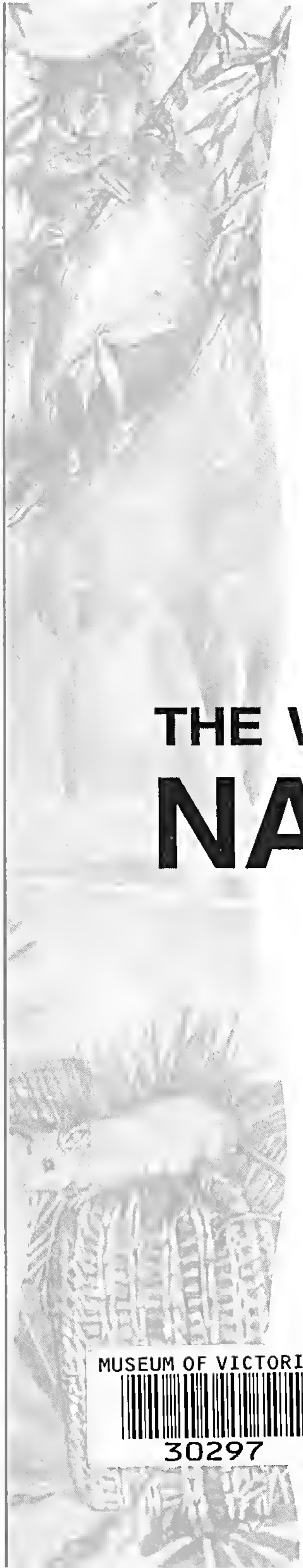

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THE EFFECTS OF RAINFALL ON THE ABUNDANCE AND SPECIES RICHNESS OF SMALL VERTEBRATES IN THE STIRLING RANGE NATIONAL PARK

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ABSTRACT

A pit-trap survey was conducted in mallee scrub from December 1986 to September 1990 within the Stirling Range National Park. Pits were opened for 8 days and 7 nights at the beginning of each month.

The first eighteen months of the survey were conducted under drought conditions and capture rates and number of species were low. Following the drought a marked increase in species richness and capture rates occurred. Frogs increased from two species pre drought to eight species after the drought. Reptiles increased from eight species pre drought to sixteen species post drought and mammals increased by one species after the drought to a total of five.

Of the twenty nine species of small vertebrate captured during this study, two species of frogs (*Heleioporus albopunctatus* and *Neobatrachus pelobatoides*), three species of reptiles (*Morethia obscura, Tiliqua rugosa* and *Pogona minor*) and one species of mammal (*Sminthopsis griseoventer*) had not been previously recorded in the Stirling Range National Park.

INTRODUCTION

The Stirling Range National Park covers an area of 115,671 ha and is situated geographically between the wetter South West and the drier Wheatbelt regions of Western Australia, 70km north of Albany. A comprehensive overview of the physical and biological characteristics of the Stirling Range is given in Thomson *et al* (1993), and only a very brief summary is presented here. The park experiences warm dry summers and cold wet winters with snow occasionally falling on the peaks during winter and spring.

Vegetation consists of Mallee scrub, *Eucalyptus marginata* scrub, *Eucalyptus wandoo* woodlands, mountain gullies of *Eucalyptus marginata* and *Eucalyptus calophylla* with a thick understorey and mountain scrub thickets.

The species richness of the Stirling Range was recognised by zoologist J T Tunney, A W Milligan and F L Whitlock in the early 1900's. It was not until 1984 however that a biological survey of the Stirling Range National Park by G Harold was undertaken. This brief survey (two weeks trapping twice in the year), concentrated mainly on small mammals but gave an indication of the abundance and species richness in parts of the Stirling Range National Park.

The current survey was carried out to examine abundance and species richness of small vertebrate fauna occurring in mallee scrub habitat, especially in relation to season and climatic variability.

METHODS

Pit-traps consisted of plastic buckets 300mm in dia. by 400mm deep and sunk into the ground with tops at ground level. A 400mm high flywire fence was run across the middle of the buckets at ground level. This then formed a line.

Survey methods improved over the first 18 months, as two additional lines were added at both sites. After the additions Site A had three lines (each 10 metres long), consisting of two lines with two buckets and the third line having five buckets in a T shape. Buckets in the T were positioned three across the top of the T and two along the downward section, giving a line 10 metres by 5 metres respectively.

Each of the three lines at Site B were 10 metres long with three buckets per line.

Pits were opened at the beginning of each month for 7 days and 8 nights (on most occasions) from December 1986 to September 1990, giving a total of 3327 pit-trap nights (543 in drought conditions and 2784 after the drought).

Animals were not marked until six months before the end of the survey, so total numbers given/trapped are not a true indication of population levels. Exception to this was *Mus domesticus* which were killed after measuring and weighing.

SURVEY AREA AND VEGETATION

Two survey areas were chosen near the junction of Bluff Knoll and Chester Pass Roads at the northern boundary of the park.

Sites A and B were 700 metres apart and dissimilar in vegetation, soil types and fuel ages. Soils at Site A consisted of grey sands while Site B had clayey sand 30cm in depth with solid clay and small sandstone rocks interspersed on the surface.

Vegetation at site A consisted of *Melaleuca pungens*, *Lambertia inermis*, *Eucalyptus tetragona*, scattered trees of *Banksia attenuata* and occasional *Nuytsia floribunda*, *Adenanthos cuneata*, *Dryandra sessilis* and *Eucalyptus pachyloma*. *Dryandra tenuifolia* and *Xanthorrhoea preissii* were common on the perimeter and *Eucalyptus marginata* bordered the northern side.

Vegetation at Site B was of two ages, with one pit-line in scrub burnt in 1972 (19 years old) east of the firebreak and the other two pit-lines west of the firebreak in an unknown fuel age (estimated at 50 years plus). Vegetation in the 19 year old fuel was open and consisted of *Lambertia inermis*, *Eucalyptus pachyloma*, *Calothamnus lateralis* and *Dryandra tenuifolia*. The unknown fuel age at the other two pit-lines was open with mature plants of *Eucalyptus tetragona*, *Dryandra*

Table 1. During and Post Drought Numbers For Mammals, Reptiles and Amphibians Stirling Range National Park

Species	Numbers Drought	Numbers Post Drought
Mammals		
* *Sminthopsis griseoventer*	1	8
Cercartetus concinnus	1	37
Tarsipes rostratus	20	250
Pseudomys albocinereus	1	0
Mus domesticus	0	41
	23	336
Reptiles		
Ramphotyphlops australis	0	2
Cryptoblepharus virgatus	0	1
Ctenotus impar	1	18
Hemiergis peronii	2	6
Leiolopisma trilineatum	1	2
Lerista distinguenda	3	29
Menetia greyii	1	3
* *Morethia obscura*	5	16
* *Tiliqua rugosa*	1	2
* *Pogona minor*	0	3
Tympanocryptis adelaidensis	0	1
Varanus rosenbergi	0	3
Aprasia pulchella	2	11
Delma australis	0	1
Diplodactylus spinigerus	0	3
Phyllodactylus marmoratus	2	10
	18	111
Amphibians		
Crinia georgiana	0	2
* *Heleioporus albopunctatus*	12	9
Limnodynastes dorsalis	2	29
Litoria adelaidensis	0	1
Myobatrachus gouldii	0	52
* *Neobatrachus pelobatoides*	0	1
* *Neobatrachus albipes*	0	3
Pseudophryne guentheri	0	110
Unidentified frogs	1	20
	15	227

* Not recorded prior to this survey

tenuifolia, Hakea lissocarpha, Xanthorrhoea preissii, Isopogon buxifolia, Dryandra armata and other small shrubs.

Both sites are similar to much of the mallee plains that occur in the Stirling Range National Park, with very few areas that have been unburnt for thirty or more years .

RESULTS

The first eighteen months of trapping (December 1986 to April 1988) were conducted under drought conditions with 320 millimetres of rain in 1987 (the driest year on record), while the remaining three years (1988, 1989 and 1990) had average to above average rainfall, with 1988 (666 millimetres), the wettest year on record. Average rainfall for the Bluff Knoll residence (700 metres from the study site) over fifteen years from 1976 to 1990 is 499.8 millimetres.

The drought broke on the second of May 1988 with 170 millimetres of rain falling over four days.

Eight frog, sixteen reptile and five mammal species were captured during the four year survey. These are listed in Table 1 along with during and post-drought numbers.

Capture rates during this drought were very low to nil, with a total of 14 frogs in two genera, 23 mammals in four genera and 18 reptiles in nine genera. The ground burrowing frog *Pseudophryne guentheri* was not recorded during the drought but two nights after the drought broke, in May 1988, single specimens were recorded at Site B and the following night at Site A. An unidentified Heleioporus species, not recorded during the drought, was captured six nights after the break of the drought at Sites A and B.

Of the seven frog species recorded only two (*Heleioporus albopunctatus* and *Lymnodynastes dorsalis*) were active during the drought. Following the drought four species, *Pseudophryne guentheri, Myobatrachus gouldii, Lymnodynastes dorsalis and Heleioporus albopunctatus,* were frequently active on the surface, with *Pseudophryne guentheri* very common. *Crinia georgiana, Neobatrachus pelobatoides, Neobatrachus albipes* and *Litoria adelaidensis* were rarely captured with only a total of seven captures recorded after the drought. *Heleioporus albopunctatus* was the only frog that did not increase after the drought, with 12 captured pre and 9 post drought.

Nine species of reptiles were recorded during the drought totalling eighteen individuals, with *Morethia obscura* being recorded most frequently (five occasions). Post drought a further seven reptile species were recorded and an increase in total captures to one hundred and eleven, with four species *Lerista distinguenda, Ctenotus impar, Morethia obscura and Aprasia pulchella* recorded on twenty nine, eighteen, sixteen and eleven times respectively. Many reptiles were captured on only a few occasions (refer Table 1).

Of the five mammal species, *Tarsipes rostratus* was most commonly caught with a total of 270 recordings, with drought numbers well down (20) compared with post drought (250) (Fig. 1). Both sites recorded similar capture rates. Numbers of *Cercartetus* trapped also

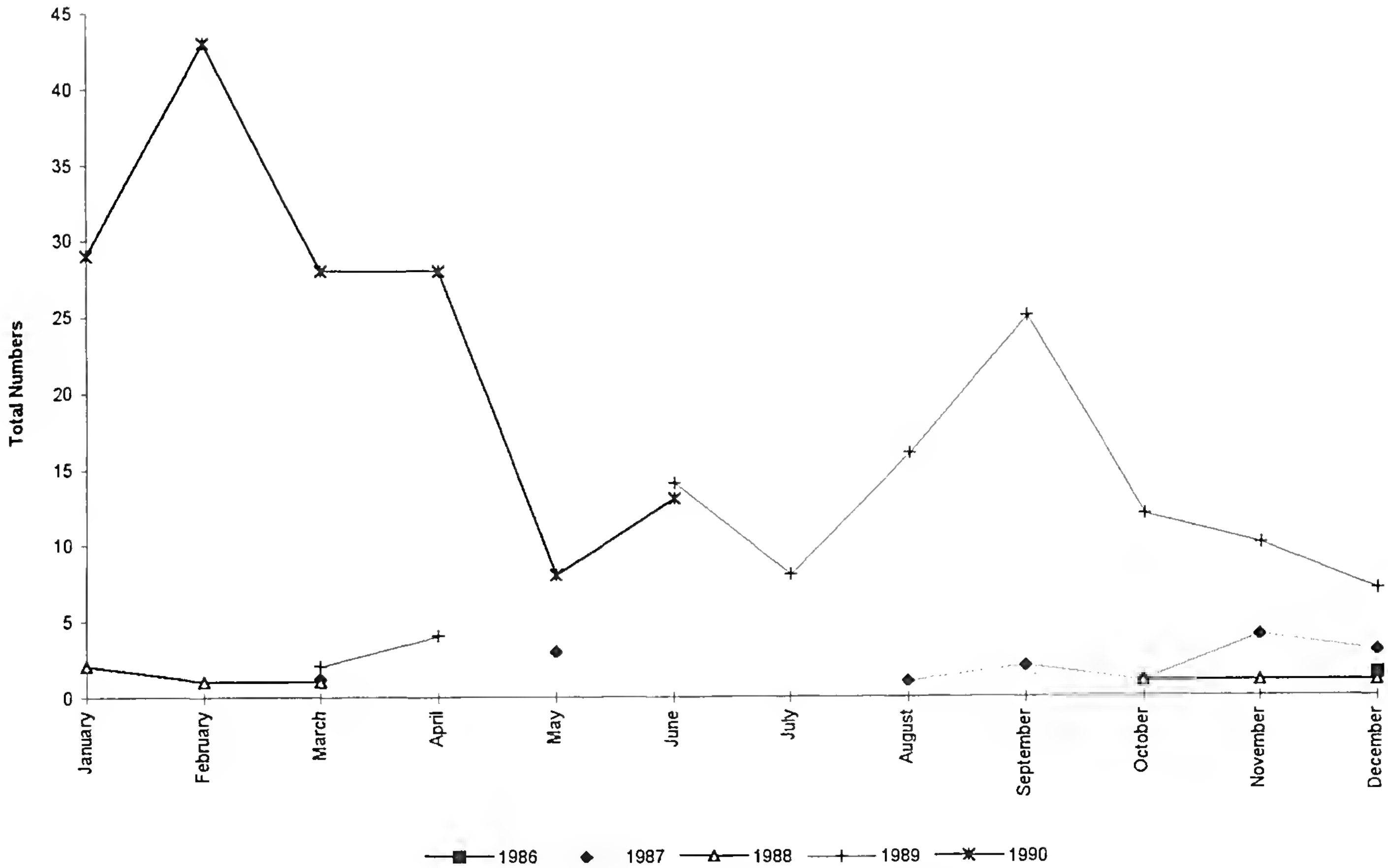

Figure 1. Capture Rates for *Tarsipes rostratus* from December 1986 to September 1990, Stirling Range National Park.

increased markedly after the break of drought.

Sminthopsis griseoventer was not recorded in the Stirling Range National Park until a male was caught on the 6 June 1988 at Site B and later identified by the Western Australian Museum.

DISCUSSION

During this study, with one exception (*Heleioporus*), all species for which there were more than 10 captures were trapped markedly more frequently after the break of drought.

The effect of drought on species numbers can be clearly demonstrated by comparing during and post drought figures for the Honey Possum (*Tarsipes rostratus*), a common species in the park. A single fence line with 3 pits at Site A captured 13 *Tarsipes rostratus* during December 1986 to April 1988 when 379 millimetres of rain fell. The same three pits captured 53 Tarsipes after the drought (December 1988 to April 1990) when 766 millimetres of rain fell.

Myobatrachus gouldii, not captured during the drought and not as common as *Pseudophryne guentheri*, was captured on 17 occasions at Site A and 35 at Site B. The harder soils at Site B may have been more favourable for burrowing than the softer sandy soils at Site A.

While *Pseudophryne guentheri*, *Neobatrachus albipes* and *Myobatrachus gouldii* were captured for the first times just after the drought broke, it was not until 6 months later that a marked increase in most species occurred. Capture rates increased and peaked in April 1989 (11 months after the drought broke), when 99 individual species (34 Site A, 65 Site B) were captured. A levelling out of capture rates for each month was then experienced, but still above drought figures.

Average to above average rainfall stimulates plant growth resulting in prolific flowering. Animals may respond to factors including this succulent growth and prolific flowering by either commencing breeding or survival rates are higher. In a three year study of 5 Scincid lizards (*Ctenotus*) in Central Australia (James, C.D. 1991), reproductive activity was higher during the second year as a result of higher rainfall.

Heleioporus albopunctatus, a large burrowing frog, would appear not to be affected by drought as it was captured on 12 occasions pre and 9 post drought. *Pseudophryne guentheri* not captured during the drought was common post drought with 110 captured, this being twice as many as the other seven species of frogs (see Table 1).

Several between site differences were also observed. *Sminthopsis griseoventer* preferred the sandy soils at Site A being captured on 8 occasions and only once at Site B on the clayey soils.

Nearly three times as many *Cercartetus concinnus* were caught at Site B. This may be attributed to the vegetation being unburnt for 50 or more years, with the dense *Dryandra tenuifolia* and *Dryandra armata* spreading to 1.5 metres in diameter. These dense mature shrubs and the thick grass skirts of *Xanthorrhoea preissii* probably offered shelter and nest sights to a number of vertebrates.

Of note were the lack of snakes captured. The only snake sighted while undertaking the survey was an individual *Notechis scutatus* near Site B. In six years, single individuals of *Morelia spilota, Notechis curtis* and *Pseudonaja affinis* have been the only snakes sighted near the residence at the Bluff Knoll turn-off.

CONCLUSION

Of the 29 species of frogs, reptiles and mammals captured, 6 had not been recorded for the Stirling Range National Park before this survey was undertaken (see Table 1).

Population levels of the unique *Tarsipes rostratus*, which relies solely on nectar for its food, may decline through droughts when plants produce little or no flowers and from the loss of many nectar rich plant species through dieback disease caused by *Phytophthora cinnamomi*.

During this survey, rainfall apparently had an effect on animals capture rates, with much reduced capture rates during drought conditions compared with a period of average to above average rainfall. Conducting a survey during a drought would result in incorrect assessment of the conservation values of the area being sampled.

While undertaking a pit-trap survey it is imperative that average rainfall and current rainfall for the study site be determined.

ACKNOWLEDGEMENTS

I thank Ron Johnstone and other staff of the Western Australian Museum for identification of specimens and printouts of all Western Australian Museum fauna for the Stirling Range National Park. Gordon Friend, Department of Conservation and Land Management provided technical assistance and commented on the manuscript. Allan Burbidge, Department of Conservation and Land Management commented on the manuscript. My wife Sandy commented on the manuscript and showed great patience during the survey.

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A YELLOW WAGTAIL *MOTACILLA FLAVA* AT LAKE MCLARTY

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SUMMARY

A Yellow Wagtail *Motacilla flava* was seen at Lake McLarty on 29 December 1993. This is the fifth known record in the south of WA, although the species is regularly recorded in the north of the State. The bird has been tentatively identified as belonging to the race *simillima*.

BACKGROUND

On Wednesday 29 December at about 1130 hrs, after having watched various wader species in the south-east corner and eastern side of Lake McLarty (32°42'S/ 115°43'E), approximately 17km south-west of Pinjarra, the attention of one of us (JH) was drawn to a bird which had flown down onto the ground some 50m in front of us. Through binoculars, it was quickly apparent by its yellow underparts, habit of briskly wagging its tail up and down and general shape that it was a Motacilla wagtail. A description was compiled and a drawing (by JH) made of the bird. The bird was identified as a Yellow Wagtail *Motacilla flava*.

The bird was viewed for approximately 1 1/4 hours between 1130 and 1400hrs. Optical aids used were 8x30 Carl Zeiss Jena and 8x40 Opticron binoculars and Bushnell Spacemaster 22WA x 60 and Nikon ED 15–45 x 60 telescopes at distances between 10 and 60m. The weather was fine, sunny and mild to warm.

HABITS

The bird was first seen flying in to land on dry mud, it walked and ran along, occasionally dashing at something. Its tail wagged up and down constantly. It once picked up a small piece (c. 2cm x 1cm) of dried plant material. It was seen along the muddy shoreline and at the water's edge and a few times was seen to pick up small items (food – insects?) when dashing about. It was also seen on the adjacent dry surrounds which had areas of short scattered grass where it preened once. The bird was hard to approach out in the open and when flushed was difficult to follow in the air as its flight was swift and strongly undulating. When flushed, it flew 150m away but we did not see it land and we did not relocate it until after lunch. At other times, it flew

30–40m away. We were once able to get to within about 10m when we approached from behind some *Melaleuca* sp. about 2m tall and once within 20–30m when we approached from the water in an endeavour to have the sun behind us. It was otherwise difficult to approach closer than 30–50m. The bird needed careful observation on the ground because at times it could not be seen immediately after having moved short distances. It was once chased for several seconds by a Willie Wagtail.

DESCRIPTION

Upperparts: Grey crown shading to olive-brown mantle, back and scapulars. At certain angles, the olive tinge was more obvious. Once when viewed from directly behind, the upper rump appeared a shade greener (olive green) than the olive-brown upperparts. Ear-coverts grey, darker than crown. From front on, it appeared to have a dark patch around the eye, but this was in fact the grey ear-coverts. Long buff supercilium reached to rear of ear-coverts. Primaries, secondaries, tertials and wing coverts dark brown. Wing coverts very finely fringed buff, the tips forming two fine wing bars but this was only visible through the telescopes. Leading edge of tertials pale. Tail long, very dark brown above with white outer tail feathers, latter not obvious at first.

Underparts: Throat whitish shading to lemon yellow breast then strongly yellow lower abdomen and undertail coverts. Across the upper breast adjacent to the carpal bend, a broad cloudy indistinct dusky band, wider at the sides of the breast. When preening, flanks under closed wing revealed as buff or very pale lemon.

Legs: Very dark grey but at certain angles when the sun fell on the legs, appeared dark brown.

Call: When flushed uttered a "zwit" call, not strong but fairly sharp.

Flight: Swift and strongly undulating. Cramp (1988) and Viney & Phillipps (1983) describe the flight as bounding. When flushed, it flew fairly high and rapidly overhead (10–20m up), while calling. Flying away from us, the bird looked thin and generally dark, with no contrast between the rump and back. No wing bars were noticed. The bird was not easy to keep in view.

IDENTIFICATION

Motacilla wagtails showing the general combination of characters described above are Citrine Wagtail *Motacilla citreola*, Grey Wagtail *Motacilla cinerea* and Yellow Wagtail *Motacilla flava*.

Motacilla citreola has grey rather than olive-brown upperparts. In addition, the dusky ear-coverts of the non-breeding male and the female are isolated in the yellow of the forehead, supercilium, sides of head and underparts (see e.g. Slater 1986). *Motacilla cinerea* has grey upperparts, a contrasting yellow rump and pale brown legs. A narrow white wing band (base of secondaries) is conspicuous in flight (King *et al.* 1978).

The combination of grey crown, long buff supercilium, olive-brown upperparts with similar coloured rump, lack of any noticeable wing bar in flight, dark legs and call of 'zwit' identifies our bird as a Yellow Wagtail *Motacilla flava*. Judging from plumage colouration and time of year the bird appeared to be an adult in non-breeding plumage, although it is possible the bird was in transitional plumage given the amount of yellow on the underparts.

An attempt was made to identify the suspecific status of the bird as this may help in an understanding of the movement of the various races. The Yellow Wagtail is, however, a bird of vast complexity in systematics and morphology (Cramp 1988). Geographic variation within this species is very irregular with similar populations occurring in very widely separated regions, such as nominate *flava* in Europe and *simillima* in far eastern Siberia, while other subspecies intergrade and are merely points along a cline (Johnstone 1982). In addition, integration between many, sometimes sharply differentiated, forms has produced variable hybrids. There are also the problems associated with sex, age, wear, condition of moult and individual variation (Johnstone 1982). Intermediate stages between immature and adult are often seen (King *et al.* 1978).

The combination of features (grey crown, olive-brown upperparts, long buff supercilium) would suggest the bird belonged to the race *simillima* which is the main visitor to eastern Indonesia (Johnstone pers. comm.) The similar nominate *flava* from Europe is unlikely to find its way to Australia. Details of some races e.g Asian have not, however, been found in available literature.

OTHER SIGHTINGS IN SOUTHERN WESTERN AUSTRALIA

The Yellow Wagtail is now a regular summer visitor to northern Australia (Johnstone 1982). In Western Australia, the bird has been recorded in the Kimberley and North West. South of the tropic, one was seen in Carnarvon on 16 February 1991 (Shannon 1991) and presumably the same bird there on 24 February 1991 (Hill and Hill 1991).

In the south of Western Australia, there have been four previous sightings of the Yellow Wagtail. One was observed at Herdsman Lake (Perth) on 28 February 1981 and 8 March 1981 by Peter Curry (Storr and Johnstone 1988). Another was seen at freshwater swamp at Wilson Inlet [near Denmark] for nine days in early May 1983 by L. Broadhurst (Storr 1991). On 8 August 1984, a male was seen by Nick Dymond on seaweed banks to the east of the Eyre observatory and it remained there until 15 August (Dymond 1984). Another was briefly viewed at Lake Claremont (Perth) in January 1987 (Tom Delaney pers. comm.).

It is likely that the presence of the Yellow Wagtail in the south-west is under recorded. There are relatively few birdwatchers in the south-west and observers at Lake McLarty the previous day (28 December) did not see the bird, nor did other observers (including us) on several days subsequently, although most were made aware of the bird's presence. It is possible that this bird was on passage or was very mobile and did not stay at the lake for more than a few hours or a day and that this sighting was therefore pure chance.

ACKNOWLEDGEMENTS

Thanks are due to Ron Johnstone for encouragement in writing this article.

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NOTES ON THE CLIMATE OF PERTH, WESTERN AUSTRALIA

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CLIMATIC DATA FOR THE NATURALIST

An extraordinary variety of climatic data may be required by the naturalist, ranging from the extreme generalisation ("Perth has a mediterranean climate...") to the extreme topicality ("... inside the termites' corridors relative humidity nears 100%..."). Some excellent general climatic in-formation is readily available in print (e.g. Cooke 1901, Hunt 1929, Bureau of Meteorology 1966, 1969, 1975) or more recently from the beginning of observations at each station on microfiche and printout (National Climate Centre, n.d.), but the naturalist must select and adapt what is most relevant to his observations.

The *time factor* may be very important. Mean or total monthly climatic data are quite useful, but organisms go through diurnal cycles of activity and rest. For instance, monthly mean daily maximum and minimum tem-peratures give the monthly mean daily range, but with still and cloudy winter weather the range may be as low as 2°C and with clear summer weather with easterly wind as high as 20°C. Ideally the naturalist would install a properly exposed clockwork hygrothermo-graph or, better, a similar electronic recording instrument as close to the observation site as possible. Dew, although occasionally reported, is not measured consistently and records are not available; in any case, a brief period of sunshine would soon evaporate it. At Perth it can be a significant source of moisture in spring and autumn nights, and naturalists would have to make their own observations, with *ad hoc* instruments and pre-dawn inspections.

Duration time may be of vital significance, especially in the case of adverse conditions such as extreme heat or drought. Daily observations are particularly needed during heat waves which might otherwise remain hidden in the monthly records. The duration of drought should also be counted in days rather than months, because a month in which a drought was effectively broken in the last few days might not appear as having had a drought at all.

There have always been climatic trends, variations, oscillations and cycles. Some of them have been detected in the climate of Perth, and will be discussed later.

CONTINUA AND QUANTA, STEPS AND THRESHOLDS

Heat, measured in practice as temperature, is a *continuum*, i.e. there are no spatial or temporal gaps in its variations. Rainfall, on the other hand, is a discontinuous (discrete) phenomenon which varies by *quanta*: level ground under a rain cloud may get soaked while adjoining ground remains dry (but sloping ground is likely to cause surface and ground water to flow across the boundary). The uplift of a moist airstream increases the chances of rain, a downdraught in the lee of a hill decreases it. Mobile organisms are not likely to be affected, but plants are, and smaller and ephemeral plants particularly so. The effects of topography were taken into account in the preparation of Fig. 2.

A temperature record, while continuous, usually presents a succession of *steps* caused by the succession of daily heating and nightly cooling. In biological field observations it may be difficult to determine how much nocturnal inactivity is due to absence of light or loss of heat, or simply to the need for rest.

All organisms are governed by *thresholds*, minimum or maximum limits for survival or for normal or optimal activity. The most quoted threshold, 0°C (freezing point) is seldom reached in Perth, and only at ground level and for a few hours. European botanists used to consider 6°C as a threshold for good plant growth; at Perth this temperature is reached on a few winter nights within the screen, but grass temperatures recorded between 1899 and 1926 showed that the lowest minimum in each month was below 0°C from late May to early November and the average monthly minimum was below 0°C 4% of the nights in May, 21% in June, 46% in July, 50% in August, 21% in September and 4% in October. Plants, relatively dormant in winter, are more active in September than in June because of the warmer and longer September days.

Temperatures above 38°C are at least inconvenient to warm-blooded animals, and temperatures above 40°C actually injure some plant tissues, but in Perth they do not last long enough to injure animals, who find suitable shelter.

THE QUALITY OF OBSERVATION SITES

The site of observation is a very small sample of the locality where it is situated, and must be chosen with regard to its most important characteristics: aptness, representativeness and (for special studies) relevance to the subject or purpose of the study.

Aptness is decided by the laws of physics: barometers may be indoors, but thermometers for standard observations must be in a well ventilated preferably louvred box (usually a Stevenson screen) in an open space, preferably grassed, 1.25 m above ground. Rain gauges are high enough from the ground to avoid splashes, and well away from any obstruction. Evaporation measurements are more controversial. Wind observations are officially made 10 m above ground to avoid ground friction and turbulence caused by trees, buildings, etc., but this requirement results in readings which are too high for anyone studying insect life near the ground, or flowers, while being very significant in the study of higher-flying insects or pollen dispersal. Whole handbooks have been written about standard instrument exposure.

Representativeness simply means that the site's records must not be very different from those that would be got from a fairly large area around the site itself, ideally half way to the nearest recording site. In flat uniform country this is easily achieved, but in hilly landscapes or near bodies of water there arise various problems that may force a considerable degree of com-promise. A rain gauge situated upwind or downwind of even a small hill or a sand dune may give accurate but very unrepresentative readings. It is up to the naturalist to make allowance for such problems, which are the very essence of topoclimatic studies.

Unfortunately the most apt and representative records may not suit the needs of the naturalist. We are here in the realm of micro-climatology: the unlined tunnel of the earthworm, the lined tunnels of the termites, the vertical and horizontal shafts of ants' nests, the humid air above a stream frequented by dragonflies, the rock or wall where the lizard suns itself, the shade where the kangaroo rests at noon, all require minute and accurate measure-ments made possible by modern instrumentation.

THE SITES CALLED PERTH

Official Perth weather and climate observations were made at various sites in the past, but until 1990 always within the present city limits. Differences between sites affect the records, particularly with regard to pressure and temperature (for which corrections are relatively regular and easy) and wind and rainfall (which are affected far less regularly and are more difficult to compare for different sites). The growth of trees or the erection of new buildings can drastically change the quality of a site and the representativeness of observations. The kind of records assembled in the 18th century was influenced by the point of view prevailing at the time: relevance to health at the beginning, atmospheric physics most of the time, agriculture in the second half of the century. In the second half of the 19th century environmental aspects of climate received more attention, and lately air pollution and air quality were measured, thus returning to the emphasis on relevance to health of nearly two centuries ago.

On the way to Western Australia, in 1829, Governor Stirling gave orders to the Colonial Surgeon "to keep a Journal of the weather and height of the Thermometer and a detail of every circumstance in the weather affecting health". Such records were kept at both the Surveyor-General's office and the

Colonial Surgery at Perth; the former series runs almost continuously from April 1830 to the end of 1876 and is available in manuscript form, but only fragments of the latter from 1842 and 1843 have been found. Both series recorded temperature, pressure, wind direction and state of the weather twice a day. There is no description of the site and exposure of the instruments. Similar records were kept inside a Perth house in 1830–31 and under a thatched hut throughout 1831. The exposure of the instruments was not often considered critical at the time, as long as direct solar radiation was avoided. The time of observations could even vary according to circumstances.

The *Inquirer* newspaper published weekly weather reports from the Surveyor-General's office (then near the crossing of Barrack Street and St George's Terrace, at about 16 m above sea level) from April 1840 to April 1845 and monthly ones from June 1845 to September 1846. In 1843 the *Journal of the Agricultural and Horticultural Society of Western Australia* (vol. 1, pp. 16–28) published pressure, wind and temperature data taken daily at 16 hours at the Surveyor-General's office, with the monthly number of rainy days. From May 1842 to May 1843 it also published wet and dry bulb temperatures obtained from Government House, a short distance eastwards along St George's Terrace. Rainfall as such was still neglected: the oldest quantitative records of rain were obtained at the Fremantle Signal Station from July 1852 to March 1859.

In 1876 a Meteorological Branch was created within the Surveyor-General's Department; observa-tions were made regularly at 0700 and 1200 hours. It is possible that the rain gauge may have been placed in a less obstructed space at the Botanical Gardens (now Government Gardens). In 1885 all instruments were transferred there, at about 11.5 m above sea level, and the times of reading were changed to 900 and 1500 hours. The number of days with rain was not recorded again until 1907. About 1924 the instruments were moved to a site less than 2 m above sea level, south of the Supreme Court building (which must have considerably

Table 1. Sites of official Perth weather observations

Period	Location	alt.m	km from sea
before 1876	Surveyor-General's Dept	c16	9.5
1876–1924	Government Gardens	11.5	9.5
1924–1930	" "	c2	9.5
1897–1967	Observatory (W.Perth)	c60	8.5
1967–1992	Regional Office (East Perth)	18.6	11.3
1993–	Aut.Weather Stn (Mt Lawley)	24.9	12
1944–1984	Airport (Guildford)	18	21
1985–June'91	" (")	12	21
July 1991–	" (Belmont)	29	21

affected earlier records), where they remained until the station was closed down in 1930.

In 1896 an astronomical observatory was built on Mt Eliza and the Government Astronomer was placed in charge of meteorological observations, which began on an adjoining grassed site, at 60 m above sea level, and continued until 1963. From 1963 to 1967 to reduce interference from new buildings, instruments were moved to a small plot of lawn near by, east of the old Hale School building. As will be shown later, the climate of the Mt Eliza sites differs significantly from those of all other Perth sites because of the greater height and more open exposure to the westerly winds. Fortunately records at Government Gardens and Mt Eliza overlapped from 1897 to 1927, so that a comparison could be made. In 1908 weather observations, at the same sites, were placed under the control of the new Commonwealth Bureau of eteorology.

In 1967 the new Regional Office of the Bureau of Meteorology opened near the corner of Wellington and East streets, east of the city, and the instruments were moved there; the site, at 18.6 m above sea level, was almost surrounded by tall buildings, particularly on the windward side, and was therefore quite unrepre-sentative. However, observations continued until April 1992. The Regional Office then moved to West Perth, without a site for observations, and records and forecasts were based on the International Airport. In November 1993 the Bureau was able to install an automatic weather station on a good, open site at about 24.9 m above sea level in Mount Lawley (City of Stirling), and official Regional Office records were resumed.

It is now a convention that weather observations for international requirements be made at airports; records at Perth Airport (Guildford) began in 1944, and were variously listed under Perth, Perth Airport, Guildford, and, after a small change of location about 1990, Belmont (National Oceanic and Atmospheric Administration, 1947–).

SITE AND TEMPERATURE

Differences in temperature between microclimates are far more important to living organisms than differences between meteorological sites. The best course to follow is to quote the relevant official temperature reading at the nearest station in order to establish a comparable base, and at the same time measure the actual temperatures in the relevant

microclimate. Also, while the official temperature is read at the prescribed regular intervals, it is nearly always desirable to record actual microclimate temperatures as often as possible, preferably continuously by means of a recording instrument. The heat of the day affects most animals, which usually if warm-blooded seek a shady spot to rest in the hottest hours and if cold-blooded have to seek heat in order to become more active. Even a passing cloud may reduce the temperature enough to affect the activities of some insects.

Table 2 assembles published and unpublished data to facilitate

Table 2. Mean monthly temperatures at the main observation sites (°C)

Mth	Period 1897–1926 Gard	Obs.	diff.	/100m	Period 1945–59 Obs.	Airp.	diff.	/10km	Period 1973–87 EPth	Airp.	diff.	/10km
Jan.	23.8	23.2	.6	1.00	23.7	23.6	.1	.08	24.8	24.5	.3	.3
Feb.	23.7	23.3	.4	.67	24.1	24.0	.1	.08	25.2	24.9	.3	.31
Mar.	22.2	21.8	.4	.67	22.8	22.4	.4	.32	23.5	22.9	.6	.62
Apr.	19.4	19.2	.2	.33	19.3	18.7	.6	.48	20.2	19.4	.8	.82
May	16.0	15.9	.1	.17	16.1	15.5	.6	.48	17.0	16.0	1.0	.97
June	13.8	13.8	0	0	14.2	13.6	.6	.48	14.9	14.0	.9	.93
July	13.0	12.9	.1	.17	13.2	12.7	.5	.40	14.0	13.1	.9	.93
Aug.	13.6	13.3	.3	.50	13.5	13.0	.5	.40	14.4	13.4	1.0	.97
Sep.	15.0	14.6	.4	.67	14.7	14.2	.5	.40	15.7	14.6	1.1	1.13
Oct.	16.7	16.0	.7	1.17	16.1	15.6	.5	.40	17.5	16.5	1.0	.97
Nov.	19.7	19.0	.7	1.17	18.7	18.3	.4	.32	20.0	19.2	.8	.82
Dec.	22.1	21.4	.7	1.17	21.0	20.7	.3	.24	22.4	21.8	.6	.62
Year	18.3	17.9	.4	.67	18.1	17.7	.4	.32	19.1	18.3	.8	.82

Data sources: Hunt (1929) and R.Tapp (priv.comm.1994)

comparison between the successive sites of official observations. Height above sea level is the most significant difference between Government Gardens and the Observatory, but the usual lapse rate of 0.55 to 0.6°C per 100 metres is mostly found before the equinoxes and in the annual means. It falls to zero about the winter solstice, and rapidly rises to double the usual rate in late spring and early summer, until the summer solstice.

The likely explanation of these differences is the absorption and storage of the increasing springtime heat at the low and sheltered Government Gardens site while strengthening daily breezes and generally more open exposure to the wind helped disperse much of the heat from around the Observatory at the top of the hill.

Diurnal variations result in a higher lapse rate in the daytime, with mean maximum temperatures being 0.5 or 0.6°C higher at the Gardens than at the Observatory during May to July, rising to be over 2°C hotter in November. Mean minimum temperatures have a negative lapse rate, the Observatory being slightly warmer than the Gardens throughout the year, or about equally warm at the equinoxes. Downhill drift of cool air from the higner ground, stagnation of the cool night air and later sunrise because of their location contribute to the lower minima at the Gardens during the cooler season.

In a comparison of records at other sites with those at the Airport differences in height become less significant than distance from the sea, and in Table 2 average temperature differences have been shown as observed and also reduced to a standard 10 km difference in distance from the sea. Generally, the Airport is cooler than the other sites, but only very slightly so in the summer, contrary to what was noticed in the Gardens-Observatory comparison. Differences become more noticeable in the winter, partly because of drainage of cool air from the scarp to the foothills and partly because of the loss of night radiation from the large bare areas of the airport. The peak of thermal difference between East Perth and the Aiport is reached at the equinoxes, particularly in the spring.

The essential thermal differences between the various sites are perhaps best expressed by the mean *daily range* of temperature, shown in Table 3. One is tempted to say that even the few kilometres further away from the coast are enough to give the Airport a more continental climate than at any other site. Differences between the other sites are very small, but possibly the East Perth site, with its relatively moderate temperature range even in summer, may be viewed as the least representative one for the Perth natural environment.

SITE AND RAINFALL

Rainfall is usually recorded for the 24 hours beginning at 0900 each day, and this means that any rain fallen between midnight and 0900 is credited to the previous day. When summer time is in force, it should be made clear whether allowance is made for it or not. When comparing monthly totals, a correction may be needed for the unequal number of days in the various months.

Rainfall may be shown as a *total* amount (as the depth of water caught in the rain gauge or pluviometer), a *frequency* (usually the number of days with rain) or an *intensity* (usually the amount fallen in each day with rain, or in shorter periods, even within 15 minutes in

Table 3. Daily range of temperature at the main observation sites (°C)

Month	Gardens 1897–1926	Observ. 1945–59	E Perth 1973–87	Airport 1945–59	Airport 1973–87
Jan.	12.9	12.2	11.6	15.1	15.1
Feb.	13.0	12.2	11.4	14.5	14.5
Mar.	12.3	11.9	11.1	14.4	14.0
Apr.	11.7	10.8	10.0	13.2	12.5
May	9.9	9.2	9.1	11.4	11.0
June	8.9	8.1	8.5	10.0	9.6
July	9.1	8.3	8.4	9.9	9.5
Aug.	9.5	9.1	8.9	10.8	10.0
Sep.	9.7	10.0	9.5	12.0	11.2
Oct.	10.2	10.4	9.8	12.6	12.1
Nov.	11.6	11.0	9.8	13.5	12.9
Dec.	12.1	11.4	10.2	14.2	14.0
Year	*10.9*	*10.4*	9.8	*12.6*	*12.2*

Data sources: Hunt (1929) and R.Tapp (priv.comm. 1994)

Table 4. Mean total rainfall (mm) and number of rain days

Mth	Gardens		Observatory				E.Perth		Airport			
	1907–29		1907–29		1945–59		1973–87		1945–59		1973–87	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan.	9.8	3.1	9.5	3.4	4.9	2.7	11.1	2.3	3.9	2.4	8.5	2.2
Feb.	13.2	2.8	14.4	3.1	18.3	2.4	18.4	2.9	13.8	2.2	17.1	3.1
Mar.	18.9	4.7	20.1	4.9	13.9	3.2	10.1	3.9	11.2	3.2	11.2	3.6
Apr.	34.4	6.7	38.0	7.0	52.3	8.6	40.1	7.3	43.8	7.9	40.3	7.4
May	130.6	14.7	136.3	15.0	125.1	14.2	111.3	13.3	114.0	14.3	101.7	13.2
June	183.6	17.5	190.9	17.6	211.5	17.8	162.6	16.3	199.0	17.9	148.8	16.2
July	179.6	18.3	185.2	18.9	193.5	19.9	170.4	17.6	170.9	18.3	157.5	17.2
Aug.	140.1	18.0	148.4	18.7	132.0	16.5	116.5	16.0	131.6	16.0	112.4	15.7
Sep.	88.6	14.5	90.7	15.8	61.7	12.5	73.3	12.1	62.9	12.8	68.2	11.9
Oct.	56.8	12.4	60.8	13.4	60.1	12.0	47.6	9.2	56.6	11.7	38.5	8.9
Nov.	18.9	6.6	20.7	7.3	30.5	7.7	25.6	7.4	29.5	8.2	28.4	6.8
Dec.	12.9	4.0	13.1	4.8	18.0	4.5	9.2	4.0	15.2	4.9	7.6	3.7
Year	887.4	123.4	930.7	129.6	921.8	122.2	796.4	112.3	852.4	119.8	740.1	110.1

special cases). Until 1973 a day with at least 1 point of rain (1/100 of an inch, or 0.25 mm) was counted as a rain day or, loosely, a wet day. With the conversion to the metric system, from 1974 onwards a day had to record 0.5 mm to be credited with rain, and days with less than 0.5 mm are recorded as having had only traces of rain.

A comparison of rainfall records between the same sites as in the preceding tables is shown in Table 4. The earlier years are omitted, because until 1907 no record was kept of the number of days with rain. Different sites may be compared only over the same period of obervations, i.e. Gardens and Observatory for 1907–29, Observatory and Airport for 1945–59, East Perth and Airport for 1973–87. No reliable comparison may be made between Observatory and East Perth data because there was only a very short overlap in the operation of both sites

Summer rainfall is very variable in time and irregular in its spatial distribution. More may fall at the Airport than at other sites because of the greater instability of the air near the Darling Scarp. The more reliable and much more plentiful May and winter rains were about 5% higher at the Observatory than at the Gardens and, in a later period, some 10% lower at the Airport than at the Observatory. In a study of rainfall in successive days Swindell (1979) found that distance from the sea was about twice as significant as altitude and aspect. On the average, during a few days, rainfall on the coastal plain decreased 0.15 mm/km away from the coast, a rate close to the 10% difference between East Perth and the Airport.

These differences are particularly significant at Perth because its normal rainfall is just sufficient to support a forest, as opposed to an open woodland such as is formed by Wandoo. A rainfall below average immediately imposes some stress on the vegetation, as shown for instance by Havel (1979).

A RAINFALL MAP OF PERTH

A metropolitan area measuring some 65 km from north to south and over 35 from west to east, and rising from sea level to over 400 m on its eastern margin, must show some areal variations in its climate. The altitudinal gradient varies from 0°C per 100 m in June to nearly 1.20 in October to December (Table 2). Distance from the sea accounts for little less than 1°C from May to August, rising to just over 1°C at the spring equinox. It is much less, 0.3°C or so, during most of the summer. Given a contoured map and using the ranges of temperature shown in Table 3 the preparation of a map of average temperatures in the Perth Metropoltan Area becomes relatively easy.

Rainfall is more difficult to estimate because it is affected by more factors and can vary substantially over a small area. On the other hand, at different times rainfall was recorded at over 90 sites in the present metropolitan area. Careful comparison of the physical attributes of the various sites and their recorded observations allows some plausible estimate for the intervening points.

Figure 1 shows the altitude and annual rainfall of the stations near the Darling Scarp. The solid line shows the average correlation between altitude and rainfall, at a rate of very nearly 1 mm per 100 m. The 865 mm in the equation would be the mean annual rainfall of a station at sea level.

Stations near dam or weir sites are shown by small circles and were excluded from the calculations because their rainfall was much higher than would have been expected, as is shown by the broken line: 2.1 mm per100m, more than double the normal rate. The explanation is simple: the recording sites are near the dam sites, near the valley floor or at most at the top of the dam, while the surrounding land, and particularly that at the back of the reservoir, rises much higher, to 400 or even 500 metres at some points. The funnelling of the westerly wind up the valleys can also increase the rainfall by increasing the thickness of the airstream.

An earlier analysis of the rainfall near the Scarp (Gentilli 1979a) showed that the Scarp has no effect on the number of rain days, but the intensity of the rain increases noticeably from near the foot of the Scarp to a short distance beyond the top. If the uplift of the airstream were the main cause of the increased rainfall there should be some increase in the number of rain days. The substantial and sudden increase in the intensity of the rain suggests that there is a more dynamic cause: the warm water of the longshore Leeuwin Current adds some moisture, warmth and instability to the westerly airstreams, and the sudden rise against the Scarp acts more like a trigger on an unstable airflow than as an incline under a steady airstream. Having lost a substantial part of its additional vapour over the Scarp, the air returns to its previous

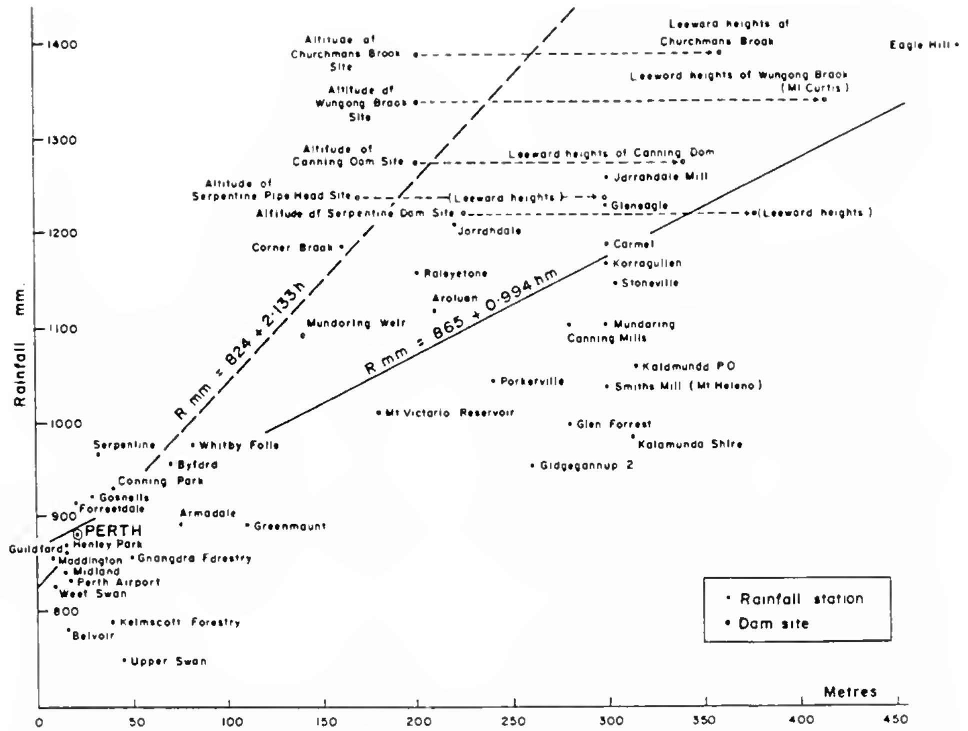

Figure 1. Altitude and mean yearly rainfall of stations near the Darling Scarp. The dashed line shows that the rainfall increases by an average of 2.133 mm for every metre of altitude. If, however, the calculation is based on the altitude of the heights to the leeward of dam sites, the rate of increase, as shown by the continuous line, drops to 0.994 mm per metre.

characteristics as it proceeds further inland.

A rainfall map of the Perth Metropolitan Area was published by the Bureau of Meteorology (1969, p. 81) but the interval of 5 inches (127 mm) between isohyets made it too general as a basis for further work. The interval was reduced to 2 inches (50.8 mm) near the coast and in the Swan Valley, but not enough account was taken of the dune topography, which is now mapped in considerable detail (DOLA 1972–). Figure 2 has taken into account these various factors and could be used by naturalists to estimate the average annual rainfall of any locality within its scope.

Rainfall is lower in the middle Swan Valley than further south because the Darling Scarp is slightly lower and displaced towards the east. The Kalamunda Spur extends further westwards and rises steeply, forcing the airstreams to climb. Besides altitude, the effect of latitude cannot be neglected; The highest average yearly falls reach 1271 mm at Canning Dam and 1337 mm at the Wungong Dam. Figure 2 shows the initials or first two or three letters of the names of stations, with the respective yearly totals, and the isohyets have been drawn taking detailed account of the topography. Isopleths over the sea and around the Cockburn Lakes, for which there are no records, are shown by dashed lines; it is surmised that the coastal dunes further west shelter the shallow depression where the lakes are enough to keep the rainfall below 850 mm per year.

GAUGE RAINFALL AND ACTUAL WATER AVAILABLE

The rainfall gauge intercepts raindrops before they reach the ground. Any obstacle in their path affects raindrops, according to the angle of impact, resulting in sideways splashing, or coalescence of small drops to form heavier ones, or continuous deflection of many drops to form a trickle, or delay or temporary retention of raindrops in some way or other. Interception by tree canopies can be very important: Wandoo intercepts about 10% of the rain, Jarrah 20%, pines (and presumably casuarinas) 30%, more if the rainfall is heavy . Light rain may totally fail to reach the ground under pine trees, and the ground may begin to dry a month or two earlier under them (data generalised from Burrows, 1987). The implications of this for small ground-living animals and plants may be very important. The naturalist may have to use makeshift gauges to measure the actual rainfall under the plant canopy, or at least will have to calculate the throughfall by subtracting the presumed interception from the gauge readings.

Conversely, the amount of water available to deep-rooted plants will be more than the gauged rainfall when the roots meet the watertable, which reaches its highest point around October every

Table 5. Rainfall intensity (mm/day)

Month	Gardens	Observatory		E.Perth	Airport	
	1907–29	1907–29	1945–59	1973–87	1945–59	1973–87
Jan.	3.2	2.8	1.8	4.8	1.6	3.9
Feb.	4.7	4.7	7.6	6.3	6.3	5.5
Mar.	4.0	4.1	4.3	2.6	3.5	3.1
Apr.	5.2	5.4	6.1	5.5	5.5	5.4
May	8.9	9.1	8.8	8.4	8.0	7.7
June	10.5	10.8	11.9	10.0	11.1	9.2
July	9.8	9.8	9.7	9.7	9.3	9.2
Aug.	7.8	8.0	8.0	7.3	8.2	7.2
Sep.	6.1	5.8	4.9	6.1	4.9	5.7
Oct.	4.6	4.5	5.0	5.2	4.8	4.3
Nov.	2.9	2.8	4.0	3.5	3.6	4.2
Dec.	3.2	2.8	4.0	2.3	3.1	2.1
Year	*7.2*	*7.2*	*7.5*	*7.1*	*7.1*	*6.7*

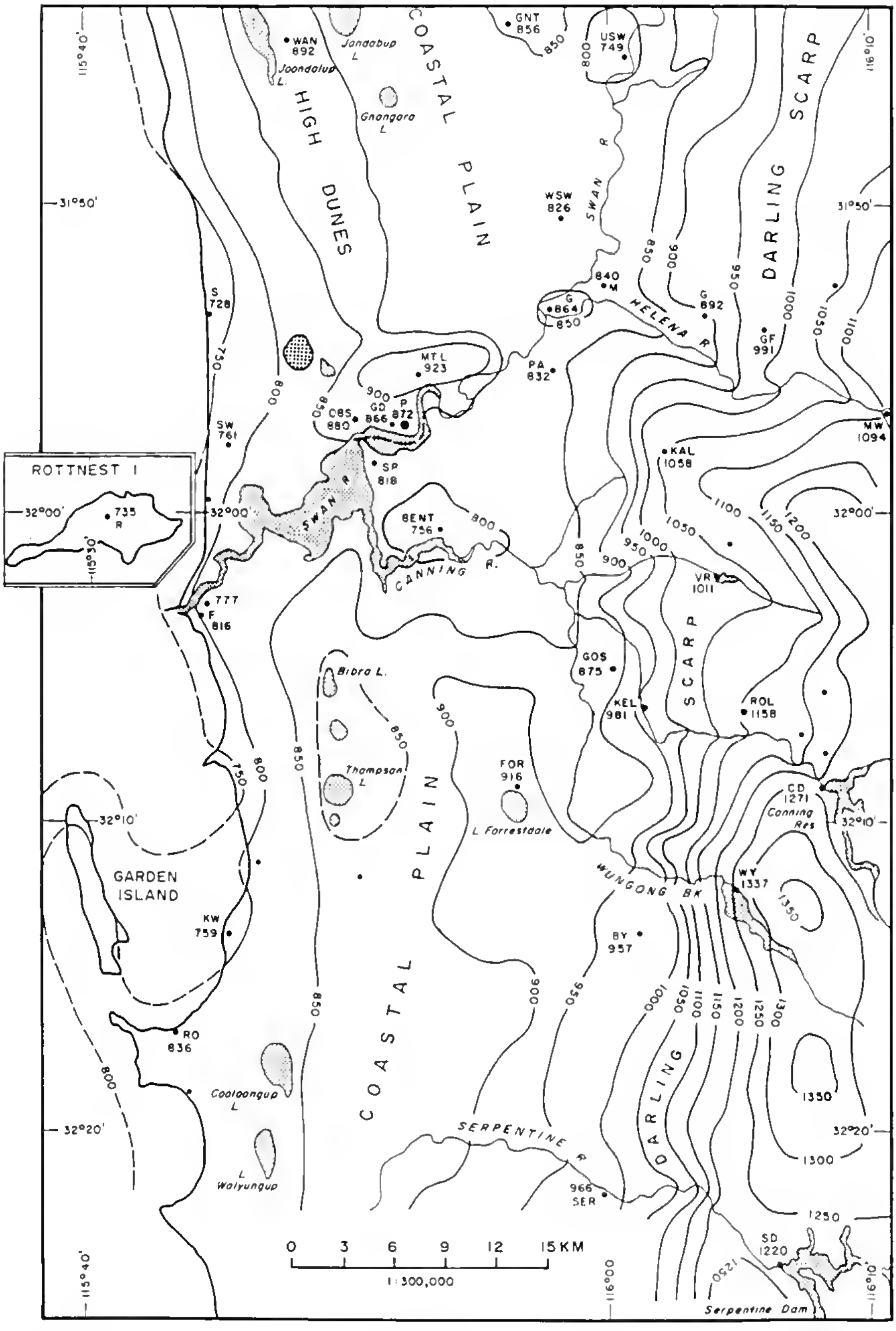

Figure 2. Mean annual rainfall of the Perth Metropolitan Area. Note the effect of topography.

year (see Figure 6 below).

On slopes, the gauged rainfall may be slightly greater near the top because of the sudden uplifting of the airstream, but the water flows rapidly downhill, so that the higher ground becomes drier sooner, while the lower slopes gather not only the direct rainfall, but also some of the runoff at the surface and immediately below. The relative size, density and foliage development of the plant cover usually reflect this trend even where the floristic composition remains the same.

OTHER RAINFALL DATA

Other very valuable data on Perth rainfall (with no distinction between Gardens and Observatory but covering separately Fremantle and Guildford town as well) are included in the 1969 Bureau of Meteorology's book. They include the yearly totals arranged in class intervals, monthly average and extreme values, percentage frequencies of monthly totals in specified ranges, highest daily rainfall on record. For Perth only there are tables showing the mean daily rainfall for each day of the year, mean number of days per month on which given amounts were received or exceeded, frequency of rain days (with at least 1 point and 10 points respectively), percentage probability of rain in any hour for each month, mean hourly rainfall for each month, monthly frequencies of occurrence of of consecutive rainless days and consecutive rain days. Other tables show the monthly frequency of rainfall in given ranges with wind from given directions. The maximum rainfall intensity recorded at Perth during

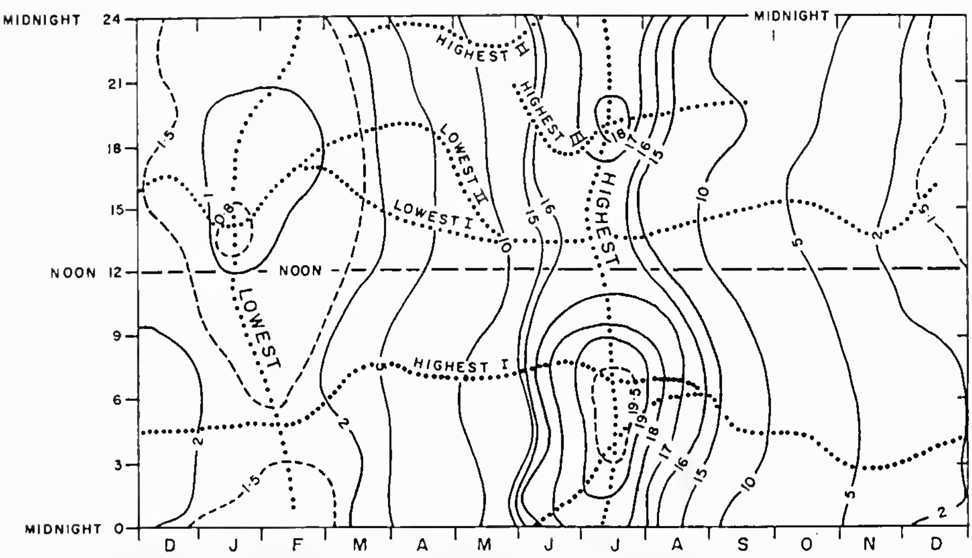

Figure 3. Mean 3-hourly (larger type) and monthly (smaller type) rainfall at Perth. Notice how several months have more than one average time of highest or lowest falls.

specified periods ranging from 5 minutes to 3 days is also shown with the respective dates, and the estimated recurrence from once in 1 year to once in 45 years is shown on a graph.

The probability of rain in any single hour in each month of the year, as published, was too detailed for practical purposes, and Figure 3 has been prepared for 3-hourly periods. The dotted lines show the times of highest and lowest average falls in 3 hours (vertical scale at the left, small writing along more or less horizontal lines) and in the year (months shown at the bottom, near-vertical lines, larger writing). The 3-hourly totals do not vary very much, and various peaks (highest I,II,III) and troughs (lowest I and II) can be seen, which may also vary considerably from year to year. There is, however, a general pattern that can be detected, especially the pre-dawn and after-sunset maxima in the winter months, and the early-afternoon minimum at mid-summer.

FREQUENCY OF GIVEN AMOUNTS OF RAIN

Extreme seasonal differences in the amount of rain received are one of the main features of the Perth climate, in fact much more so than in the Mediterranean regions from which the dry-summer climate takes its name. Tables 4 and 5 and Figure 4 are very valid representations of these seasonal differences in rainfall, but they are based on averages. Some comparison must also be made for the actual amounts received.

Table 6 shows the amounts of rain received in each month over 100 years, i.e. 1200 monthly amounts as they actually happened. Any month from November to April may be rainless, but this happened only once in November and three times each in March and April. Any

Table 6. Frequency of monthly rainfall of given amounts, 1891–1990.

Month	0 or traces	1–25	26–50	51–100	101–150	151–200	201–300	over300
Jan.	10	84	4	1	1	–	–	–
Feb.	16	70	11	2	–	1	–	–
Mar.	3	71	18	6	2	–	–	–
Apr.	3	31	26	34	6	–	–	–
May	–	3	9	27	31	23	7	–
June	–	–	–	13	19	30	35	3
July	–	–	–	10	24	41	21	4
Aug.	–	2	2	29	37	19	9	2
Sep.	–	4	19	49	22	6	–	–
Oct.	–	10	39	42	9	–	–	–
Nov.	1	68	26	5	–	–	–	–
Dec.	5	79	15	1	–	–	–	–

Year	501–600	601–700	701–800	801–900	901–1000	1001–1100	1101–1200	over 1200
	4	12	18	24	21	12	7	2

month except June and July may get fron 1 to 25 mm of rain, but in fact this is quite rare in May and August to October.

A more positive aspect of climate is shown by the number of months receiving more than, say, 50 mm of rain, as happens from April to October, except that in April and October this involves about half the years on record, while from May to August it is nearly the general rule. Further groupings or separations of months by their rainfall frequencies shown in Table 6 may be left to the naturalist, according to the needs, tolerance or limits of the organisms studied. An interesting case is that of April, which is bimodal, i.e. has two maximum frequencies, 1 to 25 and 51 to 100 mm: any organism which feels the stress of the usually dry summer (or, in the Nyoongah calendar, *birok* and *burnuru* in succession) may be drastically or even catastrophically affected by a dry April.

Distribution of yearly total amounts is smoother, with a fairly steep rise from 4 years with 501 to 600 mm to 24 years with 801 to 900 mm and tapering off slowly with the rare 2 years with over 1200 mm.

PERTH'S SEASONS

Perth's Nyoongah (Nyunga) Aborigines divided the year into six seasons, according to the weather and environmental conditions, with particular regard to food supplies and, to some extent, shelter; the same season could vary slightly from year to year, and so some seasons could be of different length. By combining the information given by Berndt and Berndt (1979), Bindon and Walley (1992) and other sources one obtains Table 7. The equivalence to the two calendar months listed for each season is only approximate.

There seems to be no great climatic difference between *birok* and *burnuru*, save for occasional more humid days towards the end (in March). Reference to Table 2 shows that mean temperatures remain above 20°C from December to March. Temperatures decline rapidly in April–May, and average less than 14°C in June to August, the traditional winter. They rise gradually in September to November. This would give four thermal seasons, with a summer of four months and an autumn of two.

Rainfall records (Tables 4 and 5) show a driest period in December–January, and rare but more intense falls in February. March has less infrequent but also less intense falls. This shows a slight difference in rainfall regime between *birok* and *burnuru*. Rainfall increases rapidly in April–May and reaches its peak in June–July. August has definitely less rain but still as many rain days, with less intense falls. September rains are lighter and less frequent, and this month is more closely linked with October–November than with August. This would give a year with six seasons, with August as a pre-spring of its own, and September to November as a three-month spring.

A tabulation of many climatic data for Perth (Gentilli 1971, pp. 298–299) still does not help to separate September from October, but shows more difference between December–January (mean monthly evaporation over 240 mm) and February–

Table 7. Names, approximate timing and characteristics of Aboriginal seasons.

Season	Approx. timing	Usual weather	Food supplies
Birak or Birok	Dec., Jan.	Hot and dry, very high evaporation, afternoon breezes.	Seeds, lizards, snakes; no shelters needed; lakes dry, firing bulrushes.
Bunuru or Burnuru	Feb., March	Hot E and N winds, high evaporation.	Roots, zamia nuts, nectar; bush firing.
Djeran or Wanyarang	April, May	Cooler, SW winds, night dew, showers.	Shelters built, skin cloaks sewn.
Makuru or Maggoro	June, July	Cold and wet, westerly squalls.	New shoots, frogs' eggs.
Djilba or Yilba	Aug., Sept.	Less rainy, becoming warmer.	Roots, flowers; lakes deepening, frogs.
Kambarang	Oct., Nov.	Rains petering out, night dews, occasional hot days.	Plenty of eggs, young animals.

March (under 220 mm). The same criterion of mean monthly evaporation allows also to link August and September (monthly evaporation 60 to 90 mm per year). Once more, autumn (in May, with evaporation around 70 mm), is shorter than spring (August–September, 60–90 mm).

Evaporation is affected by several factors, the most important of which is solar radiation. The combination of solar radiation (from Spencer 1976) and rainfall shown in Figure 4 gives a clear separation of monthly climates and of seasons, be they Aboriginal or European.

The highest position of the sun in the sky and the longest duration of daylight are reached at the solstice, on December 21, and by the beginning of February both factors have decreased slightly but noticeably, while temperatures only follow with the usual lag of five or six weeks. Figure 4 shows the compactness (the evenness) of *birok* and summer and the better suitability of *burnuru* and *djeran* to distinguish the accelerated changes of autumn, which includes a March that is very often the tail end of summer rather than part of autumn itself. At the opposite time, *makuru* is a compact wet and dark season, whereas winter is unevenly extended by the inclusion of August, when rainfall may still be frequent but becomes noticeably lighter. The kink in October is due to a sharp increase in radiation intake because of the combination of more hours of daylight and

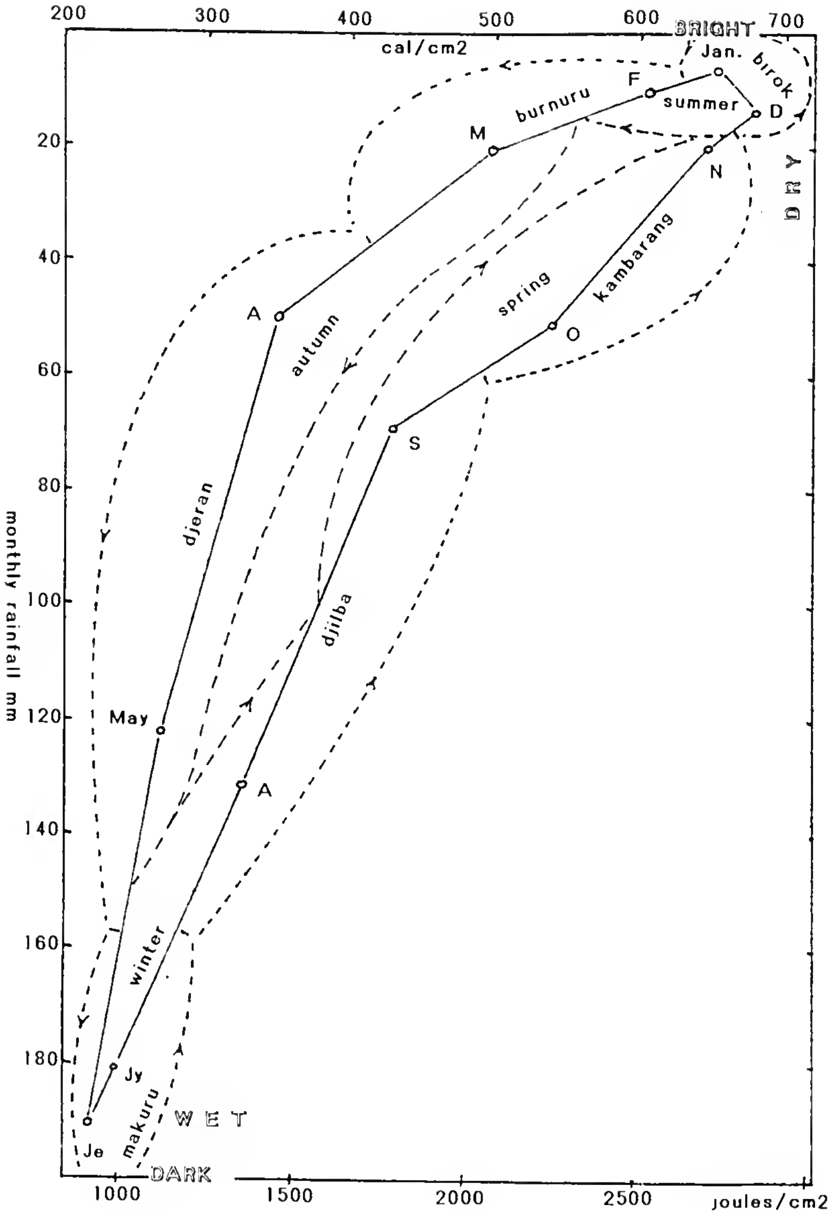

Figure 4. Monthly march of solar radiation and rainfall. Most months are shown by their initial, 2-monthly aboriginal seasons on the outside of the polygon and conventional 3-monthly seasons on the inside. Dashed lines show the seasons' approximate limits. Note the enormous differences in the rates of change between solstitial and equinoctial seasons.

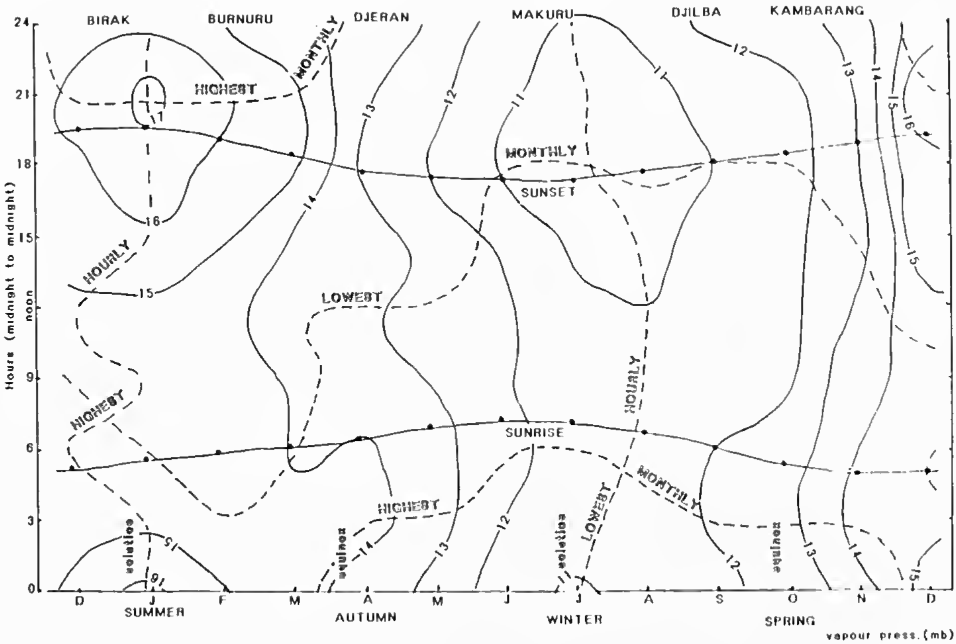

Figure 5. Hourly and monthly moisture in the air, shown as the pressure exerted by water vapour, in millibars. The highest moisture content occurs in summer afternoons and evenings, as the sea breeze brings in moisture from the ocean. The driest conditions are in the winter afternoons and evenings.

clearer sky. *Djilba* and *kambarang* are better and more even climatic subdivisions than August and spring of the European calendar.

Vapour pressure, whether expressed in millimetres of mercury or in millibars, is a very good expression of absolute humidity, which affects respiration and transpiration of organisms, Figure 5 shows the average hourly and seasonal changes in vapour pressure, expressed in millibars.

Fig. 5 is the best evidence of the fact that March belongs to the preceding season, be it *burnuru* or summer, rather than to the following season. From December to March inclusive, the most humid conditions occur from mid-afternoon to evening as a result of the cool sea-breeze which bring in moisture from the sea. By the end of March there is a sudden switch and the most humid conditions occur in the early morning, before the increased evaporation that follows sunrise. The times of lowest vapour pressure are to a great extent complementary, about sunrise in summer and March, about noon in *djeran* (April–May), and about sunset in *makuru* and *djilba* (winter and September). *Kambarang* (October–November) is the season in which the lowest humidity moves gradually from sunset to noon, while the highest humidity continues to occur before sunrise, before the advent of the hot times and the sea breezes which sweep in the extra moisture from the sea.

RAINFALL, GROUNDWATER AND LAKE LEVELS

Groundwater is recharged by rainfall and runoff. Groundwater is lost by evaporation, either directly or through the transpiration of plants. In the Perth area, away from the foothills, it may be assumed that rainfall recharges groundwater, after some lag which smoothes the process, at about the same rate, i.e. 1 mm of groundwater for every mm of rain, starting from the lowest post-summer level, usually in March . Depletion of the watertable occurs at the same rate, beginning from the highest post-winter level.

Since the lakes of Perth are the exposed part of the watertable, it follows that their level will vary accordingly, with the shallower ones becoming dry every summer, most of the others gradually reaching a lower level, contracting in area and exposing more and more dry shores, welcomed only by waders. Only through human action are there a few lakes kept at about the same level throughout the year. Lake Monger is the largest and best known of these. There are also a few small lakes that are kept as compensatory basins, best known among them the two Hyde Park lakes (Bekle and Gentilli, 1993, p. 454).

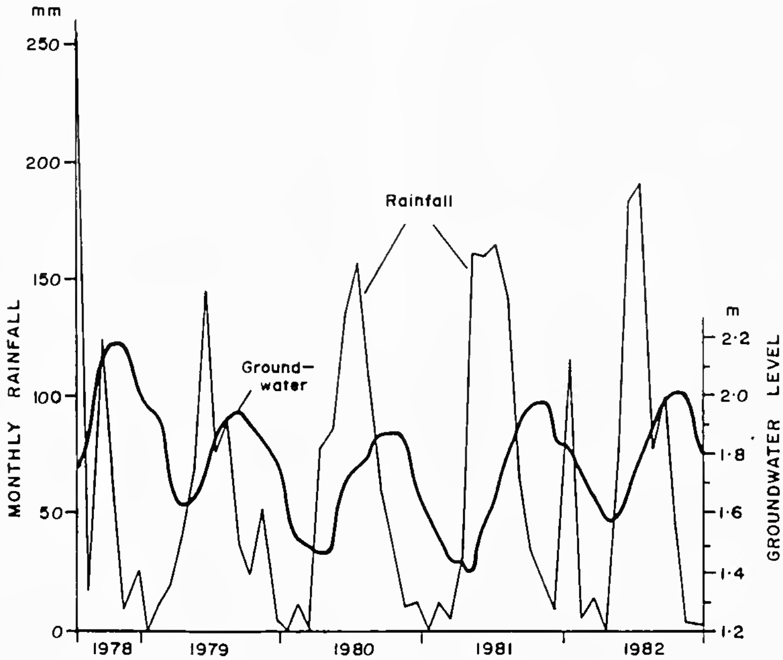

Figure 6. Rainfall and groundwater in 1978–82. There is a lag of several months between the rainfall and the recharge of groundwater, and the lighter falls may be lost through evaporation before they have any effect. *(By courtesy of Dr I.G. Eliot).*

THE WIND

Wind is a very important, yet often neglected, part of the climatic environment. Non-saturated air absorbs moisture until it reaches saturation, so not only does it cause evaporation from water surfaces, but also removes water from the surface of plant and animal bodies. Wind hastens this process as it blows past. In addition, wind exerts some pressure against exposed surfaces.

Wind data are available as tables of frequency and force from each main direction, wind roses, total wind run for 24 hours, and speed of strongest gust.

Perth has a very strong sea breeze (the "Fremantle Doctor") which blows roughly from forenoon to evening, initially almost from the south, veering to the west during the afternoon. It arises occasionally on clear warm days after the end of winter, and regularly later on, with its peak in summer. On very hot summer days with strong easterly winds it cannot arise, or at most dies down early and not far from the shore.

The sea breeze blows droplets of salt water over the shore, enough to prevent or weaken the growth of salt-sensitive plants. With a peak speed of 15–18 km/h, it causes some asymmetry in plant growth, making some shrubs and trees show poorer foliage on the upwind side, and better growth downwind.

It plays an important role in beach dynamics, steadily moving coastal waters and sand northwards; the greatest beach width is normally achieved after midsummer.

Westerly winds prevail in winter, with the strongest gales coming from the north-west. There are many factors that control the evolution of a shoreline, but the most basic controls are those of shape and orientation of the coast, and the angle of impact of the waves.

The shoreline at Quinns Rocks and Whitford was badly damaged in the winter of 1995. The trend of the shore and the long-term deposition of sand are shown in the excellent charts of coastal waters published by the former WA Department of Marine and Harbours in 1987. Figures 7.1 (Quinns Rocks shoreline) and 7.2 (Whitford shoreline), based on these charts, show some almost incredible similarities, first of all in the shape of the large areas between 5 and 10 metres deep (A).

The impact of nor'westerly blows (shown by the arrows) hits the shore at various angles; the nearer the angle to 90 degrees (head-on), the stronger the blow on the shore. The actual angle would be affected by the vicinity of obstacles such as reefs, banks, headlands etc., but the stronger the blow, the closer it is likely to be to the direction of the wind. The force of the wind increases far more than proportionally to its speed, and this is something that must be taken into account.

The impact of the waves on the shoreline removes large amounts of sand. The alignment of the coast just south of both the Quinns ramp and Whitford beach deflects much of this sand clockwise to form the sandbanks B. The breakers against the reefs at C cut the sandbanks short, although the northern reefs D do trap some sand.

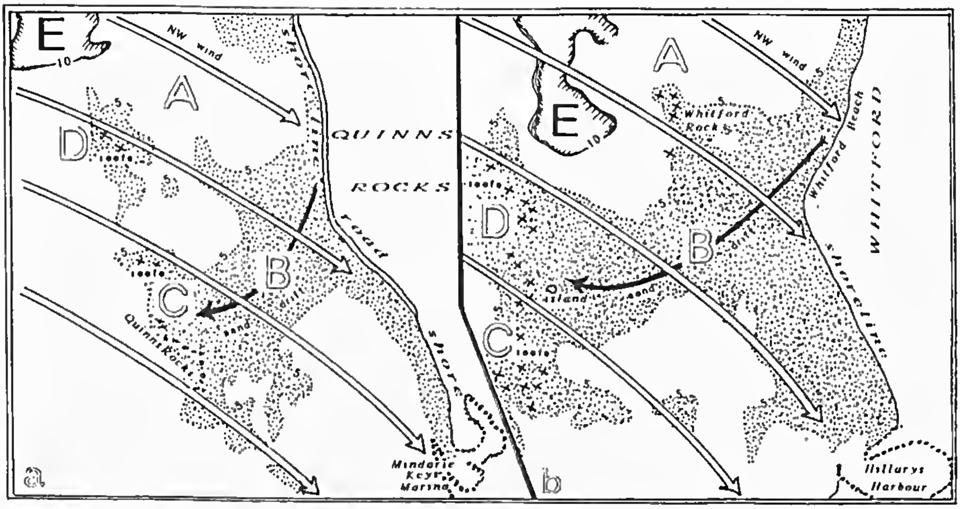

Figure 7. The effect of wind-generated waves on the shore at Quinns Rocks and Whitford Beach. See text for details. *(Base maps by Harbour and Lights Dept).*

Another striking similarity is found in the deeper "pools" at E, where the water is over 10 metres deep. The alignment of these "pools" is a resultant of the NS alignment of the former reefs and the NW alignment of wind and waves.

Needless to say, these complex coastal systems control the habitats of marine and terrestrial littoral organisms.

Exceptionally low water levels during a combination of strong easterly winds, high pressure and low astronomic tides can cause a catastrophic and lethal desiccation of countless molluscs.

CLIMATIC PERIODICITIES AND SINGULARITIES

Much has been written in the past about climatic cycles; the literature to about 1970 was reviewed (Gentilli 1971), but the search for cycles seems to have abated now, to be replaced by an extraordinary interest in El Niño and the Southern Oscillation (ENSO), with Australian implications already ably discussed by O'Mahony (1961). Perth is on the reverse side of Australia and these phenomena are far less significant here. Cycles and long-term trends in them have been sought to some extent, but have not been clearly established because of the paucity of reliable long-term records. The term *cycle* is used more rarely now, after the disappointments experienced with phantom cycles at the beginning of this century. The term *oscillation* is now preferred because it does not imply any cyclical sequence. The term *periodicity* does imply a return after a period, but without great regularity. Perhaps it might be said that 'cycle' implies the possibility of useful forecasting, whereas 'periodicity' means that the event is likely to return after the expected period, but the amplitude of any swing or changes could not be forecast. Modelling is used to forecast changes that may follow given climatic trends or events, but has given conflicting results so far (Henderson-Sellers 1991) and some disagreements between findings as to possible temperature changes near Perth would be quite amusing if they were not taken too seriously by unwary readers.

Diurnal or *circadial* cycles are fundamental in most nature studies, be they of bird song and the hourly and seasonal changes in the dawn chorus, or of mating, brooding or feeding activities. Nocturnal activities should never be neglected, and nocturnal feeding is the main source of energy for many animal species. Figures 3 and 5 may give some useful climatic background.

There is no *weekly* cycle in nature, but in any urban area animal life may be periodically disturbed by human activities, or may conversely be allowed to remain undisturbed on weekends. Noise, smoke and chemical emissions are the main sources of disturbance, with a minimum on weekends and holidays. Road traffic does not disturb coots seasonally feeding near the Stirling Highway exit of the Kwinana Freeway or doves which made occasional news by nesting in traffic lights.

The *lunar* cycle of about 28 days manifests itself in the variation of nocturnal light, felt by some animal species (e.g. magpies which carol very softly by a full moon), and in the *tidal* cycle, which affects the level and in turn the temperature of coastal waters . Some gardeners believe that 'planting by the moon' is effective, but careful experimental observations are needed, and evidence from wild life has not been gathered so far.

The *seasonal* or, more accurately, *annual* cycle is fundamental to organic life. The climate of Perth contains two major annual elements, namely heat, which is the direct result of astronomical factors and therefore follows global principles (apart from the effect of altitude), and rainfall, which is controlled by atmospheric circulation over land and sea, and therefore is strongly affected by local and regional factors. As a combined result and as shown by Table 2 and Figure 4, Perth climate has two opposite extreme seasons, very hot and very dry (*birak* plus *burnuru*, or summer) and very cool and rainy (*makuru* or winter). The intermediate seasons (Figure 4) are characterized by fast rates of change, which bring about a multitude of physiological and behavioural responses from most organisms. Fast as they may be, these seasonal changes are subject to occasional reversals of trend lasting three to six or seven days, the so-called *singularities*, which are caused by atmospheric circulation, particularly by the latitude, size and shape of the great anticyclones that travel from the Indian Ocean to the Pacific, passing nearly always over Perth.

The best known singularities of other continents, such as the 'Indian summer' of North America and the 'sheep cold spells'of Central Europe, may well have their counterparts in Australia , but have not (yet?) got into the folklore. From 35 years of temperature records (Bureau of Meteorology, 1969) we find that March 9 to 11 and 22 to 24 are on the average hotter than the days that precede them, while the general trend at that time of the year is for temperatures to become lower. This might be the counterpart of the North American 'Indian summer'. April 2 to 4, two months before the summer solstice, are often warmer than the six preceding days; this may well be the counterpart of the European 'St Martin's sommer'. From 5 to 8 October the nights are on average colder than theprevious12 nights, which could be Perth's counterpart of Germany's 'sheep cold spells'.

From 85 years of record it results that May 30–31 and June 1 and 2, and June 7 to 10, receive noticeably more rain than the preceding and following days. This is a singularity which is more likely to be due to the passage of moisture-bearing cloud bands (Gentilli 1979b). On the other hand less rainy spells (e.g. June 23–25, July 9–13, July 31 and August 1–2) are more likely the result of persisting anticyclonic regimes when a high is blocked for a few days east of Perth. It must be stressed that, while these singularities leave their mark on long-term averages, they are too unpredictable to be safely forecast.

There are climatic *periodicities* of about two-years' wave length, such as the *quasi-biennial oscillation (QBO)* of solar origin, and the *southern oscillation*, expressed by an index *(SOI)* usually based on the difference in atmospheric pressure between Tahiti and Darwin. O'Mahony (1961) found that at Perth there is a strong periodicity of 2.1 years in the August rains. A periodicity of about 2.8 years is noticeable in the March, June and October rains, while in October the period is slightly longer but still under3 years. These quasi-biennial periodicities have also been verified in some coastal processes and should be studied in relation to *biennial rhythms* in the organic world.

A relatively blurred period of about five years has been noticed, which may be half a *sunspot* cycle and/or some interference in successive quasi-biennial 'cycles'. The full sunspot cycle lasts 11 years on the average, but may be as short as eight or as long as twelve years.

Longer periods of about 18 years (Saros cycle, based on lunar nodes) and 35 years (Brückner cycle) have been verified, the former in astronomy, the latter possibly in the deposition of river sediments, but we have no evidence of their effects on organisms, not perhaps individualy, but at least on their abundance.

LONG-TERM TRENDS

The choice of the period over which to verify any long-term trend may be arbitrary and possibly misleading. Statisticians suggest that a reasonable analysis may be obtained from about 30 consecutive items. It was traditional in meteorological and climatological studies to consider the average of 30 years as the 'normal' value of temperature, rainfall, etc. In practice, however, a lot may depend on what years are included, because changes within the 30 years may even themselves out, and on the other hand some very significant changes may happen to occur just outside the chosen 30 years. Most of this study is based on half a century, the 50 years from 1940 to 1989 inclusive.

Figure 8 shows half-century trends in monthly rainfall as straight lines calculated from all the years. In reality of course the actual rainfall in each month may differ wildly from any value shown by the straight line, but the line still remains the simplest, yet quite accurate representation of the 50-year trend, unless one chooses representation by a more or less complicated curve. The calculations and the graph show that June rainfall would have been about 210 mm in 1939 and 165 by 1989, a loss of some 45 mm. July rainfall fell from about 185 to 165 mm, a loss of about 20 mm. This contrasts with earlier findings: between 1877 and 1947 June rainfall had increased an average of 42%, and July rainfall 25% (Gentilli 1952). The contrary trend appeared in January and February rainfall, which had decreased 35% and 41% between 1877 and 1947: these are the only months to show a rainfall increase between 1940 and 1989.

Figure 9 shows the percentage amounts of total yearly rainfall in four different 20-year periods, 1887–1906, 1916–35, 1940–59, and 1968–87. The black squares of 1916–36 are at the right of the graph, showing that every year of that period (except the second-wettest one) had more rain than the corresponding years of the other periods. The small circles of 1968–87 are all to the left (except the lowest one), showing that those 19 years were the driest.

The most extraordinary period was 1940–59 (small triangles) in which occurred both the wettest and the driest years among those shown. Its symbols range from top right to bottom left of the graph, while remaining tightly bunched near the middle. Obviously a period worthy of further study. On the other hand

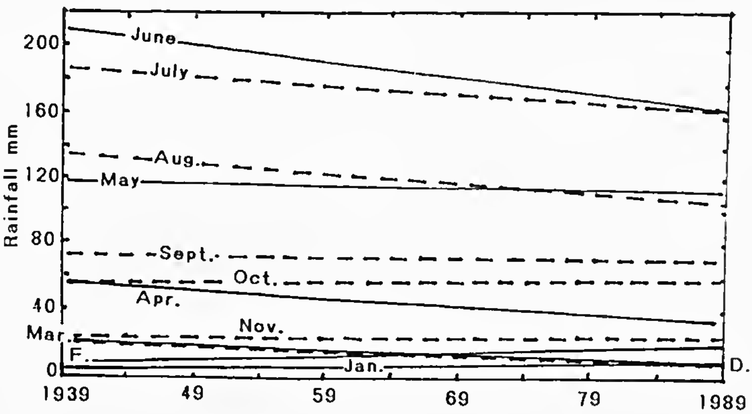

Figure 8. 50-year straight-line trends of Perth monthly rainfall. The lines are calculated taking into account every single month, and so show the true trend; individual months' falls would vary wildly on either side. Winter months have become drier.

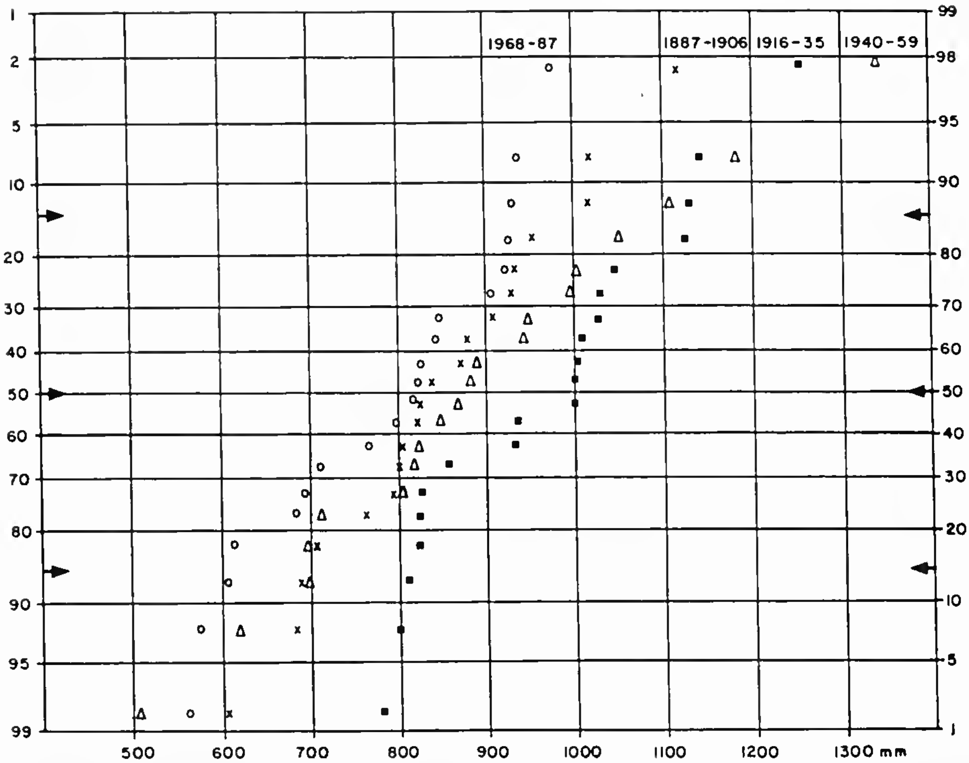

Figure 9. Percentage distribution of the annual rainfall in four 20-year periods (shown at the top with the respective simbols). Rainfall is shown at the bottom, descending and ascending percentages at the sides. 1968–87 (small circles) was driest, 1887–1906 (crosses) second driest, 1940–59 (triangles) second wettest and most uneven, 1916–35 (black squares) wettest and also most even.

1916–35 (black squares) was remarkably even and moderate in the driest third of its years, which all hovered around 800 mm each, not far below the average rainfall. A number of interesting points shown by Figure 4 would have escaped an analysis based on 30-year 'normals'.

CONCLUSION

Naturalists should always refer to standard climatic data as a firm baseline, but should be fully aware of the realities of the microclimates experienced by the subjects of their studies, noting and recording as much as possible and as often as possible. For instance, the speed of movement of most ants near the entrance to their nest seems to vary in some relation to temperature, but is this because of a direct effect of heat on insect metabolism, or is it simply the result of an effort to avoid too much exposure to potentially lethal temperatures, or both? Especially when water is scarce, the actual rainwater reaching the ground, be it in the forest or in the garden, must be measured in order to learn under which true climatic conditions plants and animals live. Measurements of wind speed at different heights can show what kind of windbreak is needed to protect sensitive plants from excessive water losses. Sensitive and accurate instruments, particularly recording ones, may be very expensive, but ingenious improvisation and careful and regular observation may enable naturalists to estimate, understand and to some extent influence climatic environments around them. The time dimension is essential, and short-term and long-term variations must be recorded and taken into account. Climate may be a most important factor in fostering or hindering the life and behaviour of the many fascinating organisms worthy of study and protection.

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OBSERVATIONS OF NECTAR FEEDING BY CARNABY'S COCKATOO *CALYPTORHYNCHUS LATIROSTRIS*.

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INTRODUCTION

There are few records of feeding behaviour of Carnaby's Cockatoo *Calyptorhynchus latirostris*, and fewer concerning nectar feeding. Robinson (1960) stated that White-tailed Black cockatoos consumed large quantities of marri nectar and blossom. Serventy and Whittell (1976) stated that White-tailed Black cockatoos consumed large quantities of nectar when gums were in flower and de Rebiera and de Rebiera (1977) recorded White-tailed Black cockatoos feeding on flowers of *Dryandra* sp. in sandplain country north of Wongan Hills.

None of these feeding records describes the feeding methods in detail nor provides any information on the quantity and quality of the nectar source. This paper describes the feeding behaviour of Carnaby's Cockatoo in gathering nectar from the flower spikes of *Callistemon viminalis* and provides measurements of the quality and quantity of nectar available.

SITE DESCRIPTION

The observations were made in the gardens surrounding buildings at the Agriculture Protection Board's Forrestfield complex during a seven-day period from 22nd to 29th October, 1993. During this time approximately 30 cockatoos were present and fed on a range of foods in addition to the nectar from *C. viminalis*. The cockatoos also fed on the seeds from *Banksia attenuata* and the seeds and flowers of *Lambertia multiflora*. The birds were also observed searching for insect larvae in the stems of flowers and fruits of *B. attentuata*. None of the cockatoos were observed feeding on marri *Eucaluptus calophylla* nuts, even though Red-capped Parrots *Purpureicephalus spurius* fed on them during that time.

There are ten mature *C. viminalis* bushes in the gardens at this site ranging in size from 2 m tall and 1.5 m in diameter to nearly 6 m tall and nearly 6 m in diameter.

METHODS

Observations of the feeding behaviour of the cockatoos were made opportunistically. The birds could be approached to within 5 m on foot and as close as 1-2 m by vehicle.

The data on the nectar were recorded on the 30th October, at the end of the feeding association. However, a few birds were still present when the data were collected and two were feeding on the nectar while the data were collected. The measurements were made between 1100 and 1230 Hrs, times when the cockatoos were regularly seen feeding on the nectar.

The nectar quality was measured by collecting samples from individual flowers on spikes which were fully open and showing no signs of damage or withering. Nectar was collected in Vitrex micro haematocrit tubes and then transfered to a Brix 0-50% Sucrose, hand-held refractometer and the sucrose concentration read immediately. Measurements were taken from five flowers per spike, on each of five spikes selected from five different *C. viminalis* bushes.

The volume of nectar available from each flower spike was determined by placing a spike into a 100 ml plastic vial and fitting the lid. The vial was then placed in to a calico bag which was spun at speed for 30 revolutions. The flower spike was then removed and the nectar which had been extracted was drawn up in a 1.0 ml graduated syringe and the volume read to the nearest 0.02 ml.

It is not possible to determine whether all the flower spikes that were pruned from the *C. viminalis* bushes had been fed from or that Carnaby's Cockatoos were the only birds involved. However, by counting the number of spikes on the ground beneath the bushes and the number remaining on the plants it is possible to estimate the maximum percentage of flower spikes removed by the cockatoos and the maximum volume of nectar potentially available to them.

RESULTS

Feeding Behaviour

If a flower spike was easily accessible the cockatoo simply opened its beak and pushed its tongue into each flower, without actually grasping the spike in its bill. Using this technique only those flowers on the dorsal surface of the spike could be probed. When the flower spike was not easily accessible the cockatoo cut the spike free with its bill and then transfered it to one of its feet. Once the spike was securely held the bird proceeded to probe the flowers. In order to get at the remaining flowers the cockatoo would grasp the spike with its bill while it loosened its foothold and turned the spike about a quarter of a revolution. Then the spike was re-grasped with the foot and the bird proceeded to probe the newly exposed flowers. This procedure was repeated until all of the flowers had been probed. Once the spike had been discarded the cockatoo ran its tongue around the inside of its bill, presumably to collect any remaining nectar in its bill.

The flower spikes were selected one at a time and there was very little wastage. The birds also appeared to only select fully opened spikes, ignoring those which were unopened or had already undergone anthesis.

Table 1. Nectar quality (% sucrose) recorded from *C. viminalis* flowers.

Spike No.	Avg. % Sucrose	s.d.	N
1	19.4	2.9	5
2	18.9	2.9	5
3	23.3	3.6	5
4	12.7	5.6	5
5	18	2.7	5

Nectar Quality and Quantity

The mean sucrose concentration of the nectar was 18.5% (Table 1), with a range of 4.0%-28.0%. The volume of nectar recovered from the flower spikes ranged from 0.22 ml to 0.64 ml with a mean of 0.47 ml (s.d.=0.15, N=10). The flower spikes which were pruned from the bushes represented a large percentage of the crop ranging from 32.2%-76.5%, and with a mean of 52.2% (Table 2).

Assuming that all of the spikes pruned from the bushes were in full flower and that the cockatoos were the only species which fed on them, the maximum volume of nectar available was nearly 2.84 litres.

DISCUSSION

The *C. viminalis* bushes at this site normally flower well, but appear to have had an exceptional year in 1993. In past years Australian Ravens *Corvus coronoides* have been observed feeding on the nectar supply but not in such a concentrated manner over such a short period. Carnaby's Cockatoos are regular visitors to this site (Mawson and Massam 1995), but have not been observed feeding on the *C. viminalis* before.

Based on the measurements made here it is clear that the *C. viminalis* provided a very rich source of food. Nectar of this concentration and in this quantiity must povide a valuable carbohydrate source. The ease with which it was collected suggests that Carnaby's Cockatoo is well adapted to feed on nectar even though it does not have a brush-tongue like members of the Loriidae.

One important feature of the feeding style of these cockatoos is that it is destructive and prevents any other species from visiting the flower spikes at a later time to gather nectar. In addition to the Australian Ravens four other

Table 2. Estimated number of flower spikes and percentage of total crop removed by cockatoos.

Plant No.	Spikes Removed	Spikes Remaining	% Total Removed	Plant Size (Ht x Diam.) in m
1	1068	328	76.5	4 x 4
2	844	620	57.6	4 x 4
3	1520	1404	51.9	6 x 4
4	1408	2960	32.2	5 x 6
5	1200	1600	42.8	6 x 6

species of bird were recorded feeding on the nectar during the period of observation; Brown Honeyeater *Lichmera indistincta*, Singing Honeyeater *Meliphaga virescens*, Red Wattlebird *Anthocharea carunculata* and Red-capped Parrot *Purpureicephalus spurius*.

The cockatoos removed the greatest proportion of flower spikes from the smaller bushes because they had a more open habit and allowed the birds access to a greater number of spikes. On some of these smaller bushes the only spikes not removed were those which were located at the ends of very thin branchlets. On the larger bushes a greater proportion of spikes were left because many were located amongst dense clumps of branchlets which prevented the cockatoos from reaching in and picking the flower spikes.

Observations of other *C. viminalis* bushes located in gardens in the surrounding suburb indicated that none were used by the cockatoos. This suggests that the more secluded location and the close proximity of large trees suitable for roosting made the site so attractive. Saunders (1979) noted Carnaby's Cockatoos seemed to favour areas where they could sit in trees when not feeding, then fly down to feed, returning to the trees after feeding. The lack of large trees near *C. viminalis* bushes in suburban gardens may have made these potential food sources unsuitable.

Having discovered such a rich food source it will be interesting to see whether the cockatoos return next year or whether this was a once-off event due to the super abundance of flowers and nectar. If nothing else the *C. viminalis* bushes have been well pruned, a requirement for good flowering next year, as the flowers only form on new growth.

ACKNOWLEDGEMENTS

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PLANT SPECIES OF THE KINGS PARK BUSHLAND

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BACKGROUND

The Swan River Colony was founded in 1829 with John Septimus Roe, the first Surveyor General for the Colony, undertaking the planning for the city. The first indication that the area of Mount Eliza was to set aside for public purposes occured in 1831 when he refused permission for timber to be cut from Kings Park. Unfortunately permission was eventually given and in 1835 five tonnes of jarrah cut from the vicinity of Mount Eliza was the first export from the Colony. For several years after that timber continued to be cut. Today, the remains of saw pits can be seen throughout the bushland. In 1872 Malcolm Fraser, the Surveyor General, gazetted 175ha on Mount Eliza as a public park and in 1890 this was increased by John Forrest to its current size of 400ha with the first Board being appointed in 1895.

The founding fathers certainly intended Kings Park to remain as bushland when Sir Malcolm Fraser wrote in the Western Australian Year Book for 1902-1904, "Everything has been done to preserve the natural trees and flora, so that the wild flowers and shrubs are a delightful feature of the Park". John Forrest expressed a similar view when he said about Kings Park being a "sanctuary of bush land right in the heart of the City". This view has continued today both with the staff of the Park and the public of Western Australia.

HISTORY OF THE BUSHLAND SINCE SETTLEMENT

The bushland of Kings Park was altered considerably before it was gazetted as a public park. As mentioned above, most of the tall timber, especially Jarrah *(Eucalyptus marginata)* was cut for use in buildings - the Perth Town Hall and Government House were built with timber felled in Kings Park. The trunks of Blackboys, *Xanthorrhoea preissii,* were taken for kindling so only a few larger specimens of these remain. Banksia trees were felled for firewood and limestone was quarried from the scarp, especially from Quarry Point near Kennedy Fountain.

In the 1930's there was an attempt to beautify the bushland of Kings Park, so several non-native species were planted. These included *Eucalyptus cladocalyx* (Sugar Gum), *Melaleuca lanceolata* (Rottnest Teatree), *Brachychiton populneus* (Kurrajong) and *Agonis flexuosa* (Peppermint Tree). Planting continued with other species including the pink flowering forms of

Eucalyptus calophylla (Marri), *Eucalyptus erythrocorys* (Illyarrie), *Acacia* species and *Chamelaucium uncinatum* (Geraldton Wax). Many of these have now become established in the bushland.

More recently seeds of *Verticordia monadelpha* were scattered through the bushland and several plants of this species can be seen mainly along the road verges. *Hakea costata* seeds, scattered in an area of the Nature Trail, have established successfully and spread considerably.

Perennial Veldgrass (*Ehrharta calycina*) was first recorded at the Crawley end of the Park in 1924 by which time there was a dense growth of about 1/4 acre in extent. The grass was then hailed as a valuable fodder grass and encouraged as a saleable commodity. The flowering heads were collected and sold to the residents of Subiaco as horse feed. This has subsequently proven to be a very unpleasant introduction. Many experiments have been undertaken to eradicate it. Between 1949 and 1951 during the flowering season of veldgrass, the Board tried to control it by means of cattle grazing. This attempt appeared to be soundly based as cattle ate the grass, but unfortunately they also ate the native vegetation. Ungerminated seeds of Veldgrass were left, the litter and soil layers were broken up by the hooves of the animals, leaving areas for this and other weeds to invade. Recently the use of a selective herbicide has been very successful and large quantities of the grass have now disappeared. It is essential that follow up spraying continue to avoid any reinfestation.

For many decades King Park has been used as a "dumping" ground by the resident of Perth and nearby suburbs. As a result many weeds have been introduced. Freesias, Gladiolus and other cormous or bulbous plants are established in the bushland and reproduce very successfully often to the detriment of the native species.

Fires have been a problem in Kings Park with a few very extensive ones having been recorded, the last being in February 1989 when about 1/2 of the bushland was burnt. For several years in the 1930's it was the Board's policy to control burn designated areas of the Park at 4 year intervals, but in the last decade very little control burning has been undertaken. Certainly there has been no regular control burns.

The bushland is considerably altered from what it was at the time of settlement. Before settlement the vegetation would have been of tall Tuart (*Eucalyptus gomphocepha*), Jarrah (*Eucalyptus marginata*) and Marri (*Eucalyptus calophylla*) with an understorey of Banksia and Allocasuarina trees. Today the structure has changed so that Banksia and Sheoak predominate (Beard, 1967). The original ecosystem of a tall open forest of Tuart-Jarrah-Marri is probably collapsing and being replaced by a Banksia-Sheoak low open woodland which is typical of excessively drained sands of low nutrient status. This is a natural sequence but has probably been accelerated by disturbance.

GEOLOGY, GEOMORPHOLOGY AND SOILS

Kings Park was classified as being

within the Spearwood Dune System with soils of the Karrakatta Soil Association (Bettenay *et al.*, 1960). These were further classified into a yellow phase (a grey to brown surface passing into a bright yellow subsoil) and a grey phase (grey surface passing into a bleached light grey to white subsurface overlying a pale yellow subsoil).

The Karakatta Soil Association is believed to have been formed between 10,000 and 6,000 years ago (McArthur and Bettenay, 1960) from calcareous beach sand (aeolianite) containing 50–70% calcium carbonate. Much of the calcium carbonate has been leached to form secondary calcite layers at greater depths. This leaching led to podzolized sands with yellow to brownish yellow sands at depth.

Most of the Park is composed of medium sized sand particles with a large area of coarse sand towards the southern end. There are significant areas of fine sand and some areas of sandy loam horizons, both of which have greater water holding capacity than the coarse and medium sands. The loam horizons also has a greater nutrient retention (Bessell-Brown, 1990).

The sandy loam horizon was found to coincide with a more vigorous vegetation cover. The sand above the layer was wet suggesting a perched water table during some months of the year. No water table was found close to the surface (Bessell-Brown, 1990).

BUSHLAND STUDY

For this study the bushland of the Park was divided into 12 areas using major tracks, firebreaks and roads (Figure 1). This survey commenced with the collecting of plants for illustration and inclusion in The Bushland Plants of Kings Park. All the species recorded (even if not recorded recently) within each of these areas is included and this list has been continually updated since 1985. After the fire of 1989, species which had not previously been recorded for the bushland were located and the number of others has been seriously depleted. The species, their areas of distribution and flowering months are given in Appendix 1.

VEGETATION RELATIONSHIPS

Referring to the map of the 12 Areas in Figure 1, Area 12 is the limestone escarpment visible from Mounts Bay Road. Area 11 is directly above this and to the east of Forrest Drive. Both of these areas have exposed limestone, which are more abundant in Area 12 than Area 11. Most of the remiander of the Park is sandy soil with a mix of Banskia and Eucalyptus woodland.

Three areas, Area 12, Area 11 and Area 2, recorded species found only in these respective areas. *Poa porphyrocladus, Hydrocotyle hispidula, Leucopogon parviflorus, Daucus glochidiatus and Trymalium ledifolium* are restricted to Area 12, *Acacia lasiocarpa, Lasiopetalum membranaceum, Lyperanthus serratus* and *Caladenia hirta* to Area 11, and *Thysanotus thyrsoideus, Pimelea leucantha* and *Leucopogon racemulosus* to Area 2.

Areas 11 and 12 have several species in common but which are restricted to these two areas. These included

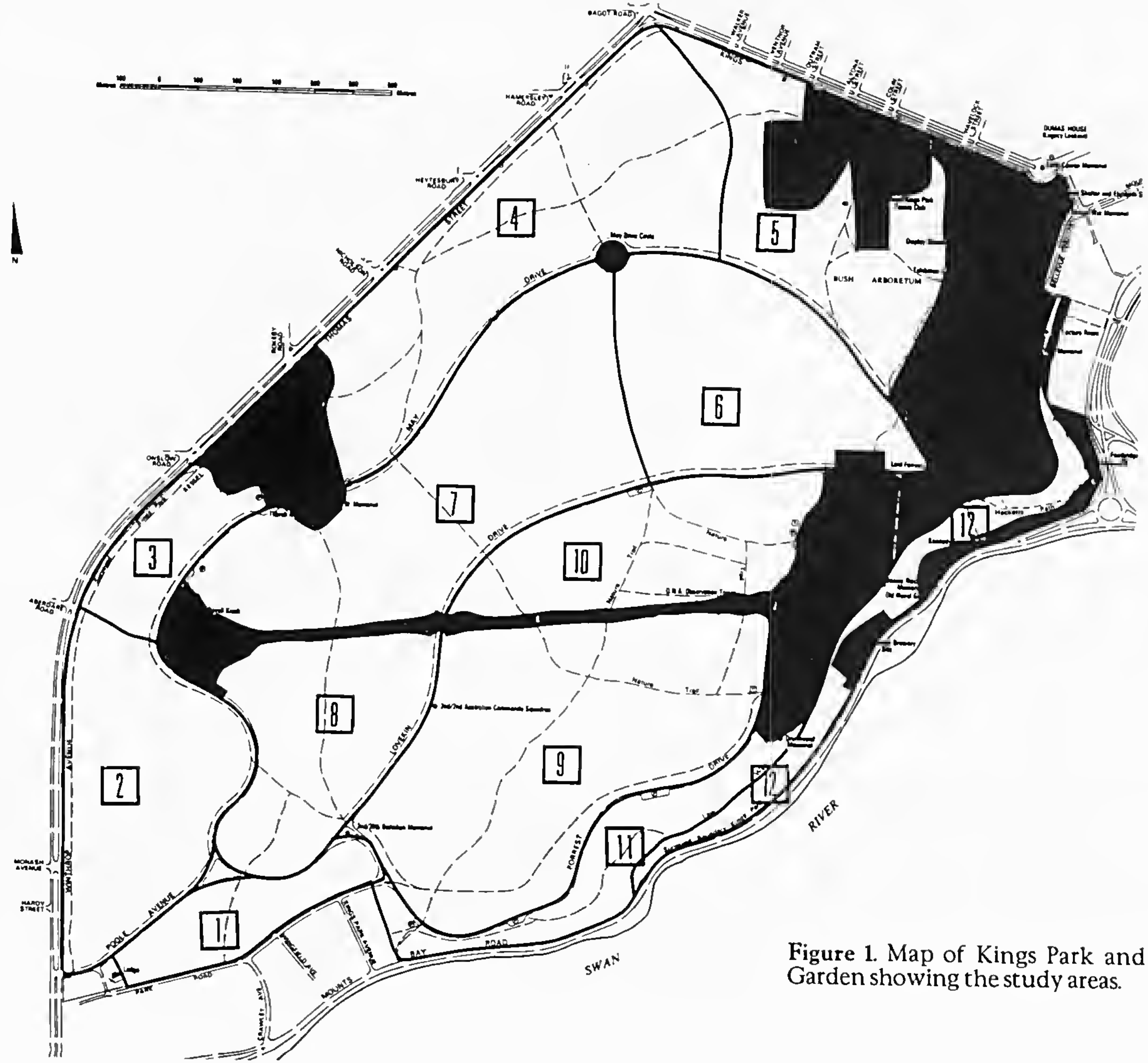

Figure 1. Map of Kings Park and Botanic Garden showing the study areas.

Acacia rostellifera, Acanthocarpus preissii, Calothamnus quadrifidus, Drosera macrantha, Gompholobium aristatum, Grevillea thelemanniana, Isolepis cernua, Isolepis nodosa, Melaleuca acerosa, Melaleuca huegelii, Stipa elegantissima and *Templetonia retusa.* As mentioned above, both these areas have limestone outcropping or close to the surface, which does not occur in the remainder of the bushland.

Occasional species are recorded as being restricted to other areas e.g. *Thelymitra crinita* to Area 2, *Arnocrinum preissii, Petrophile serruriae* and *Stylidium carnosum* (which has not been recorded recently) to Area 5, *Luzula meridonalis* to Area 6, *Pronaya fraseri* to Area 8, *Cassytha glabella* to Area 9, *Diuris brumalis, Eriochilus dilatatus* and *Schoenus brevisetis* to Area 10.

In 1987 Mattiske under took an ecological survey of Kings Park in which she recognised five Site Vegetation Types (Mattiske, 1987). The relationship between the current study and that of Mattiske are outlined in Table 2.

Site Vegetation Types, $E_{B.i}$, described as an "open forest of *Eucalyptus marginata, – Allocasuarina fraseriana – Banksia ilicifolia – Banksia attenuata* on deep moist pale yellow sands" with *Xanthorrhoea preissii, Mesomelaena pseudostygia, Bossiaea eriocarpa* and *Stirlingia latifolia* listed as indicator species. This site is included in Area 2.

Site vegetation type ($A_{G.t.}$) described as a "closed heath of mixed Proteaceae – Myrtaceae – Mimosaceae, on shallow sands with frequent limestone pinnacles" corresponds with Area 12. The indicator species listed were *Grevillea thelemanniana, Tempeltonia retusa, Grevillea crithmifolia* and *Trymalium ledifolium.*

Site Vegetation Type $B_{C.t.}$ described as "open woodland of *Eucalyptus gomphocepahala – Banksia attenuata – Allocasuarina fraseriana* on red brown sand with frequent limestone pinnacles, corresponds with Area 11. The indicator species are *Conospermum triplinervium, Phyllanthus calycinus, Dryandra sessilis* and *Melaleuca acerosa".*

The two remaining Site Vegetation Types of Mattiske are $C_{E.g.}$, woodland of *Eucalyptus gomphocephala – Eucalyptus marginata – Eucalyptus calophylla – Allocasuarina fraseriana – Banksia attenuata – Banksia grandis* on yellow sands with weakly leached surface and $D_{E.m.}$, open forest of *Eucalyptus marginata – Allocasuarina fraseriana – Banksia attenuata – Banksia menziesii* on yellow sands, with leached surface.

Table 1. Relationship between Mattiske (1987) Site Vegetation Types (SVT) and study areas.
Mattiske Site Vegetation Types A = $A_{G.t}$; B = $B_{C.t}$; C = $C_{E.g}$; D = $D_{E.m}$; E = $E_{B.i}$

AREA	SVT	AREA	SVT	AREA	SVT
1	C,D	5	C,D	9	C,D
2	C,D,E	6	C,D	10	C,D
3	D	7	C,D	11	B
4	C	8	C,D	12	A

Table 2. Origin of species occurring in the Kings Park bushland.

Number of naturally occurring species	293
Number of other Western Australian species, but introduced to the Kings Park bushland	11
Number of other Australian species, not Western Australian	10
Exotic species (extra Australian) and now naturalised	151

As these occur in pockets throughout the bushland the Areas of this study are not distinct with these Site Vegetation Types.

FLORA RESULTS

Several interesting results have arisen from this study with regard to the number of species by families, flowering times, priority listed species. These will be discussed below.

A. Number of Species

A total of 465 species has been recorded for the bushland. This includes those which are native as well as those which have been introduced and become naturalised.

A total of 38% of the Kings Park bushland flora is introduced. In the Flora of the Perth Region (Marchant, *et al.*, 1987) 27% species were recorded as alien and for the whole of Western Australia approximately 10% (Green, 1985).

There are no species endemic to the Kings Park bushland.

Table 3. Statistical Data

	Native	Alien	Total
Ferns	1	0	1
Gymnosperms	3	0	3
Angiosperms			
Dicotyledons	179	112	292
Monocotyledons	112	60	172

B. Largest Families

There are eight plant families which represent 4% or more of the total species in the Kings Park bushland. These are listed in Table 3 below in decreasing rank.

The family Poaceae has the highest percentage of species but most of these are naturalised in the bushland. The family Orchidaceae is the family with the highest percentage of native species. Of the naturalised species 46 originate from Europe and South Africa; 25 from the Mediterranean Region; 19 from Asia; 11 from north Africa; 9 from South America; 5 or less from eastern, southern and northern Australia, America, Argentina, California, India, Madagascar, Mexico, North America, Spain and Portugal.

The family with the largest number of native species in the bushland is Orchidaceae, which has only 1 naturalised species. Proteaceae and Anthericaceae both have 24 native species but there is an additional introduced species in Proteaceae. Poaceae is the family with the most naturalised species followed by Asteraceae and Papilionaceae. Anthericaceae, Cyperaceae, Haemodoraceae, Epacridaceae, Goodeniaceae and Droseraceae are all families which have no naturalised species in the bushland. It must be remembered that a naturalised species includes those which are

Table 4. Families with 4% or more of the total species in Kings Park.

FAMILY	NATIVE SPECIES	NATURALISED SPECIES	% OF TOTAL SPECIES
Poaceae	9	34	9
Asteraceae	17	23	8.5
Orchidaceae	38	1	8.3
Papilionaceae	18	12	6.4
Proteaceae	24	1	5.3
Myrtaceae	17	8	5.3
Anthericaceae	24	0	5.1
Iridaceae	2	18	4.3

native to other areas in Western Australia but which are not native to the Kings Park bushland.

Families with rankings 1–12 in Green are all represented in the bushland with the exception of Chenopodiaceae which is ranked at 9. Anthericaceae which is ranked at 24 by Green has the second largest number of native species present in the bushland. Another family of interest is Droseraceae which is ranked 36 in Green but 15 in the Kings Park bushland.

C. Flowering Times

The peak flowering months are September and October with August and November also recording many species in flower. There is a significant drop to July and December, tapering to a low in February and March as illustrated in Figure 2. It must be remembered that the months of flowering of many of the species is dependent upon the weather so if the rain comes early and is abundant the annual species will flower earlier,

Table 5. Families with 6 or more native species in the bushland and their ranking in Green (1985).

FAMILY	NATIVE SPECIES	NATURALISED SPECIES	RANKING IN GREEN
Orchidaceae	38	1	11
Proteaceae	24	1	4
Anthericaceae	24	0	24
Papilionaceae	18	12	2
Asteraceae	17	23	5
Myrtaceae	17	8	1
Cyperaceae	16	0	7
Mimosaceae	9	8	6
Haemodoaraceae	9	0	27
Poaceae	9	34	3
Epacridaceae	8	0	10
Goodeniaceae	8	0	8
Apiaceae	7	1	22
Stylidiaceae	7	0	12
Droseraceae	6	0	36

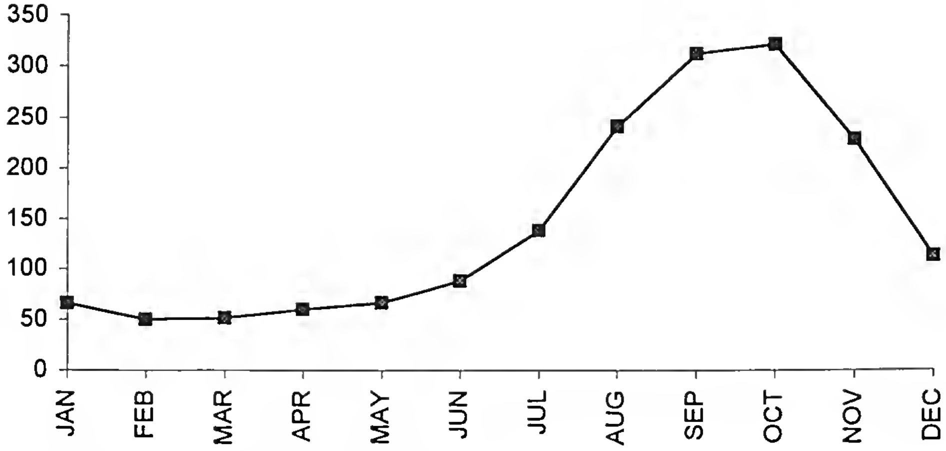

Figure 2. Number of species flowering each month.

similarly if spring ends abruptly with several hot days the bushland dries out quickly with the late flowering species quickly fading.

D. Percentage of Species in the 12 Areas.

Figure 3 illustrates the number of species in each of the 12 areas represented as a percentage of the total number of species. The difference was not significant but area 11, which is the area of the upper scarp, recorded the highest percentage. In this area there is an overlap of species from the upper

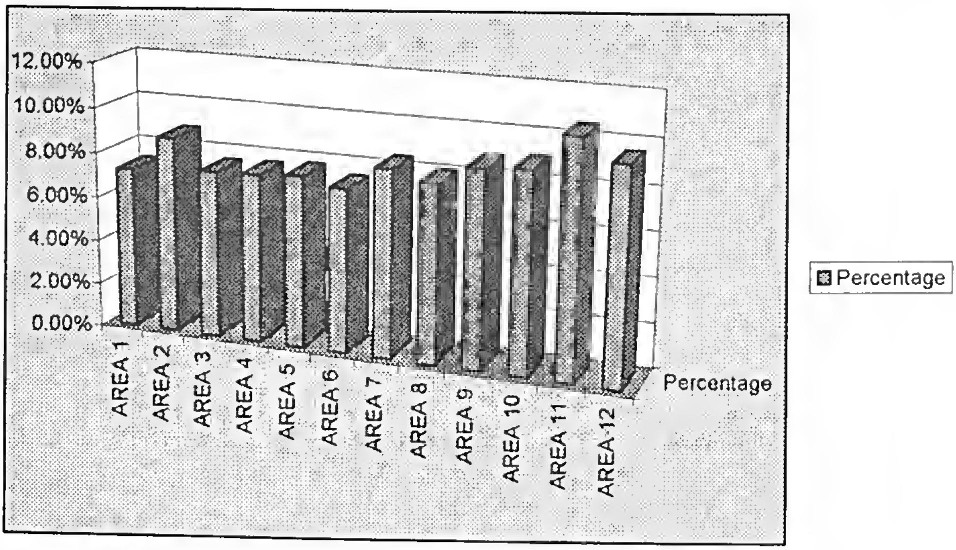

Figure 3. Percentage of total number of species occuring in each area.

sandy areas and the limestone escarpment.

E. Priority Listed Species

The Department of Conservation and Land Management publishes at regular intervals a list of priority species together with their priority number (Hopper *et al.*, 1990). The higher the number the less the plant is under threat. There are 3 priority species listed for the Kings Park bushland.

Table 6. Priority species occurring in the Kings Park bushland.

SPECIES	PRIORITY NUMBER
Dodonaea hakettiana	4
Jacksonia sericea	3
Lasiopetalum membranaceum	2

Jacksonia sericea is widespread throughout the bushland. *Dodonaea hakettiana* occurs in Areas 8, 9, 11, 12. The other species *Lasiopetalum membranaceum* is confined to the limestone escarpment. *Lasiopetalum membranaceum* is the species in the above list which is the most threatened.

F. Kings Park as a type locality.

Several type specimens have been collected from Kings Park. Many of these are now placed in synonymy under other species but the area still remains important. Many of the early collectors in the colony put the collecting locality as Swan River or Perth and it is quite likely that some of these were collected from the vicinity of Mt Eliza. However, in 1839, J.A.L. Preiss, a German botanist, made a collection of 22 species from Mt Eliza of which included type collections of 10 species and 2 varieties one of which is a fungus (Bennett, 1992). Since then other type collections have been made from the vicinity of Kings Park including *Anigozanthos manglesii* var. *flavescens* Ostenf. collected by Ostenfeld in 1914.

CONCLUSION

Although the Kings Park bushland has been altered since settlement it is still rich in native species. It is a valuable resource as remnant bushland, enjoyable for the public to walk or cycle through and see close hand some of Western Australia's unique wildflowers. It is also of importance historically for timber trees, limestone etc utilised and obtained from the Park by the early settlers.

ACKNOWLEDGEMENTS

Thanks are extended to many of the Kings Park Voluntary Guides who told me the locations of many species, in particular David Emery who provided many new locations for orchid species. Mr A. Brown provided the updated orchid names. Dr. P.R. Wycherley encouraged me with the preparation of the "Bushland Plants of Kings Park", during which time the major information was gathered.

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APPENDIX 1

Checklist of native and naturalised species of the Kings Park bushland, together with their occurrence and flowering months.
Species are arranged taxonomically under family and alphabetically under genus.

* = naturalised species
\+ = species recorded from this area
\- = not present
? = species listed as being present but no locality given.

Species Name	Area Number 111 123456789012	Flowering Months JFMAMJJASOND
ADIANTACEAE		
Anogramma leptophylla (L.)Link	-----------+	----MJJASO--
ZAMIACEAE		
Macrozamia riedlei (Fischer ex Gaudich.) C.Gardner	++++++++++++	-FM-----SO--
CUPRESSACEAE		
Actinostrobus pyramidalis Miq. in Lehm.	----+-----+-	-------ASON-
Callitris preissii Miq. in Lehm.	---+------++	--------SON-
AIZOACEAE		
Carpobrotus edulis (L.)L.Bolus*	-----------+	-------ASO--
AMARANTHACEAE		
Ptilotus drummondii (Moq.)F.Muell.	+++++++++++-	--------SON-
Ptilotus polystachyus (Gaudich.)F.Muell.	++++++++++++	------JASON-
APIACEAE		
Daucus glochidiatus (Labill.)Fischer	-----------+	---------O--
Eryngium rostratum Cav.	++++++++++++	-------ASON-
Foeniculum vulgare Miller*	-----------+	J-----JASOND
Homalosciadium homalocarpum (F.Muell.) H.Eichler	-++++++++++-	---------OND
Hydrocotyle hispidula Bunge in Lehm.	-----------+	---------ON-
Trachymene coerulea Graham	-------+--++	J--------OND
Trachymene pilosa Smith in Rees	-++++++++++-	-------ASO--
Xanthosia huegelii (Benth.)Steudel	++++++++++++	-------ASON-
APOCYNACEAE		
Vinca major L.*	----------++	-------ASON-
ASTERACEAE		
Arctotheca calendula (L.)Levyns*	++++++++++++	------JASO--
Asteridia pulverulenta Lindley	----------??	---------OND
Calocephalus angianthoides (Steetz)Benth.	----------??	---------ON-
Centaurea melitensis L.*	--------+-++	J-------SOND
Conyza albida Willd.*	++++++++++++	J------ASOND
Conyza bonariensis (L.)Cronq.*	++++++++++++	JFMAM----OND
Conyza parva Cronq.*	-------+++--	-FM---------
Cotula bipinnata Thunb.*	-----------+	--------S---
Cotula turbinata L.*	---------+++	------JASO--
Dittrichia graveolens (L.)Greuter*	--------++++	---AMJJASON-
Gnaphalium coarctatum Willd.*	----------+-	---------OND
Hedypnois rhagadioloides (L.)F.W.Schmidt*	----------+-	---------O--
Helianthus debilis Nutt.*	----------+-	--MA--------

Helichrysum bracteatum (Vent.)Andrews*	-+----------	--------SO--
Helichrysum cordatum DC.	++++++++++++	JFMA----OND
Hypochaeris glabra L.*	++++++++++++	---AMJJASON-
Lactuca saligna L.*	++++++++++++	JFMAM-------
Lactuca seriola L.*	-+-+----++--	-----------D
Lagenifera huegelii Benth. in Endl.	++++++++++++	------JASOND
Millotia tenuifolia Cass.	-----------+	---------O--
Olearia axillaris (DC.)F.Muell.	------+---++	---AMJJ-----
Olearia elaeophila (DC)F.Muell. ex Benth.	--------++--	--MAM-------
Olearia paucidentata (Steetz)F.Muell. ex Benth.	----------+-	---AMJJASON-
Osteospermum clandestinum L.f.*	----------++	------JASO--
Podolepis gracilis (Lehm.)Graham	++++++++++++	-------ASOND
Podotheca angustifolia (Labill.)Less.	++++++++++++	--------SO--
Podotheca chrysantha (Steetz)Benth.	++++++++++++	-------ASON-
Pseudognaphalium luteoalbum (L.) Hilliard & B.L.Burtt*	-+---------+	JFMAMJJASOND
Quinetia urvillei Cass.	++++++++++++	-------ASOND
Rhodanthe chlorocephala (Turcz.) P.G. Wilson subsp. *rosea* (Hook.)P.G.Wilson*	-----+--++--	-------ASO--
Rhodanthe citrina (Benth.) P.G.Wilson	-----------?	--------SON-
Senecio hispidulus A.Rich.	---------+++-	JFMAMJJ-SOND
Senecio lautus G.Forster ex Willd.	+--+--+++++-	J------ASOND
Siloxerus humifusus Labill.	-----------	J--------OND
Sonchus oleraceus L.*	++++++++++++	-----JJASOND
Taraxacum officinale Wigg.*	-------+----	JFMAMJJASOND
Urospermum picroides (L.)Scop. ex F.W Scop. ex F.W.Schmidt*	+--++++++++x	---------ON-
Ursinia anthemoides (L.)Poiret*	++++++++++++	-------AS---
Waitzia suaveolens (Benth.)Druce	++++++++++++	---------OND
BRASSICACEAE		
Brassica oxyrrhina (Cosson)Willk.*	++--------++	--------SO--
Cardamine hirsuta L.*	+++++++-----	-------AS---
Heliophila pusilla L.f.*	++++++++++++	-------ASO--
Raphanus raphanistrum L.*	----------+-	-------ASOND
BUDDLEJACEAE		
Buddleja madagascariensis Lam.*	----------++	------JA----
CAMPANULACEAE		
Wahlenbergia capensis (L.)A.DC.*	++++++++++++	--------SON-
Wahlenbergia preissii Vriese	-+++++++---+	--------SO--
CARYOPHYLLACEAE		
Cerastium glomeratum Thuill.*	--------++++	-------ASON-
Petrorhagia velutina (Guss.)P.Ball & Heyw.*	++++++++++++	--------SON-
Polycarpon tetraphyllum (L.)L.*	--------++++	--------SON-
Sagina apetala Ard.*	----------++	--------SON-
Silene gallica L.*	++--+---+++-	------JASOND
Spergula arvensis L.*	--------+++-	-------ASON-
Stellaria media (L.)Villars*	--------+++-	------JAS---
CASUARINACEAE		
Allocasuarina fraseriana (Miq.)L.Johnson	++++++++++++	----MJJASO--
Allocasuarina humilis (Otto & Dietr.)L.Johnson	--------++++	----MJJASON-

CHENOPODIACEAE		
Atriplex cinerea Poiret in Lam.	-----------+	--------SO--
Chenopodium album L.*	---++-------	--MA--------
Chenopodium ambrosioides L.*	-----------+	--MAMJJ-----
Enchylaena tomentosa R.Br.	++----+--+--	----MJJAS---
Rhagodia baccata (Labill.)Moq. in DC.	--------++++	--MAMJ------
CONVOLVULACEAE		
Ipomoea indica (Burman)Merr.*	-----------+	JFMA------ND
CRASSULACEAE		
Crassula colorata (Nees)Ostenf.	++++++++++++	-------ASO--
Hibbertia huegelii (Endl.)F.Muell.	-++--++++++-	-------ASON-
Hibbertia hypericoides (DC.)Benth.	++++++++++++	---AMJJASON-
Hibbertia racemosa (Endl.)Gilg in Endl.	-+++++++-+--	------JASON-
DROSERACEAE		
Drosera erythrorhiza Lindley	++++++++++++	--MAMJJ-----
Drosera glanduligera Lehm.	-----------?	-------ASO--
Drosera macrantha Endl. in Endl.	----------++	-----JJASO--
Drosera pallida Lindley	++++++++++-+	-------ASON-
Drosera menziesii R.Br. ex. DC.	-++-------+-	-------ASON-
Drosera stolonifera Endl. in Endl.	++++++++++++	------JAS---
EPACRIDACEAE		
Astroloma ciliatum (Lindley)Druce	------+-+---	----MJJASO--
Astroloma macrocalyx Sonder in Lehm.	++++++++++--	---AMJJ-----
Astroloma pallidum R.Br.	++++++++++++	--MAMJJASON-
Conostephium pendulum Benth. in Endl.	++++++++++++	-----JJAS---
Conostephium preissii Sonder in Lehm.	++++++++++--	----MJJ-----
Leucopogon parviflorus (Andrews)Lindley	-----------+	------JAS---
Leucopogon propinquus R.Br.	++++++++++++	--MAMJJ-----
Leucopogon racemulosus DC.	-+----------	--MAMJJ-----
EUPHORBIACEAE		
Adriana quadripartita (Labill.)Gaudich. in Freyc.	-----------+	--------SON-
Euphorbia australis Boiss.*	++++++++++++	JFMAMJJASOND
Euphorbia peplus L.*	++++++++++++	------JASO--
Monotaxis grandiflora Endl. in Endl.	++++++++++++	J------ASOND
Phyllanthus calycinus Labill.	++++++++++++	-----JJASON-
Poranthera microphylla Brogn.	-++---++++++	-------ASON-
Ricinocarpos glaucus Endl. in Endl.	--++++--+---	-----JJASO--
Ricinus communis L.*	-----------+	-------AS---
FUMARIACEAE		
Fumaria capreolata L.*	++--++--++++	------JASO--
GERANIACEAE		
Erodium botrys (Cav.)Bertol.*	++------+++-	-------AS---
Erodium moschatum (L.)LHer. in Aiton*	++------+++-	--------SO--
Geranium molle L.*	----------++	---------ON-
Pelargonium capitatum (L.)LHer. in Aiton*	++----++++++	------JASON-
GOODENIACEAE		
Dampiera linearis R.Br.	++++++++++++	------JASON-
Lechenaultia floribunda Benth. in Endl.	-------++-+-	---------ON-
Scaevola anchusifolia Benth.	--------++++	---------ON-

Scaevola canescens Benth. in Endl.	++++++++++++	--MAMJJASON-
Scaevola crassifolia Labill.	-----------+	-------ASOND
Scaevola nitida R.Br.	-----------+	----------ND
Scaevola paludosa R.Br.	++++++++++++	--------SOND
Scaevola thesioides Benth.	-----------?	--------SOND
GYROSTEMONACEAE		
Tersonia cyathiflora (Fenzl.)A.S.George	-+----------	-----JJASON-
HALORAGACEAE		
Glischrocaryon aureum (Lindley)Orch.	-+++--++----	--------SO--
Gonocarpus pithyoides Nees in Lehm.	----------?-	---------ON-
LAMIACEAE		
Hemiandra pungens R.Br.	+--++++----+	--------SO--
Leonotis leonurus (L.)W.T.Aiton*	----------++	---AM-------
Stachys arvensis (L.)L.*	-----------+	-------ASO--
LAURACEAE		
Cassytha glabella R.Br.	--------+---	JFMAMJJASOND
Cassytha racemosa Nees	----------++	JFMAMJJASOND
LINACEAE		
Linum usitatissimum L.*	-+----------	---------ON-
LOBELIACEAE		
Isotoma scapigera (R.Br.)Don	-----------+	--------SOND
Lobelia gibbosa Labill.	++++++++++++	JFM-------ND
Lobelia tenuior R.Br.	++++++++++++	J--------OND
LOGANACEAE		
Mitrasacme paradoxa R.Br.	-++---------	--------SON-
LORANTHACEAE		
Amyema miquelii (Lehm. ex Miq.)Tieghem	---------+--	--MAMJJ-----
Nuytsia floribunda (Labill.)R.Br. ex Fenzl.	--+---+-----	J---------ND
MALVACEAE		
Lavatera arborea L.*	--------+---	-------ASOND
Malva parviflora L.*	---------+--	-------ASON-
MIMOSACEAE		
Acacia acuminata Benth.*	------+---+-	------JASO--
Acacia baileyana F.Muell.*	-++---++----	------JA----
Acacia cochlearis (Labill.)H.L.Wendl.	++++++++++++	-------AS---
Acacia cyclops Cunn.ex Don	-+---------+	J-------SOND
Acacia dealbata Link*	------+-----	------JA----
Acacia decurrens (Wendl.)Willd.*	--+---------	--------S---
Acacia huegelii Benth. in Endl.	++++++++++--	---------OND
Acacia lasiocalyx C.R.P.Andrews*	-++---------	-------ASO--
Acacia lasiocarpa Benth. in Endl.	----------+-	-----JJASO--
Acacia microbotrya Benth.*	---+--+-----	---AMJJ-----
Acacia podalyriifolia A.Cunn. ex Don*	-++---+-----	-----JJA----
Acacia pulchella R.Br. in W.T.Aiton	++++++++++++	-----JJASO--
Acacia pycnantha Benth.*	---+--+-+---	-------AS---
Acacia rostellifera Benth.	----------++	-------ASO--
Acacia saligna (Labill.)H.L.Wendl.	++++++++++++	-------AS---
Acacia stenoptera Benth.	+++++++++++-	----AJJAS---
Acacia willdenowiana H.L.Wendl.	+++++++++++-	-----JJASO--

MOLLUGINACEAE		
Macarthuria australis Huegel ex Endl.	--------++++	----MJJASON-
MYOPORACEAE		
Eremophila glabra (R.Br.)Ostenf.	------+--+++	J-----JASOND
Myoporum insulare R.Br.	-----------+	-------ASON-
MYRTACEAE		
Agonis flexuosa (Sprengel)Schauer*	+++++++++++-	--------SOND
Calothamnus quadrifidus R.Br. in W.T.Aiton	----------++	-------ASOND
Calytrix angulata Lindley	---+++------	--------SOND
Calytrix flavescens Cunn.	----++--+++-	J---------ND
Calytrix fraseri Cunn.	+++++++++++-	JFM--------D
Chamelaucium uncinatum Schauer in Lehm.*	++++++++++++	-------ASON-
Eremaea pauciflora (Endl.)Druce	-+++++++++--	--------SOND
Eucalyptus calophylla Lindley	++++++++++++	JFMAM-------
Eucalyptus citriodora Hook.*	---+++++--+-	----MJ------
Eucalyptus cladocalyx F.Muell.*	---+++++--+-	JF----------
Eucalyptus decipiens Endl. in Endl.	---------++--	--------SON-
Eucalyptus erythrocorys F.Muell.*	---++-----+-	JFMA--------
Eucalyptus gomphocephala DC.	++++-+++++++	JFMA--------
Eucalyptus lane-poolei Maiden*	--------+---	-FMAM-------
Eucalyptus marginata Donn ex Smith	++++++++++++	JA------SOND
Eucalyptus todtiana F.Muell.*	--------+---	-F----------
Hypocalymma robustum (Endl.)Lindley	++++++++++++	------JASO--
Kunzea ericifolia (Smith)Heynh.	----+-+-----	--------SON-
Leptospermum laevigatum (Gaertner)F.Muell.*	----+++-----	--------SO--
Melaleuca acerosa Schauer in Lehm.	---------+++	--------SOND
Melaleuca huegelii Endl. in Endl.	----------++	J---------ND
Melaleuca lanceolata Otto	----+-++--++	JFM------OND
Melaleuca pentagona Labill.*	----------+-	--------SO--
Verticordia densiflora Lindley	----+-------	J---------ND
Verticordia monadelpha Turcz.*	-+-----+----	---------OND
ONAGRACEAE		
Epilobium hirtigerum Cunn.	-+----------	JFM-------ND
Oenothera drummondii Hook.*	-----------+	---------OND
Oenothera glazioviana Micheli*	---------+--	JFM-------ND
OROBANCHACEAE		
Orobanche minor Smith*	++++++++++++	-------ASON-
OXALIDACEAE		
Oxalis caprina Thunb.*	------+---++	---------ON-
Oxalis corniculata L.*	----------++	---------ON-
Oxalis glabra Thunb.*	-+-----+----	----MJJA----
Oxalis pes-caprae L.*	++++++++++++	-----JJASO--
Oxalis purpurea L.*	-++---+++---	----MJJAS---
PAPAVERACEAE		
Papaver rhoeas L.*	-----------+	---------O--
Romneya coulteri Harvey*	-----------+	---------ON-
PAPILIONACEAE		
Bossiaea eriocarpa Benth.	-----+++++--	------JASO--

Bossiaea ornata (Lindley)Benth	---------?--	------JASO--
Daviesia decurrens Meissner in Lehm.	-+++--++----	-------AS---
Daviesia divaricata Benth. in Endl.	++++++++++++	------JASO--
Daviesia nudiflora Meissner	++++++++++++	-----JJA----
Daviesia triflora M.D.Crisp	+++++++++++-	----MJJAS---
Gompholobium aristatum Benth.	----------++	--------SO--
Gompholobium tomentosum Labill.	++++++++++++	-------ASOND
Hardenbergia comptoniana (Andrews) Benth. in Endl.	++++++++++++	-----JJAS---
Hovea pungens Benth. in Endl.	-----------+	-----JJAS---
Hovea trisperma Benth. in Endl.	++++++++++++	-----JJAS---
Isotropis cuneifolia (Smith)Benth.	-+++-++++++-	-------ASO--
Jacksonia furcellata (Bonpl.)DC.	++-+----++-+	JFM----ASOND
Jacksonia sericea Benth.	+++++++++++-	JF---------D
Jacksonia sternbergiana Huegel	++++++++++++	JFMAMJJASOND
Kennedia prostrata R.Br. in W.T.Aiton	++++++++++++	------JASON-
Lupinus consentinii Guss.*	---------+++	-------ASON-
Lupinus mutabilis Sweet*	---------+++	-------AS---
Medicago polymorpha L.*	----+----+++	------JASO--
Melilotus indica (L.)All.*	+----------+	-------ASO--
Mirbelia dilatata R.Br.*	----------?-	--------SOND
Nemcia capitata (Benth.)Domin	++++++++++++	-----JJAS---
Templetonia retusa (Vent.)R.Br. in W.T.Aiton	----------++	---AMJJA----
Trifolium arvense L.*	--------+-++	--------SON-
Trifolium campestre Schreber in Sturm*	---++---+-++	-------ASON-
Trifolium dubium Sibth.*	---++---+-++	-------ASON-
Trifolium glomeratum L.*	--------+-++	--------SON-
Trifolium subterraneum L.*	----------+-	-------ASON-
Trifolium tomentosum L.*	--------+-+-	--------SON-
Vicia sativa L.*	++--------+-	--------SON-
PITTOSPORACEAE		
Pronaya fraseri (Hook.)E.M.Bennett	-------+----	JF---------D
Sollya heterophylla Lindley	-+---+------	JF-------OND
PLANTAGINACEAE		
Plantago lanceolata L.*	------+-----	JFM------OND
POLYGALACEAE		
Comesperma calymega Labill.	-+-----+----	--------SOND
Polygala myrtifolia L.*	-----------+	-------ASON-
POLYGONACEAE		
Emex australis Steinh.*	---------+--	-------A----
Rumex crispus L.*	-----------+	--------S---
PORTULACEAE		
Calandrinia corrigioloides F.Muell. ex Benth.	++++++++++++	-------ASON-
Calandrinia liniflora Fenzl.	-+------++--	---------ON-
PRIMULACEAE		
Anagallis arvensis L.*	++++++++++++	-------ASOND
Samolus repens (Forster and G.Forster)Pers.	-----------+	JFMAMJJASOND
PROTEACEAE		
Adenanthos cygnorum Diels in Diels & E.Pritzel	----+----+++	JF------SOND

Banksia attenuata R.Br.	++++++++++++	JF------SOND
Banksia grandis Willd.	+++++++++++-	--------SOND
Banksia ilicifolia R.Br.	-+----------	--------SOND
Banksia menziesii R.Br.	++++++++++++	-FMAMJJA----
Banksia prionotes Lindley	---+++----+-	-FMAMJJA----
Conospermum stoechadis Endl.	---------+--	------JASO--
Conospermum triplinervium R.Br.	-+---++-++--	-------ASON-
Dryandra nivea (Labill.)R.Br.	++++++++++++	----MJJAS---
Dryandra sessilis (Knight)Domin	++++++++++++	----MJJASON-
Grevillea crithmifolia R.Br.	----+-+-++++	------JAS---
Grevillea pilulifera (Lindley)Druce	----------+-	------JAS---
Grevillea thelemanniana Huegel ex Endl.	----------++	----MJJAS---
Grevillea vestita (Endl.)Meissner	-++---+++++-	-----JJAS---
Hakea costata Meissner*	---------+--	------JAS---
Hakea lissocarpha R.Br.	----------+-	-----JJAS---
Hakea prostrata R.Br.	++++-+++-+++	-------ASON-
Hakea trifurcata (Smith)R.Br.	-----+----+-	------JA----
Persoonia saccata R.Br.	-+++-++++++-	J-----JASOND
Petrophile linearis R.Br.	++++++++++++	-------ASON-
Petrophile macrostachya R.Br.	++++++++++++	-------ASON-
Petrophile media R.Br.	---------++-	--------SOND
Petrophile serruriae R.Br.	----+-------	-------ASON-
Stirlingia latifolia (R.Br.)Steudel	++++++++++++	-------ASON-
Synaphea spinulosa (Burm. f.)Merr.	-++---+++---	-----JJASON-
RANUNCULACEAE		
Clematis microphylla DC.	-+----++-++-	------JAS---
RHAMNACEAE		
Cryptandra arbutiflora Fenzl in Endl.	++++++++++++	----MJJAS---
Rhamnus alaternus L.*	++++---++-++	------JA----
Spyridium globulosum (Labill.)Benth.	-+-+++++--++	-----JJAS---
Spyridium tridentatum (Steudel)Benth.	---------+++	JF---------D
Trymalium ledifolium Fenzl. ssp *ledifolium*	-----------+	------JA----
RUBIACEAE		
Opercularia hispidula Endl. in Endl.	-----------+	---------OND
Opercularia vaginata Labill.	++++++++++++	-------ASO--
RUTACEAE		
Boronia ramosa (Lindley)Benth.	---------+--	------JASO--
Eriostemon spicatus A.Rich.	++++++++++++	-----JJASO--
SAPINDACEAE		
Dodonaea hackettiana W.Fitzg.	+-------+-++	------JASO--
SCROPHULARIACEAE		
Dischisma capitatum (Thunb.)Choisy*	+++++++++++-	-------AS---
Misopates orontium (L.)Raf.*	++----------	-------ASO--
SOLANACEAE		
Anthocercis ilicifolia Hook.	--------++++	-----JJASO--
Anthocercis littorea Labill.	--------++++	-----JJASO--
Lycium ferocissimum Miers*	+-----------	---------ON-
Nicotiana glauca Graham*	---------+--	-------ASON-
Solanum nigrum L.*	++++++++++++	JFMA--JASOND
STACKHOUSIACEAE		
Tripterococcus brunonis Endl. in Endl.	---------++-	-------ASON-

STERCULIACEAE		
Brachychiton populneus (Schott)R.Br.*	+++++++++++-	J---------ND
Lasiopetalum membranaceum (Steudel)Benth.	-----------+	--------SO--
STYLIDACEAE		
Levenhookia stipitata (Sonder)F.Muell.	++++++++++++	---------SON
Stylidium brunonianum Benth. in Endl.	+++++++++++-	--------SON-
Stylidium calcaratum R.Br.	--+++++++++-	--------SON-
Stylidium carnosum Benth. in Endl.	----+-------	--------SO--
Stylidium piliferum R.Br.	-----------?	--------SO--
Stylidium repens R.Br.	+++++++++++-	JFMAMJJASOND
Stylidium schoenoides DC.	-++++++++++-	-------ASO--
THYMELACEAE		
Pimelea leucantha Diels in Diels & E.Pritzel	-+----------	-------ASON-
Pimelea rosea R.Br.	+++-----+++-	-------ASON-
Pimelea sulphurea Meissner	+++---+++++-	------JASO--
TROPAEOLACEAE		
Tropaeolum majus L.*	-----------+	--------SON-
VALERIANACEAE		
Centranthus macrosiphon Boiss.*	++--------++	-------ASON-
VERBENACEAE		
Lantana camara L.*	-----------+	-----JJA----
VIOLACEAE		
Hybanthus calycinus (DC.ex Ging)F.Muell.	++++++++++++	------JASO--
AGAVACEAE		
Agave americana L.*	-----------+	JF----------
*Yucca filamentosa**	----------++	-FM---------
ALLIACEAE		
Allium triquetrum L.*	++++++++++++	-------AS---
*Nothoscordum gracile**	+---------+-	---------ON-
AMARYLLIDACEAE		
Amaryllis belladonna L.*	-+-+-++-----	-FMA--------
*Narcissus papyraceus**	----------++	-----JJ-----
Narcissus tazetta L.*	++++++++--++	------JAS---
ANTHERICACEAE		
Agrostocrinum scabrum (R.Br.)Baillon	++-----+--+-	--------SOND
Arnocrinum preissii Lehm. ex Endl.	----+-------	---------OND
Arthropodium capillipes Endl. in Lehm.	++++++++++++	JFM-------ND
Burchardia umbellata R.Br.	++++++++++++	-------ASO--
Caesia parviflora R.Br.	+++++++++++	--------SON-
Chamaescilla corymbosa (R.Br.)F. Muell. ex Benth.	---------+--	--------SO--
Corynotheca micrantha (Lindley)J.F.Macbr.	++++++++++++	J---------ND
Laxmannia ramosa Lindley	-----+------	----MJ------
Laxmannia squarrosa Lindley	---++++-+-++	-------ASON-
Lomandra caespitosa (Benth.)Ewart	-----+++++--	------JAS---
Lomandra hermaphrodita (C.R.P.Andrews) C.Gardner	++++++++++++	---AMJ------

Lomandra maritima T.S.Choo	-+++++++----	-------ASO--
Lomandra micrantha (Endl.)Ewart	++++++++++++	----MJJAS---
Lomandra nigricans T.D.Macfarlane	++++++++++++	-----JJA----
Lomandra preissii (Endl.)Ewart	++++++++++++	---AMJJ-----
Lomandra suaveolens (Endl.)Ewart	+++++++++++-	---AMJJ-----
Sowerbaea laxiflora Lindley	++++++++++++	-------ASO--
Thysanotus arenarius N.H.Brittan	++++++++++++	---------OND
Thysanotus dichotomus (Labill.)R.Br.	------------	--------SOND
Thysanotus manglesianus Kunth.	+++--++++++x	-------ASON-
Thysanotus sparteus R.Br.	++++++++++++	JF---------D
Thysanotus thyrsoideus Baker	-+----------	--------SON-
Thysanotus triandrus (Labill.)R.Br.	++++++++++--	--------SON-
Tricoryne elatior R.Br.	++++++++++++	JF------SOND
ARACEAE		
Zantedeschia aethiopica (L.)Sprengel*	+----------+	-------ASO--
ASPARAGACEAE		
*Myrsiphyllum asparagoides**	++++++++++++	-------AS---
*Myrsiphyllum declinatum**	++++++++++++	------JA----
CYPERACEAE		
Centrolepis drummondiana (Nees)Walp.	++++++++++++	--------SO--
Isolepis cernua (M.Vahl)Roemer & Schultes	----------++	---------OND
Isolepis marginata (Thunb.)A.Dietr.	-+++--++++++	------JASO--
Isolepis nodosa (Rottb.)R.Br.	----------++	JFM-------ND
Lepidosperma squamatum Labill.	++++++++++++	----MJJ-----
Lepidosperma costale Nees in Lehm.	-++---++----	---AM-------
Lepidosperma gladiatum Labill.	-----------+	J---------ND
Lepidosperma leptostachyum Benth.	+++++++++++-	------JAS---
Lepidosperma scabrum Nees in Lehm.	++++++++++++	---AM-------
Mesomelaena pseudostygia (Kuek.) K.L.Wilson	++++++++++++	--MA--------
Schoenus benthamii F.Muell.	------------	---------ON-
Schoenus brevisetis (R.Br.)Benth.	---------+--	---------OND
Schoenus curvifolius (R.Br.)Benth.	-+++++++++--	------JAS---
Schoenus grandiflorus (Nees)F.Muell.	++++++++++++	---AMJJ-----
Schoenus latitans S.T.Blake	-----+++----	---AM-------
Tetraria octandra (nees)Kuek.	++++++++++++	-----JJASON-
DASYPOGONACEAE		
Acanthocarpus preissii Lehm.	----------++	---AMJJA----
Calectasia cyanea R.Br.	++++++++++++	-----JJAS---
Dasypogon bromeliifolius R.Br.	-+--+++---+-	J-------SOND
COMMELINACEAE		
Cartonema philydroides F.Muell.	---------+--	---------ON-
HAEMODORACEAE		
Anigozanthos humilis Lindley	-+------+---	-------ASO--
Anigozanthos manglesii D.Don in Sweet	++++++++++++	--------SON-
Conostylis aculeata R.Br.	++++++++++++	--------SO--
Conostylis candicans Endl.	-+--------++	-------ASO--
Conostylis setigera R.Br.	+++++++++++-	--------SA--
Haemodorum laxum R.Br.	----+++++++-	---------ON-
Haemodorum paniculatum Lindley	++++++++++++	---------OND
Haemodorum spicatum R.Br.	++++++++++++	----------ND
Phlebocarya ciliata R.Br.	-----------?	-------ASON-

HYACINTHACEAE		
Ornithogalum thrysoides Jacq.*	-+--------+-	----M----O--
IRIDACEAE		
Babiana stricta (Aiton)Ker Gawler*	----+------+	-------ASO--
Chasmanthe floribunda (Salisb.)N.E.Br.*	+++++++--++-	------JASO--
Ferraria crispa Burman*	+---------+-	-------AS---
Freesia affin. *leichtlini* Klatt.*	++++++++++++	-------ASO--
Gladiolus angustus L.*	++++--++----	---------OND
Gladiolus caryophyllaceus (Burm.f.)Poiret*	+++++++++++-	-------ASO--
Hesperantha falcata (L.f.)Ker Gawler*	+---------+-	-------ASO--
Homeria flaccida Sweet*	---++++---+-	--------SON-
Ixia maculata L.*	++++++++--+-	-------AS---
Ixia maculata hybrid*	---++++-----	--------SON-
Ixia polystachya L.*	+--+--+-----	--------SO--
Lachenalia reflexa Thunb.*	--------++--	------JA----
Leucojum aestivum L.*	+---------+-	------JAS---
Orthrosanthus laxus (Endl.)Benth.	+------+--++	-------ASO--
Patersonia occidentalis R.Br.	-++++--++++-	--------SO--
Romulea rosea (L.)Ecklon*	++++++++++++	-------ASO--
Sparaxis bulbifera (L.)Ker Gawler*	++--------+-	--------SO--
Watsonia aletroides (Burm.f.)Ker Gawler*	----+-------	--------S---
Watsonia bulbillifera J.Mathews*	---++++++++-	---------OND
Watsonia meriana (L.)Miller*	+----+------	---------O--
JUNCACEAE		
Juncus pallidus R.Br.	-----------+	---------ON-
Luzula meridionalis Nordensk.	-----+------	--------SON-
JUNCAGINACEAE		
Triglochin centrocarpa Hook.	-----------+	------JASO--
ORCHIDACEAE		
Burnettia nigricans (R.Br.) Hopper & A.P.Brown	-++--++-----	-------ASO--
Caladenia arenicola Hooper & A.P.Brown	+++++++++++-	--------SO--
Caladenia arenicola x *C. georgei*	--++--+++++--	--------SO--
Caladenia discoidea Lindley	++------+---	-------ASO
Caladenia flava R.Br. ssp. *flava*	++++++++++++	-------ASO--
Caladenia flava x *C.latifolia* R.Br.	---------+--	-------AS---
Caladenia georgei Hooper & A.P.Brown	++++++++++++	--------SON-
Caladenia georgei x *C.longicauda* Lindley	----+----+--	--------SO--
Caladenia hirta Lindley	----------+-	-------ASO--
Caladenia latifolia R.Br.	++++++++++++	-------ASO--
Caladenia longicauda Lindley ssp. *calcigena* Hooper & A.P.Brown	--+---+-+++-	-------ASON-
Caladenia longiclavata E.Coleman	-++---------	-------ASO--
Caladenia macrostylis Fitzg.	+------+----	-------ASO--
Caladenia nana Endl.	--+---------	--------SO--
Caladenia reptans Lindley ssp. *reptans*	-+-------+--	------JA----
Cyanicula deformis R.Br.	+++++++++++-	-----JJA----
Cyanicula gemmata Lindley	-+------++--	-------ASO--
Cyanicula sericea Lindley	-+-------+--	-------AS---
Diuris brumalis D.Jones	---------+--	------JA----
Diuris corymbosa Lindley	++++++++++++	--------SO--
Diuris magnifica D.Jones	+++++++++++-	-------ASO--
Elythranthera brunonis (Endl.)A.S.George	-----++--+--	--------SO--

Eriochilus dilatatus Lindley	---------+--	---AMJ------
Leporella fimbriata (Lindley)A.S.George	-------+----	---AMJ------
Leptoceras menziesii R.Br.	--------+---	-------ASO--
Microtis unifolia (G.Forster)H.G.Reichb.	++++++++++++	J--------OND
Monadenia bracteata (Sw.)T.Durand*	----------+-	---------OND
Paracaleana nigrita (Lindley)Blaxell	-+----------	-------ASO--
Prasophyllum elatum R.Br.	-++----+----	-------ASON-
Prasophyllum giganteum Lindley	+++----+--++	--------SON-
Pterostylis barbata Lindley	-+++++++++--	--------SO--
Pterostylis nana R.Br.	-+----++----	------JAS---
Pterostylis recurva Benth.	++++++++++--	-------AS---
Pterostylis scabra Lindley	++++++++++--	------JA----
Pterostylis vittata Lindley	+++++++++++-	-----JJA----
Thelymitra crinita Lindley	-+----------	---------O--
Thelymitra fuscolutea R.Br.	-----+-+----	---------OND
Thelymitra nuda R.Br.	++---+-+----	--------SON-
PHORMIACEAE		
Dianella divaricata R.Br.	++++++++++++	---------ON-
POACEAE		
Aira caryophyllea L.*	-++-------++	---------ON-
Amphipogon turbinatus R.Br.	++++++++++--	--------SON-
Arundo donax L.*	-----------+	---AMJ------
Avena barbata Link in Schrader*	++++++++++++	-------ASO--
Avena fatua L.*	++++++++++++	-------ASOND
Briza maxima L.*	++++++++++++	--------SO--
Briza minor L.*	++++++++++++	--------SON-
Bromus catharticus M.Vahl.*	---------+++	--------SON-
Bromus diandrus Roth*	---------+++	--------SON-
Bromus hordeaceus L.*	----------++	-------ASO--
Bromus madritensis L.*	----------++	---------ON-
Cortaderia selloana (Schultes & J.H.Schultes) Asch. & P.Graeb.*	---------+--	-----JJAS---
Cynodon dactylon (L.)Pers.*	++++++++++++	---------ON-
Danthonia caespitosa Gaudich. in Freyc.	----------++	---------ON-
Digitaria ciliaris (Retz.)Koeler*	--------++++	JFM-------ND
Digitaria sanguinalis (L.)Scop.*	--------++++	JFMAM------D
Ehrharta calycina Smith*	++++++++++++	-------AS---
Ehrhartia longiflora Smith*	++++++++++++	------JASON-
Eragrostis curvula (Schrader)Nees*	++++++++++++	JFMAM------D
Hordeum leporinum Link*	++++++++++++	--------SO--
Lagurus ovatus L.*	++++++++++++	-------ASOND
Lolium perenne L.*	--------++++	--------SOND
Lolium rigidum Gaudin*	---------+++	--------SON-
Microlaena stipoides (Labill.)R.Br.	-+------+++-	--------SON-
Neurachne alopecuroidea R.Br.	-++----++---	-------ASON-
Paspalum dilatatum Poiret*	----++----++	JFMA-------D
Pennisetum setaceum (Forsskal)Chiov.*	----------++	------JASON-
Pennisetum villosum R.Br. ex Fresen.*	------------	FMAMJ JA SO--
Pentaschistis thunbergii Stapf in Dyer*	----------++	-------ASON-
Piptatherum miliaceum (L.)Cosson*	-----------+	J--------OND
Poa annua L.*	++++++++++++	-------ASO--
Poa porphyroclados Nees in Lehm.	-----------+	---------ON-
Polypogon monspeliensis (L.)Desf.*	-----------+	----MJJASON-
Rhynchelytrum repens (Willd.)C.E.Hubb.*	++++----+-++	------JA----

Sporobolus indicus (L.)R.Br.*	- - - - - - - - +++ -	- - MAMJ - - SON -
Stenotaphrum secundatum (Walter)Kuntze*	- + - - - - ++++ - -	JFMA - - - - SOND
Stipa compressa R.Br.	++++++++++++	- - - - - - - - SOND
Stipa elegantissima Labill.	- - - - - - - - - - ++	J - - - - - - ASOND
Stipa flavescens Labill.	+++++++++++ -	- - - - - - - AS - - -
Stipa semibarbata R.Br.	- + - - - - - - - - - -	- - - - - - - ASON -
Vulpia bromoides (L.)Gray*	++++++++++++	- - - - - - - - - OND
Vulpia membranacea (L.)Dumort*	++++++++++++	- - - - - - - - - ON -
Vulpia myuros (L.)C.Gmelin*	++++++++++++	- - - - - - JASON -
RESTIONACEAE		
Alexgeorgea arenicola Carlq.	++++++++++++	- - - AM - - - - - - -
Hypolaena exsulca R.Br.	- - - ++++ - +++ -	- - - - - - - - SOND
Loxocarya fasciculata (R.Br.)Benth.	- - - ++++ - - - - -	- - - - - - - ASOND
Loxocarya flexuosa (R.Br.)Benth.	++++++++++++	- - - - - - - - SO - -
Lyginia barbata R.Br.	++++++++++++	JF - - - - - ASOND
XANTHORRHOEACEAE		
Xanthorrhoea brunonis Endl. in Lehm.	- ++ - - - ++ - - - -	- - - - - - - ASON -
Xanthorrhoea preissii Endl. in Lehm.	++++++++++++	- - - - - - - ASON -

Great Egret feeding on birds – In the course of a late afternoon visit to Herdsman Lake, Perth, on 5 March 1995, a Great Egret (*Ardea alba*) was observed actively feeding on Welcome Swallows (*Hirundo neoxena*).

A mixed flock of some 3–400 Welcome Swallows and Tree Martins (*Hirundo nigricans*) was present. Although at any one time many of these birds were resting on dried-out mud banks or on vegetation, the majority were feeding, heading into the wind, over open water: their highest concentration being near to the edge of the bulrushes.

A Great Egret stationed itself, in approximately mid-tarsus depth water, along this main flight line and was seen to lunge at any swallow or martin that came within range. Its normal stance was crouched, the neck doubled over the back, the head being only slightly above the shoulders, and the legs slightly flexed. The bird was fixedly watching, and when a swallow or martin came near, it could be seen that the body swayed slightly, the neck was fractionally raised and the bill partially opened. If the swallow (or martin) moved off, the original posture was immediately resumed, but if it came nearer a strike was made. This frequently resulted in the otherwise static bird taking a pace or two to regain balance. In a capture, (observed through a telescope) the swallow was caught at the base of the wing.

No special effort seemed to be exerted in killing the victim, it was manipulated so that the egret's bill gripped the body lengthways, where it was held for about half a minute, after which its struggling appeared to cease. From that point the egret dipped the bird into the water and commenced trying to swallow it (always head first).

This process obviously represented quite a problem for it. Several times the swallow's wings became caught, protruding on either or both sides of the gape. The bird would then be coughed-up, re-dipped in the water and repositioned before swallowing. By the time the bird was finally swallowed it appeared to be thoroughly waterlogged. Despite the apparent difficulty in getting the bird down, no attempt to dismember or break-up the prey by tearing or stabbing etc. was noted. Once the bird was swallowed, a drink was taken and straightaway the egret was actively seeking another victim.

As a diversion to this behaviour, the egret was observed stalking through the low herbage and across the mud bank where the swallows and martins were resting, but this approach was not successful and it quickly resorted to a position along the edge of the bulrushes.

The success rate of the egret's strikes was about one in ten, which during the period of observation amounted to a capture every half an hour. Lunges were made at both Welcome Swallows and Tree Martins, but the only captures noted involved swallows.

At the time of observation the weather was fine and sunny and there was a rather fresh breeze which would have had the effect of decreasing the swallow's ground speed which probably assisted the egret's hunting method.

This behaviour has not been recorded previously by us either in Australia or elsewhere. It would be of interest to see if such active hunting methods become more common and widespread and to see if it is learned by other individuals.

– J.C. & M.H. DARNELL, 1 Farnley Way, Duncraig 6023

A blue-winged Pitta (*Pitta moluccensis*) in Western Australia – On 6 November 1994 Mr John Cord of Karratha, found a live pitta on the loading jetty for Woodside Petroleum, on Burrup Peninsula, Western Australia. The bird was exhausted and had a slightly damaged wing. It was kept by Mr Cord in a small aviary for several days then air freighted to the Perth Zoo.

Details of the bird are as follows: weight 70 g; exposed culmen 23.6 mm; entire culmen 29.3 mm; wing 115 mm; tail 41 mm; tarsus 35.8 mm; middle toe and claw 32.7 mm; iris dark brown; orbital ring grey; bill greyish brown, paler on base of lower mandible; gape pinkish orange; legs pink. Upperparts: centre of crown black; broad eyebrow stripe buffy brown, the feathers with paler tips; lore, side of face and hindneck black; back and scapulars dull dark green; rump bright purplish blue; upperwing coverts bright purplish blue, some feathers with green tips; primaries and outer secondaries black with large white patch in centre of wing; tail black with bluish green tip. Underparts: chin and throat white; neck, breast and flanks cinnamon buff to cinnamon rufous; centre of belly, vent and undertail coverts pinkish red; undertail black; underwing coverts blackish, rest of underwing dull grey with large white wing patch.

The Blue-winged Pitta breeds in eastern India, south-western China and South East Asia. On migration and in winter it ranges south and east to the Malay Peninsula, Sumatra, Java, Borneo, Sulawesi and the Philippines. MacKinnon and Phillips 1993 (*The Birds of Borneo, Sumatra, Java and Bali*) doubts the validity of the previous Australian records. There are however two other Western Australian specimens: one found dead on Mandora in November 1927 and another found dead near Derby about November 1930 (Serventy, D.L. 1968. *Bull. Brit. Orn. Cl.* 88: 160–162). The remains of one of these specimens is in the W.A. Museum. There is also a specimen in the University Museum of Zoology, Cambridge, collected on Christmas Island (Indian Ocean) on 14 December 1901.

Judging from these records it would appear that *Pitta moluccensis* is a rare non-breeding summer visitor to northern Australia from south-east Asia.

– R.E. JOHNSTONE, Western Australian Museum, Francis Street, Perth 6000 and N. HAMILTON, Perth Zoological Gardens, 20 Labourchere Road, South Perth 6151.

CLUB NEWS

Programme

General Meetings are held on the first Friday in the month at the Naturalists' Hall, 63 - 65 Meriwa Street, Nedlands, at 8p.m.

The Retired and Leisured Group meets on alternate Wednesdays at 10a.m.

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

THE WESTERN AUSTRALIAN NATURALIST

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DONATIONS TO THE CLUB

Members are reminded that they may make financial contributions to the club. This funding is very important from the Club's point of view, as it helps our publication activities, hall maintenance and other miscellaneous activities. Members are asked to remember the club and its needs when preparing their Wills and Testaments.

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Annual Membership: Senior, $38; Double Membership: $48; Family Membership: $48; Nomination Fee (Seniors only): $5; Preceding Subscriptions include "The Western Australian Naturalist". Intermediates (aged 14 - 17 years): $22; Juniors (aged 9 - 13 years $21): $22.

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