

Biological inventory of Koolan Island, Western Australia 2. Zoological notes

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Abstract – In terms of its biota, Koolan is the most thoroughly inventoried island on the Kimberley coast. We provide annotated lists of the animal species known from the island: three earthworms, eight land snails, two scorpions, one centipede, nine spiders, two ants, 34 butterflies, one amphibian, 35 reptiles, 116 birds and 18 mammals. In addition, the W.A. Museum holds unsorted collections of moths and beetles. A range of animals have been introduced, including an earthworm *Dichogaster bolau*, a land snail *Laevicaulis alte*, an ant (*Monomorium destructor*), a cockroach and four mammals including the feral goat (*Capra hircus*). Koolan's indigenous fauna is a sub-set of taxa known from the adjacent mainland, although the blind snake *Ramphotyphlops yampiensis*, and the land snails *Kimboraga koolanensis* and *Amplirhagada astuta*, appear to be endemic to the island. The bird list was accumulated during 10 years of monthly observations, but data on other components of the island's fauna are uneven because of sampling artefacts, with a bias towards large land snails, large butterflies and snakes. Nevertheless, the richness of these groups indicates that the numerous rugged sandstone islands along this tropical sub-humid coastline support complex faunas.

INTRODUCTION

Koolan is the only Kimberley island with a long history of invertebrate and vertebrate collection. While the earliest record we can find is of the land snail *Kimboraga koolanensis* described by Iredale (1939), most collections have been made since 1965.

Broken Hill Pty Ltd developed an iron ore mine on the island during the 1960's. By 1985 there were 150 houses and nearly 900 residents, and a range of exotic plants and animals had been introduced. Fortunately, domestic cats and un-sterilised female dogs were forbidden.

The geology of Koolan is described in Tyler and Griffin (1993). The island has an area of 2580 hectares. Its Proterozoic sandstone lithology is expressed as rugged slopes, ridges and uplands mantled with rock scree and shallow skeletal soils that support savanna woodland communities of eucalypts over hummock grass. The coast is steep with narrow gullies and frequent embayments, but few beaches.

Koolan has a tropical sub-humid climate. It receives an average of about 960 mm of rainfall annually. The "Wet" usually extends from December to April, although most rain falls in January, February and March. Virtually no rain falls from May to November.

Data on of the island's indigenous animals were accumulated gradually by island residents and occasional visitors. This opportunistic pattern of

sampling has left gaps in our knowledge of the island's vertebrates and macro-invertebrates, particularly among the relatively immobile taxa likely to be most affected by introduced species. The only systematic biological surveys were monthly bird observations made by one of the authors (L.F.) over the period 1983 to 1993.

From 9 to 15 February 1993, two botanists and one zoologist from CALM collected plants, earthworms, land snails, reptiles and bats to reduce this sampling bias. The field work was carried out just a few months after the mine closed to provide a basis for monitoring the persistence of indigenous and introduced species; the town and mine infrastructure were being dismantled at the time.

This paper reviews the zoological data available from Koolan. Keighery *et al.* (1995) present the corresponding botanical data.

METHODS

The majority of the zoological voucher specimens from Koolan were collected opportunistically by BHP employees resident on the island. Most are lodged at the Western Australian Museum, but some Koolan land snail specimens are held by the American Museum and the Chicago Field Museum of Natural History (Solem 1985).

A search of the invertebrate registers at the W.A. Museum revealed that L. Vernon (= L.F.), O.

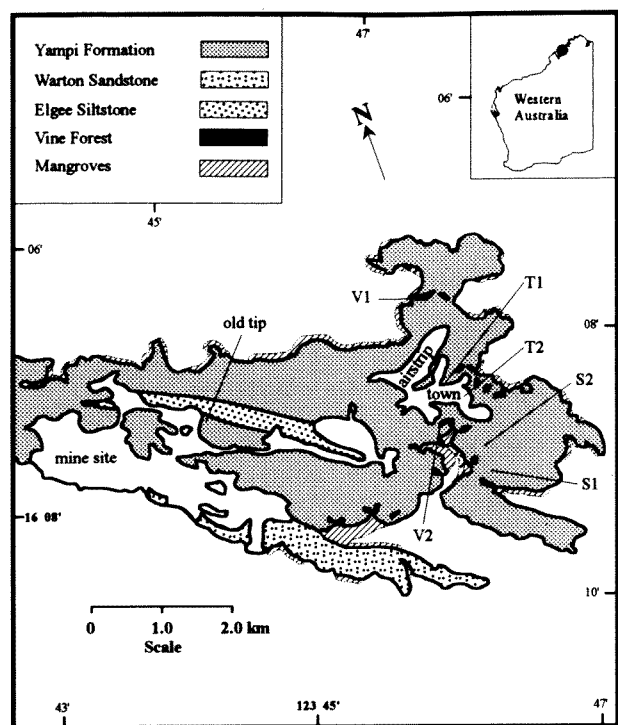


Figure 1 Eastern end of Koolan Island, showing principal 1993 collecting sites.

Milton, F.C. van Ingen and W.H. Butler collected a range of arachnid, myriapod and insect specimens from Koolan between 1965 and 1990. The bulk of these invertebrate collections remain to be identified; only the butterflies and the registered specimens of arachnids and myriapods are listed herein. Butterfly nomenclature follows Common and Waterhouse (1981). The butterflies were identified by M.R. Williams; we have incorporated the records listed by Koch and van Ingen (1969) and Koch (1975) although the relevant specimens have neither museum registration numbers nor field collection numbers.

The February 1993 field work was carried out at the height of the "Wet", when most tropical plants flower and set seed (Wheeler *et al.* 1992). This is also the best time to collect the region's indigenous earthworms. Kimberley earthworms aestivate deep in the soil profile during the six- to eight-month dry season; they are active near the surface only during the "wet" (McKenzie and Dyne 1991). There were heavy rains during the fieldwork in February 1993; soil profiles on Koolan were damp to moist. A total of 28 earthworm quadrats (cf McKenzie and Dyne 1981) were sampled in the range of habitats on the eastern part of the Island: savanna woodlands, rainforest patches (semi-deciduous vine thickets), house gardens, and along a creek on the north side of town. Additional grab samples of earthworms were taken in town to increase the number of taxonomic vouchers. The earthworms were identified by Geoff Dyne (Department of the

Environment, Sport and Tourism, Canberra). Land snails were sought opportunistically in two vine thickets and in town; earlier records were gleaned from taxonomic literature. The land snails were identified by Vince Kessner (Adelaide River, Northern Territory).

The W.A. Museum holds reptile and mammal specimens collected by island residents such as N. Lindus (from 1981 to 1993), L. Vernon (= L.F., 1983 - 1993), G. A. Robinson (1961), O. Milton (1965 - 7), F.C. van Ingen (1965 - 74). Specimens were also contributed by visitors such as W.H. Butler (June 1965 and November 1973), B. Maryan and D. Robinson (August 1992) and other biologists during brief visits. During our February 1993 field work on Koolan, we used mist nets and ultrasound recorders to survey bats that were foraging in the savanna woodlands, mangroves and town. Bats were also sought in their day-roosts in caves and buildings. We set traps for non-volant mammals in the savanna woodlands and along the edge of the mangroves and foot of the scree slope near site V2 (Figure 1), and made nighttime spotlighting traverses along the island's road network. In contrast, our approach to sampling amphibians and reptiles was entirely opportunistic.

Reptile taxonomic names follow Ehmann (1992); Numbers prefixed with "R" or "M" in the vertebrate species lists refer to specimen registration numbers at the W.A. Museum. Other specimen numbers in brackets relate to data from animals captured during the 1993 survey, but subsequently released.

One of the authors, Lee Fontanini (= L.F.) lived on Koolan Island from 1983 to 1993. The bird list herein summarises her 10 years of monthly observations in terms of species' seasonal presence, abundance and habitat-use. Nomenclature follows the Blakers *et al.* (1984). Mangroves around Koolan are either narrow fringes or difficult to reach, so her visits were infrequent (once or twice per year) and restricted to the stands in "Barramundi Bay", south of town. These are by far the largest stands on the island.

Latitude and longitude coordinates cited in the text were measured from the "Yampi" 1:100 000 series topographic map.

RESULTS

Earthworms

We recorded two indigenous species belonging to the genus *Diplotrema*, and an introduced species *Dichogaster bolau* (Michaelsen) that was only found in town gardens. In contrast, *Diplotrema* were common in the vine thickets, scarce in the savanna woodlands, and were not found in the townsite. To confirm the scarcity of earthworms in the

Table 1 Location and habitat of the sites that were systematically sampled for earthworms (see Figure 1).

Site	Location (°S, °E)	Geology ^a	Habitat	No. specimens
V1	16°07'00", 123°46'50"	Pky	vine thicket	9
V2	16°08'15", 123°46'40"	Pky	vine thicket	4
S1	16°08'50", 123°46'45"	Pky	savanna woodland	0
S2	16°08'40", 123°46'50"	Pky	savanna woodland	1
T1	16°08'00", 123°46'45"	Pky	swampy creek	0
T2	16°08'10", 123°46'45"	Pky	town gardens	20+

^aPky = Yampi Formation, comprising quartz, hematitic and feldspathic sandstone, siltstone and quartz conglomerate that, on Koolan Island, lies unconformably over Elgee Siltstone (Pke) (Tyler and Griffin 1993).

savanna woodlands, N.McK. dug more than 50 shallow potholes in valley floors, slopes and uplands north of the "old tip" (Figure 1) during our last two days on the island; no earthworms were found. The results of the formal, quadrat-based earthworm survey are summarised in Tables 1 and 2.

Land Snails

Subulinidae

Eremopeas interioris (Tate). Two dead shells were found under sandstone rocks in vine thicket V2 in February 1993 (see Table 1).

Helicarionidae

Westralcystis lissus (E.A. Smith). Two dead shells were found under sandstone rocks in vine thicket V2 (Feb. 1993).

Camaenidae

Torresitrachia bathurstensis (E.A. Smith). One dead juvenile was taken from soil on the bottom of a concrete culvert under the road near the workshop complex (Feb. 1993). Six dead shells

were found under sandstone rocks in vine thicket V2 (Feb. 1993).

Amplirhagada astuta (Iredale). The holotype (AM C.64857) was collected on Koolan Island. D. Milton sent additional specimens to the W.A. Museum in August 1966. On 14 February 1993, two were found crossing path in town after heavy rain. This species is endemic to Koolan.

Setobaudinia sp. (new species, *vide* V. Kessner). Two (live) were found under sandstone rocks in vine thicket V2 (Feb. 1993).

Kimboraga yampensis Solem. The type locality is a house garden on Koolan Island (WAM 604.80). The original specimens were collected in July 1967 by J. Milton and J. Bannister. In February 1993, one dead shell was found on the patio of a house in town, and a live specimen was taken from a pile of sandstone rocks in vine thicket V2.

Kimboraga koolanensis (Iredale). Known only from four very worn and bleached specimens from Koolan Island held by American museums (Holotype: AM C.64873, Koolan Island). The

Table 2 Occurrence of earthworms on Koolan Island.

Site	Density (m ⁻²)	Abundance ^a Biomass (g m ⁻²)	Occurrence ^b	Species recorded
Vine Thickets				
V1	52.5+/-20.6	9.5+/-6.5	3/4	<i>Diplotrema</i> sp. "koolan2"
V2	18.2+/-10.6	5.1+/-3.2	2/4	<i>Diplotrema</i> sp. "koolan1"
Total:	35.4+/-12.5	7.3+/-3.5	5/8	
Savanna Woodlands				
S1	0	0	0/5	None found
S2	5.0+/-5.0	1.0+/-1.0	1/4	<i>Diplotrema</i> sp. ^c
Total:	2.2+/-2.2	0.4+/-0.4	1/9	
Creek				
T1	0	0	0/3	None found
Town Gardens				
T2	22.5+/-14.9	1.2+/-0.8	2/8	<i>Dichogaster bolau</i>

^a Mean +/- standard error (number of quadrats sampled).

^b Number of quadrats with worms / number of quadrats sampled.

^c Too sexually immature to be placed taxonomically.

collector and date of collection are unknown. Solem (1985) commented that the species should never have been described because "The available material is so badly worn that reference to a genus with any degree of certainty is impossible. ... The large number of whorls, reflected lip, lack of body whorl inflation and lack of body whorl descension also suggest it is not a *Kimboraga*."

Veronicellidae

Laevicaulis alte (Ferussac). Three specimens of this introduced slug were taken from the garden of "house No. 90" in town.

Scorpions

Scorpionidae

Urodacus koolanensis Koch. Koolan is the type locality of this endemic Kimberley scorpion. It was collected on Koolan by O. Milton in September 1966 (WAM 68/487).

Buthidae

Lychas alexandrinus Hirst was collected by O. Milton in September 1969 (WAM 73/590). It is widely distributed in arid and semi-arid areas of Australia.

Centipedes

Scolopendridae

Scolopendra morsitans (Linnaeus). A centipede with a world-wide distribution that was collected from Koolan in September 1966 (WAM 80/1490).

Spiders

Ctenizidae

Conothele sp. This undescribed trapdoor spider was found in the Koolan Island supermarket in July 1984 (WAM 93/79), and sent to the WA Museum by L.F.

Theraphosidae

Selenocosmia stirlingi Hogg. Collected by P.R. Davis in a house in town in January 1987 (WAM 90/1931). It occurs across northern Australia.

Selenocosmia sp. (WAM 91/290-291).

Tetragnathidae

Nephila edulis (Labillardiere). An Orb-weaver collected by F.C. van Ingen in May 1979 (WAM 92/1987). Elsewhere in the northern Kimberley it is common only in savanna woodland (Main 1991). It occurs in sub-humid and semi-arid areas.

Heteropodidae

Neosparassus sp. This huntsman was collected by O. Milton in July 1967 (WAM 88/954-956).

Isopedella castanea Hirst. Collected by W.H. Butler in June 1965 (WAM 86/660). It occurs only in the Kimberley.

Actinopodidae

Missulena pruinosa Levitt-Gregg. Collected by L.F. in June 1990 (WAM 90/1720). This trapdoor spider occurs elsewhere in the Kimberley and other wetter parts of northern Australia, normally in rainforests.

Missulena sp. Collected by L.F. in July 1984 (WAM 94/947).

Barychelidae

A trapdoor spider belonging to this family was sent to Barbara York Main (Zoology Department, University of Western Australia) by P. Kovalers in February 1973.

Ants

Formicidae

Monomorium destructor (Jerdon). The Singapore Ant was accidentally introduced to Koolan in a cargo container. P.R. Davis, an entomologist with the Western Australian Department of Agriculture, assessed the problem in 1987, and reported to BHP (unpublished) that the species was common only on the eastern edge of town. By 1990 it had become a significant pest throughout the townsite (P. Bellairs, pers. comm.).

Oecophylla smaragdina (Fabricius). P.R. Davis (pers. comm.) observed Green Tree Ants during his 1987 visit.

Butterflies

Hesperiidae

Chaetocneme denitza (Hewitson). Previously known from the sub-humid Northern Territory and east coast of Queensland.

Cephrenes trichopepla (Lower). A Torresian distribution, throughout northern Australia.

Pelopidas lyelli lyelli (Rothschild). Listed as observed, but not collected, by Koch and van Ingen (1969). No specimens were located in the W.A. Museum collection. It has a Torresian distribution, occurring throughout northern Australia.

Papilionidae

Papilio demoleus sthenelus W.S. Macleay. Found throughout mainland Australia.

Papilio canopus canopus Westwood. Listed by Koch and van Ingen (1969), but we were unable to find any voucher specimens in the W.A. Museum collection. Known from the sub-humid Kimberley and Northern Territory. Koolan is at the southern limit of its range.

Graphium eurypylus nyctimus (Waterhouse and Lyell). Known only from Koolan and the sub-humid Northern Territory.

Cressida cressida cassandra (Waterhouse and Lyell). Known from the sub-humid Kimberley and Northern Territory. Koolan is at the southern limit of its range.

Nymphalidae

Euploea core corinna (W.S. Macleay). Koch and van Ingen (1969) listed *E. sylvester pelor*, but the only specimens we have been able to locate in the W.A. Museum are *E. core corinna*, all dated between 1965 and 1967.

Danaus affinis affinis (Fabricius). Occurs throughout the Torresian Zone.

Danaus hamatus hamatus (W.S. Macleay). Another pan-Torresian species.

Danaus chrysippus petilea (Stoll). Known throughout mainland Australia.

Hypolimnas bolina nerina (Fabricius). Throughout northern and eastern Australia.

Hypolimnas missipus (Linnaeus). Pan-Torresian.

Polyura pyrrhus sempronius (Fabricius). Found throughout northern, eastern and south-eastern Australia.

Acraea andromacha andromacha (Fabricius). Occurs throughout northern, eastern and south-eastern Australia.

Junonia orithya albicincta Butler. Pan-Torresian.

Junonia villida calybe (Godart). Found throughout Australia.

Vanessa itea (Fabricius). Not listed by Koch and van Ingen (1969), although there is a single Koolan specimen dated December 1964 in the W.A. Museum collection. Previously known only from southern Australia.

Hypocysta adiante antirius Butler. Known from the sub-humid Kimberley and Northern Territory. Koolan is at the southern limit of its range.

Melanitis leda bankia (Fabricius). Pan-Torresian.

Xoia arctoa arctoa (Fabricius). Occurs throughout the Torresian Zone and along the entire eastern coast of Australia.

Pieridae

Delias argenthona fragalactea (Butler). Occurs throughout the sub-humid Kimberley and Northern Territory.

Anapheis java teutonia (Fabricius). Listed by Koch and van Ingen (1969), but we were unable to find any specimens in the W.A. Museum collection. It is found throughout mainland Australia.

Cepora perimale scyllara (W.S. Macleay). Pan-Torresian.

Catopsilia scylla etesia (Hewitson). Common throughout most of the northern half of Australia.

Catopsilia pomona pomona (Fabricius). Common throughout northern and eastern Australia.

Eurema laeta lineata (Miskin). Occurs across northern Australia, north of latitude 16°S.

Eurema herla (W.S. Macleay). Widespread in northern and eastern Australia.

Eurema sana (Butler). Occurs across northern Australia, north of latitude 16°S.

Eurema smilax (Donovan). Found throughout mainland Australia.

Eurema hecabe phoebus (Butler). Common throughout most of the northern half of Australia.

Lycaenidae

Arhopala centaurus asopus Waterhouse and Lyell. Known from the Kimberley and sub-humid Northern Territory. Koolan is at the southern limit of its range.

Zizina labrudus labrudus (Godart). Occurs throughout Australia.

Prosotas ?nora (Waterhouse and Lyell). Listed by Koch and van Ingen (1969); a tentative identification based upon damaged specimens.

Amphibians

Hylidae

Litoria rubella. Seen along wet season creeks where rock bars form temporary waterholes, in garden fish ponds, around the town swimming pool and sometimes inside houses during the wet season. Numerous at the edge of an ephemeral pool in a bulldozer scrape in savanna woodland 0.5 km south-east of town (R115770, Feb. 1993).

Reptiles

Crocodylidae

Crocodylus porosus occurs at the tideline in

mangrove inlets and mudflats around the island.

Gekkonidae

Gehyra australis. Nocturnal. Very common in houses and other buildings. More active during the wet season. L.F. observed up to eight individuals at once on the lounge room wall in her house. Also seen catching insects on roads under and on street lights, especially when flying termites were active. Found under buildings, in cupboards, behind pictures hanging on walls etc during the day. Also observed drinking at a bird nectar feeder, and eating banana and mango in a basket of fruit and honey left for birds (L.F. and N.L., pers. obs.). The W.A. Museum has five records spanning the period 1965 to 1993. The most recent specimen (R115707, Feb. 1993) was on a water tank in savanna woodland overlooking aerodrome at western end of town.

Gehyra nana. Three records. One was under sandstone rocks on sandy soil in the savanna woodland in the island's central plateau north of the mine site (R115772, Feb. 93). The other two were under sandstone rock in an open savanna woodland of eucalypts over *Acacia* shrubs with a low grass understorey (R114449 - 50, Aug. 1992).

Gehyra occidentalis. Five records spanning the period 1965 to 1992. Two were under sandstone rock in an open savanna woodland of eucalypts over *Acacia* bushes in the Koolan Island townsite (R114451 -2, Aug. 1992). Another was on a fig tree in a low open savanna woodland of *Eucalyptus miniata* and *Ficus* over hummock grass in a sandstone valley (R114453, Aug. 1992). One was found on the window frame of a house in the town. (R115714, Feb. 1993).

Heteronotia binoei. Two records in August 1992 (R11419 -20). Both were found under rubbish in town. The surrounding vegetation was an open savanna woodland of eucalypts over *Acacia* shrubs on sandstone.

Heteronotia planiceps. Seven records between 1981 and 1993. Two were under rubbish in open savanna woodland of *Eucalyptus miniata* over hummock grass on a sandstone scree-slope (R114447 -8, Aug. 1992). One was in eucalypt leaf litter in an open savanna woodland of eucalypts over *Acacia* shrubs on sandstone (R114400, Aug. 1992). Another was "under rubbish" in the townsite (R114463, Aug. 1992). One was found under rocks in vine thicket V1 (R115710, Feb. 1993, see Table 1).

Oedura gracilis. One on sandstone rock (Pky) in an open savanna woodland of *Eucalyptus miniata* over hummock grass (R114396, Aug. 1992).

Oedura obscura. One on a *Calytrix* shrub in a low sandstone valley supporting a low open savanna woodland of *Eucalyptus miniata* over *Ficus* and hummock grass (R114468, Aug. 1992).

Oedura rhombifera. The W.A. Museum has two specimen records from the period 1966-7. Often found under buildings. Two lived in a hollow curtain rod in L.F.'s lounge room. They foraged for insects on the lounge room walls at night. There are no other habitat data.

Pygopodidae

Delma borea. The W.A. Museum received five specimen records between 1966 and the late 1980's. Found under leaf litter in open savanna woodland of eucalypts over *Acacia* on sandstone. In town, they were found on the ground under garden mulch and sheets of tin, and sometimes seen during the day as they crossed the road.

Lialis burtonis. Found in open savanna woodland of eucalypts over *Acacia* shrubs and grasses on sandstone. Seen on roads in town at night. Three colour phases were noted on Koolan: dorsal-surface reddish brown, dark greyish brown or light grey; ventral surface salmon, dark brown or light grey respectively. The W.A. Museum has one specimen from Koolan, taken in August 1970..

Agamidae

Diporiphora bennettii. The WAM has fifteen records between 1965 and 1993. The August 1992 record (R114397) was basking on "ironstone" rock (presumably Pky) on a rocky slope supporting savanna woodland of eucalypts over dense *Triodia* and other grasses. Another was under a sandstone rock in savanna woodland on sandy soil in the island's central plateau north of the mine site (R115708, Feb. 93).

Scincidae

Carlia amax. Three records between 1973 and 1992. One was found under rubbish in town and another on eucalypt leaf litter in open savanna woodland of eucalypts over *Acacia* shrubs on sandstone (R114401, 114423, Aug. 1992).

Carlia triacantha. Six records between 1965 and 1983. The species was found on leaf litter among sandstone rocks in vine thickets.

Cryptoblepharus carnabyi. Frequent around houses in town, on pillars and garden rockeries (N.L. pers. obs.). One was found running on rocks and leaf litter in vine thicket V2 (R115713, Feb. 1993, see Table 1).

Ctenotus inornatus. Six records between 1970 and 1993. The 12 February 1993 record was collected south-east of the town at site S1 (see Table 1) in

low open savanna woodland of *Eucalyptus* and *Terminalia* over *Triodia* hummock grassland with patches of leaf litter on red clay loam with scattered sandstone (Pky) boulders (R115709).

Cyclodomorphus (= *Omolepida*) *maximus*. Only 10 individuals were seen over 12 years (by N.L.). All were seen in town during the wet season, either crossing the road, as road kills or in gardens. The W.A. Museum has two specimen records from the late 1980's.

Glaphyromorphus (*Sphenomorphus*) *isolepis*. There are three records from Koolan. One was under rubbish in the townsite (R114464, Aug. 1992). Two were found in garden compost in town (R115711 -2, Feb. 1993).

Tiliqua scincoides. Observed at the edge of town in savanna woodland on sandstone, feeding on fallen ripe mangoes in town gardens, and drinking at bird baths (N.L., pers. obs.). Eight young were taken from a female "road kill" (January). The six that were still alive were hand-reared and released by L.F.

Varanidae

Varanus acanthurus. Four records. Three in 1986. The fourth was under sandstone rocks on sandy soil in the savanna woodland in the island's central plateau north of the mine site (R115715, Feb. 93). There are three other records from 1986.

Varanus glebopalma. The most commonly seen monitor on the island. It lived in the savanna woodlands, vine thickets, and in town where it was often seen drinking at bird baths and fish ponds. One was seen killing and eating a Green Tree Snake (*Dendrolaphis punctulatus*). The W.A. Museum has one specimen collected in 1966.

Varanus glauerti. Seen in savanna woodlands at the edge of town and in town gardens (N.L., pers. obs.). A sub-adult was rescued from a "Golden Orb Weaver's" web.

Boidae

Aspidites melanocephalus. During his June 1965 visit, W.H. Butler was shown photographs of several snakes from Koolan. According to his unpublished field notes (lodged in the W.A. Museum), one was of a Black-headed Python.

Morelia childreni. Three records between 1966 and 1982 (R29142, 41506 and 106028). The May 1972 record (R41506) was caught by R.E. Johnstone at night on a road through a savanna woodland of *Eucalyptus miniata* and *Callitris intratropica* on the edge of town.

Liasis olivaceus. The most commonly seen snake on Koolan (L.F. and N.L., pers. obs.). Observed on roads at night and in the savanna woodlands,

especially down gullies near temporary waterholes. Sometimes found in buildings. Often foraged arboreally: seen in eucalypts such as *Eucalyptus miniata*, and twice heard falling to the ground under the Mango tree (*Mangifera indica*) behind Lee Fontanini's house, having caught a flying fox (*Pteropus alecto*). Also preyed on birds drinking at leaking water bores. Prey included Yellow-throated Miner, Double-barred Finch, and domestic pets such as caged birds and Guinea Pigs.

Colubridae

Boiga fusca ornata (= *irregularis*). Observed in savanna woodlands, vine thicket (once), town gardens and at night as it crossed roads. The W.A. Museum has one Koolan specimen, collected in 1967.

Dendrolaphis punctulatus. Found in gardens, inside houses and as it crossed roads at night. Also observed moving through savanna of *Eucalyptus miniata* over hummock grass on sandstone scree, and in vine thicket (N.L., pers. obs.). The W.A. Museum has three records of the Green Tree Snake, spanning the years 1966 to 1981.

Elapidae

Furina ornata. Found on roads, in town gardens and in the savanna woodlands. The four specimens in the W.A. Museum were all collected after 1979.

Acanthophis praelongus. Found in town gardens and in the savanna woodlands. On warm nights they were seen crossing roads and lying on concrete paths. The W.A. Museum holds five Death Adders from Koolan Island. One was received in October 1966 and the other four are dated 8 August 1970.

Oxyuranus scutellatus. The W.A. Museum has three specimens of Tiapan from Koolan, one sub-adult and two adults. The species was first collected in 1984 (R91244) as a road-kill in town. In 1985, an adult was killed by a dog in town (R106029). Two other adults have been found in open savanna woodland of eucalypts over *Acacia* shrubs and grasses on sandstone (R103731, road-kill, late 1980's). All three adults were recorded on particularly hot days (N.L., pers. obs.).

Pseudechis australis. Recorded on roads at night, in town, and in the savanna woodlands of eucalypts, *Callitris*, *Acacia* shrubs and grasses on sandstone surfaces. The WAM's eight "King Brown" specimens from Koolan were recorded between 1966 and 1986. They are small and brownish (L.A. Smith, pers. comm.).

Demansia papuensis melaena. One Greater Black Whipsnake in August 1974 (R47684). There are no habitat data.

Demansia olivacea. The W.A. Museum has five Koolan specimens of the Olive Whipsnake spanning the years 1965 to 1988. It has been observed in the savanna woodlands, and foraging under leaf litter in a town garden.

Typhlopidae

Ramphotyphlops kimberleyensis. One from the townsite (R91044, May 1985). In garden rubbish: a pile of sticks, grass and leaf litter containing many ants.

Ramphotyphlops yampiensis. The only known specimen of this species was collected on Koolan (March 1966, 13 cm long). No habitat data are available (R26839).

Birds

Australian Pelican (*Pelecanus conspicillatus*). Seen once, a single bird, at wharf.

Brown Booby (*Sula leucogaster*). Seen once, marine

Least Frigatebird (*Fregata ariel*). All seasons, common, marine.

Great-billed Heron (*Ardea sumatrana*). Wet season and early dry, scarce, mangroves and coastal mudflats.

White-faced Heron (*Ardea novaehollandiae*). Scarce in dry season, rare in Wet, mangroves and town sewerage outfall.

Eastern Reef Egret (*Egretta sacra*). All seasons (resident), common, all coastal habitats.

Striated Heron (*Butorides striatus*). All seasons (resident), common, mangroves.

Black-necked Stork (*Xenorhynchus asiaticus*). Four seen in 10 years, coastal.

Sacred Ibis (*Threskiornis aethiopicus*). Two seen in 10 years, lawn of school oval.

Straw-necked Ibis (*Threskiornis spinicollis*). Four seen in 10 years, lawn of school oval.

Royal Spoonbill (*Platalea regia*). One seen in 10 years, lawn of school oval.

Black Swan (*Cygnus atratus*). Seen once in 10 years, party of 12, at wharf.

Osprey (*Pandion haliaetus*). All seasons (resident), common, coastal.

Black-shouldered Kite (*Elanus notatus*). Two seen in 10 years, foraging over airstrip.

Black Kite (*Milvus migrans*). Regularly seen in dry season, uncommon, town rubbish dump.

Brahminy Kite (*Haliastur indus*). All seasons (resident), common, foraged in all habitats.

Whistling Kite (*Haliastur sphenurus*). Regularly seen except in mid wet season.

Brown Goshawk (*Accipiter fasciatus*). All seasons (resident), common in woodlands, occasionally seen in mangroves.

White-bellied Sea-Eagle (*Haliaeetus leucogaster*). All seasons (resident), common, coast and town dump.

Wedge-tailed Eagle (*Aquila audax*). All seasons, uncommon, all habitats including town rubbish dump.

Little Eagle (*Hieraaetus morphnoides*). All seasons, uncommon, town and woodlands.

Spotted Harrier (*Circus assimilis*). Seen once in 10 years.

Peregrine Falcon (*Falco peregrinus*). Seen twice in 10 years.

Australian Hobby (*Falco longipennis*). All seasons, uncommon, woodlands and town.

Grey Falcon (*Falco hypoleucos*). Seen once in 10 years, woodland.

Brown Falcon (*Falco berigora*). Uncommon in dry season, scarce in wet season, woodlands.

Australian Kestrel (*Falco cenchroides*). Scarce, usually over open-cut mine.

Brown Quail (*Coturnix australis*). All seasons (resident), common, woodlands and town.

Red-chested Button-quail (*Turnix pyrrhothorax*). Seen once in 10 years, edge of town.

Buff-banded Rail (*Rallus philippensis*). Seen once in 10 years, in town garden.

Baillon's Crake (*Porzana pusilla*). Seen once in 10 years, in brightly lit mine workshop at night.

Bush Thick-knee (*Burhinus magirostris*). One found dead in town.

Large Sand Plover (*Charadrius leschenaultii*). Seen twice in 10 years, early wet season, coastal mudflat.

Eastern Curlew (*Numenius madagascariensis*). One seen in 10 years, wet season, coastal mudflat.

Whimbrel (*Numenius phaeopus*). All seasons, scarce, coastal mudflats.

Little Curlew (*Numenius minutus*). Late dry season and early wet, scarce, usually on lawn of school oval.

Grey-tailed Tattler (*Tringa brevipes*). Late dry and wet season, scarce, coastal mudflats.

Common Sandpiper (*Tringa hypoleucos*). All seasons, scarce, coastal mudflats and mangroves.

Greenshank (*Tringa nebularia*). One seen in 10 years, wet season, coastal mudflat.

Black-tailed Godwit (*Limosa limosa*). One seen in 10 years, late dry season, coastal mudflat.

- Australian Pratincole (*Stiltia isabella*). Three seen in 10 years, airstrip and road verges.
- Silver Gull (*Larus novaehollandiae*). All seasons, common, town rubbish dump and wharf.
- Caspian Tern (*Hydroprogne caspia*). Uncommon, marine.
- Crested Tern (*Sterna bergii*). Uncommon, marine.
- Rose-crowned Fruit-Dove (*Ptilinopus regina*). One seen in 10 years, in thicket of *Ficus opposita* near powerhouse.
- Peaceful Dove (*Geopelia placida*). All seasons (resident), common, all habitats except coastal mudflat.
- Diamond Dove (*Geopelia cuneata*). One seen in 10 years, wet season, in town.
- Bar-shouldered Dove (*Geopelia humeralis*). All seasons (resident), common, all habitats except coastal mudflat.
- Common Bronzewing (*Phaps chalcoptera*). All seasons (resident), common, all habitats except coastal mudflat.
- Red-tailed Black-Cockatoo (*Calyptorhynchus magnificus*). All seasons (visitor), common, woodlands.
- Little Corella (*Cacatua sanguinea*). All seasons except late wet, common, woodlands.
- Red-collared Lorikeet (*Trichoglossus rubritorquis*). All seasons except mid-dry (May – July), common, woodlands and town where it fed on flowering *Eucalyptus miniata*, then on garden mangos (*Mangifera indica*), then when the mango trees finished flowering, fed on flowering *Eucalyptus confertiflora*.
- Varied Lorikeet (*Psitteuteles versicolor*). Only in late dry season (when the *Eucalyptus miniata* flowered), scarce, woodlands.
- Red-winged Parrot (*Aprosmictus erythropterus*). All seasons (resident), common, all habitats except open coastal mudflats.
- Northern Rosella (*Platycercus venustus*). All seasons (resident), common, all habitats except mangroves and open coastal mudflats.
- Oriental Cuckoo (*Cuculus saturatus*). One seen in 10 years, wet season, in town.
- Pallid Cuckoo (*Cuculus pallidus*). Two seen in 10 years, in town.
- Brush Cuckoo (*Cuculus variolosus*). One seen in 10 years, October, in town.
- Black-eared Cuckoo (*Chrysococcyx osculans*). Three seen in 10 years, in town.
- Horsfield's Bronze-Cuckoo (*Chrysococcyx basalis*). Three seen in 10 years, in town.
- Common Koel (*Eudynamis scolopacea*). One seen in 10 years, wet season (March), in town.
- Pheasant Coucal (*Centropus phasianinus*). All seasons (resident), common, all habitats except coastal mudflats.
- Southern Boobook (*Ninox novaeseelandiae*). All seasons (resident), common, woodlands and town.
- Barking Owl (*Ninox connivens*). Two seen in 10 years, in an African Sausage Tree (*Kigelia pinnata* – introduced) in a town garden.
- Tawny Frogmouth (*Podargus strigoides*). All seasons (resident), common, all habitats except open coastal mudflats.
- Australian Owlet-nightjar (*Aegotheles cristatus*). One seen in 10 years (April), on beach at dusk.
- Fork-tailed Swift (*Apus pacificus*). October to April (associated with clouds during build-up to wet season), common.
- Azure Kingfisher (*Ceyx azurea*). Five seen in 10 years, four in mangroves and one at town swimming pool.
- Blue-winged Kookaburra (*Dacelo leachii*). All seasons, uncommon but rowdy, woodlands and town.
- Red-backed Kingfisher (*Halcyon pyrrhopygia*). Three seen in 10 years, woodlands.
- Sacred Kingfisher (*Halcyon sancta*). All seasons, uncommon, all habitats except open coastal mudflats.
- Rainbow Bee-eater (*Merops ornatus*). Arrived in March and departed in November, common, all habitats except open coastal mudflats.
- Dollarbird (*Eurystomus orientalis*). Five seen in 10 years, vagrant, mainly in town.
- Barn Swallow (*Hirundo rustica*). One party of six seen in 10 years, wet season, over the town.
- Welcome Swallow (*Hirundo neoxena*). One party of three seen, in July 1985, over the town.
- Tree Martin (*Cecropis nigricans*). Mainly dry season, scarce, woodlands.
- Black-faced Cuckoo-shrike (*Coracina novaehollandiae*). Scarce in wet season (January – March) and common in dry, woodlands and town.
- White-bellied Cuckoo-shrike (*Coracina papuensis*). All seasons (resident), common, all habitats except open coastal mudflats.
- White-winged Triller (*Lalage sueurii*). Dry season visitor, uncommon, woodlands.
- Kimberley Flycatcher (*Microeca flavigaster tormenti*). Two seen in 10 years, mangroves.

- Mangrove Golden Whistler (*Pachycephala melanura*).
Two seen in 10 years, mangroves.
- Rufous Whistler (*Pachycephala rufiventris*). Scarce, woodlands.
- Sandstone Shrike-thrush (*Colluricincla woodwardi*).
All seasons (resident), common, sandstone cliffs.
- Broad-billed Flycatcher (*Myiagra ruficollis*). Four seen in 10 years, mangroves.
- Leaden Flycatcher (*Myiagra rubecula*). All seasons (resident), common, woodlands and edge of mangroves.
- Shining Flycatcher (*Myiagra alecto*). Two seen in 10 years, mangroves.
- Northern Fantail (*Rhipidura rufiventris*). All seasons (resident), common, all habitats except open coastal mudflats.
- Willie Wagtail (*Rhipidura leucophrys*). Arrived in March and departed in October, common, woodlands (including town) and mangroves.
- Lavender-flanked Fairy-wren (*Malurus lamberti rogersi*). All seasons (resident), common, all habitats except coastal.
- Weebill (*Smicrornis brevirostris*). All seasons (resident), common, all habitats except open coastal mudflats.
- Varied Sittella (*Daphoenositta chrysoptera*). Mainly dry season, uncommon, woodlands.
- Silver-crowned Friarbird (*Philemon argenticeps*). All seasons (resident), common, all habitats except open coastal mudflats.
- Little Friarbird (*Philemon citreogularis*). Uncommon, dry season, woodlands (presence tied to *Eucalyptus miniata* flowering).
- Yellow-throated Miner (*Manorina flavigula*). All seasons (resident), common, all habitats except open coastal mudflats.
- White-gaped Honeyeater (*Lichenostomus unicolor*). All seasons (resident), common, all habitats except open coastal mudflats.
- White-throated Honeyeater (*Melithreptus albogularis*). All seasons (resident), common, all habitats except mangroves and open coastal mudflats.
- Brown Honeyeater (*Lichmera indistincta*). All seasons (resident), common, all habitats except open coastal mudflats.
- Rufous-throated Honeyeater (*Conopophila rufogularis*). Uncommon, mainly dry season, woodlands (while *Eucalyptus miniata* was flowering).
- Banded Honeyeater (*Certhionyx pectoralis*). Uncommon, mainly dry season, woodlands (while *Eucalyptus miniata* was flowering).

- Red-headed Honeyeater (*Myzomela erythrocephala*).
Three seen in 10 years, mangroves.
- Mistletoebird (*Dicaeum hirundinaceum*). All seasons (resident), common, all habitats except open coastal mudflats.
- Striated Pardalote (*Pardalotus striatus melanocephalus*). All seasons (resident), common, all habitats except mangroves and open coastal mudflats.
- Yellow White-eye (*Zosterops lutea*). All seasons (resident), common, all habitats except open coastal mudflats.
- Double-barred Finch (*Poephila bichenovii*). All seasons (resident), common, all habitats except open coastal mudflats.
- Gouldian Finch (*Erythrura gouldiae*). One seen in 1978, in town garden.
- Yellow Oriole (*Oriolus flavocinctus*). Three seen in 10 years, dry season, town and mangroves.
- Olive-backed Oriole (*Oriolus sagittatus*). Dry season, uncommon, all habitats except open coastal mudflats.
- Spangled Drongo (*Dicrurus hottentottus*). Late dry, scarce, woodlands and town.
- Great Bowerbird (*Chlamydera nuchalis*). All seasons (resident), common, all habitats except open coastal mudflats.
- Australian Magpie-lark (*Grallina cyanoleuca*). Arrive in April and depart in December, common, woodlands and town.
- Black-faced Wood-swallow (*Artamus cinereus melanops*). "One from low woodland" (Smith, Johnstone and Dell 1978)
- White-breasted Woodswallow (*Artamus leucorhynchus*). All seasons (resident), common, all habitats except open coastal mudflats.
- Little Woodswallow (*Artamus minor*). All seasons, uncommon, small parties in woodlands and town.
- Grey Butcherbird (*Cracticus torquatus*). All seasons (resident), common, woodlands and town.
- Pied Butcherbird (*Cracticus nigrogularis*). All seasons (resident), common, woodlands and town.
- Little Crow (*Corvus bennetti*). One flock of 20 seen at town rubbish dump in August 1985.

Mammals

Dasyuridae

- Dasyurus hallucatus* Gould. Common on Koolan Island. It was reported from the rubbish tips, wharf, mine-site and town, and was often killed on roads during the wet season. First collected

on Koolan in November 1959 (M4481, one of three males). Subsequent specimens include M6050, M7161-3 and M10606. In February 1993 we saw one at the swimming pool in town at dusk, and trapped an adult male in savanna woodland on steep sandstone scree (16°08'40"S, 123°47'35"E).

Muridae

Zyomys argurus (Thomas). The first specimen (M7562) was captured in August 1966. More recent specimens include M18568 (Kitchener 1989) and M24302-3. Seen crossing gravel road at night in open savanna woodland on sandstone scree. Also found in town garden sheds, under bags and nesting in potting mix. A 56.5 gm female with two 9.5 gm young attached to its nipples was found on 8 January 1990.

Pteropodidae

Pteropus alecto Temminck. Collected as a skull (M7848, adult) by O. Milton in 1967. The species has also been seen during the day, roosting in the mangroves south of town, and in *Ficus racemosa* in town. It was common in the savanna woodlands and town in all seasons except the mid-dry (May - July). It fed on flowering *Eucalyptus miniata* from August until November/December when the blossom finished, then on garden mangos (*Mangifera indica*) for a month or so until they finished

fruiting, after which it fed on flowering *Eucalyptus confertiflora* until late April (L.F., pers. obs.). On the nights of 11 and 12 February 1993, one was observed feeding on the flowers of *Eucalyptus cadophora* (Collection Nos: Keighery and Gibson 15 and 95, PERTH) at site T2 in town (Fig. 1).

Macroglossus minimus (Geoffroy). In 1989, one was captured in L.F.'s house in town at the time that her African Sausage Tree was flowering. It was subsequently released. We netted an adult female (not pregnant, not lactating) and an adult male at night on 11 February 1993 in the mangrove low forest south of town (mainly *Sonneratia alba*, *Camptostemon schultzei*, *Ceriops tagal*, *Avicennia marina* and *Rhizophora stylosa*).

Megadermatidae

Macroderma gigas (Dobson). Four specimens from Koolan are held by the W.A. Museum (M19707-10, June 1965). They belong to a series of seven males and four females that W.H. Butler took from their day-roost in "one of the old Japanese tunnels opposite the conveyer and the ore bin" (W.H. Butler, unpublished field notes). These adits were on the south side of the island near the loading jetty, but have subsequently been excavated as part of the ore-body.

Hipposideridae

Hipposideros stenotis Thomas. The W.A. Museum

Table 3 Observed foraging microhabitats of bats from Koolan Island in relation to species flight indices. Values were estimated using the method for live bats described in McKenzie *et al.* (1995). Where live bats were not taken on Koolan, values from adults taken elsewhere in the region have been used (mean +/- standard error).

Island	Foraging Microhabitat ^a	Aspect Ratio	Wing Loading (g cm ⁻²)	Tip Index
<i>Hipposideros stenotis</i>				
	hs1	6.22	0.045	1.48
	hs2	5.98	0.039	1.72
	M23057 ^a	6.26	0.037	1.86
<i>Nyctophilus arnhemensis</i>				
	na3	5.82	0.046	1.33
<i>Vespadalus caurinus</i> ^b (n = 7)				
	edge	6.35 (0.08)	0.040 (0.001)	1.34 (0.03)
<i>Chalinolobus nigrogriseus</i>				
	92/1	6.80	0.053	1.16
<i>Chalinolobus gouldii</i> ^c (n = 4)				
	edge	6.67 (0.06)	.063 (0.001)	0.95 (0.02)
<i>Taphozous georgianus</i> ^b (n = 11)				
	open	7.71 (0.05)	0.085 (0.003)	0.90 (0.02)
<i>Saccolaimus flaviventris</i> ^d (n = 1)				
	open	9.09	0.111	1.01

^a Categories follow Fenton (1990).

^a Bathurst Island; ^b Kununurra; ^c Barred Creek, near Broome; ^d Mitchell Plateau.

has three specimens from Koolan collected by W.H. Butler. One was caught in the "Japanese tunnels" (M19391, June 1965, adult male). The other two were taken from the "Acacia" exploration shaft at the "end of the island" (M10052-3, Nov. 1968, adult males) (W.H. Butler's unpublished field data). We found a pair roosting in a small, humid sandstone (Pky) cave overlooking the coast at 16°07'10"S, 123°44'30"E (13 Feb. 1993) and another pair roosting in a similar site at 16°07'29"S, 123°43'20"E (14 Feb. 1993). The first cave (1 m high x 3 m diameter) was under an exposed sheet of sandstone in savanna woodland on a gentle slope; the other was an upwardly angled fissure (0.7 m diameter) into a sheer cliff-face supporting hummock grass, *Ficus* and *Calytrix*. One adult male was captured from each pair (field numbers hs1 and hs2). When one of the Koolan specimens was released at night with a bioluminescent tag, its flight was slow, fluttering and within 1 m of the ground. Until it reached the cover of dense understorey shrubs, the bat had considerable difficulty controlling its height and directionality in the windy conditions at the time of its release. The species' ultrasound was recorded both hand-held (inside the darkened house at night) and at the time of release (Table 4). Flight morphology measurements from these Koolan and Bathurst individuals are presented in Table 3.

Hipposideros ater gilberti Johnson. Collected by W.H. Butler in the "Japanese tunnels" in June 1965 (M19390). A dead specimen was found in May 1990, and sent to the W.A. Museum by L.F.

Rhinonictes aurantius (Gray). A series of 7 males and 3 females was taken from their day-roost in the "Japanese tunnels" by W.H. Butler in June 1965 (M7445, 7450-2, 19388-9). He captured another in November 1968 "... at water level, in shaft near loading jetty on south side of island ..." (M10054).

Emballonuridae

Saccolaimus flaviventris (Peters). On 10 Feb. 1993, we recorded the ultrasound calls of this species as it foraged high over the woodland canopy at S1 (Figure 1; Table 4). The calls of this species are audible. In June 1982, one of the authors (N.McK.) collected a specimen (M23038) over a beach on Gibbings Island, just 19 km to the west of Koolan.

Taphozous georgianus Thomas. One was collected in the Koolan townsite in November 1961 (M4897). On 10 Feb. 1993, we recorded the ultrasound calls of this species as it foraged high over the woodland canopy at site S1 (Figure 1). On 14 Feb. 1993, we found two colonies of more than

10 individuals in their day roosts in caves on the northern face of the ridge at the old rubbish tip (16°07'40"S, 123°44'40"E); the three females discerned each had one young clinging to its underside. Additional ultrasound recordings were made in the caves.

Vespertilionidae

Nyctophilus arnhemensis Johnson. An adult male (M34448) was collected on Koolan in June 1990 by L.F. We netted another adult male (field number na3, 11 February 1993) at night in the mangrove low forest south of town (mainly *Sonneratia alba*, *Camptostemon schultzei*, *Ceriops tagal*, *Avicennia marina* and *Rhizophora stylosa*). It was later released with a bioluminescent tag, and flew away between the trees at shrub height, with frequent changes in direction. Ultra-sound was recorded both hand-held and as it flew off (Table 4). Flight morphology measurements are presented in Table 3.

Chalinolobus gouldii (Gray). Ultrasound calls referable to this species were recorded from bats flying at canopy height along the road through savanna woodland at S1 (Figure 1) on 10 February 1993. The *C. gouldii* ultrasound data used for the identification were recorded at Barred Creek near Broome (Table 4).

Chalinolobus nigrogriseus (Gould). A male was collected by W.H. Butler in November 1968 (M10055). We netted an adult male (field number 92/1) over a water tank west of town on the night of 9 February 1993. The surrounding vegetation was savanna woodland. Its ultrasound was recorded at night inside the dark house (Table 4). On 10 February 1993, we recorded the ultrasound calls of this species (Table 4) as it foraged around and under the tree canopies in savanna woodland at S1 (Figure 1). Flight morphology measurements are presented in Table 3.

Vespadalus caurinus (Thomas). First collected on Koolan in October 1963 by I. Crawford (M6012). This bat is common in the island's small caves, drains and culverts. On 10 February 1993, we captured five in their dayroost in a drain under the road at 16°08'00"S, 123°44'45"E: one adult male, one sub-adult and three females. One of the females was carrying two naked young, while a second was pregnant with twins. Three others were captured (with *Hipposideros stenotis*) at their day-roost in the cave at 16°07'10"S, 123°44'30"E (13 Feb. 1993). Three were subsequently released at night with bioluminescent tags, and their ultrasound recorded (Table 4). We recorded ultrasounds typical of this species around a house in the townsite on the night of 12 February 1993, and

as it foraged through the savanna woodland at S1 (Figure 1, Table 4) on the night of 10 February 1993.

Canidae

Canis familiaris Linnaeus. On 14 February 1993, we discovered and photographed fresh dog tracks on the western end of the island. The mine manager, Patrick Warrant, confirmed that a single feral dog appeared on Koolan about 1990.

Bovidae

Capra hircus Linnaeus. W.H. Butler (unpublished

field notes) reported the presence of feral goats in June 1965. The goat population was estimated at 120 in the mid-1980's (by L.F.), after which there were attempts to eradicate them. We found a goat skeleton behind the single men's quarters on the northern edge of the town in February 1993.

Caviidae

Cavia porcellus (Linnaeus). Guinea pigs were brought onto the island as cage pets, but there is no evidence of a feral population.

Table 4 Echolocation parameters for bats from Koolan Island recorded using D140 ultrasound detector (Pettersson Elektronik, Sweden), stored on TDK-MAXG60 Metal Type IV cassette tape using a Sony Walkman WMD6C, and measured by zero crossing analysis.

Code ¹	Situation ²	Number of calls	Average frequency (KHz) ³ CF or FM (min.-max.)	Duration ⁴ (ms)
<i>Hipposideros ater gilberti</i> (FM-CF-FM)				
E	confined	3	160(158-162)	3.2, 5.9, 5.8
<i>Rhinonictus aurantius</i> (FM-CF-FM)				
E	hand-held	44	112.5(112-113)	7.8(5.3-10.5)
E	free flying	24	110.5(110-111)	5.7(4.5-5.9)
<i>Hipposideros stenotis</i> (FM-CF-FM)				
hs2	hand-held	23	102.5(102-103)	18.1(15.4-20.9)
hs1	free flying	32	102.5(102-103)	13.5(10.2-21.1)
<i>Macroderma gigas</i> (st-st-FM, similar shape to the <i>Nyctophilus</i>)				
E	free flying	8	45.5(43.5-46.5)-56(54-59.5)	1.8(1.3-2.3)
E	perch	8	28.5(27.5-31)-36.5(35-38)	1.7(1.3-2.3)
<i>Nyctophilus arnhemensis</i> (st-st-FM)				
na3	free flying	18	42(33-49)-63.6(56-71)	2.1(1.4-3.4)
<i>Vespadalus caurinus</i> (st-FM)				
vc1	free flying	4	59.8(59-61)-66.3(64-66)	3.1(2.3-3.5)
vc2	free flying	9	60.6(58-62)-79.8(62-95)	2.5(2.0-4.5)
vc3	free flying	4	62.5(62-64)-70.7(68-74)	1.9(1.4-2.3)
<i>Chalinolobus nigrogriseus</i> (st-FM)				
92/1	confined	49	39.5*(38-41)-67.5(60-75)	1.61(0.8-2.2)
B	free flying	28	37.0(35.5-38.5)-58.7(38.5-75.5)	6.0(4.0-10.8)
<i>Chalinolobus gouldii</i> (st-FM)				
K	free flying	29	32.3(30.5-34)-47.4(34-71)	6.2(3.8-9.8)
B	free flying	30	31.3(30-33.5)-49.1(36-63)	7.3(3.4-9.8)
<i>Taphozous georgianus</i> (sh-FM)				
K	free flying	18	24.8(24-26)-26.7(26-27)	6.7(4.0-8.5)
<i>Saccolaimus flaviventris</i> (sh-FM)				
M	free flying	6	16.6(16-17)-18.5(18-19.5)	13.0(9.8-15.0)
M	feeding	5	17.4(16-19)-23.6(21-26)	6.5(3.0-8.3)

¹ Specimen code in annotated species list herein, or a recording of an unknown bat from Koolan (K), or recording of a tagged bat at Barred Creek near Broome (B), on Mitchell Plateau (M) or near Kununurra (E).

² Calls recorded either (a) after released at night with a bioluminescent tag or outside of a known roost (= free flying), (b) from bat held in the hand at night (= hand-held), (c) free flying in a confined space such as a cave or room (= confined), or (d) after perching in tree to forage (= perch).

³ CF = of constant frequency section of calls; FM = lowest and highest values of call frequency-time sweep. Call shapes include steep-sweep FM (st-FM), shallow-sweep FM (sh-FM) etc.

⁴ Average (max and min) call duration.

* In sets of one to three calls. Sets are 15 to 80 milliseconds apart, with individual calls inside a set 0.25 to 5 milliseconds apart.

Leporidae

Oryctolagus cuniculus Lilljeborg. European (White) Rabbits were brought onto Koolan as cage pets. Despite some escapes, there is no evidence of a feral population.

DISCUSSION

Koolan supports a sub-set of the Kimberley fauna. Although macro-invertebrates and vertebrates are incompletely sampled, its bird and snake faunas are surprisingly rich considering the island's small size and restricted range of habitats.

The indigenous earthworms all belonged to the genus *Diploptrema* (Acanthrodriinae *sensu*. Jamieson 1971) and are new to science. This genus is ubiquitous in rainforest patches elsewhere in the Kimberley where each patch has its own endemic species (McKenzie and Dyne 1991). The earthworm populations in Koolan Island rainforests were equivalent in terms of their density and abundance to those reported from rainforest patches on similar sandstone lithologies elsewhere in the Kimberley (mean \pm s.e. = 35.7/ \pm 5.8 m⁻², 9.2/ \pm 2.0 g m⁻², n = 42; from Tables 4 and 6 in McKenzie and Dyne 1991).

The Koolan savanna woodland specimen is the first *Diploptrema* recorded outside a rainforest environment in the Kimberley. This reflects the lack of previous attempts to survey earthworms in Kimberley savannas, exacerbated by their presence near the surface only after heavy rains and their relatively low density (Table 2). Unfortunately, the

specimen was so sexually immature that it could not be placed taxonomically in relation to the island's other *Diploptrema*: *D. "koolan1"* and *D. "koolan2"*.

Dichogaster bolau, an introduced earthworm that is cosmopolitan in tropical and subtropical parts of the world, was the only species recorded in the gardens of houses in the town. These lush tropical gardens had been established for up to 20 years, and included many species of broad-leaf trees and shrubs such as Banana palms, Sausage Trees and Frangipani. Most had reticulated watering systems to overcome the annual seven month drought of the dry season. Our failure to find *Diploptrema* in these gardens may have related to the presence of the *D. bolau*. This species was probably introduced with potted garden plants during the 1960's, although a box of earthworms was brought onto the island in the early 1980's (L.F., pers. obs.). Elsewhere in Australia, introduced earthworms are known to displace native species from disturbed soil profiles (Wood 1974, Abbott 1985). *Dichogaster bolau* was not recorded outside the town boundaries.

Only seven species of indigenous land snail have been recorded from Koolan Island. Their phylogenetic affinities are with taxa on the adjacent Kimberley mainland (Solem 1991). Three species are known only from Koolan (*Kimboraga koolanensis*, *Setaubaudinea* sp. and *Amplirhagada astuta*).

In 1988, V. Kessner (pers. comm.) recorded five other non-camaenid species on islands elsewhere in the Buccaneer Archipelago: *Gastrocopta*

Table 5 Syntopic land snail assemblages from other islands in the Buccaneer Archipelago (collected by V. Kessner in 1988).

Species	Cockatoo ¹	"Unnamed" ²	Dunvert ³
Pupillidae			
<i>Nesopupa mooreana</i> Pilsbry	–	X	X
<i>Gastrocopta macrodon</i> Pilsbry	X	X	X
<i>Pupoides pacificus</i> (Pfeiffer)	X	–	–
Subulinidae			
<i>Eremopeas interioris</i> (Tate)	–	X	X
Helicodiscidae			
<i>Stenopylis coarctata</i> (Moellendorff)	X	–	–
Charopidae			
<i>Discocharopa aperta</i> (Moellendorff)	–	–	X
Helicarionidae			
<i>Westralcystis lissus</i> (E.A. Smith)	X	X	X
Camaenidae			
<i>Torresitrachia bathurstensis</i> (E.A. Smith)	X	X	X
<i>Kimboraga yampensis</i> Solem 1985	X	X	X

¹ 16°05'15"S, 123°35'20"E. Under shady bushes on a steep sandstone (Pky) slope (23 July 1988)

² 16°12'15"S, 123°32'40"E. Vine thicket on a mudstone substrate (26 July 1988).

³ 16°17'45"S, 123°30'50"E. In a small patch of vine thicket on a very steep sandstone scree slope (26 July 1988).

macrodon, *Pupoides pacificus* *Stenopylis coarctata*, *Nesopupa mooreana* and *Discocharopa aperta*. These species are all likely to occur on Koolan because they disperse readily (see Solem and McKenzie 1991) and were found in environments that are well represented on the island (Table 5). For the same reasons, two of the other non-camaenid species that are known from the adjacent mainland might occur on Koolan: *Pumilicopta kessneri* Solem 1989 and *Gastrocopta simplex* Solem 1989 (Pupillidae). In our opinion, a further field survey is needed if a complete listing of the island's non-camaenid land snails is to be obtained.

Six camaenid species (five genera) are known from the Buccaneer Archipelago. Four of these are known to occur on Koolan. Unlike the other land snail families represented in the Kimberley, most camaenid genera show strongly localised patterns of endemism at the species level (Solem 1991). Thus, species such as *Amplirhagada astuta* and the *Setobaudinia* sp. may be endemic to just a few adjacent islands. Others such as *Kimboraga yampensis* are also known from the adjacent mainland (Solem 1991). Data in Table 5 and Solem (1991) suggest that *Torresitrachia bathurstensis*, a representative of the genus *Rhagada* and even a seventh species could also occur on Koolan (NGEN5 NSP50 *vide* A. Solem was collected by V. Kessner from an old termite nest on nearby Margaret Island, 16°09'30"S, 123°34'20"E, 26 July 1988).

We found only one introduced land-dwelling mollusc on Koolan (*Laevicaulis alte*). Although this slug occurs elsewhere in tropical Australia, and ranges as far south as Dampier in Western Australia, it is confined to watered gardens and may not persist on the Island once the town is dismantled.

The list of 34 Koolan butterflies is a sub-set of the Kimberley fauna, although the single specimen of *Vanessa itea* is the first record from the north Kimberley. The collection is dominated by large species. Except in the families Lycaenidae and Hesperidae, the island's butterfly fauna is almost identical to that recorded by Bailey and Richards (1975) from the Prince Regent Nature Reserve, approximately 125km to the north-east. The Prince Regent collections suggest that further collecting would double the list of Koolan Lycaenids and Hesperids. A preliminary examination of the W.A. Museum's moth collection from Koolan suggests a similar sampling bias towards large species.

Although ants are a significant and visible component of the island's fauna, only two species have been identified. One of these, the introduced Singapore Ant, was a significant pest in the townsite (see 'Results'). We know of only one other introduced insect. A "large black cockroach up to 1.5 inches long" was introduced to an adjacent

island (Cockatoo) about 1962, and later to Koolan Island (R. Lind, pers. comm.).

Between 1961 and 1993, 35 reptile and one amphibian species were recorded on Koolan Island. Reptile surveys on Koolan Island have been opportunistic or brief, and sampling bias is apparent from the high proportion of snakes in relation to other reptile species in the list (13 of 34). The list indicates the Torresian affinities of the island's fauna, and provides a good indication of the richness that might be expected on other islands of similar size in the Kimberley. In fact, Koolan is less diverse in terms of its substrates and vegetations than many equivalent or larger islands in the archipelagos and other island groups further north along this coast. It comprises two sandstone formations, but only small areas of mangrove and beach strand vegetation; its few rainforest patches (semi-deciduous vine thickets) are minute (< 0.2 ha), narrow, open canopied even in the wet season, and floristically poor.

A review of the reptiles known from similar habitats on other islands in the Archipelago, and/or the adjacent mainland, suggests that a variety of additional species could occur on Koolan despite its relatively narrow range of habitats (Table 6).

The absence of permanent creeks or pools provides a reasonable explanation for the lack of riparian reptiles such as *Crocodylus johnstoni*, *Elsaya dentata*, *Emydura victoriae*, *Liasis fuscus*, *Tropidonophus mairii*, *Gemmatophora gilberti*, *Varanus mertensi* and *V. panoptes*. Similarly, only a single species of amphibian has been collected on Koolan, even though 10 additional species (2 families) are known to occur on the adjacent Yampi Peninsula (Leptodactylidae: *Ranidella bilingua* and *Uperoleia* sp.; Hylidae: *Cyclorana australis*, *Litoria bicolor*, *L. caerulea*, *L. coplandi*, *L. nasuta*, *L. rothii*, *L. splendida* and *L. wotjulumensis*). Two other frog species have been seen on Koolan; both were smaller than *Litoria rubella*, but they have not been identified and no voucher specimens have been taken (L.F., pers. obs.). The lack of red sand surfaces provides a basis for arguing that species such as *Varanus gouldii* and *Ctenotus pantherinus* do not occur on the island.

The other Yampi Formation (Pky) islands in the Buccaneer Archipelago extend in a chain westward from Koolan. Their reptile faunas were sampled during a field survey of the Archipelago in 1982. The relevant collections are lodged in the W.A. Museum. These islands are smaller in area and their known reptiles faunas are subsets of the Koolan fauna. *Pseudechis australis* (Cockatoo, Irvine), *Delma borea* (Cockatoo), *Gehyra occidentalis* (Irvine, Bathurst), *Heteronotia planiceps* (Irvine, Bathurst), *Oedura gracilis* (Irvine, Bathurst), *O. obscura* (Irvine, Bathurst), *Carlia triacantha* (Cockatoo, Irvine, Bathurst), *Ctenotus inornatus*

Table 6 Additional reptiles that might occur inshore or on Koolan Island.

Cheloniidae	Scincidae
<i>Caretta caretta</i>	<i>Carlia munda</i>
<i>Chelonia depressa</i>	<i>C. rufilatus</i>
<i>C. mydas</i>	<i>Cryptoblepharus</i> <i>plagiocephalus</i>
<i>Eretmochelys imbricata</i>	<i>Ctenotus robustus</i>
Dermochelyidae	<i>C. yampiensis</i>
<i>Dermochelys coriacea</i>	<i>Egernia douglasi</i>
Chelidae	<i>Lerista praefrontalis</i>
<i>Chelodina rugosa</i>	<i>Morethia ruficauda</i>
Gekkonidae	<i>Notoscincus ornatus</i>
<i>Crenodactylus ocellatus</i>	<i>N. wotjulum</i>
<i>Diplodactylus conspicillatus</i>	<i>Proablepharus tenuis</i>
<i>D. mcmillani</i>	Varanidae
<i>D. taeniatus</i>	<i>Varanus scalaris</i>
<i>D. stenodactylus</i>	<i>V. tristis</i>
<i>D. ciliaris</i>	Elapidae
<i>Nephruurus asper</i>	<i>Demansia psammophis</i>
<i>Rhynchoedura ornata</i>	<i>Pseudonaja nuchalis</i>
Pygopodidae	<i>Rhinoplocephalus</i> <i>punctatus</i>
<i>Pygopus nigriceps</i>	<i>Vermicella multifasciata</i>
Agamidae	Colubridae
<i>Chlamydosaurus kingii</i>	<i>Cerberus rynchops</i>
<i>Ctenophorus caudicinctus</i>	<i>Fordonia leucobalia</i>
<i>Diporiphora magna</i>	<i>Myron richardsoni</i>
<i>Pogona microlepidota</i>	Hydrophidae
	<i>Hydrelaps darwiniensis</i>
	<i>Hydrophis elegans</i>

(Bathurst), *Glaphyromorphus isolepis* (Cockatoo) and *Varanus glebopalma* (Bathurst).

The 10 years of systematic bird records from Koolan provide a benchmark for assessing the potential bird richness of the many islands that are scattered along the Kimberley coastline. One hundred and sixteen species were recorded during the period, 73 non-passerines and 43 passerines. The Welcome Swallow record extends the known distribution, and Brush Cuckoo and Barking Owl have not previously been recorded on islands in the Kimberley (R.E. Johnstone, pers. comm.).

Absences from the bird list are likely to reflect the absence of suitable habitats rather than incomplete survey of resident species or regular visitors. Koolan is too dry for many Torresian bird species. Its annual average rainfall (960 mm) is significantly less than many islands of similar size further north (South-west Osborne, Katers, D'Arcy etc). This is reflected in the minute size and floristic paucity of its rainforest patches, which may explain the absence or rarity of many "rainforest birds" (*sensu*. Johnstone and Burbidge 1991) on the island. Examples include the Torresian Imperial Pigeon, Green-winged Pigeon, Orange-footed Scrubfowl, Little Shrike-thrush, Rufous Fantail, Rufous Owl, Rainbow Pitta, Varied Triller, Green-backed

Flycatcher and Figbird. Some rainforest birds were recorded only in town, probably attracted by the high proportion of broad-leaved tropical plants in the reticulated gardens of the houses: Yellow Oriole and Rose-crowned Fruit-Dove. Low rainfall may also explain the absence of massive scree species such as Black Grass-Wren and White-lined Honeyeater, although White-quilled Rock Pigeons occur in similar sandstone habitat on the adjacent mainland and on Hidden Island, further south in the Buccaneer Archipelago (N.McK., unpubl. data).

The relatively small areas of mangrove around Koolan Island allow an equivalent explanation for the rarity or absence of certain mangrove birds that are common in larger stands that occur in embayments along the mainland coast just a few kilometres away: Chestnut Rail, Little Bronze Cuckoo, Mangrove Kingfisher and Mangrove Robin were not recorded, while the Kimberley Flycatcher, Mangrove Golden Whistler, Broad-billed Flycatcher, Shining Flycatcher and Red-headed Honeyeater were seen on only a few occasions.

The absence of Golden-headed Cisticola and Tawny Grassbirds reflects the rarity of tall grasslands normally found on black-soil plains and flats around swamps on the adjacent mainland. Riparian and fresh-water swamp birds are poorly represented on Koolan because there are no permanent natural creeks or lakes. Some species were seen a few times over the 10 years of observation (e.g., Sacred Ibis, Royal Spoonbill, Baillon's Crake and Buff-banded Rail). Others typical of these habitats on the adjacent mainland were not recorded, including Brolga, White-browed Robin, Red-backed Wren, Bar-breasted Honeyeater, Yellow-tinted Honeyeater, Black-chinned Honeyeater and Chestnut-breasted Mannikan. These species will become more common if the main ore-extraction pit adjacent to the loading jetty becomes a fresh-water lake as discussed in Keighery *et al.* (1995).

A number of other land birds are known from the adjacent mainland or other islands along the coast (Smith *et al.* 1978): Spotted Nightjar, Letter-winged Kite, Black-breasted Buzzard, Collared Sparrowhawk, Grey Shrike-Thrush, Jacky Winter, Restless Flycatcher, Black-tailed Treecreeper, Singing Bushlark, Fairy Martin, Grey-crowned Babbler, Singing Honeyeater, Red-browed Pardalote, Zebra Finch, Star Finch, Masked Woodswallow, Magpie and Torresian Crow. The reason for their absence from the Koolan list is unclear. They may eventually be recorded there; a third of the birds listed from Koolan were encountered three times or less over the 10 year period of observation.

Of the four mammals introduced, only goats appear to have survived. The fourteen indigenous

mammals known from Koolan Island comprise one dasyurid, one rodent and 12 bat species. They are a biased sub-set of the Torresian mammal fauna found on the adjacent mainland.

Considering the extent, intensity and duration of human activity on the island, and the number of natural historians that have searched for ground-dwelling mammals there since 1965, the list may be complete. A field survey in 1983 found only three such species on the largest of the other islands in the Archipelago (Hidden Island, 2003 ha; *Peradorcas concinna*, *Dasyurus hallucatus* and *Mesembriomys macrurus*), two on Long (1380 ha; *Peradorcas concinna* and *Rattus* sp.), and only one species on smaller islands such as Irvine (940, *Zygomys woodwardii*), Bathurst (580, *Zygomys woodwardii*), and Margaret (270, *Mesembriomys macrurus*). The voucher specimens from this survey are lodged in the WA Museum (M23001–23059, M23150–23167).

In contrast to its non-volant mammals, Koolan is rich in bats, especially cave-dwelling species (*Taphozous georgianus*, *Hipposideros ater gilberti*, *H. stenotis*, *Rhinonicteris aurantius*, *Macroderma gigas* and *Vespadalus caurinus*). Even so, future surveys will probably reveal additional species because *Miniopterus schreibersii* and *Pteropus scapulatus* are known from nearby islands (Gibbings and King Hall respectively), and other species occur in adjacent areas of the mainland: *Chaerephon jobensis*, *Vespadalus douglasi*, *Pipistrellus westralis*, *Scotorepens sanborni*, *Myotis adversus* and *N. geoffroyi pallescens* (McKenzie and Rolfe 1986).

Little is known about the natural history of *Hipposideros stenotis* in the Kimberley. The sites and small colony-sizes we recorded on Koolan are consistent with previous observations (Kitchener *et al.* 1981, Hall 1983), including a June 1982 record from Bathurst Island (16°03'S, 123°02'E), 15 km west of Koolan, where a female (M 23057) was taken from a pair found in a small sandstone (Pky) cave overlooking the coast.

Our data show that animal-eating bats that forage in the island's open microhabitats have higher wing loadings and aspect ratios, but lower tip indices, than bats of more obstructed air-spaces (Table 3). These attributes relate to flight speed, energy-cost of flight and manoeuvrability, respectively (Norberg and Rayner 1987). Non-parametric ranked correlation analysis revealed a strong correlation between mean "wing loading" and "lowest frequency" in free-flight (Kendall Tau = -1.0, P = 0.014), and a significant correlation between mean "aspect ratio" and "lowest frequency" in free-flight (Kendall Tau = -0.8, P = 0.05), for the five bats we recorded foraging in "edge" and "open" microhabitats on Koolan (Tables 3 and 4). Such relationships are well documented from work on bat communities elsewhere (e.g. Aldridge 1987, Fullard *et al.* 1991,

McKenzie *et al.* 1995). The data presented in Table 4 suggest that the microbats known from the island can be readily distinguished in terms of the average lowest frequency of their ultra-sounds, and will facilitate future survey work.

The bias towards large land snails and butterflies, snakes and cave-dwelling bats in the Koolan Island fauna lists is a sampling artefact. Nevertheless, the richness of these groups indicates that the numerous rugged sandstone islands along this tropical, sub-humid coastline support much richer faunas than were revealed by the brief surveys carried out to date (e.g., Burbidge and McKenzie 1978).

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