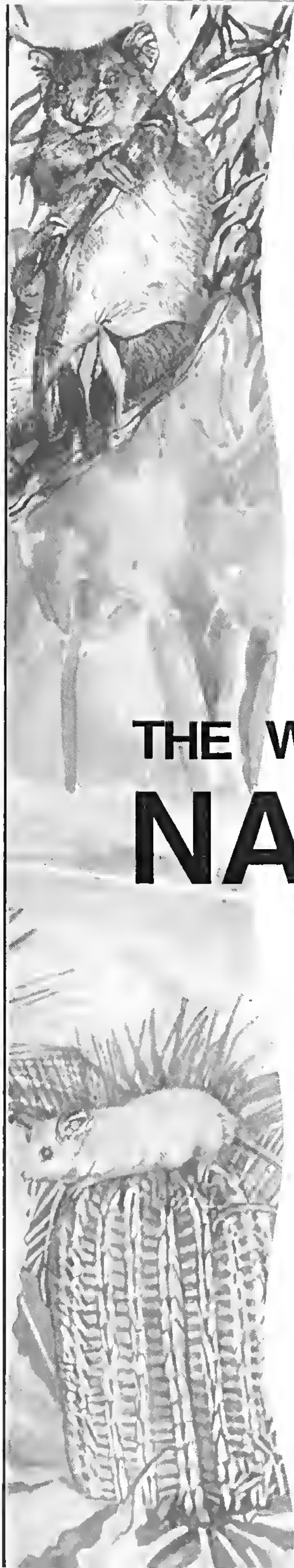

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STATUS OF THE NORTHERN POPULATION OF THE BUTTERFLY, THE WESTERN DARK AZURE (*OGYRIS OTANES*) IN WESTERN AUSTRALIA.

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ABSTRACT

The Western Dark Azure butterfly (*Ogyris otanes*) is included within a species known from scattered sites across southern Australia, including apparently disjunct populations in Western Australia. Prior to this survey the northern form was known only from two sites near Leeman and Dongara and was thought to be rare. This northern form was surveyed and found to occur in four areas spread over 200km along the coast from south of Lancelin to Dongara. It may also occur north and south of this range. It is common in places within its range. It occurs in two areas in the Beekeepers Nature Reserve, and may occur in other conservation reserves. It has been poorly surveyed in the past, and is clearly more widespread and common than previously thought. It is probably secure in several conservation reserves.

INTRODUCTION

The Western Dark Azure butterfly (*Ogyris otanes*) is included within a species known from scattered sites across southern Australia from New South Wales and Victoria to Western Australia but it was not

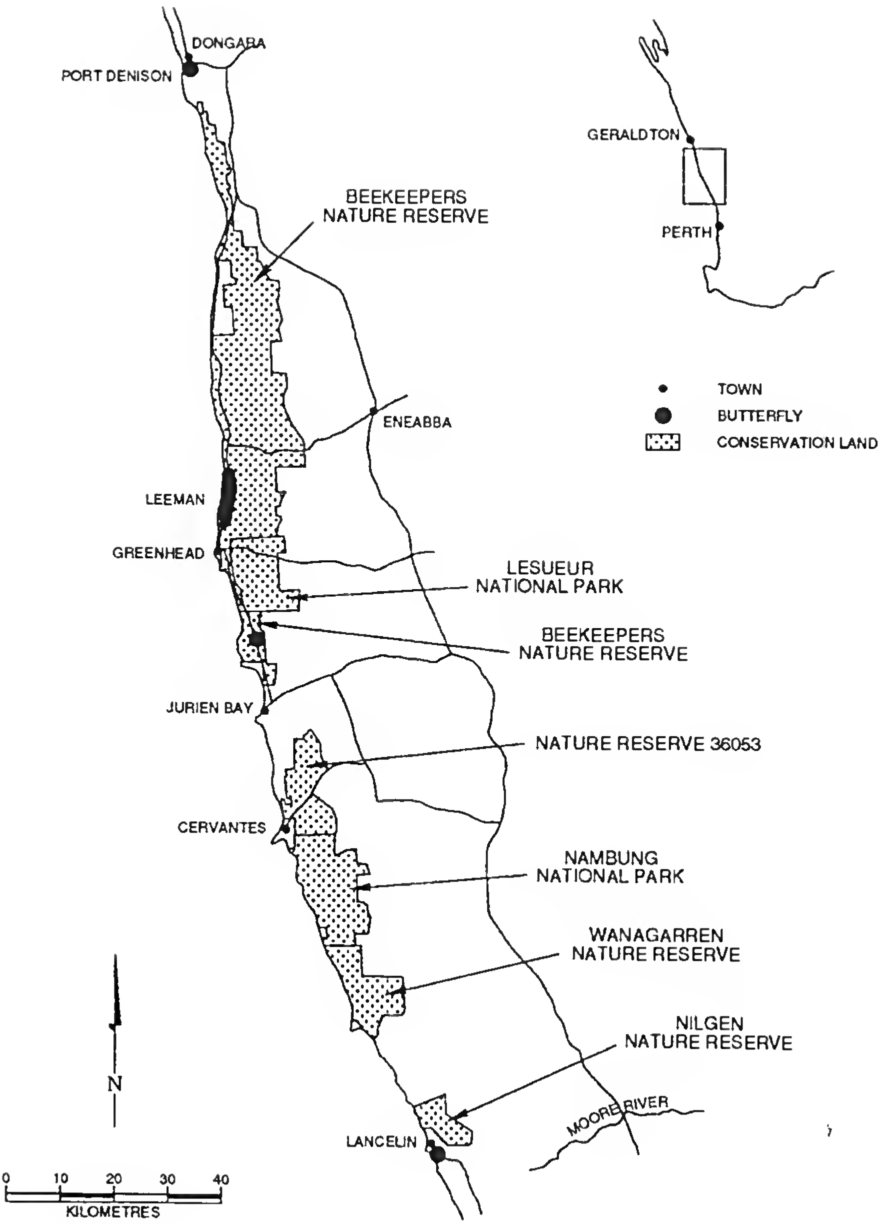

Figure 1. Distribution of the Western Dark Azure butterfly and conservation reserves.

common anywhere (Common and Waterhouse 1981). Subsequently it has been suggested that this species should in fact be divided into a series of subspecies if not species. In particular in Western Australia there are apparently disjunct populations (Edwards pers. comm., Williams pers. comm.). One occurs in the Stirling Ranges and east to past Esperance, and the other was previously known from only two sites, just south of Leeman and just south of Port Denison (near Dongara). The butterfly lives on only one host plant and has a symbiotic relationship with an ant which actively cultivates the caterpillars in return for a sugar secretion. The two populations have different host plants. The northern population is only known to use the leafless shrub *Leptomeria preissiana*. This host plant and the host ant are widespread in the south-west, but the butterflies are not necessarily found in all potential habitat. *Leptomeria preissiana* is found widely over the northern and south-eastern parts of the South-West and into the Goldfields. Griffin (1993) found it to be a common species in his study area of the coast between the Swan and Irwin Rivers, and recorded it as far south as Mandurah and as far north as Shark Bay on the coast.

This butterfly was identified as possibly rare in a regional planning study (Hammond and Elliott 1995). Following concern about the impact of urban expansion on this species around Leeman, 250km north of Perth, a survey of the status of this species was carried out.

METHODS

The larvae are found only on the host plant when they emerge from the ant nests at night, while the adults are free flying in the day time. The species can be found by catching the adults or by searching for chewed plants and observing the larvae when they emerge at night. It was found that catching the adults was the easier option.

A survey of the butterfly was carried out by Michael Powell and Mark Golding, collectors familiar with the butterfly. The known locations were visited to confirm that the butterfly could be found and captured there. An extensive survey was then carried out from Dongara south to Ledge Point (south of Lancelin) by sighting adults and taking voucher specimens. The sites examined were restricted to those readily accessible by roads, and areas of potential habitat away from roads were not examined. At each site where the butterfly was found the vegetation was described and a photograph was taken. The survey was carried out in late October 1996 in the peak season for butterfly activity. The host plant was flowering at the time of the field work and it was readily visible.

RESULTS

The butterfly was found successfully at the previously known sites near Dongara and Leeman, although the adults were not easy to catch or observe as they fly rapidly and erratically.

In total the butterfly was found in four areas from south of Port Denison to south of Lancelin (Figure 1). At each site individuals were seen but not often captured. The search was continued at each site until specimens were obtained or it proved impossible to capture voucher specimens.

The butterfly was recorded at the following sites:

Location	Number caught	Others seen (approx.)
1.4km S of Port Denison	2	15
4.5km N of Leeman	2	8
1.3km N of Leeman	4	15
0.4km N of Leeman	0	10
Southern edge of Leeman	3	10
1.9km S of Leeman	2	10
4km S of Leeman	1	10
6km S of Leeman	0	1
6.7km S of Leeman	2	10
16.2km N of Jurien Bay	5	2
1.3km S of Lancelin	2	0
2.6km S of Lancelin	0	1

The survey revealed that the host plant, *Leptomeria preissiana*, was present in all sites. The sites with butterflies were limestone flats behind dunes, low limestone ridges or sand dunes. Some of the flats were seasonally wet. The vegetation was universally dune scrub or heath variously dominated by shrubs of *Acacia rostellifera*, *Melaleuca huegelii*, *M. cardiophylla* and *M. acerosa*. *Allocasuarina lehmanniana* was also a common species, and sedges were often present. The shrubs varied from 1m to 3m in height. Most sites had not been burnt for some years, but at least one had vegetation which had not reached its full height after fire.

Potential habitat probably occurs along much of the coast from Dongara to Lancelin, but access was limited in many areas and the full extent of the potential habitat could not be mapped in this study. The two previously known sites (south of Port Denison and at Leeman) did not appear to be unusual and were similar to many other sites recorded in this survey.

Voucher specimens from a range of sites covering the distribution of the species have been placed in the collection of the W.A. Museum.

DISCUSSION

The northern form of the butterfly at Leeman was only discovered in October 1977 by D. Knowles at 6.7km south of Leeman and the Port Denison population was found in September 1992 (Williams *et al.* 1995). Its taxonomic position has not yet been decided in relation to the other populations in W.A. and those interstate.

The results of the present survey show that the northern form occurs in four areas between south of Port Denison (29° 17' S) and south of Lancelin (31° 02' S), a distance of over 200km along the coast, and it appears to be common within its preferred habitat. It was also found to be present at precisely the site of the original discovery after 19 years.

The butterfly may also occur further north and south as there is at least potential habitat with the host plant. Beard (1976, 1981) has mapped the vegetation regionally, and his maps show that similar vegetation is widespread from south of Perth to north of Geraldton, and the host plant is even more widespread (Griffin 1993).

There was no apparent unique habitat feature associated with the sites where the butterfly was found. It is likely that the numbers of butterflies are simply a result of the concentration of its host plant, although there may also be temporal variation which would not be revealed by a single survey. Although *Leptomeria preissiana* is widespread over the northern and south-eastern parts of the South-West and into the Goldfields it is not often a common species. The concentrations of plants seen along the coast considered here are unusual within the total range of the species. All sites where the butterfly was found were within a few kilometres of the coast, but the possibility that the butterfly occurs in more inland sites should not be excluded.

The butterfly did not occur in all areas of potential habitat. The presence of the butterfly was also assessed from the chewing on the host plants by the larvae. Sites of apparently suitable habitat with the host plant were found in many areas but with no evidence of the butterfly. It is not known how much the populations vary over time, or what controls the numbers of butterflies. The adults are fully mobile and it can be expected that they are able to colonise new areas after fires or where new concentrations of host plants appear for any reason. The continued presence of the species at the site of the original discovery after 19 years suggests that this population is not ephemeral.

The butterfly is not easy to observe or catch, and the most reasonable conclusion is that it has been missed by the few collectors who have searched for it in the past. There may also be a limited season when it can be found most readily.

The area where the butterfly occurred around Leeman is a mixture of townsite reserve, Shire reserves and Beekeepers Nature Reserve. It was also found in the Beekeepers Reserve north of Jurien Bay. The Port Denison and Lancelin sites are on town reserves or Shire reserves.

The butterfly occurs in two areas in the very large Beekeepers Nature Reserve and its proposed extensions, and possibly in the un-named Nature Reserve 36053 north of Cervantes, Nambung National Park, Wanagarren Nature Reserve and Nilgen Nature Reserve. None of these latter reserves were examined in the present survey. It may also occur in various other reserves vested in Shires, and on leasehold property.

This butterfly is clearly much more common and widespread than previously thought and is probably secure in several conservation reserves.

ACKNOWLEDGEMENTS

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ABORIGINAL OCCUPATION IN THE LIMESTONE CAVES AND ROCK SHELTERS OF THE LEEUWIN – NATURALISTE REGION, WESTERN AUSTRALIA: RESEARCH BACKGROUND AND ARCHAEOLOGICAL PERSPECTIVE

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ABSTRACT

The palaeontological importance of limestone caves in the Leeuwin-Naturaliste Region, in Western Australia's lower South-west, was recognised early this century when abundant marsupial and other vertebrate remains, including extinct "megafauna" species, were excavated from the Mammoth Cave floor deposit. The archaeological potential of the region's caves became clear in the late 1960s, with the publication of a human tooth and other cultural material collected a decade earlier during palaeontological excavations at Devil's Lair. Radiocarbon dated archaeological evidence from the 1970s Devil's Lair excavations show that Aboriginal groups had occupied this cave intermittently *ca* 31,000 to 6500 BP (radiocarbon years "Before Present"). In the 1990s, this archaeological record of prolonged cave occupation was supplemented by similar evidence, notably hearths, stone artefacts, vertebrate food remains, from excavations at Tunnel Cave and other regional caves and rock shelters. On-going archaeological research is in part aimed at assessing the role of these occupation sites in regional hunter-gatherer land-use systems evolving from Late Pleistocene times until recent centuries. A cross-dating program underway for Devil's Lair and Tunnel Cave is aimed at comparing these sites' existing chronological sequences, based on conventional radiocarbon dates, with other kinds of radiometric assays of various samples from their floor deposits, including OSL (optically stimulated luminescence) dating of quartz sand, TIMS (thermal ionisation mass spectrometry) uranium series dating of eggshell, AMS (accelerator mass spectrometry) radiocarbon assay of emu

eggshell, and ESR (electron spin resonance) and uranium series assay of flowstone. Continuing chronological, palaeoenvironmental, biological and archaeological investigations of the Quaternary age floor deposits in Leeuwin-Naturaliste Region limestone caves and rock shelters contribute to the development of Australia's cultural and natural heritage.

INTRODUCTION

Nearly all of the hundreds of prehistoric Aboriginal occupation sites recorded in the South-west of Western Australia over the past half-century are undated surface scatters of flaked stone artefacts. Fewer than a dozen sites have occupation deposits featuring abundant faunal and other biotic remains stratigraphically associated with artefacts and hearths. Four of these exceptional sites are located in the extreme south-western corner of the South-west, referred to here as the "Leeuwin-Naturaliste Region" (Figure 1). Specifically, they comprise the sandy floor deposits of caves and rock shelters formed in Tamala Limestone capping Pre-Cambrian metamorphic rocks comprising the Leeuwin Block (Playford *et al.* 1976: 210–212), which extends from Cape Naturaliste 100 km southward to Cape Leeuwin (Figure 1, inset). The half-dozen other, mostly much smaller and less important, south-western archaeological sites yielding biotic remains are scattered across several hundred km of the region's Southern Ocean coast.

Our purpose here is to outline the history of the prehistoric investigations carried out in the caves and rock shelters of the Leeuwin-Naturaliste Region, and to appraise prehistoric Aboriginal occupation in the region generally.

EARLY INVESTIGATIONS OF REGIONAL FOSSIL DEPOSITS

The first palaeontological excavations in the Leeuwin-Naturaliste Region were carried out in Mammoth Cave in 1904 by E. A. Le Soeuf, Director of the Perth Zoological Gardens, and T. Connolly, the cave's caretaker and tourist guide, who had accidentally discovered this cave's fossil bone bed a few years earlier. More extensive excavations at Mammoth Cave were undertaken by the WA Museum and Art Gallery during the years 1909–1915. The chief, and often the sole excavator, was Ludwig Glauert, first seconded to the Museum from the WA Mines Department, and from 1910 employed by the Museum as Assistant in Natural History and Ethnology to the Director, B. H. Woodward (Glauert 1910; 1926; 1948; Woodward 1909; 1910. In 1928, Glauert became Keeper of the Museum, and eventually was appointed Director.). These early excavations at Mammoth Cave yielded very large amounts of

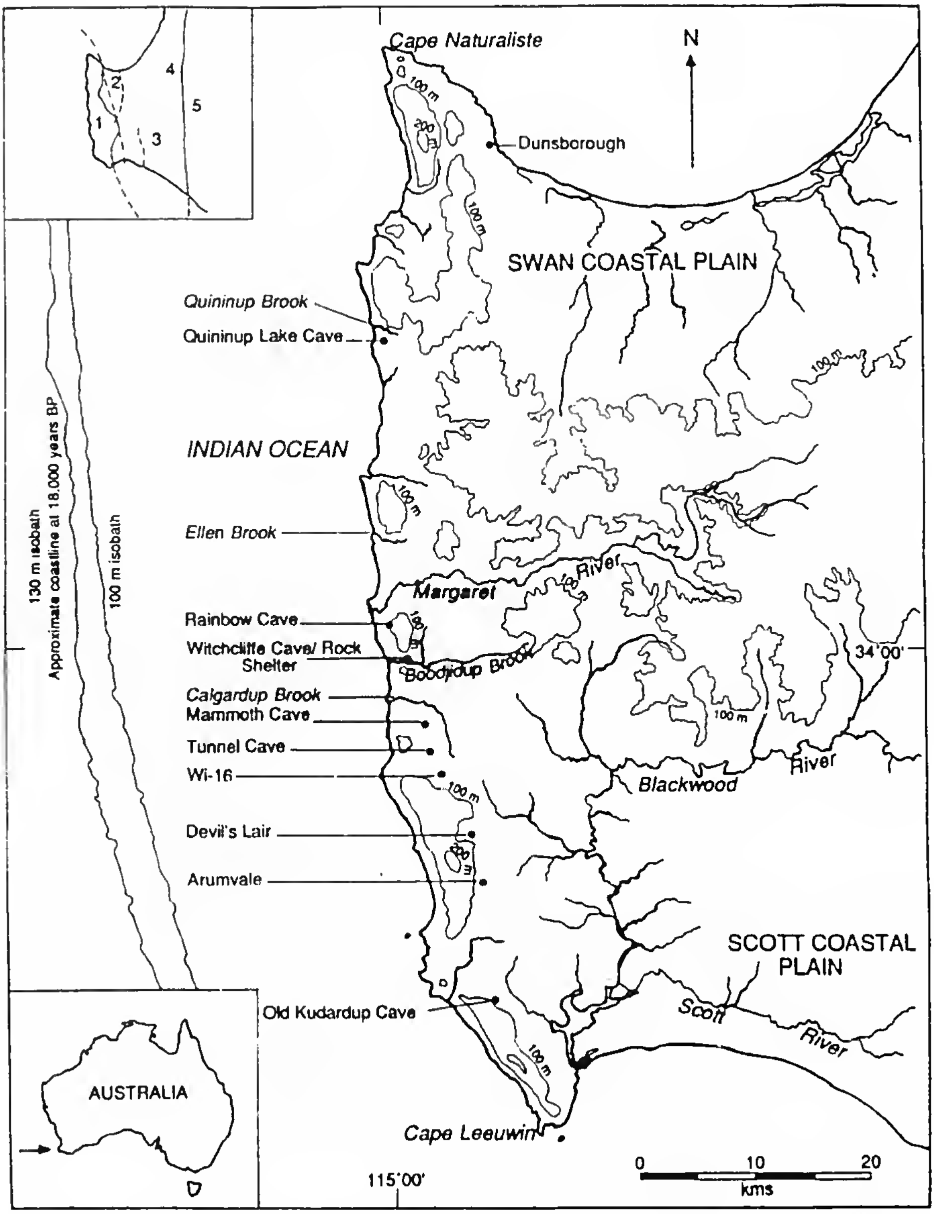

Figure 1. The Leeuwin – Naturaliste Region showing sites and localities mentioned in the text, 100 and 200 m contour lines, and 100 and 130 m depth contours (isobaths). The inset map in the upper left hand corner of the figure shows geological features in the more general area as follows: 1. Leeuwin Block; 2. Dunsborough Fault complex; 3. southern Perth Basin; 4. Darling Fault; 5. Yilgarn Block.

marsupial and other vertebrate remains, including numerous bones of extinct, large-sized species definable as "megafauna".

Forty years passed before palaeontological investigations were again planned for caves in the Leeuwin-Naturaliste Region. In 1955, Ernest Lundelius, then a visiting Fulbright scholar from the USA, began his research into the climatic and environmental implications of Late Quaternary mammalian assemblages in Australia (Lundelius 1960; 1966). Lundelius also investigated marsupial carnivore behaviour, as suggested by the vertebrate remains accumulated in these predators' dens or lairs, which in this region are characteristically limestone caves. In obtaining fossil bone samples for his research, Lundelius dug test pits in one of the region's caves notable for its prolific vertebrate remains. This cave soon came to be known as Devil's Lair, in reference to the bones of Tasmanian Devils (*Sarcophilus harrisii*) present in its floor deposit, and because of the highly fragmented nature of the bone assemblage, typical of carrion-eaters' dens, particularly those occupied by this species.

In the 1950s, the archaeological potential of Leeuwin-Naturaliste Region caves and rock shelters was not closely considered. The published reports of the Devil's Lair excavations (Lundelius 1960; 1966) do not mention very occasional stone artefacts or a piece of baler shell that Lundelius and other excavators had recovered from the Devil's Lair floor deposit. By the late 1960s, however, Quaternary investigations had expanded greatly in many parts of the world, including Australia, where research into Aboriginal prehistory was already benefitting substantially from the rapid development of these multi-disciplinary studies. Archaeological, geomorphological and palaeontological field investigations were under way in many parts of the continent, and new finds and radiocarbon datings were changing the framework of Aboriginal prehistory year by year. A leading researcher in these developments was Duncan Merrilees, a WA Museum Curator (Palaeontology Department, 1960–1978), and one of the first Quaternary researchers to consider the effects of prehistoric human migration and settlement on Australian fauna and landscape. In 1967, Merrilees found an adult human incisor tooth in a collection of kangaroo teeth previously excavated from Devil's Lair; not longer after this tooth was described by Davies (1968). In his classic "Man the destroyer" paper, Merrilees noted the presence of this tooth and the other cultural remains that had been recovered during the Devil's Lair palaeontological excavations of the decade before (Merrilees 1968:12).

WA MUSEUM INVESTIGATIONS AT DEVIL'S LAIR

In late 1970, partly as a result of the publication of the Devil's Lair cultural finds, and partly in response to the greatly increased general awareness of the potential duration and complexity of Aboriginal prehistory, the WA Museum began a series of archaeological excavations of the cave's floor deposit. The Museum team began its investigation of the Devil's Lair floor deposit by carrying out "salvage" excavations in two test pits left open since the 1950s (Dortch and Merrilees 1971). From the larger of these test pits (shown as Trench 1 in Figure 2), Lundelius had obtained a pair of radiocarbon dates based on charcoal samples. The stratigraphically uppermost sample, dated *ca* 8500 BP (radiocarbon years "Before Present", referring to uncalibrated, conventional radiocarbon dates), came from just beneath the flowstone capping of the floor deposit. The second sample, dated *ca* 12,000 BP, came from the lower part of this test pit, at a depth of 1.2 m below surface. The Museum team excavated this test pit nearly 1 m deeper, and having established that stone and bone artefacts were *in situ* in undisturbed deposit, ended their dig, and refilled the pit. They then removed collapsed sediments from a nearby, smaller test pit, dug by persons unknown, and excavating a few cm deeper in the floor of this pit again found artefacts in undisturbed cave floor sediments. This second test pit, in 1970 labelled "small excavation", eventually became the "main excavation" of the Museum investigation (Figure 2; Dortch

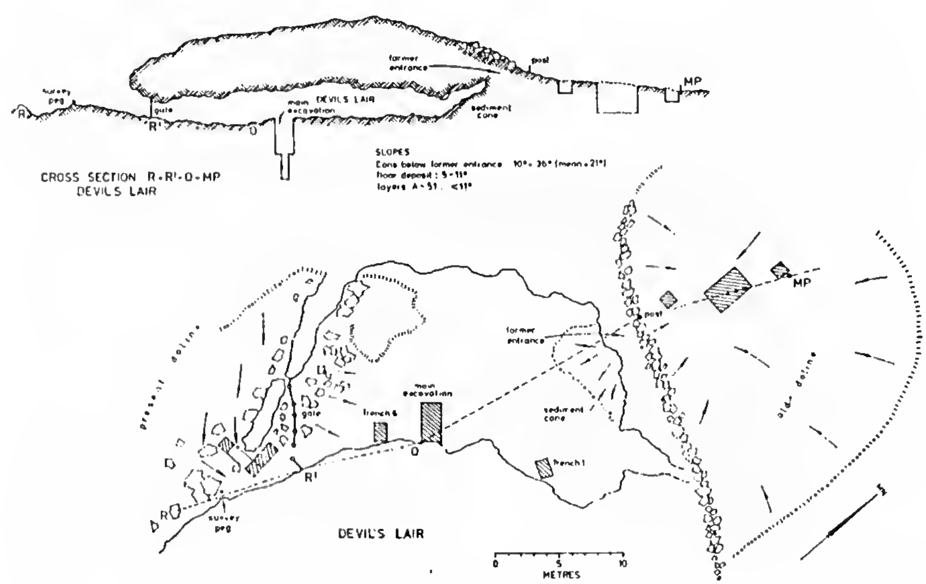

Figure 2. Cross-section and plan of Devil's Lair (after Williamson, Loveday and Loveday 1976).

and Merrilees 1971; 1973).

The systematic, long term excavations at Devil's Lair were mainly directed by Merrilees, in cooperation with one of us (CED, who then and now is a WA Museum Curator) and departmental staffers, J. Balme and J. K. Porter. The Museum team was assisted by several volunteers, notably the vertebrate palaeontologist, A. Baynes, then a Ph.D. scholar at the University of Western Australia. The seven excavation seasons at Devil's Lair, which lasted from two to six weeks each, ended in 1977, though investigations in the cave have continued intermittently since then, with the final test excavations at the base of the floor deposit being directed by ourselves in March 1997. At this point, the "main excavation" has been dug to a depth of 7.1 m below Cave Datum (*i.e.* 6.6 m below the cave floor), and the total volume of sediments excavated and sieved is more than 40 m³. The narrow lower part of the excavation is shown schematically in Figure 2. Exposed at the base of this excavation is very thick flowstone, which we have not penetrated.

Since the mid-1970s, investigators have published 26 research papers and other works on the Devil's Lair depositional, cultural, faunal, and chronometric sequences. Included are papers describing and interpreting the cave's geomorphological history, the nature and stratigraphy of its sandy floor deposit, the bones and other fossil fauna, the rare human remains and the relatively sparse, though very diverse stone and bone artefact assemblages, and the petrology and likely sources of the stone artefacts recovered in the archaeological excavations (Allbrook 1976; Baird 1986; Balme 1978; 1979; 1980a; 1980b; Balme *et al.* 1978; Baynes *et al.* 1975; Bednarik 1997; David 1993; Dortch 1974; 1976a; 1976b; 1979a; 1979b; 1979c; 1980; 1984; 1986; Dortch and Dortch 1996; Freedman 1976; Glover 1974; 1979; Merrilees 1975; 1979; Shackley 1978).

TUNNEL CAVE AND OTHER RECENT ARCHAEOLOGICAL INVESTIGATIONS OF LEEUWIN-NATURALISTE REGION

CAVES AND ROCK SHELTERS

In 1990 and 1991, I. Lilley, a University of Western Australia lecturer in archaeology, recorded hearths, quartz artefacts, and small amounts of marine mollusc shell, fish and terrestrial vertebrate remains at Rainbow Cave, near the mouth of the Margaret River, 20 km North of Devil's Lair (Figure 1). These finds, radiocarbon dated *ca* 340–4200 BP, are the first evidence of Late Holocene Aboriginal occupation of Leeuwin-Naturaliste Region caves and shelters (Lilley 1993: 36–39).

Archaeological investigations of prehistoric occupation deposits in the region's caves were again resumed in 1993, when one of us (JD) studied plans of 270 cave and rock shelter sites mostly compiled by B. Loveday, a Perth-based speleologist with many years of caving experience. As part of his Ph.D. research at the Centre for Archaeology, University of Western Australia, J. Dortch surveyed 77 cave chambers and rock shelters before deciding that at least 25 of them could have been suitable for human occupation. The most promising site was Tunnel Cave, located eight km North of Devil's Lair. Other caves thought likely to have been used by Aboriginal hunter-gatherers are Wi-16, Quininup Lake Cave, and Witchcliffe Cave (Figure 1). However, corings in the floor deposits of the two former caves and test excavation in the latter failed to yield any archaeological remains (Dortch 1996).

In April 1993, J. Dortch's test-excavation inside the wide shelter entrance at Tunnel Cave revealed numerous hearths, stone artefacts, and faunal remains deriving from many episodes of human occupation. Charcoal samples collected from the main part of the occupational sequence in the lower 2 m of the deposit (Figure 3), and dated by conventional radiocarbon method, range in age from *ca* 22,000 to 8000 BP (Dortch 1994;

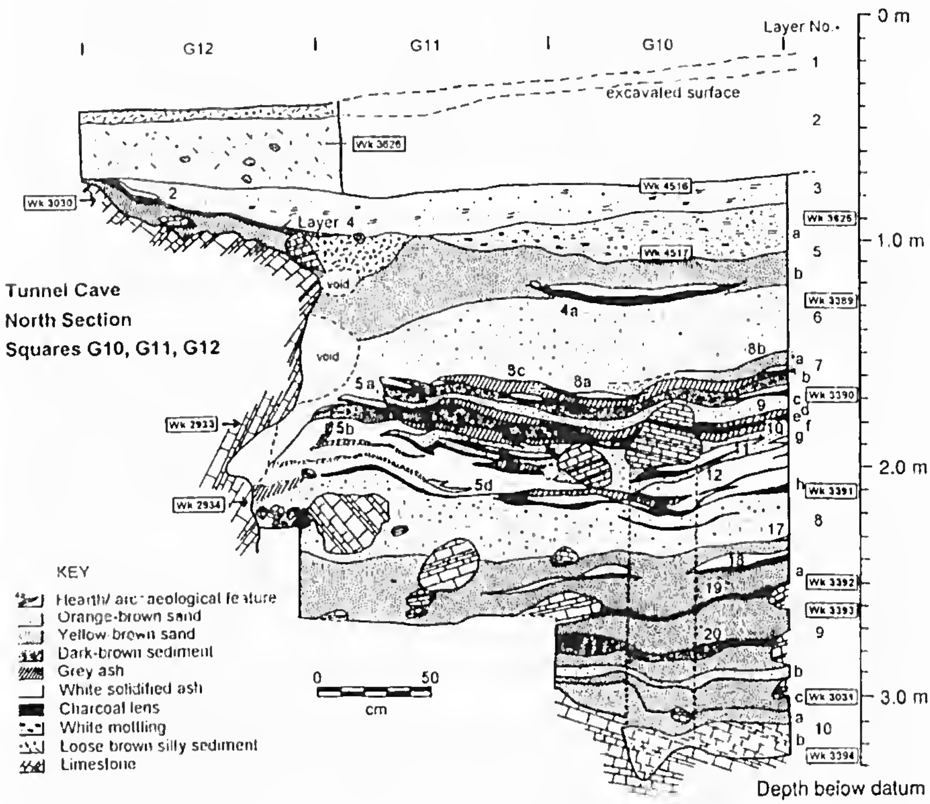

Figure 3. Trench section, north face of squares G10, G11 and G12, Tunnel Cave. The vertical pair of dotted lines indicate a column of sediment supporting a large rock.

1996: Table 2). However, in the upper part of the Tunnel Cave deposit, a handful of stone artefacts was stratigraphically associated with a hearth, from which a charcoal sample is radiocarbon dated *ca* 1300 BP. This record supplements the longer but much sparser occupational record from Devil's Lair, which spans about 25,000 years, ending about 6500 BP, as shown by some thirty radiocarbon dates from the main excavation (Dortch 1979b; 1984; Dortch and Dortch 1996).

In 1995, J. Dortch excavated at Witchcliffe Rock Shelter, which is adjacent to Witchcliffe Cave and overlooks a stream valley, a few km south of Rainbow Cave. There he recorded hearths, and collected quartz artefacts, vertebrate remains, including fish, and marine and freshwater mollusc shell in a charcoal-rich deposit radiocarbon dated 700–400 BP (Dortch 1996: Figure 5, Table 3). Human occupation of this site is contemporaneous with the upper part of the occupational sequence at Rainbow Cave, and the stone artefacts and faunal assemblages from the two sites are similar.

Several other regional caves have yielded artefacts or other evidence for prehistoric human occupation. Very occasional stone artefacts and human bones have been recovered from Skull Cave, which has a cone-shaped deposit at the base of a vertical shaft (Porter 1979). Human bones have also been collected from the sediment cone below the vertical entrance to Strong's Cave near Devil's Lair (Merrilees 1968: 12). Archer *et al.* (1980) argue that several limb bones among the "megafaunal" vertebrate remains excavated by Glauert from Mammoth Cave have been cut, broken or burnt by human beings, though that cave has yielded no other archaeological evidence. No Aboriginal painted rock art had been known from the Leeuwin-Naturaliste Region until the 1980s, when speleologists identified two human hand stencils in red ochre on the wall of Old Kudardup Cave (Morse 1984). However, of great archaeological importance, and of even greater significance in terms of present-day Aboriginal spirituality, are regionally unique engravings of animal tracks and other motifs in a sheet of lacustrine limestone exposed in a paddock near the Scott River, 40 km south-east of Devil's Lair (Figure 1; Clarke 1983).

OCCUPATIONAL EVIDENCE

Recovered from the fireplaces and fire pits at both Devil's Lair and Tunnel Cave are shattered and charred bones of marsupials and other animals interpreted as food remains. The several dozen retouched (*i.e.* purposefully edge-trimmed) stone artefacts interpreted as "tools" collected from Devil's Lair support the interpretation of occupation by groups engaged in food preparation, the manufacture of wooden implements and other "hearthside" activities. For reasons unknown, almost no retouched pieces are present among the approximately 1500 stone artefacts associated with the two hearth complexes and several isolated hearths at Tunnel Cave, though the older hearth complex, radiocarbon dated 16–17,000 BP, did yield four "points" shaped on macropod fibulae, which are similar to some of the dozen bone points from Devil's Lair, dated *ca* 12,000 to 22,000 BP (Dortch 1984). At both sites, human occupiers sometimes were family groups, judging by the very occasional human deciduous (juvenile) teeth recovered (*e.g.* Freedman 1976; Dortch 1996). Occupation is assumed to have been very intermittent, perhaps only during wet or cold weather. Numerous fragments of Emu (*Dromaius novaehollandiae*) eggshell in many layers in both sites' floor deposits suggest winter occupation, since this species lays eggs only during that season. Other faunal remains may show whether the caves were occupied during other seasons. Excavated from Pleistocene layers at Devil's Lair are three bone beads (Dortch 1979a) and two other perforated objects interpreted as pendants (Dortch 1980; Bednarik 1997), as well as three limestone fragments that were thought be intentionally incised (Dortch 1976b; 1984).

OCCUPATIONAL HIATUS?

Presently available radiocarbon dates show a gap of several millennia between, on the one hand, the mainly Late Pleistocene occupational sequences at Devil's Lair and Tunnel Cave, and, on the other, the Late Holocene occupational evidence at the latter site, and at Rainbow Cave and Witchcliffe Rock Shelter. However, at Devil's Lair occupation seems to have ceased simply because a former entrance became blocked, thus preventing people from entering the cave perhaps not long after 6500 BP. Devil's Lair may have remained entirely sealed until a few centuries ago, when roof collapse created the doline as it is today, thus again opening up the existing chamber. (Figure 2 shows the prehistoric or "former" entrance blocked by a cone of sediment at the "rear" of this cave chamber. The present-day entrance is labelled "gate". No artefacts or faunal remains were recovered from the two 1 m-deep test trenches indicated in the doline just outside this entrance.)

It is not clear whether the above noted apparent hiatus of more than 6000 radiocarbon years (8000 to ca. 1300 BP) in Aboriginal occupation at Tunnel Cave is regionally significant. Nor is it known why Witchcliffe Rock Shelter apparently was occupied only during the past few hundred years. However, several Leeuwin-Naturaliste Region open-air sites – Calgardup Brook, Dunsborough, and Ellen Brook – and also Rainbow Cave, provide a range of radiocarbon dates *ca* 4000–5000 BP, showing that human groups were present here during the Middle Holocene, when regional caves and rock shelters may or may not have been as frequently occupied as they had been during the Late Pleistocene (Figure 1; Dortch *et al.* 1984: Table 2; Ferguson 1980; Lilley 1993: Table 1). Middle to Late Holocene Aboriginal occupation at the first two named open-air sites and at a number of others in the region (e.g. at the Arumvale site: Dortch and McArthur 1985) is also implied by surface and excavated stone artefact assemblages featuring geometric microliths and other particular kinds of flaked stone "small tools" that across temperate Australia are characteristic of sites of this age. Evidence for the presence of Aboriginal groups in the Leeuwin-Naturaliste Region during the terminal prehistoric to historic periods is provided by very recent radiocarbon dates from Ellen Brook and Rainbow Cave (Bindon and Dortch 1982; Lilley 1993: Table 1), by Aboriginal artefacts flaked from European bottle glass found at Ellen Brook and elsewhere, by a number of 17th century and early 19th century European accounts describing encounters with Aborigines (*e.g.* Baudin 1974: 173–174), and by an oral tradition of the sightings of 19th century or earlier European sailing ships recounted by Aboriginal elders presently living in the region.

LEEUWIN-NATURALISTE REGION CAVES AND ROCK SHELTERS AS COMPONENTS WITHIN HUNTER-GATHERER LAND-USE SYSTEMS

Despite many millennia of episodic use, cave occupation sites may have been only of relatively minor importance in presumably complex regional hunter-gatherer subsistence and settlement patterns, in which hunter-gatherer groups exploited diverse environmental zones within and outside the Leeuwin-Naturaliste Region. This is suggested by archaeological survey showing major sites situated near diverse habitats rich in food resources here and in other parts of the South-west, and by ethno-historical accounts attesting to the very wide variety of plant and animal foods eaten by south-western Aboriginal hunter-gatherers at the time of European colonisation in the 19th century (Meagher 1974). An on-going research aim then is to assess the functions of both cave and open-air occupation sites as components in dynamically shifting Aboriginal land use systems persisting perhaps continuously in the region from the Late Pleistocene until the historic period.

Archaeological evidence for the long sequence of human occupation in the Leeuwin-Naturaliste Region mostly coincides with the Late Pleistocene to Middle Holocene time of glacio-eustatic low sea levels, when the region's western coast would have been some 10–40 km further West. During the height of the last glacial maximum (LGM, *ca* 18 000 years ago) sea level is estimated to have been *ca* 130 m below its present height (Chappell and Shackleton 1986). The western coastline of the Leeuwin-Naturaliste Region would have been situated approximately along the 100 to 130 m isobaths shown in Figure 1 (*cf.* Balme *et al.* 1978: Figure 11). Human occupation of this or other parts of the region's emergent shelf is implied at both Tunnel Cave and Devil's Lair and at dozens of open-air sites in this region and throughout the western parts of the entire Perth Basin by the presence of numerous artefacts flaked of a distinctive form of Eocene fossiliferous chert that was probably quarried from outcrops on the emergent shelf (Glover 1974; 1984; Glover and Lee 1984). Some of the Leeuwin-Naturaliste Region open-air sites, exposed in coastal dune blow-outs or road cuttings in dunes, notably Dunsborough, Quininup Brook, Ellen Brook and Arumvale, have yielded hundreds of these chert artefacts (Figure 1; Bindon and Dortch 1982; Dortch and McArthur 1985; Ferguson 1980; 1981). Very occasional marine mollusc shell fragments have also been collected from the Late Pleistocene deposits at Devil's Lair and Tunnel Cave (Dortch 1996; Dortch *et al.* 1984; Merrilees 1968: 12). This evidence clearly suggests that the emergent continental shelf was frequented by human groups during times of glacio-eustatic low sea levels.

There is as yet little other evidence suggesting the activities and movements of Late Pleistocene and later hunter-gatherer groups when they were not occupying the cave and open-air sites discussed here, which are located on or near the present coasts of the Leeuwin-Naturaliste Region. For example, despite mainly brief searches carried out sporadically since the 1970s, relatively few prehistoric sites have been recorded in the lower reaches of the Blackwood River valley 10–30 km East of Devil's Lair and Tunnel Cave, or in the western end of the Scott Coastal Plain to the South-east (Figure 1). This scarcity of evidence probably reflects the nature of the terrain rather than a genuine lack of sites, since most open-air campsites located in these districts are likely to be buried in colluvial sediments or dunes, or concealed by thick vegetation. This is suggested by the very different archaeological record from the southern end of the Swan Coastal Plain, where land clearance, road-building and other modern developments have exposed numbers of prehistoric sites. For example, the Dunsborough town site is built over a complex of open-air camp sites represented by numerous stone artefacts *in situ* in dune soils. Two of these sites provide a range of radiocarbon dates *ca* 4500 to 12, 000 BP (Ferguson 1980; unpublished data: CED, JD).

Prehistoric land-use in the Leeuwin-Naturaliste Region cannot, in our opinion, be adequately assessed without taking into account the exploitable habitats that once existed on the emergent continental shelf to the West, North and South of the present-day coast, or the low-lying areas of resource-rich wetland and woodland on the southern Swan and Scott Coastal Plains, as well as the range of habitats in the largely forested Blackwood River valley. This view of the problem has a different perspective from that of Lilley, who based his assessment of prehistoric occupation patterns in the region on a series of "transect" surveys for sites from the upper reaches of the Margaret River directly westward to the present coast (Figure 1; Lilley 1993: 35–36; 39–40).

CURRENT RESEARCH

Comparison of the cultural, faunal, environmental and chronometric records from Devil's Lair and Tunnel Cave is now underway. With the advice and help of other archaeologists, we are preparing a long overdue inventory and review of the stone and bone artefact assemblages from Devil's Lair. One of us (JD) and S. Burke are identifying the species of charcoal fragments collected from Tunnel Cave and Devil's Lair, with the aim of determining local vegetation associations throughout the periods of deposition at both sites. As yet, pollen studies have not been carried out at either Devil's Lair or Tunnel Cave, though pollen and spores have been identified in sediment samples from the former site's floor deposit.

Of crucial importance in establishing more detailed chronologies for the depositional and occupational sequences for both sites, and for Devil's Lair in particular, is the cross-dating program being carried out by R. G. Roberts, School of Earth Sciences, La Trobe University, and other specialists. The existing con-ventional radiocarbon dating sequences for both sites' floor deposits will soon be matched by a series of OSL (optically stimulated luminescence) age assays done on quartz sand samples, as well as by AMS (accelerator mass spectrometry) radiocarbon dating of Emu eggshell and charcoal samples. The AMS dating, which is the work of G. Miller of the University of Colorado, and J. Magee, Research School of Asian and Pacific Studies, Australian National University, is part of their investigation of AAR (amino acid racemization) in Emu eggshell fragments collected from the cave floor deposits, with the aim of determining changes in temperature and environment through the periods of deposition. Projected also are dating by TIMS (thermal ionisation mass spectrometry) uranium series of eggshell, and uranium series and ESR (electron spin resonance) dating of flowstone (speleothem) layers from the excavated deposits. Devil's Lair sediment samples were a decade ago subjected to palaeomagnetism assay, though with equivocal results.

THE CULTURAL AND SCIENTIFIC SIGNIFICANCE OF CAVE AND ROCK SHELTER SITES IN THE LEEUWIN-NATURALISTE REGION

Since the 1980s, Nyoongar (south-western Aboriginal) communities have come to regard Devil's Lair and other sites in the Leeuwin – Naturaliste Region as highly significant components in their cultural heritage. Nyoongar young people have participated in the excavations at Devil's Lair, Tunnel Cave, Witchcliffe Rock Shelter and other sites in the lower South-west. Many other Australians are also aware that limestone caves in this region are an important part of the nation's cultural and natural heritage, and Devil's Lair is internationally known.

The Devil's Lair and Tunnel Cave excavations provide scope for inter-disciplinary investigations aimed at reconstructing the prehistoric past, based mainly on the findings of archaeologists, palaeontologists, geologists and radiometric dating specialists. Until other kinds of sites are identified and investigated, limestone cave and rock shelter sites, notably the ones in the Leeuwin – Naturaliste Region, will continue to provide a large part of the chronological, palaeoenvironmental, biological and cultural data for the prehistory of Western Australia's South-west.

ACKNOWLEDGEMENTS

Alex Baynes, the convenor of the 1997 Conference on Australasian Vertebrate Evolution, Palaeontology and Systematics (CAVEPS), asked us to produce an earlier version of this paper as a hand-out for a post-conference tour of Quaternary sites in the Leeuwin-Naturaliste Region. We thank Alex for encouraging us to revise that document for publication, and thank Jane Balme and George Kendrick for their close reading of the revised text.

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THE GECKO, *GEHYRA AUSTRALIS*, FEEDING ON THE SAP OF *ACACIA HOLOSERICEA*.

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Australian geckos are thought to primarily be arthropod feeders (Pianka & Pianka 1976; Greer 1989). However, there have been several observations of captive and free-ranging geckos feeding on sugary solutions, nectar and sap (Cogger *et al.* 1983 cited in Couper *et al.* 1995; Dell 1985; Greer 1989; King & Horner 1993; Couper *et al.* 1995). Of these observations, Dell (1985) and Couper *et al.* (1995) have reported geckos feeding on the sap *of Acacia* spp. The arboreal gecko, *Hoplodactylus duvaceli* from New Zealand is known to feed on a variety of foods including insects, berries and nectar (Robb 1980).

We made the following observation on May 6th, 1996, in open woodland near Durack River homestead (127°21' S: 15°49' E) in the Kimberley Region, north-west Australia. At approximately 2100h an individual *Gehyra australis* (approximately 100 mm snout vent length) was observed head downward on the trunk of an *Acacia holosericea*. On closer examination the lizard was seen to repeatedly lick an exudate from a wound to the tree. The exudate appeared to be sap or gum and consisted of two components, a crumbly "crystalline" portion and a harder more solid portion. The lizard was lapping at the crumbly portion. No insects were observed in the vicinity. This behaviour was observed for approximately 10 minutes and photographed (M.L.).

The contribution that plant exudates make to the dietary intake of arboreal Australian geckos is currently unknown (Dell 1985; Greer 1989). Nectars and *Acacia* gums are high in carbohydrates (Low 1991; Latz 1995) and, when available, could represent a significant and easily obtained energy source for geckos. The ability of geckos to lick (Greer 1989; King & Horner 1993) may also predispose arboreal species to exploit these resources. However, determining the contribution that energy rich plant exudates make to the diet of geckos, through traditional studies of gut contents, is hampered by the ease with which liquid substances high in sugars are digested (Couper *et al.* 1995). Numerous observations of arboreal Australian geckos, particularly *Gehyra* spp., feeding on plant exudates suggest that some species may be omnivorous (Dell 1985; Couper *et al.* 1995).

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BOOK REVIEW

Birds of Southwestern Australia: An atlas of changes in distribution and abundance of the wheatbelt avifauna. D. A. Saunders and J. A. Ingram, Surrey Beatty & Sons. 1995.

In a small scientific community it is often difficult to offer constructive criticism without it being taken personally. Therefore, at the outset, we emphasize that the following critique is provided in the spirit of improving any subsequent edition.

This attractively presented book is in large part based on observations of 187 rural observers from 1987 to 1990 (covering some 15,000 recording weeks). As could be expected from a database that depends on field observations of a largely amateur group, some records are suspect. Furthermore, the book is marred by lack of cognisance of important literature, an inadequate methodology, an ambivalent focus, and over-reliance on data (often irrelevant) from outside Western Australia. For such accounts to be scientifically valuable there needs to be a vigorous sorting of field observations and close checking of records with known distributions and accounts.

Philosophy – The underlying rationale for atlassing is not disclosed or referenced. Acknowledgment of the limitations and benefits of this approach along the lines provided by Paton *et al.* (1984) would have been useful.

Literature – Adequate use is not made of important scientific papers. Kitchener *et al.* (1982), the first major assessment of wheatbelt bird conservation, is not cited at all and only 3 of its 14 subsidiary papers are referred to, and then only in passing. Storr (1991), which is a monumental synthesis of about one million authenticated records, is mentioned only briefly.

Methodology – The book attempts to quantify decline in distribution of wheatbelt species by comparing the results collected from 187 localities during 4 years with those from 10 localities during 37 years. This comparison is too unbalanced. A more valid approach would be to select 1 or 2 localities as close as possible to each of the 10 historical localities and execute a pairwise comparison using presence/absence data for species. The point source data in Appendix 1 of Kitchener *et al.* (1982) could also have been treated similarly.

The study region – In the first year of the study, nearly all observers were located in the wheatbelt as defined by the authors. However, inexplicably, the study was subsequently broadened to include up to 16 localities in the higher rainfall portion of the southwest. Hence the ambivalence in the book's title. It must be conceded that the small sample from the wetter southwest is inadequate, adds little to our knowledge of the avifauna of the

Swan Coastal Plain and forest, and detracts from the initial emphasis on the wheatbelt. It also pads out the book with several species not found in the wheatbelt eg: Red-winged Fairy-wren *Malurus elegans* and Red-eared Firetail *Stagonopleura oculata*, and results in the omission of restricted species eg: White-breasted Robin *Eopsaltria georgiana*, Noisy Scrub-bird *Atrichornis clamosus* and Western Whipbird *Psophodes nigrogularis*.

Irrelevant data – The text is padded with data derived from the eastern states, particularly information on status, food, and breeding. Sometimes this is misleading eg: Striated Pardalote *Pardalotus striatus* does not nest in creek banks in WA.

Misidentifications – We acknowledge that bird faunas are not fixed. In very wet years it is not uncommon for more coastal species to penetrate farther inland; conversely, in droughts some species appear closer to the coast. Notwithstanding this, we think that some occurrences out of normal range as listed in Storr (1991) represent errors in identification.

Some congeneric species are notoriously difficult to identify in the field. Extra vigilance is therefore needed in evaluating field identifications of these species. For example, confusion is evident in the following species. Hoary-headed Grebe and Australasian Grebe; Black Falcon, Grey Falcon and Brown Falcon (records of the Black and Grey Falcons are probably based on dark and light morph Brown Falcons); Brown Quail and Stubble Quail (the former does not occur in the wheatbelt); Brush Bronzewing and Common Bronzewing (records east of Grass Valley of the former); Horsfield's Bronze Cuckoo and Shining Bronze Cuckoo (southwest records of the former); Boobook Owl and Barking Owl (northern records of the latter); Scarlet Robin and Red-capped Robin (northern and inland records of the former); Gilbert's Whistler, Golden Whistler and Rufous Whistler; Red-winged Fairy-wren and Blue-breasted Fairy-wren; Red Wattlebird and Little Wattlebird; Grey-fronted Honeyeater and Yellow-plumed Honeyeater; White-naped Honeyeater and Brown-headed Honeyeater (inland records of former = latter); New Holland Honeyeater, White-cheeked Honeyeater and White-fronted Honeyeater.

Perhaps for some of these species the authors should have adopted the solution they used to accommodate confusion between Carnaby's and Baudin's Cockatoos, namely combining their distributions. Other questionable records of species include: Southern Emu-wren (northern record); Shy Hylacola (westernmost records); Redthroat (westernmost records); Western Thornbill (northern records); White-eared Honeyeater (southern record); White-plumed Honeyeater (southern record); and Yellow-rumped Pardalote (northern records; the mist netted specimens of the latter should have been photographed or at least one retained as a voucher specimen).

The book concludes with some practical advice as to how landholders in the wheatbelt can make a difference in conserving the local bird fauna.

Our overall conclusion is that the book is a useful record of the distribution, during the final four years of the ninth decade of the 20th century, of the easily recognizable and/or common bird species in the wheatbelt of Western Australia – eg: Emu, Pelican, Mountain Duck, Black Duck, Wedge-tailed Eagle, Malleefowl, Galah, Budgerigah, Rainbow Bee-eater, Black-faced Cuckoo-shrike, Willy Wagtail, Brown Honeyeater, Magpie Lark, and maybe Raven. For reliable information on the distribution of cryptic species, species not favoured by farmland, and species easily confused with others, we prefer the accounts of Kitchener *et al.* (1982) and its primary references and Storr (1991).

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VEGETATION AND FLORA OF SCOTT NATIONAL PARK AND ADJACENT RECREATION RESERVES

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ABSTRACT

Scott National Park and adjacent recreation reserves are the largest publicly owned remnant of the Scott Coastal Plain's original vegetation. The vegetation of the study area is predominantly Jarrah-Marri woodlands on upland areas and sedgelands of variable composition in the extensive wetlands. A regionally significant community, the Scott Coastal Plain Ironstones is only found in the recreation reserve. The study area contains a flora of at least 734 species of vascular plant. Of these 681 are natives and 53 are weeds.

INTRODUCTION

Scott National Park (Reserve 25373)is found approximately 5 kilometres east of Augusta on the eastern side of the Blackwood River and Hardy Inlet. The national park is contiguous with the naturally vegetated recreation reserve A12951/4753 (vested in the shire of Augusta-Margaret River) and these areas are treated together in this paper. The total area of these reserves is 3,516 hectares. These reserves constitute the only substantial conservation reserve on the western side of the Scott Coastal Plain an area noted for it's level of localised endemics (Keighery and Robinson, 1992).

There have been no previous lists of vascular plants prepared for the national park. The current list is based on extensive field survey undertaken in 1990 and 1991.

RESULTS

NOTES ON VEGETATION ASSOCIATIONS – SCOTT NATIONAL PARK

The vegetation map was prepared using colour aerial photography and extensive foot traverse. We have distinguished 14 vegetation complexes and 12 combinations of several of these types (Figure 1). The combinations are usually in the wetlands where small changes in topography greatly influence the depth and duration of inundation and hence the dominant plant species present. These could not be mapped separately even at this small scale.

Major vegetation associations:

1. Riverine Rushes

Juncus kraussii and *Baumea juncea* form homogenous populations up to 30 m wide or in association with *Melaleuca cuticularis*, *Melaleuca polygaloides*, *Melaleuca pauciflora*, *Gahnia trifida*, *Samolus repens*, *Samolus junceus* and *Apium prostratum*. Confined to shores of Blackwood and Scott Rivers as far as salt water incursion. Covers a total of 1.2 Ha. (0.0034% of the study area).

2. *Restio – Anarthria Sedgeland*

Restio ustulatus, *Anarthria prolifera* and *Anarthria scabra* association covers substantial areas, particularly in the southern section of the National Park, around wetland complexes. Typically occurring with *Evandra aristata*, *Leucopogon gilbertii*, *Leucopogon* aff. *gilbertii*, *Hypocalymma ericifolium*, *Pericalymma crassipes*, *Andersonia caerulea*, *Sphenotoma gracile*, *Mesomelaena tetragona*, *Euchiliopsis linearis*, *Lysinema conspicuum*, *Adenanthos obovatus* and *Lechenaultia expansa*. This association on sandy soils is winter wet but not inundated. Covers a total of 815.5 Ha (23.2% of the study area).

3. *Leptocarpus – Pericalymma* Wetlands

Usually discrete (circular) sandy depressions which are seasonally inundated. Association comprised mainly of *Leptocarpus* spp. and *Pericalymma spongiocaule* but occasionally *Hakea linearis*, *H. ceratophylla* or *Calothamnus lateralis* may occur. Covers a total of 281.8 Ha (8.015% of the study area).

4. *Leptocarpus – Agonis floribunda* Wetland

Very similar to association 3, with *Pericalymma ellipticum* replaced by *Agonis floribunda* as depth of seasonal inundation becomes greater. Few other species comprise this association but *Melaleuca lateritia* may occur in the deepest wetlands. Covers a total of 47.5 Ha (1.28% of the study area).

5. Wet Heath

Seasonally inundated sandy areas with some water flow, characterised by tall shrubs *Homalospermum firmum* and *Beaufortia sparsa*. Other typical species include *Evandra aristata*, *Astartea fascicularis*, *Agonis linearifolia*, *Hypocalymma* aff. *cordifolium*, *Gymnoschoenus anceps*, *Actinotus laxus*, *Aotus carinata*, *Dampiera hederacea*, *Acacia uliginosa* and sedges. Covers a total of 34.9 Ha (0.99% of the study area).

6. Dry Heath

Sandy areas not seasonally inundated and characterised by tall emergent *Kunzea recurva*. Other main species are *Melaleuca thymoides*, *Dasypogon bromeliifolius*, *Agonis parviceps*, and *Patersonia occidentalis*. This association often merges with *Restio – Anarthria* Sedgeland. Covers a total of 43.1 Ha (1.226% of the study area).

7. Paperbark Flat

Open areas, usually a series of minor depressions with *Melaleuca preissiana* over elements of wet heath. *Banksia littoralis, Banksia occidentalis* and *Eucalyptus patens* may occur. Covers a total of 17.1 Ha (0.486% of the study area).

8. Watercourse Paperbarks

Dense stands of *Melaleuca cuticularis* occur along the salt sections of both rivers, often with Riverine Rushes as understorey. Fresh water creeklines and river are often marked by *Melaleuca rhaphiophylla* with a dense understorey of *Melaleuca polygaloides, Lepidosperma gladiatum, Agonis fascicularis, Dampiera hederacea* and *Taraxis grossa*. Covers a total of 8.9 Ha (0.25% of the study area).

9. Banksia Woodland

Banksia ilicifolia on sandy ridges with a low heath of *Melaleuca thymoides, Kunzea recurva, Jacksonia horrida, Adenanthos meisneri* and *Lysinema ciliatum*. Covers a total of 84.0 Ha (2.39% of the study area).

10. Jarrah – Banksia Woodland

Association of *Banksia ilicifolia* with stunted *Eucalyptus marginata* on sandy ridges with a tall understorey of *Jacksonia horrida, Daviesia flexuosa, Melaleuca thymoides, Kunzea recurva, Agonis flexuosa, Anarthria scabra* and *Phlebocarya ciliata*. Covers a total of 49.7 Ha (1.41% of the study area).

11. Jarrah – Paperbark Flat

Similar to Paperbark Flat with the addition of stunted *Eucalyptus marginata*. Covers a total of 102.6 Ha (2.91% of the study area).

12. Jarrah – Marri Forest

This association on sandy soils comprises the bulk of the National Park forest and is typified by an overstorey of *Eucalyptus marginata* with a lower tree storey of *Agonis flexuosa, Banksia grandis* and *Xylomelum occidentale* and an understorey of *Bossiaea linophylla, Hovea elliptica, Anarthria scabra, Agonis parviceps, Acacia myrtifolia, Acacia divergens, Persoonia longifolia, Adenanthos obovatus* and *Hibbertia hypericoides*. Covers a total of 1469.3 Ha (41.79% of the study area).

13. Karri Forest

Tall forest of *Eucalyptus diversicolor* with *E. calophylla* and some *E. marginata*. The understorey of *Agonis flexuosa, Agonis parviceps, Hakea oleifolia, Bossiaea linophylla, Hovea elliptica, Hakea linearis, Anigozanthos flavidus, Lepidosperma longitudinale, Logania vaginalis, Leucopogon verticillatus* and some *Chorilaena quercifolia* is noteable for the absence of *Acacia subracemosa* and *Bossiaea disticha* which are typical of Karri forest around Augusta, just across the river. Covers a total of 111.1 Ha (3.16% of the study area).

14. Laterite Heath

Association on exposed laterite or shallow soils over laterite with surface runoff in winter. Characterised by occasional *Melaleuca preissiana* with a shrub layer of *Hakea tuberculata*, *Pericalymma ellipticum, Grevillea* sp. nov., *Viminaria juncea, Hakea sulcata, Hemiandra pungens, Hakea oleifolia, Calothamnus* aff *crassus, Melaleuca polygaloides, Petrophile squamata, Mesomelaena tetragona, Loxocarya magna* and *Hibbertia stellaris.* Covers a total of 31.2 Ha (0.916% of the study area).

WETLAND COMPLEXES (EXCEPT 16 AND 25)

15. *Leptocarpus – Agonis floribunda*/Wet Heath/Paperbark Flat (Complexes 4, 5 and 7). Covers a total of 85.7 Ha (2.44% of the study area).
16. Jarrah/Banksia Woodland/Jarrah/Marri Forest (Complexes 10 and 12). Covers a total of 115.9 Ha (3.3% of the study area).
17. *Leptocarpus – Pericalymma* Wetland/Paperbark Flat (Complexes 3 and 7). Covers a total of 29.2 Ha (0.830% of the study area).
18. *Leptocarpus – Pericalymma* Wetland/Leptocarpus – Agonis floribunda Wetland (Complexes 3 and 4). Covers a total of 30.1 Ha (0.856% of the study area).
19. Riverine Rushes/Watercourse Paperbarks (Complexes 1 and 8). Covers a total of 40.1 Ha (1.141% of the study area).
20. Wet Heath/Paperbark Flat (Complexes 5 and 7). Covers a total of 21.6 Ha (0.614% of the study area).
21. *Restio – Anarthria* Sedgeland/Wet Heath/Dry Heath (Complexes 2, 5 and 6). Covers a total of 13.8 Ha (0.392% of the study area).
22. *Leptocarpus – Pericalymma* Wetland/Watercourse Paperbarks (Complexes 3 and 8). Covers a total of 12.2 Ha (0.346% of the study area).
23. *Leptocarpus – Pericalymma* Wetland/Wet Heath (Complexes 3 and 5). Covers a total of 27.3 Ha (0.776% of the study area).
24. *Restio – Anarthria* Sedgeland/*Leptocarpus – Pericalymma* Wetland (Complexes 2 and 3) Covers a total of 20.8 Ha (0.592% of the study area).
25. Dry Heath/Jarrah – Marri Forest (Complexes 6 and 12). Covers a total of 6.9 Ha (0.196% of the study area).
26. *Restio – Anarthria* Sedgeland/Wet Heath (Complexes 2 and 5). Covers a total of 13.7 Ha (0.399 % of the study area).

Total area: 3516.3 Hectares.

Smith (1973) mapped the major vegetation formations for the Scott Coastal Plain at a scale of 1:250,000 and gave the study area as being Jarrah/Marri low woodland and Herblands. At the much smaller scale reported here we have distinguished 14 vegetation complexes and 12 combinations of several of these types. The main vegetation complexes are, as Smith (1973) noted; Jarrah/Marri forest and woodland (42% of the study area) and Restio-Anarthria sedgelands (23% of the study area). There are also, however, significant areas of Karri Forest, Woodlands of Paperbark (*Melaleuca* species), Jarrah/Banksia or Jarrah/Melaleuca, Shrublands and

Sedgelands. The lateritic heath confined to the recreation reserve is a unique vegetation type confined to the Scott Coastal Plain and contains many of the Scott Plains endemic plants. It is the western most example of this vegetation type and one of two pristine examples still remaining it should be managed as part of the National Park. The Karri forest is one of the few stands of this vegetation type on the Scott Coastal Plain and it has a different understorey to that on the Leeuwin-Naturaliste ridge lacking *Acacia subracemosa* and *Bossiaea disiticha* (Keighery, 1996) as major components of the understorey. These are replaced by *Acacia scapelliformis*, here at its western limit.

FLORA

Current records of the vascular flora present inside the boundaries of the national Park and adjacent recreation reserves are given in Table 1.

Despite it's small size and limited range of habitat's the flora of the park is rich, being composed of over 734 (681 natives and 53 weeds)taxa of vascular plants. Of these 7 are Ferns, Fern allies and Gymnosperms, 251 are Monocotyledons and 476 are Dicotyledons.

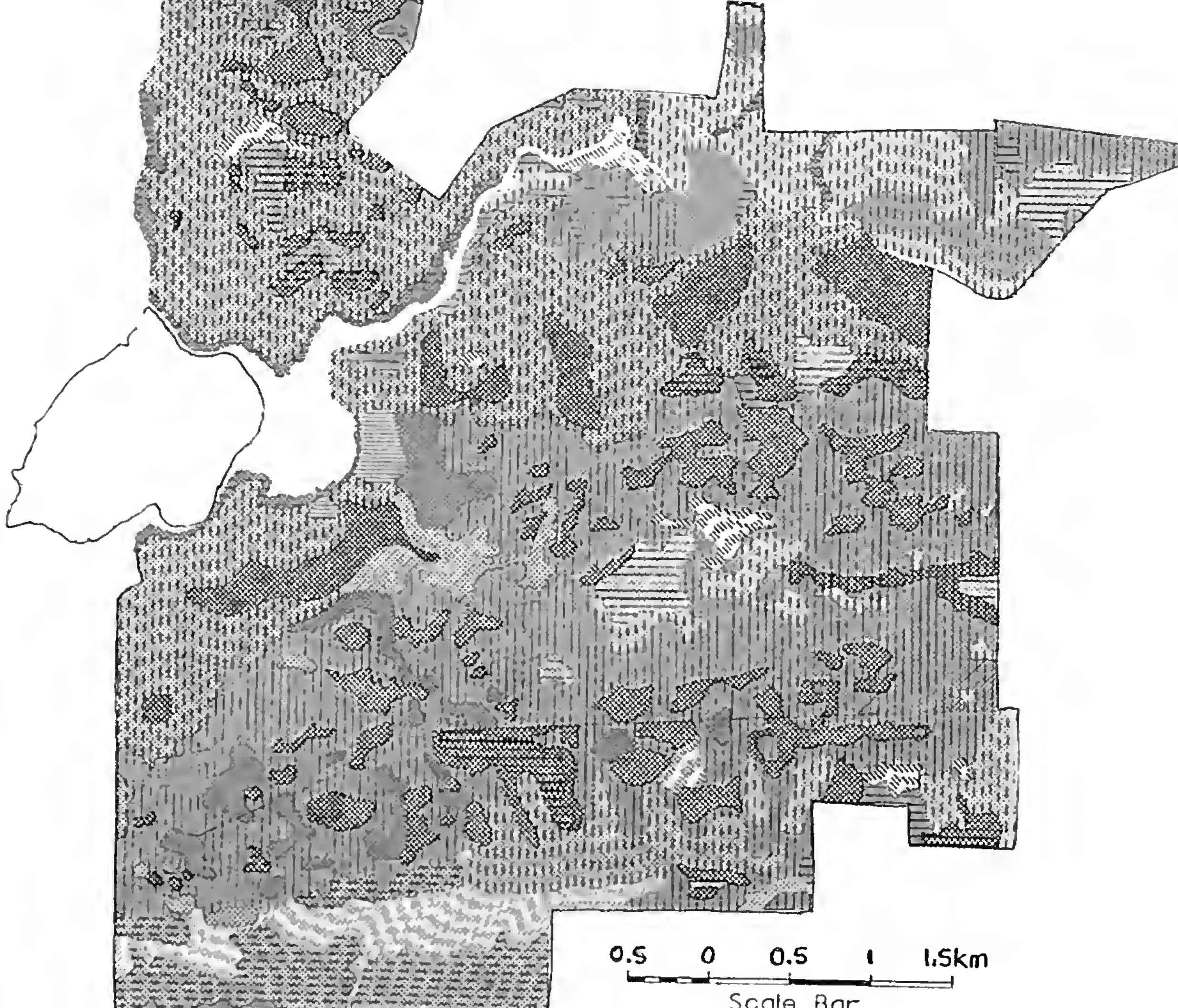
The largest families are the in the Monocotyledons, Orchidaceae (51 natives, 1 weed), Cyperaceae (44 natives, 2 weeds), Restionaceae (33 natives), Poaceae (18 natives, 12 weeds). In the Dicotyledons, Papilionaceae (51 natives, 6 weeds), Proteaceae (49 natives), Myrtaceae (41 natives, 1 weed), Asteraceae (29 natives, 13 weeds), Epacridaceae (29 natives), Stylidiaceae (29 natives). and the Goodeniaceae (18 natives).

The largest genera are *Stylidium* (29 species), *Leucopogon* (18 species), *Acacia* (16 species), *Schoenus* (14 species) and *Caladenia* (14 species).

The flora is representative of the higher rainfall zone (Warren Botanical subdistrict)of southern Western Australia being rich in herbaceous species especially, Orchidaceae, Cyperaceae, Restionaceae and Stylidiaceae (Hopper *et al*, 1992) and small shrubs of the Epacridaceae (Keighery, 1996).

GEOGRAPHICALLY SIGNIFICANT RECORDS

As noted previously because this is one of the few large areas of bushland remaining on the Scott Coastal Plain, an area containing numerous endemic, disjunct and geographically restricted taxa (Keighery and Robinson, 1992). The Department of Conservation and Land Management under the provisions of the Wildlife Conservation Act has listed some flora under imminent threat of extinction as Declared Rare Flora (DRF), which gives them legal protection on all types of land. Other plant species of conservation concern (and in some cases are candidates for declaration as rare flora) which are poorly known or not under immediate threat are informally listed as priority flora (P1; plants known from 1 or few populations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VEGETATION ASSOCIATIONS

(1) Riverine Rushes
(2) Restio-Anarthria Sedgeland
(3) Leptocarpus-Pericalymma Wetlands
(4) Leptocarpus-Agonis Floribunda Wetland
(5) Wet Heath
(6) Dry Heath
(7) Paperbark Flat
(8) Watercourse Paperbarks
(9) Banksia Woodland
(10) Jarrah-Banksia Woodland
(11) Jarrah-Paperbark Flat
(12) Jarrah-Marri Forest
(13) Karri Forest
(14) Laterite Heath

COMBINATIONS

(4) & (5) & (7)	(2) & (5) & (6)
(10) & (12)	(3) & (8)
(3) & (7)	(3) & (5)
(3) & (4)	(2) & (3)
(1) & (8)	(6) & (12)
(5) & (7)	(2) & (5)

which are under threat. P2; plants known from 1 or few populations not under immediate threat. P3; Plants known from several populations and not believed to be under immediate threat and P4 plants that are well known and while rare are not currently threatened but require monitoring). It is not surprising that there are 31 species on CALM's Priority Flora list (Atkins, 1997) and two species of Declared Rare Flora present in the study area. These are *Dryandra nivea* ssp. *uliginosa* (Declared Rare), *Acacia horridula* (Priority (P)3, southernmost population), *Acacia semitrullata* (P3), *Ampera micrantha* (P2), *Ampera simulans* (P1), *Anthotium junciforme* (P4), *Aotus carinata* (P4, a Scott Plains endemic,), *Astartea* sp (Scott River) Backshall 88233 (P4), *Blennospora* sp (Ruabon) B.J. Keighery and N. Gibson 20 (P3), *Boronia exilis* (P1, a Scott Plains endemic), *Caladenia abbrevata* (P2), *Calothamnus* aff. *crassus* (P2), *Conospermum paniculatum* (P3), *Conospermum quadripetalum* (P2), *Cyathochaeta stipoides* (P3), *Gonocarpus pusillus* (P3), *Grevillea brachystylis* ssp. *australis* (P2, a Scott Plains endemic), *Grevillea* sp (G.J. Keighery 4070) (P1, a Scott Plains endemic), *Hakea tuberculata* (P2) *Hybanthus volubilis* (P2), *Hypocalymma* sp (Scott River) (P4), *Isopogon* sp Busselton (G.J. Keighery 11534) (P3), *Lambertia orbifolia* (Declared Rare), *Leptomeria ericoides* (P2), *Lepyrodia heleocharoides* (P3), *Leucopogon gilbertii* (P3), *Meeboldinia thysanantha* (P3), *Microtis media* ssp. *quadrata* (P4), *Philydrella pygmaea* ssp. *minima* (P1, a Scott), *Restio gracilior* (P3), *Schoenus loliaceus* (P2), *Sphenotoma parviflorus* (P3), *Stylidium leeuwinense* (P3) and *Stylidium mimeticum* (P3).

The previous list includes a rich representation of the endemics of the Scott Coastal Plain (the priority code of these species being highlighted in the above list), including *Aotus carinata*, *Astartea* sp. (Scott River), *Boronia exilis*, *Grevillea brachystylis* ssp. *australis*, *Grevillea* sp. Scott River (GK 4070), *Hypocalymma* sp. Scott River, and *Philydrella pygmaea* spp. *minima*. Species endemic to the Scott Plain not in the study area include *Adenanthos detmoldii* (P4), *Synaphaea nexosa* (P1)., which do not extend this far west)., *Darwinia ferricola* (DRF) and *Restio isomorphus* (P2, both confined to the Scott Ironstones but not present on the sheet in the study area).

A feature of the Scott Plains is the number of species occurring disjunctly here and then on the Southern Swan Coastal Plain (Gibson, *et al.* 1994) but not present on the Blackwood Plateau. Species present in the study area include *Banksia meisneri* var *ascendens*, *Grevillea brachystylis*, *Loxocarya magna*, *Calothamnus* aff. *crassus*, *Dryandra nivea* ssp. *uliginosa*, *Stylidium leeuwinense* and *Stylidium* aff *bulbiferum*.

There are also a number of species that range from the Scott plains to Albany, often disjunct in occurrence. These include *Conospermum quadripetalum*, *Hakea tuberculata* and *Lambertia orbifolia*.

Another species with a highly disjunct distribution is *Leptomeria* *ericoides*. The collection from Scott National Park is the third record of this species. Previously this species has been only recorded in recent times from Ambergate Regional Park (Keighery *et al*, 1996), SW of Busselton.

DISCUSSION

Several long term residents of the Augusta area stated that "prior to the establishment of all weather access to East Augusta being provided through the park, Pitcher Plants (*Cephalotus follicularis*) were found in the Wet Heath association". The disturbance to natural drainage patterns said to be causing their loss. This association was searched extensively for *Cephalotus follicularis* without success. Pitcher plants appear to have declined in most of their western margins of their range (Keighery, unpub. obs.), although they were still present at West Bay in Leeuwin-Naturaliste National Park in 1991.

Scott National Park despite its small size is of considerable conservation significance. It contains a rich flora of over 734 taxa of vascular plants of which 681 are native. The largest families and genera reflect those listed as most diverse for the Warren Botanical District by Hopper *et al* (1992). Of the 12 taxa endemic to the Scott Coastal Plain, 8 are present and conserved in Scott National Park and adjacent recreation reserves.

Of the native species 31 are on CALM's priority flora list and eight of these are endemic to the Scott Coastal Plain. The whole study area should be managed for the conservation of flora and fauna as it's primary objective.

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SCOTT NATIONAL PARK – VEGETATION ASSOCIATIONS

1. Riverine Rushes
2. *Restio* – *Anarthria* Sedgeland
3. *Leptocarpus* – *Pericalymma* Wetlands
4. *Leptocarpus* – *Agonis floribunda* Wetland
5. Wet Heath
6. Dry Heath
7. Paperbark Flat
8. Watercourse Paperbarks
9. Banksia Woodland
10. Jarrah – Banksia Woodland
11. Jarrah – Paperbark Flat
12. Jarrah – Marri Forest
13. Karri Forest
14. Laterite Heath

APPENDIX ONE: SCOTT NATIONAL PARK

FLORA LIST

Key: Names and numbers in brackets refer to voucher collections held in the Western Australian Herbarium (PERTH) at Como. Collectors are: CJR: C. Robinson, GJK: G. Keighery. BJK/ NG: Bronwen Keighery and Neil Gibson. An " " around the species name refer to Restionaceae manuscript names currently used at PERTH. An * indicates a naturalised weed. The list is in systematic order as used in PERTH Herbarium.

FERNS AND FERN ALLIES

DENNSTAEDTIACEAE
Pteridium esculentum (G. Forst.) Cockayne

LINDSAEACEAE
Lindsaea linearis SW.

LYCOPODIACEAE
Phylloglossum drummondii Kunze

SELAGINELLACEAE
Selaginella gracillima (Kunze) Alston

OPHIOGLOSSACEAE
Ophioglossum lusitanicum L.

GYMNOSPERMS

PODOCARPACEAE
Podocarpus drouynianus F. Muell.

ZAMIACEAE
Macrozamia reidlei (Fisch. ex Gaud.) C.A. Gardner

MONOCOTYLEDONS

CENTROLEPIDACEAE
Aphelia cyperoides R.Br.
A. brizula F.Muell.
A. nutans Hook. ex Benth.
Centrolepis aristata (R.Br.) Roem. et Schultz
C. drummondiana (Nees.) Walp
C. inconspicua W.V. Fitz.
C. mutica (R.Br.) Hieron

CYPERACEAE
Baumea articulata (R.Br.) S.T. Blake
B. juncea (R.Br.) Palla
B. vaginalis (Benth.) S.T. Blake
Chorizandra cymbaria R.Br.
C. enodis Nees.
Cyathochaeta avenacea Benth.
C. clandestina (R.Br.) Benth.
C. stipoides K.L. Wilson
**Cyperus tenellus* L.f.
Evandra aristata R.Br.
Gahnia trifida Labill.
Gymnoschoenus anceps (R.Br.) C.B. Clarke
Isolepis cyperoides R.Br.
I. marginata (Thunb.) A. Dietr.
I. nodosa (Rottb.) R.Br.
*I. prolifera (Rottb.) C.B. Clarke
.*I setiformis* (S.T.Blake) K.L.Wilson
I. stellata (C.B. Clarke) K.L.Wilson
I. sp. (CJR375)
Lepidosperma carphoides F.Muell. ex Benth.
L. effusum Benth.
L. gladiatum Labill.
L. longitudinale Labill.
L. pubisquameum Steudel
L. squamatum Labill.
L. tetraquetrum Nees.
Mesomelaena graciliceps (C.B. Clarke) K. Wilson
M. stygia (R.Br.) Nees
M. tetragona (R.Br.) Benth.
Schoenus asperocarpus F.Muell.
S. bifidus (Nees) Boekel
S.cruentus (Nees.) Benth.
S. curvifolius (R.Br.) Benth.
S. discifer Tate
S. efoliatus F.Muell.

S. elegans S.T.Blake
S. indutus (F.Muell.) Benth.
S. loliaceus Kuek.
S. maschalinus Roem. et Schultes
S. nitens (F.Muell.) Benth.
S. odontocarpus F. Muell.
S. subflavus Kuek.
S sp (CJR 402)
Tetraria capillaris (F. Muell.) J. Black
T. octandra (Nees.) Kuek.
Tricostularia neesii Lehm.

TYPHACEAE
Typha domingensis Pers.

RUPPIACEAE
Ruppia polycarpa Mason

JUNCAGINACEAE
Triglochin calcitrapum Hook.
T. huegelii Endl.
T. striata Ruiz. et Pav.
T. trichophora Nees. ex Endl.

POACEAE
Agrostis avenacea J. Gmelin
**Aira caryophyllea* L.
Amphipogon laguroides R.Br.
A. turbinatus R.Br.
**Anthoxanthum odoratum* L.
Austrostipa compressa (R.Br.) Jacobs & Everet
A. flavescens (Labill.) Jacobs & Everet
A. semibarbata (R.Br.) Jacobs & Everet
**Avellina michelii* (Savi) Parl.
**Avena barbata* Link
**Briza maxima* L.
**B. minor* L.
**Bromus diandrus* Roth.
**Cynodon dactylon* (L.) Pers.
**Dactylis glomerata* L.
Danthonia pilosa R.Br.
Deyeuxia quadriseta Benth.
Dichleachne crinita (L.f.) Hook.
Diplopogon setaceus R.Br.
**Ehrharta longiflora* Sm.
**Hainardia cylindrica* (Willd.) Greuter
Hemiarthria uncinata R.Br.
Microlaena stipoides (Labill.) R.Br.
Neurachne alopecuroidea R.Br.
Poa drummondiana Nees.
P. porphyroclados Nees.
**Polypogon monspeliensis* (L.) Desf.
P. tenellus R.Br.
Sporobolus virginicus (L.) Kunth
Tetrarrhena laevis R.Br.

RESTIONACEAE
Anarthria gracilis R.Br.
A. prolifera R.Br.
A. scabra R.Br.
Chaetanthus leptocarpoides R.Br.
Empodisma gracillimum (F. Muell.) Johnson
Hypolaena exsulca R.Br.
Leptocarpus coangustatus Nees.
L. scariosus R.Br.
L. "diffusus"
L. tenax (Labill.) R.Br.
L. tenellus (Nees) F. Muell.
L. "roycei"
Lepyrodia heleocharoides Gilg.
L. "rivularis"
L. "porterae"
Loxocarya "castanea"
L. cinerea R.Br.
L. flexuosa (R.Br.) Benth.
L. magna Meney et Dixon
Lyginia barbata R.Br.
Meeboldina denmarkica Suess.
Meeboldinia thysanantha
Restio amblycoleus F. Muell.
R. applanatus Spreng.
R. leptocarpoides Benth.
R. tremulus R.Br.
R. ustulatus F. Muell. ex Ewart
R. "cracens"
R. gracilior (F. Muell.) Benth.
R. "serialis"
Sporodanthus strictus (R.Br.) L.Johnson et Cutler
Taraxis glauca L.Johnson et Briggs
T. grossa L.Johnson et Briggs

HYDATELLACEAE

Trithuria bibracteata D.A. Cooke

T. submersa J.D. Hook.

XYRIDACEAE

Xyris gracillima F. Muell.

X. lacera R.Br.

X. lanata R.Br.

X. laxiflora F. Muell.

X. roycei Wakefield

PHILYDRACEAE

Philydrella pygmaea (R.Br.) Caruel var *minima* L.Adams

JUNCAEAE

Juncus amabilis E. Edgar

**J. articulatus* L.

J. bufonius L.

**J. capitatus* Weigel

J. gregiflorus L.Johnson

J. holoschoenus R.Br.

J. kraussii Hochst.

**J. microcephalus* Kunth.

J. pallidus R.Br.

J. pauciflorus R.Br.

J. planifolius R.Br.

J. subsecundus Wakefield

Luzula meridionalis Nordensk.

DASYPOGONACEAE

Acanthocarpus preissii Lehm.

Baxteria australis R.Br.

Dasypogon bromeliifolius R.Br.

Kingia australis R.Br.

Lomandra caespitosa (Benth.) Ewart

L. integra T.D. Macfarlane

L. nigricans T.D. Macfarlane

L. odora (Endl.) Ewart

L. pauciflora (R.Br.) Ewart

L. preissii (Endl.) Ewart

L. purpurea (Endl.) Ewart

L. sericea (Endl.) Ewart

L. sonderi (Endl.) Ewart

XANTHORRHOEACEAE

Xanthorrhoea preissii Endl.

PHORMIACEAE

Stypandra grandiflora Lindl.

ANTHERICACEAE

Agrostocrinum scabrum (R.Br.) Baillon.

Caesia micrantha Lindl.

C. aff. *micrantha* (GJK12471)

C. occidentalis R.Br.

Chamaescilla corymbosa (R.Br.) F. Muell. ex Benth.

Hodgsoniola junciformis F. Muell.

Johnsonia acaulis Endl.

J. lupulina R.Br.

Laxmannia sessiliflora Dcne. ssp. *australis* Keighery

Sowerbaea laxiflora Lindl.

Thysanotus arenarius N.H. Brittain

T. dichotomus R.Br.

T. multiflorus R.Br.

T. patersonii R.Br.

T. tenellus Endl.

T. triandrus (Labill.) R.Br.

Tricoryne elatior R.Br.

T. humilis Endl.

ASPHODELACEAE

Bulbine semibarbata (R.Br.) Haw.

COLCHICACEAE

Burchardia multiflora Lindl.

B. umbellata R.Br.

HAEMODORACEAE

Anigozanthos flavidus Redoute

A. manglesii Don.

A. viridis Endl.

Conostylis aculeata R.Br.

C. laxiflora Benth.

C. setigera R.Br.

Haemodorum laxum R.Br.

H. simplex Lindl.

H. sparsiflorum F.Muell.

H. spicatum R.Br.

Phlebocarya ciliata R.Br.

Tribonanthes australis Endl.

T. violacea Endl.

HYPOXIDACEAE

Hypoxis occidentalis Benth.

IRIDACEAE

Orthrosanthos laxus (Endl.) Benth.
Patersonia juncea Lindl.
P. occidentalis R.Br. var *occidentalis*
P. occidentalis R. Br. var *angustifolia* Benth.
P. umbrosa Endl. var. *xanthina* (F. Muell.) Domin.
**Romulea rosea* (L.) Ecklon

ORCHIDACEAE

Caladenia abbreviata Hopper et Brown
C. aphylla Benth.
C. brownii Hopper
C. ensata Hopper et Brown
C. cairnsiana F. Muell.
C. gardneri Hopper et Brown
C. flava R.Br.
C. georgei Hopper et Brown
C. infundibularis A.S. George
C. latifolia R.Br.
C. longiclavata E. Coleman
C. marginata Lindl.
C. nana Endl. subsp. *unita*
C. longicauda Lindl.
C. reptans Lindl.
Cryptostylis ovata R.Br.
Cyanicula gemmata (Lindl.) Hopper et Brown
C. sericea (Lindl.) Hopper et Brown
Diuris laevis W.V. Fitz.
D. longifolia R.Br.
Drakea glyptodon W.V. Fitz.
Elythranthera brunonis (Endl.) A.S. George
E. emarginata (Lindl.) A.S. George
Epiblema grandiflorum R.Br.
Eriochilus dilatatus Lindl.
E. scaber Lindl.
Leporella fimbriata (Lindl.) A.S. George
Leptoceras menziesii (R.Br.) Lindl.
Lyperanthus forrestii F. Muell.
L. serratus Lindl.
Microtis alba R.Br.
M.atrata Lindl.
M. media R. Br. *ssp quadrata* R. Bates
**Monadenia bracteata* (Sw.) Durand et Shinz.
Prasophyllum brownii Reichb.
P. calcicola R. Bates
P. elatum R.Br.
P. hians Reichb.
P. macrostachyum R.Br.
P. parvifolium Lindl.
P. ringens Reichb.
Pterostylis barbata Lindl.
P. vittata Lindl.
P. aff. *nana* R.Br.
Pyrorchis nigricans (R.Br.) D.Jones
Thelymitra crinita Lindl.
T. cornicina Reichb.
T. flexuosa Endl.
T. fuscolutea R.Br.
T. mucida W.V. Fitz.
T. pauciflora R.Br.
T. aff. *holmesii* Nicholls

DICOTYLEDONS

CASUARINACEAE

Allocasuarina fraseriana (Miq.) L. Johnson

PROTEACEAE

Acidonia teretifolia (R.Br.) L. Johnson et Briggs
Adenanthos barbigerus Lindl.
A. meisneri Lehm.
A. obovatus Labill.
Banksia attenuata R.Br.
B. grandis Willd.
B. ilicifolia R.Br.
B. littoralis R.Br.
B. meisneri Lehm. var. *ascendens* A.S. George
B. occidentalis R.Br.
Conospermum caeruleum R.Br. ssp. *debile* (Kipp. ex Meisn.) Bennett
C. capitatum R.Br.
C. flexuosum R.Br. ssp. *laevigatum* Bennett
C. paniculatum Bennett
C. quadripetalum Bennett

Dryandra sessilis (Knight) Domin.
D. nivea (Labill.) R.Br. ssp. *uliginosa* A.S. George
Grevillea brachystylis Meisn. ssp. *australis* Keighery
G. papillosa (McGillivray) Olde et Marriott
G. *manglesioides* Meisn. ssp. *manglesioides*
G. *manglesioides* Meisn. ssp. nov. (GJK 4070)
G. *quercifolia* R.Br.
Hakea amplexicaulis R.Br.
H. ceratophylla (Sm.) R.Br.
H. falcata R.Br.
H. linearis R.Br.
H. lissocarpha R.Br.
H. oleifolia (Sm.) R.Br.
H. prostrata R.Br.
H. ruscifolia Labill.
H. sulcata R.Br.
H. tuberculata R.Br.
H. varia R.Br.
Isopogon axillaris R.Br.
I. sp. Busselton (Keighery 11534)
Lambertia orbifolia C.A. Gardner
Persoonia elliptica R.Br.
P. graminea R.Br.
P. longifolia R.Br.
Petrophile acicularis R.Br.
P. diversifolia R.Br.
P. linearis R.Br.
P. media R.Br.
P. squamata R.Br. ssp. *pluridissecta* Keighery
Stirlingia simplex Lindl.
Synaphea floribunda A.S. George
S. gracillima Lindl.
S. petiolaris R.Br.
Xylomelum occidentale R.Br.

SANTALACEAE
Leptomeria ericoides Miq.
Leptomeria scrobiculata R.Br.
L. squarrulosa R.Br.
L. spinosa (Miq.) DC.

LORANTHACEAE
Nuytsia floribunda (Labill.) R.Br. ex Fenzl.

POLYGONACEAE
Muehlenbeckia adpressa (Labill.) Meisn.
**Rumex acetosella* L.
**R. conglomeratus* Murray
**R. crispus* L.

CHENOPODIACEAE
**Atriplex prostrata* M.Boucher ex DC.
**Chenopodium multifidum* L.
**C.murale* L.
Halosarcia indica (Willd.) P.G. Wilson
Rhagodia baccata (Labill.) Moq.
Sarcocornia quinqueflora (Bunge ex Ung.-Sternb.) A.J. Scott
Suaeda australis (R.Br.) Moq.

AMARANTHACEAE
Alternanthera nodiflora R.Br.

PORTULACACEAE
Calandrina corrigioloides F. Muell. ex Benth.

CARYOPHYLLACEAE
**Cerastium glomeratum* Thuill.
**Corrigida litoralis* L.
**Petrohagia velutina* (Guss.) P. Ball. ex Heyw.
**Silene gallica* L.

RANUNCULACEAE
Clematis pubescens Hueg. ex Endl.
Ranunculus colonorum Endl.

LAURACEAE
Cassytha glabella R.Br.
C. micrantha Meisn.
C. racemosa Nees.

BRASSICACEAE
**Heliophila pusilla* L.f.
Stenopetalum robustum Endl.

DROSERACEAE
Drosera bulbosa Hook.
D. enodes Marchant et Lowrie

D. erythrorhiza Lindl.
D. gigantea Lindl. ssp. *geniculata* Lowrie
D. glanduligera Lehm.
D. huegelii Endl.
D. menziesii R.Br.
D. myriantha Planch.
D. nitidula Planchon ssp.*omissa* (Diels.) Marchant et Lowrie
D. neesii Lehm.
D. pallida Lindl.
D. platypoda Turcz.
D. pulchella Lehm.

CRASSULACEAE
Crassula colorata (Nees.) Ostenf.
*C. *decumbens* Thunb.
C. exserta (Reader) Ostenf.
*C. *natans* Thunb.
C. pedicellosa (F. Muell.) Ostenf.
C. peduncularis (Smith) Meigen

SAXIFRAGACEAE
Eremosyne pectinata Endl.

PITTOSPORACEAE
Billardiera variifolia DC.
Cheiranthera preissiana Putterl.

ROSACEAE
**Rubus discolor* Weihe et Nees

MIMOSACEAE
Acacia alata R.Br.
A. browniana Wendl. var. *browniana*
A. cochlearis (Labill.) Wendl.
A. divergens Benth.
A. extensa Lindl.
A. hastulata Smith
A. horridula Meisn.
A. huegelii Benth.
A. lateriticola Maslin
A. myrtifolia (Sm.) Willd. var. *angustifolia* Benth.
A. pulchella R.Br.
A. scalpelliformis Meisn.
A. stenoptera Benth.
A. tetragonocarpa Meisn.
A. uliginosa Maslin
A. urophylla Benth. ex Lindl.

PAPILIONACEAE
Aotus carinata Meisn.
A. intermedia Meisn.
A. sp. aff *genistoides* (Kenneally 2571)
Bossiaea linophylla R.Br.
B. ornata (Lindl.) Benth.
B. praetermissa J. Ross
Callistachys lanceolata Vent.
Chorizema diversifolium DC.
C. ilicifolium Labill.
C. spathulatum (Meisn.) Taylor et Crisp
Daviesia cordata Sm.
D. decurrens Meisn.
D. flexuosa Benth.
D. gracilis M.D. Crisp
D. inflata M.D. Crisp
Euchilopsis linearis (Benth.) F. Muell.
Eutaxia epacridioides Meisn.
E. obovata (Labill.) C.A. Gardn.
E. virgata Benth.
Gompholobium capitatum Cunn.
G. confertum (DC) Crisp
G. knightianum Lindl.
G. marginatum R.Br.
G. amplexicaule Meisn.
G. polymorphum R.Br.
G. preissii Meisn.
G. scabrum Smith
G. tomentosum Labill.
Hardenbergia comptoniana (Andr.) Benth.
Hovea chorizemifolia (Sw.) DC.
H. elliptica (Sm.) DC.
H. stricta Meisn.
H. trisperma Benth.
Isotropis cuneifolia (Sm.) Benth. ex B.D. Jackson
Jacksonia furcellata (Bonpl.) DC.
J. horrida DC.
Jansonia formosa Kipp. ex Lindl.
Kennedia carinata (Benth.) Domin
K. coccinea Vent.
Latrobea diosmifolia Benth.
**Lotus angustissimus* L.

**L. uliginosus* Schk.
**Medicago polymorpha* L.
Mirbelia dilatata R.Br.
**Ornithopus compressus* L.
Oxylobium lineare (Benth.) Benth.
O. forrestii Ewart
Pultenaea reticulata (Sm.) Benth.
Sphaerolobium grandiflorum (R.Br.) Benth.
S. medium R.Br.
S. nudiflorum (Meisn.) Benth.
S. racemulosum Benth.
S. vimineum Sm.
**Trifolium glomeratum* L.
**T. subterraneum* L.
Viminaria juncea (Schrad. et Wendl.) Hoffsgg.

GERANIACEAE
Pelargonium littorale Hueg.

RUTACEAE
B. anceps P.G. Wilson
Boronia crenulata Sm.
B. denticulata Sm.
B. exilis P.G. Wilson
B. fastigiata Bartl.
B. juncea Bartl.
B. megastigma Nees. ex Bartl.
B. molloyae J. Drumm.
B. spathulata Lindl.
Chorilaena quercifolia Endl.
Eriostemon spicatus A. Rich.
Phebalium anceps DC.

TREMANDRACEAE
Platytheca galioides Steetz.
Tetratheca setigera Endl.
Tremandra diffusa R.Br. ex DC.
T. stelligera R.Br. ex DC.

POLYGALACEAE
Comesperma calymega Labill.
C. flavum DC.
C. nudiusculum DC.
C. virgatum Labill.
C. ciliatum Steetz

EUPHORBIACEAE
Ampera ericoides Adr. Juss
A. protensa Nees.
A. volubilis F. Muell. ex Benth.
A.? micrantha (CJR227, 110)
Calycopeplus oliganthus Henderson
Monotaxis occidentalis Endl.
Phyllanthus calycinus Labill.
Poranthera ericoides Klotzch
P. microphylla Brongn.

STACKHOUSIACEAE
Stackhousia huegelii Endl.
S. pubescens A.Rich
Tripterococcus brunonis Endl.
T. sp. (CJR 414)

SAPINDACEAE
Dodonaea viscosa Jacq. ssp. *angustissima* (DC.) West

RHAMNACEAE
Spyridium globulosum (Labill.) Benth.
Trymalium floribundum Steud.
T. ledifolium Fenzl.

MALVACEAE
Sida hookeriana Miq.

STERCULIACEAE
Rulingia corylifolia R.A. Grah.
Thomasia pauciflora Lindl.

DILLENIACEAE
Hibbertia amplexicaulis Steud.
H. cuneiformis (Labill.) Sm.
H. cunninghamii Ait. ex Hook.
H. ferruginea J.R. Wheeler
H. furfuracea (R.Br. ex Benth.)
H. glomerosa (Benth.) F. Muell.
H. hypericoides (DC.) F. Muell.
H. inconspicuua Ostenf.
H. stellaris Endl.
H. sp. "rigid bracts" (Wheeler 3220)

VIOLACEAE
Hybanthus volubilis E.M. Bennett

THYMELAEACEAE
Pimelea angustifolia R.Br.

P. ferruginea Labill.
P. hispida R.Br.
P. lanata R.Br.
P. longiflora R.Br. ssp. *longiflora*
P. preissii Meisn.

MYRTACEAE
Actinodium cunninghamii Schau.
Agonis flexuosa (Sprengel) Schau.
A. floribunda Turcz.
A. juniperina Schau.
A. linearifolia (DC.) Schau.
A. parviceps Schau.
Astartea fascicularis (Labill.) DC.
A. aff. *fasicularis*-erect (GJK 14586)
A. sp. Scott River (Backshall 88233)
Beaufortia sparsa R.Br.
Calothamnus lateralis Lindl.
C. schaueri Lehm.
C. aff. *crassus* (Royce 84)
Calytrix flavescens Cunn.
Darwinia oederoides (Turcz.) Benth.
Eucalyptus calophylla R.Br.
E. diversicolor F. Muell.
E. marginata Donn. ex Sm.
E. megacarpa F. Muell.
E. patens Benth.
E. rudis Endl.
Homalospermum firmum Schau.
Hypocalymma angustifolium (Endl.) Schau.
H. ericifolium Benth.
H. sp. Scott Plains (A S George 11773)
K. recurva Schau.
Kunzea spathulata Toelken
K. hybrid (*spathulata* x *recurva*)
**Leptospermum laevigatum* (Gaertn.) F. Muell.
Melaleuca basicephala Benth.
M. cuticularis Labill.
M. incana R.Br.
M. lateritia A. Dietr.
M. pauciflora Turcz.
M. preissiana Schau.
M. rhaphiophylla Schau.
M. thymoides Labill.
Pericalymma ellipticum (Endl.) Schau.
P. crassipes Lehm.
P. spongiocaule Cranfield
Verticordia lehmannii Schau.
V. plumosa (Desf.) Druce var *brachyphylla* A.S.George

ONAGRACEAE
Epilobium billardierianum Ser.

HALORAGACEAE
Gonocarpus benthamii Orch.
G. hexandrus (F. Muell.) Orch.
G. paniculatus (R.Br. ex Benth.) Orch.
G. pusillus (R.Br. ex Benth.) Orch.
Haloragis brownii (J.D. Hook.) Schindler

APIACEAE
Actinotus glomeratus Benth.
A. laxus Keighery
A. omnifertilis (F.Muell.) Benth.
Apium annuum P.S.Short
A. prostratum Labill. ex Vent ssp. *prostratum*
Centella asiatica (L.) Urban
Daucus glochidiatus (Labill.) Fisch., C. Meyer et Ave-Lall.
Erynigium pinnatifidum Bunge.
Homalosciadium homalocarpum (F. Muell.) Eichler
Hydrocotyle alata A. Rich.
H. blepharocarpa F. Muell.
H. callicarpa Bunge.
H. diantha DC.
H. pilifera Turcz.
H. plebeja A. Rich
Pentapeltis peltigera (Hook.) Bunge
Platysace anceps (DC.) Norman
P. filiformis (Bunge) Norman
P. pendula (Benth.) Norman
P. tenuissima (Benth.) Norman
Schoenolaena juncea Bunge
Trachymene pilosa Sm.
Xanthosia candida (Benth.) Steud.
X. huegelii (Benth.) Steudel ssp. southern (GJK 2165)
X. pusilla Bunge.

EPACRIDACEAE

Andersonia caerulea R.Br.
A. involucrata Sond.
A. micrantha R.Br.
Astroloma ciliatum (Lindl.) Druce
A.pallidum R.Br.
Leucopogon alternifolius R.Br.
L. australis R.Br.
L. carinatus R.Br.
L. conostephioides DC.
L. cordatus Sonder
L. distans R.Br. var. *contractus* Benth.
L. gilbertii Stschegl.
L. glabellus R.Br.
L. hirsutus Sond.
L. pendulus R.Br.
L. reflexus R.Br.
L. revolutus R.Br.
L. striatus R.Br.
L. squarrosus Benth.
L. unilateralis Stschegl.
L. verticillatus R.Br.
L. aff. *gilbertii* (CJR192) "tenuicaulis"
L. aff. *propinquus* (CJR 253)
Lysinema ciliatum R.Br.
L. conspicuum R.Br.
Needhamiella pumilio (R.Br.) L. Watson
Sphenotoma capitatum (R.Br.) Lindl.
S. gracile (R.Br.) Sw.
S. parviflorum F. Muell.

PRIMULACEAE

**Anagallis arvensis* L.
Samolus junceus R.Br.
S. repens (Forst. and G. Forst.) Pers.
**S. valerandi* L.

LOGANIACEAE

Logania campanulata R.Br.
L. serpyllifolia R.Br.
L. vaginalis (Labill.) F. Muell.
Phyllangium paradoxum (R.Br.) Dunlop

GENTIANACEAE

**Centaurium erythraea* Rafn.
**C. spicatum* (L.) Fritsch ex Janchen
**Cicendia filiformis* (L.) De larbe
Sebaea ovata (Labill.) R.Br.

MENYANTHACEAE

Villarsia albiflora F. Muell.
V. lasiosperma F. Muell.
V. latifolia Benth.
V. parnassifolia (Labill.) R.Br.
V. violifolia F. Muell.

LAMIACEAE

Hemiandra pungens R.Br.
H. sp. nov. (CJR 430)
Hemigenia sp. Albany (GJK 8712)
**Mentha pulegium* L.
**Stachys arvensis* (L.) L.

SCROPHULARIACEAE

**Bellardia trixago* (L.) All.
Glossostigma drummondii Benth.
Grattiola peruviana L.
**Parentucellia latifolia* (L.) Caruel
**P. viscosa* (L.) Caruel
Veronica calycina R.Br.

SOLANACEAE

Anthocercis littorea Labill.
**Solanum nigrum* L.

LENTIBULARIACEAE

Polypompholyx multifida (R.Br.) F. Muell.
Utricularia hookeri Lehm.
U. menziesii R.Br.
U. simplex R.Br.

MYOPORACEAE

Myoporum oppositifolium R.Br.

OROBANCHACEAE

**Orobanche minor* Sm.

RUBIACEAE

Opercularia apiciflora Labill.
O. echinocephala Benth.
O. hispidula Endl.
O. vaginata Labill.
O. volubilis R.Br. ex Benth.

CAMPANULACEAE

**Wahlenbergia capensis* (L.) A.DC.
W. gracilenta Loth.
W. multicaulis Benth.

LOBELIACEAE

Grammatotheca bergiana (Cham.) C.Presl.
Isotoma hypocrateriformis (R.Br.) Druce
Lobelia alata Labill.
L. gibbosa Labill.
L. rhombifolia Ur.
L. rhytidosperma Benth.
L. tenuior R.Br.
*Monopsis simplex (L.f.) Wimmer

GOODENIACEAE

Athotium junciforme (Benth.) D.A. Morrison
Dampiera alata Lindl.
D. hederacea R.Br.
D. leptoclada Benth.
D. linearis R.Br.
D. trigona DVr.
Diaspasis filifolia R.Br.
Goodenia eatoniana F. Muell.
G. *micrantha* R.Br.
G. *pulchella* Benth.
G. *pusilla* (DVr.) DVr.
Lechenaultia biloba Lindl.
L. expansa R.Br.
Scaevola calliptera Benth.
S. globulifera Labill.
S. nitida R.Br.
Velleia macrophylla (Lindl.) Benth.
V. trinervis Labill.

STYLIDIACEAE

Levenhookia dubia Sond.
L. pauciflora Benth.
L. preissii (Sond.) F. Muell.
L. pusilla R.Br.
Stylidium adnatum R.Br.
S. amoenum R.Br.
S. brunonianum Benth.
S. bulbiferum Benth.
S. calcaratum R.Br.
S. crassifolium R.Br.
S. diversifolium R.Br.
S. ecorne (F. Muell. ex Erickson et Willis) Farrell et James
S. falcatum R.Br.
S. glaucum Labill
S. guttatum R.Br.
S. inundatum R.Br.
S. junceum R.Br.
S. leeuwinense Lowrie
S. lineatum Sond.
S. luteum R.Br. ssp. *glaucifolium* Carlquist
S. mimeticum Carlquist et Lowrie
S. piliferum R.Br.
S. pulchellum Sond.
S. repens R.Br.
S. scandens R.Br.
S. schoenoides DC.
S. spathulatum R.Br.
S. violaceum R.Br.
S. sp. aff. *bulbiferum* (CJR450)

ASTERACEAE

**Arctotheca calendula* (L.) Levyns
**Aster subulatus* Michaux
Asteridea pulverulenta Lindl.
Blennospora sp. Ruabon (BJK/ NG 020)
**Carduus pycnocephalus* L.
Centipedia minima (L.) A.Br. et Aschers
**Cirsium vulgare* (Savi) Ten.
**Conyza bonariensis* (L.) Cronq.
**C. albida* Willd.
Cotula coronopifolia L.
Craspedia variabilis J. Everett
Gnaphalium sphaericum Willd.
Hyalosperma demissum (A.Gray) P.G.Wilson
H.simplex (Steetz) P.G. Wilson *ssp. simplex*
H. pusillum (Turcz.) P.G.Wilson
**Hypochaeris glabra* L.
Ixiolaena viscosa Benth.
Lagenifera huegelii Benth.
*Leontodon saxatile Lam.
Leptorhynchos scabrus (Benth.) Haegi
Millotia inopinata Schodde
Olearia axillaris (DC.) F. Muell. ex Benth.
O. elaeophila (DC) F. Muell.
O. paucidentata (Steetz.) F. Muell. ex Benth.
Ozothamnus cordatus (DC) Andenbr.

Pithocarpa melanostigma Lewis et Summerhayes
Podolepis gracilis (Lehm.) R.A. Grah.
Podotheca angustifolia (Labill.) Less.
**Pseudognaphalium luteo-album* (L.) Hilliard & B.L. Burtt
Pterochaeta paniculata (Steetz.) F. Muell. ex Benth.
Quinetia urvillei Cass.
Rhodanthe citrina (Benth.) P.G. Wilson
Senecio glomeratus Desf. ex Poir.
S. hispidulus A. Rich
S. lautus Forst. ex Willd.
Siloxerus humifusus Labill.
**Sonchus asper Hill*
S. hydrophyllus L. Bolus
**S. oleraceus* L.
Trichocline sp (GJK 6382)
**Ursinia anthemoides* (L.) Poir.
**Vellereophyton dealbatum* (Thunb.) Hilliard et Burtt
Waitzia suaveolens (Benth.) Druce

SMALL TERRESTRIAL VERTEBRATE COMMUNITIES IN REMNANT VEGETATION IN THE CENTRAL WHEATBELT OF WESTERN AUSTRALIA.

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ABSTRACT

Small terrestrial vertebrate communities in the central wheatbelt of Western Australia were sampled repeatedly in nine remnants of native vegetation ranging from 10 ha to 1030 ha. Over 11,000 animals of 51 species were captured in 65,000 trapnights. The most common taxa were skinks (4,588 captures), mammals (2,348) and frogs (1,754). The most commonly caught species were *Ctenotus schomburgkii* (2,309) and *Mus domesticus* (2,062). Capture rates were low, with only four species having rates greater than 20 per 1,000 trapnights. Total species richness in the main vegetation formations (woodland, mallee, shrubland, heath) varied from 35 to 43; only 10 species were recorded in salt complex and 16 species on and around rock outcrops.

Communities in the different vegetation formations showed little similarity. Using the Bray-Curtis modification of the Sorensen index, similarity indices between formations were low (0.15 to 0.34) except for woodland/mallee (0.54) and shrubland/heath (0.74). Total species richness and lizard richness were significantly correlated with area in remnants with diverse vegetation but not in the woodland remnants alone. These studies suggest that repeated surveys may be needed in remnant vegetation to reliably document the range of terrestrial vertebrates that is present, and show further that, while large remnants may be preferred, remnants as small as 10 ha can have considerable conservation for small vertebrates if they retain diverse vegetation.

INTRODUCTION

The regional distribution of small mammals, reptiles and amphibians in the wheatbelt of Western Australia has been well documented (Kitchener & Vicker 1981; Storr *et al.* 1981, 1983, 1986, 1990; Tyler *et al.* 1984). However, data on individual nature reserves or remnants of native vegetation in the wheatbelt are less extensive and confined largely to the 24 reserves surveyed by the Western Australian Museum in the 1970s (Kitchener 1976). These data have been summarised by Kitchener *et al.* (1980a, & b) and Chapman & Dell (1985) in terms of the relationships between species richness and reserve area, and habitat variables and zoogeography.

Accounts of the small terrestrial vertebrate fauna at spatial scales intermediate between regional and reserve scales are lacking, yet it is at this scale that management is often aimed. The increasing awareness of the importance of privately owned remnants of native vegetation, together with attempts to reintegrate the landscape remnants for both conservation and economic values, make data of this scale important (Hobbs and Saunders 1993). This paper draws together data from a number of studies to give an overview of terrestrial vertebrate communities and their habitat use in an area of 1680 km² between Kellerberrin and Trayning in the central wheatbelt of Western Australia. It also discusses the implications of the sampling results for conservation and restoration of these communities in the future.

STUDY AREA AND METHODS

The studies were carried out in a 1680 km² area between Kellerberrin and Trayning, 200 km east of Perth, Western Australia. The area has low relief (<100 m), with broad valleys and scattered breakaways and rock outcrops. The climate is mediterranean with hot dry summers and cool wet winters. Seasonal daily average temperatures are spring 17°. C, summer 25°. C, autumn 19°. C and winter 12°. C. Annual rainfall is 330 mm, with 50 percent falling in winter. The original vegetation was a complex mosaic of heath, shrublands and woodlands (Beard 1980), which has been cleared extensively for wheat and sheep farming. The remaining native vegetation occupies seven percent of the area, occurring in 450+ small (< 100ha) remnants and on road verges. Detailed descriptions are given by Arnold and Weeldenburg (1991), Saunders *et al.* (1993) and McArthur (1993).

During the period 1987 to 1994, 811 pitfall traps were established in eight remnants and on an extensive area of salt lakes (648 trap-nights) (Fig. 1) and were operated for a total of 65182 trap-nights. The number of trap-nights is each remnant are given in Table 4. The pitfall traps were 20 litre plastic pails (28cm diameter and 39cm deep) with a seven metre fence of flywire mesh 24cm high buried at its base, spanning the pail. The number of traps and their configuration varied between studies; 8 to 54 traps were laid out in grids with the distance between traps varying from 10 to 25 metres. Grids were established in all the major vegetation formations of the district; woodland, mallee, shrubland, heath and salt complex (natural

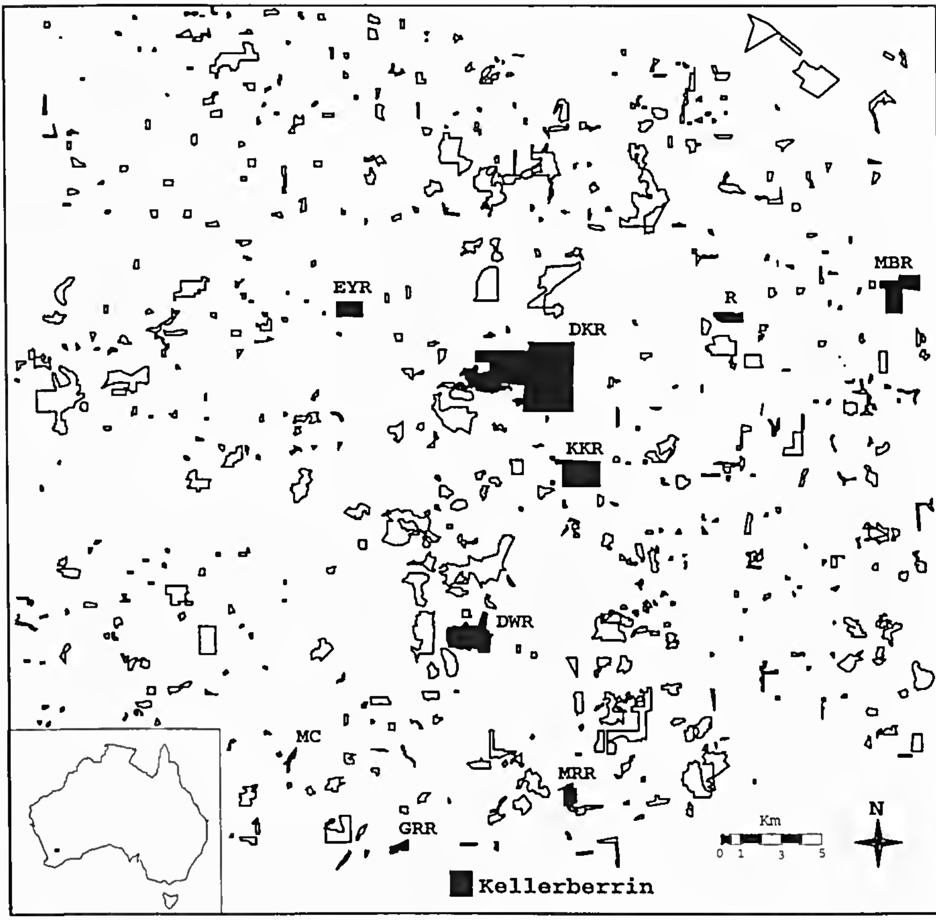

Figure 1. Map of the remnants of native vegetataion in the CSIRO study area north of Kellerberrin, showing the location of those remnants used in this study. DKR – Durokoppin Nature Reserve, NBR – North Bandee Reserve, DWR – Deep Well Reserve, EYR – East Yorkrakine Nature Reserve, R – Ryans (private land), MRR – Mooranoppin Reserve, GRR – Goldfields Road Reserve, MC – McClellands (water reserve), KKR – Kodj Kodjin Nature Reserve.

not anthropogenic). The number of trap-nights in each formation is given in Table 1. The number of trapping seasons (October to April) that each grid was operated varied from one to six. Within each trapping season, the traps were operated for four consecutive nights in October, November, December and for two or three periods in the months of January to April. The Goldfields road reserve has a long history of grazing and the salt complex area has been grazed infrequently in recent years, the other remnants have no history of grazing. In addition, observations were made

Table 1. List of all small terrestrial vertebrates captured in the Kellerberrin-Trayning district, the number caught in pitfall traps and the number caught per 1000 trap-nights in Woodland (WL), Mallee (M), Shrubland (SL), Heath (H), Salt complex (SC) and those species observed on and around rock outcrops (L). * Observation only. Taxonomy follows STORR *et al.* 1981, 1983, 1986 and 1990; TYLER *et al.* 1994.

VERTEBRATES	TOTAL CAPTURED	No. CAPTURES / 1000 TRAP-NIGHTS					
MAMMALS		WL	M	SL	H	SC	L
Sminthopsis crassicaudata	28	0.3	0.3	0.1	0.3	15.4	
Sminthopsis dolichura	258	3.5	3.8	16.9	15.4	17.0	
Pseudomys albocinereus	*				*		
Mus domesticus	2062	18.3	7.1	3.0	42.7	54.0	
REPTILES							
Gekkonidae							
Crenadactylus ocellatus	4	<0.1	0.1	0.1	0.1	0.0	
Diplodactylus granariensis	154	2.3	1.6	2.7	2.6	0.0	
Diplodactylus mainii	233	0.1	0.0	5.5	9.3	0.0	
Diplodlactylus pulcher	336	5.4	8.3	3.6	3.8	26.2	*
Diplodactylus spinigerus	44	0.1	0.1	1.4	1.3	0.0	
Gehyra variegata	467	17.0	1.2	0.2	0.2	12.3	*
Heteronotia binoei	1	<0.1	0.0*	0.0	0.0	0.0	*
Oedura reticulata	36	1.4	0.0	0.0	0.0	0.0	
Underwoodisaurus milii	*						*
Pygopodidae							
Delma australis	35	0.2	0.1	1.1	0.7	0.0	*
Delma fraseri	28	1.0	0.1	0.0*	0.0	0.0	*
Delma grayii	2	0.0	0.0	0.0	0.1	0.0	
Lialis burtonis	33	1.0	0.0	0.1	0.4	0.0	
Pygopus lepidopodus	5	0.0*	0.0	0.2	0.1	0.0	
Agamidae							
Ctenophorus cristatus	46	0.4	1.3	0.3	0.1	0.0	
Ctenophorus maculatus	241	0.0	0.0	6.4	9.1	0.0	
Ctenophorus ornatus	*						*
Ctenophorus reticulatus	38	0.7	2.6	0.1	0.0	0.0	*
Ctenophorus salinarum	13	0.0	0.0	0.0	0.0	20.1	
Moloch horridus	100	0.0	0.3	4.4	2.1	0.0	
Pogona minor	461	4.2	5.8	9.3	10.6	0.0	
Scincidae							
Cryptoblepharus plagiocephalus	90	3.3	0.4	0.1	0.0	0.0	
Ctenotus impar	5	0.0	0.0	0.1	0.2	0.0	
Ctenotus pantherinus	748	2.2	1.3	20.7	23.2	0.0	*
Ctenotus schomburgkii	2309	<0.1	1.0	50.4	96.4	0.0	
Eremiascincus richardsonii	1	<0.1	0.0	0.0	0.0	0.0	

Table 1 (cont.)

VERTEBRATES	TOTAL CAPTURED	No. CAPTURES / 1000 TRAP-NIGHTS					
Lerista distinguenda	80	0.4	0.1	2.6	1.9	0.0	
Lerista macropisthopus	60	2.0	0.5	0.1	0.2	1.5	*
Lerista muelleri	123	2.4	2.0	1.8	0.6	12.3	*
Menetia greyii	616	20.0	2.5	2.1	2.2	17.0	*
Morethia butleri	1	<0.1	0.0	0.0	0.0	0.0	
Morethia obscura	494	0.4	1.6	15.6	15.0	0.0	
Tiliqua occipitalis	12	0.0*	0.3	0.5	0.2	0.0	
Tiliqua rugosa	48	0.9	0.7	0.9	0.9	0.0	
Varanidae							
Varanus gouldii	40	0.6	0.8	0.5	1.0	0.0	
Varanus tristis	9	0.3	0.0	0.1	0.0	0.0	
Typhlopidae							
Ramphotyphlops australis	8	0.5	0.1	0.1	0.0	0.0	
Ramphotyphlops hamatus	3	0.1	0.0	0.0	0.0	0.0	*
Ramphotyphlops waitii	29	0.8	0.0	0.4	0.2	0.0	
Boidae							
Morelia spilotus	*		*				
Elapidae							
Pseudechis australis	*				*		
Pseudonaja modesta	2	0.0*	0.3	0.0	0.0	0.0	
Pseudonaja nuchalis	21	0.1	0.9	0.4	0.2	1.5	*
Rhinoplocephalus gouldii	14	0.2	0.3	0.3	0.2	0.0	
Vermicella bertholdi	23	0.7	0.0	0.1	0.2	0.0	
Vermicella semifasciata	23	0.0	0.0	0.8	0.8	0.0	
FROGS							
Leptodactylidae							
Heleioporus albopunctatus	702	1.2	3.8	17.3	24.0	0.0	
Limnodynastes dorsalis	33	0.7	0.0	0.1	0.8	0.0	
Myobatrachus gouldii	1	0.0	0.0	0.1	0.0	0.0	
Neobatrachus kunapalari	498	3.7	10.2	12.2	9.0	0.0	*
Neobatrachus pelobatoides	4	0.0	0.3	0.1	0.0	0.0	
Pseudophryne guentheri	516	2.8	2.8	16.4	11.2	0.0	*
Ranidella pseudinsignifera	*						*
TOTAL CAPTURES	11 138						
NO. TRAPNIGHTS		22,054	7,632	14,648	16,200	648	0

on and around rock outcrops in the area, and in 24 small isolated remnants of Gimlet *Eucalyptus salubris* woodland.

RESULTS

A total of 11138 small vertebrates of 51 species were captured, comprising 2348 mammals (3 species), 1275 geckos (8 species), 103 legless lizards (5 species), 899 dragons (6 species), 4587 skinks (13 species), 49 monitors (2 species), 40 blind snakes (3 species), 83 snakes (5 species) and 1754 frogs (6 species). The number of captures exclude the small number of recaptures within a trapping session, but include animals that died or were killed in the traps. *Mus domesticus* occasionally killed and ate small reptiles, but usually left sufficient remains to identify the species.They were not killed to check stomach contents.

The most frequently caught species were the skink *Ctenotus schomburgkii* (2309 captures) and the introduced House Mouse *Mus domesticus* (2062). Fifteen species were captured between 100 and 1000 times, 21 species between 11 and 100 times and 13 species were captured on less than 10 occasions. A further six species were recorded only from observations (Table 1).

The number of species in each taxon that were recorded in the major vegetation formations is given in Table 2. Woodland and shrubland had the most species (43), heath and mallee had 38 and 35 species respectively, whereas only 10 species were recorded in salt complex. The small number of species recorded in salt complex is in part due to the small number of trap-nights (648 – Table 1), run in one season. However, examination of data

Table 2. Number of species in the small terrestrial vertebrate taxa recorded in Woodland (WL), Mallee (M), Shrubland (SL), Heath (H), Salt Complex (SC) and on and around rock outcrops (L).

VERTEBRATES	WL	M	SL	H	SC	L
Mammals	3	3	3	3	3	0
Geckos	8	6	6	6	2	4
Legless Lizards	4	2	4	4	0	2
Dragons	3	4	5	4	1	2
Skinks	12	10	11	10	3	4
Monitors	2	1	2	1	0	0
Blind Snakes	3	1	2	1	0	0
Snakes	4	4	4	5	1	1
Frogs	4	4	6	4	0	3
Total Lizards	29	23	28	25	6	12
Total	43	35	43	38	10	16

from pitfall traps operated in woodland and mallee at the same time, showed that two to three times as many lizard species were captured in an equivalent number of trap nights in these formations. Further, the comparison suggested that the absence of frogs may be real or that the populations are very low compared with mallee and woodland. Apart from salt complex, there were no marked variations in the number of species in the various taxa between the other vegetation formations. On rock outcrops three species of frogs were recorded breeding in pools (Table 1). The gecko *Gehyra variegata* was found on all outcrops searched, whereas the dragon *Ctenophorus ornatus* was found only on the larger outcrops. The remaining species were found under rocks on the apron of the outcrops and were the more common species, that have generalised habitat requirements.

The capture rate per 1000 trap-nights for each species in each vegetation formation is given in Table 1. The overall capture rate was 171.2 animals per 1000 trap-nights. Capture rates for legless lizards (1.6), monitors (0.8), blind snakes (0.6) and snakes (1.3) were extremely low, suggesting low populations or that pitfall traps were not an efficient method for their capture. In the case of monitors and larger snakes, only the dispersing young were captured. Capture rates for the other taxa ranged from 13.8 per 1000 trap-nights for dragons to 70.5 for skinks. Capture rates for most individual species in the vegetation formations were low. Thirty-one percent of species had capture rates greater than one per 1000 trap-nights and only 10.5% were greater than 10/1000 trap-nights.

Nine species were recorded in all vegetation formations and a further 17 were recorded in all but the salt complex. Combined, the two groups consisted of 3 mammals (*Sminthopsis crassicaudata, S. dolichura, Mus domesticus*), 5 geckos (*Crenadactylus ocellatus, Diplodactylus granariensis D. pulcher, D. spinigerus, Gehyra variegata*), one legless lizard (*Delma australis*), 2 dragons (*Ctenophorus cristatus, Pogona minor*), 9 skinks (*Ctenotus pantherinus, C. schomburgkii, Lerista distinguenda, L.macropisthopus, L. muelleri, Menetia greyii, Morethia obscura, Tiliqua occipitalis, T. rugosa*), 1 monitor (*Varanus gouldii*), 2 snakes (*Pseudonaja nuchalis, Rhinoplocephalus gouldii*) and 3 frogs (*Heleioporus albopunctatus, Neobatrachus kunapalari, Pseudophryne guentheri*). The percentage of species in each taxon that showed broad habitat preferences is as follows; mammals (75%), geckos (56%), legless lizards (20%), dragons (29%), skinks (69%), monitors (50%), blind snakes (0%), snakes (43%), and frogs (43%). Species with more precise habitat preferences were determined by using the capture rates for species captured more than 20 times. Species were considered to show a strong preference if the captures rate in one vegetation formation was more than twice that in any other formation. If the capture rates in the two most commonly used formations differed by less than a factor of two and the capture rate in the second most commonly used formation was three times that in the next most commonly used formation, then the species was considered to have a strong preference for the combined vegetation formations. Six species (*Oedura reticulata, Delma fraseri, Lialis burtonis, Cryptoblepharus plagiocephalus, Ramphotyphlops waitii, Vermicella bertholdi*) were most commonly captured in woodlands; two (*Ctenophorus cristatus, Ctenophorus reticulatus*) in mallee; one, *Moloch horridus* in shrubland; none in heath; four (*Sminthopsis crassicaudata, Diplodactylus pulcher, Ctenophorus salinarum, Lerista muelleri*) in salt complex which has small patches of woodland. *C.salinarum* was captured only in samphire and two (*Ctenophorus ornatus, Ranidella pseudinsignifera*) were recorded only on rock outcrops. *Limnodynastes dorsalis* was found most commonly in woodland and heath; *Gehyra variegata, Lerista macropisthopus* and *Menetia greyii* were captured most commonly in woodland and salt complex. Eleven species were found most commonly in shrubland and heath (*Diplodactylus mainii, D spinigerus, Delma australis, Ctenophorus maculatus, Ctenotus pantherinus, C. schomburgkii, Lerista distinguenda, Morethia obscura, Vermicella semifasciata, Heleioporus albopunctatus, Pseudophryne guentheri*). *Sminthopsis dolichura*, while present in all formations was captured most frequently in shrubland, heath and salt complex.

The similarity of the assemblages of species in the various vegetation formations was examined using the Sorensen index (Southwood 1978). The highest similarity was found between shrubland and heath (0.89), however, there was little difference between woodland, mallee, shrubland and heath. The index was low (0.46) for the comparison between salt complex and rock outcrop and both formations showed low similarity indices

Table 3. Values on the right of the diagonal line are the Sorensen indices for comparisons of the assemblages in the vegetation formations, those on the left are for comparisons using the Bray and Curtis modification of the Sorensen index. WL – woodland, M – mallee, SL – shrubland, H – heath, SC – salt complex, L – rock outcrop.

	WL	M	SL	H	SC	L
WL		0.85	0.84	0.79	0.34	0.47
M	0.54		0.82	0.74	0.40	0.51
SL	0.23	0.34		0.89	0.34	0.41
H	0.25	0.27	0.74		0.38	0.37
SC	0.35	0.22	0.15	0.29		0.46
L						

with the other formations (Table 3). These relationships changed markedly when abundance (capture rates) of species was taken into account in the Bray and Curtis modification (Southwood 1978) (Table 3). The high similarity between shrub-land and heath was maintained, that between woodland and mallee is reduced, whereas in all other comparisons the indices were low.

The area of the eight remnants in which the studies were carried out varied from 10 ha to 1030 ha. The numbers of species in each taxon in each remnant are shown in Table 4; data from the Western Australian Museum survey of Kodj Kodjin nature reserve (Chapman and Kitchener 1978, Dell and Chapman 1978) together with additional observations have been included. The largest remnant (1030 ha) had 46 species while the smallest remnant (10 ha) had the second highest number of species (33). The correlation between area and number of species was significant ($r = 0.818$, $p < 0.01$). However, when the largest remnant was deleted from the set, the correlation became negative and non-significant ($r = -0.206$). The relationship between area and the number of species of lizards was similar with $r = 0.848$ reducing to 0.017 when the largest remnant was removed from the data set. Four of the remnants were predominantly woodland sites and the correlation between area and total and lizard species richness was not significant (r = -

Table 4. Number of species of small terrestrial vertebrates of various taxa in the study remnants in the Kellerberrin-Trayning district. Numbers in parenthesis are from surveys carried out by the Western Australian Museum. DKR – Durokoppin Nature Reserve, NBR – North Bandee Reserve, DWR – Deep Well Reserve, EYR – East Yorkrakine Reserve, R – Ryans, MRR – Mooranoppin Reserve, GRR – Goldfields Road Reserve, MC – McClellands – KKR – Kodj Kodjin Reserve (observational records for eight species have been added to Museum list for KKR)

VERTEBRATES	DKR	KKR	NBR	DWR	EYR	R	MRR	GRR	MC
Mammals	4 (3)	(2)	3	3	3 (2)	2	3	3	3
Geckos	7 (9)	(5)	4	3	5 (4)	5	5	3	6
Legless Lizards	4 (4)	(1)	1	3	3 (2)	0	3	2	2
Dragons	6 (5)	(3)	2	1	4 (3)	3	2	2	2
Skinks	11 (8)	(9)	6	7	8 (6)	5	5	4	9
Monitors	2 (0)	(1)	1	1	1 (0)	2	0	2	1
Blind Snakes	1 (0)	(0)	1	2	1 (0)	0	2	1	2
Snakes	5 (3)	(2)	2	2	4 (0)	2	1	2	3
Frogs	6 (2)	(3)	2	3	3 (1)	2	4	2	5
Total	46 (34)	26	22	25	32 (18)	22	25	21	33
Area (ha)	1030	204	174	118	80	50	40	27	10
# Trap nights	23252	–	3190	6408	11184	3308	6408	6408	4376

0.004 (NS) and 0.208 (NS) respectively). The other four remnants had diverse vegetation, ranging from woodland to heath and the comparable r values were 0.843 ($p<0.05$) and 0.941 ($p<0.01$). The latter result was strongly influenced by the results from Durokoppin. However, the large number of trap-nights in this remnant probably did not influence the result. In one set of pitfall trap grids operated for six years (2960 trapnights/year), 31 of the 36 species were caught in the first year. Comparable increases with further trapping in the other remnants would not significantly change the correlation. Further, species accumulation curves for the other remnants indicated that they were at or close to the asymmote and that few additional species would be expected to be captured.

DISCUSSION

This study has drawn together data from a number of studies over the last decade. One factor that the long term studies have shown is that the number of individuals and species captured is highly variable on time scales varying from days to years. Thus, combining the results of studies undertaken at different times restricts the types of analyses that can be undertaken. However, given the large body of data, the broad conclusions developed below should be reasonably robust.

The Western Australian Museum's surveys of wheatbelt reserves (Chapman and Kitchener 1978, Dell and Chapman 1978, Kitchener and Chapman 1980, Chapman and Dell 1980)included three within the study area, namely Durokoppin, East Yorkrakine and Kodj Kodjin reserves (Table 4), the first two were used in this study. The present study recorded an additional 15 species in Durokoppin and 14 species in East Yorkrakine, an indication of the value of long-term sampling and the use of pitfall traps. The majority of these additional species were captured infrequently or were seasonally active (frogs and *Moloch horridus).* The only moderately common species not recorded was *Diplodactylus pulcher* in East Yorkrakine, where it was captured frequently during our studies. The museum survey recorded four species not found in these reserves in the present study, *Crenadactylus ocellatus* in East Yorkrakine and *Heteronotia binoei, Underwoodisaurus milii and Delma fraseri* in Durokoppin. The first three species had total captures ranging from one to four in the combined studies. It is not known if these species are still on the reserve. The status of *D. fraseri* in Durokoppin is uncertain. Although only 28 captures were made of this species in all studies, its absence from Durokoppin suggests inadequate sampling in its preferred woodland habitat, rather than absence. These results indicate that in remnant vegetation, repeated surveys, carried out over long periods may be needed to obtain a reasonably complete picture of the range of vertebrate species that is present.

A total of 57 species was recorded in the district, 46 of which were found on Durokoppin. To obtain the full assemblage, data from a minimum of seven reserves had to be used. Similarly, the three reserves surveyed by the museum recorded only 36 species, but the inclusion of data from two adjacent reserves (Yorkrakine Rock; Kitchener and Chapman 1980, Chapman and Dell 1980, and Billyacatting Hill, Chapman and Kitchener 1981, Dell and Chapman 1981) provided the same list of 57 species. Clearly, even relatively large reserves with diverse vegetation such as Durokoppin will not support all species in a district. To provide an adequate catalogue of the species present, a number of reserves need to be surveyed to ensure sampling of all microhabitats and to allow for wide variations in population densities. Distributional data (Chapman and Dell 1985) indicate that only four species that could be expected to occur in the district (*Ramphotyphlops pinguis*, *Aspidites ramsayi*, *Morelia stimsoni*, *Vermicella bimaculata*) may be absent, and *A.. ramsayi* may in fact be extinct in the wheatbelt (Smith 1985).

Habitat data suggest that the majority of species can occur in a variety of vegetation types. However, 43% of species with more than 20 captures, showed a strong association with one vegetation formation and a further 46% showed a similar association with two formations. The latter group was dominated by 11 species associated with shrubland and heath, which show a number of structural and floristic similarities and in some areas are intermixed on a small scale. To some extent, the apparently broad range of habitats used, arises from the small scale mosaic of vegetation formations in the areas sampled and the high probability of species moving out of their preferred habitat at some stage in their life cycle, (e.g. the only *Ctenophorus cristatus* captured in shrubland and heath were dispersing juveniles). The conclusion that most species have a tighter habitat preference than the simple presence or absence data would suggest, is supported by the comparison of the Sorenson index from presence/absence data with that from the Bray and Curtis modification, which gives a low similarity rating to all comparisons between vegetation formations except that between shrubland and heath. Habitat data for reptiles and frogs given by Chapman and Dell (1985) provide a comparable picture, both in the number of vegetation formations used and the degree of association. The minor differences in the recorded habitat use between the two studies are most likely to be a result of the differences in the methods used, pitfall trapping versus observation and searching.

Area is an important variable in determining species richness in remnants (Kitchener *et al.* 1980a, 1980b; Kitchener and How 1982, How and Dell 1994, Smith *et al.* 1996). In the small sample of remnants in this study, area also was significantly correlated with total species richness and with lizard richness. However, the correlations between total species and lizards and area were strongly influenced by the data from the largest and smallest remnants, as illustrated by the lack of a significant correlation when Durokoppin was dropped from the analysis. Durokoppin Nature Reserve had the largest number of total species and lizards, whereas the small (10 ha) McClellands remnant, had the second highest total number of species and the third highest number of lizards. The reason for the high species richness in McClellands is uncertain, but is probably related to diversity of vegetation (14 associations ranging from heath to woodland, GTS unpublished data) which was in good condition and ungrazed. The fifth largest reserve (East Yorkrakine nature reserve – 80 ha) had a comparable diversity of vegetation and was in good condition and ungrazed. It had the second largest number of lizards and the third highest total of species. The four remnants with diverse vegetation ranging from heath to woodlands (Durokoppin NR, East Yorkrakine NR, Ryans and McClellands) had significant correlations between total species and lizard richness and area, a result that probably was not strongly influenced by the differences in trapping effort. In contrast, the four remnants that were dominated by woodlands had no significant correlation between area and measures of species richness. These results support the findings of Kitchener *et al.* (1980a & b) that various measures of habitat diversity are important variables in determining species richness and may be more important than area for species with low spatial requirements.

Despite the fact that 93% of the district has been cleared for at least 50 years, there is no evidence that any species of reptiles or amphibians, with the exception of *A. ramsayi*, have become extinct in the district. Species have been lost in individual remnants of woodland, especially those that are small, isolated and grazed (Smith *et al.* 1996). Capture rates suggest that the populations of some species may be very low and hence prone to extinction. *Eremiascincus richardsoni* and *Myobatrachus gouldii*, for example were captured only once despite extensive trapping over a number of years in the sites. However, we have no data to indicate whether low trapping rates are due to low population or low trapping efficiency for most species. However, *M.gouldii* is readily trapped in pitfall traps in other areas (Arnold *et al.* 1991). Studies on *Oedura reticulata* by Sarre *et al.* (1995) and Sarre (1995) indicate that small populations of species with poor dispersal abilities in small remnants are highly vulnerable to extinction from stochastic processes. Whereas the remnants in this study were considerably larger that those in the *O. reticulata* study, species with small populations may still be vulnerable to stochastic extinctions in the long-term.

Conservation of the small vertebrate fauna in the district will depend on maintaining an adequate number of remnants in good condition and minimising disturbance from grazing and/or weed invasion. While larger remnants may be preferred, small remnants with diverse vegetation can be important in providing 'hot spots' for particular areas. While Kitchener *et al.* (1980a), suggested a minimum size of 30 ha, this study shows that remnants of the order of 10 ha may have considerable value. Remnants of this size and even smaller may play an important role in the increasing trend to rehabilitate landscapes in agricultural regions (*Smith et al.* 1996).

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