THE WESTERN AUSTRALIAN NATURALIST

Vol. 20 No. 4
December 29 1995

Print Post Approved
PP 635823/00015
ISSN 0726 9609

Western Australian Naturalists' Club

Naturalists' Hall, 63-65 Meriwa Street Nedlands
Postal Address: P.O. Box 156 Nedlands, W.A. 6009

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THE WESTERN AUSTRALIAN NATURALIST

CONTENTS OF VOLUME 20
1995

PERTH
Published by the
WESTERN AUSTRALIAN NATURALISTS' CLUB

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NATURALIST

Vol. 20 29th December, 1995 No. 4

A BIOLOGICAL SURVEY OF GARDEN ISLAND, WESTERN AUSTRALIA: 1. BIRDS AND REPTILES.

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ABSTRACT

Sixty-four species of birds were seen during a biological survey of Garden Island in 1991. Of these, 15 had not been recorded previously, bringing to 94 the total number of bird species now listed for the island. Thirteen species of terrestrial reptiles were found, while, one previously-recorded species, *Morethia lineoocellata*, was not observed.

The Brush Bronzewing, the Lined Skink and the Carpet Python all are either extinct, endangered or have very small distributions on the adjacent mainland. The ecological requirements of these three species therefore deserve special consideration in future plans of management of Garden Island.

INTRODUCTION

This paper summarises the results of a biological survey of the birds and terrestrial reptiles of Garden Island between March 1991 and April 1992. Also included are some previous faunal observations dating back to the 1920s.

There is no evidence of recent Aboriginal occupation of Garden Island, as the few artefacts found (Dortch 1991) appear to pre-date the island's formation (7000 BP). From 1829 to 1970, Garden Island was occupied intermittantly by Europeans (Anon 1979, McArthur and Bartle 1981). Since 1915, it has been under the control of the Commonwealth of Australia. Development of the island as a naval base commenced in 1972 and a causeway connecting the island to the mainland was completed in 1973. H.M.A.S. Stirling (the naval base) was commissioned in 1978 and naval facilities occupy about one third of the island. The Department of

Defence is responsible for environmental management and the public have restricted access to areas outside naval facilities.

Geologically, Garden Island is a ridge of Pleistocene aeolianite (Tamala Limestone) covered by Holocene calcareous sand dunes. It has been separated from the mainland for approximately 7000 years (Main 1961). The landforms and soils have been mapped by McArthur and Bartle (1981) and McArthur (unpublished) has mapped the vegetation, recognizing as major vegetation communities *Acacia rostellifera* Scrub, *Melaleuca huegelii* Scrub, *M. lanceolata* Low Forest, *Callitris preissii* – *M. lanceolata* Low Forest, *C. preissii* – *M. lanceolata* – *M. huegelii* Low Forest, *A. rostellifera* – *M. lanceolata* communities, *A. rostellifera* – *Lepidospermum gladiatum* Scrub, *A. rostellifera* – *A. cochlearis* Scrub and Clifftop vegetation.

METHODS

We censused birds and reptiles in each of the major vegetation communities described by McArthur. For each community, two 100m² quadrats were estab-lished, one on the northern half of the island and one in the south. In the low forest communities, quadrats were located in areas burnt by a wildfire in 1956, as well as in areas that probably have not been burnt since the 1930s. The locations of the 20 sampling quadrats are shown in Figure 1 and detailed descriptions of vegetation, soil and microhabitat within each sampling site are given in Brooker (1992). Ten pitfall traps (on a 5 x 2 grid with 15m interval) and 10 Elliott traps (within 2–3 m of each pitfall) were installed on each quadrat. Each pitfall consisted of a 20 l plastic bucket with 7 m drift fence.

Two five-day censuses were made, one in April and one in November 1991. During each census diurnal land birds were counted on each quadrat four times (early am, late am, early pm, late pm) using a 15 minutes random search method. Pitfall and Elliott traps were opened for four nights.

On two occasions (1 July and 2 December 1991) shore birds were counted by observers who walked the entire coastline (27.6 km).

Available published and unpublished observations were reviewed and a search for relevant information was made from museum and other archival sources.

RESULTS

(a) Birds

The survey added 15 new species to the 79 species previously recorded for Garden Island (Table 1); *viz* Southern Giant Petrel, Rufous Night Heron, Pacific Black Duck, Square-tailed Kite, Collared Sparrowhawk, Little Eagle, Stubble Quail, Painted Button-quail, Red Knot, Greenshank, Whiskered Tern, Southern Boobook, Ground Cuckoo-shrike, Little Wattlebird and Striated Pardalote.

Details of the quadrat counts are given in Brooker (1992). Of the 94 species now recorded, at least half are land birds, of which only 13 can be considered resident. Of these, the Grey Butcher-bird, Grey Fantail, Golden Whistler, Western Gerygone and Silvereye were confined

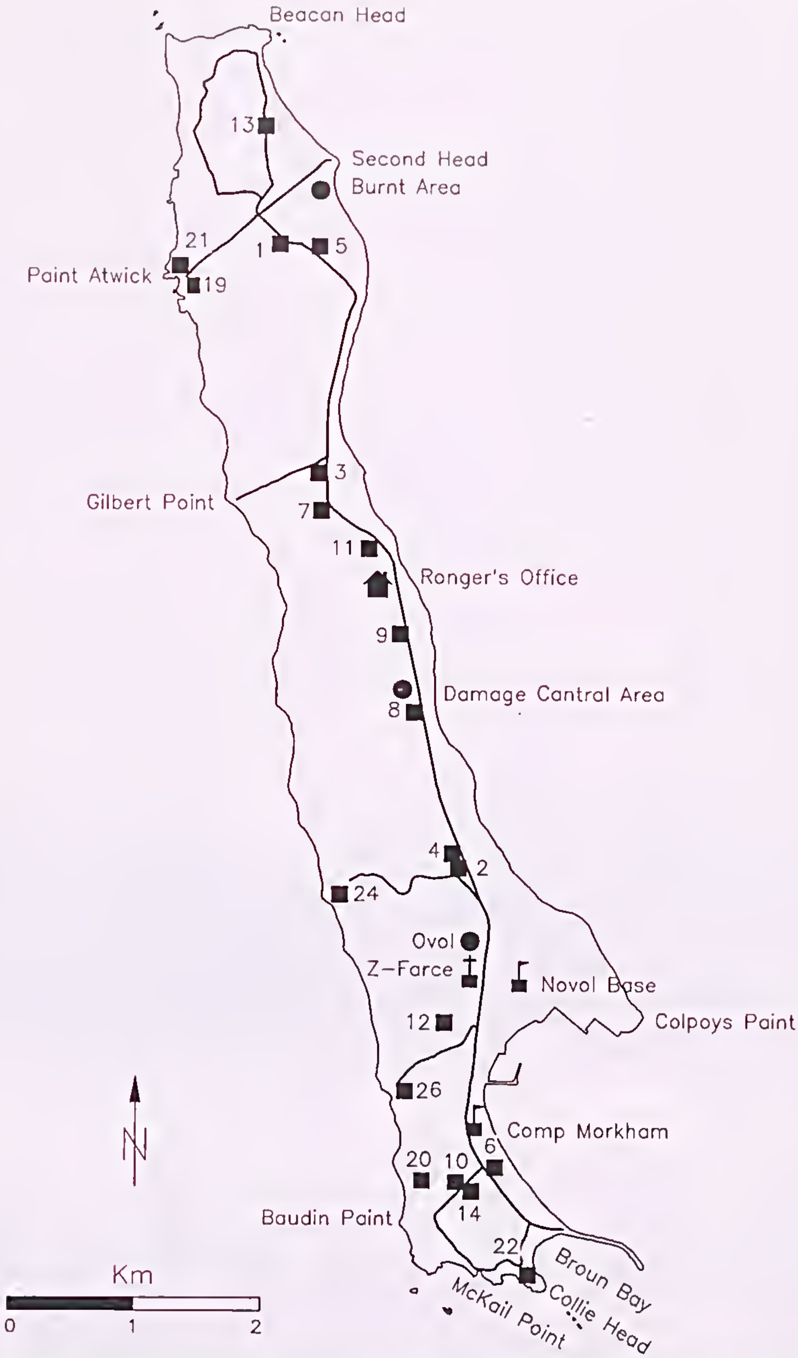

Figure 1. Map of Garden Island showing approximate locations of 20 study sites for the census of landbirds, reptiles and small mammals.

Table 1. Species of birds recorded on Garden Island. Those recorded during the present survey are shown in bold type. (A = Alexander 1921b; B = Serventy 1938; C = Sedgwick (1940); D = Buller 1949; E = Calderwood 1953; F = Anon 1979; G = Davies 1980; H = Abbott 1980; I = L. Schmidt, pers. comm.; J = Present study 1991; * cited by Storr and Johnstone 1988, but on no other list; ** S. Bowler, unpub.; *** P/O Wright, pers. comm.).

Common Name	Scientific Name	Source A	B	C	D	E	F	G	H	I	J
Southern Giant Petrel	***Macronectes giganteus***										+
Australian Pelican	***Pelecanus conspicillatus***									+	+
Australasian Gannet	*Morus serrator*						+				
Darter	***Anhinga melanogaster***									+	+
Black Cormorant	*Phalacrocorax carbo*						+	+		+	
Little Pied Cormorant	***Phalacrocorax melanoleucos***			+			+	+		+	+
Little Black Cormorant	*Phalacrocorax sulcirostris*						+	+			
Pied Cormorant	***Phalacrocorax varius***	+		+			+	+		+	+
White-faced Heron	***Ardea novaehollandiae***						+	+			+
Eastern Reef Egret	***Egretta sacra***			+			+	+		+	+
Rufous Night Heron	***Nycticorax caledonicus***										+
Australian Shelduck	***Tadorna tadornoides***	+							+	+	+
Pacific Black Duck	*Anas superciliosa*										+
Osprey	***Pandion haliaetus***						+	+	+	+	+
Black-shouldered Kite	***Elanus notatus***									+	+
Brown Goshawk*	*Accipiter fasciatus*										
Square-tailed Kite	***Lophoictinia isura***										+
Collared Sparrowhawk	***Accipiter cirrhocephalus***										+
White-bellied Sea-Eagle	***Haliaeetus leucogaster***									+	+
Little Eagle	***Hieraaetus morphnoides***										+
Marsh Harrier*	*Circus aeruginosus*										
Australian Kestrel	***Falco cenchroides***	+	+	+	+	+	+	+	+	+	+
Stubble Quail	***Coturnix novaezelandiae***										+
Painted Button-quail	***Turnix varia***										+
Sooty Oystercatcher	*Haematopus fuliginosus*						+	+		+	
Pied Oystercatcher	***Haematopus longirostris***			+			+	+	+	+	+
Red-capped Plover	***Charadrius ruficapillus***			+			+	+		+	+
Banded Lapwing	***Vanellus tricolor***				+		+	+		+	+

Grey Plover	***Pluvialis squatarola***			+			+	+		+	+
Large Sand Plover	*Charadrius leschenaultii*						+			+	
Ruddy Turnstone	***Arenaria interpres***	+					+	+			+
Sharp-tailed Sandpiper	***Calidris acuminata***			+							+
Sanderling	***Calidris alba***						+	+		+	+
Red-necked Stint	***Calidris ruficollis***			+			+	+		+	+
Red Knot	*Calidris canutus*										+
Great Knot	*Calidris tenuirostris*						+	+			
Broad-billed Sandpiper	*Limicola falcinellus*						+	+			
Bar-tailed Godwit	***Limosa lapponica***						+	+			+
Whimbrel	***Numenius phaeopus***						+	+		+	+
Grey-tailed Tattler	***Tringa brevipes***						+	+			+
Common Sandpiper	***Tringa hypoleucos***						+	+			+
Greenshank	*Tringa nebularia*									+	
Bush Stone Curlew	*Burhinus magnirostris*								+		
Great Skua	*Stercorarius skua*					+					
Silver Gull	***Larus novaehollandiae***	+		+			+	+	+	+	+
Pacific Gull	*Larus pacificus*			+							
White-winged Tern	*Chlidonias leucoptera*	+									
Whiskered Tern	*Chlidonias hybrida*										+
Caspian Tern	***Hydroprogne caspia***						+	+	+	+	+
Bridled Tern	***Sterna anaethetus***	+									+
Fairy Tern	***Sterna nereis***			+			+	+	+	+	+
Crested Tern	***Sterna bergii***			+			+	+	+	+	+
Feral Pigeon	***Columba livia***					+	+	+			+
Common Bronzewing	*Phaps chalcoptera*						+	+			
Brush Bronzewing	***Phaps elegans***	+					+	+	+	+	+
Spotted Turtledove	*Streptopelia chinensis*		+	+	+	+			+		
Laughing Turtledove	***Streptopelia senegalensis***	+	+	+	+	+	+	+	+	+	+
Galah**	*Cacatua roseicapilla*										
Red-capped Parrot	***Purpureicephalus spurius***						+	+			+
Port Lincoln Ringneck	*Barnardius zonarius*						+	+			
Rock Parrot	*Neophema petrophila*								+		
Pallid Cuckoo	*Cuculus pallidus*								+		
Fan-tailed Cuckoo	***Cuculus pyrrhophanus***						+	+		+	+

Table 1 (cont.)

Common Name	Scientific Name	Source A	B	C	D	E	F	G	H	I	J
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*				+						
Southern Boobook	*Ninox novaeseelandiae*										+
Spotted Nightjar*	*Caprimulgus guttatus*										
Fork-tailed Swift	*Apus pacificus*									+	
Laughing Kookaburra	*Dacelo gigas*		+								
Sacred Kingfisher	*Halcyon sancta*			+		+	+	+	+	+	+
Rainbow Bee-eater	*Merops ornatus*						+	+		+	+
Tree Martin	*Cecropis nigricans*		+			+	+	+		+	+
Fairy Martin	*Cecropis ariel*						+				
Welcome Swallow	*Hirundo neoxena*		+	+	+	+	+	+	+	+	+
Richard's Pipit	*Anthus novaeseelandiae*			+	+	+	+	+	+	+	+
Ground Cuckoo-shrike	*Coracina maxima*										+
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*									+	+
Golden Whistler	*Pachycephala pectoralis*			+	+	+	+	+	+	+	+
Rufous Whistler	*Pachycephala rufiventris*						+	+			
Grey Shrike-thrush	*Colluricincla harmonica*									+	
Grey Fantail	*Rhipidura fuliginosa*			+	+	+	+	+	+	+	+
Willie Wagtail	*Rhipidura leucophrys*	+		+	+	+	+	+	+	+	+
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*						+	+			
Western Gerygone	*Gerygone fusca*		+	+	+	+	+	+	+	+	+
Little Wattlebird	*Anthochaera chrysoptera*										+
Yellow-throated Miner**	*Manorina flavigula*										
Singing Honeyeater	*Lichenostomus virescens*	+	+	+	+	+	+	+	+	+	+
Brown Honeyeater*	*Lichmera indistincta*										
White-fronted Chat	*Ephthianura albifrons*	+					+	+			
Striated Pardalote	*Pardalotus striatus*										+
Silvereye	*Zosterops lateralis*	+	+		+	+	+	+	+	+	+
Australian Magpie-lark	*Grallina cyanoleuca*						+	+			+
Grey Butcherbird	*Cracticus torquatus*		+	+	+	+	+	+	+	+	+
Australian Magpie	*Gymnorhina tibicen*		+	+	+	+			+		+
Australian Raven	*Corvus coronoides*	+	+	+	+		+	+	+	+	+

largely to habitats with tall tree canopy, while the Welcome Swallow, Singing Honeyeater, Willie Wagtail and Australian Raven were found in more open heath vegetation. Richard's Pipits and Australian Kestrels were found in sparsely vegetated areas and Brush Bronzewings and Painted Button-quails appeared to be ubiquitous.

The shore bird counts obtained for Garden Island (Table 2) were comparable to those obtained from a similar survey of Rottnest Island in June and December 1983 (Saunders and de Rebeira, 1986).

Annotated List of Selected Species

Little Pied Cormorant is more common on Garden Island than on Rottnest Island, which may reflect the fact that Garden Island is much closer to the mainland, where the species is relatively common.

Rufous Night Herons were found roosting on the eastern side of the island in February (2 adults) and July 1991 (1). This is unusual in a species that prefers fresh wetland habitats. They are common in wooded freshwater wetlands on the mainland.

Australian Shelduck with five small ducklings were seen near the sewerage farm on 10 September 1991 and other pairs were observed around the coast. On Rottnest Island the species nests in the limestone caves or in crevices on cliffs. As the species requires freshwater to breed successfully, the lack of suitable habitat for establishing brood territories will restrict the population on Garden Island.

Ospreys had one active nest at Collie Head in 1991 and two nestlings were banded. Several other nest sites were found at Baudin Point, Point Atwick and Second Head, but no more than two have been occupied in any one season.

Black-shouldered Kite visit the island occasionally. We recorded one on 10 September 1991. The species is probably an autumn-winter visitor to the coastal plain.

Square-tailed Kite was recorded once on the southern end of the island on 25 February 1991.

Collared Sparrowhawk was recorded flying over Site 14 on 11 April 1991. This is a scarce and easily overlooked species which is probably resident on the adjacent coastal plain.

Little Eagle were recorded on 8 May 1990 and 11 April 1991.

Australian Kestrel were seen in small numbers throughout the year, which suggests that they are breeding residents on the island.

Stubble Quail were positively identified during spotlighting on 10 April 1991 and unidentified quail were seen on several occasions.

Painted Button-Quail is possibly a breeding resident. One was seen during the spotlight count on 28 November 1991 and an abandoned nest with 3 eggs was found under *Acanthocarpus preissii* on Site 8 in April 1991. The eggs were identified by N. Kolichis (pers. comm.). The numbers of Painted Button-quail have recently declined on the Swan Coastal Plain according to Storr and Johnstone (1988).

Pied Oystercatchers with two juveniles were seen on Site 22 on 25 November.

Table 2. Shore, marine and waterbirds seen on two "entire perimeter" Beach Counts of Garden Island (28 km) and results of similar counts on Rottnest Island (RI) (37 km).

Species	WINTER 1/7/91 W Coast	E Coast	Total	14–15/6/83 RI+	SUMMER 2/12/91 W Coast	E Coast	Total	12–13/12/83 RI+
Southern Giant Petrel	2*							
Australian Pelican		1	1					
Darter		1	1					
Little Pied Cormorant	1	64	65	22	52	52	2	
Pied Cormorant	48	195	243	334	43	65	108	151
Eastern Reef Heron		1	1	1	1	1	1	
Rufous Night Heron		1	1					
Australian Shelduck	5	5	15	2	2			
Pacific Black Duck	8	8						
Osprey	3	3	12	7**	2	9	7	
White-bellied Sea-Eagle	1	1						
Pied Oystercatcher	5	5	9	14	10	24	18	
Red-capped Plover	19	16	35	43	9	52		
Grey Plover	5	1	6	1	19	4	23	10
Ruddy Turnstone	3	3	21	18	19	37	71	
Sanderling	4	4	10	105	17	122	32	
Red-necked Stint			3	4	7			
Red Knot			3	3				
Bar-tailed Godwit			1	8	2	10	7	
Whimbrel			1	1	2			
Grey-tailed Tattler			2	2	2			
Common Sandpiper			1	1	2	2		
Greenshank				1	1			
Silver Gull	92	251	343	Rec	268	147	415	Rec
Whiskered Tern	11	11						
Caspian Tern	4	1	5	11	2	2		
Bridled Tern			3	3	6	24		
Fairy Tern			1	30	3	33	262	
Crested Tern	190	116	306	880	14	19	33	90

* Seen at mainland end of Causeway ** Plus 2 nestlings + Saunders and de Rebeira (1986 & unpub.)
Rec Recorded, not counted

Banded Lapwings were first recorded in 1948 by Buller (1949), who saw "about eight on the beach near the homestead". During 1991, it was recorded on the grassed areas, those near the Oval in particular. Up to 30 were counted there (22 March) and breeding was recorded in July (nest with 4 eggs), September (2 runners) and November (4 runners).

Sanderling prefers sandy beaches and feeds along the shore at the edges of the waves, so Garden Island is an important wintering area for this species as the western coast provides ideal habitat.

Silver Gulls were the most abundant shore birds but did not approach the densities found on Rottnest Island (DAS per. obs.). They nested in rocks along the southern end of the Causeway and on Collie Head (20 pairs, September 1991).

Bridled Terns were recorded during the December census around Beacon Head. From the behaviour of one bird, it is likely they were nesting there. Alexander (1921a) reported nesting on an islet off the north-west shore in December 1919. They are probably breeding migrants on Garden Island, but only in small numbers.

Fairy Tern is also a breeding migrant occurring in smaller numbers than on Rottnest. The species nests on some of the beaches on Garden Island but does not necessarily use the same colony site every year.

Feral Pigeon were seen regularly on the Causeway, although only one was recorded on the island during the survey, when it was seen flying out of a cave near McKail Point.

Brush Bronzewing was observed on most survey days, although it was not recorded on many of the sites. It was formerly widespread in coastal and inland scrub but disappeared from Rottnest Island early this century. Storr and Johnstone (1988) give only four sightings for the Swan Coastal Plain and adjacent islands since 1958. Garden Island now appears to be the stronghold for the Brush Bronzewing in this region. Brush Bronzewings are secretive birds which often run rather than fly from an intruder. Their biology is poorly known. Data on their diet from elsewhere in Australia includes the seeds of herbs, grasses and shrubs, including *Acacia* and *Phyllanthus* species (Frith 1982). On North Island in the Abrolhos, Brush Bronzewings eat the seed of the littoral plant *Cakile maritima* (Storr *et al.* 1986a), which occurs also on Garden Island (McArthur and Bartle 1981). They breed from late July to February and their nests are often built close to the ground, making them vulnerable to introduced predators such as cats and rats.

Spotted Turtledove were not seen on the island in 1991. They were recorded by Abbott (1980) in the mid 1970s but not by L. Schmidt (pers. comm.) in the early 1980s.

Laughing Turtledove were seen in small numbers, mainly on the east coast near Camp Markham. They were reported on the island in all previous lists (Table 1) and are probably resident.

Galahs were seen in the Damage Control Area and at the Base in 1986 or 1987 (Petty Officer Wright, pers. comm.) and W. McArthur (pers.

comm.) saw three on the northern end of the island on 14 August 1994.

Red-capped Parrots were seen in the burnt area on 11 October 1991.

Fan-tailed Cuckoos were recorded, one near Site 9 on 25 February 1991 and another near Broun Bay on 1 July 1991. This parasitic species probably visits the island infrequently as none of its commonly used host species (Brooker and Brooker 1989) occur there.

Southern Boobook do not appear on the previous bird lists. All of our records were for January (one) and April 1991 (five) and W. McArthur (pers. comm.) saw a single bird on 11 April 1995, which gives support to Storr and Johnstone's (1988) status classification of the bird as a "passage migrant".

Fork-tailed Swifts were observed by L. Schmidt (pers. comm.) on 3 March 1984 and by W. McArthur (pers. comm.) (6 individuals) on 11 April 1995.

Sacred Kingfisher is a breeding migrant in the Perth area and a breeding resident on Rottnest Island (Saunders and de Rebeira 1985). However it is probably a non-breeding visitor to Garden Island, as none were seen during the November Census. Several records have been made during March and April which suggests that these were of birds moving north. Some may over-winter there [one adult was seen at Site 12 on 27 May 1992 and L. Schmidt (pers. comm.) made a July sighting].

Rainbow Bee-eaters were recorded once, during the November Census. These are regular spring-summer migrants to the Swan Coastal Plain.

Tree Martins were recorded only twice during the survey (February and November 1991). They are common on the mainland and Rottnest Island during the summer and early autumn (Saunders and de Rebeira 1985).

Welcome Swallows were common and widespread in all the more open habitats.

Richard's Pipit was seen only once (on the Oval, 22 March 1991). It is remarkable that the species was not more common, as it was included on all previous lists made since 1940 and is common and widespread on the mainland and on Rottnest Island.

Ground Cuckoo-shrike were seen by W.M. McArthur in the burnt area (see Figure 1) on 15 April 1991. The species is a rare visitor to the Perth region, although there were two other records from coastal areas of the mainland at around the same time.

Black-faced Cuckoo-shrikes were not recorded on the study sites but were seen elsewhere in March, April, May, August, October and November 1991. Their status here is unclear. They appear to be making greater use of Garden Island in the last decade as there are no published records prior to March 1983.

Willie Wagtails were common in the more open habitats and along roads. Along beaches, they feed among the waders and appeared to be more abundant there in July (at least 13 were recorded during the shore bird counts) than in December 1991 (three).

Little Wattlebird was found dead on the road near Site 2 on 25 February 1991.

Yellow-throated Miner, usually a sedentary species, was recorded as common by the then Senior Warden, S. Bowler in February, April and November 1961. As this was the only recorded sighting, it probably represents an unsuccessful colonisation attempt.

Singing Honeyeater is common on Garden Island and is the only resident honeyeater. It has a similar status on Rottnest Island. The birds on Garden Island are heavier than those on the mainland near Perth (26.8 ± 0.5g vrs. 25.8 ± 0.3g) according to Wooller *et al.* (1985).

Striated Pardalotes were heard near Camp Markham on 22 February 1991.

Australian Magpie-larks were seen at the Naval Base (8 April 1991 and 9 June 1992) and Camp Markham (26 March 1991). They are probably confined to the more disturbed parts of the island. None were recorded prior to 1979 (Table 1).

Grey Butcherbirds nested on Sites 1 and 5 in November 1991.

Australian Magpie were recorded twice: two individuals were seen near the Oval on 26 November 1991 and a pair at southern end of the main road on 9 June 1992. If resident, the species is probably confined to the disturbed eastern side of the island.

Australian Ravens were seen in small numbers throughout the island during the survey. One young fledgling was observed on 11 October 1992. The species may be a breeding resident here, although the overall numbers were much smaller than presently found on Rottnest Island (DAS pers. obs).

(b) Reptiles

The reptile fauna of Garden Island consists of two geckoes, one legless lizard, nine skinks, one python and one elapid snake. This includes one skink (*Morethia lineoocellata*) which was not recorded during this survey or by Robinson *et al.* (1987) but was collected previously from Garden Island by R. B. Humphries. Full details are given in Brooker (1992).

Analysis of the relationship between the distribution of the reptiles and the vegetation showed no pattern of association between any habitat variable and the reptile fauna (Brooker 1992). Most species range across the majority of vegetation types and there were no differences between reptile communities found in burnt and unburnt forest sites. *Egernia kingii* was present more often on sites at the northern and southern ends of the island which probably were not burnt in 1957 (9 of 13 sites), than on sites in the middle which were burnt (2 of 7).

The total of 14 terrestrial reptiles now recorded for Garden Island (13 in this study) compare with 16 for Rottnest Island (Humphries and Storr, 1985; Table 3). Five of the species recorded on Garden Island are not found on Rottnest Island, whereas seven species on Rottnest Island have not been recorded on Garden Island.

Annotated List of Species

Diplodactylus spinigerus (Spiny-tailed Gecko). Recorded on 10 of the sites during the census in all vegetation types except *Melaleuca lanceolata* Low Forest.

Phyllodactylus marmoratus

(Marbled Gecko) was not recorded on the sites during the census but was seen outside the census period at Camp Markham, near Site 19 and near the Ranger's Office. Robinson *et al.* (1987) found it to be uncommon in *Acacia rostellifera – Melaleuca lanceolata* scrub and under limestone slabs among clifftop vegetation. Although this species is generally arboreal in areas without rock outcrops, it is commonly caught in pitfall traps. The lack of captures in this study suggests that it is rare to uncommon over most of the island.

Lialis burtonis (Burton's Legless Lizard) was captured only in *Lepidospermum gladiatum* habitat on Sites 24 and 26. However, it was commonly seen during the summer spotlight surveys on roads in scrub habitats.

Cryptoblepharus plagiocephalus (Wall Skink) was recorded on only three sites during the census. However, despite being arboreal, it is commonly caught in pitfall traps. Its low trapping rate here suggests that the species is scarce on the island. Robinson *et al.* (1987) recorded it as very common.

Egernia kingii (King Skink) was recorded on 11 of the sites in all major vegetation associations, although it was most common in Clifftop Vegetation where limestone outcrops provide abundant shelter. This conspicuous species was not seen by W.M. McArthur and G.A. Bartle over several months in 1978–79, nor by W.M. McArthur in 1951 (pers. comm.) and may have increased in abundance.

Hemiergis quadrilineata was found on 10 of the sites during the census in all major vegetation types.

Bassiana trilineata was found on nine of the study sites in all major vegetation types. It appears to be common on Garden Island, although Robinson *et al.* (1987) classed it uncommon.

Lerista lineata (Lined Skink) is confined to the coastal plain from Perth to Mandurah and on Rottnest and Garden Islands. It was found on nine of the sites during the spring census. The species may be extinct on Rottnest Island as it has not been collected there since 1930. Ten of the 13 animals trapped in this survey were on sites with *Melaleuca lanceolata* Low Forest or *M. huegelii* Scrub and only one was found on a site without trees (Site 20). Therefore, the absence of the species on Rottnest Island could be due to the clearing of the forests there. It was not recorded in Clifftop Vegetation or in *Acacia rostellifera – Lepidosperma gladiatum* Scrub.

Lerista praepedita was recorded on only four of the sites (5, 10, 12, 21).

Morethia obscura was found in all vegetation associations (17 sites).

Morethia lineoocellata was not recorded in this study nor by Robinson *et al.* (1987). Three specimens (R28475–77) in the Western Australian Museum were collected on Garden Island by R.B. Humphries on 23 January 1967.

Tiliqua rugosa (Bobtail) is rare on Garden Island, with only three sightings during this survey.

Morelia spilota (Carpet Python) was fairly common on Garden Island with records on 4 of the sites during the censuses, near Site 13 on 25 November 1991 and on two of the

Table 3. A comparison of the herpetofauna of Garden Island and Rottnest Island with an estimate of status based on this survey and Robinson et al. (1987) for Garden Island and Humphries and Storr (1985) for Rottnest Island (C = common; UC = uncommon; R = rare; E = extinct)

Species	Garden Is.	Rottnest Is.
Leptodactylidae – Southern Frogs		
Heleioporus eyrei	C	
Ranidella insignifera	C	
Hylidae – Tree Frogs		
Litoria moorei	UC	
Gekkonidae – Geckoes		
Diplodactylus spinigerus	C	C
Phyllodactylus marmoratus	UC	C
Pygopodidae – Legless Lizards		
Aprasia repens	R	
Lialis burtonis	C	C
Scincidae – Skink Lizards		
Cryptoblepharus plagiocephalus	C	
Ctenotus fallens	C	
Egernia kingii	C	UC
Egernia napoleonis	R/E	
Hemiergis quadrilineata	C	C
Bassiana trilineata	UC	UC
Lerista elegans	UC	
Lerista lineata	UC	E ?
Lerista lineopunctulata	UC	
Lerista praepedita	C	
Morethia lineoocellata	R	C
Morethia obscura	C	
Tiliqua rugosa	UC / R	C
Typhlopidae – Blind Snakes		
Ramphotyphlops australis	R	
Elapidae – Front-fanged Snakes		
Notechis scutatus	C	
Pseudonaja affinis	C	
Boidae – Python Snakes		
Morelia spilota	C	

spotlight counts (10 April 1991 and 14 April 1992).

Notechis scutatus (Tiger Snake) was common in all vegetation associations on the island. The apparent abundance of this top predator is of interest as frogs, their major prey (Storr *et al.* 1986b), are absent.

DISCUSSION

When compared to the adjacent mainland, Garden Island is depauperate in land birds. Probably only 20 of the 52 species recorded, regularly occur there. Conspicuous by their absence are small, low nesting, insectivorous species such as fairy-wrens, scrubwrens, thornbills and chats.

The land birds occur in two recognizable communities. Small insectivorous passerines, such as Grey Fantails, Golden Whistlers and Western Gerygones, are found in the forest and scrub vegetation types containing tree cover. The more open heathlands support a community comprised of aerial foragers (Welcome Swallows), ecotone birds (Willie Wagtails) and omnivorous feeders (Singing Honeyeaters, Australian Raven).

From a conservation viewpoint, the presence of the Brush Bronzewing on Garden Island is of importance. Formerly widespread in coastal and inland scrubs, the species is now extinct on Rottnest Island and is becoming increasingly rare on the Swan Coastal Plain. In fact, Garden Island now appears to be the stronghold for this species in the region.

The avifauna of the coast (shore birds) is typical of that found in similar coastal areas along the Swan Coastal Plain and other offshore islands. However, the relatively undisturbed nature of the Garden Island coastline provides feeding areas for Sanderlings and nesting sites for Fairy Terns. Such secluded habitats close to Perth will become increasingly rare as urban development increases.

The absence of frogs on Garden Island, compared to three species found on Rottnest Island, reflects the lack of permanent or ephemeral water for breeding. Jones *et al.* (1966) present anecdotal evidence that there were once natural springs in the Colpoys Point area which ran streams into the sea. Their disappearance was attributed to the lowering of the water-table by bores sunk for Army purposes in the 1940s.

The reptile fauna of Garden Island is also depauperate compared to that on the adjacent mainland, possibly due to the lower habitat heterogeneity on Garden Island and the stochastic loss of species in the time since separation from the mainland (How and Dell 1994). It does, however, include the Lined Skink which has a very small geographic range and the Carpet Python which is a declining species on the adjacent mainland.

ACKNOWLEDGEMENTS

This project was undertaken under contract for the Department of Defence. The authors acknowledge the cooperation of the staff of HMAS Stirling, especially Captain Reg Cook, Captain Keith Eames and Claire Newman. Additional information was provided by Ted Brown (Archivist), Ron Johnstone (WA Museum), Denis King (APB), Nick Kolichis (Oologist), Bill McArthur (Botanist), Lud Schmidt (UWA), Wayne Taylor (CALM) and John Wombey (CSIRO). Dion Steven and Lyn Atkins helped to set up the sites and Lesley Brooker typed the manuscript. To all we are most grateful.

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PATTERNS OF GENETIC VARIATION AMONG ISLAND AND MAINLAND POPULATIONS OF NATIVE PELLITORY (*PARIETARIA DEBILIS*, URTICACEAE)

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ABSTRACT

Isozyme electrophoretic techniques were used to study patterns of genetic diversity within and between three island and two mainland populations of *Parietaria debilis*. With the exception of the Trigg population which was significantly different from all others the level of genetic divergence between populations was low and there was no obvious pattern in relation to genetic divergence between island and mainland populations. These data suggest that there are unlikely to be any detrimental effects resulting from gene exchange between original mainland populations and artificial mainland populations established from the more abundant island seed.

INTRODUCTION

Parietaria debilis has a cosmopolitan distribution and occurs in and adjacent to the Perth Metropolitan area in coastal sites, on islands and on granites of the Darling Scarp. Populations on Garden and Rottnest Islands have probably been isolated from the mainland for 6000 and 8000 thousand years respectively. Although there appears to be no morphological differences between mainland and island forms it is possible that prolonged isolation may have resulted in significant genetic divergence with the island populations now represented by distinct and possibly unique gene pools.

This may have important implications if new mainland populations are established with non local seed material from the larger and more accessible island populations (see Hopper and Coates, 1990; Ledig, 1986). There is increasing interest in growing this plant in cultivation, since it is the native food plant in south-western Australia of the Australian admiral butterfly (*Vanessa itea*) (Powell, 1993).

Population genetic studies using molecular markers such as isozymes have the potential to accurately determine the level of genetic divergence between populations or groups of populations within species. The technique of isozyme electrophoresis has proven to be a particularly cost effective means of producing reliable genetic markers that can be used to analyse patterns of genetic variation within and between plant populations (see

Soltis and Soltis 1989). The aim of this study was to investigate the levels of genetic differentiation between island and mainland populations of *P.debilis* by using isozyme electrophoretic techniques.

MATERIALS AND METHODS

Up to 50 seeds per population were germinated and seedling material prepared for isozyme analysis as described by Coates (1988). Isozyme methods were based on the Helena Laboratory cellulose acetate plate electrophoresis system (see Hebert and Beaton, 1989)

Fifteen enzyme systems were initially assayed: aspartate aminotransferase (AAT, E.C. 2.6.1.1), acid phosphatase (ACP, E.C. 3.1.3.2), alcohol dehydrogenase (ADH, E.C.,1.1.1.1), esterase (EST, E.C. 3.1.1.-), glucose 6 phosphate dehydrogenase (G6PDH) glutamate dehydrogenase (GDH, E.C. 1.4.1.2), isocitrate dehydrogenase (IDH, 1.1.1.42), lactate dehydrogenase (LDH, 1.1.1.27). leucine aminopeptidase (LAP, 3.4.17.1), malate dehydrogenase (MDH, 1.1.1.37), mannose-phosphate isomerase (MPI, E. C. 5.3.1.8), menadione reductase (MDR, E.C. 1.6.99.22)), 6 phosphogluconate dehydrogenase (6PGD, E.C. 1.1.1.44) phosphoglucose isomerase (PGI, E.C. E.C. 5.3.1.9), phosphoglucomutase (PGM, E.C. 2.7.5.1) shikimate dehydrogenase (SDH, E.C. 1.1.1.25). Of these six (AAT, MDH. MDR, 6PGD, PGI, PGM) gave reliable and reproducible results. In total, 10 zones of activity were scored and each zone was assumed to represent a single locus.

The average number of alleles per locus (*A*), percentage polymorphic loci (*P*), observed heterozygosity (*Ho*) and expected heterozygosity (*He*) were calculated as described by Brown and Weir (1983). The partitioning of genetic variation among populations was analysed using Nei's (1978) genetic distance (*D*). This was calculated for each pairwise combination of populations and a UPGMA phenogram constructed. The single locus diversity measures *A*, *P*, *He* and *Ho*, and *D*, were determined using the computer program BIOSYS-1 (Swofford and Selander, 1981). The UPGMA phenogram and standard errors for branch lengths were calculated as described by Ritland, 1989).

RESULTS

Three polymorphic loci were detected (*Pgi*–1, *Pgi*–2 and *Pgm*–1). This relatively low number of variable loci may be partly a reflection of the low level of genetic differentiation between populations but is probably also due to the difficulties in carrying out isozyme analysis of *P. debilis* material. Three alleles were detected at the *Pgi*–1 locus with the common allele occurring at a high frequency (0.83–0.98) in all populations. Two alleles were detected at the *Pgi*–2 locus and four at the *Pgm*–1 locus with both these loci showing some variation in allele frequencies between all populations (Table 1).

The single locus diversity measures (Table 2) provide only limited information because of the low number of loci analysed. They show, however, that the Trigg populations of *P. debilis* have relatively low levels of genetic diversity with fewer alleles detected per locus, and a

Table 1. Allele frequencies for the three polymorphic loci in the five populations of *P. debilis*

Population Locus/ Allele	Rottnest	Trigg	Burns Bch	Garden Is 1	Garden Is 2
Pgi–1					
A	0.17	0.02	0.00	0.07	0.11
B	0.83	0.98	0.98	0.87	0.89
C	0.00	0.00	0.02	0.06	0.00
Pgi–2					
A	0.43	0.96	0.42	0.16	0.23
B	0.47	0.04	0.58	0.84	0.77
Pgm–1					
A	0.12	0.00	0.03	0.02	0.15
B	0.86	1.00	0.92	0.89	0.50
C	0.01	0.00	0.05	0.09	0.35
D	0.01	0.00	0.00	0.00	0.00

Table 2. Genetic variability based on single locus diversity measures *N* (mean sample size per locus), *A* (Average number of alleles per locus), *P* (percentage of loci polymorphic), *Ho*(observed heterozygosity) and *He* (expected heterozygosity or gene diversity index) (standard errors in parentheses)

Population	*N*	*A*	*P*	*Ho*	*He*
Rottnest	45.1	1.5 (0.30)	30.0	0.04 (0.02)	0.10 (0.06)
Trigg	22.2	1.2 (0.10)	20.0	0.00 (0.00)	0.01(0.01)
Burns Bch	45.2	1.4 (0.20)	30.0	0.02 (0.02)	0.07 (0.05)
Garden Is 1	34.4	1.5 (0.30)	30.0	0.06 (0.03)	0.07 (0.04)
Garden Is 2	36.5	1.4 (0.20)	30.0	0.11 (0.06)	0.12 (0.07)

significantly lower observed heterozygosity (*Ho*) and gene diversity index (*He*). The other populations all show similar levels of genetic diversity although they are generally lower than levels usually found in vascular plants (Hamrick and Godt, 1989).

Patterns of genetic differentiation between populations based on a UPGMA cluster analysis (Fig. 1) indicate no significant differentiation between the Rottnest, Burns Beach and Garden Island populations. Only the Trigg population shows some divergence from the other populations but as indicated below this is probably due to sampling error and the low level of genetic variation within that population rather than an indication of significant genetic differences. It is important to note that the standard error bars in Figure 1 are relatively large which shows that the overall divergence between populations is low. This is probably also a reflection of the low

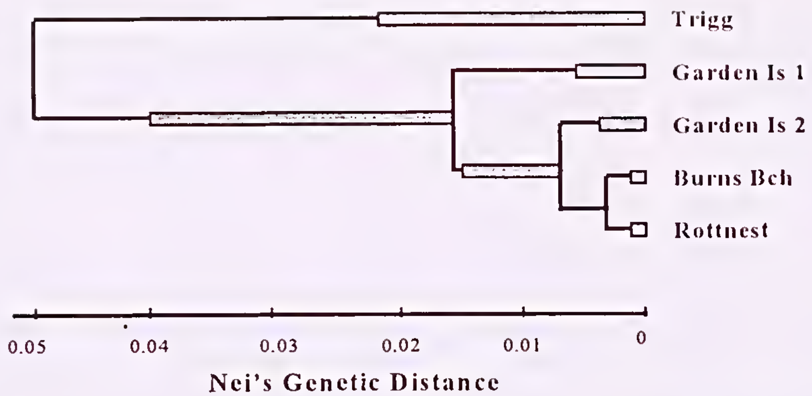

Figure 1. UPGMA clustering, with standard error bars for each branch length, based on Nei's (1978) genetic distance (*D*) between the populations of *P. debilis*. Branch lengths are significant if the standard error bar is less than half the branch length.

number of diagnostic isozyme markers available for analysis in *P. debilis*.

CONCLUSIONS

The isozyme analysis of the *P. debilis* material was not as detailed as was initially hoped. Of the fifteen isozyme systems screened for activity in *P. debilis* six gave reliable and reproducible results enabling the resolution of ten isozyme loci. The level of genetic divergence between all populations was generally low and there was no obvious pattern in relation to genetic divergence between island and mainland populations. Indeed the two Garden Island populations show greater between population divergence than the Rottnest, Burns Beach and Garden Island 2 populations.

The differences between the Trigg population and the other populations, both in terms of within population genetic diversity and divergence between populations, was unexpected given the closest population at Burns Beach shows no such differences. It seems likely that the distinct nature of the Trigg population is probably due to sampling error and small population size reflected in the significantly lower genetic diversity estimates (Table 2). Demographic data would be needed before any definite conclusion could be reached in relation to this population's reduced genetic variation and genetic uniqueness.

In conclusion there is no indication from these isozyme data to suggest that the establishment of artificial mainland populations of *P. debilis* using island material will have any detrimental effects, in terms of hybridisation and outbreeding depression, on any nearby natural mainland populations.

ACKNOWLEDGEMENTS

This project was the initiative of Robert Powell, who also supplied seed for the isozyme studies. It was funded by a grant from the Gordon Reid Foundation for Conservation to the Western Australian Insect Study Society.

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PREDATION BY FERAL CATS UPON LIZARDS

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The impact of both feral and domestic cats *Felis catus* on native wildlife has received increasing attention recently, in both the popular press and in scientific literature.

Paton (1991) reported on the loss of wildlife to domestic cats and found that the average domestic cat takes approximately 30 vertebrate prey items per year. This was considered to underestimate the true predation rate by as much as 50%. Predation on birds alone (an annual average of 8 birds per cat) accounted for approximately 50% of the standing crop of birds in suburban areas, because of the high density of cats in such areas. Paton (1991) concluded that suburban areas act as a sink for birds because of this high predation rate, and that this pressure could affect the populations of birds in surrounding regions.

Dickman (1993) has suggested that feral cats introduced prior to European settlement, perhaps as early as the seventeenth century from Dutch or Asian trading vessels, were responsible for the disappearance of several small (50–800 g) mammal species by the early nineteenth century. This pre-dated the decline of larger mammal species in the late nineteenth and early twentieth centuries which is believed to have been caused by the introduction and spread of the Red Fox *Vulpes vulpes* and to changes in fire regimes (Burbidge and McKenzie 1989). Dickman (1993) also notes that the disappearance of island populations of several mammal species, including the 4–10 kg Tammar Wallaby *Macropus eugeni*, has been linked with the introduction of cats.

There are many other observations on the impact of predation by cats upon native wildlife, but there are few data on the diet of feral cats. Coman and Brunner (1972), in an examination of the stomach contents of 80 feral cats collected in Victoria (primarily in the east of the state), found that the diet was 88% mammals by volume. Rabbits *Oryctolagus cuniculus* and House Mice *Mus musculus* were the most abundant mammals in the diet of cats in developed areas, but native mammals were more significant in the diet of cats living in native vegetation.

Brooker (1977), however, working on Western Australia's Nullarbor Plain, found the stomach contents of 9 cats to be composed mostly of a single lizard species, *Tympanocryptis lineata*, which accounted for 60% of 103 vertebrate prey items. Reptiles made up 101 of the vertebrate prey items, the remaining two items being birds. Traces of rabbit fur were found.

Chapman and Kitchener (1978) also

found reptiles to be a significant component of the diet in one stomach sample collected in Durokoppin Nature Reserve, in Western Australia's wheatbelt. Of 10 to 12 items, 2 were insects, 4 were lizards and 4 or possibly 6 were Gould's Wattled Bat *Chalinolobus gouldii*.

Jones (1989) summarizes information on feral cats and with respect to diet, concludes that they are generally opportunistic in their selection of prey items. Items taken reflect availability but cats are "first and foremost, predators of small, terrestrial mammals".

The impact of these sorts of predation by cats upon native wildlife can be difficult to assess, except in extreme cases, without information on the abundance of the prey species. Therefore, every opportunity should be taken to determine the diet of feral and domestic cats where data have been collected on the abundance of native fauna.

As part of the Environmental Management Programme of Tiwest Joint Venture, a sand-mining company working at Cooljarloo (30°40'S, 115°25'E) approximately 140 km north of Perth in Western Australia, detailed fauna studies have been conducted since 1986. These studies have involved intensive bird-censussing and pitfall-sampling for frogs, reptiles and small mammals in *Banksia* low woodland on Vacant Crown Land. The density of birds (found using an area-search technique) is in the order of 2–7 /ha, with honeyeaters being the most abundant group. Equivalent data are not available for frogs, reptiles and small mammals, but the relative abundances of different species from pitfall sampling are presented on Table 1. In addition, intensive searching and pitfall-trapping within fenced enclosures suggest lizard densities of *ca*. 400 individuals/ha, densities of the Honey Possum *Tarsipes rostratus* of *ca* 16/ha and densities of *M. musculus* of *ca* 30/ha (Bamford and Bamford, 1992 & 1993). It should be stressed that these density estimates for terrestrial vertebrates are only provisional results from ongoing studies.

Feral cats are occasionally seen at Cooljarloo, but on 6 November 1991, a freshly-killed specimen was found on the Brand Highway about 5 km south of the study area. The cat was black, male and with a total length (including tail) af 750 mm. It was not weighed, but was in good condition with heavy deposits of intestinal and sub-cutaneous fat. The stomach was full and contained the following items:

Reptilia
- Pygopodidae (legless lizards}
  - *Aclys concinnna*: 1;
  - *Delma grayi*: 2;
- Gekkonidae (geckoes)
  - *Diplodactylus spinigerus*: 2,
- Scincidae (skinks)
  - *Ctenotus fallens*: 7

Aves
- Meliphagidae (honeyeaters)
  - chicks: 2;

Mammalia
- small tufts of fur, probably rabbit.

Insecta
- Acrididae (grasshoppers)
  - unidentified species: 1.

Table 1. Numbers of captures of frogs, reptiles and small mammals in pitfall traps from 1989 to 1991 (13,110 trap-nights). Scientific names are based on: frogs (Tyler *et al.* 1984), reptiles (Storr *et al* . 1981, 1983, 1986 and 1990) and mammals (Strahan 1983 and Kitchener *et al.* 1984).

Species	No. caught	Percent. of total
FROGS		
Crinia pseudinsignifera	4	0.1
Heleioporus albopuncatus	4	0.1
Heleioporus eyrei	386	12.0
Limnodynastes dorsalis	5	0.2
Myobatrachus gouldii	220	6.8
Neobatrachus pelobatoides	254	7.9
Pseudophryne guentheri	90	2.8
REPTILES		
Aclys concinna	8	0.2
Aprasia repens	1	0.03
Delma grayii	1	0.03
Lialis burtonis	3	0.09
Pletholax gracilis	3	0.09
Diplodactylus alboguttatus	35	1.1
Diplodactylus spinigerus	36	1.1
Phyllodactylus marmoratus	9	2.8
Pogona minor	109	3.4
Tympanocryptis adelaidensis	418	13.0
Cryptoblepharus plagiocephalus	18	5.6
Ctenotus fallens	160	5.0
C. gemmula	63	2.0
C. impar	165	5.1
C. lesueurii	13	0.4
C. pantherinus	2	0.06
Egernia napoleonis	3	0.09
Lerista elegans	15	0.5
L. praepedita	20	0.6
Morethia lineoocellata	52	1.6
M. obscura	130	4.0
Ramphotyphlops australis	3	0.09
Notechis curtus	3	0.09
Rhinoplocephalus gouldii	1	0.03
Vermicella calonotus	2	0.06
MAMMALS		
Sminthopsis dolichura	13	0.4
S. granulipes	7	0.2
S. griseoventer	2	0.06
Tarsipes rostratus	549	17.1
Mus musculus	251	7.8
Pseudomys albocinereus	144	4.9
Rattus fuscipes	11	0.3
TOTAL	3213	

As the stomach contents were fresh, this sample represents prey items taken over one night only, and possibly over only part of that night. Although small mammals are abundant in the area where the cat had been foraging (small mammals comprised 30% of pitfall captures), none was present in the sample. The abundance of reptiles in the sample probably reflects their abundance in the area where the cat had been foraging, and possibly also the ease of capture. Jones (1989), however, states that reptiles are only an important dietary item in arid areas, whereas Cooljarloo has a mediterranean climate with reliable winter rainfall. The importance of mammals in the diet of cats suggested by Jones (1989) possibly reflects a south-eastern Australian bias to most data on the diet of cats. Small mammals may simply be abundant in eastern Victoria, for example, where Coman and Brunner (1972) found mammals to be the most numerous prey items.

Most of the reptiles were presumably taken when inactive, although *D. spinigerus* is nocturnal and some species of pygopodids are crepuscular (pers. obs.). The reptiles present had all been recorded in pitfall-sampling but were not the commonly-caught species (Table 1). This may be due to a bias on the part of the cat, or to a bias in the pitfall sampling. Intensive searching suggests that *Tympanocryptis adelaidensis*, although freqently pitfalled, is not as abundant as suggested by pitfall data, while geckoes and pygopodids are more abundant than the numbers of captures in pitfalls would indicate. The capture of a single *D. grayi* during pitfall trapping over three years, compared with the capture of two by the cat in one night of foraging, is nonetheless remarkable. Possibly, *D. grayi* is vulnerable to predation by cats by virtue of its behaviour.

Paton (1991) estimates the density of domestic cats in rural areas as 0.01/km^2, while Jones and Coman (1982) report densities of feral cats as 0.34 to 3.5 cats/km^2. It is possible to estimate the impact of cat predation on reptile numbers at Cooljarloo by taking an estimate of the density of cats, the density estimate of 400 lizards per ha and the number of lizards eaten by the road-killed cat in one night. The same cannot realistically be done with nestling honeyeaters, as the density estimates for birds are for adults only. If a value of 1 cat/km^2 is used, then predation by feral cats at Cooljarloo could account for 4,380 reptiles per km^2 annually. This accounts for 11%. of the estimated 40,000 lizards/km^2.

These calculations clearly make many assumptions and are based on a small data set, but they indicate that feral cats may be significant predators of reptiles. Furthermore, if their predation concentrates on a few species, then the proportion of these species' populations being taken annually may be very high indeed. More detailed data on the diet of cats and on the abundance of their prey items would make it possible to be more confident of the significance of cat predation on native fauna.

ACKNOWLEDGEMENTS

This work was funded by Tiwest

Joint Venture as part of the company's Environmental Management Programme.

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BRYOPHYTE FLORA OF RESERVE 3694 IN METROPOLITAN PERTH

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ABSTRACT

A species list of bryophytes collected on Reserve 3694 in suburban Kensington has been compiled to supplement a previously published list of vascular plants for this reserve.

INTRODUCTION

In September 1992 the authors visited reserve 3694 to sample the moss and liverwort flora. This collection was undertaken to prepare a species list of bryophytes to supplement a vascular plant publication (Cranfield & Parker, 1992). Lists of bryophyte flora for specific areas are not very common in Western Australia and the production of this list may encourage other similar publications.

METHOD

Random sampling was carried out in all recognised different vegetation types as indicated in the 1992 vascular plant publication. The samples were collected by removing portions of moss sward and vouched for the Herbarium collection. A total of twenty collections were made and the following identifications resulted.

RESULTS

Bryophyte Flora – Mosses

Barbula calycina Schwaegr.
Barbula hornschuchiana Schultz
Bryum albo-limbatum (Hamp.) Jaeg.
Bryum caespiticium Hedw.
Bryum camplothecium Tayl.
Campylopus introflexus (Hedw.) Brid.
Weissia controversa Hedw.

Bryophyte Flora – Liverworts

Cephaloziella arctica Bryhn et Douin subsp. *subantarctica* R.M. Schuster

DISCUSSION

The distribution of the bryophytes collected is worth commenting on as this indicates that many of the Australian species have world wide representation.

Barbula calycina
Australia, New Zealand, Chile, SE Asia, ?S. Africa (Doubtful).

Barbula hornschuchiana
Europe, Middle East, SW Asia, N. Africa, S. Africa, Australia (southern states). It is uncertain wether it is native or introduced.

Bryum albo-limbatum
Australia (WA, SA, QLD) endemic.

Bryum caespiticium
Almost cosmopolitan.

Bryum campylothecium
Australia, New Zealand.

Campylopus introflexus
Australia, New Zealand, Pacific Islands, introduced to UK, N. & S America, S. Africa.

Weissia controversa
Cosmopolitan.

Cephaloziella arctica subsp. *subantarctica*
Southern Australia, New Zealand.

There is some confusion over the use of *Bryum albo-limbatum* in Australian literature. Elsewhere it is recognised as a synonym for *Bryum capillare*, which this Australian moss is not. It is possible that it is in fact, *Bryum andicola*; if so the distribution would be: N, S and central America, E and S Africa and southern Australia. Further collections of this species may provide information that could clarify the above riddle.

CONCLUSIONS

This bryophyte flora list although not considered comprehensive, when used in conjunction with other articles produced on this reserve (Turpin, 1991, Cranfield & Parker, 1992) will enable the readers to develop an overall understanding of the natural dynamics involved.

ACKNOWLEDGEMENTS

We wish to thank Dr N.G. Marchant for his guidance.

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DIET OF *VARANUS CAUDOLINEATUS* (REPTILIA: VARANIDAE)

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ABSTRACT

The diet of museum specimens of *Varanus caudolineatus* is significantly different from those caught on Atley Station in Western Australia. The museum specimens had a much broader range of prey types, (predominantly spiders, grasshoppers and lizards) than those found on Atley Station that had a very high predominance of scorpions and a lower, but significant number of terrestrial spiders in their stomachs and intestines. These data suggest that *V. caudolineatus* at the Atley site essentially forage primarily on the ground rather than in trees as might be expected for an arboreal lizard.

INTRODUCTION

Varanids are generally reported as being carnivorous and opportunistic feeders, eating predominantly invertebrates. However, a few species specialise on prey types that reflect their habitat (Losos and Greene 1988). Diets of many species of varanids have been determined from museum specimens (Pianka 1968, 1969, 1970 a, b, 1971, Greene 1986, Losos and Greene 1988, James *et al.* 1992) or from freshly caught specimens from a diverse range of locations (King and Green 1979, Pianka 1968, 1969, 1970a 1971, 1986). There are few reports of the diet of varanids based on stomach contents collected from a single location (Shine 1986, Thompson in press). Significant ecological information is often inferred from dietary data.

Varanus caudolineatus is an arboreal pygmy goanna that usually takes refuge under loose bark or in the hollows of mulga trees; it is not usually found in spinifex or sand plain habitats (Pianka 1969). Its diet is quite varied and includes mainly grasshoppers, roaches and geckos.

This study reports the stomach contents of 88 Western Australian Museum (WAM) specimens of *V. caudolineatus* and contrasts this data with diet of 33 specimens caught in December 1991 in close proximity on Atley Station, W.A. (119°07'E, 28°25'S), 4 caught in July 1991 North of Ajana, W.A. (114°45'E, 27°35'S) and the 78 other specimens (largely from the W.A. and S.A. Museum) previously examined by Pianka (1969).

METHODS AND MATERIALS

A ventral incision was made in museum specimens (WAM) and the gut contents removed and identified. Stomach contents or scats were collected from 24 individual *V. caudolineatus* caught in tree hollows and pit traps on Atley Station and four *V. caudolineatus* caught in tree hollows in the area north of Ajana. Nine of the monitors were subsequently recaptured at least five days later on Atley Station and their stomach contents or scats were again collected. Stomach contents were flushed with tepid water, using a technique similar to that reported by Legler and Sullivan (1979). Scats were collected from the calico bags used to temporarily hold *V. caudolineatus* on the Atley and Ajana sites. The stomach contents and scats were stored in a dilute solution of formalin (approximately 10%) for later identification. Neither stomach contents nor scats were collected from seven of the 33 lizards examined from the Atley site. Three of the four lizards from Ajana provided prey items from their stomach.

The Atley Station site contains red loamy soils which supports a vegetation consisting mainly of spinifex (*Triodia sp.*), grasses, mulga (*Acacia sp.*) and gum (*Eucalyptus sp.*) trees. A representative sample of the potential small vertebrate and invertebrate prey items were collected from 60 pit traps (20 litre plastic containers) with 10m drift fences installed on the Atley site.

The analysis of the difference between the stomach contents of museum specimens and those from the Atley site was done using the SPSS/PC discriminant analysis program.

RESULTS

The stomachs of 46 of 88 museum specimens examined were empty. The contents of the remaining 42 stomachs contained predominantly spiders, grasshoppers and lizards (Table 1). Seven of the lizards were identified as geckos, *Gehyra sp.*, and one stomach contained at least two *Gehyra sp.* tails. Most stomachs contained only one item but four contained two or more identifiable items.

Three stomachs of the 4 *V. caudolineatus* from the site north of Ajana contained prey items; these were a spider, a beetle and a cricket (Table 1).

V. caudolineatus from the Atley site fed predominantly on scorpions, followed by a lesser number of large spiders, that were often found in holes in the ground during the day, and lizards (Table 1). Two of the lizards were skinks, one was a juvenile *Menetia greyii* the other was the dismembered parts of a small *Ctenotus schomburgkii*. In addition, three *V. caudolineatus* from the Atley site and one from the site north of Ajana had red gravel in their stomachs. This was probably ingested while they were capturing prey on the ground.

There is a significant difference (chi-square 74.63, df 6, $p<0.0001$) in the gut contents of the museum

Table 1. The number of stomachs (and scats*) with the incidence of prey items in *V. caudolineatus*

	Museum specimens	Pianka 1969	Atley site*	Ajana site
No specimens examined	88	78	33	4
No stomachs empty	46	44	7	1
PREY TYPE				
Centipedes	1	2	1	
Scorpions			17	
Spiders	10	6	7	1
Grasshoppers	8	10	2	
Roaches	3	11		
Moths		1	1	
Larva	4	4	0	
Beetles	1		1	1
Unidentified invertebrate	8	6	0	
Egg sac	1			
Bee		1		
Cricket		1		
Lizards – egg sac		1		
– other parts	9	10	3	
Twigs		2	1	
Red gravel		3	1	

* the contents of lizard scats are included in the data from the Atley site.

specimens we examined and those caught on the Atley Station. 91.2% of the gut contents were classified correctly with the group centroids being 1.95 for the Atley site and – 1.13 for the museum specimens.

Potential prey items captured in the 60 pit traps located on the Atley site were placed into three groups, depending on their relative abundance in the traps (Table 2). In addition, *Gehyra variegata* and *Egernia depressa* were found in relatively low number in trees in which *V. caudolineatus* were found.

DISCUSSION

There is a similarity between the stomach contents of the museum specimens we examined and those examined by Pianka (1969), with the exception that Pianka's sample contained a relatively higher number of roaches. This similarity would have been expected.

There is however a significant difference between the diets of *V. caudolineatus* found on the Atley site, and those examined by us in the Western Australian Museum collection. The very high predominance of scorpions and lower, but significant number of terrestrial spiders in the stomachs and intestines of *V. caudolineatus* from the Atley site contrasts with the much broader range of prey types in the museum specimens we examined and in Pianka's (1969)

Table 2. Relative abundance of potential prey items found in pit traps on the Atley site.

Item	Pit trap catch frequency Often caught	 Seldom caught	 Rarely caught
INSECTA			
Thysanura (silverfish)		*	
Blattodea (roaches)		*	
Isoptera (termites)			*
Mantodea (preying mantids)			*
Orthoptera (grasshoppers)		*	
Phasmatodea (stick insects)			*
Coleoptera (beetles)	*		
Hymenoptera (ants)	*		
ARACHNIDA			
Scorpionida (scorpions)	*		
Araneae (spiders)	*		
CHILOPODA			
Scolopendrida (centipedes)	*		
REPTILIA			
Scincidae (skinks)	*		
Gekkonidae (geckos)		*	
Varanidae (goanna)		*	

samples. In this particular circumstance the stomach contents of specimens coming from a variety of locations [museum and Pianka (1969)] do not necessarily provide a good indication of the diet of the same species at a particular site. This is similar to the situation for *V. mertensi* (Shine 1986).

The different diet of the small monitors at the Atley site probably reflects the food items available and able to be captured and ingested. Centipedes were abundant there, but the adults may be too large or too difficult to subdue. Many of the beetles present there might also have been too large and their exoskeletons too difficult to penetrate for them to become prey for *V. caudolineatus*. The small skinks caught in the pit-traps were predominantly *Ctenotus schomburkii* and *Ctenotus leonhardii*, while the predominant gecko was *Rhynchoedura ornata*. *C. schomburkii* and *R. ornata* appear to be within the suitable prey size range for *V. caudolineatus* to ingest but may be too difficult to locate and capture. *C. leonhardii* is a larger skink and may be too fast and too large for *V. caudolineatus* to capture. *Gehyra variegata*, which was relatively abundant in the stomachs of museum specimens, but was not found in the stomachs of the Atley site monitors, was caught only once in the pit-traps, but were occasionally found under the bark of trees.

All identifiable species of scorpions and spiders found in the stomachs and scats of these small monitors are ground dwelling invertebrates. In addition, both *M. greyii* and *C. schomburgkii* are both ground dwelling skinks that live around the base of spinifex clumps or in holes in the ground. This supports other behavioural data (Thompson, unpublished) that indicate that *V. caudolineatus* retreat to trees when threatened, to sleep or to observe their surrounds, but essentially forage on the ground.

No *V. caudolineatus* were captured at night in the pit-trapping program on the Atley site, although the ambient temperature at night was often in the mid-to-high 30°C's. Scorpions, and many of the spider species that were preyed-upon, were only found out of their burrows after dark. On two occasions in soft red loamy soils clear tracks of *V. caudolineatus* were found leading to the entrance of scorpion holes, suggesting that these lizards enter burrows in search of prey. The red gravel in the stomachs of monitors may be ingested when they are eating scorpions or spiders captured in burrows.

This study provides further support for the point made by Shine (1986) and Thompson (in press) that the diets of varanids vary significantly with locality and time of the year. Much of the dietary data and the derived ecological information for varanids comes from museum specimens (Losos 1988, Greene 1986, James *et al.* 1992). It would therefore appear inappropriate to draw specific conclusions about the diets of varanids at a particular location from museum specimens or from those caught in other locations. It would be interesting to know however, if there was a relationship between the density of *V. caudolineatus* and the high availability of scorpions at the Atley site or whether this small monitor would feed on other invertebrates in the absence of scorpions.

Contrary to Pianka's (1969) suggestion that V. caudolineatus are not found in spinifex habitats, most of the Atley sites from which V. caudolineatus were collected had patches of spinifex ground cover and a sparse cover of mulga trees.

ACKNOWLEDGEMENTS

The field work component of this research was made possible by the financial assistance of Edith Cowan University and the University of Western Australia. The assistance of P. Hately, W. Thompson and S. Thompson in digging in pit-traps, catching *V. caudolineatus* and checking pit-traps was very much appreciated. The comments of P. C. Withers significantly improved the manuscript. K. Aplin and L. Smith provided access to the collections of the Western Australian Museum. The approval by R. and J. Broadhurst to have access to Atley Station was appreciated. All lizards were caught under licence issued by the Department of Conservation and Land Management to G. Thompson. Animal experimentation on live specimens was done with the approval of the Animal Welfare Committee of the University of Western Australia.

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D. L. SERVENTY'S GOOSEBERRY HILL PLANT LIST

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INTRODUCTION

The late D. L. Serventy worked at the CSIRO laboratory in Helena Valley, and owned Lot 306, The Knoll, Gooseberry Hill, which he used as a weekend cottage. At his behest, G. M. Storr of the WA Museum collected 74 plants on The Knoll on 5th October 1957. Dr Serventy continued sporadic collections at the locality until 1967, reaching a total of 92 taxa. The specimens collected by Storr were identified by C. A. Gardner, Serventy's by R.D. Royce or A.S. George, all of the WA Herbarium.

I became aware of the existance of the collection when Dr Serventy permitted me to use the house as a base for school biology/geography excursions during the 1970s. After his death, the Serventy family kindly gave me the collection to assist with my study of the flora of Gooseberry Hill. It is described here as a distinct historical collection, and the specimens have been lodged in the WA Herbarium [PERTH].

A list of the plants represented in the collection is given in Table 1. The arrangement and nomenclature follows Marchant *et al.* (1987) but where taxonomic changes have occurred, the name originally applied is given in brackets.

DISCUSSION

Gooseberry Hill is a promontary of lateritic caprock which forms the southern edge of the Helena Valley where it cuts through the Darling Scarp. The site, geology, soil and vegetation has been described in Hussey (1993) Basically, it is a narrow plateau of massive laterite, breaking sharply away on the north, west and south sides to form steep scree slopes. The vegetation is open forest of Jarrah, *Eucalyptus marginata*, and Marri, *Eucalyptus calophylla*, with a heath understorey.

D. L. Serventy's block occupied part of the caprock and scree slope, facing north over the Helena Valley and the CSIRO laboratories where he worked. At the time when the collection was made very few blocks were developed, now almost all are. With the exception of two species, *Hovea pungens* and *Conostylis androstemma*, the specimens come from the laterite area, possibly even from Lot 306 itself.

Currently, the species list for the lateritic section of the public land on The Knoll stands at 188 species. Since this collection contains only 90 plants, it is clearly not exhaustive – there are only three members of the Proteaceae, for example, and no Myrtaceae at all. It cannot therefore be used to infer the species composition, relative abundance or percentage of exotics in the community at that time. Nevertheless, it includes some interesting taxa.

The following four species have not been noted recently:

Guichenotia micrantha is not recorded by Marchant *et al.* (1987) as occurring within the Perth area, although it is widespread across the Wheatbelt. The nearest locality is Sawyers Valley. It could have been destroyed by development, but it may still exist on a private block.

Styphelia tenuifolia is common on laterite elsewhere, and it may still occur on private land.

Senecio gilbertii is endemic to the Darling Range and not common, the nearest population is at Glen Forrest. Despite specific searches, it has not been found recently, but a fire in December 1993 may have stimulated germination.

Elymus scabrus is uncommon in the Perth region, though it has been noted from Swan View. The niche it would have occupied on The Knoll is now filled by introduced grasses such as *Ehrharta calycina*, and so this population may have succumbed to competition.

There are currently 23 introduced species on The Knoll, and the 14 species in this collection all still occur there.

ACKNOWLEDGEMENTS

Thanks to the late Dom Serventy, who first introduced me to Gooseberry Hill, and to the Serventy family for giving me the collection.

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Table 1. List of specimens in D.L. Serventy's Gooseberry Hill herbarium. (GMS = G. M. Storr, DLS = D. L. Serventy, * = introduced species)

Family	Name	Collector	Date
Adiantaceae	*Cheilanthes austrotenuifolia (Cheilanthes tenuifolia)*	GMS	5/10/57
Lauraceae	*Cassytha racemosa*	GMS	5/10/57
Ranunculaceae	*Clematis pubescens*	GMS	5/10/57
Amaranthaceae	*Ptilotus drummondii (Trichinium drummondii)*	GMS	5/10/57
Caryophyllaceae	*Petrorhagia velutina* * *(Tunica prolifera)*	GMS	5/10/57
	Silene gallica *	GMS	5/10/57
Dilleniaceae	*Hibbertia commutata (Hibbertia montana)*	GMS	5/10/57
	Hibbertia hypericoides	GMS	5/10/57
	Hibbertia serrata (Hibbertia montana var. *major)*	GMS	5/10/57
Sterculiaceae	*Guichenotia micrantha*	GMS	5/10/57
Droseraceae	*Drosera macrantha*	GMS	5/10/57
	Drosera ? pallida (vegetative material)	DLS	29/5/58
Epacridaceae	*Styphelia tenuiflora*	DLS	15/5/60
Primulaceae	*Anagallis arvensis* * var. *caerulea (Anagallis arvensis* ssp. *foemina)*	GMS	5/10/57
Pittosporaceae	*Billardiera drummondiana (Marianthus drummondiana)*	GMS	5/10/57
	Pronaya fraseri (Pronaya elegans)	DLS	23/2/63
Mimosaceae	*Acacia pulchella*	GMS	5/10/57
Fabaceae	*Bossiaea ornata*	GMS	5/10/57
	Davesia cordata	GMS	5/10/57
		DLS	1/9/62
	Gompholobium marginatum	GMS	5/10/57
	Gompholobium preissii	GMS	5/10/57
	Hovea chorizemifolia	DLS	13/6/65
	Hovea pungens	DLS	19/7/64
	Hovea trisperma	GMS	5/10/57
	Kennedia coccinea (Kennedya coccinea)	GMS	5/10/57
	Kennedia stirlingii (Kennedya stirlingii)	DLS	30/9/67
	Trifolium campestre *	GMS	5/10/57
Proteaceae	*Dryandra nivea*	GMS	5/10/57
	Grevillea synapheae	GMS	5/10/57
	Petrophile striata	GMS	5/10/57

Table 1 (cont.)

Family	Name	Collector	Date
Thymeliaceae	*Pimelea argentea*	GMS	5/10/57
	Pimelea ciliata		
	(Pimelea rosea)	GMS	5/10/57
Stackhousiaceae	*Stackhousia pubescens*	GMS	5/10/57
	Triptrococcus brunonis		
	(Stackhousia brunonis)	GMS	5/10/57
Euphorbiaceae	*Phyllanthus calycinus*	GMS	5/10/57
Polygalaceae	*Comesperma ciliatum*		
	(Comesperma volubile)	GMS	5/10/57
Rutaceae	*Boronia ovata*	GMS	5/10/57
	Eriostemon spicatus	GMS	5/10/57
Oxalidaceae	*Oxalis corniculata* *	DLS	10/8/58
Apiaceae	*Daucus glochidiiatus*		
	(Erodium cicutarium)	GMS	5/10/57
Gentianaceae	*Centaurium erythraea* *		
	(Erythraea centaurium)	DLS	23/11/58
Orobanchaceae	*Orobanche minor* *		
	(Orobanche cernua)	GMS	5/10/57
Lobeliaceae	*Isotoma hypocrateriformis*	DLS	23/11/58
Stylidiaceae	*Stylidium affine*	GMS	5/10/57
	Stylidium amoenum		
	(Stylidium striatum)	GMS	5/10/57
	Stylidium calcaratum	GMS	5/10/57
	Stylidium piliferum	GMS	5/10/57
Goodeniaceae	*Dampiera alata*	GMS	5/10/57
	Dampiera linearis		
	(Dampiera triloba)	GMS'	5/10/57
	Lechenaultia biloba	GMS	5/10/57
	Scaevola calliptera		
	(Scaevola pilosa)	GMS	5/10/57
	Scaevola platyphylla	GMS	5/10/57
	Scaevola striata	GMS	5/10/57
Asteraceae	*Helichrysum macranthum*		
	(Helichrysum bracteatum		
	var. *albidum)*	GMS	5/10/57
	Hypochaeris glabra *	GMS	5/10/57
	Millotia tenuifolia	GMS	5/10/57
	Olearia paucidentata	DLS	15/5/60
			19/5/62
	Podolepis gracilis	GMS	5/10/57
	Podolepis lessonii		
	(Podolepis nutans)	GMS	5/10/57
	Rhodanthe corymbosa		
	(Helipterum corymbosum)	GMS	5/10/57

Table 1 (cont.)

Family	Name	Collector	Date
	Senecio gilbertii	GMS	5/10/57
	Senecio lautus	GMS	5/10/57
	Sonchus oleraceus *		
	(Sonchus olivaceus)	GMS	5/10/57
	Trichocline spathulata		
	(Trichocline scapigera)	DLS	23/11/58
	Ursina anthemoides *	GMS	5/10/57
Dioscoreaceae	*Dioscorea hastifolia*	DLS	29/5/58
Anthericaceae	*Agrostocrinum scabrum*	GMS	5/10/57
	Arthropodium capillipes	DLS	28/12/58
	Caesia parviflora	GMS	5/10/57
	Sowerbaea laxiflora	GMS	5/10/57
	Thysanotus manglesianus		
	(Thysanotus patersoni)	GMS	5/10/57
	Thysanotus multiflorus	GMS	5/10/57
Colchicaceae	*Burchardia multiflora*	DLS	25/8/62
	Burchardia umbellata	GMS	5/10/57
	Wurmbea pygmaea		
	(Anguillaria dioica)	DLS	29/5/58
Iridaceae	*Orthrosanthus laxus*	GMS	5/10/57
Orchidaceae	*Caladenia longicauda*		
	(Caladenia patersonii)	GMS	5/10/57
	Diuris corymbosa		
	(Diuris longifolia)	GMS	5/10/57
	Eriochilus dilatatus	DLS	29/5/58
	Prasophyllum elatum	GMS	5/10/57
Haemodoraceae	*Conostylis androstemma*	DLS	19/7/64
	Conostylis setosa		
	(Conostylis discolor)	GMS	5/10/57
Cyperaceae	*Lepidosperma angustatum*	GMS	5/10/57
	Lepidosperma scabrum	GMS	5/10/57
Poaceae	*Avena barbata* *	GMS	5/10/57
	Briza maxima *	GMS	5/10/57
	Briza minor *	GMS	5/10/57
	Danthonia caespitosa		
	(Danthonia semiannularis)	GMS	5/10/57
	Elymus scabrus		
	(Agropyron scabrum)	GMS	5/10/57
	Neurachne alopecuroidea	GMS	5/10/57
	Poa drummondiana		
	(Poa bulbosa)		
	Vulpia myuros *	GMS	5/10/57

A BIOLOGICAL SURVEY OF GARDEN ISLAND, WESTERN AUSTRALIA: 2. TERRESTRIAL MAMMALS.

By M.G. BROOKER, G.T. SMITH, J. LEONE and J.A. INGRAM
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ABSTRACT

The Tammar *Macropus eugenii* and two introduced species, the House Mouse *Mus domesticus* and Feral Cat *Felis catus*, were the only terrestrial mammals recorded during a biological survey of Garden Island in 1991–92. Tammars were widespread and abundant in all habitats. A comparison of our Tammar counts with those obtained in the 1970s and 1980s indicated an increase in numbers. On the basis of diet and foraging range, we suggest that probably three groups of Tammars exist – the "urban" animals at the Naval Base, a "roadside" group and "native" Tammars confined to the natural vegetation away from the Base, roads and firebreaks.

Garden Island has few introduced mammals compared to the mainland. Sheep and Rabbits have been removed and Feral Cat numbers are low. However, the House Mouse was found on all sampling sites and may now play an important role in the ecosystem of the island.

INTRODUCTION

A biological survey of Garden Island was undertaken during 1991 and 1992. A short history of the European settlement of the island, a description of the vegetation and the findings of a bird and reptile census are given in Brooker 1992 and Brooker *et al.* (this volume). This paper deals with observations of the terrestrial mammals, with special reference to the only native species, the Tammar *Macropus eugenii*.

Tammars are small (3–7 kg) wallabies which were once widespread in dense thickets in south-western Australia and coastal South Australia (Poole *et al.* 1991). Their distribution has contracted considerably since white settlement (Perry 1973). In Western Australia, some isolated populations still persist on the mainland and five Western Australian island populations are extant, with that on Garden Island being the largest.

METHODS

Tammars and other nocturnal terrestrial vertebrates were counted by spotlight on an 18.1 km transect (see Figure 1) over 14 nights.

The survey team consisted of a driver and two observers with 100 watt spotlights, recording the total

Figure 1. Map of Garden Island showing sections (numbered as in Table 1) of road transect on which Tammar counts were made.

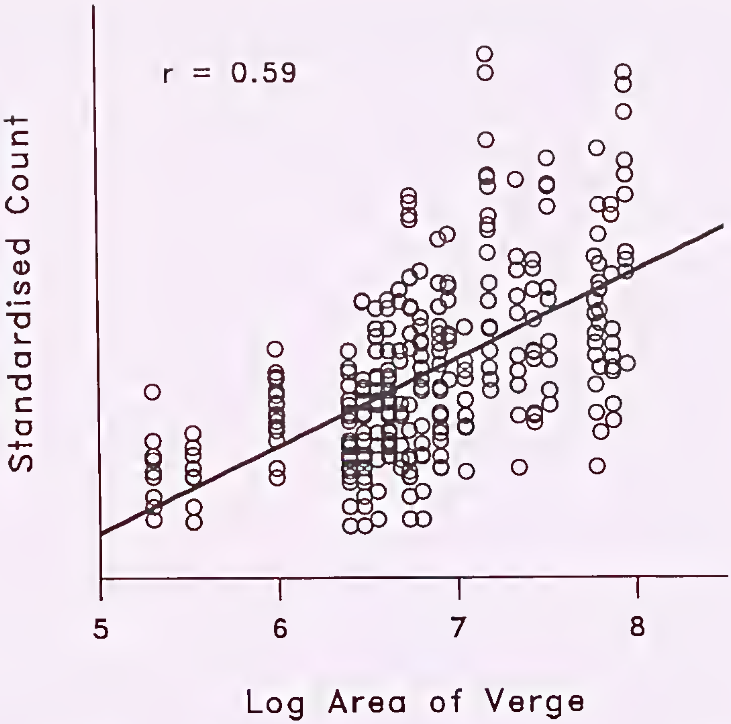

Figure 2. Relationship between the numbers of Tammars (plotted as residuals from the regression of season on Tammar number, thereby producing counts "standardised" for seasonal effects) and the log area of the verge (m^2).

numbers of Tammars seen on each 0.5 km section of the transect. Separate counts were made of the two large grassed areas on the Naval Base, near the Oval and the Z Force Memorial. The width of the road verge was measured and the proportions of each different vegetation community present in each section was obtained from a vegetation map (W. McArthur, unpubl.)

Ten pitfall and 10 Elliott traps were set in each of twenty $100m^2$ quadrats which sampled the major vegetation communities present on the island. The traps were operated over four nights, first in April 1991 and again in November 1991. A full description of the quadrats is given by Brooker (1992).

RESULTS

Tammar *Macropus eugenii*

The numbers of Tammars counted during 14 spotlight transects are shown in Table 1. A subset of these data (8 counts, two replicates for each census month) were analysed for sectional and seasonal effects. Omitted from the analysis were the counts made in April 1991 (missing data), 25 November (low temp-

Table 1. Numbers of Tammars counted on 36 Sections of Transect (see Figure 1) 8 March 1991 – 14 April 1992 (Time = WST; Wind = Beaufort Scale, Cloud and Moon estimated in eighths; NR = not recorded).

Section		8.4.91	9.4.91	10.4.91	11.4.91	22.7.91	23.7.91	25.11.91
1		2	5	2	2	3	0	5
2		3	4	0	2	4	2	7
3		5	3	0	4	10	1	11
4		28	9	15	18	6	12	17
5		9	8	12	15	11	3	16
6		11	3	7	9	10	4	8
7		13	8	11	26	14	1	25
8		20	24	15	24	14	6	10
9		15	19	31	33	15	15	24
10		12	34	16	28	45	25	49
11		20	10	3	14	36	19	63
12		44	3	9	23	49	7	45
13		3	4	3	4	19	7	6
14		17	10	5	8	5	2	4
15		9	5	2	4	19	10	14
16		21	9	11	9	20	6	8
17		32	12	10	16	4	5	1
18		8	11	6	4	19	6	9
19		4	10	5	3	20	22	9
20		9	7.	4	4	13	13	3
21		45	8	10	13	9	6	9
22		0	5	2	3	11	7	5
23		1	2	3	0	4	3	5
24		3	3	3	0	6	3	4
25		14	2	5	6	8	4	2
26		11	1	6	2	3	2	2
27		6	3	9	8	13	9	5
28		2	2	2	3	7	2	1
29	Second Head Rd	11	5	9	6	7	11	13
30	Point Atwick Rd	33	2	8	5	11	22	24
31	Gilbert Point Rd	17	9	2	9	13	23	14
32	Denham Rd East	NR	NR	NR	NR	16	7	39
33	Denham Rd West	NR	NR	NR	NR	29	4	20
	Total Denham Rd	55	13	20	21	45	11	59
34	Oval	220	24	120	175	298	138	376
35	Beagle Rd	21	0	0	13	9	18	9
36	Z-Force	60	15	37	27	24	3	24
Time		20:08	20:00	21:55	22:10	18:15	18:18	20:45
Wind		1	3	3	1	1	3	3
Temperature		20	17	16	14	14	16	16
Rain			Yes	Yes				
Cloud		1	5	2	1	4	3	6
Moon		0	0	0	0	0	7	0

Table 1 (cont.) (26 November 1991 – 14 April 1992)

Section		26.11.91	27.11.91	28.11.91	28.1.92	29.1.92	13.4.92	14.4.92
1		7	7	4	2	2	1	0
2		2	1	5	6	0	0	0
3		16	13	19	10	10	14	14
4		9	9	8	18	10	23	11
5		5	6	1	11	7	2	7
6		4	9	13	3	5	1	1
7		14	12	22	6	13	4	2
8		13	12	15	13	10	7	5
9		25	25	28	12	7	13	20
10		53	69	77	35	24	68	45
11		44	45	29	20	12	32	37
12		37	44	49	11	9	18	7
13		3	1	19	5	6	6	7
14		1	13	13	4	8	10	4
15		8	6	25	5	3	5	9
16		8	4	7	5	6	7	6
17		4	7	4	1	6	5	2
18		11	5	7	4	7	3	2
19		6	4	10	4	10	5	10
20		15	9	6	4	2	14	5
21		4	4	14	21	17	25	16
22		7	5	4	2	20	0	0
23		NR	9	9	1	0	0	2
24		NR	3	12	7	1	1	3
25		NR	10	4	4	4	1	4
26		NR	4	6	1	12	2	2
27		NR	4	3	4	4	3	5
28		2	1	1	0	3	1	2
29	Second Head Rd	12	16	20	31	33	22	12
30	Point Atwick Rd	23	21	28	22	15	48	35
31	Gilbert Point Rd	45	42	49	6	7	14	8
32	Denham Rd East	57	53	64	23	20	20	27
33	Denham Rd West	15	28	23	1	8	11	14
	Total Denham Rd	72	81	87	24	28	31	41
34	Oval	350	376	345	230	132	194	174
35	Beagle Rd	4	9	18	12	1	25	16
36	Z-Force	23	23	20	11	19	15	4
Time		20:45	21:00	20:45	19:55	20:20	18:55	18:30
Wind		3	2	2	1	1	2	2
Temp.		18	20	21	24	25	21	21
Rain								
Cloud		0	1	0	1	0	4	1
Moon		0	0	0	0	0	4	5

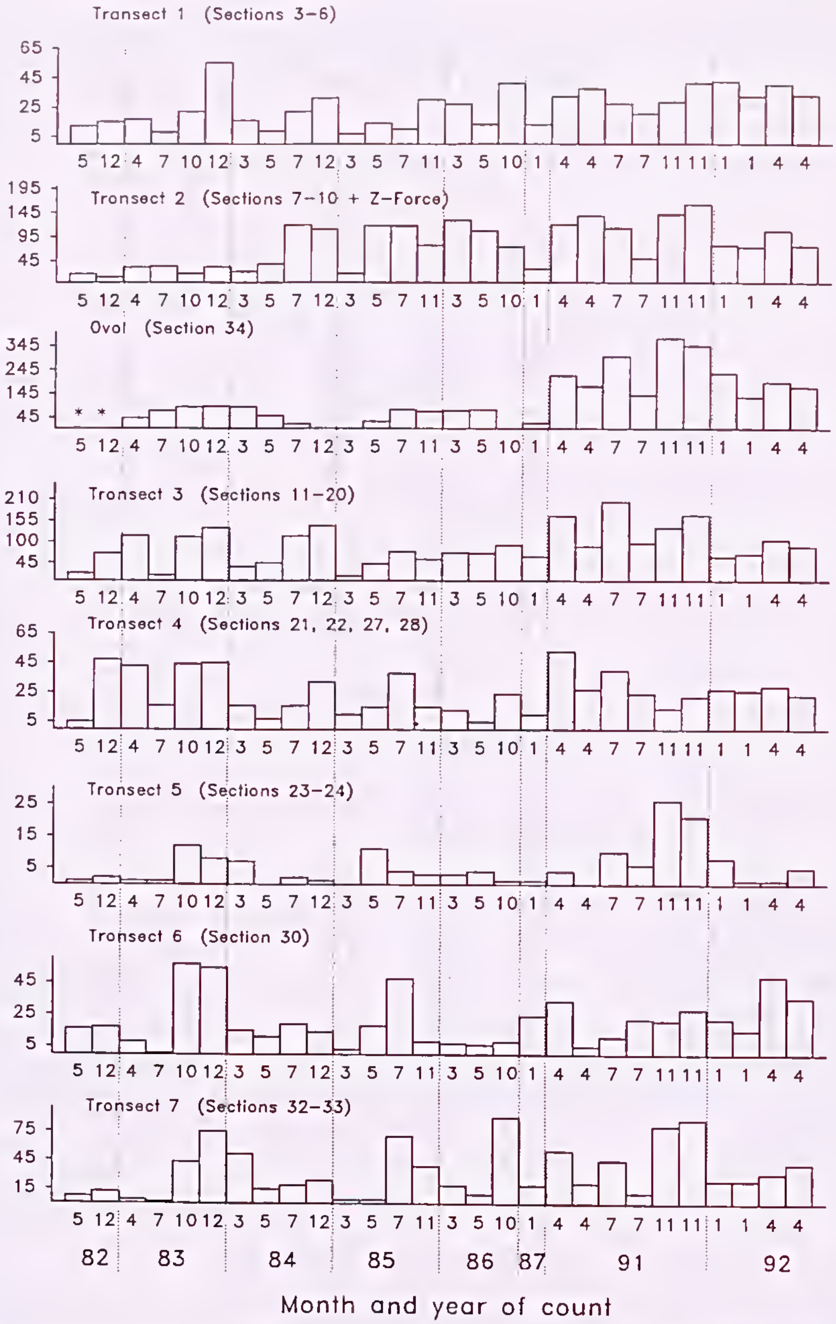

Figure 3. Numbers of Tammars counted by UWA (18 counts, 1982–87) and present survey (10 counts, 1991–92). The UWA data were obtained on transects which approximate one or more of the Sections in this study (* = not counted).

erature) and 26 November (missing data).

An analysis of variance of the transformed counts ($\sqrt{x + 0.5}$) showed no significance difference between replicates ($F_{1,234} = 1.26$; n.s.), but highly significant differences among sections of transect ($F_{33,234} = 12.09$; $P < 0.001$) and among seasons ($F_{3,234} = 10.92$; $P < 0.001$). The lowest counts were in July and the highest in November 1991.

The mean counts for each section were examined also for sectional effects such as verge area (sections of approximately equal length varied in width of verge) and vegetation type. We found a significant positive relationship between the Tammar counts and the verge area (see Figure 2). In addition, the counts were positively correlated with the presence of *Melaleuca huegelii* but showed no relation to the presence/absence of *Acacia rostelliferra*, *M. lanceolata* or *Callitris preissii*.

The count data from this study were compared with the numbers obtained by the University of Western Australia (UWA) in the 1980s (Figure 3; data supplied by L. Schmidt). The transect averages from the road counts were from 28% (Transect 5) to 240% (Transect 7) greater than the UWA counts.

Similarly, the numbers of Tammars on Transect 1, which was counted by UWA in 1973–4 (data from Anon 1974), averaged 5.4 ± 4.8, compared to 20.1 ± 12.7 in 1982–7 (UWA, N=18) and 33.2 ± 7.3 in 1991–2 (present survey, N=10). The numbers seen on the Oval were also considerably higher in 1991 and 1992 than had been reported previously. This could have been due to changes in the management of the Oval fence which did not exclude animals at the time of the 1991–2 survey.

House Mouse *Mus domesticus*

The introduced House Mouse was the most numerous vertebrate caught in traps during the survey (Brooker 1992). They were found on all sites in autumn (mean number per site 3.4 ± 2.1) and on 14 of the 20 sites in spring (1.5 ± 1.6) (see Table 2).

Black Rat *Rattus rattus*

According to Anon (1979), "non-native" rats have established breeding populations on the island, although none were trapped during this survey. Nevertheless, they have been seen by Naval Staff at the mainland end of the Causeway and an immature Black Rat *Rattus rattus* was trapped there in May 1991.

Feral Cat *Felis catus*

Only one Cat was seen during the survey – on Section 32 (Denham Road) on the night of 28 January 1992. This suggests that control measures for this species have been effective, as 12 individuals were seen on 13 spotlight transects during 1973–74 (Anon 1974).

DISCUSSION

The Tammar and two introduced species, the House Mouse and Feral Cat, were the only terrestrial species of mammals present.

Tammars were found in all surveyed vegetation types on the island, although most frequently in *Acacia rostellifera – Melaleuca huegelii* Scrub. They were least common in

Table 2. Numbers of House Mice captured in Pitfall (P) and Elliott (E) Traps, Autumn and Spring 1991.

SITE	Autumn P	Autumn E	Autumn Total	Spring P	Spring E	Spring Total
1	0	1	1	0	0	0
2	1	1	2	0	0	0
3	2	4	6	2	0	2
4	0	5	5	0	0	0
5	1	1	2	0	0	0
6	3	0	3	3	0	3
7	0	1	1	1	0	1
8	2	4	6	2	3	5
9	0	4	4	1	0	1
10	3	3	6	1	0	1
11	1	4	5	1	0	1
12	1	0	1	1	0	1
13	2	3	5	0	2	2
14	1	1	2	0	4	4
19	1	0	1	0	0	0
20	1	2	3	1	0	1
21	1	2	3	0	0	0
22	1	0	1	3	2	5
24	3	0	3	1	1	2
26	4	4	8	1	0	1
Sum	28	40	68	18	12	30
Mean	1.4	2.0	3.4	0.9	0.6	1.5
SD	1.1	1.7	2.1	1.0	1.2	1.6
per 100 TN*	3.5	5.0		2.2	1.5	

* TN = trap nights

south-west coastal areas. The number counted was highest during the November survey, coinciding with the period when most young had left the pouch (Inns 1980, Bradshaw 1988).

Compared to surveys undertaken in the 1970s and 1980s by the University of Western Australia, the numbers of Tammars counted in the present survey were higher and the numbers on the Oval were considerably higher than before. In fact the counts suggest that Tammars may now be more abundant than in the 1970s and 1980s, although this conclusion must be qualified by the knowledge that differences in spotlighting techniques and observers and possible changes in the extent, composition and management of the road verge and lawn areas could account for the differences in numbers.

The food resources (mainly exotic plants) provided along fire breaks, roads and facilities and the invasion of other exotics into the natural vegetation could be responsible for any increase in the numbers of Tammars. Bell *et al.* (1987) found that their preferred diet included *Asphodelus fistulosus*, which is found on most verges and fire breaks, together with another onion weed *Trachyandra divaricata*. Also eaten was the Asparagus Fern *Asparagus asparagoides* which is extending its range into the native vegetation. The lawn areas of the Oval, at the Base and along the roads consist mainly of Couch Grass *Cynodon dactylon*, which is grazed extensively by the Tammars. Thus the Tammars on Garden Island could be divided by diet into three groups – the "urban" animals at the Naval Base, the "roadside" animals whose home ranges include areas of road verge and the "native" animals in natural vegetation away from the Base and roads.

Garden Island has few introduced mammals compared to the mainland. Sheep and rabbits have been removed and Feral Cat numbers are low. Only the House Mouse was numerous, being found on all sites. Mice may therefore contribute to the abundance of Carpet Pythons *Morelia spilota* and Tiger Snakes *Notechis scutatus* on the island, since it is likely that mice feature prominently in their diets. The presence of Black Rats on the Causeway is of concern, as an infestation of the island could have a serious impact, particularly on low-nesting birds such as Fairy Terns *Sterna nereis* and Brush Bronzewings *Phaps chalcoptera*.

ACKNOWLEDGEMENTS

This survey was undertaken under contract for the Department of Defence. The authors acknowledge the cooperation of the staff of HMAS Stirling, especially Captain Reg Cook, Captain Keith Eames and Claire Newman. Additional information was provided by Don Bradshaw (UWA), Ted Brown (Archivist), Ron Johnstone (WA Museum), Denis King (APB), Bill McArthur (Botanist), Lud Schmidt (UWA), Wayne Taylor (CALM) and John Wombey (CSIRO). Dion Steven and Lyn Atkins helped to set up the sites and Lesley Brooker typed the manuscript. To all we are most grateful.

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Excursions and field days are planned from time to time and will be advertised in the Club's monthly newsletter "The Naturalist News".

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