Reptile assemblage of the Abydos Plain, north-eastern Pilbara, Western Australia

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Abstract

A seventy-four day survey extending over three years recorded a diverse herpetofaunal assemblage of 72 species. Five frog species were recorded after episodic rainfall events, while fifteen snake species and one turtle were infrequently recorded. Data from 51 lizard species showed strong habitat preferences. Lizard assemblages on loams associated with creek lines differed from those on the sands of the Abydos Plain and those adjacent to rocky substrates. These habitat preferences, marked seasonal patterns in activity, and a high proportion of rarely captured species indicate that additional species probably remain to be recorded. Fire had a marked effect on the abundance and composition of species in *Triodia* habitats on sandy soils with burrowing and fossorial forms surviving best.

Keywords: herpetofauna, lizards, diversity, variation, habitat preference, fire response

Introduction

The diverse herpetofauna of Australia's arid regions came to international prominence with the pioneering work by Pianka (1969, 1986) and Pianka & Pianka (1976) and the comparisons that were made between lizard assemblages in desert regions of North America, Africa and Australia. Those studies have now been extended for over thirty years (Pianka 1996) and have made a major contribution to the field of community ecology as well as our understanding of lizard assemblages in arid Australia.

The arid zone of Australia covers over 55% of the continent (Williams & Calaby 1985), but studies of arid zone reptile species have mainly focussed on populations and assemblages in *Triodia*-dominated habitats of central Australia (James 1994; Downey & Dickman 1993; Masters 1996) and the Great Victorian Desert (Pianka 1986, 1996) with some studies in more heterogeneous areas of the southern arid interior (Read 1995; Smith *et al.* 1997; Thompson *et al.* 2003a; Cowan & How 2004). There have been no published studies examining the herpetofauna of the extensive arid Pilbara region of Western Australia.

The Pilbara bioregion covers 179 287 km^2 (Thackway & Cresswell 1995) and is considered to comprise four subregions (McKenzie *et al.* 2000). One of these, the Chichester subregion, consists of Archaean granite and basaltic plains covered by shrub steppe of *Acacia pyrifolia* and *Triodia pungens* with Snappy Gum (*Eucalyptus leucophloia*) tree steppes on the ranges. This component encompasses the Abydos Plain, the major landform on Woodstock and Abydos stations of the northeastern Pilbara (Tinley 1991a).

Despite the large area and extensive anthropogenic activity in the Pilbara, there have been few attempts to document the faunal diversity of the region on a systematic basis (Dunlop & Sawle 1980; R.Teale, Biota Environmental Sciences unpubl; P.K Kendrick, CALM Karratha unpubl.) The herpetofauna of the Pilbara is known to have high endemism with many species confined to small geographic areas within the broader limits of the Pilbara bioregion (Storr *et al.* 1983, 1990, 1999, 2002).

As part of a three year survey to document the faunal diversity of Woodstock and Abydos stations, data were gathered on the composition and structure of numerous vertebrate assemblages in the area (How *et al.* 1991; How & Cooper 2002) to provide baseline information on species habitat preferences and diversity for future management of the area (Berry *et al.* 1991). Woodstock and Abydos stations cover an area of over 150 000 ha of the north-eastern Pilbara and have been the focus of several pioneering biological studies of the arid zone in Western Australia including plants (Burbidge 1943, 1945, 1959), mammals (Ealey 1967a, 1967b, 1967c) and fire (Suijendorp 1967).

In this study, we examine the composition and habitat relationships of the reptile assemblages on the extensive Abydos Plain over a three-year period and compare this information with other studies of reptile assemblages in arid Australia.

Survey Methods

Woodstock and Abydos stations lie some 150 km south of the township of Port Hedland, and the study area covers the upper reaches of the Yule and Turner Rivers that drain northwesterly across a major physiographic unit of the Pilbara, the Abydos Plain. Over the three years of this study, rainfall showed appreciable seasonal and annual variation (Table 1). Major episodic rainfall events in March 1988, during the first survey period, and February 1989, after the fourth survey, flooded Coorong Creek and all other ephemeral streams and drainage lines associated with it.

Table 1

Rainfall registered at Woodstock Station for each month between January 1987 and October 1990 and the mean for 1905 to 1989. Data from the Bureau of Meteorology WA.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
1987	95.2	78.8	–	–	4.8	–	8.5	–	–	–	–	23.0	210.3
1988	61.9	10.0	252.2	8.0	109.2	0.8	–	49.7	–	0.4	1.9	72.4	566.5
1989	63.4	227.0	0.4	46.2	9.0	117.9	2.3	–	–	–	4.0	11.2	484.4
1990	79.2	6.6	–	–	–	3.4	–	–	–	–			
Mean 1905-89	77.5	64.7	59.0	21.1	22.5	25.2	9.9	5.8	1.5	3.1	8.3	36.2	334.8

Sampling Sites and Climate

The regional landforms and vegetation of the Abydos/Woodstock area were described in detail by Tinley (1991b) and formed the basis of selection of sampling sites for the study of small vertebrates (see Fig 5.1, How *et al.* 1991).

Eight major sampling sites, representing the principal habitats identified on the sands of the Abydos Plain, were selected for intensive pit and cage trapping programs and opportunistic collecting. An additional 20 subsidiary sites were selected to sample the granite tors on the Abydos Plain and adjacent rocky escarpments of the Gorge Fold Ranges where substrates precluded the use of pitfall traps.

The eight major sampling sites were:

WS1 *Eucalyptus camaldulensis, Melaleuca leucadendra* 5-8 m tall, 35% canopy cover, over *Acacia* sp. 1-2 m tall, *c.* 5% canopy cover over *Cenchrus ciliaris* <0.5 m tall, *c.* 90% canopy cover. Deep alluvium supporting a narrow belt of riverine woodland on the edge of Coorong Creek. 21°37′01″S, 118 ° 57′13″E

WS2 *Acacia pyrifolia*, 2–3 m tall, 3% canopy cover, *Hakea suberea*, 2–3 m tall, <0.5% canopy cover and *Acacia* sp. 2–3 m tall, <0.5% canopy cover over *Triodia* spp. (2) *c.* 0.5 m tall, 80% canopy cover. Coarse sandy loam with granite bedrock at 30–40 cm and located 200 m from Coorong Creek. Site was burnt in January 1990. 21 ° 36′42″S, 118 ° 57′20″E

WS3 *Triodia* spp. <1 m tall *c.* 60% canopy cover with occasional *Acacia* spp. as emergents. Red sandy loam in an ephemeral drainage line. Site was burnt in January 1990. 21 ° 36′35″S, 118 ° 57′44″E

WS4 *Acacia pyrifolia*, 2–4 m tall, *c.* 5% canopy cover, over *Acacia ancistrocarpa*, 1.5–2 m tall, 50%–70% *Triodia* spp. canopy cover. Occasional ephemerals after rain. Red sandy loam soil, >60 cm deep. Site was burnt in January 1990. 21 ° 36′34″S, 118 ° 58′28″E

WS5 *Triodia secunda* and *T. longiceps* <0.5 m tall, *c.* 70% canopy cover. Soil was white sandy silt over clay. 21 ° 36′35″S, 118 ° 59′16″E

WS6 *Acacia orthocarpa*, 3–4 m tall, *c.* 7% canopy cover, and occasional *A. pyrifolia*, over *Triodia lanigera c.* 0.5 m tall, 50% canopy cover. Skeletal red granitic sandy soil. 21 ° 36′35″S, 119 ° 01′17″E

WS8 *Eucalyptus terminalis*, 3–5 m tall, *c.* 2% canopy cover, over oval leaf wattle 1–1.5 m tall, *c.* 2% canopy cover, over *Triodia c.* 0.5 m tall, *c.* 40% canopy cover. Site includes valley between, and the steep slopes of calcrete mesas. Valley soil is calcareous clay loam. 21 ° 36′25″S, 119 ° 02′23″E

WS10 *Acacia* sp. 1.5–2.5 m tall, <0.5% canopy cover, *Hakea* sp. 1.5–2.5 m tall, <0.5% canopy cover, over *Acacia* sp. <1m tall, *c.* 3% canopy cover, over *Triodia* sp. <0.5 m tall *c.* 60% canopy cover. Deep red loamy sand. Extensive surface water after heavy rain. 21 ° 40′15″S, 119 ° 02′30″E

Fires were frequently seen around the study area during the dry summer months, and numerous small areas on the eastern edge of Woodstock Station were burnt in January and February 1989. In January 1990, lightning strikes started several small fires; three of which burnt out sampling sites WS2, WS3 and WS4 and parts of the surrounding areas. The remaining major sampling sites showed no evidence of having been burnt for numerous years.

Sampling Methods

At each of the eight major sampling sites, a line of fenced pitfall traps that comprised a 50-m long by 30-cm high fly screen mesh fence that crossed six pitfall traps inserted 600 mm into the substrate was established. Pitfall traps were generally made of 175 mm diameter PVC pipe 600 mm deep, but at several sites where the soil was less than this depth, the piping was replaced by 400 mm deep conical pits. At each of the eight major sampling sites, a line of 15 Elliott Type A traps, baited with universal bait, were set 15 m apart and within 50 m of the fenced pitfall trapline. Traps were checked twice daily, shortly after dawn and again in the late afternoon.

At most of the 20 subsidiary sampling sites only Elliott Type A traps were used but on some rockpiles the larger Type B Elliott traps were interspersed with the smaller traps.

Sampling was undertaken between 21–31 March 1988, 2–9 May 1988, 22–30 September 1988, 9–17 February 1989, 16–24 April 1989, 16–24 September 1989, 26 February–7 March 1990, 25 July–2 August 1990 and 24 October–1 November 1990. Sampling was designed to cover summer (February–March) and spring (September–October) in each of the three years, with three additional sampling periods to examine activity at other times of the year. Routine trapping of the 8 major sampling sites and the 20 subsidiary sites was undertaken on all surveys except for May 1988, when only the fenced pitfall traplines were operated, and April 1989, when only Elliott traplines, in the subsidiary sampling sites, were set. All major sampling sites were also subjected to daily routine searching methods and nocturnal head-torching to document herpetofauna not prone to capture in the

Elliott or pitfall traps. Subsidiary sites were checked daily for captures in Elliott traps, but also searched opportunistically (using a head-torch for night searches).

Pitfall traplines were operated on 61 days of the 72 days over which sampling occurred.

All individuals captured were identified, measured and weighed prior to release. For several lizard taxa, individuals were also marked by toe-clipping before release. Voucher specimens were taken of all lizard species and examined in the laboratory to determine their sex and reproductive condition and to collect tissue samples for later molecular studies. The stomach contents of voucher specimens have been published separately as a study on the diet of selected species (Twigg *et al.* 1996).

Analyses

Assemblage analyses were carried out using the NTSYS (2000) program with an examination of the Bray-Curtis index of dissimilarity matrix clustered using the UPGMA method.

Measures of diversity and evenness were derived from the software package on ecological methods (Krebs 2000) using the Shannon measure [H] and the α of the log series for diversity assessment and the Simpson index [E] for evenness.

Results

Herpetofaunal Assemblage

The known herpetofaunal assemblage of the Abydos/ Woodstock stations consists of 5 species of amphibians in two families, 15 species of snakes in three families, a turtle and 51 species of lizards from five families (Table 2).

The only species previously known to occur on the study area but not collected during this survey were a legless lizard, *Delma nasuta*, and a skink, *Ctenotus schomburgkii* (Table 2). Both of these species were collected in the late 1950's, and an additional specimen of *Delma nasuta* was collected in 1963 (WA Museum records).

During the final survey in October 1990, the second records of each of the elapid snakes *Acanthophis wellsi* and *Pseudonaja modesta* were obtained; single specimens of these had previously been collected in 1959 and 1958 respectively (WA Museum records). However, Chapman (WA Museum pers. comm.) had seen *A. wellsi* in 1981 near the airstrip and K. Young (WA Museum pers. comm.) recorded this species at Woodstock Homestead indicating that the species may be widespread but not commonly recorded. The only previous specimen of the blind snake *Ramphotyphlops grypus* from Woodstock was collected in 1953 (WA Museum records). The addition of 25 previously unrecorded species during this survey of Abydos/Woodstock and the continued increase of new species recorded during the 72 days of sampling over three years suggests that additional species of reptile could still be recorded from the area (Fig 1).

Activity of herpetofaunal species is strongly seasonal (Table 3) . The highest number of species and individuals were recorded in the summer sampling period of each year. Fewer species and individuals were trapped during the spring sampling, and far fewer individuals were

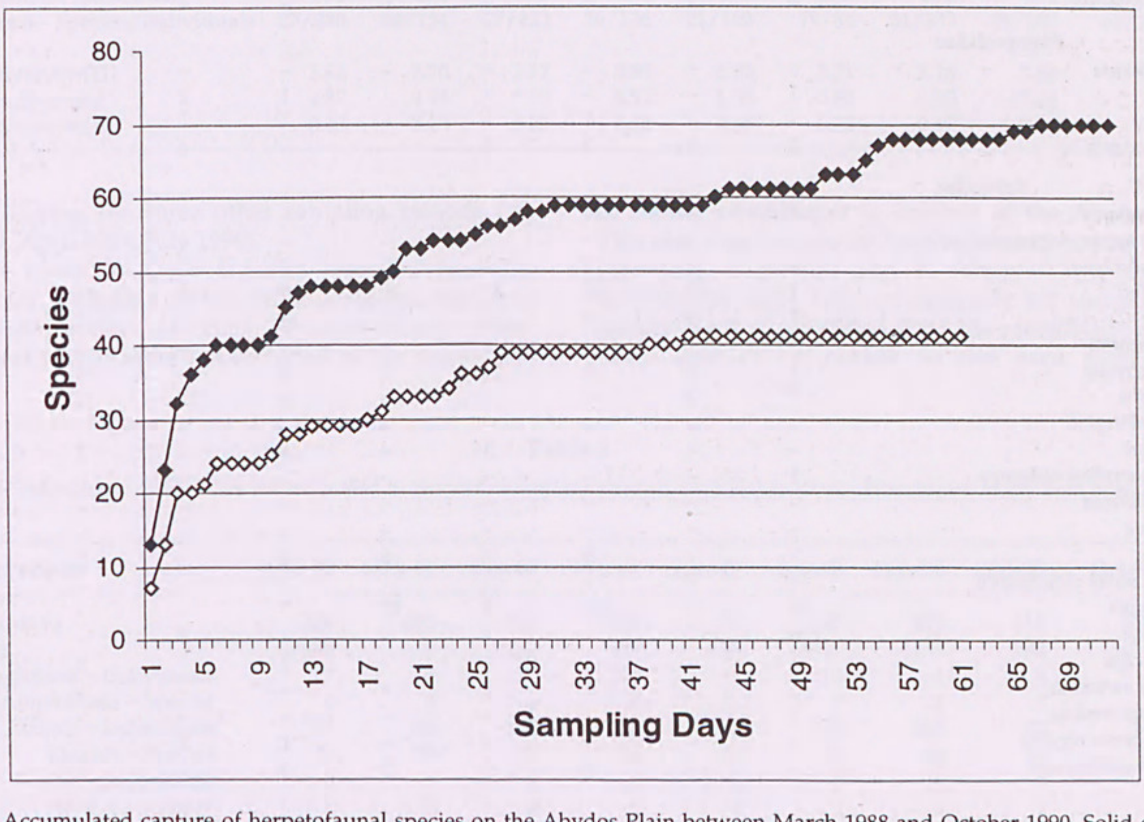

Figure 1. Accumulated capture of herpetofaunal species on the Abydos Plain between March 1988 and October 1990. Solid diamonds represent species captured by all techniques on all sampling days, open diamonds are species captured only by pitfall trapping.

Table 2

The herpetofauna of the Abydos/Woodstock Study area indicating the number of individuals of each species captured at each of the major sampling sites and from all other locations combined. An asterisk [*] indicates the species had been previously collected, and a plus [+] indicates an observational record.

Sites	WS1	WS2	WS3	WS4	WS5	WS6	WS8	WS10	Others
No. pittrap days	288	276	330	348	330	318	318	276	
No. Elliotts	595	605	675	725	675	635	635	485	3101
Hylidae									
* *Cyclorana maini*	39	10	1	1	3	2	3	2	12
* *Litoria rubella*	11	–	–	–	–	–	3	–	34
Myobatrachidae									
* *Limnodynastes spenceri*	82	3	1	2	3	4	–	–	8
Uperoleia glandulosa	2	–	–	–	–	–	–	–	1
* *U. russelli*	81	12	6	–	–	–	4	1	20
Cheluidae									
* *Chelodina steindachneri*	+	–	–	–	–	–	–	–	+
Agamidae									
* *Ctenophorus caudicinctus*	–	1	–	–	–	–	5	2	19
* *C. isolepis isolepis*	–	2	3	9	6	8	–	10	9
* *C. nuchalis*	–	4	8	4	5	–	1	1	6
Diporiphora winneckei	–	–	–	1	–	–	–	1	1
* *Lophognathus longirostris*	4	1	–	–	1	–	2	–	4
Pogona minor	–	1	–	3	1	–	–	2	2
Gekkonidae									
Diplodactylus conspicillatus	–	4	3	9	3	7	–	1	–
D. stenodactylus	1	6	2	6	1	3	3	2	–
Gehyra pilbara	1	2	–	–	–	–	–	–	64
* *G. punctata*	–	–	–	–	–	–	3	–	55
* *G. variegata*	4	–	–	7	–	–	2	–	10
Heteronotia binoei	6	1	1	1	–	–	4	1	1
Heteronotia spelea	–	–	–	–	–	–	–	–	1
* *Nephrurus levis pilbarensis*	1	–	6	2	3	–	–	6	2
Rhynchoedura ornata	–	1	1	4	–	–	4	1	1
* *Strophurus elderi*	–	–	1	1	–	1	2	1	–
Strophurus jeanae	–	1	–	–	–	–	–	–	–
Pygopodidae									
* *Delma nasuta*	–	–	–	–	–	–	–	–	–
* *D. pax*	1	–	–	–	–	1	2	–	1
D. tincta	–	–	1	–	–	–	–	–	–
* *Lialis burtonis*	2	1	2	2	–	–	4	–	1
Scincidae									
Carlia munda	8	–	–	–	–	–	–	–	1
Cryptoblepharus plagiocephalus	–	–	–	–	–	–	–	–	9
Ctenotus duricola	–	1	2	4	10	5	–	6	–
* *C. grandis*	1	61	48	37	31	5	45	14	20
C. helenae	1	9	6	4	2	13	5	7	3
C. nigrilineatus	–	–	–	–	–	–	–	–	2
* *C. pantherinus*	1	1	2	11	7	8	–	19	1
* *C. saxatilis*	7	3	–	–	–	2	27	1	51
* *C. schomburgkii*	–	–	–	–	–	–	–	–	–
C. serventyi	–	–	–	3	–	–	–	2	–
* *Cyclodomorphus melanops*	1	–	–	–	–	–	–	–	–
Egernia depressa	–	–	–	–	–	–	–	–	1
* *E. formosa*	–	–	–	-	-	-	-	-	11
* *E. striata*	-	-	3	7	6	6	-	5	-
* *Eremiascincus richardsonii*	-	-	-	-	-	-	-	-	1
* *Lerista bipes*	16	1	11	5	10	7	-	-	1
* *L. muelleri*	6	1	-	-	-	-	3	-	1
Menetia greyii	1	-	-	-	-	2	-	2	-
* *Morethia ruficauda*	-	-	2	2	-	-	-	-	-
Notoscincus ornatus	1	-	-	-	-	-	-	-	1
* *Proablepharus reginae*	-	-	-	-	-	1	3	-	-
* *Tiliqua multifasciata*	-	-	5	5	2	4	1	4	1

Table 2 (cont.)

Sites	WS1	WS2	WS3	WS4	WS5	WS6	WS8	WS10	Others
No. pittrap days	288	276	330	348	330	318	318	276	
No. Elliotts	595	605	675	725	675	635	635	485	3101
Varanidae									
* *Varanus acanthurus*	1	1	1	2	-	1	4	1	12
* *V. brevicauda*	-	2	-	-	4	2	-	9	-
V. eremius	-	-	1	1	1	-	-	-	1
* *V. giganteus*	-	+	-	-	-	-	-	+	1
* *V. gouldii*	-	+	1	3	1	-	1	+	1
V. panoptes	+	-	-	-	-	-	-	-	-
* *V. pilbarensis*	-	-	-	-	-	-	-	-	2
* *V. tristis*	-	-	-	-	-	-	-	-	3
Typhlopidae									
Ramphotyphlops ammodytes	1	-	3	-	-	-	1	-	-
* *R. grypus*	-	-	-	-	2	-	-	-	-
* *R. pilbarensis*	-	2	-	-	-	-	-	-	-
Boidae									
* *Antaresia perthensis*	-	-	-	-	-	-	-	-	1
* *Antaresia stimsoni*	-	-	1	-	-	-	-	-	3
Aspidites melanocephalus	-	-	-	-	-	-	-	1	-
* *Liasis olivaceus barroni*	-	-	-	-	-	-	-	-	1
Elapidae									
* *Acanthophis wellsi*	-	-	-	-	-	-	-	+	1
Brachyurophis approximans	-	1	-	-	-	-	-	-	-
* *Demansia psammophis cupreiceps*	-	-	-	-	-	-	-	-	3
* *Furina ornata*	-	-	-	-	-	-	-	-	1
* *Pseudechis australis*	-	+	-	-	-	-	1	1	4
* *Pseudonaja modesta*	-	-	1	-	-	-	-	-	-
* *P. nuchalis*	-	1	-	-	1	-	-	-	2
* *Suta punctata*	-	-	-	-	-	-	-	-	-
Amphibians – Species/Individuals	5/215	3/25	3/8	2/3	2/6	2/6	3/10	2/3	5/75
Turtles – Species/Individuals	1/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/0
Lizards – Species/Individuals	20/64	23/105	21/110	24/133	17/94	17/76	19/121	24/98	35/302
Snakes – Species/Individuals	1/1	4/4	3/5	0/0	2/2	0/0	2/2	3/2	8/16
Herpetofauna – Species/Individuals	27/280	30/134	27/123	26/136	21/102	19/82	24/133	29/103	49/393
Shannon diversity [H]	3.61	2.70	3.17	3.89	3.32	3.71	3.14	3.88	
α log series diversity	9.87	8.99	7.70	8.55	6.06	6.80	6.33	10.01	
Simpson evenness [E]	0.43	0.13	0.22	0.38	0.38	0.22	0.17	0.17	

captured during the three other sampling periods (*viz* May 1988, April 1989, July 1990).

Snakes from the three families were infrequently captured (or recorded) on the major sampling sites, and only occasionally at the 20 subsidiary sites. Consequently, they were not included in the assessment of reptile assemblages in habitats of the Abydos Plain. This also was the case for larger goannas such as *Varanus giganteus*, *V. gouldii* and *V. panoptes* and, although juveniles of these were occasionally pit trapped, these species were also omitted from the assemblage analysis. Most species of snakes in the area were active

Table 3

Number of individuals of each species recorded in the nine sampling periods undertaken at the Woodstock study area between 1988-1990.

Sampling Periods	Mar-88	May-88	Sep-88	Feb-89	Apr-89	Sep-89	Mar-90	Jul-90	Oct-90
No. pittrap days	324	282	312	318	24	240	432	216	336
No. Elliotts	1560	0	1240	900	448	1017	1167	782	1017
Amphibian – Individuals	77	95	14	132	1	14	4	3	1
Amphibians – Species	4	4	3	4	1	2	1	1	1
Lizards – Individuals	187	56	131	215	32	120	248	30	91
Lizards – Species	31	24	32	32	13	25	38	10	25
Snakes – Individuals	6	2	4	4	1	2	11	1	3
Snakes – Species	5	2	4	3	1	2	9	1	3
Reptile α diversity	13.04	18.11	16.06	11.75	9.18	10.72	16.77	6.09	13.49

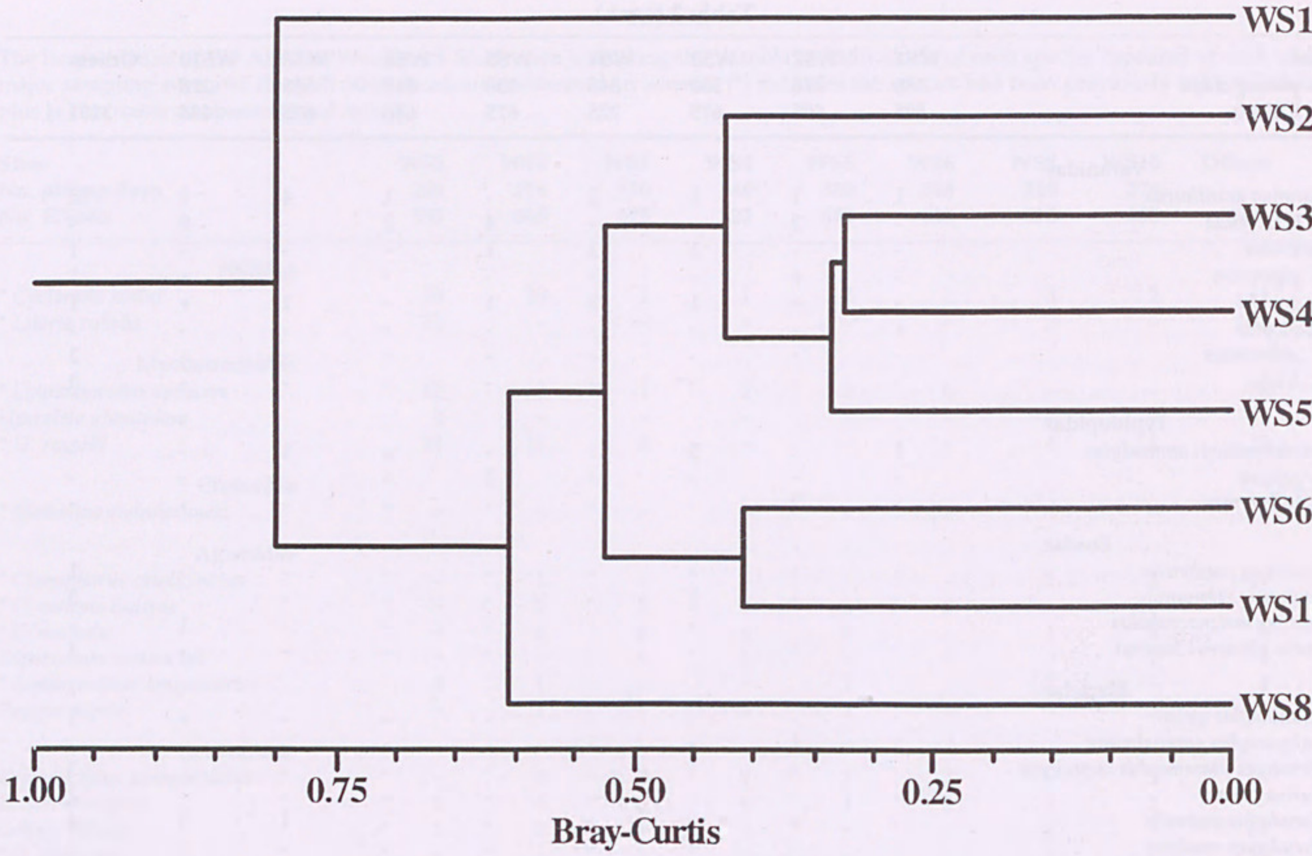

Figure 2. Similarity of lizard assemblages for the eight major sampling sites on the Abydos Plain during the period March 1988 to October 1990.

nocturnally, although *Pseudonaja* spp. and *Demansia psammophis* were seen during the day and *Aspidites melanocephalus* was seen shortly after sunrise.

Amphibians were only captured after summer rain and were most abundant in sites near permanent watercourses, like WS1, and seasonal drainage lines, like WS2. Frogs were also excluded from assessment of assemblages in the major sampling sites of the study area (Fig 2).

Habitat Associations

Although 72 species of herpetofauna are known from the Abydos/Woodstock area, variation was apparent in the number of species caught in the eight major sampling sites with the number of species ranging from 19 to 30 (Table 2).

An analysis of the lizard assemblages from the eight major sampling sites, using the Bray-Curtis index of dissimilarity on abundance data from Table 2 showed that marked differences occurred between habitats (Fig 2). The deeper loams and litter associated with the fringing woodlands of Coorong Creek (WS1) has a distinctive lizard assemblage, as did the habitat adjacent to a rocky breakaway (WS8). The six remaining habitats sampled on the deeper sands of the Abydos plain had assemblages that had similarity of 50% or greater.

Eight lizard species were captured only on subsidiary sites, however, the majority of the 41 lizard species captured on the major sampling sites were also captured on subsidiary sites and these captures provide important complementary assessments of habitat preferences in certain species. Lizards that showed strong preference for rocky habitats and were infrequently captured on sandy substrates included *Ctenophorus caudicinctus, Gehyra punctata, G. pilbara, Heteronotia spelea, Cryptoblepharus plagiocephalus, Ctenotus saxatilis, Egernia formosa, E. depressa, Varanus acanthurus* and *V. pilbarensis*. Species that were generally captured on the extensive sandy loams included *Ctenophorus isolepis, Diplodactylus conspicillatus, D. stenodactylus, Nephrurus levis, Rhynchoedura ornata, Lialis burtonis, Ctenotus duricola, C. grandis, C. helenae, C. pantherinus, C. serventyi, Egernia striata, Lerista bipes, Morethia ruficauda, Varanus brevicauda* and *V. eremius*. Smaller litter-frequenting lizards such as *Heteronotia binoei, Carlia munda, Lerista muelleri, Menetia greyii* and *Proablepharus reginae* were captured where litter accumulated in depth adjacent to watercourses or under larger shrubs. The arboreal species *Lophognathus longirostris, Pogona minor, Gehyra variegata* and *Varanus tristis* were caught at sites where shrubs or short trees predominated.

Effects of Fire on Lizards

Fire initiated by lightning strikes burnt three of the major sampling sites during January 1990. This occurred two years after the survey commenced and the effects of the fire were followed through for nine months over three sampling periods afterwards (Table 4).

The capture of lizard species and individuals from the three major sites that were burnt (WS2, WS3, WS4) and three relatively similar [*c.* 50% similar, Fig 2] sites that

Table 4

Number of pit-trap days at sampling sites burnt in January 1990 (WS 2, 3, 4) and those that remained unburnt throughout the study (WS 5, 6, 10). Species and individuals caught during the two years sampling pre-burn [1988, 1989] and year post-burn [1990] are presented.

	Burnt sites			Unburnt sites		
SPECIES Pitdays	88B 372	89B 222	90B 360	88U 312	89U 216	90U 396
Diplodactylus conspicillatus	2	3	8	2	3	6
Diplodactylus stenodactylus	3	2	5	2	3	0
Gehyra variegata	0	4	0	0	0	0
Heteronotia binoei	2	1	0	0	0	1
Nephrurus levis	3	3	0	2	2	3
Rhynchoedura ornata	2	0	1	1	0	0
Strophurus elderi	0	1	1	1	0	1
Delma pax	0	0	0	0	0	1
Lialis burtonis	0	4	0	0	0	0
Ctenophorus caudicinctus	0	1	0	0	0	0
Ctenophorus nuchalis	0	1	11	2	1	0
Ctenophorus isolepis	3	1	0	5	8	5
Pogona minor	0	3	0	1	1	0
Ctenotus duricola	2	4	0	6	5	10
Ctenotus grandis	10	8	0	3	2	4
Ctenotus helenae	0	3	0	4	0	4
Ctenotus pantherinus	5	7	0	11	6	12
Ctenotus serventyi	1	1	1	0	2	0
Egernia striata	4	0	5	3	5	8
Lerista bipes	6	2	2	11	4	1
Menetia greyii	0	0	0	1	0	3
Morethia ruficauda	2	0	0	0	0	0
Notoscincus ornatus	0	0	0	0	0	1
Proablepharus reginae	0	0	0	0	0	2
Tiliqua multifasciata	2	0	2	0	0	0
Varanus acanthurus	0	1	0	0	0	0
Varanus brevicauda	2	0	0	4	3	6
Varanus eremius	2	0	0	0	0	1
Varanus gouldii	0	1	1	0	0	0
No. species	16	19	10	16	13	17
No. individuals	51	51	37	59	45	69
Indiv/10 pitdays	1.37	2.29	1.03	1.89	2.08	3.64
Shannon Diversity [H]	3.74	3.90	2.80	3.57	3.47	3.64
Log series diversity [α]	8.00	10.98	4.50	7.22	6.12	7.20
Simpson Evenness [E]	0.69	0.64	0.55	0.58	0.75	0.60

remained unburnt (WS5, WS6, WS10) throughout are presented for each year of sampling in Table 4.

On the burnt sites both the number of species and individuals declined in the nine months post fire and these areas had both a lowered species diversity and evenness (Table 4). In the sites that remained unburnt, species number fluctuated less and both species diversity and evenness showed smaller changes. The similarity of lizard assemblages on the area burnt (B) in the third year and assemblages on the unburnt (U) area over each of the three years is presented in Figure 3. The least similar assemblage was recorded in the area burnt by the fire of January 1990.

The species least affected by fire, at least in the short term, were those that live in burrows or are primarily fossorial. In the burnt sample sites, 32 of the 37 individuals trapped after the fire belonged to the species *Ctenophorus nuchalis*, *Diplodactylus conspicillatus*, *D. stenodactylus*, *Rhynchoedura ornata*, *Egernia striata* (four of these are nocturnal and all live in burrows) or *Lerista bipes* (which is fossorial).

Discussion

The opportunistic collections of the fauna made over the past 50 years from the 1,500 km² Abydos/Woodstock area has resulted in a substantial body of knowledge on mammals (How & Cooper 2002) and birds (Storr 1984; How *et al.* 1991) but the herpetofauna remains the least known group of vertebrates. The 24 species of reptile and one frog that were recorded on the study area for the first time during this survey included the endemic skink, *Ctenotus nigrilineatus*, which was subsequently described from two specimens collected from one localised rockpile in the study area (Storr 1990).

The herpetofaunal assemblage of the Abydos/Woodstock area, comprising 5 amphibians and 67 reptiles, is one of the richest recorded in Australia. In a recent review of studies defining the diversity of reptiles in arid and mesic habitats of Australia, Thompson *et al.* (2003a) compared the findings of 14 areas that sampled reptiles at three broad geographic scales, *viz.* bioregional, landscape and biotope. The number of reptile species recorded in the 12 landscape level surveys reported in

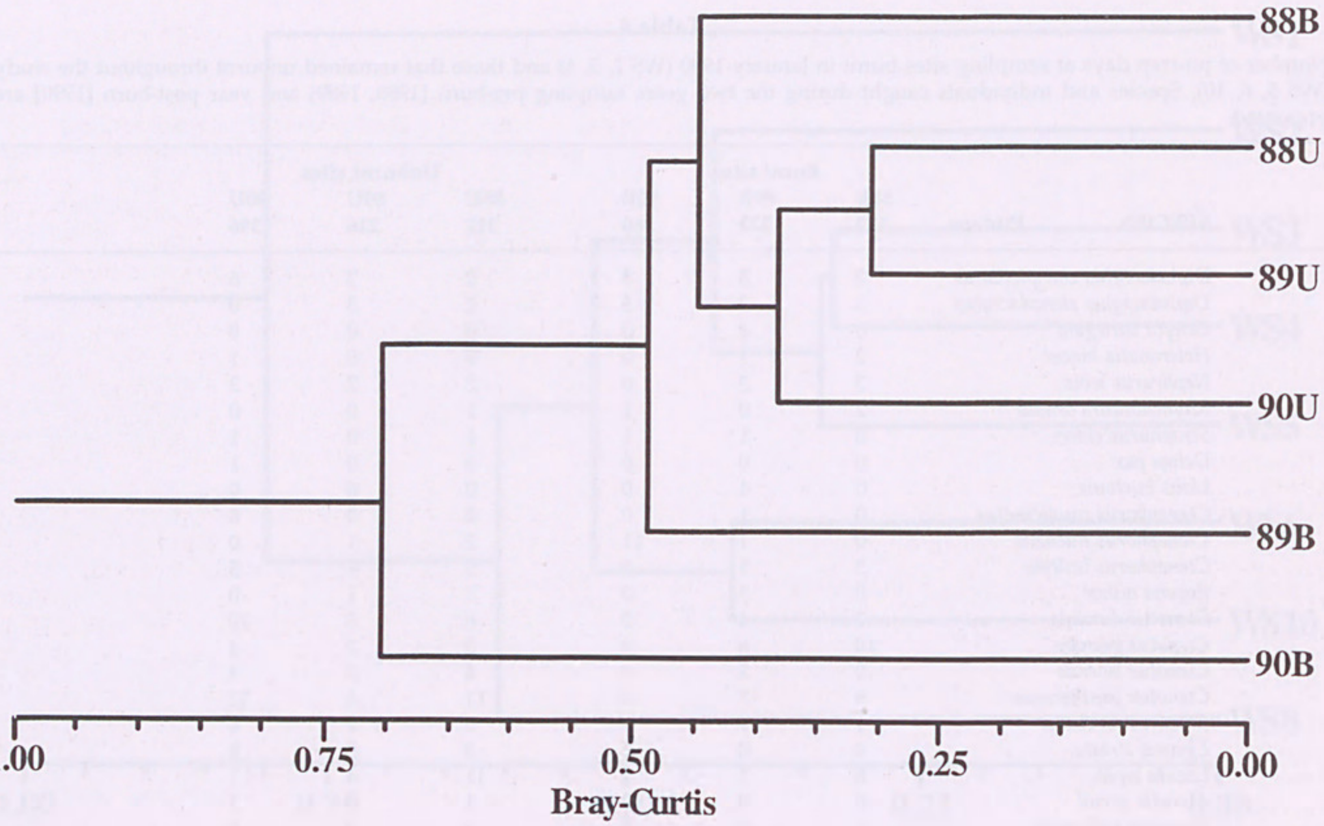

Figure 3. Similarity of lizard assemblages for the three years of study on an area that was burnt (B) by the fires of January 1990 and a similar adjacent area that remained unburnt (U).

the literature, identified between 26 and 68 species, while the two bioregional surveys had 57 and 76 species. The 67 reptiles species recorded at Abydos/Woodstock is, therefore, surpassed only in number by one bioregional survey, the Carnarvon Basin survey by Rolfe and McKenzie (2000) and the Red Sands survey in the Great Victoria Desert of Pianka (1996). The Carnarvon Basin bioregional survey encompassed an area of nearly 92,000 km^2, over 60 times greater than that of the present survey area. However, in contradistinction, the Red Sands survey in the Great Victoria Desert of Pianka (1996) covered around 1 km^2 of *Triodia* dominated red dune landform, indicating that diversity at a small landscape level may also be exceedingly rich in arid desert environments. Thompson *et al.* (2003a) also calculated the Shannon diversity index of their fourteen sites as ranging from 2.00 [Tanami Desert B] to 3.60 [Carnarvon Basin] and the α log series diversity as ranging from 4.05 [Bold Park] to 17.29 [Carnarvon Basin]. The same diversity measures applied to the reptile survey for Abydos/Woodstock area are 4.64 and 14.94, respectively, indicating the exceptionally high diversity of the study area. The total herpetofauna of Abydos/Woodstock is comparable in number (72) to the four times larger Hamersley Range [Karajini] National Park (Johnstone 1983) that lies 200 km to the south.

The Chichester subregion of the Pilbara bioregion contains 105 reptile and 10 frog species in an area that encompasses over 90, 000 km^2 (How & Cowan unpubl.). The Abydos/Woodstock area lies within the Chichester subregion and the 67 species recorded represents 64% of the total known subregional reptile fauna. The five amphibian species recorded in this survey represent only 50% of the total amphibian fauna documented for the subregion.

Snakes generally are infrequently captured or observed during herpetofaunal surveys (How 1998; M. Cowan, CALM Kalgoorlie pers. comm.) such that their true representation in reptile assemblages is often underestimated by short-term sampling surveys. This is clearly demonstrated in the data compiled in Thompson *et al.* (2003a), where snakes reach their highest proportion in assemblages in studies that have the longest temporal span, *e.g.* Bold Park (How 1998), Red Sands (Pianka 1996) and Bungalbin (Withers unpublished). During the present study each of the 15 species of snakes contributed less than 0.5% of individual records, a percentage regarded as representing 'rare' species by Thompson *et al.* (2003a). A more realistic comparison of diversity and assemblage similarity is therefore best confined to the more easily recorded lizard species.

The richness of lizards (51 species) from the Abydos/Woodstock area is exceptional and represents the third most speciose lizard assemblage yet reported in Australia. Pianka (1996) recorded 53 species on the Red Sands site in the Great Victoria Desert and Rolfe and McKenzie (2000) recorded 71 species for the Carnarvon Basin survey. James (1994) recorded 40 lizard species on the central Australian study site, which was dominated by *Triodia*. In contrast to the central Australian study and the present one in the Pilbara, Pianka sampled for nearly four years of field time over a 28 year period compared to the 74 days of sampling during the present survey and the 180 sampling days of James (1994). An exceptionally high lizard richness of 57 species has also been documented on Lorna Glen Station in the eastern Gascoyne bioregion (Cowan pers. comm.). The duration of sampling thus plays a very significant role in defining species richness and the use of species accumulation curves has been proposed to define the probable richness of sites sampled over a limited temporal span (Thompson & Withers 2003; Thompson *et al.* 2003b).

The diversity of the herpetofauna in the study area probably reflects the juxtaposition of diverse habitats, such as the extensive areas of *Triodia* spp. grasslands on sandy soils, with isolated rockpiles and breakaways, and also the loamy soils and fringing woodlands of creeks and drainage lines. Forty-one lizard species were recorded from the eight main sampling sites and an examination of relationships between lizard assemblages on sites (Fig 2) provides some support for this proposition. The assemblage on the loams associated with riparian vegetation at WS1 is quite dissimilar to the remaining sites that are located on sands dominated by *Triodia*. Additionally, the site close to a rocky breakaway, WS8, also has a distinct assemblage from those on the surrounding sandy plain. James (1994) recorded between 23 and 32 lizard species at the subsites in central Australia, considerably more than the 17–25 recorded in this study. However, similarity between subsites was high at around 58% (James 1994), such that only 40 species were recorded in total compared to the 41 in this study. Further differences in the two studies occurred in the period of peak activity of reptiles. In central Australia, activity was greater in spring than autumn (James 1994), while on the Abydos Plain activity was greater in late summer than in spring (Table 3). Thompson *et al.* (2003a) contrast species diversity and evenness across 12 subsites (biotopes) at Bungalbin and 10 at Ora Banda, both in the Eastern Goldfields of Western Australia, and indicate that species richness varies from 17 to 26 in the former and 14–28 in the latter. They concluded that "These data indicate considerable variation in reptile assemblages for closely related sites both with and without similar soils and vegetation".

Pianka (1986) suggested that the richness of Australia's arid herpetofauna resulted from the influence of several environmental factors, such as the interdigitating of several habitats, presence of the ubiquitous and unique *Triodia* spp. grasses, a variable and unpredictable rainfall and the replacement of the role of mammalian predators by reptilian taxa. Morton and James (1988) proposed a multi-causal scheme to explain the diversity and abundance of Australian desert lizards that invoked an interaction between climatic, edaphic and (a complex of) biotic factors. Their synthesis was re-examined by Pianka (1989) who evaluated eleven causal factors that made a contribution to the richness of desert lizards, including the role of fire and the biogeographic history of regions. Pianka concluded that many links in Morton and James' causal network were well established, but for others the evidence was weak. Certainly, the role of fire in creating a complex of seral community stages is significant in enhancing lizard diversity (see below).

The reproductive activity of reptiles from the Woodstock/Abydos study area indicated that most species were reproductively active during the spring and summer (How *et al.* 1991) and that reproductive activity may be curtailed when environmental conditions had been unfavourable for many months. How *et al.* (1991) also concluded that the lower incidence of reproductive activity seen in March 1988, compared with subsequent February–March samplings, was the result of a long drought that preceded that sampling. James (1991b) stated that most species of lizard in the central Australian study site reproduced only once during the three year study with most species failing to reproduce in a 'dry' year. It is highly likely that many reptile species in the Pilbara reproduce opportunistically following improved environmental conditions after episodic rainfall events and thus show similar stochastic population responses following rain to those reported by James (1994) in central Australia.

The above average rainfall during the first two summers of this study promoted rapid growth and seeding in *Triodia* spp. and other grasses, while numerous shrubs and trees produced vegetative growth and flowers. The impact of this was to provide visibly improved trophic resources for vertebrates in the form of new plant growth, grass seeds and insect prey, and contrasted with conditions observed at the very beginning and the end of our study period. Amphibians responded almost immediately to the March 1988 deluge and the breeding chorus was extensive over the study area.

The diets of three sympatric *Ctenotus* skinks at Woodstock were examined (Twigg *et al.* 1996) and indicated that, despite a large dietary overlap, two of the species showed dietary separation on a seasonal basis. James (1991a) also showed a seasonal change in diet within species of *Ctenotus* in central Australia that responded to changes in abundance of their main dietary prey. These seasonal shifts in dietary pattern in selected abundant species of lizard could conceivably be extrapolated to less abundant taxa and, when coupled with improved conditions for reproduction, could account for many of the long-term changes in abundance of species in arid study sites. The long-term appraisal of the lizard assemblages in the Great Victoria Desert showed only minor changes in use of resource states by lizards when examined nearly 12 years apart, and although some taxa increased in number between these periods, others declined but the general use of space, diet and time remained similar (Pianka 1986).

Fire has played an important part in structuring arid zone assemblages (Pianka 1989), and at Abydos/Woodstock fire has previously been the focus of considerable research (Suijendorp 1967). However, with knowledge of the regeneration rate in areas burnt in January 1989 and January 1990, it was apparent that at least ten years had elapsed since the major sampling sites were previously burnt. Other studies of the impact of fire on arid zone reptiles (Caughley 1985; Fyfe 1980; Masters 1996) have relied on examining the assemblages in areas burnt at various times prior to the study. In our study the same major sampling sites were monitored for two years before and one year after burning (Table 4).

Pianka (1989) has reviewed the available data on the impact of fire on desert reptile assemblages and concluded that it played a key role in contributing to the richness of lizards. The impact of fire on the lizard fauna of areas subject to intensive sampling on the study area showed a reduction in both the number of species and individuals in burnt areas. Those species best able to survive the short term effects of fire were burrowing or fossorial species. It is not known what the longer term response to fire might be as the study was concluded 10 months after the fire and during one of the driest periods for 20 years when post fire regeneration of vegetation was minimal. Teale (personal observation) has recorded similar initial responses to fire in the Pilbara with burrowing species showing a marked increase in numbers trapped immediately post-fire. These data are in close agreement with the findings of Caughley (1985) who recorded four burrowing species that forage over open ground as the most abundant species in most recently burnt areas of mallee in western New South Wales. The data of Caughley (1985) also indicate that there is a continuous replacement of species as the vegetation passes through successional stages after fire, such that the number of species remains relatively constant.

This study has indicated that there is significant spatial and temporal variation in the lizard community of the Abydos Plain that responds to periodic fluctuations in environmental parameters, habitat differences and fire history. This variation can account for the high diversity of lizards, and by analogy all reptiles, documented for this dominant landscape in the Chichester subregion of the Pilbara bioregion.

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