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Comparisons of ground vertebrate assemblages in arid Western Australia in different seasons and decades

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Abstract – Assemblages of mammals, reptiles and frogs were sampled 20 years apart on the same five Eastern Goldfields sites and in the same months using the same techniques for the same periods of time. None of nine species of snakes were captured on both surveys and three additional species of lizard were added to the 32 recorded on the first survey. No new mammal or frog species were recorded but the relative abundance of most vertebrate species changed over two decades. The greatest change in relative abundance occurred in a group of lizards that are long lived – the geckos. All sampling sites continued to show an increase in species richness with continued sampling time. Differences in assemblages were greatest between surveys and least between seasons suggesting long-term changes occurred in assemblage structure.

INTRODUCTION

The first approach to defining biodiversity usually comes from examining species lists derived variously from the literature or biological surveys. These species lists form the basis of identifying areas of high biodiversity and their significance to conservation at spatial scales ranging from global (Myers *et al.*, 2000) to regional (Gomez de Silva and Medellin, 2001) or evaluating the impacts of development on local environments (WA Government, 2002). The adequacy of these lists to accurately determine species richness is seldom assessed, particularly for faunal groups.

The vertebrate fauna of the arid zone of Western Australia has been documented by several broad scale surveys over the last 30 years that have shown inland regions to be biologically diverse, particularly for reptiles (Burbidge *et al.*, 1976, McKenzie and Burbidge, 1979; McKenzie and Robinson, 1987). The vertebrate diversity of the Eastern Goldfields region was examined in more detail by a major biological survey in the late 1970s to early 1980s (Biological Surveys Committee, 1984) resulting in the publication of 12 reports outlining the diversity of vascular plants and vertebrates at over 120 sites in the region. Recent work by environmental consultants has confirmed the diversity of the vertebrate fauna of the Goldfields by undertaking further intensive site-specific samplings but within a longer temporal framework (Thompson and Thompson, 2002). These studies have revealed a larger number of rare species as well as several species that occur well outside their previously known ranges.

As part of a recent biodiversity audit of the Eastern Goldfields, the Kalgoorlie regional office of the Department of Conservation and Land Management (CALM) commenced a program in 2001 to document the vertebrate diversity of pastoral leases that have been acquired for conservation purposes. The first local survey of vertebrate fauna was undertaken on Goongarrie Station and one objective of the survey was to resample five sites that had been sampled in 1978–1981 by the Western Australian Museum during the survey of the Eastern Goldfields (Dell *et al.*, 1988).

This paper describes changes in the composition and relative abundances of the ground faunal assemblages of these five habitats sampled 20 years apart but in the same seasons.

SURVEY LOCATIONS AND METHODS

In the early 1990s the Department of Conservation and Land Management commenced an acquisition program of leasehold properties to add to the State's conservation reserves. Early amongst these was Goongarrie Station, acquired in 1995 as a property that spanned the major biogeographic feature of the Mulga- Eucalypt line that delineates the South West Interzone and Eremaean Province of Beard (1980) and forms the boundary between the Murchison and Coolgardie Bioregions (Thackway and Cresswell, 1995).

Study Area and Sampling Sites

The broad vegetation and soil characteristics of the study area and the five sampling sites reexamined in this paper are described in detail in Dell *et al.* (1988). Codes for the eastern Goldfields survey were based on a sites' location in the 1:250000 topographical map series, in this case the Edjudina and Menzies [Em] sheets. The sampling of the five sites in each of the CALM and Museum surveys are identified as GS and GG, respectively. The brief descriptions of the five re-sampled sites are as follows:

Em3=GG26=GS26: *Acacia coolgardiensis* Tall Shrubland on Dunefield landform unit with red loamy sand to greater than 3 m.

Em13=GG27=GS27: *Eucalyptus leptopoda* Mallee on Sandplain landform unit with yellowish red sandy loams to 40 cm with gravels below.

Em22=GG28=GS28: *Eucalyptus concinna* Mallee on Broad Valley landform unit with dark red sandy loam to >80cm.

Em21=GG29=GS29: *Casuarina pauper* Low Woodland on Broad Valley landform unit with shallow calcareous earths to > 1m.

Em15=GG30=GS30: *Acacia stowardii* Tall Shrubland on Undulating Plain landform unit with dark red brown loam or clay loam to 10cm and quartz and calcrete below

Sampling sites were selected, in the first instance, to cover the gradient of landform and soil types in a catena from an outlying sand dune to the loams on a quartzite rise in broad valley.

There was no evidence that any of the sites have been subjected to fire between the two surveys while grazing has continued, albeit at a very low level, on both sites 29 and 30 throughout the period.

Survey and Sampling Periods

Two major surveys and four discrete sampling periods have been undertaken on the five sampling sites. The Western Australian Museum sampled the five sites over six days between 10–15 March 1979 and 6–11 October 1980,while CALM sampled the same sites for seven or six days, respectively, between 24–30 October 2001 and 6–11 March 2002.

The sampling periods of the CALM survey were selected to represent the two main periods of faunal activity in the semiarid of Western Australia [spring (October) and late summer (March)] and be comparative with the earlier study by the Museum. A third sampling of five days was undertaken by the Museum in July 1981, however, data for this winter period are not included as few ground vertebrate species were captured and none that were not already known for the sites (Dell *et al.* 1988).

Sampling at all sites involved the use of pitfall traplines with drift fences, Elliott mammal traps and extensive opportunistic sampling that included both foraging and headtorching techniques. Sampling at GG30 by the Museum did not involve the use of fenced pitfall traps but extensive opportunistic searching and mammal trapping occurred around a campsite based on this location allowing a comparison of assemblage structure and abundances.

The majority of captures from the Museum's survey were vouchered into the State's collections while less than five percent of the CALM survey individuals were vouchered.

Analysis

Comparisons between sampling sites and surveys were made using the Bray – Curtis coefficient of dissimilarity for species abundance data and principal co-ordinates plot of these matrices.

How (1998) indicated that upwards of 50 days of sampling are required to sample 70% of a reptile assemblage on the Swan Coastal Plain and this was due to the infrequent capture rates of snakes in particular. However, when only lizards were considered, over 60% of the assemblage was captured after 30 days. As only 25 days of sampling occurred during the four sampling periods of the two surveys, only the lizard assemblages are compared between sampling periods and sites for this study.

The calculation of the magnitude of change in lizard abundances between surveys was calculated following the methods of Pianka (1986). This involved calculating the proportion of the total captures for each taxon in each survey and comparing the change in this proportion between surveys by dividing the larger proportion by the smaller.

RESULTS

Assemblage Composition

The abundance and location of all ground vertebrate species captured at Goongarrie during each survey and at each sampling site are presented in Table 1.

Amphibians and Reptiles

The CALM survey of 2001–2002 added three species of lizard [*Strophurus assimilis, Underwoodisaurus milii, Varanus tristis*] and six snakes [*Ramphotyphlops australis, R. bituberculatus, R. hamatus, Brachyurophis fasciolata, B, semifasciata, Simoselaps bertholdi*] to the previously known assemblage. Conversely, eight lizards [*Gehyra purpurascens, Heteronotia binoei, Delma butleri, Pygopus nigriceps, Cryptoblepharus carnabyi, Cyclodomorphus melanops, Egernia formosa, Morethia butleri*] and three snakes [*Demansia psammophis, Parasuta monachus, Pseudonaja modesta*] were captured during the Museum survey in 1979–1980 that were not recorded during the CALM survey.

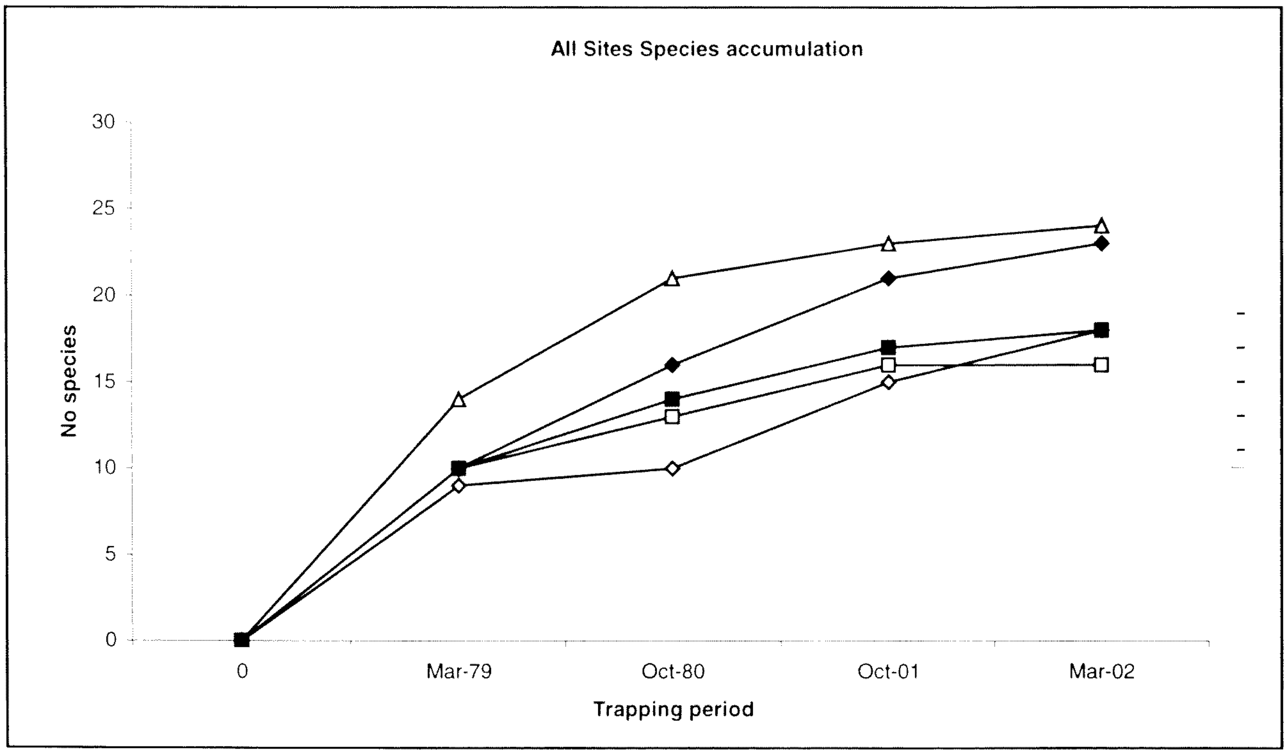

Figure 1 Species accumulation for the five sampling sites over the four sampling periods

No additional species of frogs were recorded during the CALM survey, such that 2 amphibian and 44 reptile species are now recorded from the five sites.

The cumulative total of species recorded for each sampling site over the four sampling periods is presented in Figure 1. On all sites, additional species continued to be caught during the last survey period, March 2002, indicating that further species should continue to be recorded with future sampling. Particularly, additional species of snakes could be expected as their cryptic nature, low density and seasonal activity make them very difficult to document over short duration surveys such as those undertaken to date.

Mammals

Seven species of ground mammal were recorded during the Museum's survey. The CALM survey did not record additional species but added species to the assemblages of individual sites (Table 1). Of particular significance was the high number of juvenile individuals of most species recorded during the March 2002 survey.

Lizard Assemblages

Table 1 indicates that neither of the two frogs nor any of the nine species of snakes were recorded on both Museum and CALM surveys, consequently only the lizards were considered in changes in relative abundances between the two surveys.

Thirty-two lizards with 278 records were documented on the Museum survey while 27 species with 178 records were recorded on the CALM survey. Of the combined 35 lizard species recorded, 19 decreased in relative abundance and 16 increased between the surveys (Table 1). The mean change in relative abundance of the 24 species in common between both surveys was 2.74±2.84(24) times. The relative abundance of the lizard fauna on each survey is presented in Figure 2.

Comparisons between the lizard assemblages of the four sampling periods, using the Bray-Curtis distance index, showed the CALM sampling of March and October were most similar to one another (Table 2) and were also more similar to the Museum's March survey than any were to the Museum's October assessment (Figure 3). These differences are accounted for by marked changes in the abundance of species between sampling periods, especially for the Museum's October sampling (Table 1).

Comparison between the lizard assemblages on sampling sites between the two surveys using abundance data (Table 3) showed the most similar site between the two surveys was Site 29 (0.471) while the least similar sites was Site 30 (0.761). The mean dissimilarity between sites [0.560±0.12(5)] sampled 20 years apart was less than the dissimilarity among sites [0.707±0.16(40)] over the same period. Figure 4 details the relationship between sites over the two surveys, using principal co-ordinates analysis, and indicates that three main groupings occur on axis 1 that represent 39% of the variation and reflect the main soil types. Sites 26, 27 and 28 are habitats on sands and sandy gravels,

Table 1 The number of individuals of each species of ground vertebrate fauna recorded on the five sample sites during each survey. The change in relative abundance is also presented for lizard taxa.

TAXON	GG26	GG27	GG28	GG29	GG30	**Total GG**	GS26	GS27	GS28	GS29	GS30	**Total GS**	**CHANGE**	GG Mar	GG Oct	GS Mar	GS Oct
Trap days	300	240	120	120		**780**	156	156	156	156	156	**780**		390	390	420	360
AGAMIDAE																	
Ctenophorus cristatus (Gray, 1841)			5			**5**			1	1		**2**	**-1.60**	4	1	1	1
Ctenophorus fordi (Storr, 1965)	22	42	15	2		**81**	6	9	2	2		**19**	**-2.73**	19	62	3	16
Ctenophorus reticulatus (Gray, 1845)					2	**2**					1	**1**	**-1.28**	1	1	1	
Ctenophorus scutulatus (Stirling and Zietz, 1893)		3	3	7	1	**14**				8	3	**11**	**+1.23**	8	6	6	5
Moloch horridus Gray, 1841		1			1	**2**	1	2		1		**4**	**+3.12**	1	1	4	
Pogona minor (Sternfeld, 1919)	1	1	1	1	3	**7**	1	1		3		**5**	**+1.12**	2	5	3	2
GEKKONIDAE																	
Diplodactylus granariensis Storr, 1979			1	2		**3**	4	8	5	8	4	**29**	**+15.10**	1	2	15	14
Diplodactylus maini Kluge, 1962			2	1		**3**			2			**2**	**+1.04**	2	1	1	1
Diplodactylus pulcher (Steindachner, 1870)					1	**1**				1	2	**3**	**+4.69**	1		2	1
Gehyra purpurascens Storr, 1982			2			**2**						**0**	**-**	1	1		
Gehyra variegata (Duméril and Bibron, 1836)	1	1	3		1	**6**		2	4	6	3	**15**	**+3.90**	5	1	3	12
Heteronotia binoei (Gray, 1845)					2	**2**						**0**	**-**	1	1		
Nephrurus laevissimus Mertens, 1958	18	18	2			**38**	12	9	1	1		**23**	**-1.06**	32	6	17	6
Rhynchoedura ornate Günther, 1867		2	2	1		**5**	1		2	3		**6**	**+1.87**	4	1	2	4
Strophurus assimilis (Storr, 1988)						**0**	3					**3**	**+**			3	
Underwoodisaurus milii (Bory, 1825)						**0**					9	**9**	**+**			4	5
PYGOPODIDAE																	
Delma butleri Storr, 1987	1		1			**2**						**0**	**-**		2		
Pygopus nigriceps (Fischer, 1882)				1		**1**						**0**	**-**	1			
SCINCIDAE																	
Cryptoblepharus carnabyi Storr, 1976					3	**3**						**0**	**-**		3		
Cryptoblepharus plagiocephalus (Cocteau, 1836)			3	1		**4**		1				**1**	**-2.56**	2	2		1
Ctenotus atlas Storr, 1969	4	3	4	1		**12**	2	3	3	2		**10**	**+1.30**	5	7	5	5
Ctenotus brooksi (Loveridge, 1933)	17					**17**	3					**3**	**-3.63**	3	14	1	2
Ctenotus schomburgkii (Peters, 1863	4	9	5	3		**21**		1	5	1		**7**	**-1.92**	7	14	5	2
Ctenotus uber Storr, 1969				1	6	**7**					1	**1**	**-4.48**	3	4	1	
Cyclodomorphus melanops (Werner, 1910)			2			**2**						**0**	**-**	1	1		
Egernia depressa (Günther, 1875)				2	10	**12**				2	2	**4**	**-1.92**	4	8	2	2
Egernia formosa Fry, 1914					5	**5**						**0**	**-**	3	2		
Egernia inornata Rosén, 1905	3	2		1		**6**	2	4	2			**8**	**+2.08**	5	1	5	3
Lerista macropisthopus (Werner, 1903)			1			**1**	2					**2**	**+3.12**		1	1	1
Lerista muelleri (Fischer, 1881)			1	1	1	**3**	2				2	**4**	**+2.08**	3		2	2
Menetia greyii Gray, 1845	1	2	1	1	1	**6**		1	1	1		**3**	**-1.28**	3	3		3
Morethia butleri (Storr, 1963)					2	**2**						**0**	**-**	1	1		
Tiliqua occipitalis (Peters, 1863)		1				**1**		1				**1**	**+1.56**		1	1	

VARANIDAE																
Varanus gouldii (Gray, 1838)				2	**2**			1			**1**	-1.28		2	1	
Varanus tristis (Schlegel, 1839)					**0**					1	**1**	+				1
ELAPIDAE																
Brachyurophis fasciolata (Günther, 1872)					**0**		1				**1**					1
Brachyurophis semifasciata (Günther, 1863)					**0**	1				1	**2**					2
Demansia psammophis (Schlegel, 1837)			2		**2**						**0**			2		
Parasuta monachus (Storr, 1964)			1		**1**						**0**			1		
Pseudonaja modesta (Günther, 1872)		1	3		**4**						**0**		2	2		
Simoselaps bertholdi (Jan, 1859)					**0**				1		**1**					1
TYPHLOPIDAE																
Ramphotyphlops australis (Gray, 1845)					**0**	1			2		**3**				2	1
Ramphotyphlops bituberculatus (Peters, 1863)					**0**			1			**1**					1
Ramphotyphlops hamatus Storr, 1981					**0**				1		**1**					1
MYOBATRACHIDAE																
Neobatrachus sp	1				**1**						**0**		1			
Neobatrachus wilsmorei (Parker, 1940)		3		2	**5**						**0**		5			
DASYURIDAE																
Ningaui ridei Archer, 1975	1				**1**	5		4	3		**12**		1		7	5
Sminthopsis crassicaudata (Gould, 1844)	1				**1**				1		**1**			1	1	
Sminthopsis dolichura Kitchener, Stoddart and Henry, 1984	1	1	1	1	**4**	2	2		1	12	**17**		1	3	16	1
MURIDAE																
Mus musculus Linnaeus, 1758					**0**	2	4	1			**7**					7
Notomys alexis Thomas, 1922	9	3	1	1	**14**				2		**2**		6	8		2
Notomys mitchellii (Ogilby, 1838)	1				**1**						**0**		1			
Pseudomys hermannsburgensis (Waite, 1896)		2			**2**	1			4		**5**		2		1	4

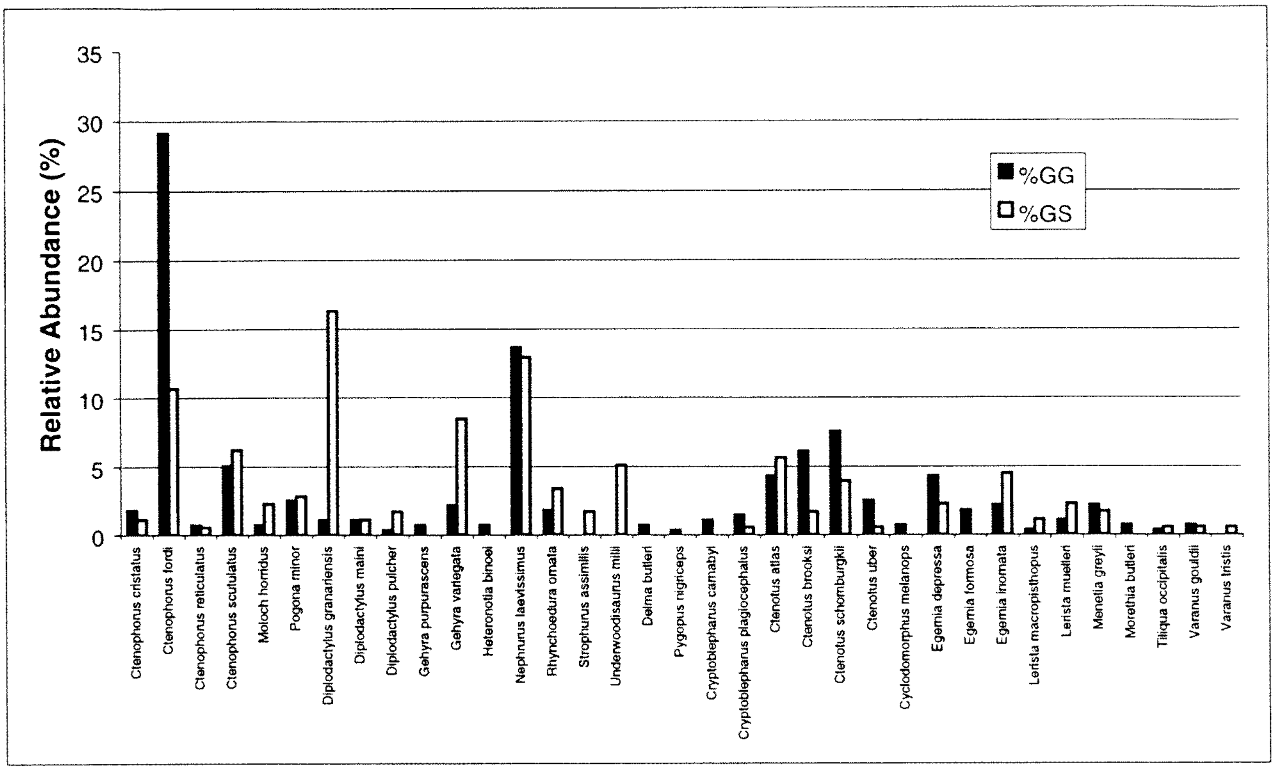

Figure 2 Relative abundance of the lizard assemblages at Goongarrie during the two major surveys undertaken by the Museum (%GG) and CALM (%GS).

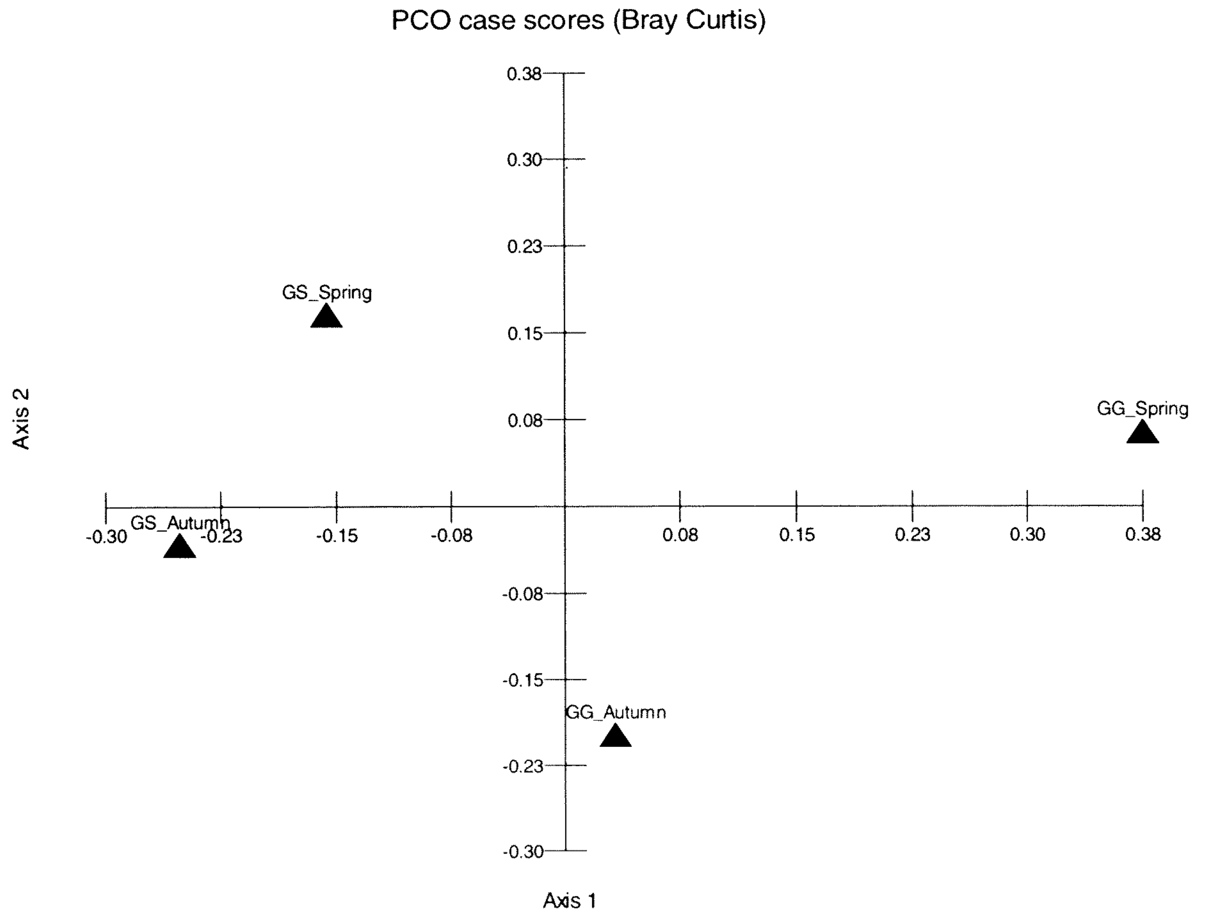

Figure 3 Principal coordinate plot of lizard assemblages on the four sampling periods of the two surveys based on abundance data and Bray-Curtis index of dissimilarity.

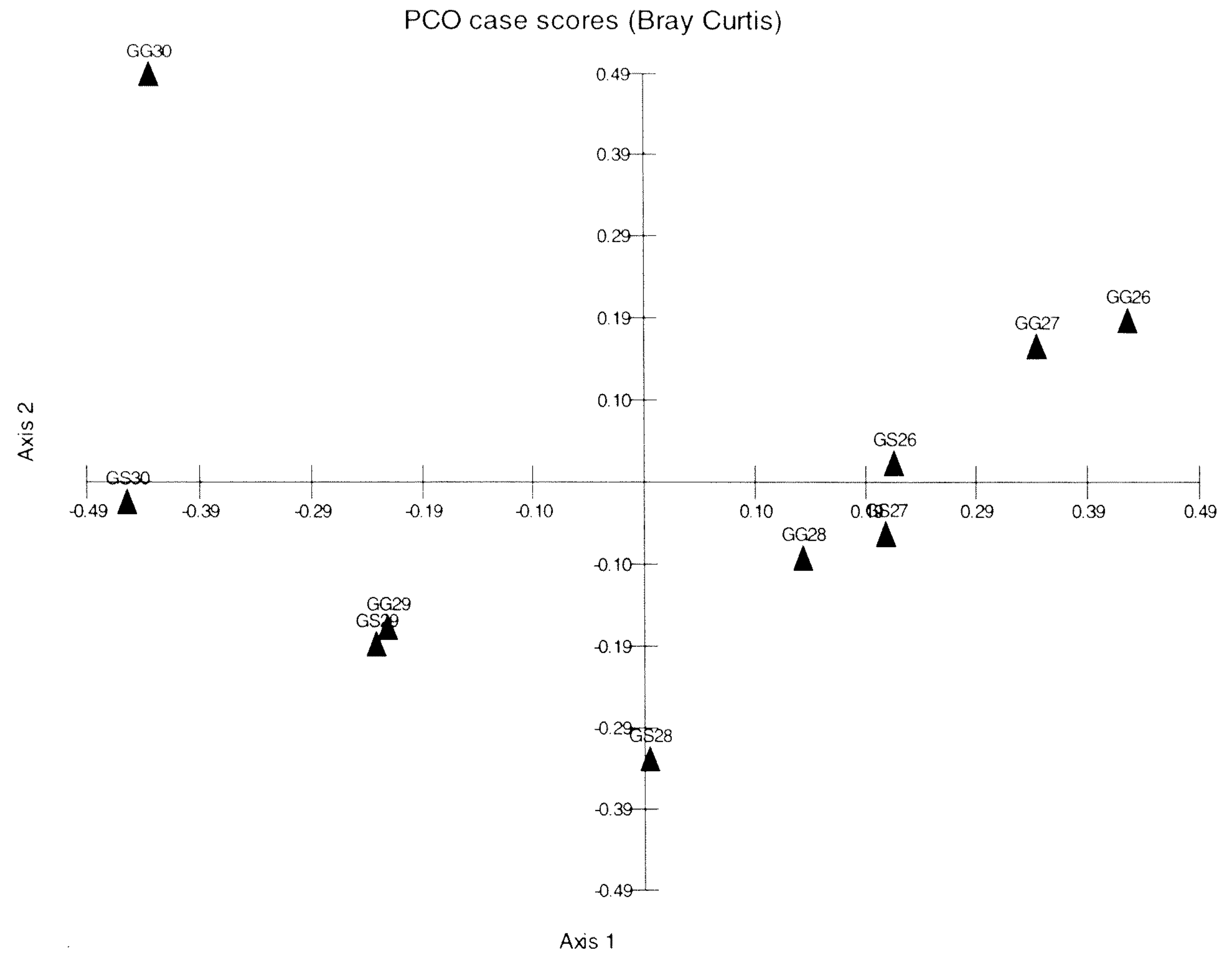

Figure 4 Principal co-ordinates plot of lizard assemblages of the five sampling sites on each of the two surveys, based on abundance data and the Bray-Curtis index of dissimilarity. Key GG26=GS26, GG27=GS27, GG28=GS28, GG29=GS29

while site 29 occurs on calcareous earth and site 30 on clay loam.

Species Preferences

The absence of frogs in the CALM sampling periods is probably attributable to the lack of any significant rainfall immediately prior to or during those samplings. However, some minor precipitation on one evening during October 2001 did allow activity by fossorial snakes of the genera *Ramphotyphlops* and *Vermicella* (Table 1). No species of snake was common to both surveys.

The relatively high dissimilarity between sites in their lizard species assemblages (Figure 4) indicates that there are species with defined habitat preferences that are abundant on some sites and absent from others (see also Table 1). Ignoring species that are represented by a single or very few records, two sites have species that were not recorded on adjacent or other nearby sites. Site 26 has the only records of *Strophurus assimilis* and *Ctenotus brooksi*, while site 30 has the only or the great majority of records of *Ctenophorus reticulatus, Underwoodisaurus milii, Cryptoblepharus carnabyi, Ctenotus uber* and *Egernia formosa*. Some other species (*Ctenophorus cristatus, C. fordi, Diplodactylus granariensis, Cryptoblepharus plagiocephalus, Ctenotus atlas, C. schomburgkii, E. inornata* etc.) occurred in abundance on the sands and sandy loams of sites 26–29 but were not recorded on the clay loams of

Table 2 Matrix of survey relationships of the lizard faunas based on Bray-Curtis of dissimilarity.

	GG_Autumn	GG_Spring	GS_Autumn	GS_Spring
GG_Autumn	0			
GG_Spring	0.468	0		
GS_Autumn	0.419	0.65	0	
GS_Spring	0.417	0.577	0.348	0

Table 3 Matrix of sampling site relationships of the lizard faunas based on Bray-Curtis of dissimilarity.

	GG26	GG27	GG28	GG29	GG30	GS26	GS27	GS28	GS29	GS30
GG26	0									
GG27	0.338	0								
GG28	0.54	0.525	0							
GG29	0.82	0.77	0.61	0						
GG30	0.946	0.919	0.892	0.791	0					
GS26	0.532	0.597	0.677	0.731	0.923	0				
GS27	0.509	0.543	0.563	0.714	0.901	0.383	0			
GS28	0.723	0.702	0.494	0.544	0.941	0.647	0.521	0		
GS29	0.839	0.76	0.617	0.471	0.747	0.696	0.537	0.449	0	
GS30	0.98	0.929	0.805	0.679	0.761	0.821	0.829	0.754	0.618	0

site 30. These habitat specialists account for the low similarity between sites on these two types of soil types (Figure 4).

Major increases in the relative abundance of several species (*Diplodactylus granariensis, D. pulcher, Gehyra variegata, Underwoodisaurus milii*) occurred between the two surveys, while others showed marked decreases (*Ctenotus uber, C. brooksi, Ctenophorus fordi*). These changes contribute substantially to the differences noted in the similarity between different decades.

Amongst the mammals *Mus musculus, Sminthopsis dolichura* and *Ningaui ridei* were more abundant on the CALM survey while *Notomys alexis* was more frequently encountered on the Museum survey (Table 1). A great number of juvenile *S. dolichura* was the captured on GS30 on the March 2002 sampling.

DISCUSSION

More than twenty years after the initial vertebrate survey of five diverse sites in the Eastern Goldfields, a new survey has shown major changes have occurred in both composition and abundance of ground vertebrate species. The re-sampling of five Museum sites near Comet Vale by CALM during October 2001 and March 2002 added nine species (three lizards and six snakes) of ground vertebrates to the known fauna. The herpetofauna recorded from the five sites now totals two species of amphibians and 44 reptile taxa. No new species of mammals were recorded during the CALM survey, with seven small mammal species comprising the known assemblage.

The majority of the six additional species of snake recorded on the CALM survey were attributed to trapping during an evening of precipitation (Cowan personal observation) suggesting that numerous additional species may be expected when sampling continues and incorporates changed seasons and weather conditions. Also, many wideranging species of lizards [eg *Lialis burtonis Tiliqua rugosa*] that have distributions encompassing the Goongarrie area (Storr *et al*., 1983, 1990, 1999, 2002) should be recorded with additional sampling.

The Museum sampling sites were established at the edge of the transition between the more mesic vegetation types and landforms of southwestern Western Australia and those of the arid desert regions (Dell *et al*.1988). Less than 5 km east of the five sampling sites reported in this study are several additional Museum sampling sites that have recorded the most south-westerly records of *Strophurus wellingtonae, S. strophurus, Lerista picturata, Varanus caudolineatus* and *V. giganteus*. Some of these species are replaced by their ecological homologues on the study sites [*S. wellingtonae* by *Strophurus assimilis* and *L. picturata* by *Lerista macropisthopus*] but the other species could potentially be recorded on the five sites under consideration. When additional information is included from Dell *et al.* (1988) three frogs, 11 snakes and 43 lizards have been recorded from an area that extends over just 11 km but which spans the boundary of two major bioregions.

The mammal assemblages of the five sampling sites were not changed by the CALM survey. However, Cowan (unpublished) and Thompson and Thompson (2002) have shown that up to seven additional species occur nearby and these could be captured with additional trapping effort. These are *Antechinomys laniger, Ningaui yvonneae, Pseudantechinus woolleyae, S. hirtipes, Cercartetus concinnus, Pseudomys albocinereus*, and *P. bolami*.

As well as the additional reptile species recorded during 2001–2002, some significant changes to species relative abundances were noted (Table 1 and Figure 2). None of the nine species of snakes recorded from the five sampling sites were captured on both surveys. This supports the characteristic pattern of snake captures that have been noted elsewhere (How, 1998) in that they are infrequently captured and usually in low numbers. Only the lizard species were considered in an analysis of changes in relative abundances.

Comparison of lizard species between samplings 20 years apart showed that 19 species decreased in relative abundance while 16 increased (Table 1). The dragon, *Ctenophorus fordi*, and the skinks, *Cryptoblepharus plagiocephalus, Ctenotus brooksi, C. uber, Egernia depressa*, were relatively more abundant on sites during the 1979–80 survey, while *Moloch horridus*, the geckos *Diplodactylus granariensis*, *D. pulcher*, *Gehyra variegata* and the skink, *Lerista macropisthopus*, had much greater relative abundances on the 2001–02 survey (Figure 2). These changes in relative abundances between surveys reflected, constantly, in changes of relative abundances on the same sites between surveys as well (Table 1).

In his classic study of desert reptiles, Pianka (1996) reported the average magnitude of change in relative abundance of 26 lizards in the decade between 1967–1978 was 2.70±1.55, while for 31 lizards on the same site between 1978–1990 the average change was 3.01±3.46. Using the same method of calculation, our data show that the average magnitude of change at Goongarrie for 24 lizards over a 20 year period was 2.74±2.84. The majority (62.5%) of the 24 species had changes in relative abundance of less than 2.5 times between surveys (Table 1). James (1994) showed that lizard assemblages were highly variable during his three and a half year study and changed in patterns similar to those reported by Pianka (1986) in the Great Victoria Desert, but that this stochasticity was highly seasonal and occurred over small areas.

Pianka (1986) examined shifts in microhabitat and dietary niche as well as changes in relative abundance over 10 year intervals and concluded that the changes in niche parameters and relative abundance were not correlated, suggesting a large amount of stochasticity in the assemblage structure and function. Our data indicate that long-lived species, particularly geckos, show the greatest change in relative abundance over the 20-year time interval. These changes are not correlated with any habitat changes as evidenced by the lack of fire or alteration due to grazing intensity. Changes in the relative abundances of uncommon species are probably artifacts of small sample size and may not have real biological significance.

How and Dell (2000) showed that the mean similarity of lizard assemblages sampled on the same bushland remnants on successive years was 77%. The total lizard assemblage in this study showed that only 24 of the 35 (68.6%) lizard species recorded were common to both surveys. The two Museum surveys were 75% similar while the two CALM surveys were 67% similar based on species occurrence. When abundance data were evaluated using the Bray-Curtis index, the pattern of similarity is reversed with the two CALM surveys being least different and the two Museum surveys most different (Table 2). The four sampling periods encompassed only 25 sampling days at each site, considerably less than the 75 days suggested by How (1998) as being necessary to record 80 percent of the lizard assemblages on sites in the Swan Coastal Plain. James (1994) recorded 32 of 39 (82%) lizard species within the first 25 days of sampling at Ewaninga, central Australia, however the last 3 species recorded were trapped only between days 160 and 180 of sampling. The addition of previously unrecorded species to the assemblages at Goongarrie during all sampling periods and at all sites (Figure 1) strongly supports this contention of an incomplete documentation.

The high diversity of ground vertebrates at Goongarrie is probably explained by the juxtaposition of differing soil and habitat types in a study area traversing a major biogeographic interface (Dell *et al.*, 1988). Marked changes in habitat and soils over a small distance would also account for the high turnover in lizard species between sites shown during this study.

Consideration of assemblages on the basis of species presence, alone, has been questioned by Balmer (2002) who concluded, "that analyses that do not include species' relative abundances do not reveal the real ecological patterns in the data". Our data examining differences in lizard assemblages using abundance data for both between sampling periods (Figure 3) and sites (Figure 4) indicate that 'real' changes have occurred in lizard assemblages between surveys 20 years apart.

This study also lends support to the findings of Thompson and Thompson (2002) and How (1998), who evaluated the significance of sampling regime bringing into question the ability of short-term surveys to adequately determine vertebrate assemblages for environmental impact assessments. If the objective of surveys is to document levels of biodiversity to be able to detect future change in relation to changed management criteria, then short-duration surveys of species present do not provide appropriate information. If threatened or rare species are to be the focus of management decisions then short-term surveys infrequently encounter such species and therefore provide little information to assist managers. This study suggests that significant longer-term changes occur in assemblages that cannot easily be detected by shorter but more intensive sampling regimes and it also indicates that changes in assemblage structure are better able to be evaluated using abundance data.

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REFERENCES

Balmer, O. (2002). Species lists in ecology and conservation: abundances matter. *Conservation Biology* **16**: 1160–1161.

Beard, J.S. (1980). A new phytogeographic map of Western Australia. *Western Australian Herbarium Research Notes* **3**, 37–58.

Biological Survey Committee. (1984). Biological survey of the Eastern Goldfields of Western Australia. Part 1. Introduction and methods. *Records of the Western Australian Museum, Supplement* **18**: 1–19.

Burbidge, A.A., McKenzie, N.L., Chapman, A. and Lambert, P.M. (1976). The wildlife of some existing and proposed nature reserves in the Great Victoria and Gibson Deserts, Western Australia, *Wildlife Research Bulletin* No. 5.

Dell, J., How, R.A., Milewski, A.V. and Keighery, G.J. (1988). Biological Survey of the Eastern Goldfields of Western Australia. Part 5. Edjudina-Menzies study area. *Records of the Western Australian Museum Supplement* **31**: 1–137.

Gomez de Silva, H. and Medellin, R.A. (2001). Evaluating completeness of species lists for conservation and macroecology: A case study of Mexican land birds. *Conservation Biology* **15**: 1384–95.

How, R.A. (1998). Long-term sampling of a herpetofaunal assemblage on an isolated urban bushland remnant. *Journal of the Royal Society Western Australia* **81**: 143–148

James, C.D. (1994). Spatial and temporal variation in structure of a diverse lizard assemblage in arid Australia. Chapter 13. *In* Vitt, L.J. and Pianka, E.R. (eds), *Lizard Ecology: Historical and Experimental Perspectives:* 287–317. Princeton University Press, Princeton, New Jersey.

Kovach,W.L. (1999). MVSP-A Multivariate Statistical Package for Windows, ver 3.1. Kovach Computing Services, Pentraeth, Wales, U.K.

McKenzie, N.L. and Burbidge, A.A. (1979). The wildlife of some existing and proposed nature reserves in the Gibson, Little Sandy and Great Victoria Deserts, Western Australia. *Wildlife Research Bulletin* No. 8.

McKenzie, N. L. and Robinson, A. C. Eds. (1987). *Biological Survey of the Nullarbor Region South and Western Australia in 1984.* Department of Environment and Planning, South Australia.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–58.

Pianka, E. R. and Pianka, H. D. (1976). Comparative ecology of twelve species of nocturnal lizards (Gekkonidae) in the Western Australian desert. *Copeia* 1976: 125–142.

Pianka, E. R. (1986). *Ecology and Natural History of Desert Lizards.* Princeton Univ. Press, Princeton, N. J., USA.

Pianka, E.R. (1996). Long-term changes in lizard assemblages in the Great Victoria Desert: Dynamic habitat mosaics in response to wildfires. Chapter 8. *In* Cody, M.L. and Smallwood, J.A. (eds.) *Long-term Studies of Vertebrate Communities*: 191–215. Academic Press

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1999). *Lizards of Western Australia I. Skinks.* Western Australian Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1983). *Lizards of Western Australia II. Dragons and Monitors.* Western Australian Museum, Perth.

Storr, G.M., Smith, L.A. and Johnstone, R.E. (1990). *Lizards of Western Australia III. Geckos and Pygopods.* Western Australian Museum, Perth.

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

Thackway, R. and Cresswell, I.D. (1995). *An interim biogeographic regionalisaton for Australia: a framework for setting priorities in the national reserves system cooperative program.* Reserves System Unit. ANCA. Canberra.

Thompson, G. G. and Thompson, S.A. (2002). Terrestrial fauna surveys: why when and how much? *In "The Boundary Fence and Beyond"*:25–36. Proceedings of 2002 workshop on Environmental Management in Arid and Semi-Arid Areas, Goldfields Environmental Management Group, Boulder, Western Australia

Western Australian Government. (2002). *Terrestrial biological surveys as anelement of biodiversity protection.* Position Statement No 3. Environmental Protection Authority, Perth, Western Australia.

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