02
Pogona minor abundance	0.59, 0.45

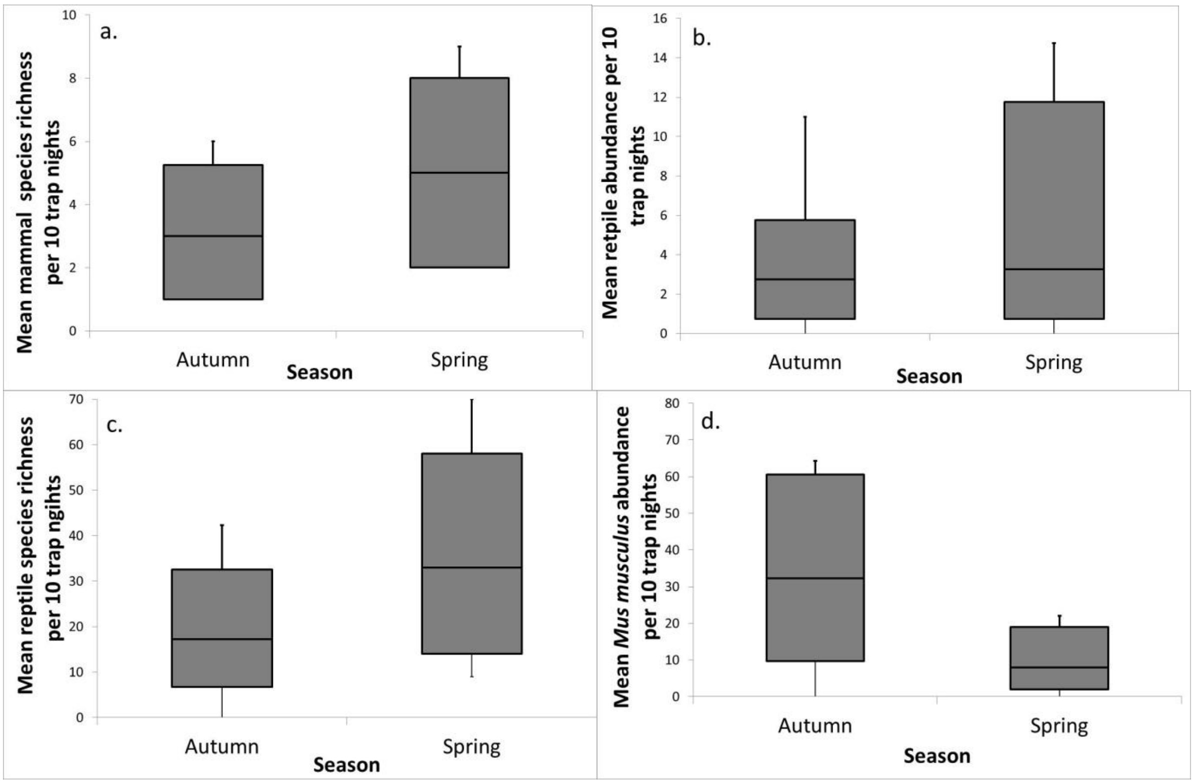


Figure 7: Box and whisker plots (range, quartiles and median) of the (a) mean mammal species richness, reptile (b) abundance and (c) species richness and, (d) *Mus musculus* abundance per 10 trap nights from the autumn and spring 2012 surveys.

Differences in the trap types in the spring 2012 survey

There were no significant difference in the abundance and species richness of the fauna captured in 20L buckets and PVC pipes (Table 4).

Table 4: Relationships between mammal abundance, mammal and reptile species richness, amphibian species richness and individual mammal species' abundance and the trap type in 2012 (20L buckets and PVC tubes) using a one way ANOVA (*F* and *P* values in bold are significant).

Dependant variable	*F* and *P* values
Mammal abundance	1.68, 0.21
Mammal species richness	0.64, 0.43
Reptile species richness	3.41, 0.08
Reptile abundance	3.47, 0.08
Mus musculus abundance	3.86, 0.07
Pseudomys albocinereus abundance	0.23, 0.63
Sminthopsis griseoventer abundance	0.81, 0.38
Tarsipes rostratus abundance	0.78, 0.39
Ctenophorus adelaidensis	0.003, 0.95
Ctenotus fallens abundance	0.71, 0.41
Lerista elegans abundance	0.40, 0.53
Pogona minor abundance	0.05, 0.82

Captures in 1986

A total of 600 trap nights using pitfall and Elliot traps captured many terrestrial species in 1986. Three amphibian species were trapped and seen by two opportunistic records (Table 10 and 12). Four mammal species including one introduced species, *Mus musculus* and three native species, *Pseudomys albocinereus*, *Sminthopsis griseoventer* and *Tarsipes rostratus* were captured in the pitfall traps (Table 10). Additionally, seven mammal species were noted from opportunistic records, diggings and scats (Table 12). Seventeen reptilian species from a range of families were captured in 1986 from pitfall trapping including, one Gekkonidae, three Pygopods, two Agamidae, six Scinidae and five elapids (Table 10). Systematic searches and opportunistic records recorded additional reptile species, *Lialis burtonis*, *Morelia spilota* and *Pygopus lepidopodus* (Table 12).

A total of 70 bird species were seen during the systematic searches in 1986 including parrots, honeyeaters, raptors, cuckoos and many more (Table 11).

Five bat species were recorded during the mist netting of 1986 including *Nyctinomus australis* (white-striped freetail bat), *Nyctophilus geoffroyi* (lesser long-eared bat), *Nyctophilus gould* (Gould's long-eared bat), *Chalinlobus gouldii* (Gould's wattled bat) and *Vespadelus regulus* (southern forest bat).

Comparison of 1986 and 2012 surveys

Trapping effort between 1986 and 2012 varied dramatically and entailed many different trapping and surveying methods. Despite the differences in trap types and effort several differences over the years are evident (Table 5). More reptile species were captured in 2012 than 1986 (Figure 8a), including many new species not seen in 1986 (Appendix 10). More *Mus musculus*, an introduced rodent were captured in 2012 than 1986 (Figure 8b). Less *Pseudomys albocinereus* and *Tarsipes rostratus*, a native rodent and possum respectively were found in 2012 than 1986 (Figure 8c and d). Mammal abundance and species richness and, amphibian species richness and *Sminthopsis griseoventer* abundance were unchanged between the two years (Table 5).

Table 5: Relationships between mammal abundance, mammal and reptile species richness, amphibian species richness and individual mammal species' abundance and the year (1986 and 2012) using a one way ANOVA (*F* and *P* values in bold are significant).

Dependant variable	*F* and *P* values
Mammal abundance	F_1 =0.70, P =0.41
Mammal species richness	F_1 =0.09, P =0.76
Reptile species richness	**F_1 =14.54, P =0.001**
Amphibian species richness	F_1 =0.08, P =0.76
Mus musculus abundance	**F_1 =4.78, P =0.04**
Pseudomys albocinereus abundance	**F_1 =11.81, P =0.003**
Sminthopsis griseoventer abundance	F_1 =0.01, P =0.91
Tarsipes rostratus abundance	**F_1 =4.58, P =0.04**

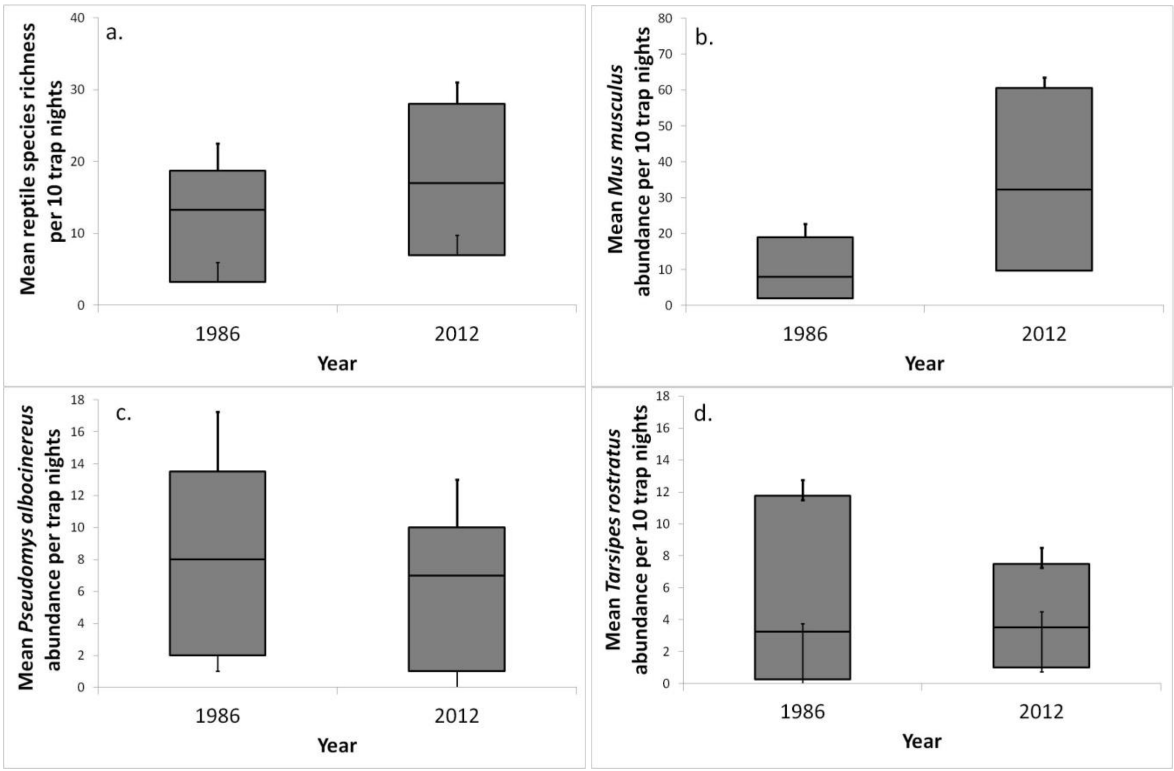


Figure 8: Differences in the mean (a) reptile species richness, (b) *Mus musculus* abundance, (c) *Pseudomys albocinereus* abundance and (d) *Tarsipes rostratus* abundance per 10 trap nights in 2012 and 1986 surveys demonstrated using box and whisker plots (range, quartiles and median).

Comparison of 1986 and autumn 2012 surveys

When examining the differences between just the autumn 2012 survey and the 1986 survey excluding spring 2012 surveys to account for the effect of seasonality on trapping results there were some differences (Table 6). Mammal species richness, reptile species richness, amphibian species richness and *Pseudomys albocinereus* abundance was significantly different in 1986 to autumn 2012 (Table 6). More mammal and reptile species were seen in 1986 compared to autumn 2012 but less amphibian species in 1986 (Figure 9a, b and c). When comparing all of the 2012 surveys and 1986, reptile species richness was higher in 2012 (Figure 9a). There were also less of the native rodent *P. albocinereus* in autumn 2012, similar to the results using all of 2012 surveys (Figure 9d). Overall mammal abundance and *M. musculus*, *S. griseoventer* and *T. rostratus* abundances' were unchanged between the two years (Table 10).

Table 6: Relationships between mammal abundance, mammal and reptile species richness, amphibian species richness and individual mammal species' abundance in autumn 2012 and 1986 using a one way ANOVA (*F* and *P* values in bold are significant).

Dependant variable	*F* and *P* values
Mammal abundance	3.61, 0.08
Mammal species richness	**42.15, 0.000**
Reptile species richness	**13.72, 0.003**
Amphibian species richness	**22.84, 0.001**
Mus musculus abundance	3.49, 0.08
Pseudomys albocinereus abundance	**8.645, 0.01**
Sminthopsis griseoventer abundance	1.19, 0.29
Tarsipes rostratus abundance	4.04, 0.06

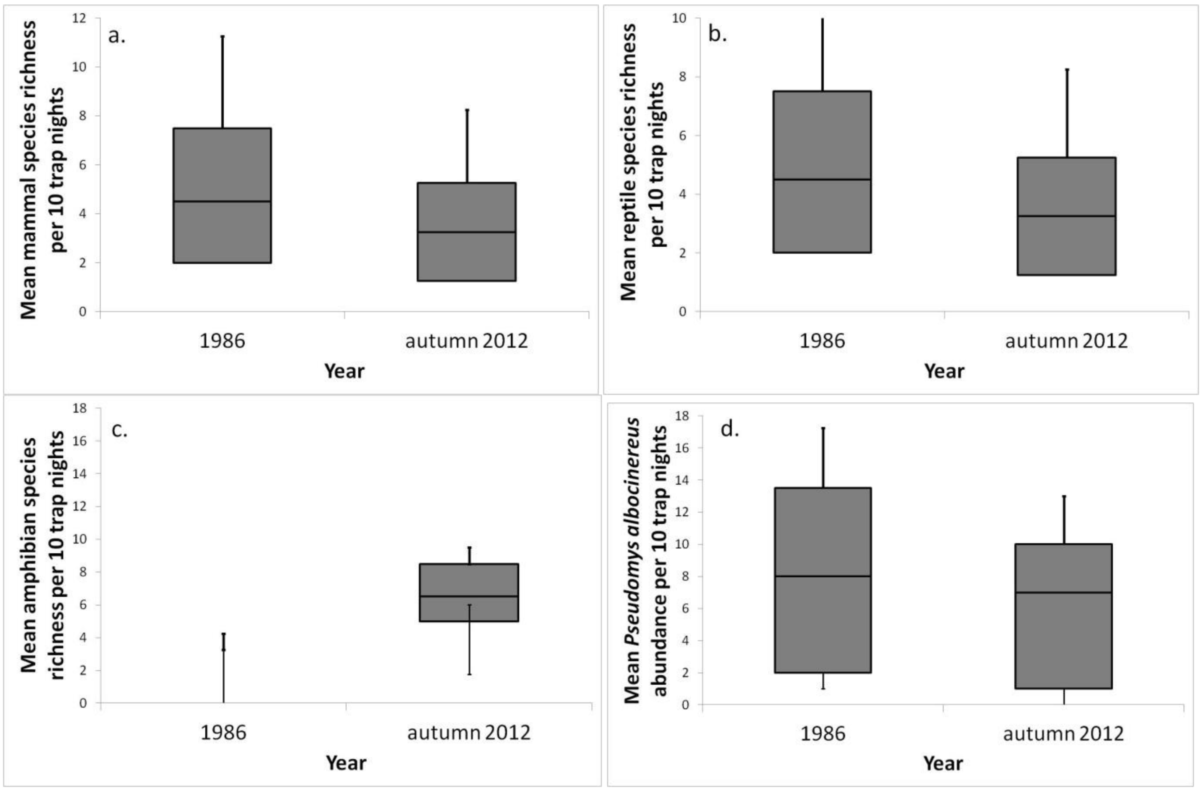


Figure 9: Box and whisker plots (range, quartiles and median) demonstrating the difference in mean (a) mammal species richness, (b) reptile species richness, (c) amphibian species richness and (d) *Pseudomys albocinereus* abundance per 10 trap nights in autumn 2012 and 1986.

Individual mammal species' capture data (1986 and 2012)

Tarsipes rostratus, *M. musculus*, *P. albocinereus* and *S. grisoventer* are four mammal species that were captured in both 1986 and 2012. More *T. rostratus* and *P. albocinereus* were captured in 1986 and in 2012 more *M. musculus* and *S. grisoventer* were captured. As seen from tables five, six and seven some of these relationships were significantly different. Weights in 2012 for all species were in the same range as those found in 1986 (Table 7). Sex ratios for all small mammal species differed slightly between the years (no statistical analysis has been performed; Table 7).

Table 7: Capture data of *Tarsipes rostratus*, *Mus musculus*, *Pseudomys albocinereus* and *Sminthopsis grisoventer* including number of captures, sex ratio and body weights of males and females in 1986 (range) and 2012 (± SD, range). 1986 data taken from (Burbidge *et al.* 1996).

Species	Captures in 1986	Captures in 2012	Sex ratio (M:F) 2012	Sex ratio (M:F) 1986	Body weight males 2012 (grams)	Body weight males 1986 (grams)	Body weight females 2012 (grams)	Body weight females 1986 (grams)
Tarsipes rostratus	30	24	12:10	14:16	6.78 ± 4.19 (3.1-17.5)	5.3-7.0	7.5 ± 3.92 (2-12)	6.0-11.3
Mus musculus	14	234	67:97	9:05	11 ± 4.14 (4-32)	8-17.5	9.54 ± 2.62 (3-19)	8.5-14.5
Pseudomys albocinereus	23	17	11:06	10:13	17.93 ± 6.45 (10-28)	16.2-32	20.4 ± 6.78 (10.5-25.5)	15.5-28
Sminthopsis grisoventer	7	25	13:10	5:02	8.25 ± 4.43 (5-19)	9.5-11.5	10.4 ± 4.87 (4.1-18)	9.5-13.5

Across the reserve *M. musculus* were captured at all sites. *Pseudomys albocinereus* were captured at five sites towards to the northern sections of the reserve. *Sminthopsis griseoventer* were captured at all sites except for five and 11. *Tarsipes rostratus* were captured in eight sites scattered all over the reserve (Figure 10).

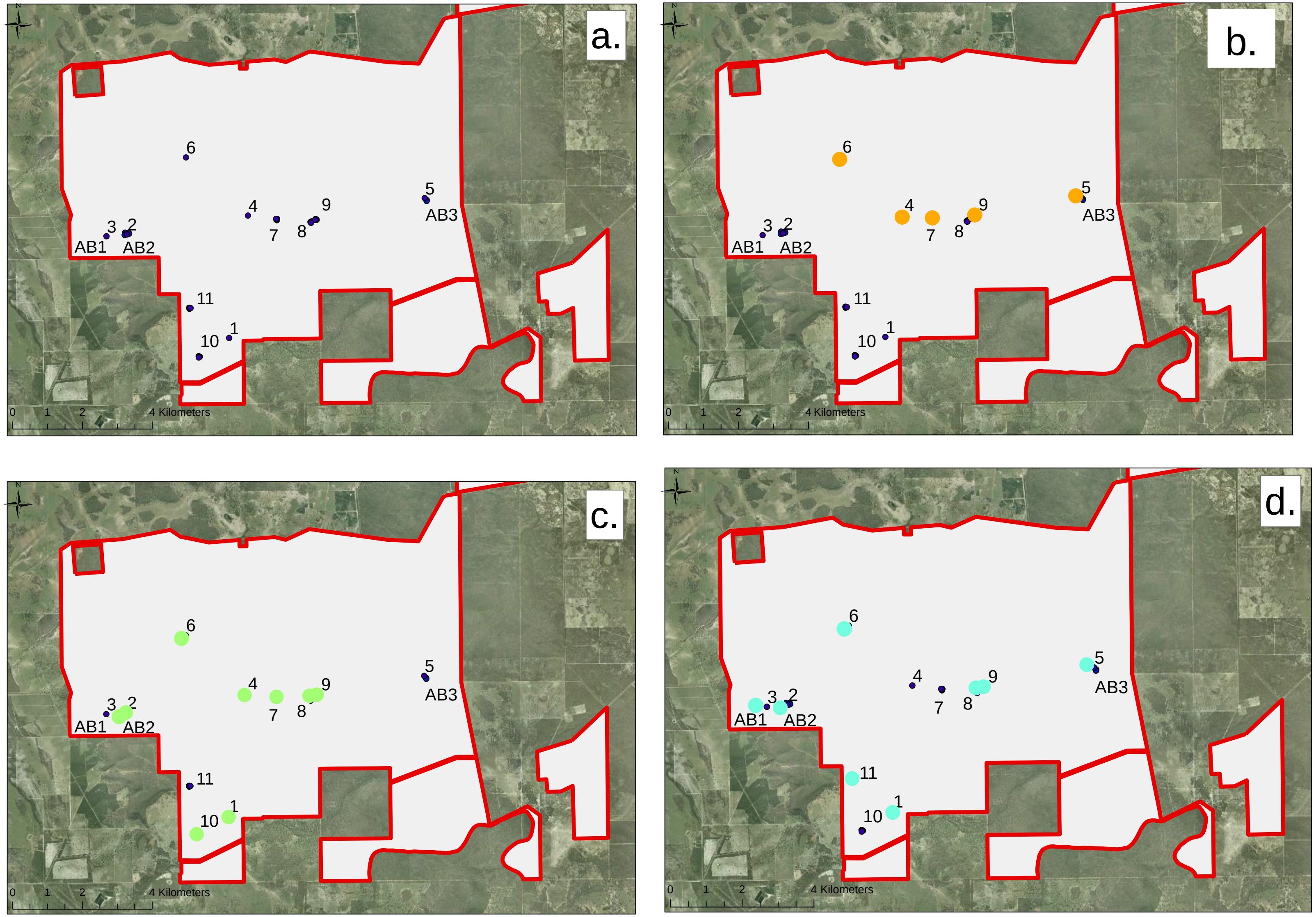
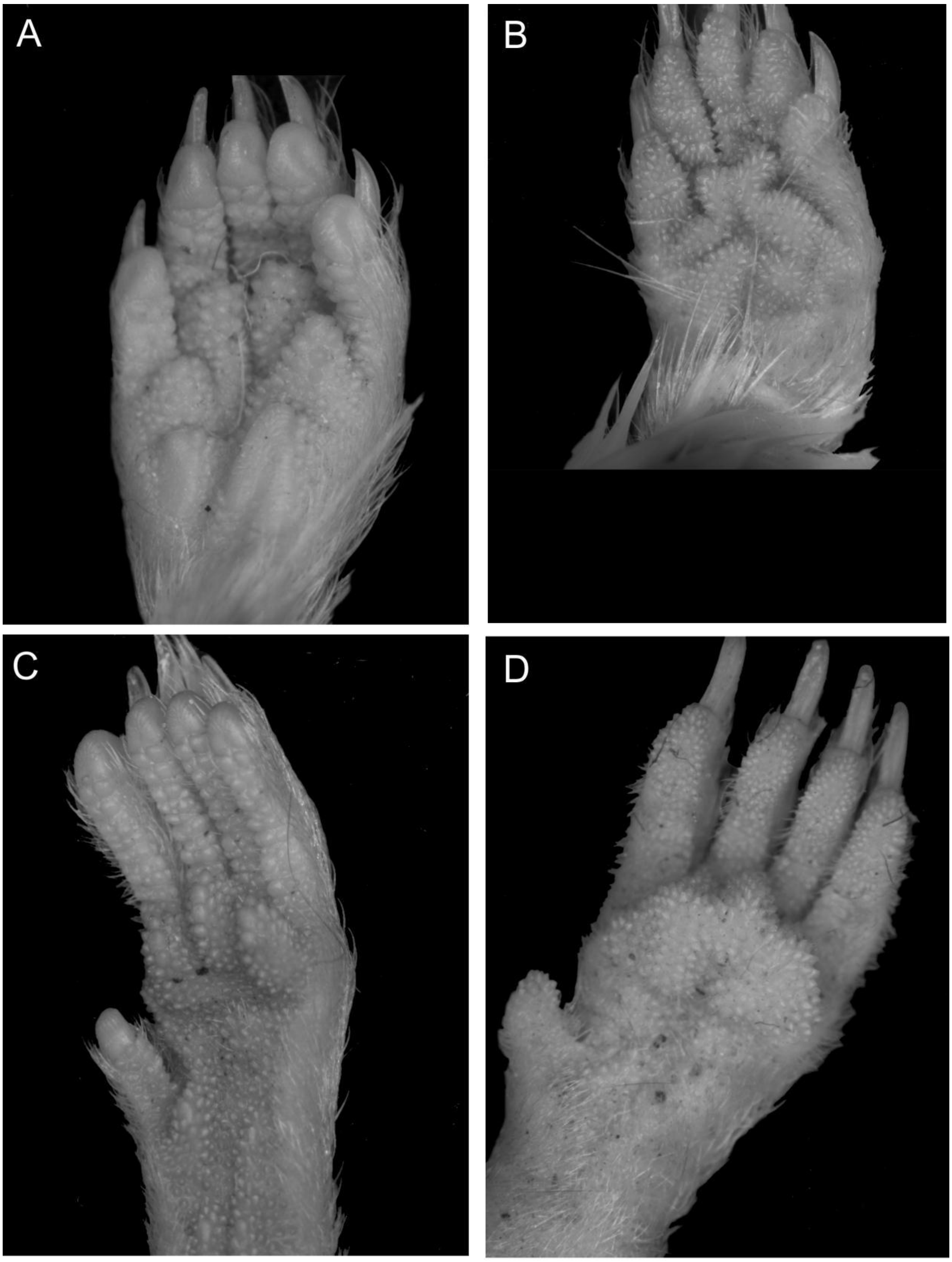


Figure 10: Locations of captures sites (a; *M. musculus* was captured at all sites), *Pseudomys albocinereus* captures (b; orange), *Sminthopsis griseoventer* captures (c; green) and *Tarsipes rostratus* catpures (d; light blue) in Boonanarring Nature Reserve in 2012. The dark blue dots in b, c and d indicate no capture of the mammal species.

Mammal species identification

Identifying smaller mammals can be erroneous. There was some difficultly identifying species from the *Sminthopsis* genus during this study. There are potentially three species of *Sminthopsis* that can be captured in the reserve including *Sminthopsis griseoventer* (grey bellied), *granulipes* (white-tailed) and *crassicaudata* (fat-tailed) (*Sminthopsis dolichura* is on the border of the extent and unlikely to be captured). The main differences between this species lies in the tail, head body length and the soles of their pes and manus. *Sminthopsis crassicaudata* differs from the other two Sminthopsis by a fat tail. *Sminthopsis griseoventer* does not have granulated pes and manus whereas *S. granulipes* does, as signified by their name (Figure 11). If unexpectedly *S. dolichura* was captured it is discernible from *S. griseoventer* by a black eye ring and longer tail than head-body length (*S. griseoventer* has an equal tail to head body-length; *S. granulipes* and *crassicaudata* has a shorter tail than head-body length). Never the less these are still difficult species to discern and the reference guide rates them highly on the frustration index, therefore four *Sminthopsis* sp. individuals are only identified to genus (Ed. Van Dyck *et al.* 2013; Gomez *et al.*).



A) M9972 *S. griseoventer* manus
C) M9972 *S. griseoventer* pes

B) M50426 *S. granulipes* manus
D) M 53437 *S. granulipes* pes

Figure 11 : Pes and manus of *Sminthopsis griseoventer* (A and C) and *granulipes* (B and D). *Sminthopsis griseoventer* has a short proximal groove on the terminal digits and digits II-IV are separated with 3-4 enlarged granules of a similar size. *Sminthopsis granulipes* is granulated on both the manus and pes, between digits II-IV it is partly fused and covered in more granules, the manus is deeply wrinkled (Gomez *et al.*).

Time since last fire and fauna

The only faunal measures related to time since last fire was mammal species richness and abundance of *P. albocinereus* (Table 8). Both were related negatively to time since last fire (Figure 12) with the highest abundances' of mammals and *P. albocinereus* at around 5 years since last burn.

Table 8: Relationships between mammal abundance, mammal and reptile species richness, amphibian species richness and individual mammal species' abundance and time since last fire from multiple regressions (Adjusted R^2, β and *P* values).

Dependant variable	Adjusted R^2, β and *P* values
Mammal abundance	-0.10, -0.06, 0.84
Mammal species richness	**0.44, -0.70, 0.01**
Reptile species richness	-0.03, -0.26, 0.43
Reptile abundance	0.06, -0.39, 0.22
Mus musculus abundance	-0.11, -0.008, 0.98
Pseudomys albocinereus abundance	**0.63, -0.82, 0.002**
Sminthopsis griseoventer abundance	-0.11, -0.01, 0.97
Tarsipes rostratus abundance	-0.03, 0.25, 0.44
Ctenophorus adelaidensis	0.10, -0.43, 0.17
Ctenotus fallens abundance	-0.07, 0.18, 0.58
Lerista elegans abundance	0.02, 0.25, 0.28
Pogona minor abundance	-0.004, -0.31, 0.35

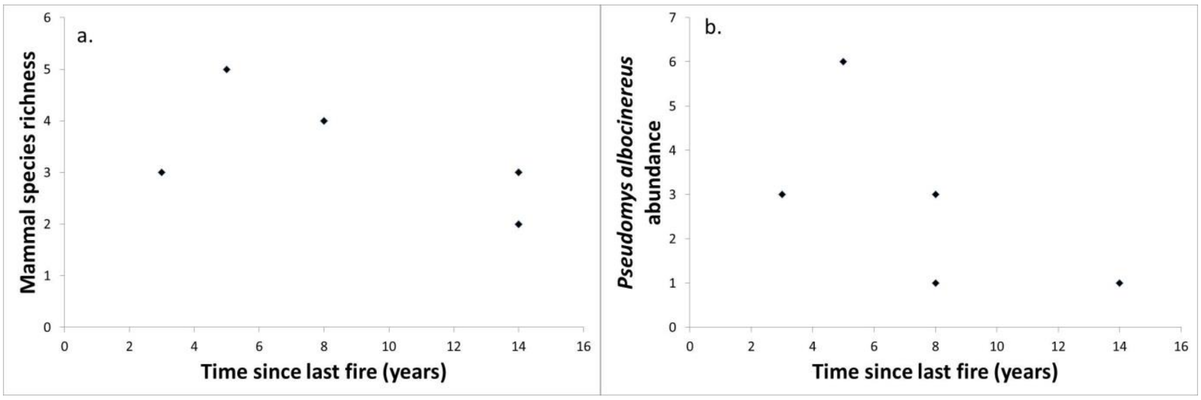


Figure 12: Relationships between times since last fire and mammal species richness (a) and *Pseudomys albocinereus* abundance (b).

Predator estimates

Vulpes vulpes were far more active in Boonanarring Nature Reserve than *F. catus*. *Vulpes Vulpes* were active every day of the survey with most activity on day two and the least on day five. *Felis catus* left one track on the 16 sand pads each day except for day three (Table 9). In 1986 both species were active in the area and *Canis familiaris* scats were noted as well (Burbidge *et al.* 1996). In comparison to recent predator surveys in nearby reserves, *V. vulpes* activity is lower than Yanchep National Park but higher than Yeal Nature Reserve (Table 9).

Table 9: Estimated predator activity (*Vulpes vulpes* and *Felis catus*) in Boonanarring Nature Reserve for each day the sand pads were checked, average daily activity index (standardised by the 16 sand pads) and daily predator activity in Yeal NR (Moore 2012) and Yanchep NP (Reaveley 2009) for comparison.

Day	*Vulpes vulpes*	*Felis catus*
1	0.375	0.0625
2	0.4375	0.0625
3	0.3125	0
4	0.375	0.0625
5	0.0625	0.0625
Average daily activity index	0.3125	0.05
Yeal NR	0.09	0.24
Yanchep NP	0.54	

Discussion

Current faunal assemblage in Boonanarring Nature Reserve. Has it changed since 1986?

Reptiles

When examining the 1986 survey and the autumn 2012 survey only, we could assume that the number of reptile species has dropped. However, when incorporating the data from an additional spring survey in 2012 the reptile species richness has increased over the years. When a direct comparison of the numbers of captures from 1986 to 2012 we can assume reptile species richness has increased. Reasons for this increase may be the regular burning regime that has created a more open habitat, providing basking habitat for reptiles (Driscoll and Henderson 2008; Fox 1982; Letnic and Dickman 2005; Letnic *et al.* 2004; Lindenmayer *et al.* 2008a; Lindenmayer *et al.* 2008b). Reptiles are related to habitat variables and time since last fire as a result of the resources available (Valentine *et al.* 2012). Although the analyses between time since last fire and reptiles revealed no significant relationships, stronger relationships may be seen when abundance data is used. More likely an explanation is the timing of the 1986 failed to capture all of the reptile species as autumn sees fewer reptiles active, therefore fewer captures than in spring (Bamford 1986; Jenkins *et al.* 2003; Wardell-Johnson and Grant 1983). However, not much more can be said about these results without abundance data. Future monitoring should include on-going trapping of the terrestrial fauna.

Mammals

Pitfall and cage trapping revealed more mammal species and captures in 2012 than 1986. However, when the opportunistic data including sightings, sand pads, scats and diggings, analyses demonstrated that mammal species richness has dropped from 1986. Differences in the results for a direct comparison of 2012 and 1986 data (between the all 2012 or autumn only 2012 analyses) demonstrate that the abundance of individual mammals has dropped. More specifically the numbers of *T. rostraus* and *P. albocinereus* have reduced over the years. The introduced rodent *M. musculus* has increased in abundance since 1986. In particular its capture rates were higher in autumn, aligning with Bamford's (1986) study at a nearby reserve where *M. musculus* was captured more commonly in autumn than any other time of the year. These changes in abundances could be a result of many factors including prescribing burning, changes in water availability, introduced weeds and predators (Bleby *et al.* 2009; Craig *et al.* 2010; McLeod and Gates 1998; Torre and Diaz 2004; Valentine *et al.* 2012; Valentine and Schwarzkopf 2008; Wilson *et al.* 2010). Increased presence of *M. musculus* is particularly concerning as they may invade nesting and shelter sites used by the native rodents as well as the food resources.

Tarsipes rostratus requires complex habitat for shelter including leaf litter and, flowering plants and shrubs for food resources (Clancy 2011; Dundas 2008; Dundas *et al.* 2013; Garavanta *et al.* 2000). This small mammal has decreased in abundance since 1986 in Boonanarring Nature Reserve. Several studies in the northern pine plantations and banksia woodlands, as well as further south demonstrate that this species is related to older fire ages for a complex habitat (Bamford 1992; Clancy 2011; Garavanta *et al.* 2000; Wilson *et al.* 2010). The direct causes of a decrease in this species are unknown. However, prescribed burning must preserve a mosaic of fuel ages to ensure the resources required by *T. rostratus* are present in the reserve and that feral predators are reduced. Although we have no control over the changes in water availability, water is required for plants and shrubs to flower and provide food for the small mammal. Again, future work should expand on the knowledge from Clancy (2011) and Garavanta (2000), particularly as there is conflicting results between these two studies as to the movement and survival of *T. rostratus*.

There is little ecological work completed on *P. albocinereus* to comment on their abundances in relation to their ecology (Bamford 1986; Barker *et al.* 2012; Morris and Bradshaw 1981). It is recommended from this study that future work incorporate ecological studies on *P. albocinereus* to determine their nesting, feeding and general behaviour within this reserve. This is particularly important as they have a restricted range on the Swan Coastal Plain that could be further restricted by inappropriate burning regimes, changes to their habitat and introduced predators.

Birds

Without any statistical analyses it is evident that more bird species were witnessed in 1986. This is most likely due to the more thorough bird surveys completed in 1986. To properly examine the changes in time to the bird species present more bird surveys in the reserve are required.

Amphibians

Overall the amphibian abundance is unchanged from 1986 to 2012. However, when examining just the autumn surveys in 2012 and 1986 surveys more amphibians were captures occurred in autumn 2012. This may be explained due to the higher incidences of *M. gouldii* captures in autumn 2012 following a rainfall event.

Fire and fauna

Boonanarring has a relatively young fire history with the oldest sites 14 years since last burn. Relationships noted demonstrate negative relationships between mammal abundance and *P. albocinereus* and time since last fire. *Pseduomys albocinereus* has been noted in one prior study (Bamford 1986) to be optimally captured in sites one to three years post fire and steadily increase in numbers six years post fire and numbers of the small rodent drop off after 11 years post fire, aligning with this studies' work. Although the small rodent was present 20 years post fire indicating its ability to persist in many fire aged habitats (Bamford 1986). Bamford's (1986) work is the only study outlining the relationships about fire and *P. albocinereus* and further work is required to strongly hypothesize any relationship between fire and the small rodent. Interestingly, similar results were found for mammal abundance and time since last burn, with the highest abundances' being recorded in sites with the fire history of 4-5 year since last burn. This perhaps is a result of the high numbers of *M. musculus* captured whom also prefer habitat with a younger fire history (Kelly *et al.* 2010; Kelly *et al.* 2011; Kelly *et al.* 2012). Prescribed burns are planned for this area and future work should investigate these relationships more thoroughly to determine the best prescribed burning guidelines that preserve these species.

Feral predator control

Introduced predators were present in Boonanarring Nature Reserve in both 1986 and 2012. *Vulpes vulpes* and *F. catus* were both active the reserve in 2012; additionally *C. familiaris* was present in 1986. All are known predators of native fauna, can also be competition for resources and a point of disease transmission (Norton and May 1996). Surveys in 1986 and 2012 have demonstrated that this unique reserve is home to a great abundance of native faunal species that need preservation. More active management in terms of feral animal control is recommended to preserve the native species, particularly *P. albocinereus* that has a restricted range on the Swan Coastal Plain.

The future for Boonanarring Nature Reserve

Boonanarring Nature Reserve is unique in its fauna and vegetation structure. No other reserves on the Swan Coastal Plain contain as many vegetation types and unique faunal species on Dandaragan soils. Boonanarring Nature Reserve is also one of the larger intact remnants on the plain, allowing many of the faunal species to persist since 1986 mostly unchanged. It is also a known Carnaby's black and Forest red tail cockatoo nesting site (Karen Bettink, Pers Comm, Department of Parks and Wildlife) and part of the restricted range of *P. albocinereus*, who although not endangered are one of the few native mice species left in the southwest of Western Australia. With these facts in mind more active management of the reserve, including feral animal control and prescribed burning, is required to ensure the size and quality of the reserve remains unchanged.

Future monitoring and research of *P. albocinereus* is recommended to better conserve this species and their habitat. Additionally, more current bird surveys are needed to update the species list and on-going monitoring of the terrestrial fauna to ensure the management of the reserve is not negatively influencing the fauna.

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Appendix

Table 10: Species captured in the 2012 and 1986 surveys of Boonanarring Nature Reserve.

	Total captures	
	1986	2012
Amphibians		
Heleioporous eyerii	1	0
Limnodynastes dorsalis	5	10
Litoria adelaidensis	0	0
Myobatrachus gouldii	5	52
Reptiles		
Gekkonidae		
Crenadactylus ocellatus	1	1
Diplodactylus polyophthalmus	0	1
Nephurus milii	0	1
Strophurus spinigerus	0	17
Pygopodidae		
Aprasia repens	8	3
Delma fraseri	3	1
Lialis burtonis	0	1
Pletholax gracilis gracilis	1	0
Pygopodus lepidopodus	0	11
Agamidae		
Ctenophorus adelaidensis	5	36
Pogona minor	2	32
Varanidae		
Varanus tristis tristis	0	2
Scinidae		
Cryptoblepharus buchananii	2	14
Ctenotus australis	0	1
Ctenotus fallens	2	26
Ctenotus schomburgkii	0	7
Lerista christinae	0	5
Lerista distinguenda	2	7
Lerista elegans	0	21
Lerista praepedita	8	11
Menetia greyii	0	18
Morethia butleri	0	2
Morethia lineocellata	0	1
Morethia obscura	1	15
Tiliqua rugosa	1	6

Typhlopidae		
Ramphotyphlops australis	0	13
Elapidae		
Brachyurophis semifasciatus	2	13
Neelaps bimaculatus	4	6
Notechis scutatus	2	0
Pseudechis australis	0	1
Pseudonja affinis	1	0
Simoselaps bertholdi	0	2
Simoselaps calonotos	1	0
Mammals		
Mus musculus	14	234
Pseudomys albocinereus	23	17
Rattus rattus	0	3
Sminthopsis sp.	0	3
Sminthopsis granulipes	0	1
Sminthopsis griseoventor	7	29
Tarsipes rostratus	30	24
Total	132	647

**Pygopus lepidopodus*, *Lialis burtonis* and *Litoria adelaidensis* had opportunistic records in 1986 and are listed in table 6.

Table 11: Birds observed and surveyed in the 1986 and 2012 at Boonanarring Nature Reserve. A 1 denotes that the species was seen and a 0 denotes the species was not seen. Observations from 1986 were completed during systematic searches and opportunistic records. The 2012 observations were from the bird surveys and opportunistic records.

Common name	Species name	1986	2012-Autumn	2012-Spring
New Holland Honeyeater	*Phylidonyris novaehollandiae*	1	1	0
White-cheeked honeyeater	*Phylidonyris nigra*	0	1	0
Peregrine falcon	*Falco peregrinus*	0	1	0
Silvereyes	*Zosterops lateralis*	1	1	0
Western Spinebill	*Acanthorhynchus superciliosus*	1	1	0
Australian Magpie	*Gymnorhina tibicen*	1	1	0
Inland thornbill	*Acanthiza apicalis*	1	1	1
Western thornbill	*Acanthiza inornata*	1	1	0
Australian Ringneck	*Barnardius zonarius*	1	1	1
Splendid fairy-wren	*Malurus splendens*	1	1	1
Western Gerygone (Warbler)	*Gerygone fusca*	1	1	1
Willie Wagtail	*Rhipidura leucophrys*	0	1	0
Laughing Kookaburra	*Dacelo novaeguineae*	0	1	0

Common Bronzewing	*Phaps chalcoptera*	1	0	1
Red-capped Robin	*Petroica goodenorii*	1	0	0
Weebill	*Smicrornis brevirostris*	1	1	0
Tree Martin	*Petrochelidon ariel*	1	0	0
Emu	*Dromaius novaehollandiae*	1	0	1
Grey Fantail	*Rhipidura albiscapa*	1	1	1
Barn owl	*Tyto alba*	1	0	0
Varied Sitella	*Daphoenositta chrysoptera*	1	0	0
Grey Butcherbird	*Cracticus torquatus*	1	0	0
Nakeen Kestrel	*Falco cenchroides*	0	0	0
Red Wattlebird	*Anthochaera carunculata*	1	0	0
Red-capped parrot	*Purpureicephalus spurius*	1	0	0
Rufous whistler	*Pachycephala rufiventris*	1	0	0
Galah (Pink and Grey)	*Eolophus roseicapillus*	1	0	0
Australian Shelduck	*Tadorna tadornoides*	1	0	0
Black shouldered kite	*Elanus axillaris*	1	0	0
Whistling kite	*Haliastur sphenurus*	1	0	0
Brown goshawk	*Accipiter fasciatus*	1	0	0
collared sparrowhawk	*Accipiter cirrocephalus*	1	0	0
Wedgetailed eagle	*Aquila audax*	1	0	0
little eagle	*Accipiter fasciatus*	1	0	0
brown falcon	*Falco berigora*	1	0	0
Australian hobby	*Falco longipennis*	1	0	0
Australian (nankeen) kestrel	*Falco cenchroides*	1	0	0
Painted-button quail	*Turnix varius*	1	0	0
Crested pigeon	*Ocyphaps lophotes*	1	0	0
Carnaby's cockatoo	*Calyptorhynchus latirostris*	1	0	0
Purple crowned lorikeet	*Glossopsitta porphyrocephala*	1	0	0
pallid cuckoo	*Cacomantis pallidus*	1	0	0
fan-tailed cuckoo	*Cacomantis flabelliformis*	1	0	0
Horsefield's bronze cuckoo	*Chrysococcyx basalis*	1	0	0
Shining-bronze cuckoo	*Chrysococcyx lucidus*	1	0	0
southern boobook	*Ninox novaeseelandiae*	1	0	0
Tawny frogmouth	*Podargus strigoides*	1	0	0
Australian owlet nightjar	*Aegotheles cristatus*	1	0	0
sacred kingfisher	*Todiramphus sanctus*	1	0	0
rainbow bee-eater	*Merops ornatus*	1	0	0
white-winged fairy wren	*Malurus leucopterus*	1	0	0
striated pardalote	*Pardalotus striatus*	1	0	1
yellow-rumped thornbill	*Acanthiza chrysorrhoa*	1	0	0
little wattlebird	*Anthochaera chrysoptera*	1	0	0
yellow-throated miner	*Manorina flavigula*	1	0	0
singing honeyeater	*Lichenostomus virescens*	1	0	0
yellow-plumed honeyeater	*Lichenostomus ornatus*	1	0	0

brown honeyeater	*Lichmera indistincta*	1	0	0
brown-headed honeyeater	*Melithreptus brevirostris*	1	0	0
tawny crowned honeyeater	*Gliciphila melanops*	1	0	0
white-fronted chat	*Epthianura albifrons*	1	0	0
scarlet robin	*Petroica boodang*	1	0	0
hooded robin	*Melanodryas cucullata*	1	0	0
golden whistler	*Pachycephala pectoralis xanthoprocta*	1	0	0
grey-shrike thrush	*Colluricincla harmonica*	1	1	0
magpie-lark	*Grallina cyanoleuca*	1	0	0
white-winged triller	*Lalage tricolor*	1	0	1
black faced cuckoo shrike	*Coracina novaehollandiae*	1	0	0
dusky woodswallow	*Artamus cyanopterus*	1	0	0
Australian raven	*Corvus coronoides*	1	0	1
Australian pipit	*Anthus richardi*	1	0	0
Mistletoe bird	*Dicaeum hirundinaceum*	1	0	0
white-backed swallow	*Cheramoeca leucosterna*	1	0	1
welcome swallow	*Hirundo neoxena*	1	0	0
rufous songlark	*Cincloramphus mathewsi*	1	0	1

Table 12: Passive survey observations including sand pads (SP), camera traps (CT), sign of diggings (D) or scats (S), spotlighting (SL) systematic searches (SS) and opportunistic records (OR).

Species	1986	Autumn 2012	Spring 2012
Crinia glauerti	OR/SS		
Litoria adelaidensis	OR/SS		
Lialis burtonis	OR/SS		OR
Pygopus lepidopodus	OR/SS		
Morelia spilota	OR/SS		
Canis familaris	S		
Felis catus	OR	SP	SP
Vulpes vulpes	OR	SP/CT	SP
Macropus fuliginosus	OR	SP/CT	SP
Macropus irma	OR		
Mus musculus		SP	
Oryctolagus cuniculus	OR		
Tachyglossus aculeatus	D		
Unidentified lizard		SP	SP
Unidentified mammal		SP	SP
unidentified Elapid		SP	SP
unidentified owl			OR