Preliminary studies of the biology and ecology of *Reedia spathacea* F.Muell. (Cyperaceae)

Catherine Tauss
Graduate Diploma of Science
Botany Department
University of Western Australia
December. 2000

Table of Contents

Chapter 1: Introduction 1
1.1 Background 3

Chapter 2: Biological studies of Reedia spathacea 7
2.1 Introduction 7
2.2 Methods 8
2.3 Results 9
2.4 Discussion 14
2.5 Conclusion 20

Chapter 3: An ecohydrological study of *Reedia spathacea* wetlands 21
3.1 Introduction 21
3.2 Regional setting of the study areas 22
3.3 Methods 26
3.4 Results 31
3.4.1 Blackwood Rd Transect (*BR*) 32
3.4.2 Shannon Transect (*SHE*) 35
3.4.3 Angove Rd Transect (*AR*) 38
3.4.4 Woolbales Transect (*WB*) 40
3.5 Discussion 43
3.6 Conclusions 45

Chapter 4: Vegetation assemblages and habitats of *Reedia spathacea* wetlands 47
4.1 Introduction 47
4.2 Methods 48
4.3 Results 51
4.4 Discussion 71
4.5 Conclusions 74

Chapter 5: Summary of findings, conservation issues and directions for further study 76

Chapter 6: References 78

Ovenden H-B

Abstract

Reedia spathacea F. Muell. is an uncommon sedge confined almost exclusively to the humid, warm temperate Warren Biogeographical Region of south-west Western Australia. Previous to this study, very little was known about the biology and wetland habitat of this monotypic genus.

This study used an eco-hydrological approach to investigate factors maintaining wetlands inhabited by *Reedia spathacea* in two disjunct study areas centered on the Blackwood Plateau and the Walpole-Pt D'Entrecasteaux areas respectively. Multivariate analysis was used to define floristic assemblages and explore environmental gradients of these wetlands. Biological studies included morphology, phenology and SEM pollen character imaging.

Reedia spathacea was found to inhabit paluslopes and floodplains in association with two distinct restionaceous assemblages. The vegetation patterns of these wetlands are primarily related to water level gradients. Sub-surface run off and storage of rainwater in confined aquifers and peat maintains the paluslopes, whilst the water budget of the floodplains receives contribution from deeper regional aquifers. The phylogenetic isolation of *Reedia spathacea* was supported by findings of its pollen characters and pollination syndrome.

Cover illustration:
Botanical illustration of *Reedia spathacea* F.Muell
reproduced from Mueller (1859)

Acknowledgements

This study is dedicated to Vladimir Glazov 1896-1952 and all the 'young naturalists'.

The study would not have been completed without the practical support and kindness of volunteers from the South West and Perth who assisted in the field or provided other resources. Chief amongst these were L. Tauss, D. Chinner, K. O'Brien, J. Kolo, J, J. & J. Wall-Roberts, R. Ensley, S. Ami, I. Kirczenow, B. Damiani, D. Corbyn, I. Donaldson, J. Alford, S. Selby, J. Jardine, B. Forster, N. Poulter, H. Roberts and J. & M. Frith.

My supervisors for the study, Dr W. Loneragan and Dr V Semeniuk are thanked for their support and patience. In particular, I am most indebted to the research of V & C Semeniuk which has fundamentally altered my perception of botany. This study had its origins in the long term commitment of the V&C Semeniuk Research Group to natural history research in the Walpole area. Financial support for this study was provided by the V&C Semeniuk Research Group and this is most gratefully acknowledged along with: assistance of staff with augering in the establishment of the study transects; the opportunity to participate in an aerial survey of the vegetation; permission to use data from site ARN2; and provision of transport and resources.

Dr L Milne from the University of W A Geography Department is thanked for the use of the Palynology Laboratory, for her enthusiastic teaching of palynology methods and for taking the photomicrographs of Fig 2.5(a, b, c). C. Reeves and N. Tauss are thanked for their expert drafting of illustrations. The Centre for Microscopy and Microanalysis at the University of WA is thanked for use of the Phillips 505 SEM, photographic facilities and kind assistance of staff, particularly N Poulter. Dr N. Marchant, staff and volunteers of the W A Herbarium are thanked for use of facilities, permission to collect pollen samples, the use of Florabase and their friendly assistance. Department of Conservation and Land Management regional staff, in particular R Hearn, are also thanked for their assistance and cooperation.

Dr T Bell and Dr P Grierson of the University of W A Botany Department are thanked for discussions of methods. D Faithfull of the University of W.A. Chemistry Department is thanked for water analyses. D Chinner is thanked for the photo in Fig 1.2. and B. Hanich of the W.A Museum is thanked for assistance in invertebrate identification.

List of Appendices

Appendix 1. Glossary of terms

Appendix 2. Additional transect figures

Appendix 3. Environmental variable database

Appendix 4. Additional statistical tables

Appendix 5. Floristic inventory of study sites

Appendix 6. The significance of the catena in vegetation science

Chapter 1: Introduction

Mueller (1859) assigned *Reedia spathacea*[1] to the large family Cyperaceae which currently consists of over 5000 species and 120 genera. Subsequently, while this monotypic genus has been repeatedly treated in suprageneric classifications of the family (Koyama 1956, Bruhl 1995, Goetghebeur 1998), only small increments have been made to knowledge of its basic morphological and anatomical characters. *Reedia* has features of the 'arborescent monocotyledenous habit' (term of Staff & Waterhouse 1981) or 'pachycauly' (term of Corner 1964), long leaves armed with prickle hairs and a spadix-like inflorescence, enclosed in spathe-like bracts, borne on a 2.5m scape. It thus displays a conspicuously robust physiognomy when compared to other Cyperaceae family members endemic to the south-west of Western Australia. However due to a lack of critical character data, the phylogenetic position of *Reedia* with regard to the Cyperaceae has remained largely untested. *Reedia* is even less well known ecologically with Bruhl's (1995) short description of it as a 'helophyte, calcifuge and glycophyte' being a typical reference to all that is known anecdotally of its habitat.

The present study which commenced in March 1998, has been undertaken as a prelude to the more detailed examination of specific issues of the phenology, ecology, phylogeny, historical biogeography and conservation of *Reedia*. My interest in *Reedia* was prompted in part by the nature of its endemicity. There is a great deal of evidence that much of the extant Australian vegetation originates from Gondwanan stock (Hill *et al.* 1999). The eastern Australian rainforests appear to be vicariant relics of the ancient Gondwanan floras (Webb *et al.* 1986, Schodde 1989, Weston & Crisp 1994, Hill *et al.* 1999). However the floristic relationships between temperate regions of eastern and western Australia are not at all clear (Hill *et al.* 1999) apart from a recognition of the Nullabor as a barrier between east and west from the early Tertiary (BMR Palaeogeographic Group 1990). It is however generally established that south-west Western Australia is a globally significant centre of endemism (Takhtajan 1986, Boden & Given 1995, Crisp *et al.* 1999) at the generic and specific levels. The rich spectrum of endemic species in this region is thought to have radiated in the climatic and edaphic fluctuations of the post-Tertiary eras in the region (Hopper 1979, Walter 1985). The Transitional Rainfall Zone of south-west Western Australia (Hopper 1979) is host to many of

---

[1] Hereafter *Reedia spathacea* F.Muell. is referred to as *Reedia*.

these. Integral to this significant trend, but less well known, are the few relictual taxa adapted to humid climates which were previously more widespread in the south-west of Western Australia and which have now become concentrated in the High Rainfall Zone (Hopper *et al.* 1996). Taxa such as these, which could be termed paleoendemics (Major 1988, Cronk 1987, 1992) by virtue of their long history, their phylogenetic and often geographical isolation, possess quantities of genetic information which may be very different or unique compared to other extant taxa and are of high scientific importance in elucidating Gondwanan vegetation history. Examples of such taxa could include: the Tingle eucalypts (Wardell-Johnson 1997); *Reedia spathacea, Cephalotus follicularis* and *Podocarpus drouynianus* (Hopper *et al.* 1996); *Anthocercis sylvicola* (McFarlane & Wardell-Johnson 1996); and *Acidonia microcarpa* (Weston, 1994). *Reedia* fulfills several criteria that are potentially characteristic of a paleoendemic taxon (Major 1988): its populations are geographically disjunct and are believed to have been more widespread in the past; its present habitat appears to be both uncommon and very limited in extent; and available evidence (Bruhl 1995) indicates its phylogenetic isolation. However sufficient details of the biology and ecology of *Reedia* have hitherto not been available to effectively examine the proposition that *Reedia* is a paleoendemic species with possible Gondwanan affinities.

The orientation of this preliminary study is primarily ecological. Its major research objectives centre around *Reedia*'s habitat with an aim to examine the hydrological processes maintaining *Reedia*- inhabited wetlands, to characterize the wetland plant assemblages associated with *Reedia* and to explore the relationships of these assemblages to some of the environmental gradients in these wetlands. However, it also aims to augment the biological database on *Reedia* particularly with regard to characters of systematic significance which may be useful in examining *Reedia's* phylogenetic status with regard to the other members of the family Cyperaceae and within the larger commelinid monocotyledenous group (*sensu* Linder & Kellogg 1995).

1.1 Background

Reedia occurs in about twenty five populations, mainly in peat-based wetlands of the Warren and Jarrah Forest Biogeographical Regions (Thackway & Cresswell 1995) of the south-west of Western Australia. Population clusters centre on two main areas (Fig 1.1): the Blackwood Plateau south east of Margaret River (Fig 1.2); and the Walpole-Nornalup and D'Entrecasteaux National Parks between Walpole and Mt Chudalup near Northcliffe (with northern outliers to Granite Peak). Nearly 100 km separate the *Reedia* populations in the Blackwood area from its nearest known neighbours, the *Reedia* populations adjacent to Mt Chudalup. Vegetation studies in the region have been largely confined to floristic survey and taxonomic studies (Hopper *et al.* 1992, Florabase 1998, Lyons *et al.* 2000). These have indicated a diverse, highly endemic wetland flora, however, wetland assemblages (including those associated with *Reedia*) and the ecology of the wetland flora remains largely undescribed. A quantitative floristic study of part of the Walpole –Nornalup area (the 'Tingle Mosaic') by Wardell- Johnson & Williams (1996), sampled mainly forests and woodlands and acknowledged the need for further detailed survey of wetlands. The V& C Semeniuk Research Group (1997) identified and mapped wetlands (at the scale of 1: 25 000) and consangineous suites of wetlands (at the scale of 1: 250 000) in the Walpole to Augusta region. This study used the geomorphic classification system of wetlands (Semeniuk & Semeniuk 1995) and geomorphic, stratigraphic and hydrologic criteria for consanguinity as detailed in Semeniuk (1988).

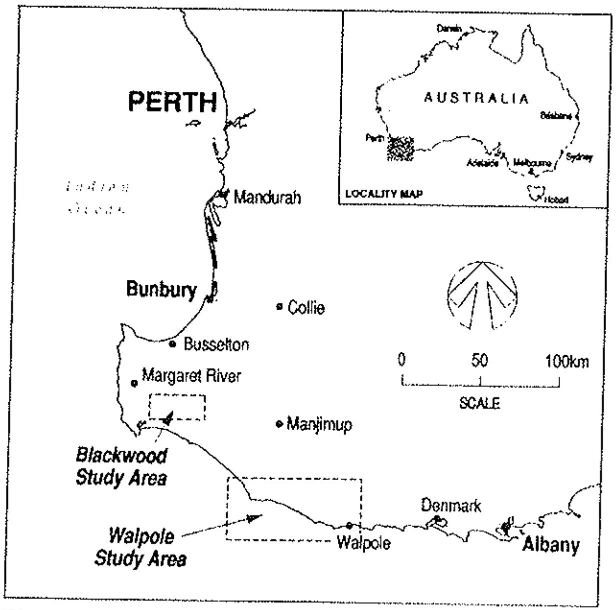


Figure 1.1 Location of Study Areas

Figure 1.2 ***Reedia spathacea*** **at the Blackwood Road transect of this study**

Ecological studies of the Walpole and Nornalup Inlets (V & C Semeniuk Research Group 1999) included a comprehensive description of the hydrology of the wetlands bordering the inlets and small scale (1: 6250) mapping of their vegetation.

The wetland flora and ecology of the southern Jarrah Forest Region is less well known. Floristic data of the Jarrah Forest is summarized in Gioia *et al.* (1998) and Florabase (1998), however, there have been no dedicated studies of the wetlands (Fig 1.2) except the geological and hydrogeological study of Baddock (1993). Fauna studies of the Warren Biogeographical Region or the southern Jarrah Forest wetlands include Main & Main (1991), Wardell-Johnson & Roberts (1993) and Horwitz (1994), and have described high endemicity of freshwater and terrestrial invertebrates and frogs.

Australian wetlands and wetland vegetation studies are reviewed in Jacobs & Brock (1993), Pressey & Adam (1995), and Jacobs (1999). Peat-based wetlands (mires) in Australia are uncommon and limited in area and their study has been largely confined to the alpine or sub-alpine zones of Tasmania (Whinam & Kirkpatrick1994) and highland Eastern Australia (Wahren *et al.* 1999). Bryophytes, especially *Sphagnum* spp. are dominant components of the vegetation in many of these wetlands unlike some rare New Zealand mires in which Restionaceae species prevail (Campbell 1964). The latter mires are located in lowland coastal settings near Auckland in a warm temperate and humid climate similar to that of the Warren Biogeographical Region (Walter 1985).

There are, however, little quantitative data of the relationships between environmental gradients and vegetation for southern hemisphere mires compared to the intensively studied northern hemisphere mires. Many of the latter studies investigated vegetation relative to water chemistry gradients (Glaşer *et al.* 1990, Vitt & Chee 1990, Nicholson 1995, Anderson *et al.* 1996). Other wetland studies utilized soil chemistry data to examine environmental conditions (Clymo 1983, Jeglum & He 1995). A limited number of ecological studies integrated hydrological studies with soil and water chemistry and other environmental variables (Bridgham and Richardson 1993, Wassen & Grootjans 1996). Redox potential of sediments has also recently been measured in phytoecological studies and was considered by deMars & Wassen (1999) as a more accurate indicator of wetland conditions in regard to wetland vegetation variation than water levels alone. Most of the above studies were conducted in cool temperate or boreal climatic zones (except Bridgham & Richardson, 1993) where wetland vegetation and chemistry is often dominated by bryophytes, (mainly *Sphagnum* spp). Wetlands of the above studies ranged from ombrotrophic (maintained almost exclusively by meteoric water and which are low in base cations and acidic), through to minerotrophic (maintained to a greater degree by telluric water and which are usually higher in base cations and pH). Most of these studies have highlighted the role of base cation and acidity gradients, water level gradients and nutrient gradients with regard to mire vegetation distribution.

The functional ecology of the vegetation of the rare New Zealand restionaceous mires (Campbell 1964) inhabited by *Empodisma minus* and *Sporadanthus traversii* requires futher discussion. Agnew *et al.*(1993) showed it had several unique features which differentiated the mode of peat accumulation in these mires from that found in *Sphagnum* dominated systems. They found the dominant species of these wetlands, *Empodisma minus,* to have a base exchange capacity comparable to *Sphagnum*, a very high rainfall capture efficiency and high water holding capacity by virtue of its specialized capillaroid roots (Lamont 1982). Kuder *et al.* (1998) found that *E minus* also contained lignin and non-lignin polyphenols, which are not found in *Sphagnum,* and considered that these substances may promote peat formation in wetlands inhabited by *E minus* by allelopathic decay inhibition. Extremely conservative evaporation rates from the canopy of this type of wetland vegetation (equivalent to that found above arid land vegetation), were demonstrated by Campbell & Williamson (1997). *E. minus* is also widespread in Tasmania, other regions of eastern Australia such as the Bogong High Plains (Wahren *et al.* 1999) and it extends north into Queensland. Invariably these records of *E. minus* are from alpine and subalpine climates in vegetation dominated by *Sphagnum* spp.(e.g.Whinam & Kirkpatrick1994). Therefore, it is unknown if peat wetlands dominated by *E.minus* are limited to the few known from New Zealand. The sole congener of *Empodisma minus*, *Empodisma gracillimum,* is endemic to south-west Western Australia where it is prominent in many peat based wetlands of the Warren Biogeographical Region including *Reedia*-inhabited wetlands. Although the functional ecology of *E.gracillimum* has not been investigated, and it is not the focus of this study, it seems probable that the restionaceous mires of New Zealand are the wetlands most comparable to south-west Western Australian peatlands inhabited by *Reedia.*

Chapter 2: Biological studies of Reedia spathacea

2.1 Introduction

Apart the original description of the *Reedia* by Mueller (1859) and the subsequent inclusion of *Reedia* in Flora Australiensis (Bentham, 1879) further systematic treatments of *Reedia* have included several suprageneric classifications of the genus within the family Cyperaceae (Table 2.1). Historically, several conflicting interpretations of homologies in flowers, spikelets and inflorescences in the Cyperaceae have arisen and these remain unresolved (Bruhl 1995, Goetghebeur 1998, Muasya *et al.* 2000). Morphological studies have been hampered by the size of the family, the lack of universally accepted terms for Cyperaceae floral parts and the reduced appearance of floral parts. Kubitzki (1987) placed the difficulties experienced with the interpretation of Cyperaceae flowers in the broader context of the origin of trimerous flowers and their relationship to flowers with spiral anthotaxy. Bruhl (1991) reviewed the various interpretations of Cyperaceae flowers and successfully utilized floral ontogeny in several taxa to elucidate floral structure. The differences between authors instanced in the case of the suprageneric classification of *Reedia* (Table 2.1) are largely the product of widely differing interpretations of Cyperaceae floral characters by these authors.

Table 2.1: Suprageneric classification of Reedia (Cyperaceae) from 1927 to 1998.
Subfamily and (tribe) are shown.
(* cited in Metcalfe 1971, ** cited in Goetghebeur 1998)

	Suprageneric classification of *Reedia*
*Pfeiffer (1927)	Lepidospermeae
Koyama (1956)	Rhynchosporeae (Gahniinae)
**Goetghebeur (1986)	Cyperoideae (Schoeneae)
Bruhl (1995)	Caricoideae (Schoeneae)

Reedia anatomy was investigated briefly by Metcalfe (1971) who noted thick-walled cells surrounding the sub-stomatal cavities of the leaf. In the cladistic analysis of suprageneric relationships of the family Cyperaceae by Bruhl (1995), *Reedia* and *Gymnoschoenus* the only Cyperaceae genera in which this character state has been confirmed, formed a strongly-supported group.

Wheeler & Bruhl (2000) indicated that comparative reproductive biology, including pollen characters, could be potentially informative with regard to Cyperaceae systematics. Muasya *et* *al.* (2000) successfully used a combined morphological and molecular (*rbc*L sequences) analysis to produce a suprageneric phylogeny of Cyperaceae which differed to those of Goetghebeur (1986) and Bruhl (1995). However *Reedia* was not included amongst the genera of the study of Muasya *et al.* (2000).

The current study aims to augment the biological database on *Reedia*, particularly with regard to characters of possible phylogenetic significance. It also seeks to collect basic data with regard to *Reedia* phenology and morphology which would facilitate the design and interpretation of ecological studies and enable the subject of these studies to be seen in a more holistic context.

2.2 Methods

As a part of the monthly monitoring between April 1998 and October 1999 of twelve transects established through *Reedia* populations for the ecological studies, records were maintained of *Reedia* phenology, photographs were taken and other biological investigations were conducted. Branching patterns and other gross structure of large *Reedia* plants were examined by sawing cross-sections through the caudex of shoots. Thin sections of the caudex were cut with a microtome, stained with Toluidine Blue and examined by optical microscopy. Fertile seeds were very uncommon and timing of seed set, relative to field trip schedules, precluded collection and study of these. Seedlings were collected after fire, within several weeks of germination.

Several invertebrate taxa were collected from *Reedia* populations and these were preserved in ethanol until identification in the laboratory and at the W A Museum. Beetle taxonomy follows Matthews (1987).

Reedia pollen was initially air-dried, mounted on stubs with double-sided adhesive tape, gold coated and imaged on a Phillips 505 Scanning Electron Microscope. A further (comparative) study of *Reedia* and nine other Cyperaceae species was then conducted using *Reedia* pollen from the field and pollen of *Lepidosperma effusum*, *Gymnoschoenus anceps*, *Evandra aristata*, *Schoenus grandiflorus*, *Chorizandra enodis*, *Chrysithrix distigmatosa*, *Cyathochaeta clandestina* and *Mesomelaena tetragona*, collected from herbarium sheets with permission from the W A Herbarium. All pollen in this study was prepared by the same method to enable resulting images to be compared for size and other characters. The pollen was acetolysed following the technique of Erdtman (1986), with modifications following Milne (1997), mounted on slides, examined with light microscopy and imaged in Nomarski photographs. The diameters of 10 grains of each species were measured and their apertures were counted.

For imaging the fine surface details of grains, pollen prepared as above was fixed with chloroform-soluble adhesive to coverslips which were then mounted on stubs. Samples were sputter coated with platinum prior to imaging on the Phillips 505 at short working distance. Pollen terminology used follows Jarzen & Nichols (1996).

Definitions of various terms used are presented in the glossary (Appendix 1). Parts of the *Reedia* flower and inflorescence are referred to using general Cyperaceae terminology Goetghebeur (1998)[2]. However the outer three inflorescence bracts are referred to as spathes in this study. Subsequent smaller inflorescence bracts are referred to as spathels. These two terms are from the palm terminology of Corner (1966) as equivalent Cyperaceae terms do not exist.

2.3 Results

Phenology, morphology, pollination and general observations

A diagrammatic representation of the growth of *Reedia* (in longitudinal section) from the seedling stage to maturity is shown in Fig 2.1. Phenological and biological findings will be reported below in the form of a narrative with reference to various stages of the life cycle of *Reedia* as depicted in this diagram.

---

[2] ***Reedia*** **F.Muell.**

" Tufted perennial on woody rhizome. Culms scapose. Leaves eligulate(?), sheaths often +/- inflated. Inflorescence condensed paniculate with numerous spikelets, resembling a spadix, enclosed by several large spathelike bracts, these lower primary bracts empty, bract at the base of the inflorescence probably subtending a partial inflorescence, higher bracts smaller and partly hidden by the densely arranged spikelets. Spikelets with many densely spiral to subdistichously arranged, deciduous(?) glumes of increasing length, upper 2-3 larger glumes each subtending a flower. Lower flower functionally male, upper bisexual. Bristles absent. Stamens 6, top of filaments connivent, in the bisexual flower enclosing the style branches. Style 3-fid, style base not distinct, thickened, persistent. Achene obovate, rounded, trigonous, beaked, surface smooth, dark and shining. Only one sp., *R. spathacea* F. Muell., SW and W Australia, in swamps." **Goetghebeur (1998)**

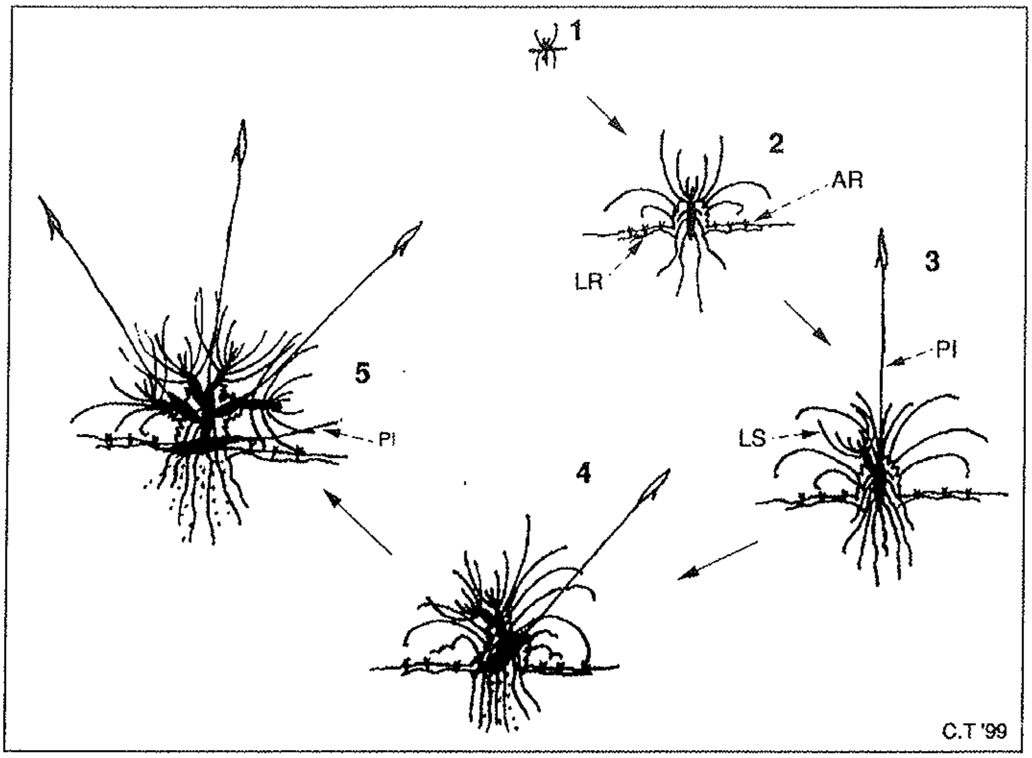


Figure 2.1 Gross morphology and growth of *Reedia.*

The establishment phase of the *Reedia* genet commences with germination of seeds in about January (Fig 2.1.1) and proceeds to a single shoot (Fig 2.1.2) consisting of an upright woody caudex with leaves initiated from an apical meristem and shoot-borne roots arising just below this. The primary shoot-borne roots typically proceed down vertically, penetrating the thick layers of leaf bases which sheath the caudex. Once the primary roots reach the soil, or less often whilst they are still contained within the leaf bases, secondary lateral roots (LR) are produced which further ramify into shorter apogeotropic roots (AR) which appear similar to pneumatophores. These apogeotropic roots (shown in detail in Fig 2.2) typically protrude just above the waterlogged soil surface and produce prolific rootlet clusters below their tips. Thus the surface 20cm of soil surrounding a live *Reedia* shoot and any dead *Reedia* shoots nearby are infiltrated, particularly in winter, by a network of lateral roots and their apogeotropic extensions.[3]

---

[3] The uncommon oligachaete *Megascolex ?swarbrickii*, a 'giant earthworm' that is considered a relictual taxon of humid climate zones (Main 1993) was collected from amongst *Reedia* and *Homalospermum firmum* roots in peat at Walpole.

The leaf bases of *Reedia* which sheath the caudex, form reservoirs which collect precipitation and fine debris. It was possible to extract up to 100ml or more of this solution from a single shoot on a mature plant in summer. This solution contained dissolved elements and nutrients at concentrations comparable to the interstitial waters of *Reedia*-inhabited wetlands (Appendix 3).

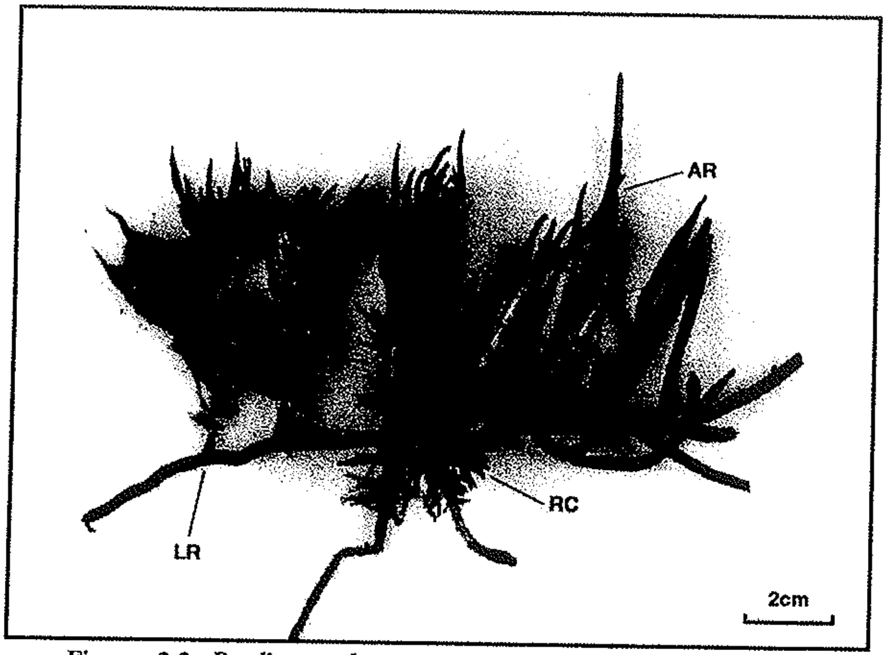


Figure 2.2 *Reedia spathacea* lateral root (LR) with vertical apogeotropic roots (AR) and associated rootlet clusters (RC)

Typically the production of the first inflorescence and lateral shoots (LS) begins while the *Reedia* plant still consists of just a single shoot (Fig 2.1.3). The inflorescences become evident by early September although they can be seen to be developing much earlier by dissecting shoots. Lateral shoots also form, less frequently, below non-flowering shoot apices. The primary inflorescence scape (PI) grows rapidly reaching a total length of about 2.5m by mid- November when flowering commences. During flowering, the outermost three or four extra- floral bracts (spathes) which subtend the inflorescence remain vertical. The thick, papery- textured spathes are part of a homologous series from leaf bases to spikelet glumes. All members of this series conform to the general spiro-distichous phyllotaxy of *Reedia*. The spathes loosely enclose the inflorescence forming a relatively weather-proof chamber. They are of a light straw colour and conspicuous on their tall scapes, even in scrub vegetation. The smaller distal bracts of the inflorescence (spathels), which have a thinner papery texture than the spathes, hang between the spathes and flutter in the air currents creating a sound similar to that of a large insect's wings. The male flowers of each spikelet, proximal to the rhachis of the inflorescence, are the first to reach anthesis. The flowers are fragrant with a strong but not unduly sweet odour. This becomes particularly apparent on anthesis of the distal bisexual flowers which occurs several days after that of the male flowers. The bisexual flowers are protogynous i.e the styles emerge from the glumes before the stamens. By this stage all the anthers from the proximal male flowers have dehisced with much of the pollen accumulating inside the base of the spathes. During flowering a number of insects visit the flowers and also congregate in the spathes amongst shed pollen. Pollen can be seen adhering to their bodies.[4]

As the inflorescence senesces (Fig 2.1.4), the production of stem- borne roots just below the apical meristem of the new lateral shoot and the growth and subsequent further sympodial branching of the shoot (which is often assymetrical) often cause the original axis of the plant to be displaced and eventually it may assume a near-to-horizontal position. This was often observed in the burnt remants of old inflorescences (PI) on highly branched plants (Fig 2.1.5). Not all seedlings proceed to the aerially branched sympodial structure as detailed above. Rare examples of tall monopodial shoots of *Reedia* were observed. The tallest specimen seen was a single,vertical, dead shoot in which the woody caudex (after removal of leaf bases to accurately measure it) was 70 cm in height from the soil to the apical meristem. Several sympodially branched caudices from large plants were dissected but these were all less than 25 cm in length. Caudex thin sections showed no sign of secondary thickening.

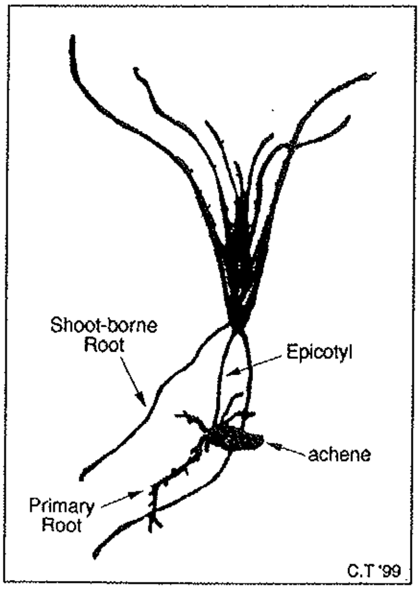


Figure 2.3 Seedling of *Reedia spathacea* (x1)

By later December, about a month after anthesis of the first bisexual flowers, there are no fertile achenes on the infructescence. The fertile fruits (if at all present earlier) appear to be shed, or possibly consumed by birds and insects by this time. Seedlings were found in most transects but were more evident in some of the populations which had recently experienced fire. Seeds appear to be viable for at least one year in the soil and are capable of surviving fire. Some populations after fire produced no seedlings at all or seedlings at a very low rate.

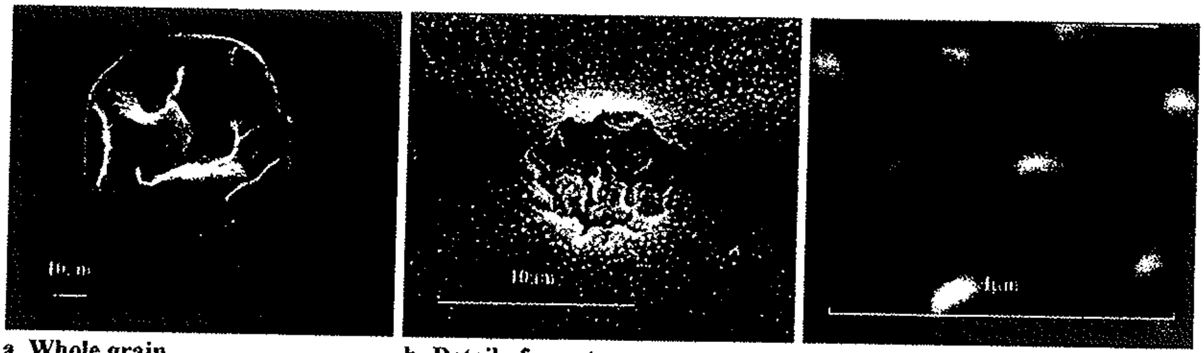
---

[4] Two common taxa of small beetles were collected from *Reedia* spathes in November. These are both from the series Cucujiformia, one from the Lathridiidae family and the other, a flea beetle, from the Chrysomeloidea tribe Alticini. Honeybees (*Apis mellifera*) were also observed visiting the stigmas of the flowers.

The *Reedia* seedling (Fig 2.3) germinates hypogeally and has a compact cotyledon with its distal end remaining in the seed as a haustorium. The primary root shows short laterals. An elongated epicotyl was observed in many but not all *Reedia* seedlings collected. There was no evidence of a coleoptile in any of the *Reedia* seedlings observed.

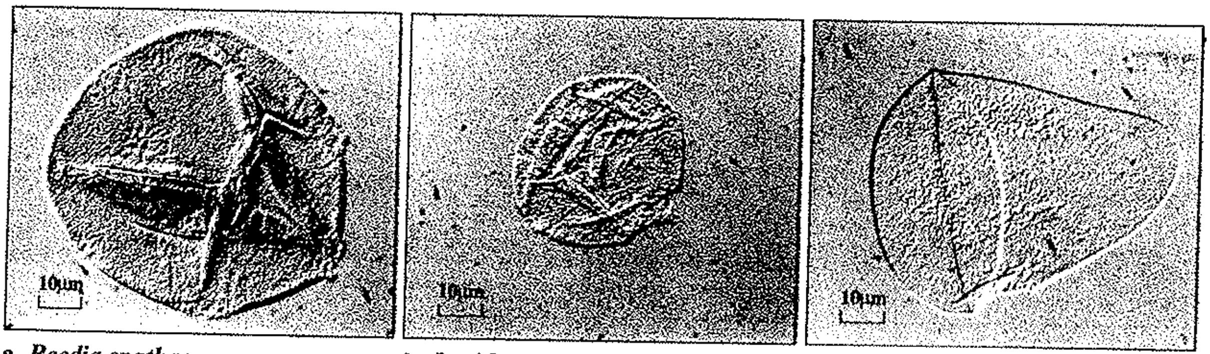
Pollen characters

Reedia spathacea pollen is shed as monads (Fig 2.4.a). The grain surface is perforate and microverrucate (Fig 2.4.b & Fig 2.4.c) and similar to the other two species examined for these characters, *Evandra aristata* and *Gymnoschoenus anceps. Reedia* pollen (Fig 2.5.a) is circular in common with *Gymnoschoenus anceps* and *Lepidosperma effusum* (Fig 2.5.b) in contrast to the cuneiform pollen of *Schoenus grandiflorus* (Fig 2.5.c) and all other species examined. *Reedia* pollen is, however, much larger than the other circular pollens in this study (with a mean diamenter of 74 μm) and pantoporate with 12 apertures which also distinguishes it from the latter species which have eight or fewer apertures (Table 2.1).



a. Whole grain **b. Detail of aperture** **c. Detail of surface texture**

Figure 2.4 *Reedia spathacea* pollen (SEM)



a. *Reedia spathacea* **b. *Lepidosperma effusum*** **c. *Schoenus grandiflorus***

Table 2.1. Pollen characters of nine Western Australian Cyperaceae species.

Species	Shape of pollen	Mean diameter of grain (μm)	Number of apertures
Reedia spathacea	circular	74	12
Gymnoschoenus anceps	circular	47.8	6-8
Lepidosperma effusum	circular	41.2	8
Mesomelaena tetragona	cuneiform	51.2 equatorial 89.1 polar	4
Schoenus grandiflorus	cuneiform	52.2 equatorial 76.9 polar	4
Evandra aristata	cuneiform	59.6 equatorial 71 polar	4
Cyathochaeta clandestina	cuneiform	43.2 equatorial 52.9 polar	4
Chorizandra enodis	cuneiform	41.4 equatorial 50.1 polar	1
Chrysitrix distigmatosa	cuneiform	41.2 equatorial 43.8 polar	1

2.4 Discussion

Reedia exhibits a number of characters and character states which are either unique or atypical in Cyperaceae. These include: the long inflorescence scape of the inflorescence; spathe-like outer inflorescence bracts; a thick spadix-like rhachis of the inflorescence; open leaf sheaths; and spirodistichous phyllotaxy. Observations in this study also have found: pneumatophore roots with their associated rootlet proliferation; leaf sheath water tanks; an entomophilous pollination syndrome; and a unique pollen type.

In the geographical setting of this study, pneumatophores have been described previously in only the freshwater wetland species *Viminaria juncea* of the Papilionaceae (Walker *et al.*

1983). Roots of this type have not been observed in Cyperaceae before. Leaf sheath water reservoirs are best developed in the Bromeliaceae where they are termed phytotelmata (Janetzky & Vareschi 1993). Lamont (1981) demonstrated proliferation of roots within leaf bases and absorption of soluble nutrients from this source in *Kingia australis* (Dasypogonaceae) however, this type of structure has also not been recorded previously from the Cyperaceae.

Rudall (1991) reviewed the occurrence in monocotyledenous taxa of lateral meristems and stem-thickening growth. She considered that the presence of a primary thickening meristem near the shoot apex of almost all monocotyledons predisposes them to evolve into many 'pachycaul' types (Corner 1964). The primary thickening meristem is however, not homologous to the uncommon phenomenon of secondary stem thickening present in monocotyledenous taxa such *Draceana* and *Xanthorrhoea.* Trial caudex sections taken from *Reedia* in this study showed a complex anatomy consistent with the presence of a primary thickening meristem with no indication of secondary thickening. Rudall (1991) considers the primary thickening meristem of monocots, most probably, a pleisiomorphic trait involved in both primary stem thickening and the production of shoot-borne roots. The pachycauly of *Reedia* is thus not informative with regard to cladistic analysis in which apomorphic traits are used to delineate groups. Similarly, features such as the leaf sheath water tanks and the root proliferation within them can be seen as the retention of possibly pleisiomorphic character states related to the generally large dimensions of *Reedia.* These characters may parallel similar features in other unrelated taxa which inhabit similar environments however do not constitute character states which may be useful in phylogenetic analysis.

Tillich (2000) classified seedling characters of monocotyledons by evolutionary level and proposed that these characters were often very important in detecting phylogenetic relationships at the family level in monocotyledons. The *Reedia* seedling does not appear to develop a coleoptile, has a compact cotyledon and an elongated epicotyl. A similar elongated epicotyl to that seen in *Reedia* occurs in some Restionaceae species (Pate & Meney, 1999). Cyperaceae seedlings typically develop a very distinctive coleoptile which functions as a green assimilating organ before the first true leaves are produced and this is considered to be a highly derived condition (Tillich 1995). The coleoptile is a delicate structure which is only present very early in the life of a seedling. Therefore it is possible that *Reedia* seedlings do develop a coleoptile and their collection from the field occurred when the coleoptile had already degenerated. Therefore, pending the collection of very young seedlings or the germination *in vitro* of the seeds of *Reedia,* it is premature to interpret the structure of *Reedia* seedlings with regard to Cyperaceae systematics.

The thick-walled cells lining the sub-stomatal cavities of the *Reedia* leaf (Metcalfe 1971, Bruhl 1995) have also been recorded by: Cutler (1969) in some Juncaceae and Thurniaceae; Pate & Delfs (1999) in some Restionaceae; and other more distantly related taxa such as Dasypogonaceae and Xanthorrhoeacea (Fahn 1954). This character is therefore considered of dubious systematic value and this conclusion brings into question the systematic significance of the association between *Reedia* and *Gymnoschoenus* seen in the analysis of Bruhl (1995). It seems more probable that sclerified sub-stomatal cells have evolved in parallel amongst these taxa as 'protective cells' (Pate & Delfs 1999) in response to low nutrient conditions.

Pollen and Pollination

Most genera in Cyperaceae for which pollen characters are known have cuneiform pollen grains with four indistinctly marked apertures, including one ulceroid aperture on the wide end of the grain and three lateral, faintly-marked, poroid or elongate apertures (Erdtmann 1986 and Goetghebeur 1998). The genus *Carex* (Erdtman 1986) and *Gahnia* (Wheeler & Bruhl 2000) are examples of this type of pollen. In the current study, *Mesomelaena tetragona, Schoenus grandiflorus, Evandra aristata* and *Cyathochaeta clandestina* were found to have pollen of this type. A less common pollen type in Cyperaceae is cuneiform pollen with one aperture on the wide end of the grain as seen in *Chrysitrix capensis* and *Lepironia mucronata* of the subfamily Mapaniodea (*sensu* Goetghebeur 1998) by Erdtman (1986). In this study, *Chrysithrix distigmatosa* and *Chorizandra enodis,* local members of the subfamily Mapaniodea were consistent with this. Circular pollen grains have also been reported from Cyperaceae in *Calyptrocarya* (with four apertures) and *Hypolytrum* and *Mapania* (one aperture) (Erdtman 1986). Two *Lepidosperma* spp. examined by Wheeler & Bruhl (2000) have circular grains with at least six apertures as seen from the SEM images published, although the number of apertures was not reported. *Gymnoschoenus anceps* and *Lepidosperma effusum* in this study were shown to have pollen of approximately the same size, shape, and with 6-8 and 8 apertures respectively. The large circular pollen grain of *Reedia* (at least 54% larger than *Gymnoschoenus* and 80% larger than *Lepidosperma* above) with 12 or more apertures is therefore a pollen type not previously observed in Cyperaceae. The perforate, micro-verrucate surface patterning observed in *Reedia,* however, seems widespread in Cyperaceae (as seen from lower magnification SEM images of pollen of other taxa in the literature) and as confirmed in the two species examined for this character in this study: *Evandra aristata* and *Gymnoschoenus anceps.*

Although the surface texture of *Reedia* pollen is relatively fine and resembles that of entomophilous taxa of Cyperaceae, *Reedia* pollen has been seen to adhere readily to the bodies of insects which visit the flowers. The *Reedia* pollen grain is unusually large compared to pollen grains in general (Erdtman 1986) and Cyperaceae in particular (as described above), and this mitigates against wind pollination. *Reedia* has a number of other features suggestive of entomophily. The production of copious fodder pollen early in the flowering cycle is a well known primary attractant for pollinators (Faegri & van der Pijl 1979) with secondary visual and olfactory attractants provided by the prominent spathes which enclose the inflorescence and the fragrance of the flowers respectively. Faegri & van der Pijl (1979) recognise movement of flower parts as a secondary attractant, however little is known of this phenomenon. Thus the flickering of the *Reedia* inflorescence spathels may be significant in attracting pollinators however further study is needed to validate this. The *Reedia* inflorescence is compact and the flowers have simple stigmas unlike the loose panicles and large feathery stigmas common in anemophilous taxa of Cyperaceae, Restionaceae and Poaceae. In *Reedia* although anthers from the male flowers of each spikelet have dehisced when the styles from the bisexual protogynous flowers emerge, pollen from the former accumulates in the spathes and so autogamy could potentially also occur, however this has not been investigated. The rare occurrence of fertile seeds and infrequent seedlings observed in this study in *Reedia* populations do not necessarily indicate inefficient pollination or fertilization as other factors such as the post-zygotic failure often seen in Restionaceae (Meney *et al.* 1999) may intervene. Although a more detailed study of the reproductive biology and pollination of *Reedia* would be required to demonstrate obligate entomophily in *Reedia*, all available evidence suggests it is well adapted to entomophily and at least partially pollinated by insects.

Although about two thirds of all monocotyledenous species are zoophilous (Vogel 1998), Cyperaceae is generally an anemophilous family. However Faegri and van der Pijl (1979) considered that the Cyperaceae were undoubtedly derived from entomophilous stock. They listed the following Cyperaceae taxa (with their insect-attracting features) as reversions to entomophily: *Dichromena* and *Sickmannia* (pollen and involucral bracts); *Chrysithrix* *capensis* (blue filaments and orange anthers); and *Mapania* (ageeable scent, probably from pollen). Keighery (1983) proposed possible entomophily in the tropical Australian species *Cyperus pulchellus* and the South African *Ficinia radiata.* Goetghebeur (1998) concluded that while most Cyperaceae are clearly adapted to anemophily, a few species of *Mapania, Hypolytrum, Ascolepis, Bolboschoenus, Cyperus, Carex, Cymophyllus, Eleocharis* and *Ficinia* were known to be visited by pollen- gathering invertebrates. In these entomophilous members of the Cyperaceae, despite the inconspicuous (aphananthous) flowers, extrafloral structures such as prominent white, yellow or orange inflorescence bracts function similarly to the spathes of aroids and many palms to attract insects (Vogel 1998). These genera typically inhabit tropical forests. Wind velocity in these habitats is reduced, high humidity and rain hamper wind pollination and insects are plentiful (Faegri & van der Pijl 1979). Goetghebeur considered that morphological adaptations for entomophily in Cyperaceae appear to have arisen independently in several parallel lines. Thus entomophily observed in Cyperaceae could be an example of convergent evolution of taxa in similar environments rather than the retention of an ancestral familial trait. Keighery (1983) however suggested insect pollination in Cyperaceae was a possible reversion to an ancestral monocotyledenous mode of pollination. Vogel (1998) cited Cretaceous fossil evidence (Herendeen & Crane 1995) which showed aphananthy as a very early trait of monocots and angiosperms in general. He postulated that early unspecialized aphananthous monocots may have been open to adapt in two ways: floral reduction and inability to acquire nectaries leading to anemophily; or evolution of other forms of attractants such as spathes and chemical attractants leading to zoophily.

The mapanioids (*sensu* Goetghebeur 1998) such as *Mapania, Hypolytrum* and *Chrysithrix;* and other insect pollinated genera listed above have been shown recently by Muyasa *et al.*(1999) to be separated widely in the Cyperaceae family. The position of *Reedia* in Cyperaceae is uncertain and it was not included in the combined morphological and molecular analysis of the latter study. Therefore, there appear to be at least two distinct groups of Cyperaceae genera which are insect pollinated.

One of the few synapomorphies defining the family Cyperaceae is its unique type of microsporogenesis (Dahlgren *et al.* 1985). Cyperaceae microsporogenesis results in pseudomonad pollen grains, unlike other plants in which all four microspore products of division of the microspore mother cell reach maturity to form four single pollen grains (monads) or a tetrad of grains. In Cyperaceae, three out of four of the microspores degenerate leaving only one 'pseudomonad' to mature into a pollen grain. It is unknown if *Reedia* has pseudomonad pollen.

2.5 Conclusion

The unique pollen characters and entomophilous pollination syndrome observed in *Reedia*, are substantial indicators of the isolation of this monotypic genus with regard to other genera of Cyperaceae. Studies of microsporogenesis, floral ontogeny and molecular analysis will potentially resolve this. However, *Reedia* also exhibits a number of vegetative characteristics that are of limited or no systematic significance but which are uncommon or unusual in its geographical setting and indicate a high level of adaption to its environment.

Chapter 3: An ecohydrological study of *Reedia spathacea* wetlands

3.1 Introduction

The wetlands inhabited by *Reedia* in the Walpole and Blackwood study area are relatively unstudied in terms of their plant assemblages and environmental gradients. However ecological studies of the Walpole and Nornalup Inlets (V & C Semeniuk Research Group 1999), have comprehensively described the hydrology of the wetlands bordering the inlets. Paluslopes or seasonally waterlogged slopes (Semeniuk & Semeniuk, 1995) underlaid by peat were found to be widespread in this humid climatic zone.

Peat formation has been intensively studied in the northern hemisphere. Ivanov (1981) considered that watertables sufficiently high to waterlog soils and create conditions suitable for peat formation were possible on slopes and interfluves in climates of excess humidity, given suitable stratigraphy and topography (that is relief lower than a critical profile). Ivanov (1981 citing Kamenskiy) described the height of the water table on an interfluve as a mathematical function of: the mean supply of moisture (i.e mean precipitation – mean evaporation); the hydraulic conductivity of the water permeable soils constituting the aquifer and specific topographical parameters. The principles of Ivanov were developed from extensive observations of parameters in Russian peatlands, however they provide a theoretical basis for exploring hydrological conditions contributing to peat formation in the humid zones of south- west Western Australia.

Ecohydrology is the science of the hydrological aspects of ecology which aims to understand the hydrological factors determining the natural development of wetland ecosystems (Wassen & Grootjans 1996). In this approach, wetlands are analyzed in a landscape-ecological context and differences in water chemistry are often used to distinguish various hydrological processes and systems.

The research aims of this study were to examine some of the hydrological mechanisms maintaining *Reedia* -inhabited wetlands.

3.2 Regional setting of the study areas

Location

Known extant *Reedia* populations inhabit two distinct regional-scale physiographic units in south-west Western Australia as described below (Fig 3.1).

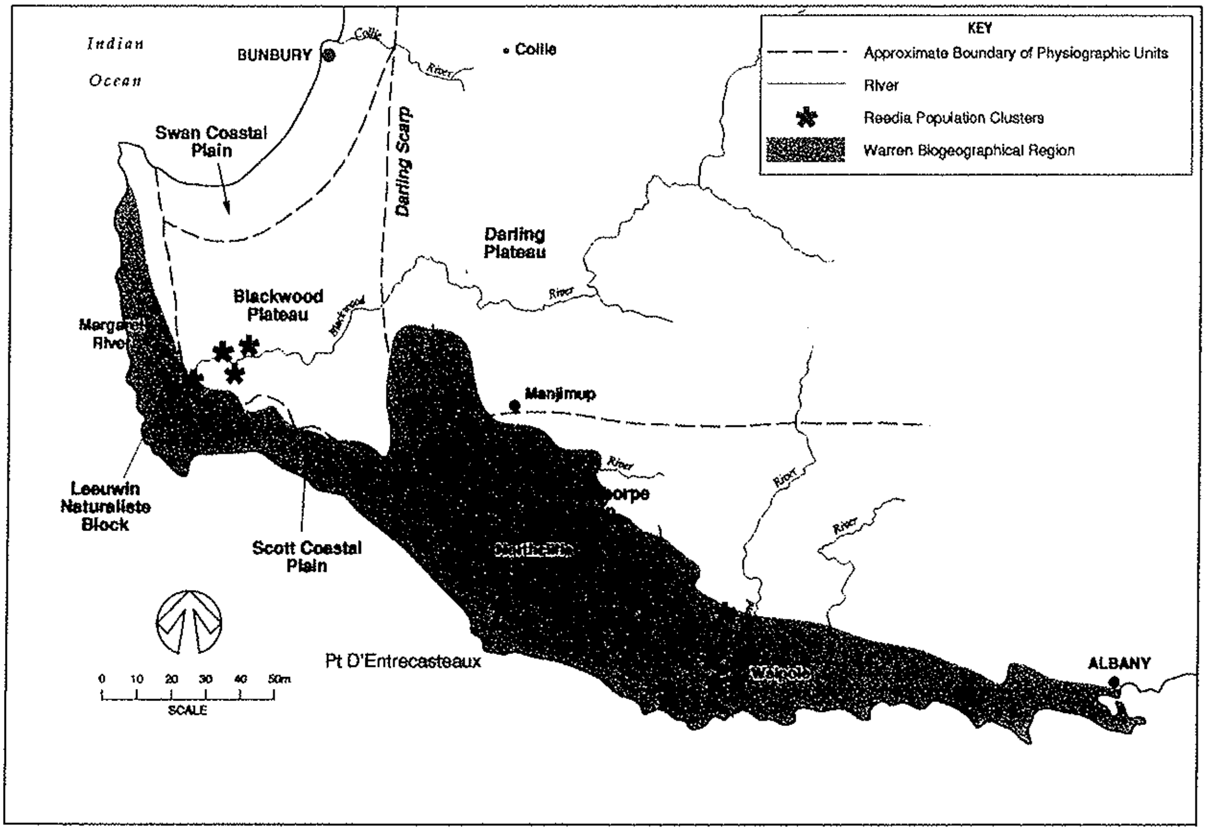


Figure 3.1 Landforms of south-west Western Australia

For practical reasons in this study these two groups of populations are referred to as being located in the Blackwood study area and the Walpole study area. (Fig 1.1). The Blackwood study area is centred on -34°9'3", 115°26'6" and populations are located in State Forest and adjoining farmland. The Walpole study area extends from Walpole to Pt D'Entrecasteaux and inland approximately 30km to Granite Peak. It is centred on -34°55'6", 116°20'10". The Walpole study area is fully contained within the Warren Biogeographical Region whilst the Blackwood study area is located in the extreme south of the Jarrah Forest Biogeographical Region (Thackway & Cresswell 1995). Throughout the remainder of this study the term 'Warren Biogeographical Region' will be used for convenience to refer to the location of both of these groups of *Reedia* populations unless specific details of either of the biogeographical regions are under discussion.

Climate

The climate of the Warren Biogeographical Region has been described as moderate mediterranean (Beard 1981) with warm summers, cool winters, predominantly winter rain and 3-4 drier months per year. Walter (1985) however describes the climate of the Karri zone of south-west Western Australia (which corresponds to the Warren Biogeographical Region) as warm temperate and humid with rainfall ocurring principally in winter and little summer drought. He equated the climate of this region to that of other areas which lie along the western seabords of continents such as the *Sequoia sempervirens* forest zone of northern California and the Valdivian evergreen rain forests of southern Chile. Eastern sides of continents which are host to a more humid sub-type of this climate, according to Walter (1985), include areas such as: Florida and North Carolina in North America; the south east coast of South Africa, parts of lowland New Zealand and the *Eucalyptus-Nothofagus* forest zones of eastern Australia.

Mean annual summer and winter temperatures for Margaret River (north west of the Blackwood study area) are 21.2C and 10.7C and for Denmark (the nearest centre to Walpole with long term temperature data) are 20.5C and 9.8C respectively (W A Bureau of Meteorology 2000). Very few days of frost are experienced, on average less than 6 days per year at Denmark, with less than 2 days per year frost at Margaret River.

The highest rainfall zone in the south west of Western Australia, with a mean rainfall in excess of up to 1400 mm p.a. and annual evaporation of 1000 mm p.a. or less (W A Bureau of Meteorology 2000), extends through coastal areas from Walpole to where the Donnelly River emerges from the Darling Scarp, north-west of Northcliffe (Fig 3.2, adapted from Gentilli 1989). Annual rainfall declines rapidly inland from this zone. Another small zone of similar high mean annual rainfall (>1300mm p.a.) occurs on the Blackwood Plateau east of Margaret River. Mean solar radiation in the Warrren Biogeographical Region is amongst the lowest in Australia, partly due to cloud cover. Mean solar radiation of 14-16 MJ/cm^2/ day (Nix 1981) occurring in this region is comparable to that of central Tasmania and southern Victoria. Consequently the Warren Biogeographical Region can be regarded as being located in a zone of high humidity (Fig 3.2).[5] The Walpole study area, and to a lesser degree the

---

[5] Humidity for the purposes of this discussion is defined as the difference between mean annual rainfall and mean total summer evaporation as illustrated in Fig 3.2 which has been adapted from Gentilli (1989).

Blackwood study area, do not experience a prolonged summer drought as occurs north and north east from these areas. For example, long term records of the W A Bureau of Meteorology (2000), indicate Walpole experiences, on average, one month per year in summer with a mean monthly rainfall of less than 30mm compared to Perth's five months per year of low rainfall in this range. *Reedia* population clusters are concentrated in the highest zones of humidity (as defined above) south- west of Walpole and adjacent to Walpole. However *Reedia* occurs in zones of humidity as low as 600-700mm at Granite Peak north of Walpole and on the Blackwood Plateau. Zones of comparable humidity also occur on the Darling Plateau west of Collie and at Dwellingup but there are no records of *Reedia* from these localities.

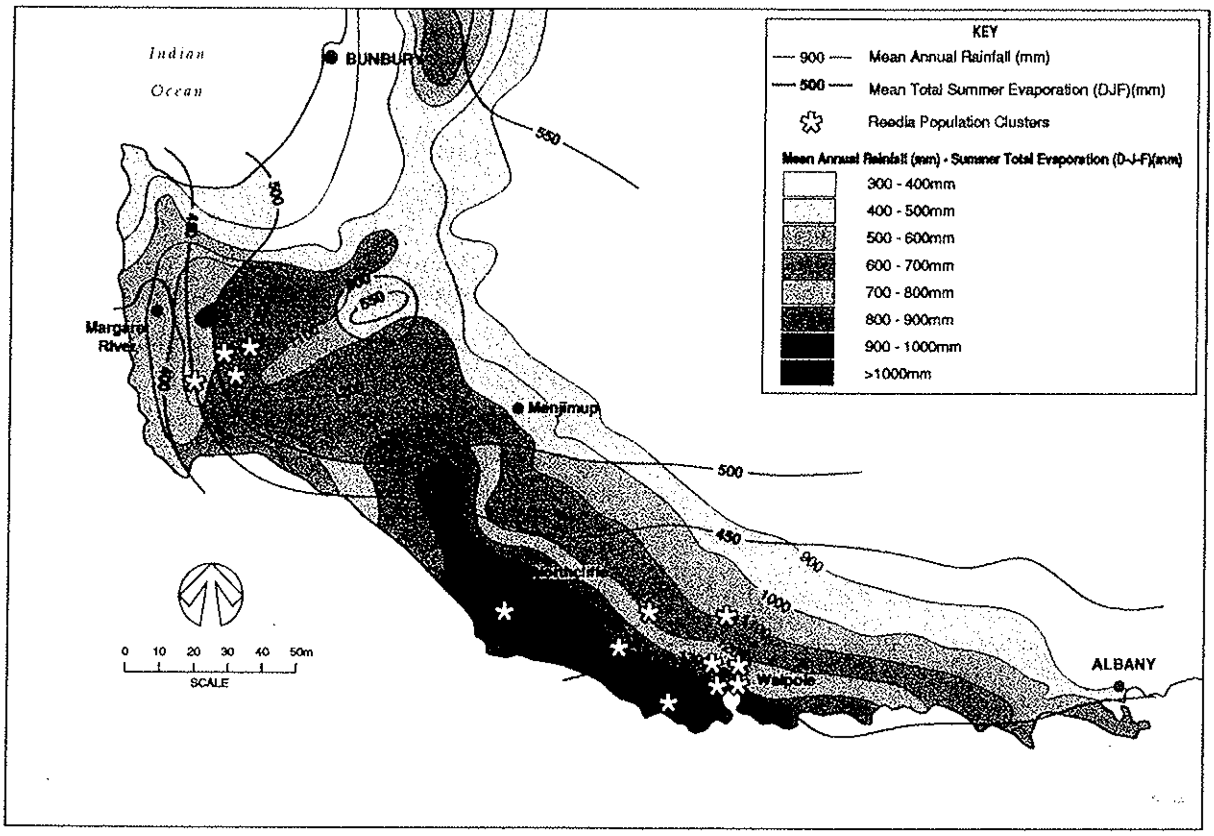


Figure 3.2 Rainfall and evaporation in South-west Western Australia (adapted from Gentilli 1989)

Geology

The Blackwood study area is located near the southern end of the Perth Basin, that in this region lies between the Archaean Yilgarn Craton in the east and the Proterozoic Leeuwin Complex in the west. Baddock (1993) described the geology and hydrogeology of this area. Rifting, associated with the separation of southern Australia from the rest of Gondwana, resulted in block–faulted breakup. The Darling Fault marks the eastern boundary of the Perth Basin and the Dunsborough Fault its western boundary with the Leeuwin Complex. Several other faults run north/south in this area. Cretaceous rocks from the upper part of much of the southern Perth Basin are relatively unfaulted. The Cretaceous rocks are superficially lateritized and covered by shallow Quaternary aeolian sands in some areas (Baddock 1993).

The Albany Fraser Orogen, consisting of Proterozoic granite and gneiss, forms the foundation of the Walpole study area (Wilde & Walker 1984). To the north this adjoins the Archaean Yilgarn Craton. The bedrock of the area is covered with extensive areas of saprolite (*in- situ* weathered bedrock), laterite and Tertiary and Quaternary estuarine sediments within areas that were flooded at times by higher sea levels (V&C Semeniuk Research Group, 1999).

Landforms and Stratigraphy

The Blackwood study area is located on the Blackwood Plateau, which is a dissected plateau ranging in elevation from about 150m AHD in the north to about 40m AHD in the south. It is dissected by small watercourses draining into the middle Blackwood River. Adjoining the Blackwood Plateau in the east is the Darling Scarp and the higher Darling Plateau. A less well-defined scarp occurs between the Blackwood Plateau and the Scott Costal Plain to the south. The Walpole study area, described by Wilde & Walker (1984), is encompassed by the Ravensthorpe Ramp (Cope 1975), which formed when Australia separated from Antarctica. This ramp descends gradually from a geomorphic feature known as the Jarrahwood Axis on the Yilgarn Plateau (about 100 km inland) down to the south coast. Secondary smaller-scale geomorphic units are the Precambrian hinterland, inland Tertiary alluvial valleys and flats and the coastal zone. The hinterland consists of dissected plateaus and ranges with broad steep-sided valleys and short young drainage lines running down the ramp. Major watercourses are the Frankland River and the Warren –Tone River. Tertiary alluvial deposits underlie the floors of wider shallow valleys. The coastal belt (V&C Semeniuk Research Group 1999) comprises: Holocene dunes of calcareous sands; Pleistocene dunes of unconsolidated quartz sands or limestone and Tertiary estuarine flats. Twenty four consanguineous suites of wetlands were identified in the Walpole to D'Entrecasteaux region (V&C Semeniuk Research Group 1997). These included the Walpole River suite which was described as a suite of paluslopes sometimes associated with microscale creeks (Table 3.1).

Table 3.1. Characteristics of the Walpole River wetland consanguineous suite (from V& C Semeniuk Research Group, 1997).

Wetland suite	Geologic/ geomorphic framework	Description of wetlands	Stratigraphy	Origin of wetlands
Walpole River suite	Tertiary colluvium flats and slopes	Paluslopes:sometimes associated with microscale creeks; vegetation maculiform; groundwater fresh.	Slopes underlain by quartz sand which overlies coffee rock, over sandy mud and silt, or by a sequence of black peat over peaty sand over sand. Creeks underlain by peaty sand overlying layers of black to brown muddy sand and black terrestrial clay, over quartz sand.	Some soil horizons create a perched aquifer above the regional water table.

Throughout the Walpole study area, exposed bedrock occurs as granite and gneiss monadnocks and saprolite (often lateritized) mantles hills and slopes. Tertiary colluvial sands and muds are present on slopes and flats, more recent alluvial deposits in near- coastal estuarine basins, and peat on slopes and in basins.

3.3 Methods

Location of *Reedia* populations

A comprehensive search was conducted to compile a full list of locations of extant populations of *Reedia*. This search included:

- Perth Herbarium records (Florabase CALM, 1998) and consultation with CALM staff. This yielded 14 extant populations. The location of the Maslin collection east of Alexandra Bridge could not be found and *Reedia* was presumed to be no longer extant there. Royce's Nillup population was presumed to be the ***BR*** site.
- Five additional populations in the Walpole town vicinity, were located in previous studies (V&C Semeniuk Research Group, 1999).
- Correspondence with all Australian capital city herbariums, other researchers (J Bruhl, K Wilson, K Meney) and the literature search did not yield extra populations.

Selection of study transects, sites and parameters monitored

All known populations were plotted on 1:50 000 scale CALM maps, along with isohyets from Department of Water and Rivers data, as an initial assessment of climate and topography.

Transects were established in 12 out of the known 25 *Reedia* populations. Each transect was identified by use of codes referring to nearby landmarks and these are listed in Table 3.3. A large number of *Reedia* populations were included in the study (at least one from each cluster of populations), in order to sample as fully as possible the taxon's climatic and edaphic range.

Reedia populations and adjoining vegetation units at each study transect were mapped using colour aerial photos at a scale of 1: 6250 and ground truthing. Units were defined by the structure of the dominant taxa (height vs % projected foliage cover). Up to three strata of vegetation (rushes and sedges, shrubs and trees) were described in this manner for the sites. The topography of each transect was surveyed using a laser level relative to a zero benchmark at the top of each transect where the first study site was located.

Site positions within each transect were chosen to be representative of small scale topographical units discerned down the slopes, the *Reedia* vegetation assemblage and adjacent vegetation units. Each transect had at least one study site in the *Reedia* vegetation assemblage and at least two other study sites immediately outside the boundaries of the *Reedia* zone. The latter two sites were usually located one upslope and one downslope from the *Reedia* assemblage. A piezometer was installed at each study site. Data was also collected from another site (***ARN2***) in the Walpole area where *Reedia* does not occur but environmental conditions and vegetation appeared similar to the transects inhabited by *Reedia*. A *Reedia* population at Spearwood Swamp (***SS***) (in the Blackwood region), which was severely affected by fire just before the beginning of the study, was not included as a transect. However, a partial set of data was later collected here as it became apparent the location exhibited atypical features compared to the other observed Blackwood *Reedia* populations.

Data collected for each transect site included:

a. An initial description of the stratigraphy and vegetation.

b. Monthly monitoring of rainfall, water table levels, salinity and pH of all waters (from May 98 to October 99) at the beginning of each month (except for several omissions through the study due to flood, fire or other site access problems).

c. One determination (April 1999) in all sites of soil moisture and soil organic matter from upper layers of soil.

d. One determination (September 1999) in all sites of soluble Mg, Ca, Na, K, Fe, Al, Zn, S, PO_4, NH_4 and NO_3 of the piezometer and surface waters.

Stratigraphy and Hydrology

Stratigraphy and hydrology methods generally followed that of V&C Semeniuk Research Group (1999). Water levels and water chemistry was monitored via piezometers installed in the sites in April 1998 and later in the study. Piezometers were made from slotted PVC pipe. At some sites more than one piezometer was installed as statigraphy indicated complex hydrology. The lengths of piezometers ranged from 30cm to 420cm. In two transects, ***CR*** and ***SHE,*** the piezometers were lost to fire in November 1998 and December 1999 respectively and were replaced. Where the perched water table was seasonal rather than permanent, the minimum water table value for the perched watertable aquifer was recorded as that of the corresponding deep aquifer. This represented a conservative estimate of depth to water table at the driest time of the year.

Simple rain gauges were constructed from PVC pipes surmounted by a large plastic funnel packed with fibreglass aquarium filter wool to filter debris and reduce evaporation. Rain gauges were installed for ***WB, PR, SHE, GP, CDS,*** and ***BR / AB.*** Rainfall data from the Walpole Post Office was used for sites within 10 km of Walpole (***CMB, CR, AR, SB, CT***). Volume of rainwater collected was converted to standard units (mm) by dividing the volume by the surface area of the funnel mouth.

The piezometers were monitored monthly for water levels (to the nearest cm) and water samples were collected. Seepage of water into piezometers was extremely slow at some sites therefore it was not practical to empty the piezometers prior to water sampling.

pH was measured in the field with a Eutech portable pH meter accurate to 0.2 units. The meter was calibrated at least once per day with a standard pH 4 solution made freshly each time. Water samples were frozen at the end of each field trip, re-thawed in the lab and conductivity measured with a Eutech portable TDS meter calibrated with a conductivity standard (1,413MS/cm @25C). Conductivity was automatically converted to total dissolved solids or salinity (ppm) by the meter. It was not necessary to filter these samples as most were either initially clear of particles or the supernatant was clear of particulate matter after the bottles had stood undisturbed to thaw overnight.

Water samples (100ml) for analysis of nutrients and other elements were collected in September 1999. These were filtered in the field, placed on ice and frozen at the end of each day. Water samples were analyzed for cations, other soluble elements and nutrients by inductive-coupled emission spectrometry for soluble Mg, Ca, Na, K, Zn, S, Fe, Al and atomic absorption spectrometry for PO_4, NO_3 and NH_4.

Stratigraphy at each selected site was investigated by manually augering, collecting sediments at 10 cm intervals and recording their characteristics. These comprised visual textural character, colour, presence of organic matter and general moisture. The on-site stratigraphic observations formed the basis for decisions regarding the installation of the piezometers. The sediment samples were later examined in the laboratory with a stereoscopic microscope and analyzed for moisture and organic matter content to verify field observations. The moisture content (% by weight) of samples collected in the driest month, April (Bureau of Meteorology, 2000) was determined by oven-drying pre-weighed soil samples at 110° C to constant weight. Soil organic matter was determined by % dry weight loss on ignition (combusting the dried soil samples for 4 hours at 550° C). The stratigraphy of sites was described directly by the properties of the materials encountered without resorting to soil horizon description and soil nomenclature. For the purposes of recording stratigraphy, peat was defined as organic mud-sized particles and field assessment was checked by organic matter determination as above. The Wentworth Scale (Krumbein & Pettijohn, 1938) (Table 3.2), a geometric scale used in geology and hydrogeology, was employed to categorize grainsizes of particles.

Table 3.2: The Wentworth Scale of grain size classes and grain size terms.

Size class of grains (µm)	Grain size term
>2000	gravel
2000-1000	very coarse sand
1000-500	coarse sand
500-250	medium sand
250-125	fine sand
125-63	very fine sand
<63 (63-4)	mud (silt)
<63 (4)	mud (clay)

Textural characteristics of the materials were defined by the size of the particles which formed the support framework of the material and the size and proportion of particles interstitial to this framework (V& C Semeniuk Research Group 1999). Classes of sediments were thus:

Sand: sand-sized particles dominant i.e. <10% mud or organic matter ;

Muddy sand (or peaty sand): a dominant sand frame with mud-sized mineral (or organic) interstitial particles i.e. mud (or peat) content 10-40% by volume;

Sandy mud (or sandy peat): mud (or peat) dominant and supporting sand grains i.e sand 10-40% by volume;

Mud (or Peat): mud-sized mineral (or organic) particles dominant i.e. content of peat >90%.

Nomenclature of wetland types follows the geomorphic classification of Semeniuk (1988) and Semeniuk & Semeniuk (1995).

3.4 Results

Twelve locations (Table 3.3) were chosen for inclusion as transects in the study.

Table 3.3. Study transect location and characteristics.

Code	Location	Mean Annual Precipitation (mm p.a.)	Landform
AB	Adelaide Brook Blackwood Plateau	1100-1200	Valley floor near head of small tributary of Blackwood River.
AR	Angove Rd Walpole	1300-1400	Valley slope of Walpole River Valley.
BR	Blackwood Rd Blackwood Plateau	1100-1200	Valley floor of small tributary of the Blackwood River.
CDS	Mt Chudelup Northcliffe	1400+	Seaward slope of a dune on the flanks of Mt Chudelup.
CMB	Knoll Drive Walpole	1300-1400	Slope adjacent to Walpole Inlet.
CR	Cemetery Rd Walpole	1300-1400	Slope at the head of valley. Collier Creek headwaters.
CT	Chugg St Walpole	1300-1400	Slope of Butler Creek Valley.
GP	Mitchell Rd Granite Peak	1100	Slope at head of valley tract on flanks of Granite Peak.
PR	Pingerup Rd D'Entrecasteaux NP	1400+	Slope of valley tract: tributary of the lower Shannon River.
SB	Sandy Beach Walpole	1300-1400	Slope adjacent to Nornalup Inlet. 6
SHE	Shannon Airstrip S W Highway	1100-1200	Slope at head of valley, ?headwater of Weld River.
WB	Woolbale Hills Crystal Springs	1400+	Slope and valley floor of small tributary of Broke Inlet.

Of the four known populations in the Blackwood study area the only population in near to pristine condition was the Blackwood Rd population (***BR***). Other sites at the Blackwood study area showed disturbance due to feral pig grazing, fire or both of these. In most other populations the condition of the vegetation was in near to pristine condition except for disturbance due to fire during the study at ***CR*** and ***SHE,*** evidence of severe fire at ***GP*** and ***PR*** and damage to vegetation by feral pigs at ***PR***. Only one naturalized alien plant was recorded in the study. This was *Histiopteris incisa*[6] which became established at ***CR3*** after the fire described above.

After preliminary assessment of rainfall isohyets, landforms, soils, and vegetation units inhabited by known *Reedia* populations, it was possible to predict the likely locations of additional populations. A further aerial search was conducted and six additional populations were found at Chesapeake Brook (lower Shannon), Pingerup Rd, Nelson Rd north of Shannon airstrip, Woolbale Hills and adjacent to the Walpole airstrip.

The hydrological trends of the study transects will be discussed with reference to transects ***BR***, ***SHE***, ***AR*** and ***WB***. Results from ***CR, PR, CDS*** and ***AB*** are presented in Appendix 2 and will be discussed only briefly in this chapter and relevant data from this study will be included in Chapter 4. The hydrology of ***CMB, SB, GP, CT*** and ***AR*** will be reported in detail elsewhere (Semeniuk *et al.* in prep.) but relevant data will be included in Chapter 4. Transect setting in terms of stratigraphy, landform, vegetation, hydrographs, rainfall patterns and salinites for waters in the transects are summarized by diagrammatic cross sections (Figs 3.3-3.6 and Appendix 1).

The environmental characteristics of the study sites are summarized in Table 4.3 and will be discussed in Chapter 4. The complete environmental database is presented in Appendix 3.

3.4.1 Blackwood Rd Transect (*BR*)

This transect is located in the narrow and shallow valley of a small watercourse which drains to the Blackwood River (Fig 3.3) (see also Fig 1.2). Vegetation comprises a diverse sedgeland dominated by *Reedia spathacea* in the valley, with taller shrubs (mainly *Agonis linearifolia)* edging the watercourse and the valley floor transition to *Eucalyptus marginata/Eucalyptus megacarpa* forest uplands. The stratigraphy of the sites investigated is relatively uniform. The upland site ***BR1*** constitutes a cream coloured muddy sand (below a shallow humified zone) with sandy mud at depth. Minor ferruginous mottling is present in the zone of seasonal

---

[6] *Histiopteris incisa* is considered as a naturalized alien species in this study. This species is otherwise recorded from the Kimberley Region of Western Australia (Florabase 1998) and from the Walpole –Denmark area by Wardell –Johnson (1999).

fluctuation of the water table between about 50 and 100 cm below the surface of the soil. The wetland sites are underlain by similar materials however these are dark grey in colour. Soil texture of the wetland sites varies with muddy sand surface sediments in the watercourse (***BR4***) and sandy mud surface sediments at the outer edge of the valley floor (***BR2***).

The hydrographs (Fig 3.3) showed water level fluctuations at each of the four sites conforming to the annual precipitation pattern with highest water levels in spring and lowest levels at the end of autumn. Water levels in the sites ***BR4, BR3*** and ***BR2*** were perennially high and reached higher maxima than ***BR1.*** The amplitude of seasonal fluctuation at the former sites was also less than that at ***BR1***.

Water salinity monitoring at this transect (Fig 3.3) showed that in general rainwater was the least saline, groundwater salinity at ***BR4*** was higher than rainwater and also comparable to that of groundwater at ***BR3.*** Surface waters (***BR4***sw, ***BR3***sw and ***BR2***sw) were of a comparable low salinity. Groundwater at ***BR2*** fluctuated greatly with values spiking to nearly 450 ppm at the beginning of winter but stabilizing for the rest of the year at about 200 ppm. The latter salinity was comparable to groundwaters at ***BR4*** and ***BR3***.

The pH of the waters at ***BR*** (Fig 3.3) did not fluctuate greatly through the year. ***BR2*** and ***BR1*** showed consistently more acidic groundwater than the circumneutral waters of ***BR3*** and ***BR4***. The other transect from the Blackwood study area (Adelaide Brook) (Appendix 1) showed similar stratigraphy and hydrology to ***BR.*** However a thick layer of superficial sand covered the sandy mud of the upland at ***AB5***. Watertables were generally slightly higher than for ***BR*** and with a lesser amplitude of seasonal fluctuation. There was no surface water at this transect in summer and autumn although surface water was present in winter and spring. Salinity of waters was generally lower than at ***BR*** and did not rise to the high levels of some sites of ***BR*** in autumn and early winter.

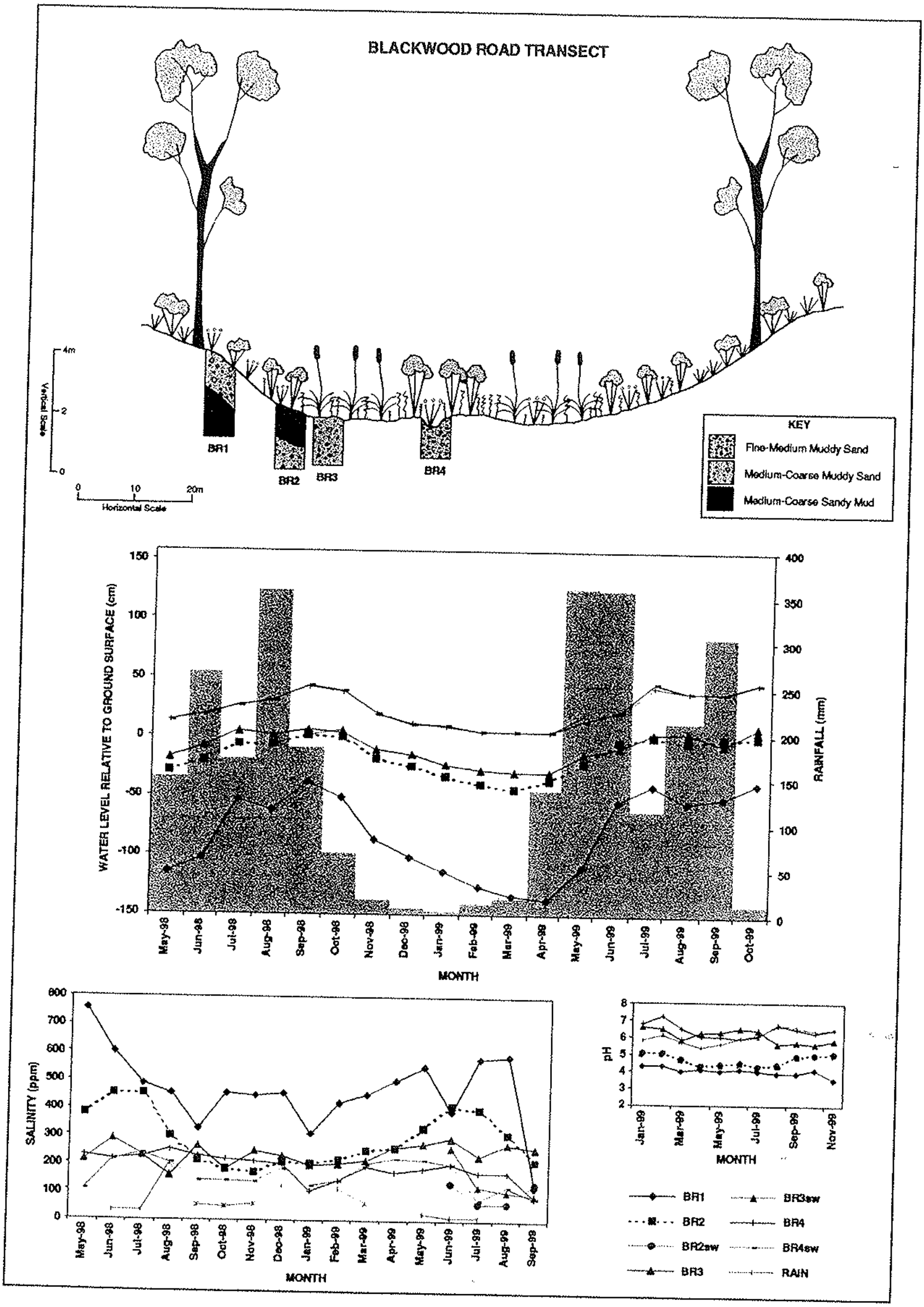


Figure 3.3 Blackwood Road Transect

3.4.2 Shannon Transect (*SHE*)

This transect (Fig 3.4) is located at an elevation of about 80m AHD, on a relatively steep slope (approximately 1m in 10m), at the head of a small valley which appears to be isolated from the current drainage system of the Weld River (a tributary of the Deep River). Upland vegetation at this transect comprises a low woodland of *Eucalyptus marginata* and low diverse shrubs. This is replaced downslope by a *Homalospermum firmum* open scrub over closed rushes/sedges dominated by *Empodisma gracillimum* (with *Reedia spathacea*) and a taller closed scrub at ***SHE3*** with a closed understorey of *Taraxis grossa.*

A sandy colluvium underlies the slope grading to muddy sand at ***SHE3.*** This is overlaid by a peat lens, less than about 1m thick at its maximum, which extends from just below ***SHE1*** to ***SHE3***.

Two piezometers (***SHE2s*** and ***SHE2d***) were installed at site ***SHE2***, intercepting the colluvium and the peat respectively. Water levels at all the sites (Fig 3.4) generally fluctuated in concert with each other and the precipitation pattern. ***SHE2s*** however exhibited a permanent water table which had a considerably smaller amplitude of fluctuation than ***SHE2d***, a subtle difference in fluctuation pattern to the other piezometers and distinctly lower water levels than ***SHE2d*** for most of the year. The upland site ***SHE1*** had the lowest water levels throughout the study. ***SHE3,*** the lowest site on the part of the slope surveyed, showed intermediate water levels. the highest water levels were found at ***SHE2d*** where a piezometric surface of up to 30 cm above the surface of the ground was present for eight months of the year despite surface water being absent from the slope (apart from several centimetres of surface water in shallow depressions of the peat surface). Salinity of waters in this transect (Fig 3.4) was generally lower and more uniform than that at Blackwood Rd above. ***SHE1*** showed the lowest salinity except in late winter and spring when it temporarily exceeded that of all the other sites. ***SHE2s*** was generally slightly more saline than the other waters with the exception of high fluctuations of ***SHE1.*** Rainwater salinity fluctuated from very low salinity to values comparable with the higher levels of ***SHE1***. ***SHE3*** was distinguished from ***SHE1***, ***SHE2s*** and ***SHE2d*** by its considerably less acidic waters.

Stratigraphic and hydrological conditions similar to the above were recorded from transects ***CMB, CDS, GP, SB, PR*** and ***CR***. Piezometric surfaces however were generally not above the surface of the soil in peaty sites (except for ***CMB3d*** and ***GP4***). ***PR*** was a considerably less peaty slope than other transects. Some of the water chemistry trends for these transects will be discussed in Chapter 4.

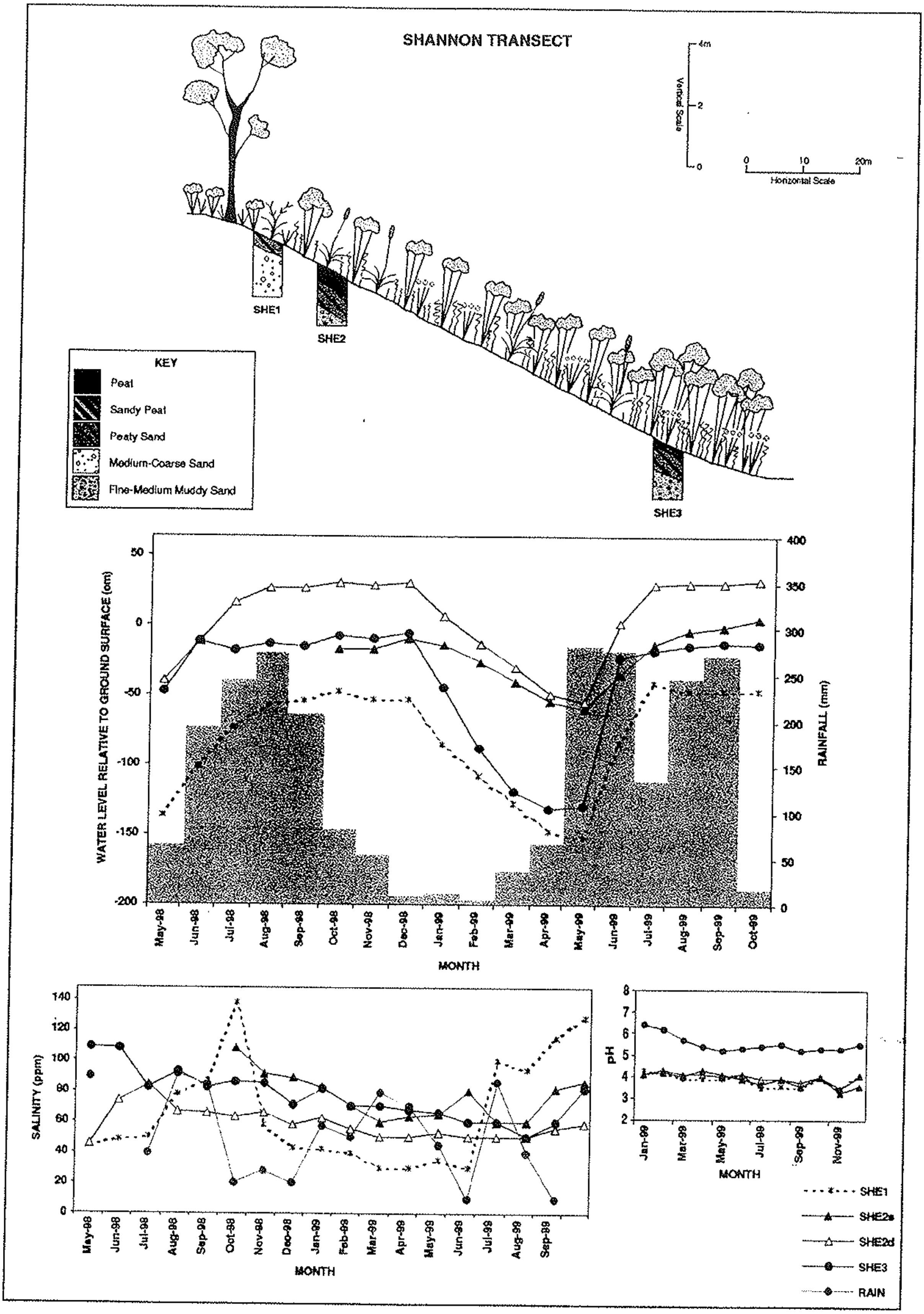


Figure 3.4 Shannon Transect

3.4.3 Angove Rd Transect (*AR*)

This transect (Fig 3.5) is located on a gentle slope (approximately 1m in 26m) at elevation of about 40m AHD in the Walpole River valley. It is vegetated by a low woodland of *Eucalyptus marginata*/*Banksia ilicifolia* upslope from a *Homalospermum firmum* open heath which grades into a sedgeland/open heath dominated by *Reedia spathacea* and *Empodisma gracillimum* above a small cliff about 1m in height. Below this cliff the vegetation consists of an open heath of *H. firmum* with *Evandra aristata* grading to an *Agonis parviceps*/*Anarthria scabra* open heath/sedgeland with emergent *Eucalyptus marginata* shrubs.

The slope is underlaid at depth by a mud layer (which is evident at about 2m at ***AR2*** and ***AR1***). Sandy colluvium grading to muddy sand covers this mud layer from ***AR5*** to the cliff. A wedge of peat, (extending from just above ***AR4*** through ***AR3*** to the cliff), with a maximum thickness of approximately 1m at the cliff end, overlies the colluvium. Muddy sand and sand constitute surface sediments of the slope below the cliff at ***AR2*** and ***AR1***.

As in ***SHE2,*** two piezometers were installed at ***AR3*** (***AR3d*** and ***AR3s***) to intercept the colluvial and peat layers respectively. The lowest water levels of the transect occurred at ***AR5***. Seasonal fluctuations of the watertables at ***AR5*** , ***AR4*** , ***AR3*** and the rainfall exhibited a common pattern. ***AR2*** and ***AR1*** showed steeper rises in the watertable than the latter sites at the beginning of winter and steeper falls at the beginning of summer. These watertables were also more responsive to minor fluctuations in rainfall. The watertable at ***AR1*** and ***AR3s*** were not present for the entire year. ***AR3,*** and ***AR4*** to a lesser degree, showed a piezometric surface exceeding the surface of the soil in winter and spring despite the lack of surface water on this slope.

Salinity of waters for ***AR5***, ***AR4***, ***AR3d*** and ***AR3s*** (Fig 3.5) showed minor seasonal fluctuations within the range of values 40-140 ppm but did not display an easily discernible seasonal pattern. ***AR1*** and ***AR2*** however exceeded this range in summer and a peak of 240 ppm was recorded from ***AR1*** at the start of winter. All waters were very acidic with values ranging between pH 3.5 and 4 throughout the year and minimum values below this in November 1999.

Transect ***CT*** showed similar topography, stratigraphy and hydrology to transect ***AR.***

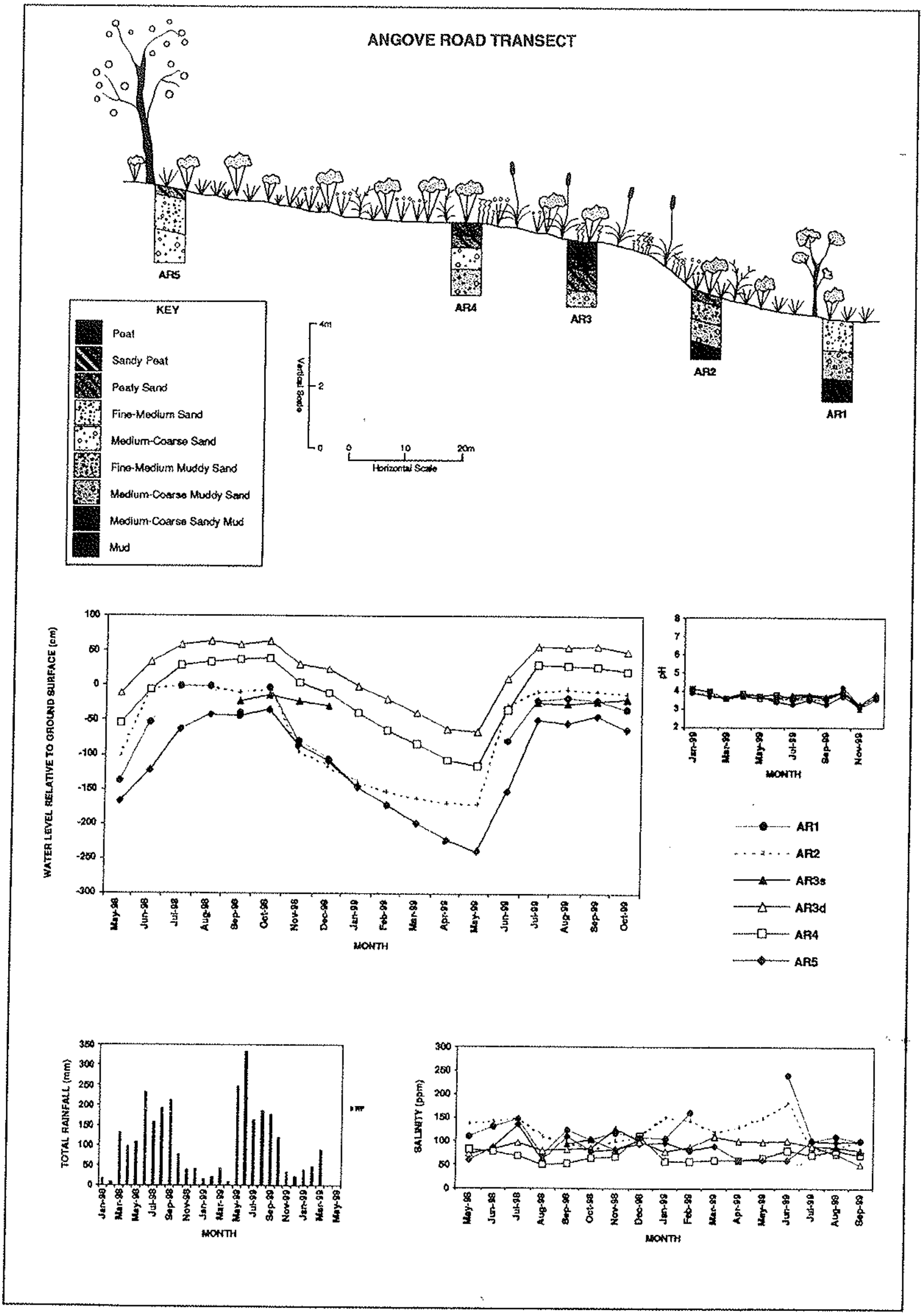


Figure 3.5 Angove Road Transect

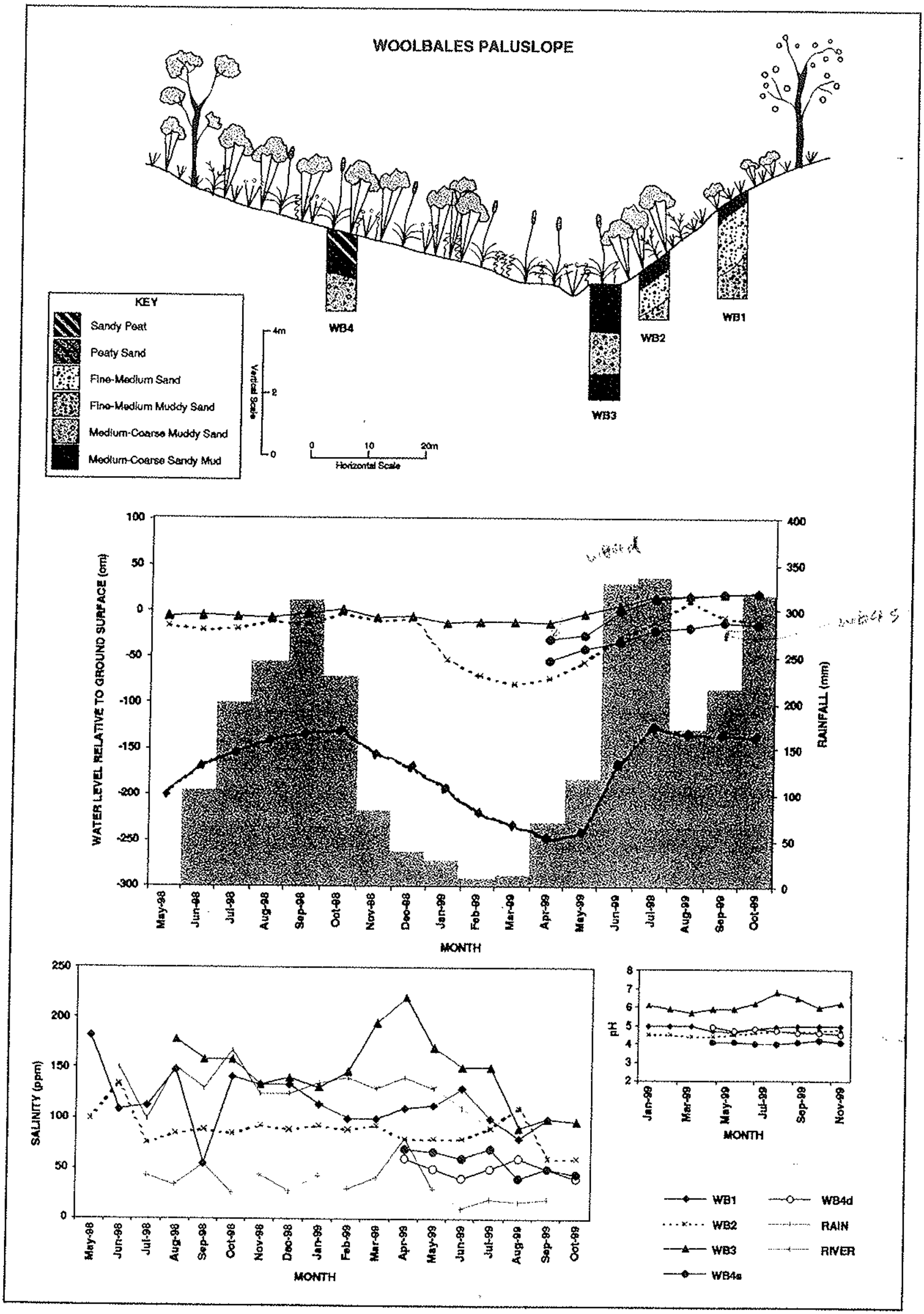
3.4.4 Woolbales Transect (*WB*)

This transect (Fig 3.6) is located on the valley slopes and floor of a small watercourse which drains the Woolbale Hills before entering Brooke Inlet. The two sides of the valley are assymetric with upland vegetation comprising a low open woodland of *Eucalyptus patens* over an open scrub of *Agonis parviceps* and *Anarthria scabra* on one side of the valley and *Banksia ilicifolia* with a diverse heath of *Agonis parviceps* and *Anarthria scabra* on the other side. Downslope these merge into an open scrub of *Homalospermum firmum* and *Reedia spathacea/ Schoenus multiglumis* and a closed scrub of *Homalospermum firmum/Evandra aristata* respectively. A small perennial watercourse runs along the narrow valley floor and is vegetated by *Reedia spathacea, Empodisma gracillimum* and *Baumea rubiginosa* with sparse shrubs of *Agonis linearifolia.*

Sandy mud underlies the valley slopes and constitutes the floor of the valley with an overlying muddy sand colluvium and peat on the gentler slope inhabited by *Reedia* and deep sand on the other steeper slope. Superficial sand lines the bed of the watercourse.

Flowing surface water was present in the watercourse throughout the study period. Two piezometers (***WB4s*** and ***WB4d***) were installed at site ***WB4***, intercepting the colluvium and the peat respectively. A permanent water table persisted at shallow depths in the peat at ***WB4s*** (Fig 3.6). The piezometric surface of ***WB4d*** stood considerably above the surface of the soil for much of the year despite there being no surface water in evidence. ***WB3*** was permanently waterlogged and surface water was present for part of the year especially in the wetter winter and spring of 1999. Further up the slope ***WB2*** was waterlogged for at least six months of the year. Water levels were lowest at ***WB1*** and waterlogging never occurred. All water levels varied in concert with the rainfall however ***WB4s, WB4*** and ***WB3*** had the least amplitudes of fluctuation.

The watercourse generally had constantly high salinity levels (around 150 ppm) compared to the other waters except ***WB3*** but this became fresher in the winter of 1999. The salinity of ***WB3*** rose to a peak of 230 ppm in late autumn but otherwise was similar to that of the watercourse. ***WB3*** was also distinguished from the other sites by its high pH which was within 5.7-6.8 through the year as opposed to the more acid waters of other sites which ranged between pH 4 and 5.2. Rainwater salinity was very low, at times down to 10 ppm the lowest recorded in the study. Salinity of ***WB4s*** and ***WB4d*** was very low and only slightly higher than the rainwater. ***WB2*** and ***WB1*** recorded salinities intermediate to the watercourse and the other slope piezometers.



wetted

waters

should be the same [illegible]

Figure 3.6 Woolbales Transect

3.5 Discussion

At the Blackwood Rd transect there is a permanently inundated small channel with a seasonally inundated flat valley floor (inhabited by *Reedia*) adjacent to it. On these criteria, the wetlands at this site can be described as a microscale river and floodplain respectively (Semeniuk & Semeniuk 1995).

The salinity of the waters showed there were generally two sources of water maintaining these wetlands: groundwater and rainwater. The groundwater level was perennially high with seasonally fresher rainwater overlying this. There was significant surface water flow through the floodplain in winter and spring and this flushing, especially during heavy winter downpours, was not conducive to the accumulation of soil organic matter. (However conditions were suitable for peat formation elsewhere in the district as seen from peat on the slopes of the wider valley tract of the perennial watercourse at the location known as Spearwood Swamp). The upland site showed considerable concentration of water salinity at times and high seasonal fluctuation in water levels and this may be attributed to varying rates of forest vegetation transpiration. The site at the edge of the floodplain showed a flow-on from the upland with fluctuating and sometimes high salinity compared to much more stable water levels and salinity conditions further into the wetland.

Similar conditions occurred at Adelaide Brook with an upslope sand aquifer additionally contributing seepage of fresher water into the wetlands for part of the year. The water levels in the wetland here were generally higher and showed less seasonal fluctuation than at Blackwood Rd, probably due in part to the upland conditions noted above. Permanent inundation was not present anywhere in this system although groundwater was generally higher and surface water was higher than at Blackwood Rd in winter. Therefore the Adelaide Brook wetlands could be classified as a microscale creek with an adjoining floodplain (Semeniuk & Semeniuk 1995).

Perennial streams have rarely been found in the Jarrah Forest even in the high rainfall zone as groundwater discharge is usually exceeded by evapotranspiration from stream-side vegetation as rainfall declines (Stokes 1985). Streamflow normally ceases in December except where local geological formations create unusual conditions which prolong discharge of groundwater (Schofield 1989). The latter appears to be the case in this study at Blackwood

Rd, Adelaide Brook and Spearwood Swamp. In addition, the findings from this study are consistent with Baddock (1993) who investigated the hydrogeology of the southern Blackwood Plateau and the Scott Coastal Plain by deep drilling. Baddock (1993) recorded strong upward piezometric heads into the valleys of tributaries to the Blackwood River and the river itself from what is generally known as the deep regional Leederville aquifer, which is thought to underlie much of the Perth Basin. Baddock (1993) recorded these conditions from several areas including the vicinity of the study transects above, north west of Alexandra Bridge, Darradup and the middle Donnelly River. Chemical analyses of the water from the Leederville aquifer in Baddock(1993) also conform with findings of this study. The Leederville aquifer is located largely in Cretaceous sediments and is recognized as a long standing hydrological feature of the Blackwood Plateau.

Wetland conditions which were very different to those of the Blackwood transects prevailed in *Reedia* populations of the Walpole study area as can be seen from the transects reported above at Shannon, Angove Rd and the Woolbale Hills. Sloping topography characterized all these transects. The surface soil of the slopes which are host to *Reedia* populations at each of the ten Walpole study area transects was waterlogged for at least part of the year and therefore these wetlands could be classified as paluslopes following Semeniuk & Semeniuk (1995). Stratigraphy and water chemistry of these wetlands conforms to those described in general terms by V& C Semeniuk Research Group (1997) as paluslopes and microscale watercourses of the Walpole River consangineous suite. Similar hydrological conditions to those existing on paluslopes of this study were previously described in detail from many slopes around the Walpole and Nornalup Inlets by V & C Semeniuk Research Group (1999). In this study and in some sites of the study of V&C Semeniuk Research Group (1999) piezometric surfaces of many of the deeper bores located in the peaty sections of the paluslopes were well above the surface of the soil for part of the year despite there being negligible surface water present at these sites. This phenomenon is known as artesian pressure and is a characteristic of confined aquifers. The paluslopes of this study are known to be underlain at depth by materials with very low hydraulic conductivity such as saprolite (V&C Semeniuk Research Group 1999), or alluvial mud layers such as were observed at shallow depths in many transects e.g. ***CMB, WB, AR.*** The sandy colluvium observed overlying these aquitards is overlain by peat which often contains a perennial perched water table.

Seasonal changes in the concentrations of dissolved elements in peat interstitial waters and factors contributing to these are complex (Proctor *et al.* 1994). However the trend to increased salinity and lower water levels in peat aquifers in this study in summer and autumn can, at least in part, be attributed to increased evaporation during this period. At sites where the perched water table in the peat layer is only seasonal (such as ***AR3*** and ***SB3***), high moisture levels are never-the-less maintained through to the driest period in autumn due to the very high water holding capacity of peat. Specific physical properties of the permanently waterlogged zone of such perched peat aquifers, which is termed the catotelm (Ivanov 1981), have shown that virtually no vertical or lateral seepage from this peat layer occurs. Movement of water between peat aquifers and the aquifers located in colluvium which underly the peat layers in this study was not investigated. However it was noted that seepage from the confined aquifers located in the colluvium could be impeded by colluvial and alluvial mud at the base of slopes. This situation was particularly evident at the Angove Rd paluslope where there appears to be very little if any seepage from the peat wedge above the small cliff to the slope below as evidenced by both the hydrographs and chemical characteristics of aquifers above and below the peat cliff.

Rainwater infiltration of sands upslope from the paluslopes and sub-surface run off along confining layers at depth both contribute water to the confined aquifers of this study. The salinity of the rainwater reservoirs thus formed below the peat layers varies due to the catenary relationships of the sites such that soluble salts accumulate in the waters of the sites situated lowest in the topographical sequence. Thus efficient water harvesting and conservation mechanisms in these paluslopes create water reservoirs in both the confined aquifer located in colluvial sediments on paluslopes and in the perched peat aquifers which overlie these.

3.6 Conclusions

The constantly high watertables of *Reedia* -inhabited floodplains and paluslopes are maintained by the humid climate and, more importantly, other hydrological factors. Flow from deep regional aquifers, for example the Leederville aquifer in the Blackwood Plateau area, maintains *Reedia*-inhabited floodplains in the Blackwood study area. *Reedia*-inhabited paluslopes occur predominantly in the Walpole study area. Stratigraphy and topography suitable for sub-surface flow, collection of water from large catchments and the establishment of local confined aquifers exists in the Walpole study area and these factors maintain wetlands in the settings where *Reedia* populations occur. Peat formation promoted by almost constantly waterlogged soils in these conditions, by virtue of its high water-holding capacity, provides a constant humid environment.

Therefore in both the Blackwood and the Walpole study areas the *Reedia*-inhabited wetlands are maintained by hydrological mechanisms which result in these wetlands having high resilience with regard to potential climate fluctuations.

Chapter 4: Vegetation assemblages and habitats of *Reedia spathacea* wetlands

4.1 Introduction

Although *Reedia* does not occur commonly, it is generally a major structural component of the twelve wetlands examined in this study. These floodplains of the Blackwood area and paluslopes and floodplains of the Walpole to D'Entrecasteaux area constitute a small sample of the wetlands of the Warren and Jarrah Forest Biogeographical Regions (V& C Semeniuk Research Group 1997). The *Reedia*- inhabited zone of each of these wetlands is hydrologically distinct to the rest of the wetland in each case, being characterized by perennially high water tables such that the surface soil is almost permanently waterlogged in most of this zone at each location. In contrast, the adjoining wetland zones have a shorter hydroperiod. Maintenance of the wetland conditions in the *Reedia*- inhabited zone is through hydrological mechanisms that have the potential to considerably moderate the influence of reduced rainfall conditions, should they occur. These wetland zones thus have a high degree of resilience with regard to climate fluctuation even when compared to adjoining wetland zones. They are particularly resilient when compared with wetlands maintained by the balance of precipitation and evapotranspiration such as those situated on shallow unconfined aquifers such as the Gnangara Mound on the Swan Coastal Plain or other unconfined aquifers identified in the Walpole area by V& C Semeniuk Research Group (1997,1999). Wetlands are often identified by the presence of hydrophilic vegetation typically adapted to life in areas inundated or saturated by water with the appropriate duration and frequency to promote that vegetation. Hydroperiod can be considered on a historical time scale with regard to *Reedia's* persistence in its wetland settings, however a historical biogeographic analysis of this uncommon species should be preceded by an ecological description of its present habitat.

Even in the currently humid Warren region, the relatively stable wetland environment contrasts sharply in vegetation structure, soil type and soil moisture with adjoining upper slopes and ridges, dunes and rock outcrops. This contrast was observed in transects of the study as detailed above and has also been noted by Wardell Johnson and Williams (1996) as sharp ecotones between vegetation units in the region. The inter-assemblage differences within wetlands, for example between the *Reedia* floristic assemblages and those of extensive adjoining wetland vegetation such as *Homalospermum firmum* scrubs, appear to be more subtle (apart from the absence of *Reedia* in the latter). There is however an immediately apparent difference between the Walpole *Reedia* and Blackwood *Reedia* assemblages in both floristics and structure that deserves particular attention.

In this preliminary ecological study I focus on the inter-assemblage or inter-zone differences within particular suites of wetlands. The wetland zones are related and connected to each other via flow of water, soluble elements and plant propagules. However, the *Reedia* populations of the paluslopes are somewhat isolated from the rest of the wetlands by virtue of being more or less dependent on perched peat aquifers which have built up above the deeper mineral soil-based aquifers that support the other vegetation assemblages in these wetlands. With this in mind, some of the hydrological and water chemistry data obtained from the twelve transects chosen to be representative of the habitat of *Reedia* will be examined from a different perspective, along with detailed floristic data to pursue the following research objectives:

to identify and describe the wetland plant assemblages associated with *Reedia spathacea* and the habitat conditions experienced by these assemblages; and to explore the relationships of these assemblages to some of the environmental gradients in these wetlands.

4.2 Methods

Study Sites

The regional setting of the twelve study transects, their locations, stratigraphy and hydrological mechanisms has been described in Chapter 3. Specific details of the location of the study transects, choice of study sites, stratigraphic and hydrological methods are described in the methods of Chapter 3. Vegetation occurring along these transects and sites as mapped during the design of the study are illustrated in transect diagrams (Figs 3.3-3.6 and Appendix 1). Data from one additional site from Walpole (***ARN2***) was included in the study. This site is located on a paluslope underlain by deep peat. It did not support a *Reedia* population but otherwise appeared very similar floristically to *Reedia*- inhabited sites.

Field Studies

1. Floristic study

In November to December 1998, a total of 38 sites were selected from the twelve transects for the floristic study. The majority of sites chosen had been observed to be either waterlogged or inundated for part of the year and could thus be classified as wetland sites. In each transect at least one *Reedia-* inhabited site and two others adjacent to the *Reedia* zone, usually one upslope and one downslope, were included in the floristic study. The quadrat size for sampling the vegetation was determined by recording the number of species in nested quadrats from 0.125 m^2-16 m^2 for each site. The resultant species area curves showed that beyond a quadrat size of 2 m^2 the rate of occurrence of extra taxa declined markedly. The 1 m x1 m quadrat size was therefore selected as being the most practical in the very thick vegetation encountered and suitable for surveying the floristic variation of relatively homogeneous units of vegetation. Ten quadrats were surveyed at each site (i.e. 30 quadrats per transect), ensuring only quadrats falling in the appropriate vegetation zone (as determined in Chapter 3) were included. The immediate surrounds of the piezometers, where vegetation was trampled and inundated vegetation of large peat holes (considered to represent a different habitat to that inhabited by *Reedia*) were avoided. Abundance of each taxon of the vascular flora in each quadrat was recorded as percentage projected foliage cover in the following classes:

0 = not present;
<5% = 1;
6-25%= 2;
26-75%= 3; and
76-100%= 4.

Nomenclature generally followed Paczkowska and Chapman (2000), except for *Sphaerolobium* (Butcher, pers. comm. 2000) and the suprageneric classification of monocotyledenous taxa (Kubitzki, 1998). Data regarding geographic distribution of taxa is from the W A Herbarium FloraBase (1998) and voucher specimens collected in this study are lodged with this Herbarium.

2. Environmental gradient study

Environmental variable data was available from all the 38 sites of the floristic study. Field and laboratory methods for the collection and analysis of the 18 environmental variables selected for investigation are detailed in Chapter 3.

The variables were:
Soil moisture at 30cm below soil surface (late autumn);
Minimum water table level (late autumn);
Maximum water table level (spring);
pH;
Water salinity (measured as specific conductivity) (late autumn and spring);
Spring water chemistry variables: (Mg, Na, Ca, S, Fe, Al, Zn, K, NH_4, NO_3, PO_4); and
Soil organic matter at 10 cm below the soil surface (measured as loss on ignition at 550° C).

3. Data base and Statistical Analysis

A mean % cover for each species over the 10 quadrats at each site was calculated by first converting each cover class value recorded to the mean % of the cover class range. Environmental variable data were range standardized prior to analysis.

Classification was considered the most convenient way of defining probable floristic assemblages. The floristic data set was classified by sites and by species using the numerical, polythetic, sub-divisive classification program TWINSPAN (Hill 1979). The classification of sites was used to determine floristic assemblages. Whilst classification identifies groups of species and/or sites, more precise assessment of individual relationships is possible by ordination since the location of each species and/or site is specified by a set of coordinates.

Ordination of the floristic data set (136 spp, 38 sites) and environmental data set (18 variables, 38 sites) were performed separately (indirect gradient analysis), on sites and species, using detrended correspondence analysis or DECORANA, a subprogram within the CANOCO package (ter Braak 1990).

The relationships between the vegetation patterns identified by the classification and ordination and the environmental patterns identified by ordination were explored as follows. The environmental and vegetation axes generated by DECORANA were tested for correlation with each other and each of the 18 environmental variables. This process allowed the identification of possible environmental factors underlying the observed vegetation pattern. The means of environmental variables for the groups of sites identified by the TWINSPAN classification of the floristic data were compared using t-tests for the two groups at the first division level and single factor ANOVA (at the second division level). Tests of means were carried out by Fisher's Protected LSD (where group variances were homogeneous) or Scheffe's test (where group variances were heterogeneous) after Zar (1998).

A process known as complementary analysis (Kent & Ballard 1988) was then used as a means of creating an overall summary of the vegetation and environmental patterns.

4.3 Results

The structure of this section follows the progression of the data from a summary of the quadrat floristics and environmental variable data through several processes of analysis, each with their own results, to a final synthesis of results in descriptions of the vegetation of the floristic assemblages determined and their habitat. It is thus structured in several sections as below.

1. Floristics are reported as general floristic results; provisional floristic assemblages identified in the classification; and comparison of aspects of the study flora to the regional flora.
2. Environmental variable data for the study sites are presented.
3. The patterns observed in the ordinations performed on the floristic and environmental data are each presented separately.
4. Complementary analysis:
   a. the provisional floristic assemblages superimposed on ordination space of both the floristic and environmental ordinations of sites enables the validation of some of the assemblages identified above and the rejection of others;
   b. the validated assemblages are then shown in terms of the environmental gradients which were determined for the ordinations;
   c. environmental means of these assemblages are used to show habitat differences between the assemblages more clearly; and

d. A description of the floristic assemblages in terms of their vegetation and habitats.is presented incorporating information of landforms they inhabit and their vegetation structure.

1. Floristics

Floristics results of the study are reported as:

a. general results of taxa found and some of their characteristics;
b. floristic supergroups, groups and provisional assemblages identified in the TWINSPAN classification of floristic data by sites; and
c. comparison of the flora of *Reedia* assemblages of this study with the general flora of the region.

a. General results of taxa found and some of their characteristics

The floristic study recorded a total of 136 taxa from the 380 quadrats (1 m x 1 m) at the 38 study sites (Appendix 4). Of these, twelve species endemic to the Warren Biogeographical Region (Lyons *et al.* 2000), many others endemic to the extreme south-west of Western Australia and ten CALM priority species (Florabase 1998) were found (Table 4.1). Families represented in the study included Cyperaceae (15 spp), Papilionaceae (14 spp), Myrtaceae (10 spp), Epacridaceae (9 spp), Restionaceae (8 spp), Goodeniaceae, Droseraceae and Orchidaceae (7 spp each) and Xyridaceae (6 spp). Two previously undescribed sedges, ?*Baumea* sp. Blackwood C Tauss 981 pn and *Lepidosperma* sp. Floodplain C Tauss 982pn, were collected at the Blackwood sites. An undescribed Papillionaceae species of *Sphaerolobium* sp. Chudelup C Tauss 983 pn, was collected at the Chudelup and Blackwood transects. Insufficient material for a positive identification of a ?*Scaevola* sp. was found at a Blackwood study site and further collections need to be made to determine this taxon.

Table 4.1: Priority and endemic species and monotypic genera found in the total study and specifically in *Reedia*-inhabited study sites.

	CALM Priority Species	Monotypic Genus	Warren BioRegion endemic spp.	Species occurring in *Reedia*-inhabited sites
Acidonia microcarpa		*		*
Actinotus laxus			*	*
Amperea protensa	P2		*	*
Aotus cordifolia	P3			
Baxteria australis		*		
Cephalotus follicularis		*		*
Comesperma nudiusculum			*	*
Corybas abditus			*	*
Cosmelia rubra		*		*
Cyathochaeta teretifolia	P3			*
Diaspasis filifolia		*		*
Diplopogon setaceus		*		
Drosera binata	P2			*
Drosera hamiltonii			*	*
Gonocarpus simplex	P3			*
Gymnoschoenus anceps			*	*
Homalospermum firmum		*		*
Reedia spathacea	P4	*		*
Schizaea rupestris	P2			*
Schoenus multiglumis			*	*
Sphaerolobium rostratum	P3		*	*
Sporadanthus rivularis ms	P3			*
Stylidium laciniatum			*	
Taraxis grossa		*		*
Tetratheca filiformis			*	*
Xyris roycei			*	*
Utricularia paulineae			*	*

b. Floristic supergroups, groups and provisional assemblages identified by the TWINSPAN classification of floristic data by site.

The TWINSPAN classification (Fig. 4.1) grouped sites on the basis of their floristic composition. Groups of sites were named by the relevant indicator species for the TWINSPAN divisions which created the group in question or a species which occurred at high constancy in the group. Groups of sites identified at the first and second level and third levels of divisions were called floristic supergroups, floristic groups and provisional floristic assemblages respectively (Fig 4.2), pending analysis of the classification.

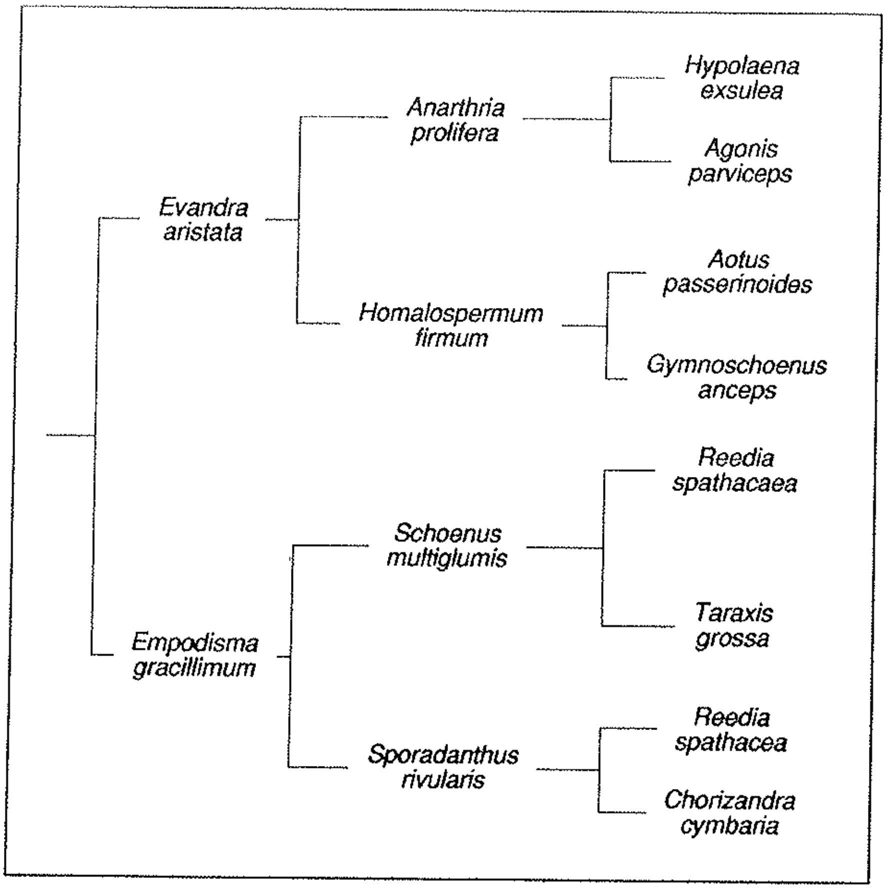


Figure 4.1 TWINSPAN classification of floristic data by sites with indicator species shown

Two distinct provisional floristic assemblages, *Empodisma –Sporadanthus –Reedia* and *Empodisma-Schoenus-Reedia*, associated with *Reedia* at the third level of divisions were thus identified . The twelve Walpole *Reedia* sites, along with four other sites from the Walpole area (***CDS3, GP4, SB4, ARN2***) which were floristically very similar to the *Reedia* sites despite the absence of *Reedia* in them, were placed in the *Empodisma-Schoenus-Reedia* provisional assemblage. The two Blackwood *Reedia* sites, along with two other floristically similar Blackwood sites (***AB3, BR2***) which were not inhabited by *Reedia*, were placed in the *Empodisma-Sporadanthus-Reedia* provisional assemblage. Floristic sister groups of the two *Reedia* provisional assemblages were the *Empodisma-Schoenus-Taraxis* provisional assemblage in the Walpole area and the *Empodisma-Sporadanthus-Chorizandra* provisional assemblage in the Blackwood area. Several classification ambiguities were noted by TWINSPAN.[7]

---

[7] In TWINSPAN classifications there are sometimes uncertain situations where sites or species can be misclassified by the program, however these are notified in the output. In the above classification the following, at the first and third level of division respectively, were noted: ***AR4***, as a misclassification; and ***PR3*** as a marginal group.

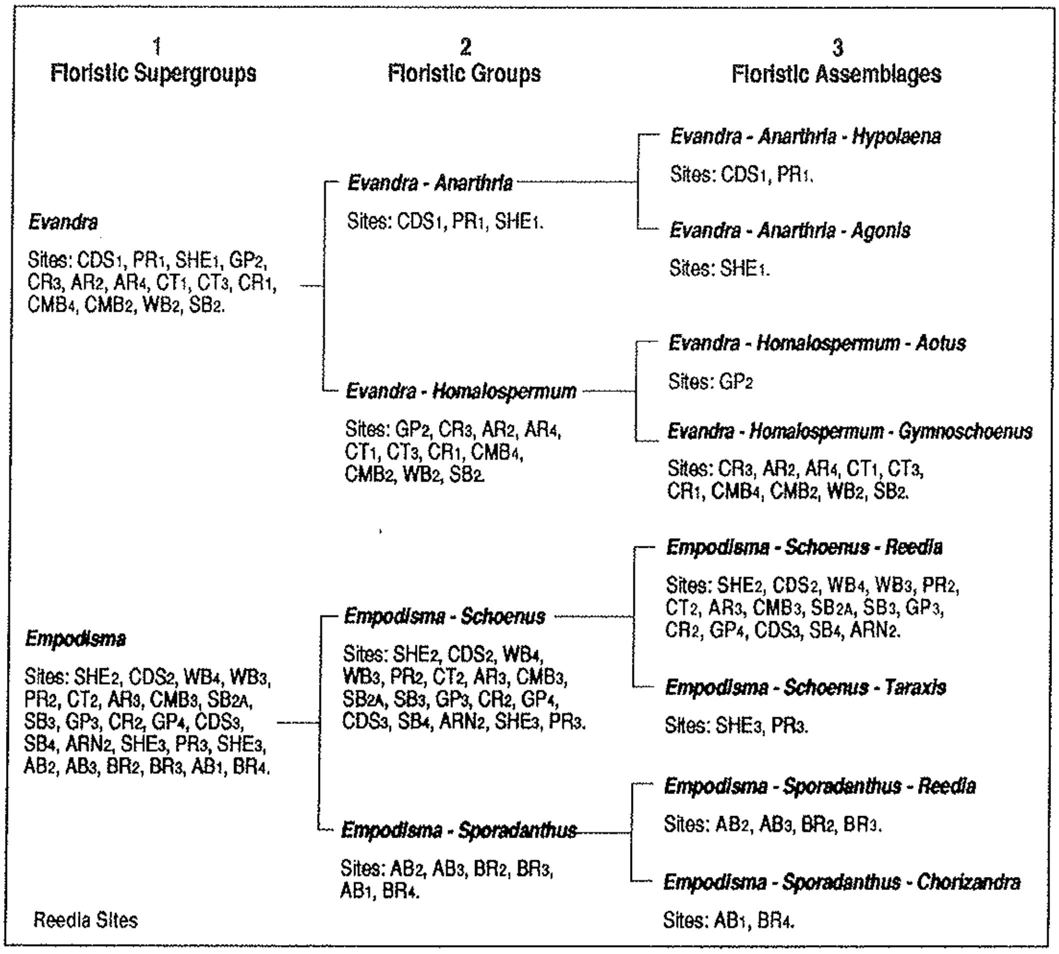


Figure 4.2 Floristic supergroups, groups and provisional assemblages at three TWINSPAN division levels.

c. Comparison of some characteristics the flora of the Walpole and Blackwood study area *Reedia* assemblages with the total known flora of the region.

The Walpole study area *Empodisma-Schoenus-Reedia* provisional assemblage, which will also be referred to as the Walpole *Reedia* assemblage, was found to be disproportionately rich in Warren Biogeographical Region endemic species and phylogenetically isolated taxa (monotypic genera) when compared to estimates of the total regional flora (Lyons *et al.*, 2000) (Table 4.2).

Table 4.2: Characteristics of the flora of the *Empodisma-Schoenus-Reedia* assemblage of this study compared to the total known flora of the Warren Biogeographical Region.

	No. of species (% of regional flora)	No of Warren endemic spp (% of regional flora endemics)	No of monotypic genera (% of regional monotypics)
Walpole *Reedia* assemblage of this study	58 (2.54%)	11 (15%)	7 (47%)
Warren Bioregion flora (Lyons *et al.* 2000)	2283(100%)	72 (100%)	15 (100%)

The *Empodisma-Sporadanthus-Reedia* assemblage from the Blackwood study area (which will also be referred to as the Blackwood *Reedia* assemblage) was found to contain one CALM priority species (*Aotus cordifolia*). A number of taxa for which there are few records in FloraBase and that appear to have a limited distribution and thus be possibly endemic to the wetlands of the Blackwood Plateau were also found: *Platychorda rivalis* ms; *Xyris gracillima*; *Xyris maxima;* and particularly *?Baumea* sp. Blackwood.

2. Environmental Variable Data

Predominantly wetland sites were chosen for this study and the environmental characteristics of the 38 study sites (Table 4.3 and Appendix 3) reflect this in the high mean watertable levels and high mean soil moisture values in autumn. It is difficult to classify the wetlands of this study in terms of their water chemistry and thus compare them to other wetlands in this region and globally. The validity of any such comparisons is questionable anyway considering the differences between wetlands in terms of origin, history, climatic/edaphic setting, vegetation and anthropogenic impacts. In addition, there are no generally accepted water chemistry classification systems in current use (Mitsch & Grosselink 1999). Therefore findings of this study are summarized below, and several general comparisons are made although few conclusions are drawn from these comparisons.

Waters were of acid to circumneutral pH and fresh (as defined by Hammer 1986 for waters with a salinity less than 1000 ppm total dissolved solids). Most waters were below 200 ppm all year, two notable exceptions being those of ***BR2*** and ***CDS3.*** The salinity of the water from these two sites increased to a maximum of around 500 ppm in autumn. Spring water salinity generally was lower than in autumn but some sites showed very little seasonal change. The concentrations of Mg and Ca of waters of this study, were comparable generally, to those reported from 'poor fens' and 'bogs' in Nicholson's (1995) review. Mean Na was comparable to rich fens and maximum Na observed was slightly beyond the range of the wetlands reviewed (Nicholson 1995). Nutrients of most waters in this study were in the oligotrophic to mesotrophic classes (as loosely defined by OECD 1982). These were comparable to, or slightly higher than, waters from pristine sites near Walpole in the study of V&C Semeniuk Research Group (1999). Exceptions to this were two sites ***GP2*** and ***CR3*** which could be classed as eutrophic. These were comparable to those of anthropogenically-influenced sites such as the Walpole Country Club golf course and farmland in the above study.

Soil organic matter ranged widely from low (in sandy and muddy sites) to extremely high values in peaty sites. Paluslope sites ***SB2A, ARN2*** and ***CDS2*** recorded the highest organic matter content and ***SB2A*** and ***ARN2*** had the deepest peats in the study. Upslope sandy sites, downslope muddy sites and floodplain sites were generally low in organic matter.

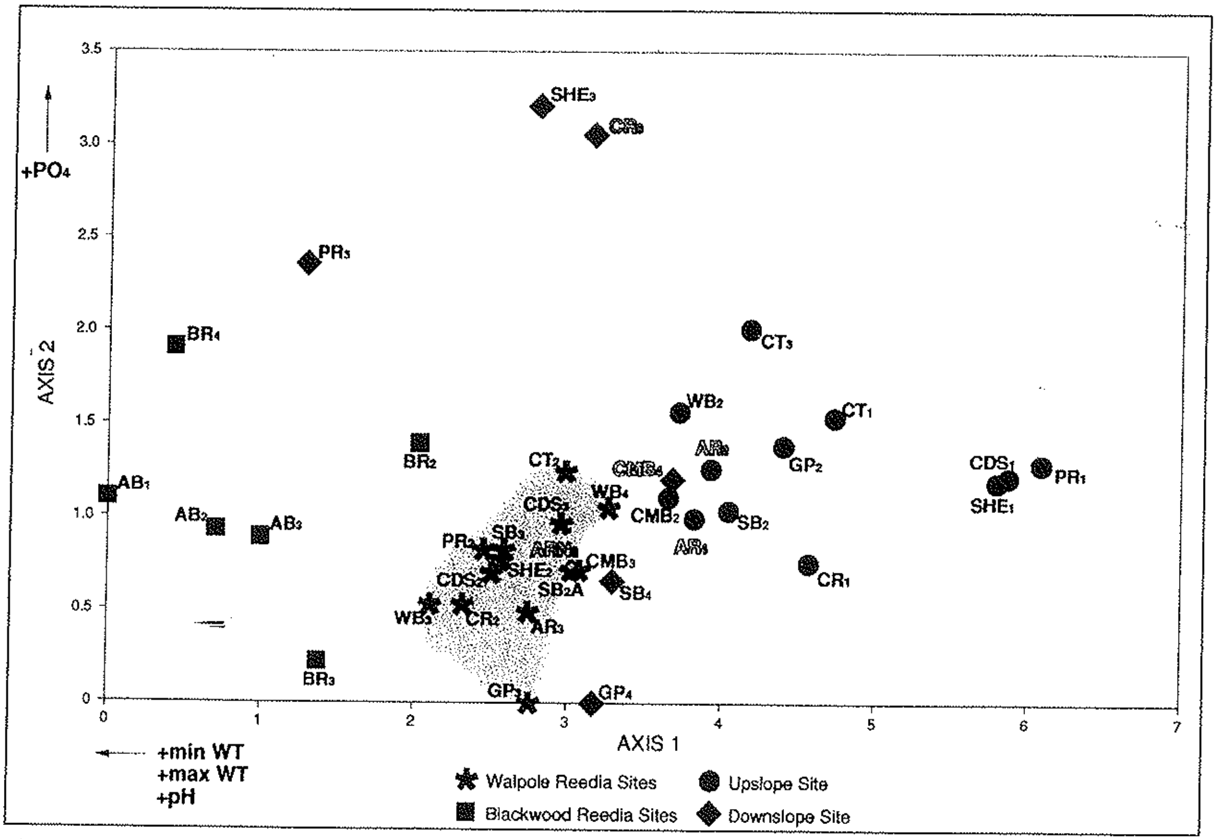
Table 4.3: Summary of environmental characteristics of the 38 study sites.

Variable		Mean	SD	Min	Max
Min water level	cm	-82	56	-190	4
Max water level		-5	22	-65	46
pH (spring)		4.4	0.9	3.4	6.5
Salinity, (autumn)	ppm	141	91	30	500
Salinity, (spring)		105	67	30	310
Na	ppb	25,200	16,000	10,400	84,800
Ca		998	879	330	5350
Mg		2003	1370	810	6990
Al		258	196	150	1300
Fe		66	59	40	340
Zn		70	40	40	160
S		1418	747	500	3800
K		1225	932	40	4490
PO4		90	200	<1	1248
NO3		60	50	9	276
NH4		188	332	<1	2053
Soil moisture	% by wt	44.3	23.5	5.1	77.9
Soil organic matter	% dry wt	40.4	33.2	4.3	98.1

Significant positive correlations were found (Appendix 4), between: soil moisture and minimum annual watertable level; salinity and Na and relationships between base cations (Na , Mg and Ca). Less significantly correlated variables were: pH and maximum annual watertable level; pH and salinity in spring; pH and base cations; Na and K; NH_4 and Zn; NO_3 and organic matter. Negatively correlated variables at this level were pH and organic matter.

3. Ordinations

In the ordination of sites based on floristic data axis 1 vs axis 2 (Fig 4.3), a fairly continuous distribution of sites is shown along axis 1 apart from: three upslope sites (***CDS1***, ***PR1*** and ***SHE1***) which formed a small cluster at high values of the axis; and a concentration of sites (most of which are Walpole *Reedia*-inhabited sites (except ***ARN2***, ***SB4*** and ***GP4***) at intermediate values of this axis. There was also a separation from the other sites of downslope sites ***SHE3***, ***CR3*** and to a lesser extent ***PR3***, which had values high on axis 2, from the other sites. ***GP3*** and ***GP4*** were slightly removed from the Walpole *Reedia* cluster at the lowest values of axis 2. Blackwood sites were separated from Walpole *Reedia*-inhabited sites, and Walpole upland sites, and were located at low values of axis 1 and intermediate to low values of axis 2. Blackwood *Reedia*-inhabited sites were at similar values of axis 2 to the Walpole *Reedia* -inhabited sites. Site ***WB3*** was the closest site of the Walpole *Reedia* cluster to the Blackwood *Reedia* site ***BR3***.



The ordination of species (Fig 4.4) illustrated these two dimensional trends in floristic distribution more fully. The species on this diagram could be viewed as distributed relatively continuously in four directions from a central vacant space, with considerable attenuation of data points towards the high positive levels of axis 1.

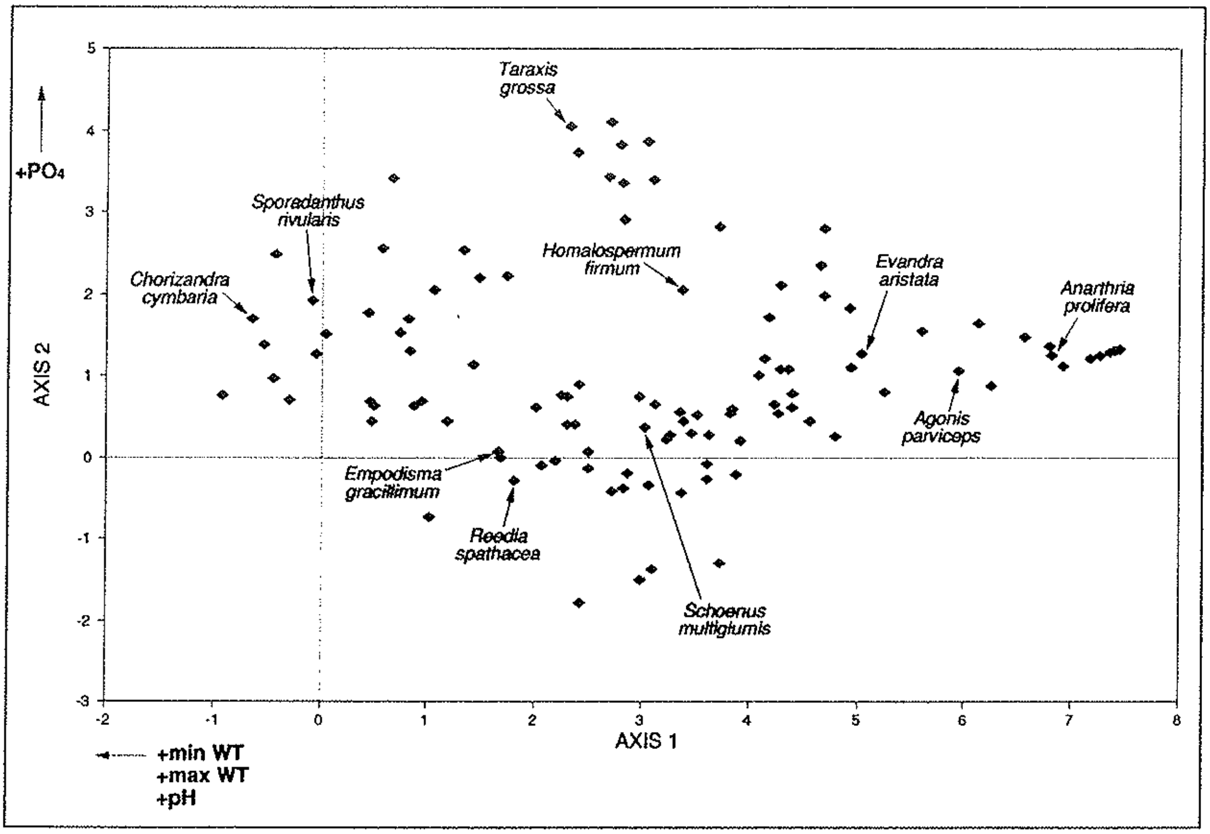


Figure 4.4 Ordination of floristic data by species with indictor species of TWINSPAN floristic groups and assembalages shown

Axis 1 of the floristic ordination showed a negative correlation ($p < 0.001$) with both minimum and maximum water levels and pH (Appendix 4). Axis 2 was less significantly correlated in a positive direction with PO_4 ($p < 0.05$).

In the ordination of the study sites based on the environmental data (Fig 4.5) (axis 1 vs axis 2), the twelve sites inhabited by *Reedia* in the Walpole area formed a cluster well separated from all of the Blackwood area sites. *Reedia* was, however, not present in five sites (***CR3***, ***ARN2***, ***AR4***, ***AR2*** and ***CMB4***) found in the vicinity of the Walpole *Reedia* cluster of this ordination diagram and these sites are called 'anomalous sites' below.) Sites upslope from the *Reedia* zone in Walpole slope transects are shown linked by arrows (Fig 4.5) to the sites downslope from the *Reedia* zone of the same transect with arrowheads indicating the downslope site in each case.

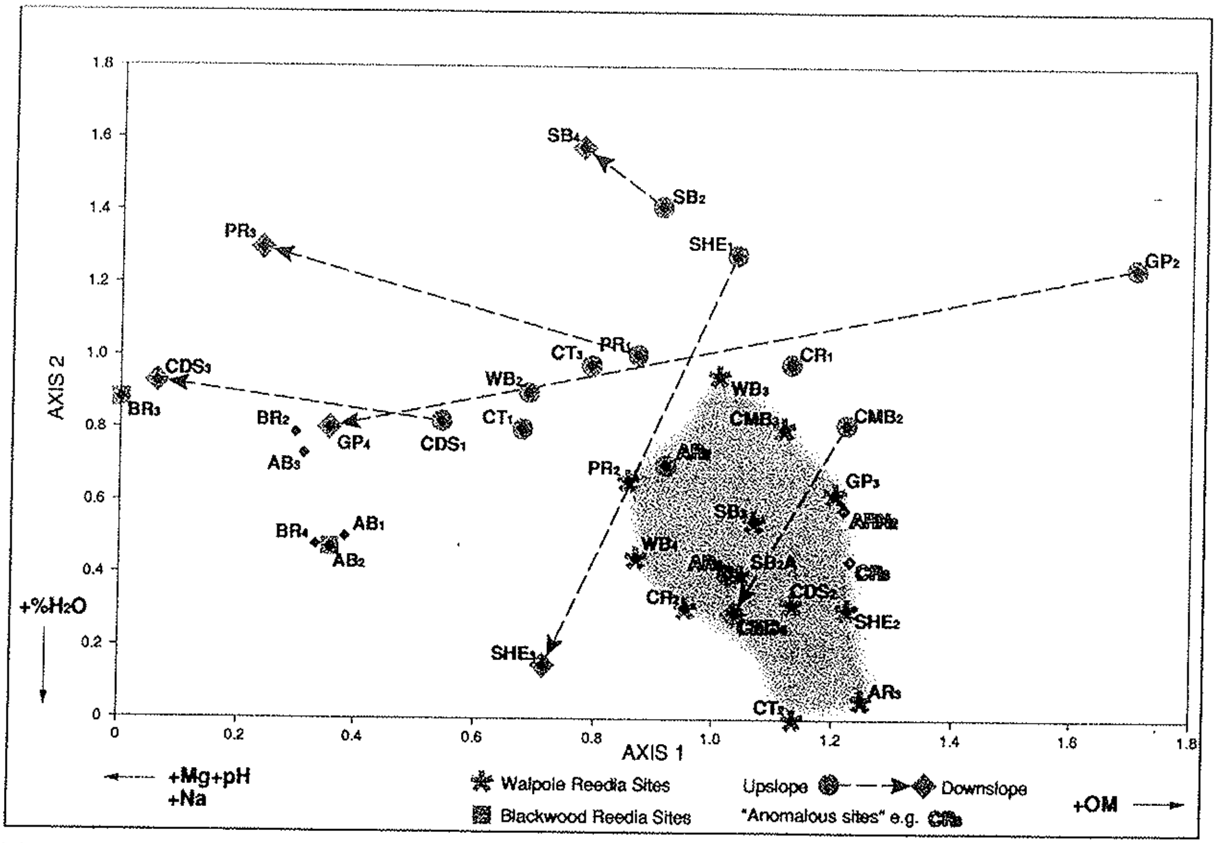


Figure 4.5 Ordination of sites (environmental data)

Base cations (Mg, Na) and pH, were negatively correlated ($p < 0.001$) with axis 1 of the ordination and organic matter content was positively correlated ($p < 0.001$) (Appendix 4). Axis 2 showed a negative correlation ($p < 0.001$) with soil moisture. *Reedia* (in the context of the environmental range of this study) thus inhabits sites of moderate to high soil moisture, low to high organic matter and a wide range of base cation and pH conditions. The Walpole *Reedia* sites cluster at low to intermediate positions on the pH and base cation gradient and moderate to high positions on the soil moisture and soil organic matter content gradient. Sites ***CT2*** and ***AR3*** were somewhat separated from this Walpole *Reedia* cluster. The Blackwood *Reedia* sites were situated at high pH and base cation levels relative to the Walpole *Reedia* sites, low soil organic matter and similar soil moisture levels. The Blackwood sites formed three small clusters with ***BR3*** associating with ***CDS3*** of the Walpole area rather than other Blackwood clusters. ***GP2*** was an outlier from all other sites as were ***PR3*** and ***SHE3*** to a lesser degree. At Walpole paluslope transects, upslope sites had low pH and base cation levels relative to their respective downslope site, with the exception of transects ***CR***, ***WB*** and ***CT***. The absolute values of the base cations and pH differed from transect to transect, but the relationship of upslope to downslope site was constant. Soil moisture in downslope sites was sometimes higher than that of its corresponding upslope site (***GP, SHE, CMB***) and sometimes lower (***SB4***, ***PR3*** and ***CDS3***).

Axis 3 of this ordination was correlated positively with Zn ($p < 0.001$), and negatively with K and positively with NO3 ($p < 0.05$) (Appendix 4). In the third dimension (axis 1 vs axis 3 diagram) of the ordination the 'anomalous sites' (***ARN2***, ***AR4***, ***CMB4***, ***AR2*** and ***CR3***) which were present in the *Reedia* sites cluster are seen to be removed from the cluster (particularly so in the case of ***CR3***). On the other hand, sites ***CT2*** and ***AR3*** (*Reedia*- inhabited sites which were a little removed from the main Walpole *Reedia* sites cluster in the axis 1 vs axis 2 diagram) became consolidated into the Walpole *Reedia* sites cluster. Sites ***SB2*** and ***SB4*** associated more closely with the other non-*Reedia* sites from Walpole and ***CDS3*** remained in association with ***BR3***. ***GP2*** remained a distant outlier from all other sites. ***PR3*** associated more closely with Blackwood sites and ***SHE3*** maintained its distance from ***PR3***, however it associated more closely with other Walpole non- *Reedia* sites.

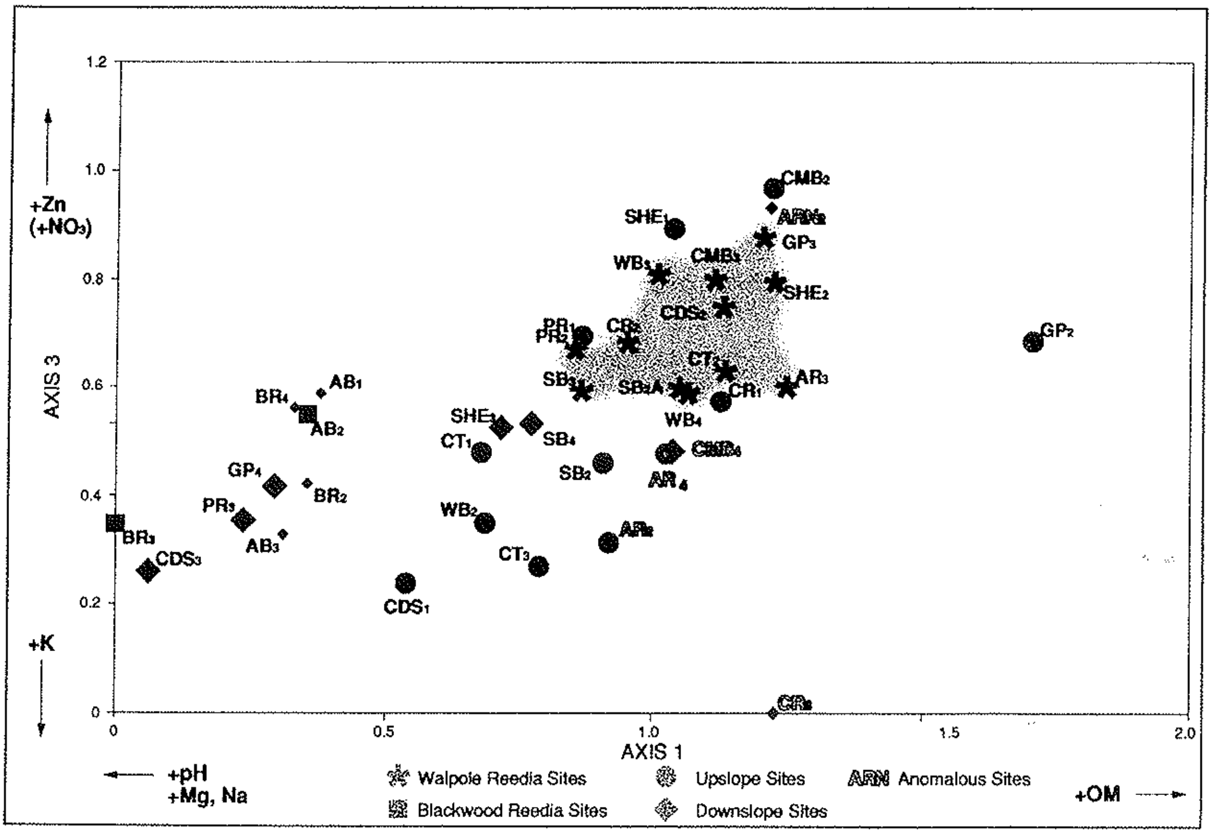


Figure 4.6 Ordination of sites (environmental data)

4. Complementary analysis

a. Classification and ordination

Superimposing the four floristic groups identified by the TWINSPAN classification of floristics, at the second level (Fig 4.2), over the site ordination of the floristic data (axis 1 vs axis 2) (Fig 4.3), enabled a more detailed examination of the floristic groups and provisional floristic assemblages (Fig 4.7).

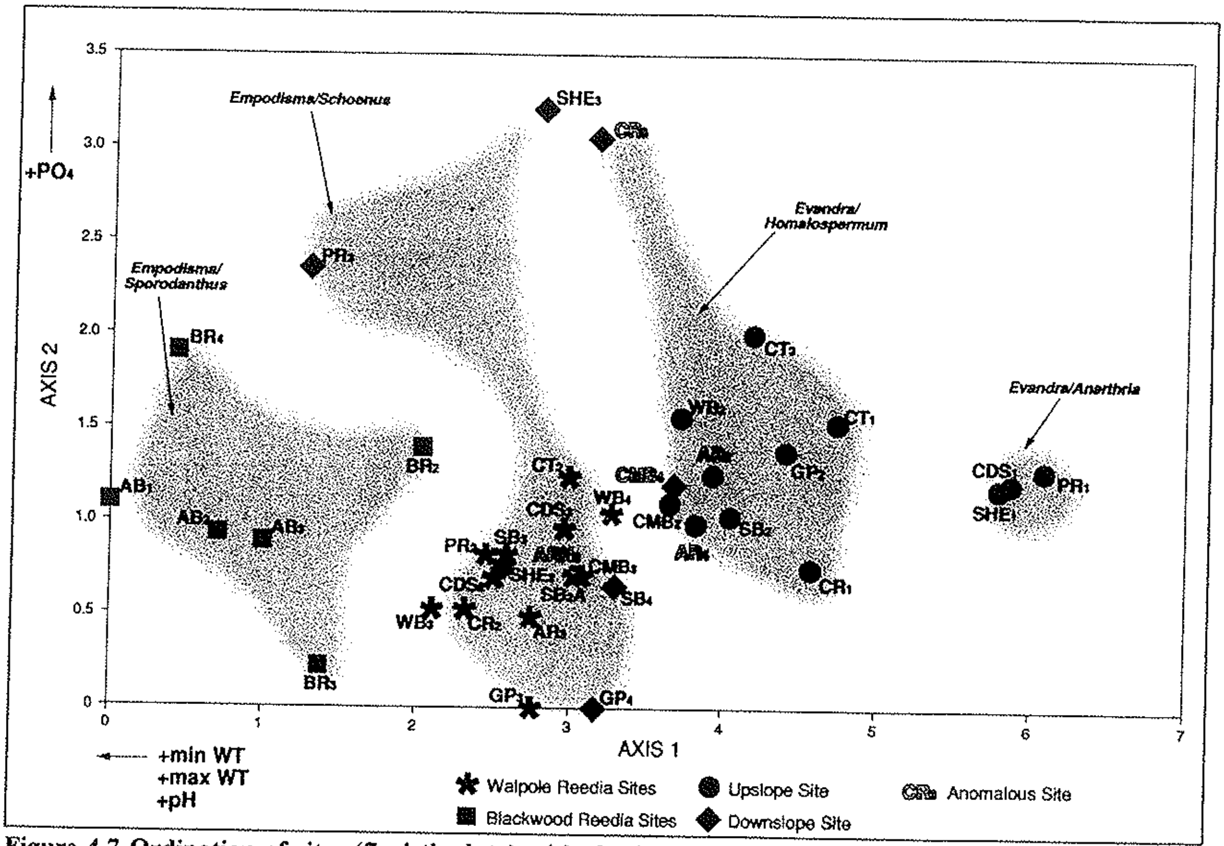


Figure 4.7 Ordination of sites (floristic data) with the four floristic groups of TWINSPAN classification superimposed

The separate cluster of sites low on the watertable and pH gradient corresponded to the *Evandra -Anarthria* floristic group. It was cautiously decided to adopt this floristic group as a valid assemblage of the study without further dividing it into its provisional assemblages due to its coherent nature in the ordination space. However, it was recognized that the database for this assemblage was small and therefore further validation of *Evandra-Anarthria* group is required.

Within the *Empodisma- Schoenus* group, the *Empodisma -Schoenus -Reedia* provisional assemblage was evident as a fairly discrete cluster intermediate on axis 1 and low on axis 2 (Fig 4.7) and this was well separated from its sister group the *Empodisma-Schoenus-Taraxis* provisional assemblage (which consisted of two sites ***PR3*** and ***SHE3***) high on axis 2.

Likewise some separation within *Empodisma-Sporadanthus* of the sister provisional assemblages *Empodisma-Sporadanthus-Reedia* (sites ***AB2, AB3, BR3*** and ***BR2***) and *Empodisma -Sporadanthus-Chorizandra (sites **AB1*** and ***BR4)*** was also evident. Therefore it was decided to adopt the three provisional assemblages *Empodisma-Schoenus -Reedia, Empodisma-Sporadanthus –Reedia* and *Empodisma-Sporadanthus -Chorizandra* as valid assemblages with some reservations regarding the validity of the latter two assemblages due to the small numbers of sites representing these in the database.

The floristic assemblage affiliation of several sites which were isolated in the ordination (Fig 4.7) were examined next. TWINSPAN originally recognised ***PR3*** as having only a marginal position in the *Empodisma-Schoenus-Taraxis* provisional assemblage. This uncertainty in the classification of ***PR3*** can be visualized more clearly by examining its location in ordination space, where ***PR3*** appeared more closely allied in a floristic sense with the Blackwood stream-side site ***BR4*** (of the *Empodisma –Sporadanthus-Chorizandra* assemblage adopted with reservations above) than with the *Empodisma –Schoenus –Reedia* assemblage (as adopted above). Site ***PR3*** was thus adopted into the *Empodisma-Sporadanthus-Chorizandra* assemblage with once more some reservations regarding the small database supporting this decision.

Site ***SHE3*** of the *Empodisma-Schoenus-Taraxis* assemblage was seen on the ordination axes in Fig 4.7 to be very closely allied floristically to ***CR3***. Site ***CR3*** was classified into the *Evandra –Homalospermum* floristic group and finally separated as a singleton at the fourth and last TWINSPAN division (not shown above). From its position in ordination space (Fig 4.7) it appeared that ***CR3*** was more akin floristically to ***SHE3*** and thus could be considered as part of the *Empodisma-Schoenus-Taraxis* provisional assemblage. Thus the *Empodisma-Schoenus-Taraxis* assemblage would consist of two sites ***SHE3*** and ***CR3.*** The latter assemblage was adopted with reservations due to the small database but also due to the status of site ***CR3*** as probably an anthropogenically influenced site.

Site ***GP2*** appeared floristically similar to the rest of the *Evandra-Homalospermum* floristic group in the ordination space whilst the classification separated it from the latter floristic group at the third level into the *Evandra-Homalospermum-Aotus* provisional assemblage. It was decided to retain ***GP2*** in the group *Evandra-Homalospermum* and adopt *Evandra-*

Homalospermum (which formed a cohesive group of 10 sites) as an assemblage. The provisional assemblage *Evandra-Homalospermum-Aotus* was discarded.

b. Final floristic assemblages and their relationships to environmental gradients of the study.

Through the processes employed above the four floristic groups (*Evandra-Anarthria, Evandra-Homalospermum, Empodisma-Schoenus* and *Empodisma-Sporadanthus)* remained valid. There was also justification for adopting the *Empodisma-Schoenus-Reedia* and the *Empodisma-Sporadanthus-Reedia* provisional assemblages (subgroups of *Empodisma-Schoenus* and *Empodisma-Sporadanthus* respectively) as valid assemblages. *Empodisma-Sporadanthus-Chorizandra* and *Empodisma-Schoenus-Taraxis* were less valid as assemblages being based on much less data.

When these assemblages were examined with regard to the environmental gradients of the two ordinations (Figs 4.3, 4.5, 4.6) broadly defined habitat characteristics of the floristic groups and assemblages became evident. Within the ranges of the environmental variables of this study, the habitats of the floristic assemblages and floristic groups could be broadly circumscribed in terms of the composite environmental gradients of the first three axes of the environmental ordination and the first two axes of the floristic ordination (Table 4.4).

Table 4.4. Environmental gradient position of the floristic assemblages.

Floristic group or provisional assemblage	Habitat factors from ordinations	low	medium	high
Evandra-Anarthria	Soil moisture	*	*	
	Min & max WT	*		
	Base cations/ pH	*	*	
	Organic matter		*	
	Zn/ $N0_3$/ K	*	*	*
	$P0_4$		*	
Evandra-Homalospermum	Soil moisture	*	*	
	Min & max WT	*	*	
	Base cations/ pH	*	*	
	organic matter		*	
	Zn/ $N0_3$/ K	*	*	*
	$P0_4$		*	*
Empodisma -Schoenus –Reedia	soil moisture		*	*
	min & max WT		*	
	base cations/ pH		*	
	organic matter			*
	Zn/ $N0_3$/ K		*	
	$P0_4$	*		
Empodisma-Schoenus-Taraxis	soil moisture	*		*
	min & max WT		*	*
	base cations/ pH		*	*
	organic matter	*	*	
	Zn/ $N0_3$/ K		*	
	$P0_4$			*
Empodisma-Sporadanthus-Reedia	soil moisture		*	
	min & max WT			*
	base cations/ pH			*
	organic matter	*		
	Zn/ $N0_3$/ K		*	
	$P0_4$	*		
Empodisma-Sporadanthus-Chorizandra	soil moisture		*	
	min & max WT			*
	base cations/ pH			*
	organic matter	*		
	Zn/ $N0_3$/ K	*		
	$P0_4$		*	

c. Environmental means of the floristic supergroups and floristic groups.

Mean soil moisture and minimum water level in the *Empodisma* floristic supergroup (Appendix 4) was significantly higher ($p < 0.001$) than that of the *Evandra* floristic supergroup. The means of the *Empodisma* supergroup for pH, salinity in spring, salinity in autumn, maximum water level, S, Mg, Ca, Na and organic matter were also higher ($p < 0.05$) than the means of these variables for the *Evandra* supergroup. The means of Al, PO_4 and NH_4

of the *Empodisma* supergroup were however, lower ($p < 0.005$) than their means for the *Evandra* supergroup.

Comparison of the environmental means of the four floristic groups of sites identified by TWINSPAN at the second level of divisions (Table 4.5) showed significant differences between groups in pH, minimum and maximum water levels, water salinity, Na, Mg and organic matter content of soils. For the remaining variables, Ca, Al, Fe, NO_3, PO_4, Zn, K, NH_4 and S, differences in the means of the four groups of sites were not significant. Results of differences in group means were described further in the context of the floristic ordination of sites results below.

Table 4.5: Significant differences of environmental means of the four floristic groups of sites. Number of sites in each floristic group = n. The mean and (SD) for each variable is shown and also F and p for the ANOVA. Superscript letters in rows denote significant differences ($p = 0.05$) for tests of means.

Variable	*Empodisma-Sporadanthus* n=6	*Empodisma-Schoenus* n=18	*Evandra-Homalospermum* n=11	*Evandra-Anarthria* n=3	F	p
%H_2O	50.4^{a} (4.6)	57.5^{a} (20.7)	28.4^{b} (19)	11^{b} (6.7)	9.73	0.0001
min WT	-19^{a} (16)	-65^{b} (42)	-120^{c} (47)	-161^{c} (26)	12.96	0.0001
pH	6^{a} (0.7)	4.4^{b} (0.6)	3.9^{b} (0.4)	3.8^{b} (0.2)	22.03	0.0001
max WT	14^{a} (16)	-4^{b} (7)	-5^{b} (21)	-57^{c} (14)	16.87	0.0001
Sal A	214^{a} (70)	156^{b} (107)	92^{b} (37)	87^{b} (51)	3.36	0.0298
Sal S	192^{a} (82)	98^{b} (61)	81^{b} (28)	70^{b} (40)	5.89	0.0024
Mg	3.263^{a} (1.939)	2.092^{ab} (1.343)	1.365^{b} (0.614)	1.283^{b} (0.526)	3.31	0.0316
Na	37.800^{a} (19.998)	26.411^{ab} (18.070)	19.227^{b} (6.130)	14.633^{b} (3.444)	2.43	0.0819
OM	6.4^{a} (2.4)	58.6^{b} (34.9)	36.9^{a} (21.4)	12.6^{a} (5.9)	6.82	0.0036

d. Description of the floristic assemblages in terms of their vegetation and habitats

When significant differences in the means of environmental variables of the second level TWINSPAN floristic groups (Table 4.5) were integrated into the floristic ordination diagram (Fig 4.8), along with information of wetland types at the various sites (from Chapter 3) and floristic and structural descriptions of the sites, a more complete picture emerged of assemblages and their habitats.

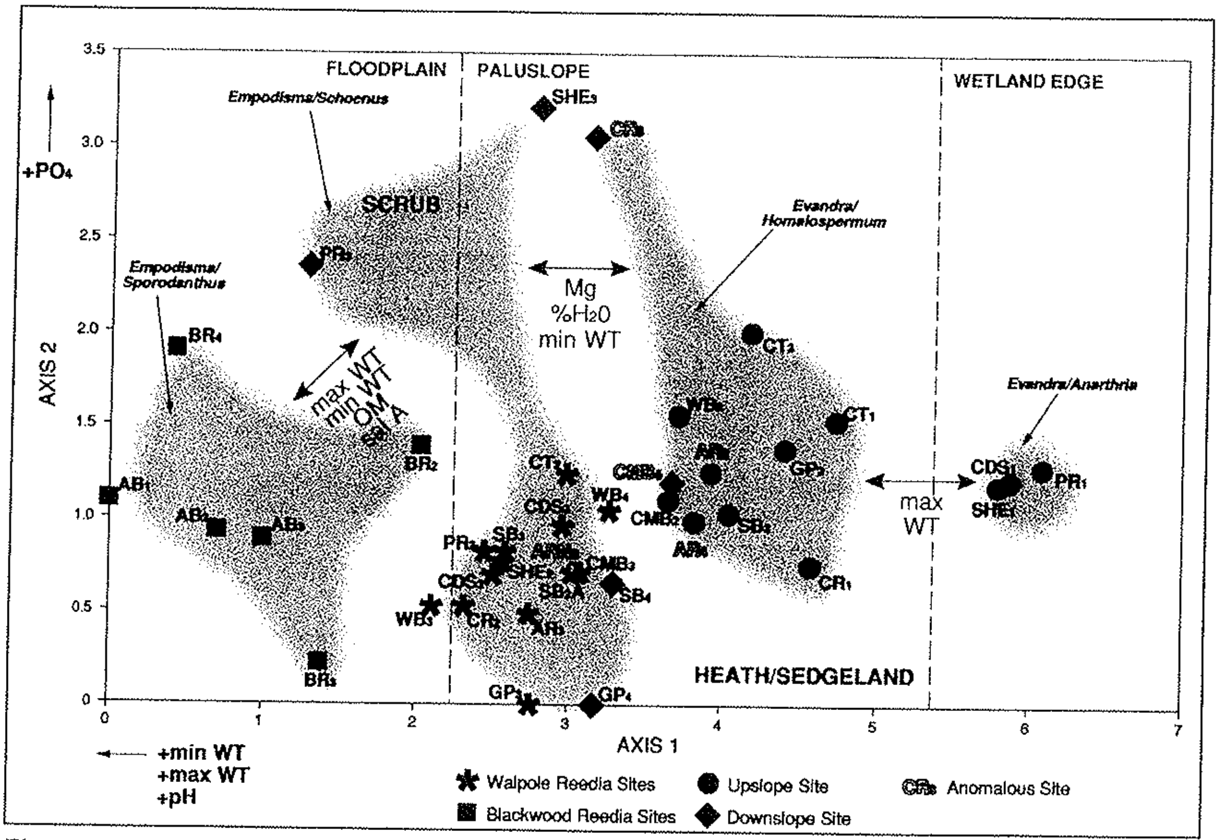


Figure 4.8 Ordination of sites (floristic data) with: four floristic groups; significant differences in means of environmental variables between floristic groups; wetland types; and vegetation structure.

1. *Evandra- Anarthria* assemblage.

The *Evandra-Anarthria* group inhabited sites upslope from all other slope assemblages examined in the Walpole study area. The low mean water table level (-57 cm) in spring of these sites differentiated the habitat of the *Evandra-Anarthria* assemblage from that of other assemblages. The *Evandra-Anarthria* floristic assemblage could thus be considered to inhabit the edge of the Walpole wetland habitats in this study. However, considering the small database on which the above assemblage is based, further studies of this assemblage and its habitat are recommended.

A site which represented this assemblage was ***CDS1*** and could be described as a sedgeland dominated by *Evandra aristata* and *Anarthria prolifera* (cover over 70%) under 1m in height with open shrubs (cover 42%) dominated by *Agonis parviceps* under 1m in height. Associates include: *Acacia hastulata, Anarthria scabra, Bossiaea praetermissa, Dasypogon bromeliifolius, Drosera roseana, Gompholobium confertum, Hypolaena exsulca, Pimelia hispida, Pultenaea reticulata, Leptomeria scrobiculata, Scaevola calliptera* and *Sphaerolobium* sp Chudelup.

2. *Evandra-Homalospermum* assemblage

The *Evandra-Homalospermum* assemblage of the Walpole study area was found generally, but not always, upslope from the *Empodisma-Schoenus-Reedia* assemblage on slopes in the Walpole study area. Its habitat was distinguished from that of the latter by its significantly lower soil moisture levels in autumn, lower watertables in autumn and lower soil organic matter content. With maximum watertable levels at a mean value of 5 cm below the surface of the soil in spring, the soil of these sites was waterlogged for part of each year. The *Evandra-Homalospermum* floristic assemblage was found to be characteristic of paluslopes of the Walpole area surveyed in this study.

A site which represented this assemblage was ***CMB2*** and could be described as a diverse open heath (cover 46%) dominated by *Homalospermum firmum* under 1m in height and sedges (cover 35%) dominated by *Evandra aristata*. Associates include: *Acacia hastulata, Agonis* sp. Coarse Agonis, *Amperea protensa, Astartea fascicularis, Beaufortia sparsa, Dampiera leptoclada, Diaspasis filifolia, Diplopogon setaceus, Gymnoschoenus anceps, Gonocarpus simplex, Leptocarpus tenax, Leucopogon gracilis, Sphaerolobium* sp. *nov, Sphenotoma gracile, Stylidium glaucum, Xyris flexifolia* and *Xyris lananta.*

3. Significantly higher mean soil organic matter was a distinguishing feature of the *Empodisma-Schoenus* floristic group compared to all the other groups. Whilst the mean minimum water table level for *Empodisma-Schoenus* floristic group was significantly lower than that of the *Empodisma-Sporadanthus* floristic group, it was significantly higher than that of the two assemblages discussed above. The mean minimum watertable of this group was 65 cm below soil surface, rising to a mean of 4 cm below the surface in spring. The *Empodisma-Schoenus* floristic group was found on paluslopes of the Walpole study area and also at an uncommon floodplain site (***WB3***) in the Walpole study area where surface water was present in spring.

The *Empodisma-Schoenus* floristic group in this study was further differentiated into the: *Empodisma-Schoenus-Reedia* assemblage; and the *Empodisma-Schoenus-Taraxis* assemblage (sites ***SHE3*** and ***CR3***).

In this study the vegetation structure of the *Empodisma-Schoenus-Taraxis* assemblage was always a closed scrub located at the base of paluslopes. The *Empodisma-Schoenus-Reedia* assemblage however, was most commonly an open heath/sedgeland with some sites tending towards an open scrub/sedgeland structure. The habitat difference between these two assemblages was related to a positive phosphate gradient down the slopes examined. The *Empodisma-Schoenus-Reedia* assemblage is well supported by data in this study. However, considering the small data base on which the *Empodisma-Schoenus-Taraxis* assemblage is based, further studies of this assemblage and its habitat are recommended.

3a. Empodisma-Schoenus-Reedia assemblage.

This assemblage was found to inhabit paluslopes and a floodplain in the Walpole study area, downslope from the *Evandra-Homalospermum* floristic group and comprised either open heath/sedgland or open scrubs.

A site which represented this assemblage was ***SB2A*** which could be described as sedges and rushes (cover 48%) dominated by *Reedia spathacea* and *Empodisma gracillimum* with open shrubs (cover over 27%) under 1.2m in height dominated by *Homalospermum firmum.* Associates include: *Acacia hastulata, Actinotus omnifertilis, Acidonia microcarpa, Adenanthos obovatus, Cephalotus follicularis, Comesperma nudiusculum,Cosmelia rubra, Drosera hamiltonii, Gonocarpus simplex, Leucopogon australis, Leucopogon gracilis, Leptocarpus tenax, Lycopodiella serpentina, Schoenus multiglumis, Sphaerolobium rostratum, Stylidium glaucum* and *Tetratheca filiformis.*

3b. *Empodisma-Schoenus-Taraxis* assemblage.

This assemblage was always a closed scrub located at the base of paluslopes often adjoining small watercourses in the Walpole study area. A site which represented this assemblage was ***SHE3*** which could be described as a closed scrub (cover of 73%) dominated by *Homalospermum firmum* over 2m in height with rushes /sedges of *Taraxis grossa* and *Schoenus multiglumis* (cover of 76%) to 1.5m in height. Associates include: *Astartea* *fascicularis, Leucopogon australis, Pteridium esculentum, Sphenotoma squarrosum, Sphaerolobium sp. nov, Stylidium scandens* and *Tetratheca filiformis.*

4. The *Empodisma/Sporadanthus* group had significantly higher mean pH, higher year-round watertables and water salinity than all the other groups and lower soil organic matter than the Walpole *Empodisma-Schoenus* group. The *Empodisma-Sporadanthus* group was further differentiated on floristics into the:
Empodisma-Sporadanthus-Reedia assemblage inhabiting floodplains (sites ***AB2, AB3, BR2*** and ***BR3***) in the Blackwood area; and the *Empodisma-Sporadanthus-Chorizandra* assemblage inhabiting stream margins (sites ***BR4, AB1, PR3***) in the Blackwood and Walpole study area.

4a. *Empodisma-Sporadanthus-Reedia* assemblage.

This assemblage was found on floodplains of the Blackwood study area and comprised sedgelands with emergent low shrubs.
A site which represented this assemblage was ***BR3*** and this could be described as a diverse sedgeland (cover >70%), dominated by *Reedia spathacea* with subdominants *Empodisma gracillimum* and *Cyathochaeta teretifolia* and sparse shrubs (<10% cover) of *Acacia pulchella / Agonis linearifolia* under 1.2m in height. Associates include: *Actinotus laxus, Astartea aff. fascicularis, ?Baumea* sp Blackwood, *Baumea rubiginosa, Boronia fastigiata, Diaspasis filifolia, Drosera myriantha, Gymnoschoenus anceps, Leptocarpus tenax, Sporadanthus rivularis, Stylidium squamosotuberosum, Utricularia paulineae* and *Xyris gracillima.*

4b. *Empodisma-Sporadanthus-Chorizandra* assemblage

This assemblage inhabited the margins of perennial or seasonal streams in the Blackwood study area and comprised open heath/sedgelands to open scrub/sedgelands. However, considering the small data base on which the above is based, further studies of this assemblage and its habitat are recommended.

A site which represented this assemblage was ***BR4*** and this could be described as an open scrub (cover 40%) dominated by *Agonis linearifolia* about 2 m in height with diverse sedges (cover 41%) dominated by *Sporadanthus rivularis.* Associates include: *Acacia pulchella* var. *goadbyi, Astartea fascicularis, ?Baumea* sp. Blackwood, *Baumea rubiginosa, Boronia fastigiata, Chorizandra cymbaria, Cyathachaeta teretifolia, Empodisma gracillimum,* *Leptocarpus tenax, Meeboldina decipiens, Troglochin huegelii, Villarsia lasiosperma* and *Xyris lacera.*

4.4 Discussion

This study centered around the identification and description of floristic assemblages and associated environmental conditions in the wetlands inhabited by *Reedia* and the exploration of some of the environmental gradients in these wetlands.

Six of the eight provisional floristic assemblages identified by TWINSPAN at the third level of divisions were validated by further complementary analysis of ordinations and classification. However, not all of these six assemblages were supported by sufficient data to be adopted without reservations. Thus well supported assemblages emerging from this analysis were: *Empodisma- Schoenus-Reedia* in the Walpole study area; *Empodisma-Sporodanthus-Reedia* in the Blackwood study area; *and Evandra-Homalospermum* in the Walpole study area.

Three other assemblages were less well supported by the data available. These assemblages were: *Evandra-Anarthria* in the Walpole study area; *Empodisma-Sporadanthus-Chorizandra* in the Blackwood study area; and *Empodisma- Schoenus-Taraxis.* These assemblages require further study if they are to be validated.

The Warren Biogeographical Region is recognized as an important centre of endemism for 'conservative relictual high rainfall taxa' with most endemics confined to wetlands, coastal heaths and granitic outcrops rather than forests (Hopper *et al.* 1992, Lyons *et al.* 2000). This study, which has focussed on a small sample of the wetlands of the region, has also identified endemism at an assemblage level in the wetland flora. The Walpole area *Reedia*-inhabited sites are disproportionately rich in Warren Biogeographical Region endemic species and phylogenetically isolated taxa (monotypic genera) when compared to estimates of the total regional flora. Apart from the monotypic endemic family Cephalotaceae, the families Myrtaceae, Epacridaceae, Proteaceae, Goodeniaceae, Cyperaceae and Restionaceae are represented in the Walpole study area *Empodisma-Schoenus-Reedia* assemblage as monotypic genera. Two of these monotypic genera, *Acidonia* (Weston 1994) and *Cephalotus* are generally recognized as relic taxa. However, further study is needed to determine if other monotypics in the Walpole *Reedia* assemblage are relict taxa or products of more recent local evolution.

The *Empodisma –Sporadanthus-Reedia* assemblage from the Blackwood area identified in this study, whilst not rich in endemics as the Walpole *Reedia* assemblage, occurs less commonly and many of its component taxa are poorly known taxonomically. From this study this assemblage is known from only four sites and three of these show considerable degradation.

In the Walpole study area, the sites ***GP3*** and ***GP4*** were somewhat separated on floristics from the other sites (Fig 4.4). The Granite Peak transect is an outlier site in terms of the Walpole study area. It is located in the least humid zone and also shows signs of a severe fire in recent years. All these factors could contribute to these floristic differences. Site ***WB3***, being situated in a floodplain is floristically more closely allied to the Blackwood floodplain sites than other Walpole *Reedia*- inhabited sites as evident from Fig 4.4.

At Walpole paluslope transects, upslope sites exhibited low pH and base cation levels relative to their respective downslope site, with the exception of transects ***CR*** and ***CT***, thus showing a catenary relationship. These exceptions were transects where the upslope sites were not part of the same catena as the sites downslope from the *Reedia*- inhabited sites. This also also occured in the Angove Rd transect and was discussed in more detail in Chapter 3. Thus, absolute values of the base cations and pH differed from transect to transect, presumably due to transect- specific conditions such as slope lithology, slope length and slope gradient, but the relationship of upslope to downslope site was constant. Soil moisture in downslope sites was not always higher than that of its corresponding upslope site (as seen in ***SB4***, ***PR3*** and **CDS3)** and this can be explained by the differing hydrological and stratigraphic conditions of the various transects (see Chapter 3). Soil moisture is correlated with water table levels and soil texture. Thus, sandy or muddy downslope sites with low water tables in autumn such as ***SB4***, ***PR3*** and ***CDS3*** had lower soil moisture levels in the upper strata than peaty downslope sites with a relatively high water table in autumn (such as ***CMB4***, and ***SHE3)*** or muddy sites with a high autumn water table such as ***GP4.***

Several sites (***GP4, CDS3, SB4*** and ***ARN2***) where *Reedia* was absent were included in the *Empodisma-Schoenus-Reedia* floristic assemblage by TWINSPAN (Fig 4.2) on the basis of floristic similarity with Walpole *Reedia*- inhabited sites. From ordination analysis, the environmental differences between these four sites and Walpole *Reedia*–inhabited sites became clearer. ***ARN2, GP4*** and ***AR4*** experienced subtle habitat differences to the *Reedia*-inhabited sites, and these differences only became evident as axis 3 of the ordination was examined (Fig 4.6). Salinity appears to be contributing to an absence of *Reedia* at ***CDS3.*** Site ***SB4,*** clearly lay outside the habitat range of *Reedia* in this analysis on the basis of low soil moisture.

Therefore, the environmental conditions at sites surveyed in this study which are inhabited by *Reedia* in the Walpole area appear to be different (albeit quite subtly in some cases) from other sites examined in the study where *Reedia* does not occur but where floristics are similar enough to those in the *Reedia* populations to warrant inclusion of these sites in the *Empodisma-Schoenus-/Reedia* floristic assemblage.

High salinity may contribute to the absence of *Reedia* at sites ***BR2*** (and ***CDS3*** as discussed above) although more direct study would be necessary to conclusively show that salinity above abouth 300 ppm on a regular basis is not tolerated by *Reedia* or precludes the establishment of *Reedia.*

Soluble nutrients in most study sites were generally low and comparable to pristine sites near Walpole (V&C Semeniuk Research Group, 1999), with notable exceptions being sites ***CR3*** and ***GP2.*** At ***CR3*** in particular, phosphate recorded was comparable to anthropogenically-influenced sites such as the Walpole Golf Course and farmland in the above study. This site was located on the edge of a creek downslope from a large tract of farmland and a narrow buffer of woodland. None of the waters further up the valley (in the *Reedia*-inhabited zones of the wetland) were nutrient enriched. However, the catchment for these sites was National Park forest rather than farmland.

The less extreme nutrient enrichment of site ***GP2*** (PO_4 values about three times those observed in most other study sites) is not easily explained. This site also has extremely acid waters (at pH 3.4 the lowest recorded in the study). The catchment area for this site is pristine forest where the only discernible anthropogenic influence is the fire regime. The site is recovering from a fire several years ago and litter resulting from this fire is abundant. The peat zone immediately downslope from this site is also severely fire-affected with remnant shrubs residing in pedestals of peat about 30cm above burnt-out substrate. Most of the *Reedia* plants in this zone are dead or moribund. In the absence of nutrient cycling studies, there is insufficient data to propose explanations for the anomalous water chemistry at this site.

The *Empodisma-Sporadanthus* group of floristic sites appeared to be relatively heterogeneous with regard to floristic composition (Fig 4.6). The *Empodisma-Sporadanthus-Chorizandra* sites are slightly higher on the waterlevel and pH gradient than the sites of the other assemblage *Empodisma-Sporadanthus-Reedia* and this may be significant. In the more precise location of ***PR3*** defined by the ordination (Fig 4.3) it was seen that ***PR3*** was more closely allied in a floristic sense with the Blackwood stream-side site ***BR4*** than with either ***SHE3*** or the *Empodisma-Schoenus-Reedia* floristic assemblage. This is also supported by the stream-side location of ***PR3*** compared to the slope location of ***SHE3.***

4.5 Conclusions

Three well supported floristic assemblages and their habitats were identified in the wetlands of this study:

1. the *Empodisma-Schoenus-Reedia* assemblage that inhabited paluslopes with long hydroperiods of the Walpole study area and also some floodplains of this area;
2. the *Empodisma-Sporadanthus-Reedia* assemblage that inhabited floodplains of the Blackwood study area; and
3. the *Evandra-Homalospermum* assemblage that inhabited paluslopes with shorter hydroperiods of the Walpole study area.

One other floristic assemblage, that was considered characteristic of the upslope edges of paluslopes in the Walpole study area, and two other wetland floristic assemblages were also identified, however, these assemblages were not based on sufficient data to be fully substantiated.

Therefore, *Reedia* inhabited two distinct floristic assemblages corresponding to the Walpole and Blackwood study areas respectively. In addition, the Spearwood Swamp paluslope inhabited by *Reedia* in the Blackwood study area may also constitute another *Reedia*-inhabited floristic assemblage but there was insufficient data to test this grouping.

Environmental gradients identified in the wetlands of the study that were correlated with the distribution of vegetation were: the autumn and spring water levels; the acidity and base cation gradient; and less significant gradients related to water phosphate, nitrate, potassium and zinc concentrations. In terms of the range of environmental variables in this study, *Reedia* populations inhabited sites with medium to high autumn and spring water levels, medium to high base cations and acidity, and low nutrient levels.

This study also identified endemism at an assemblage level in the wetland flora. The Walpole area *Empodisma-Schoenus- Reedia* assemblage was disproportionately rich in Warren Biogeographical Region endemic species. At a generic level the *Reedia*-inhabited wetlands of this study exhibited floristic affinities with the New Zealand wetlands that are also dominated by the Restionaceae genera *Empodisma* and *Sporadanthus*. This finding provides a biogeographical context for the *Reedia* assemblages that prompts further examination.

Chapter 5: Summary of findings, conservation issues and directions for further study

The preliminary biological and ecological studies of *Reedia spathacea* have resulted in the compilation of a substantial database about a previously relatively unknown taxon and its habitat. This database will serve to inform further studies and conservation measures to investigate the natural history of *Reedia spathacea* and that of the unique biogeographical region it occurs in and to protect this uncommon relictual species and its limited habitat.

The unique pollen characters and the entomophilous pollination syndrome observed in *Reedia spathacea* in these studies are indicators of the isolation of this monotypic genus with regard to the other genera of the family Cyperaceae. Future studies of the microsporogenesis and the floral ontogeny of *Reedia spathacea* will potentially resolve this issue further.

The ecohydrological study found that the constantly high watertables of *Reedia spathacea* - inhabited floodplains and paluslopes are maintained by humid climates, and more importantly, other hydrological factors. Flow from deep regional aquifers, for example the Leederville aquifer in the Blackwood Plateau area, is important in maintaining *Reedia-spathacea* inhabited floodplains in the Blackwood study area. Sub-surface flow and local confined aquifers maintain *Reedia spathacea*-inhabited paluslopes. Suitable stratigraphy and topography to facilitate these hydrological factors exists in the Walpole study area wherever *Reedia spathacea* populations occur. Peat formation, promoted by almost constantly waterlogged soils, constitutes a further buffer in these wetlands against climatic fluctuation. Exploration of the Blackwood Plateau to comprehensively map the *Reedia spathacea* populations of this area and further eco-hydrological study of these populations are indicated.

Three well supported floristic assemblages and their habitats were identified in the wetlands of this study: the *Empodisma-Schoenus-Reedia* assemblage; the *Empodisma-Sporadanthus-Reedia* assemblage; and the *Evandra-Homalospermum* assemblage. Environmental gradients important in the distribution of vegetation in the wetlands of the study were water levels, acidity/ base cations and nutrients. Compared to the total Warren Biogeographical Region flora, a high level of endemism at the assemblage level was identified in the Walpole area *Empodisma-Schoenus-Reedia* assemblage. Further study is indicated to examine other assemblages identified in this study which were less well supported by small databases.

Potential exploitation of the Leederville aquifer by the growing population of the Augusta-Bussleton area poses a potential threat to the conservation of the uncommon Blackwood *Reedia spathacea* populations and associated poorly-known flora. Several *Reedia spathacea* populations at Walpole are threatened by potential urban and industrial development. Degradation of vegetation due to feral pig grazing and digging is evident in some *Reedia spathacea* populations of both areas. Research into the fire ecology of *Reedia spathacea* is a priority to refine management strategies commensurate with the conservation and scientific significance of this taxon.

At a generic level, the *Reedia*-inhabited wetlands of this study exhibited floristic affinities with the rare restionaceous peat-based wetlands of lowland, warm temperate New Zealand. This provides a biogeographical context for the *Reedia spathacea* assemblages that prompts further study on an international scale.

Chapter 6: References

Agnew, A. D. Q., Rapson, G. L., Sykes, M. T., and Wilson, J. B. (1993). The functional ecology of *Empodisma minus* (Hook, f.) Johnson & Cutler in New Zealand ombrotrophic mires. *New Phytologist* 124: 703-710

Anderson, D. S., Davis, R. B., Rooney, S. C., and Campbell, C. S. (1996). The ecology of sedges (Cyperaceae) in Maine peatlands. *Bulletin of the Torrey Botanical Club* 123(2): 100-110.

Baddock, L. J. (1993). *The geology and hydrogeology of the Scott Coastal Plain, Perth Basin.* Department of Minerals and Energy, Perth.

Beard, J. S. (1981). *Vegetation Survey of Western Australia,* 1:1 000000 series Sheet 7: Swan. University of Western Australia Press, Nedlands.

Bentham, G. (ed). (1878). Cyperaceae. In: *Flora Australiensis: a description of the plants of the Australian territory.* Vol 1: 246-449. L. Reeve and Company, London.

Boden, R. & Given, D. (1995). Regional overview: Australis and New Zealand. In: S. D. Davis, V. H. Heywood and A. C. Hamilton (eds), *Centres of plant diversity: a guide and strategy for their conservation. Vol 2 . Asia, Australasia and the Pacific*: 433-518. World Wide Fund for Nature/ IUCN, Cambridge.

BMR Palaeogeographic Group (1990). *Australia: evolution of a continent.* Bureau of Mineral Resources, Geology & Geophysics, Canberra.

Bridgham, S. D., and Richardson, C. J. (1993). Hydrology and nutrient gradients in North Carolina peatlands. *Wetlands* 13(3): 207-218.

Bruhl, J. J. (1991). Comparative development of some taxonomically critical floral/inflorescence features in Cyperaceae. *Australian Journal of Botany* 39: 19-127.

Bruhl, J. J. (1995). Sedge genera of the world: relationships and a new classification of the Cyperaceae. *Australian Systematic Botany* 8: 125-305.

Bureau of Meteorology (2000). W. A. Bureau of Meteorology Data Consultancy, Perth, Western Australia.

Butcher, R. pers. comm.(2000). Department of Botany, University of Western Australia.

Campbell, D. I., and Williamson, J. L. (1997). Evaporation from a raised peat bog. *Journal of Hydrology* 193: 142-160.

Campbell, E. O. (1964). The restiad peat bogs of Motumaobo and Moanatuatua. *Transactions of the Royal Society of New Zealand* 2: 221-4.

Clymo, R. S. (1983). Peat. In: A .J.Gore (ed), *Mires: swamp, bog, fen and moor. Ecosystems of the world 4A*. pp. 159-224. Elsevier Scientific, New York.

Cope, R.N., (1975). *Tertiary epeirogeny in the southern part of Western Australia*. Western Ausralian Geological Survey Annual Report. 1974. 46-50.

Corner , E. J. H. (1964). *The life of plants*. University of Chicago Press, Chicago.

Corner, E. J. H. (1966). *The natural history of palms*. Weidenfeld and Nicholson, London.

Crisp, M. D., West, J. G., & H. P. Linder. (1999). Biogeography of the terrestrial flora. In: *Flora of Australia*. Vol 1, Introduction, 2nd edition. Melbourne: ABRS/CSIRO Australia.

Cronk, Q. G. B. (1987). The history of the endemic flora of St Helena: a relictual series. *New Phytologist* 105: 509-520.

Cronk, Q. G. B. (1992). Relict floras of Atlantic islands: patterns assessed. *Biological Journal of the Linnean Society* 46: 91-103.

Cutler, D. F. (1969). Anatomy of the Monocotyledons. IV. Juncales. Clarendon Press, Oxford.

Dahlgren, R. M. T., Clifford, H. T., and Yeo P. F. (1985). *The families of the monocotyledons.* Springer-Verlag, Berlin.

Erdtman, G. (1986). *Pollen morphology and plant taxonomy.* E J Brill, Leiden.

Faegri, K., and van der Pijl, L. (1979). *The principles of pollination ecology.* 3rd revised edition. Pergamon Press, Oxford.

Fahn, A. (1954). The anatomical structure of Xanthorrhoeaceae Dumort. *Botanical Journal of the Linnaen Society* 55: 158-184.

FloraBase (1998). W. A. Herbarium. Department of Conservation and Land Management, Perth.

Gentilli, J. (1989). Climate of the Jarrah forest. In: B. Dell, J. J. Havel, and Malajczuk (eds), *The Jarrah forest.* Kluwer Academic Publishers: Dordrecht.

Gioia, P., Piggott, J. P., Cranfield, R. J. and Chapman, A.R.(1998). *Distribution and key ecological attributes of plant species in the south-west forest region.* Department of Conservation and Land management unpublished report for the Regional Forests Agreement for Western Australia.

Glaser, P. H., Janssens, J. A., and Siegel, D. I. (1990). The response of vegetation to chemical and hydrological gradients in the Lost River peatlands, Northern Minnesota. *Journal of Ecology* 78: 1021-1048.

Goetghebeur, P. (1998). Cyperaceae. In: K. Kubitzki (ed), *The families and genera of vascular plants.* IV, 41-189. Springer, Berlin.

Hammer, U. T. (1986). *Saline lake ecosystems of the world.* W Junk Publishers, The Hague.

Herendeen , P. S., Crane, P. R. (1995). The fossil history of the monocotyledons. In: P. J. Rudall, P. J. Cribb, D. F Cutler, L. J. Humphries (eds), *Monocotyledons: systematics and evolution.* 1-23. Royal Botanic Garden, Kew.

Hill, M. O. (1979). TWINSPAN- a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. *Ecology and Systematics.* Cornell University, Ithaca, New York.

Hill, R. S., Truswell, E. M., McLoughlin, S., and Dettman, M. E. (1999). Evolution of the Australian flora: fossil evidence. In: *Flora of Australia.* Volume I. 2nd edition. 230-251. ABRS/CSIRO, Australia.

Hopper, S. D. (1979). Biogeographical aspects of speciation in the southwest Australian flora. *Annual Review of Ecology and Systematics* 10: 399-422.

Hopper, S. D., Keighery, G. J., and Wardell-Johnson, G. (1992). Flora of the Karri forest and other communities in the Warren Botanical Subdistrict of Western Australia. In: *Research on the impact of forest management in south-west Western Australia.* Department of Conservation & Land Management Western Australia, Occasional Paper 2/92.

Hopper, S. D. (ed.)(1996). *Gondwanan heritage past present and future of the Western Australian biota.* Chipping-Norton, Sydney.

Horwitz, P. (1994). *Patterns of endemism in the freshwater fauna of the far southern peatlands and shrublands of Southwestern Australia.* Report to the Australian Heritage Commission and the Heritage Council of Western Australia.

Ivanov, K. E., (trans A. Thompson, H. A. P. Ingram), (1981). *Water movement in mirelands.* Academic Press, London.

Jacobs, S. W. L., and Brock, M. A. (1993). Wetlands of Australia: southern (temperate) Australia. In: D. F. Whigham, D. Dykyjova, and S. Henty (eds), *Wetlands of the World 1: Inventory Ecology and Management.* Handbook of Vegetation Science 15/2. 244-304. Kluwer Academic Publishers, Dordrecht.

Jacobs, S. W. L. (1999). Terrestrial wetlands and waterplants. In *Flora of Australia*. Volume I. 2nd edition. ABRS/CSIRO, Australia.

Janetzky, W., and Vareschi, E (1993). Phytotelmata in bromeliads as microhabitats for limnetic organisms. In: W. Barhtlott, C.M Naumann, K. Schmidt-Loske, K. L. Schuchmann (eds.). *Animal-plant interactions in tropical environments*. 199-209. Bonn. Zool. Forschungsinst. Mus. A. Koenig.

Jarzen, D. M., and Nichols, D. J. (1996). Pollen. In: J. Jansonius, and D. C. McGregor (eds), *Palynology: principles and applications*. American Association of Stratigraphic Palynologists Foundation. Vol 1: 261-291.

Jeglum, J. K., and He, F. (1995). Pattern and vegetation – environment relationships in a boreal forested wetland in northeastern Ontario. *Canadian Journal of Botany* 73: 629-637.

Keighery, G. J. (1983). Insect pollination in the Cyperaceae. *Western Australian Naturalist* 15 (7): 175-178.

Kent, M. and Ballard, J. (1988). Trends and problems in the application of classification and ordination methods in plant ecology. *Vegetatio* 78: 109-124.

Koyama, T. (1956). Taxonomic study of the Cyperaceae. *Botanical Magazine of Tokyo* 69: 59-67.

Krumbein, W. C., and Pettijohn, F. J. (1938). *Manual of sedimentary petrology*. Vols 1 & 2. Appleton-Century-Crofts, New York.

Kubitzki, K. (1987). Origin and significance of trimerous flowers. *Taxon* 36(1):21-28.

Kubitzki, K (ed.) (1998). *The families and genera of vascular plants*. Vol 3 & 4. Springer, Berlin.

Kuder, T., Kruge, M. A., Shearer, J. C., and Miller, S. L. (1998). Environmental and botanical controls on peatification- a comparative study of two New Zealand restiad peat bogs using Pt-GC/MS, petrography and fungal analysis. *International Journal of Coal Geology* 37: 3-27.

Lamont, B. (1981). Availability of water and inorganic nutrients in the persistent leaf bases of the grasstree Kingia australis and uptake and translocation of labelled phosphate by the embeeded aerial roots. *Physiology of Plants* 52: 181-186.

Lamont, B. B. (1982). Mechanisms for enhancing the nutrient uptake in plants with bparticular reference to mediterranean South Africa and Western Australia. *Botanical Reviews* 48: 597-689.

Linder, H. P., and Kellogg, E. A. (1995). Phylogenetic patterns in the commelinid clade. In: P. J. Rudall, P. J.Cribb, D. F. Cutler, C. J. Humphries (eds), *Monocotyledons: systematics and evolution*. pp. 473-496. Royal Botanic Gardens: Kew.

Lyons, M. N., Keighery G. J., Gibson, N and Wardell-Johnson, G (2000). The vascular flora of the Warren bioregion, south-west Western Australia: composition, reservation status and endemism. *CALMScience* 3(2):181-250.

Macfarlane, T. D., and Wardell-Johnson, G. (1996). *Anthocercis sylvicola* (Solanaceae) a rare new species from the Tingle forests of Walpole south western Australia. *Nyutsia* 11(1): 71-78.

Main, A. R., and Main, B. J. (1991). *Report on the southern forest region of W A.* Unpublished report to the Australian Heritage Commission, Canberra.

Main , B.J. (1993). Spiders and other invertebrates.In: Thompson, C. Hall, G and Friend G. 117-128. *Mountains of mystery: a natural history of the Stirling Range*. Department of Land Management, Perth.

Major, J. (1988). Endemism: a botanical perspective. In: A. A. Myers, and P. S. Giller (eds), *Analytical biogeography: an integrated approach to the study of animal and plant distributions*. Chapman & Hall, London, New York.

de Mars, H., Wassen, M. J., and Peeters, W. H. M. (1996). The effect of drainage and management on peat chemistry and nutrient deficiency in the former Jegrznia-floodplain (NE Poland). *Vegetatio* 126: 59-72.

de Mars, H., and Wassen, M. J. (1999). Redox potentials in relation to water levels in different mire types in the Netherlands and Poland. *Plant Ecology* 140: 41-51.

Mathews, E. G., (1987). *Beetles of South Australia. Part 7.* Museum of South Australia.

Meney, K. A., Dixon K.W., and Pate J.S. (1999). Seed reproduction and germination ecology of Restionaceae. In: K. A. Meney and J. S. Pate (eds), *Australian Rushes.* pp. 3-23. University of Western Australia Press, Perth.

Metcalfe, C. R. (Ed.) (1971). *Anatomy of the Monocotyledons. Vol. V: Cyperaceae.* Clarendon Press, Oxford.

Milne, L. A. (1997). *Palynology of selected extant Proteaceae and Eocene palynofloras of Western Australia.* Unpublished doctoral thesis, Botany Department, University of Queensland.

Mitsch, W. J., and Grosselink, J. G. (2000). *Wetlands.* John Wiley & Sons Inc., New York.

Muasya, A. M., Bruhl, J.J., Simpson, D. A., Culham, A.and Chase, M.W., (2000). Suprageneric phylogeny of the Cyperaceae: a combined analysis. In: K. L. Wilson and D. A. Morrison (eds), *Monocots : systematics and evolution.* 644-652. CSIRO Publishing, Melbourne.

von Mueller F (1859). *Fragm. Phyt. Austral.*

Nicholson, B. J. (1995). The wetlands of Elk Island National Park: Vegetation classification, water chemistry, and hydrotopographic relationships. *Wetlands* 15:(2) 119-133.

Nix H. A. (1981). The environment of Terra Australis. In: A. Keast (ed), *Ecological biogeography of Australia.* pp. 103-134. W Junk, The Hague.

OECD, (1982). *Eutrophication of waters: monitoring assessment and control.* Organization for Economic Cooperation and Development, Paris.

Pate, J. S., and Delfs, J. C. (1999). Anatomical features of Restionaceae and allied families. In: K. A. Meney, and J. S. Pate (eds), *Australian Rushes.* pp. 57- 70. University of Western Australia Press, Perth.

Pate, J. S., and Meney, K. A. (1999). Morphological Features of Restionaceae and Allied Families. In: K. A. Meney, and J. S. Pate (eds), *Australian Rushes.* pp. 3-23. University of Western Australia Press, Perth.

Pressey, R. L., and Adam, P. (1995). A review of wetland inventory and classification in Australia. *Vegetatio* 118: 81-101.

Proctor, M. C. F. (1994). Seasonal and shorter term changes in surface- water chemistry in four English ombrogenous bogs. *Journal of Ecology* 82: 597-610.

Rudall, P.J. (1991). Lateral meristems and stem-thickening growth in moncotyledons. *The Botanical Review* 57(2): 150-168.

Schodde, R. (1989). Origins, radiations and sifting in the Australasian biota-changing concepts from new data and old. *Australian Systematic Botany Society Newsletter* 60: 2-11.

Schofield, N. J., Stoneman, G. L., and Loh, I. C. (1989). Hydrology of the Jarrah forest. In: B. Dell, J. Havel and N. Malajczuk (eds), *The Jarrah forest.* Kluwer Academic Publishers, Dordrecht.

Semeniuk, C. A. (1988). Consangineous wetlands and their distribution in the Darling System, south western Australia. *Journal of the Royal Society of Western Australia* 70: 69-87.

Semeniuk, C. A., and Semeniuk, V. (1995). A geomorphic approach to global classification for inland wetlands. *Vegetatio* 118: 103-124.

Staff, I. A.and Waterhouse, J. T. (1981). The biology of arborescent moncoyledons, with special reference to Australian species. 216-257. In: J. S. Pate and A. J. McComb (eds), *The biology of Australian plants.* University of W. A. Press, Nedlands.

Stokes, R. A. (1985). Stream water and chloride generation in a small forested catchment in south Western Australia. *Hydrology Branch Water Authority of W. A., Report* No. WH7.

Takhtajan, A. (trans T. J. Crovello) (1986). *Floristic regions of the world.* University of California Press, Berkeley.

Ter Braak, C. J. F. (1987). Ordination. In: R.H.G. Jongman, C. J. F. Ter Braak and O. F. R. Van Tongeren (eds), *Data analysis in community and landscape ecology.* Pudoc, Wageningen.

Thackway, R., and Cresswell, I. D. (eds) (1995). *An interim biogeographical regionalisation for Australia.* Reserve Systems Unit. Australian Nature Conservation Agency, Canberra.

Tillich, H. J. (1995). Seedlings and systematics in monocotyledons. In:. P. J. Rudall, P. J. Cribb, D. F. Cutler and C. J. Humphries (eds), *Monocotyledons: systematics and evolution.* 48-79. Royal Botanic Gardens, Kew.

Tillich, H. J. (2000). Ancestral and derived character states in seedlings of monocotyledons. In K. L. Wilson and D. A. Morrison (eds), *Monocots: systematics and evolution.* CSIRO, Melbourne.

V&C Semeniuk Research Group (1997). *Mapping and classification of wetlands from Augusta to Walpole in the south west of Western Australia.* Report to the Water and Rivers Commission. River and Waters Commission, Policy and Planning Division, East Perth, Western Australia.

V&C Semeniuk Research Group (1999). *A baseline study of the Walpole and Nornalup Inlet environment.* Unpublished report to the Manjimup Shire's Walpole and Nornalup Inlets Systems Advisory Committee. Shire of Manjimup, Western Australia.

Vitt, D. H., and Chee, W. L. (1990). The relationships of vegetation to surface water chemistry in fens of Alberta Canada. *Vegetatio* 89: 87-106.

Vogel, S. (1998). Floral biology. In: K. Kubitzki (ed), *The families and genera of flowering plants. Vol III.* pp. 36-39. Springer, Berlin.

Wahren, C. H., Williams, R. J., and Papsi, W. A. (1999). Alpine and subalpine vegetation on the Bogong High Plains, South-eastern Australia. *Australian Journal of Botany* 47: 165-188.

Walker, B.A., Pate, J.S., and Kuo, J. (1983). Nitrogen fixation by the nodulated roots of *Viminaria juncea* (Schrad. & Wendl.) Hoffmans (Fabaceae) when submerged in water. *Australian Journal of Plant Physiology* 10: 409-21.

Walter, H. (1985). *Vegetation of the earth and ecological systems of the geo-biosphere.* Translated from the fifth German edition by O. Muise. Springer-Verlag, Berlin.

Wardell Johnson, G. W., and Horwitz, P. (1996). Conserving biodiversity and the recognition of heterogeneity in ancient landscapes : a case study from south-western Australia. *Forest Ecology and Management* 85: 219-238.

Wardell-Johnson, G. W., and Roberts, J. D. (1993). Biogeographic barriers in a subdued landscape. In: The distribution of Geocrinia rosea complex in South Western Australia. *Journal of Biogeography* 20: 95-108.

Wardell-Johnson, G. W., and Williams, M. (1996). A floristic survey of the Tingle Mosaic, south-western Australia: applications in land use planning and management. *Journal of the Royal Society of Western Australia* 79: 249-276.

Wardell-Johnson, G.W. (1997). *Local endemism and four dominant eucalypts in South-Western Australia.* Unpublished PhD thesis. Department of Botany, University of Western Australia.

Wardell-Johnson, G W. (1999). A new record for the fern flora of south-western Australia: a single plant of *Histiopteris incisa* from Mt Lindsay. *Nyutsia* 13(1): 259-260.

Wassen, M. J., and Grootjans, A. P. (1996). Ecohydrology: an interdisciplinary approach for wetland management and restoration. *Vegetatio* 126: 1-4.

Wassen, M. J., and Joosten, J. H. J. (1996). In search of a hydrological explanation for vegetation changes along a fen gradient in the Biebrza Upper Basin (Poland). *Vegetatio* 124: 191-209.

Webb, L. J., Tracey, J. G., and Jessup, L. W. (1986). Recent evidence for autochtony of Australian tropical and subtropical rainforest floristic elements. *Telopea* 2: 575-589.

Weston, P. H. (1994). The Western Australian species of the subtribe Persooniianae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 16(1): 51-165

Weston, P. H., and Crisp, M. D. (1994). Cladistic biogeography of Waratahs (Proteaceae: Embrothrieae) and their allies across the Pacific. *Australian Systematic Botany* 7: 225-249.

Wheeler, M. A., and Bruhl, J. J. (2000). Taxonomic utility and ecological significance of comparative reproductive biology in sedges (Cyperaceae: Schoeneae). In: K. L. Wilson and D. A. Morrison (eds), *Monocots : systematics and evolution.* pp. 644-652. CSIRO Publishing, Melbourne.

Whinam, J., and Kirkpatrick, J. B. (1994). The Mt Wellington string bog Tasmania. *Journal of the Royal Society of Tasmania* 128:63-68.

Wilde, S. A., and Walker, I. W. (1984). Pemberton Sheet. Geological Survey of Western Australia.

Zar, J. H. (1999). *Biostatistical Analysis.* Prentice Hall.

Appendix 1

Glossary of terms

Achene. A dry, indehiscent fruit formed from a superior ovary of one carpel and containing one seed which is free from the pericarp.

Adventitious roots. Roots that arise in unusual positions such as parts of the shoot system of plants.These often develop in flood-tolerant plants, as adaptations to anoxia, just above the anaerobic zone or when shoots are damaged in some way. See also 'shoot-borne roots'.

Anemophilous. Pollinated by wind:

Apogeotropic roots. Negatively geotropic roots i.e. roots which ascend against the stimulus exerted by gravity which usually causes roots to descend.

Bisexual flower. Bearing both male and female organs together in the same flower.

Bog. A peat -accumulating wetland that receives most of its water from precipitation and only minimal drainage from surrounding mineral soil.

Catotelm. Lower layer of a peat deposit with constant water content , low hydraulic conductivity, absence of aeration and minimal biological activity.

Caudex. Woody thick stem or trunk of a monocotyledenous plant, usually developed via a primary thickening meristem except in rare cases such as *Dracaena* or *Xanthorrhoea.*

Cortex. The region of a srtem or root surrounding the vascular cylinder but inside the epidermis.

Cotyledon. The primary leaf of an embryo.

Dehisce. Break open at maturity to releas contents.

Distal. Remote from the point of origin or attachment. c.f. proximal

Entomophilous. Pollinated by insects.

Eutrophic. Nutrient rich. Imprecise term originally used to describe plankton productivity rather than chemical composition, as is often currently. Also often used synonymously with 'anthropogenically enriched'.

Exine. The outer layer of the wall of a pollen grain or spore.

Fen. A peat –accumulating wetland that receives some drainage from surrounding mineral soil.

Genet. An individual with a unique genome i.e. not a member of a clone. A plant originating from sexual reproduction not vegetative reproduction.

Glume. A bract in the inflorescence of a grass, sedge or a similar plant.

Haustorium. An absorbing organ through which the developing plant absorbs nourishment stored in the seed until it develops other absorptive organs such as roots and leaves. (More often applied to organs by which parasitic plants absorb nutrients from their hosts).

Hydraulic conductivity (also permeability). The capacity of soil to conduct water.

Hydroperiod. The seasonal pattern of water level in a wetland.

Hydrophyte. Plant adapted to wet conditions

Hydric soils. Soils that formed under conditions of saturation for periods long enough to develop anaerobic conditions in their upper layers and accumulate undecayed organic matter.

Hypogeal germination. Having the cotyledon(s) remaining within the the seed coat.

Inflorescence. The grouping or arrangement in which flowers are borne on a plant.

Infructescence. The grouping or arrangement in which fruits are borne on a plant.

Meristem. Growing tissues of a plant in which cells that have retained their embryonic characteristics, or have reverted to them secondarily, divide to produce new cells.

Microspore. The smaller of the two types of spore formed after meiosis in heterosporous species and usually designated male.

Microspore mother cell. A cell that gives rise by meiosis to four haploid cells that develop into microspores.

Microsporogenesis. The process by which microspores develop into pollen grains. All four haploid cells which are produced from the microspore mother cell by meiosis usually develop into microspores except in Cyperaceae where three out of four of the haploid cells degenerate.

Mineral soils. Usually soils with less than 20-35 % organic matter.

Minerotrophic peatlands (also called rheotrophic petlands or rich fens). Peatlands that receive water that has passed through mineral soil.

Mire. Synonymous with any peat-accumulating wetland.

Monopodial growth. Growth with a persistent terminal growing point producing many lateral organs succesively. c. f. sympodial growth

Monotypic. Containing only one taxon of the next lower rank. e.g. monotypic genus, a genus containing only one species.

Oligotrophic. Nutrient poor. Imprecise term generally used to describe plankton productivity in lakes, however also used in descriptions of other wetlands. Nearly synonymous with dystrophic, however, dystrophic implies unfavourable or toxic conditions with regard to particular organisms

Ombrotrophic. Literally rain fed, referring to wetlands that depend on precipitation as the sole source of water. Ombrotrophic peatland is synonymous with bog.

Ontogeny. The development of a single organism or organ, i.e. the sequence of stages through which it passes during its lifetime.

Pantoporate pollen grain. Having rounded apertures all over the surface.

Peat. Organic sediment which accumulates autogenically i.e. *in- situ* as a result of incomplete decay of vegetation.

Peatland. A generic term of any wetland that accumulates partially decayed plant matter (peat).

Piezometer. Groundwater well which measures the piezometric (pressure) head of a groundwater body.

Phyllotaxy (or phyllotaxis). The arrangement of leaves on a stem, which can be expressed quantitatively as the fraction of the circumference of the stem that separates two successive leaves.

Pleisiomorphic character. Ancestral or primitive character.

Pneumatophore. An air vessel or organ protruding above the substratum or water level containing gas conducting tissues or otherwise functioning to transport gases to and from the roots of the plant.

Poor fen (also mesotrophic peatland or transition fen). Peatland intermediate between minerotrophic and ombrotrophic.

Protogynous. Having the female sex organs maturing before the male. In a flower, the stigma being receptive before the pollen of that flower is shed.

Proximal. Near to the point of origin or attachment

Redox potential or reduction-oxidation potential. A measure of the electron pressurte (or availability) in a solution, or the measure of the tendency of the soil solution to oxidixe or reduce substances. Low redox indicates educed conditions; high redox indicates oxidized conditions.

Rhachis. The axis of an inflorescence.

Rhizome. An underground stem usually growing horizontally

Shoot-borne roots. Roots arising from the shoot system of a plant not from other roots. c.f. with ‘adventitious roots’ which implies an unusual cause for the initiation of these roots.

Spadix. A spicate inflorescence with a thick, often succulent axis.

Spathe. A large bract enclosing the inflorescence.

Spicate inflorescence. An unbranched inflorescence in which the flowers are without stalks and a flower terminates the growth of the axis.

Spirodistichous phyllotaxy. Leaves arranged such that there is slightly more than 180^0 between successive leaves and the leaves form two spirally arranged series.

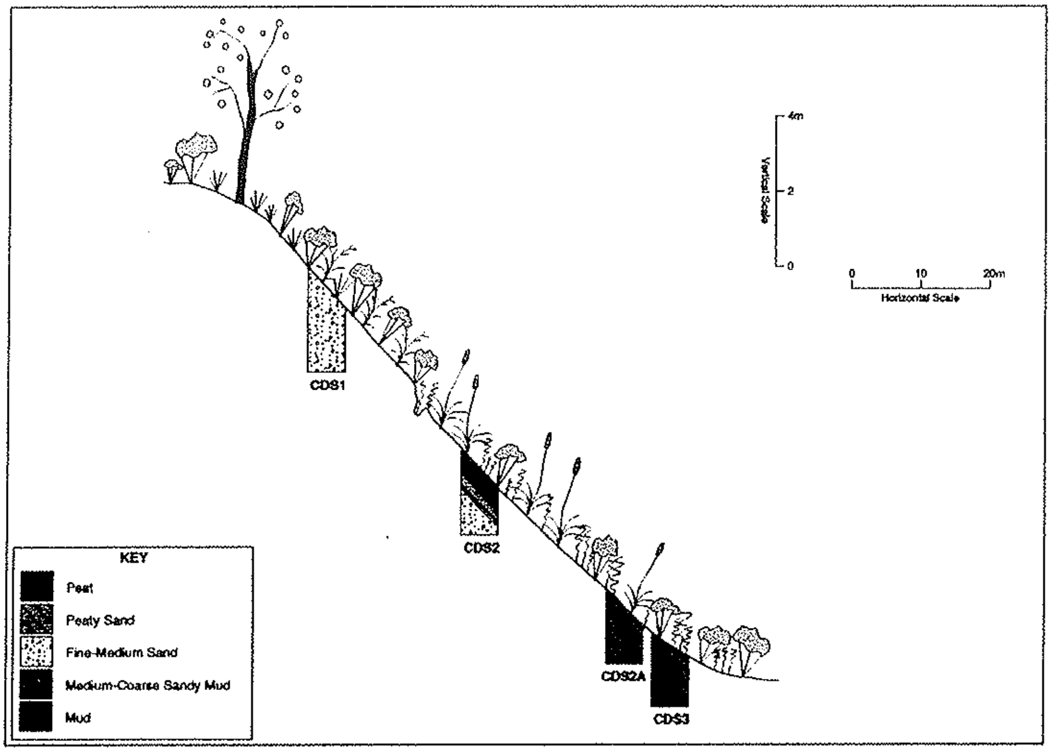
Streamflow. Channelized surface water flow.

Synapomorphy. A derived, homologous character shared by a group of taxa.

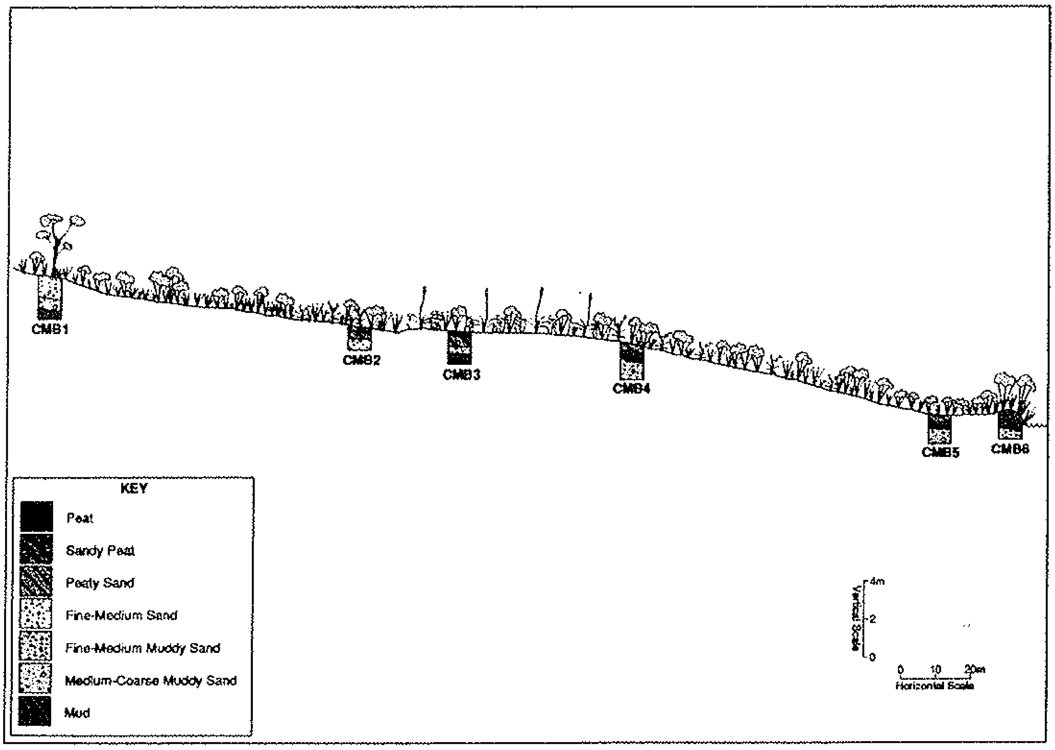
Sympodial growth. Growth without a single persistent growing point, that is, growth that changes direction by frequent replacement of the growing apex by a lateral growing point below it.

Wetland. Definitions vary but generally wetlands are characterized by the presence of water above or closely below the surface of the soil for part of the year, are inhabited by organisms adapted to this wet environment and have soil indications of the wet conditions such as hydric soils.

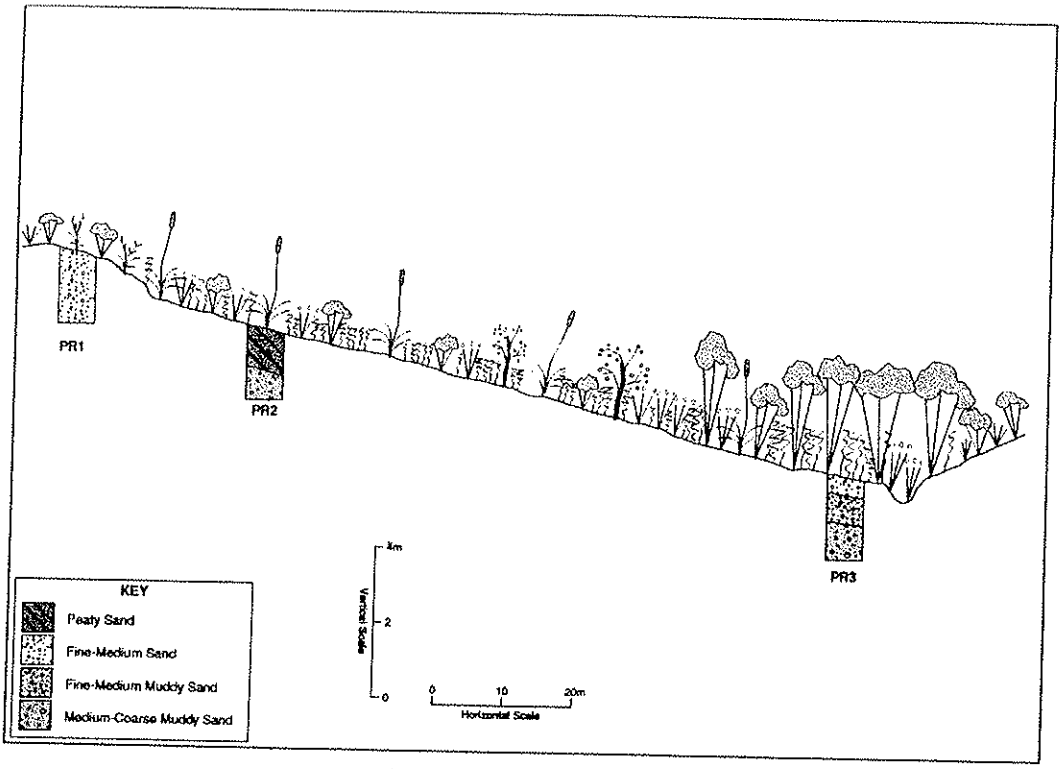
Appendix 2



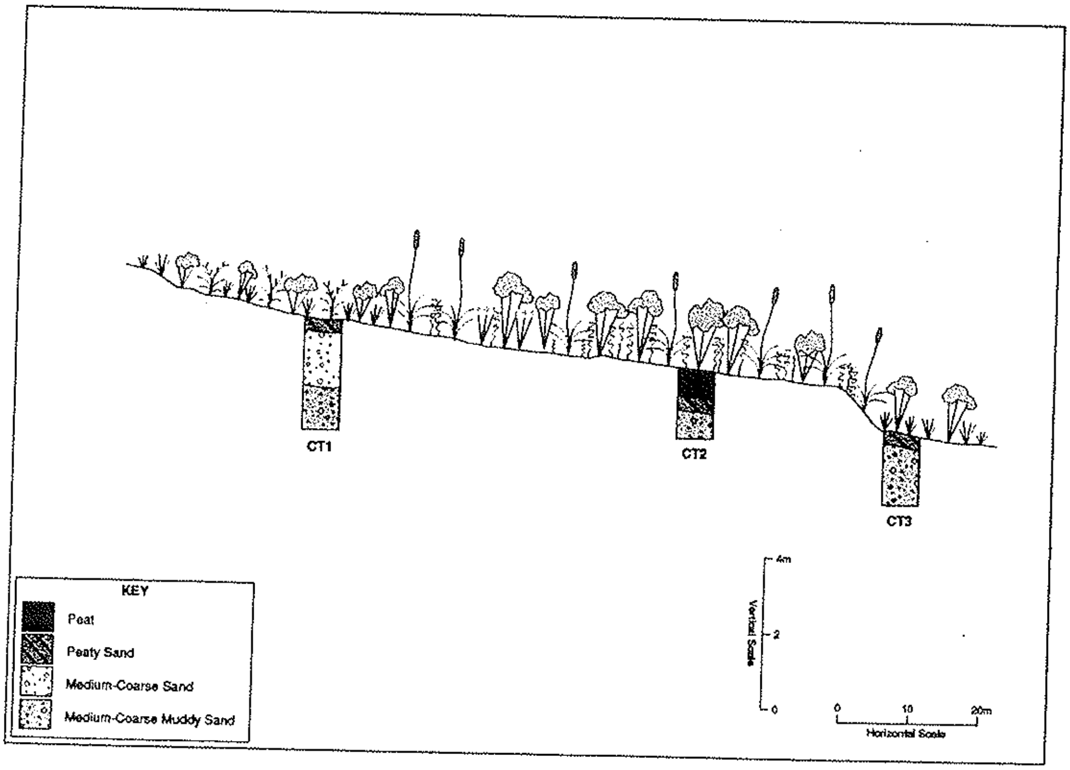
Paluslope South of Mt Chudelup



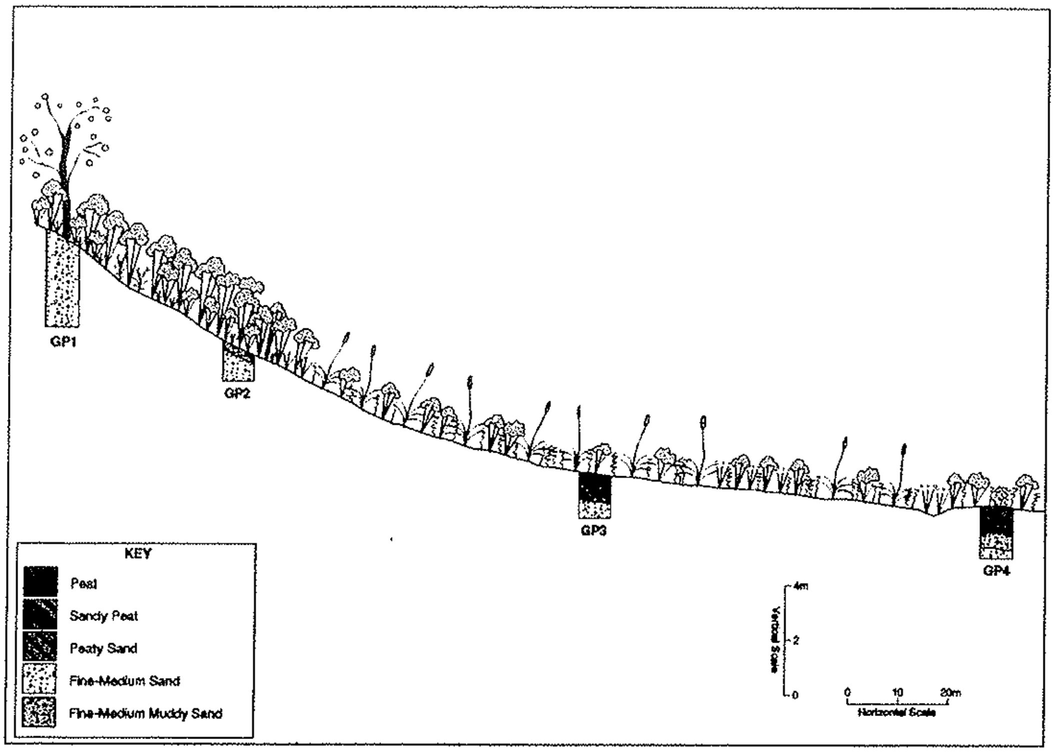
Knoll Drive Paluslope



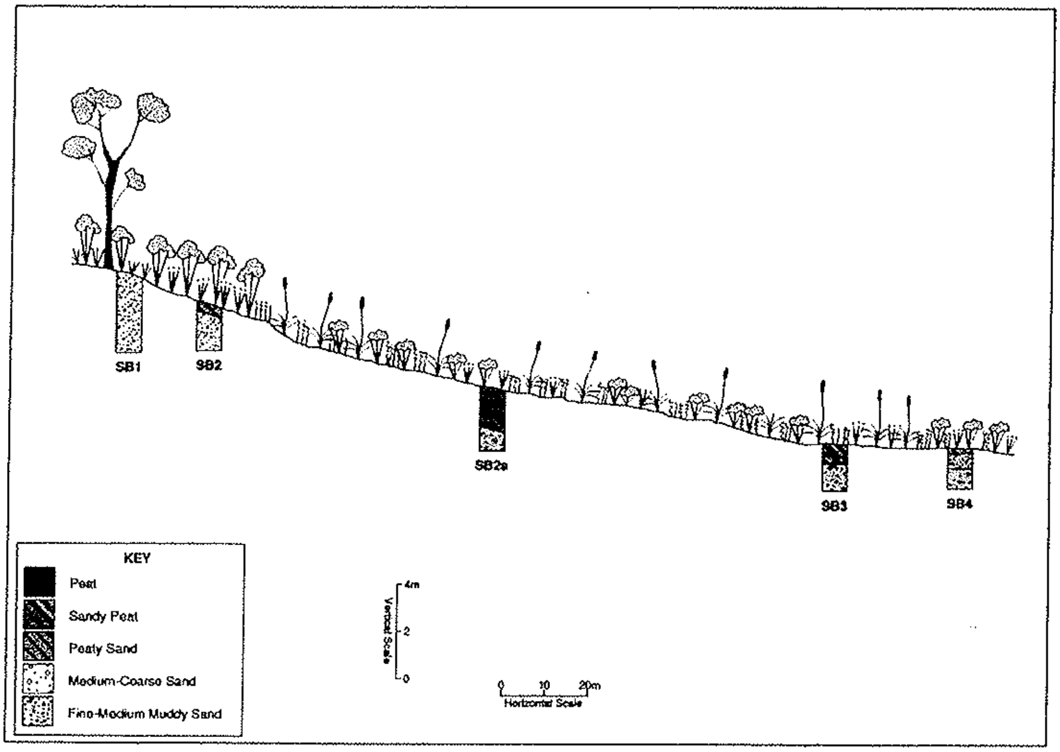
Pingerup Road Paluslope



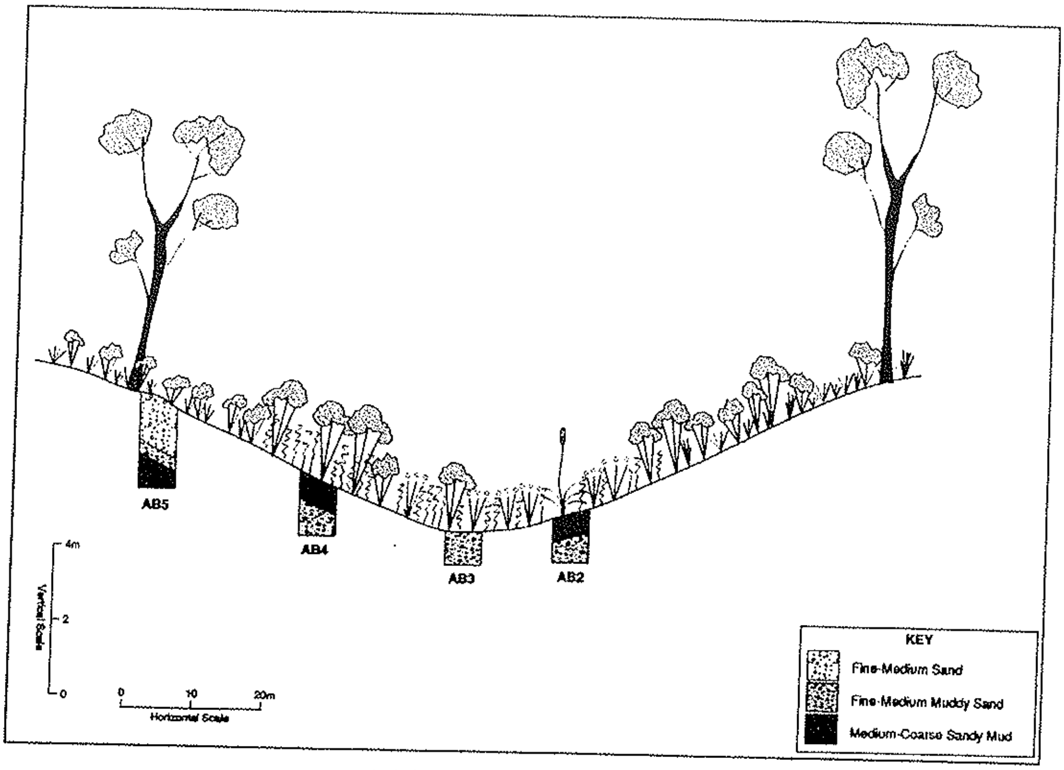
Butler Creek Paluslope



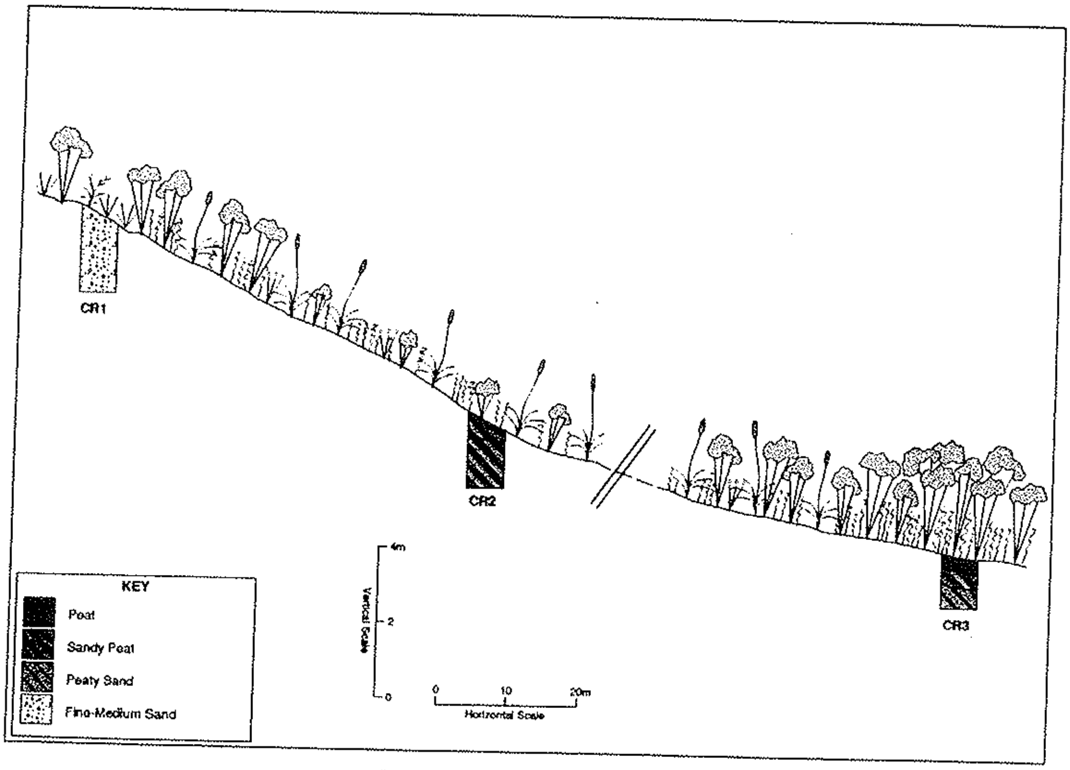
Mitchell Road Paluslope (near Granite Peak)



Sandy Beach Paluslope



Adelaide Brook Floodplain



Cemetary Road Paluslope

Appendix 3

Environmental value database for study sites

	sm30 % by wt	miW cm	pH	maW cm	tds April ppm	tds Sept ppm	S ppm	Mg ppm	Fe ppm	Al ppm	Ca ppm	K ppm	Na ppm	Zn ppm	PO4 ppm	NO3 ppm	NH4 ppm	O M %dry wt
BR2	41.5	-44	4.8	1	332	310	2	2.27	0.04	0.15	0.5	1.75	30.5	0.04	0.001	0.009	0.07	4.68
BR3	51.3	-27	6.5	12	260	270	1.6	6.99	0.04	0.15	5.35	3.06	76.7	0.04	0.035	0.009	0.151	7.88
BR4	55	4	6.5	46	170	170	0.9	2.13	0.04	0.15	0.63	1.11	26.7	0.04	0.004	0.013	0.027	5.12
AB1	51.4	-12	6.3	6	150	150	0.7	2.38	0.04	0.15	0.93	1.46	26	0.04	0.01	0.075	0.085	10.5
AB2	50.5	-21	6.1	8	200	90	0.8	2.01	0.04	0.15	0.91	1.24	25.3	0.04	0.01	0.027	0.074	6.04
AB3	52.6	-16	5.6	13	170	160	2.3	3.8	0.04	0.15	0.89	4.49	41.6	0.04	0.036	0.017	0.058	4.34
CDS1	5.1	-190	3.9	-65	100	70	0.7	0.81	0.04	0.15	0.33	1.02	12.4	0.04	0.059	0.04	0.081	9.84
CDS2	55.3	-49	4.1	-12	130	100	1.3	1.25	0.04	0.15	0.37	0.84	17.2	0.08	0.065	0.039	0.058	96.88
CDS3	34.2	-93	5.7	4	500	290	1.2	5.46	0.04	0.15	2.02	2.56	84.8	0.04	0.009	0.039	0.381	14.96
GP2	21.8	-136	3.4	-63	100	90	1.6	1	0.04	0.4	0.5	1.14	16.9	0.16	0.356	0.069	2.053	21
GP3	77.5	-54	4.4	-6	150	100	2.3	1.49	0.04	0.3	0.58	1.24	21.9	0.1	0.029	0.276	0.245	92.89
GP4	70.8	-23	4.8	0	130	80	3.5	4.87	0.04	0.2	1.52	1.94	52.6	0.04	0.018	0.028	0	7.16
SHE1	18.3	-152	3.6	-41	30	110	2.3	1.85	0.06	0.3	0.93	0.68	18.6	0.1	0.087	0.073	0.05	19.35
SHE2	56.1	-59	3.9	5	60	60	1.5	1.27	0.04	0.2	0.63	0.25	12.9	0.07	0.057	0.056	0	88
SHE3	59.9	-131	5.5	-6	60	50	0.6	0.97	0.04	0.15	0.72	2.02	13.6	0.04	0.028	0.023	0.124	46.7
PR1	9.7	-141	3.9	-64	130	30	0.9	1.19	0.04	0.2	0.65	1.47	12.9	0.07	0.038	0.032	0.116	8.62
PR2	61.1	-38	4.3	2	110	80	1.4	1.5	0.08	0.3	1.41	0.64	22	0.07	0.047	0.035	0.004	32.82
PR3	6.8	-139	5.3	0	180	96	3.8	3.12	0.19	0.15	2.42	1.24	26.9	0.04	0.014	0.017	0.046	6.71
WB2	28.3	-79	4.7	-3	80	60	0.9	1.22	0.18	0.3	0.63	1.29	18.7	0.04	0.014	0.027	0.101	17.92
WB3	72	-15	4.4	8	180	60	1.9	1.69	0.1	0.4	1.28	1.23	26.6	0.14	0.056	0.042	0.366	14.12
WB4	53.5	-54	4.2	-12	70	50	1.7	1.84	0.04	0.15	0.8	0.8	17.1	0.05	0.065	0.042	0.144	35.74
AR2	13.9	-171	3.5	1	130	80	1.2	1.41	0.04	0.15	0.62	0.8	16.8	0.04	0.12	0.075	0.124	37.35
AR3	64.7	-66	3.7	-15	110	80	0.7	0.91	0.04	0.15	0.42	0.26	14.5	0.04	0.142	0.097	0.039	94.1
AR4	41.8	-116	3.6	0	60	80	1.3	1.11	0.04	0.15	0.59	0.71	20.8	0.04	0.106	0.067	0.074	49.12
SB2	15.4	-165	3.6	22	130	150	2.5	2.93	0.04	1.3	0.77	0.71	31.2	0.06	0.013	0.066	0.132	29.82
SB2A	68.7	-34	3.8	-7	180	130	1.3	1.74	0.04	0.3	0.8	0.59	23.7	0.06	0.067	0.05	0.229	98.09
SB3	60	-93	3.9	-8	240	102	0.9	1.01	0.04	0.4	0.9	0.59	15.1	0.06	0.053	0.056	0.319	55.77
SB4	10.7	-161	3.8	3	300	210	1.8	3.65	0.34	0.4	1.61	0.46	43.8	0.14	0.07	0.075	0.319	30.17
CMB2	31.2	-82	4	0	50	90	1.2	1.09	0.04	0.3	0.55	1.61	20.5	0.12	0.055	0.141	0	51.21
CMB3	61.8	-43	4	-1	150	60	1.2	2.44	0.12	0.3	1.21	1.8	26.8	0.14	0.071	0.108	0.042	79.61
CMB4	39.5	-75	4.1	3	80	60	0.5	0.92	0.04	0.3	0.46	0.88	12.8	0.04	0.086	0.039	0.105	47.9
CT1	16.6	-184	3.9	-16	91	90	1.3	1.12	0.04	0.15	0.57	0.37	26.9	0.05	0.057	0.031	0.113	24.98
CT2	65.6	-61	4.1	-11	110	80	0.7	0.86	0.04	0.15	0.76	0.04	10.4	0.04	0.062	0.035	0.128	89.67
CT3	7.9	-163	4	3	150	80	0.6	1.09	0.11	0.2	0.63	0.28	13.3	0.04	0.09	0.059	0.229	18.27
CR1	19.9	-109	4.1	-6	30	40	1.3	1.01	0.1	0.4	0.36	0.89	10.9	0.06	0.053	0.058	0.268	19.44
CR2	77.6	-19	4.5	-9	83	80	1.4	1.76	0.04	0.15	0.67	0.93	26.9	0.05	0.012	0.114	0.093	74.49
CR3	75.6	-40	3.9	0	110	70	0.9	2.12	0.09	0.3	0.88	3.58	22.7	0.06	1.248	0.058	0.486	88.35
ARN2	77.9	-46	4.2	0	60	50	1.2	1.82	0.06	0.3	2.14	0.59	18.6	0.14	0.061	0.046	0.198	96.12

Note: All values below detection limit converted to detection limit value for purposes of ordination

Reedia Leaf Base Solution Analyses (ppm)

	PO4	NO3	NH4
shoot 1	0.025	0.009	n/a
shoot 2	0.291	0.013	0.961
shoot 3	0.096	0.078	0.584
shoot 4	0.037	0.024	0.081

Appendix 5

Floristic Inventory of Study Sites

Mean % cover is shown in each site

	AB1	AB2	AB3	AR2	AR3	AR4	ARN2	BR2
Acacia hastulata					0.3		0.3	
Acacia myrtifolia								
Acacia pulchella var. goadbyi	16.5							1.2
Acidonia microcarpa								
Actinotus glomeratus								
Actinotus laxus								3
Actinotus omnifertilis								
Adenanthos obovatus				1.55	0.6		0.6	
Agonis CoarseAgonis Wheeler pn							1.55	
Agonis linearifolia	5.55	10.25	16.1					12.5
Agonis parviceps								
Amperea protensa				1.5	1.2		0.6	
Anarthria prolifera								
Anarthria scabra				1.55				
Aotus cordifolia								0.3
Aotus genistoides								
Aotus intermedia								
Aotus passerinoides					0.3			
Astartea aff. fascicularis		2.15	0.9				4	4.9
Banksia quercifolia							6.85	
Baumea rubiginosa	4.25		4.25					0.3
Baumea vaginalis								
Baxteria australis				4.6		0.3		
Beaufortia sparsa				7.75	4	11.2	1.85	3.95
Billardiera variifolia								
Boronia fastigiata								2.7
Boronia spathulata								
Boronia stricta							0.3	
Bossiaea praetermissa								
Burchardia muliflora								
Callistemon glaucus								
Cassytha racemosa								0.6
Cephalotus follicularis							1.6	
Chorizandra cymbaria	1.2							
Comesperma flavum								
Comesperma virgatum								
Corybas abditus								
Cosmelia rubra					0.3			
Cryptostylis ovata					0.3			
Cyathochaeta teretifolia	0.3	9.25	15.25					3.65
?Baumea sp. Blackwood Tauss pn	8.95	1.85						1.2
Dampiera hederacea								
Dampiera leptoclada				0.6	6.15	3.95	0.9	
Dampiera linearis								
Dasypogon bromeliifolius								
Daviesia flexuosa								
Diaspasis filifolia		1.5	0.9	1.2		0.3		
Diplopogon setaceus				3.95		0.6		
Drosera binata								

	AB1	AB2	AB3	AR2	AR3	AR4	ARN2	BR2
Schizaea fistulosa								
Schizaea rupestris								
Sphaerolobium BR		0.3						0.9
Sphaerolobium sp. Chudelup Tauss pn								
Sphaerolobium fornicatum								
Sphaerolobium sp. nov. *Butcher*					0.6		0.6	
Sphaerolobium rostratum					0.6		1.5	
Sphenotoma gracile							1.85	
Sphenotoma squarrosum								
Sporodanthus rivularis	3.65	15.85						0.9
Stylidium glaucum						0.6		
Stylidium laciniatum								
Stylidium scandens								
Stylidium squamosotuberosum								0.3
Taraxis grossa								
Tetratheca filiformis							1.2	
Thelymitra cucullata								
Thelymitra flexuosa								
Thelymitra mucida								
Thysanotus pauciflorus					0.3		0.3	
Thysanotus pseudojunceus	1.5							
Thysanotus tenellus								
Triglochin huegelii								
Utricularia paulineae	0.9							1.5
Velleia trinervis								3.4
Villarsia lasiosperma								
Xanthorrhoeaea preisii								
Xanthosia rotundifolia								
Xyris flexifolia					2.15		0.6	
Xyris gracillima	1.5	15.25	14.95					4.25
Xyris lacera								
Xyr lanata						0.3		
Xyris maxima	3.05							
Xyris royceii								

	BR3	BR4	CDS1	CDS2	CDS3	CMB2	CMB3	CMB4
Acacia hastulata			0.6	3.9	14	2.7	4.25	4.25
Acacia myrtifolia								
Acacia pulchella var. goadbyi	3.05	8.95						
Acidonia microcarpa				8.75	1.85		0.3	
Actinotus glomeratus								
Actinotus laxus	0.3			0.3				
Actinotus omnifertilis								
Adenanthos obovatus			1.2	0.3	2.45			3.1
Agonis Coarse Agonis Wheeler pn						6.9		1.55
Agonis linearifolia	2.1	21.75						
Agonis parviceps			31.75					1.55
Amperea protensa						0.3	2.7	3.35
Anarthria prolifera			21.95					
Anarthria scabra			14					
Aotus cordifolia								
Aotus genistoides				2.15				
Aotus intermedia								
Aotus passerinoides								
Astartea aff. fascicularis	0.3	3.4				7.2		1.85
Banksia quercifolia								
Baumea rubiginosa	1.5	2.7						
Baumea vaginalis		0.6						
Baxteria australis								
Beaufortia sparsa						5.5	5.85	5.75
Billardiera variifolia								
Boronia fastigiata	0.9	1.5						
Boronia spathulata								
Boronia stricta					0.6			
Bossiaea praetermissa			0.9					
Burchardia muliflora								
Callistemon glaucus			0.3					
Cassytha racemosa								
Cephalotus follicularis				2.4				
Chorizandra cymbaria		1.5						
Comesperma flavum								
Comesperma virgatum								0.3
Corybas abditus							0.9	
Cosmelia rubra				3.95	1.2		1.2	
Cryptostylis ovata								
Cyathochaeta teretifolia	3							
?*Baumea* sp Blackwood Tauss pn	2.1	1.55						
Dampiera hederacea								
Dampiera leptoclada						2.1	1.2	2.4
Dampiera linearis								
Dasypogon bromeliifolius			3.1					
Daviesia flexuosa								
Diaspasis filifolia	0.9					1.5	0.9	3
Diplopogon setaceus						0.6		1.2
Drosera binata								
Drosera roseana			0.9					
Drosera erythrogyna								
Drosera hamiltonii				0.6			0.6	

	BR3	BR4	CDS1	CDS2	CDS3	CMB2	CMB3	CMB4
Drosera menziesii				2.1		1.2	2.4	1.2
Drosera myriantha	0.9							
Drosera pulchella								
Empodisma gracillimum	3	2.45		38.1	16.25	0.6	8.95	1.8
Eucalyptus marginata								
Evandra aristata			35.45			14.1		11.2
Gompholobium confertum			0.3					
Gompholobium sp.								
Gonocarpus diffusus		0.6						
Gonocarpus simplex						0.6	0.6	1.83
Gymnoschoenus anceps	2.45			0.6	19.4	11.45	3.4	20
Haemodorum sp.								
Hibbertia perfoliata								
Histiopteris incisa								
Homalospermum firmum	1.5	3.05		45.3	38.95	16.5	13.7	26.7
Hypolaena exsulca			1.2					
Hypolaena fastigiata								
Jacksonia horrida								
Johnsonia lupulina								
Kunzea sulphurea								
Lepidosperma Floodplain Tauss pn		0.3						
Leptocarpus sp.	1.8	0.9						
Leptocarpus tenax						3	4.25	3
Leptomeria scrobiculata			1.2					
Leucopogon alternifolius								
Leucopogon australis				1.55				
Leucopogon glabellus			0.9					
Leucopogon gracilis				0.3		3	2.7	3
Logania serpyllifolia								
Lomandra sonderii								
Lycopodiella serpentina				1.9				
Meeboldina decipiens		1.8						
Melaleuca microphylla								
Mesomelaena graciliceps								
Microtis sp.	0.9							
Platychorda rivalis								
Platysace pendula								
Podocarpus drouyinianus								
Pimelia hispida								
Pimelia longiflora			1.2					
Pteridium esculentum								
Pultenea reticulata			1.5					
Reedia spathacea	48.1			27.6			30.5	
Scaevola BR	0.3							
Scaevola calliptera			0.9					
Schoenus cruentus								
Schoenus multiglumis				9.55	11.2	5.5	3	3
Schoenus sp.								
Schoenus sublateralis								
Schoenus sublaxus								
Schizaea fistulosa								
Schizaea rupestris								
Sphaerolobium BR								

	BR3	BR4	CDS1	CDS2	CDS3	CMB2	CMB3	CMB4
Sphaerolobium sp. Chudelup Tauss pn			1.2	3	2.7			
Sphaerolobium fornicatum								
Sphaerolobium sp. nov. Butcher						2.4		1.8
Sphaerolobium rostratum							2.7	
Sphenotoma gracile					0.9	2.7	3	2.4
Sphenotoma squarrosum				0.3				
Sporodanthus rivularis	1.8	28.95			10.3			
Stylidium glaucum						0.3		
Stylidium laciniatum								
Stylidium scandens						0.9	3.05	3.05
Stylidium squamosotuberosum	0.3	0.3						
Taraxis grossa				0.9				0.6
Tetratheca filiformis				1.5				0.3
Thelymitra cucullata				0.3				
Thelymitra flexuosa								
Thelymitra mucida						0.3		
Thysanotus pauciflorus								
Thysanotus pseudojunceus								
Thysanotus tenellus								
Triglochin huegelii.		0.6						
Utricularia paulineae								
Velleia trinervis								
Villarsia lasiosperma		10						
Xanthorrhoeaea preisii								
Xanthosia rotundifolia								
Xyris flexifolia						4.6	3	2.7
Xyris gracillima	8.95							
Xyris lacera	0.3	0.9						
Xyr lanata					0.3	2.1		2.4
Xyris maxima								
Xyris royceii								

	CR1	CR2	CR3	CT1	CT2	CT3	GP2	GP3	GP4
Acacia hastulata		2.7	0.3		2.4			0.6	5.2
Acacia myrtifolia	0.9								
Acacia pulchella var. goadbyi									
Acidonia microcarpa									
Actinotus glomeratus									
Actinotus laxus									
Actinotus omnifertilis	2.7			2.1			1.2		
Adenanthos obovatus	0.6			0.3		1.85			
Agonis sp CoarseAgonis Wheeler pn	2.15	3.35						4.3	9.6
Agonis linearifolia		4.95							4
Agonis parviceps	11.1			1.5	0.3		10.3		
Amperea protensa									
Anarthria prolifera	2.7			1.2		1.2	0.3		
Anarthria scabra	0.6			21.2		8			
Aotus cordifolia									
Aotus genistoides									
Aotus intermedia									
Aotus passerinoides							0.6		
Astartea aff. fascicularis		5.65	25.7			14	7.2		
Banksia quercifolia									
Baumea rubiginosa								0.6	
Baumea vaginalis									
Baxteria australis				0.3					
Beaufortia sparsa	11.7	0.3		2.15	0.3	2.75	22		
Billardiera varifolia									
Boronia fastigiata									
Boronia spathulata							1.2		
Boronia stricta					1.5				
Bossiaea praetermissa									
Burchardia muliflora				0.3					
Callistemon glaucus								1.8	15
Cassytha racemosa	0.6								
Cephalotus follicularis							2.75	0.6	
Chorizandra cymbaria									
Comesperma flavum							0.3		
Comesperma virgatum									
Corybas abditus									
Cosmelia rubra								2.1	
Cryptostylis ovata									
Cyathochaeta teretifolia									
?Baumea sp Blackwood Tauss pn									
Dampiera hederacea									
Dampiera leptoclada	3	2.15		2.7	1.2	2.1		3.65	8.95
Dampiera linearis									
Dasypogon bromeliifolius	0.6								
Daviesia flexuosa							0.6		
Diaspasis filifolia				0.3		0.6			
Diplopogon setaceus									
Drosera binata									
Drosera roseana									
Drosera erythrogyna	0.9								
Drosera hamiltonii		0.6			4.9			1.2	

	CR1	CR2	CR3	CT1	CT2	CT3	GP2	GP3	GP4
Drosera menziesii		0.9			0.9			3	1.5
Drosera myriantha									
Drosera pulchella								0.9	
Empodisma gracillimum		14.5			3			10.5	8
Eucalyptus marginata									
Evandra aristata	0.3		0.3	13.4		5.55	4		
Gompholobium confertum									
Gompholobium sp.							3.7		
Gonocarpus diffusus									
Gonocarpus simplex									
Gymnoschoenus anceps	4.95	0.3		2.45	1.2				
Haemodorum sp.		0.3			0.6				
Hibbertia perfoliata			5.5						
Histiopteris incisa			8.7						
Homalospermum firmum	5.35	6.55	19.3	21.7	54.6	9.65		20.2	8.15
Hypolaena exsulca									
Hypolaena fastigiata				2.1		3			
Jacksonia horrida									
Johnsonia lupulina	0.3								
Kunzea sulphurea							1.55		
Lepidosperma Floodplain Tauss pn									
Leptocarpus sp.									
Leptocarpus tenax	4.25	5.5			2.1		0.3	1.2	6.75
Leptomeria scrobiculata									
Leucopogon alternifolius									
Leucopogon australis									
Leucopogon glabellus									
Leucopogon gracilis									
Logania serpyllifolia									
Lomandra sonderii							0.3		
Lycopodiella serpentina		2.4			1.4			0.3	
Meeboldina decipiens									
Melaleuca microphylla									
Mesomelaena graciliceps				0.9					
Microtis sp.									
Platychorda rivalis									
Platysace pendula									
Podocarpus drouyinianus									
Pimelia hispida									
Pimelia longiflora							0.9		
Pteridium esculentum			1.55						
Pultenea reticulata	0.6								
Reedia spathacea		24.3			13.2			14.8	
Scaevola BR									
Scaevola calliptera									
Schoenus cruentus					0.9				
Schoenus multiglumis		2.15			4.9	1.2		13.7	10.4
Schoenus sp.									
Schoenus sublateralis				1.2		2.7			
Schoenus sublaxus				1.2		2.7			
Schizaea fistulosa									
Schizaea rupestris									
Sphaerolobium BR									

	CR1	CR2	CR3	CT1	CT2	CT3	GP2	GP3	GP4
Sphaerolobium sp. Chudelup Tauss pn									
Sphaerolobium fornicatum									
Sphaerolobium sp. nov. Butcher				0.9					
Sphaerolobium rostratum					0.6			2.1	0.9
Sphenotoma gracile									
Sphenotoma squarrosum									
Sporodanthus rivulans									
Stylidium glaucum		0.3			0.6	0.9			
Stylidium laciniatum			0.3						
Stylidium scandens			1.2					1.5	0.3
Stylidium squamosotuberosum									
Taraxis grossa					1.5				
Tetratheca filiformis			0.3					0.3	
Thelymitra cucullata									
Thelymitra flexuosa								0.3	
Thelymitra mucida								0.3	0.6
Thysanotus pauciflorus				0.3				2.4	2.4
Thysanotus pseudojunceus									
Thysanotus tenellus									0.3
Triglochin huegelii.									
Utricularia paulineae									
Velleia trinervis									
Villarsia lasiosperma									
Xanthorrhoeaea preisii							1.55		
Xanthosia rotundifolia	4.9								
Xyris flexifolia					0.3				
Xyris gracillima									
Xyris lacera									
Xyr lanata									
Xyris maxima									
Xyris roycei					0.6				

	PR1	*PR2*	*PR3*	*SB2*	*SB2A*	*SB3*	*SB4*	*SHE1*	*SHE2*
Acacia hastulata	0.3		1.5	2.75	3.95	0.3		0.3	2.75
Acacia myrtifolia									
Acacia pulchella var. goadbyi									
Acidonia microcarpa		0.6			0.6				
Actinotus glomeratus	1.5								
Actinotus laxus		3.05	6.15						2.1
Actinotus omnifertilis	0.6			1.5	3.65	0.3			
Adenanthos obovatus	1.5			0.6	3.4	0.6	5.25		
Agonis sp CoarseAgonis Wheeler pn				3.4	0.3		4.3		
Agonis linearifolia			33.8						
Agonis parviceps	9.9							23.5	
Amperea protensa		4.25							
Anarthria prolifera	6.75							5.55	
Anarthria scabra	28.2							15.35	
Aotus cordifolia									
Aotus genistoides									
Aotus intermedia									0.6
Aotus passerinoides									
Astartea aff. fascicularis			6.15	0.3			4	0.3	0.3
Banksia quercifolia	0.3	0.3						18.85	1.55
Baumea rubiginosa			6.15						
Baumea vaginalis									
Baxteria australis							0.3		
Beaufortia sparsa	1.55			36.5			8.45	1.85	
Billardiera varifolia								0.3	
Boronia fastigiata									
Boronia spathulata									
Boronia stricta		8	0.6			0.3			0.9
Bossiaea praetermissa	2.75								
Burchardia muliflora									
Callistemon glaucus	1.5								
Cassytha racemosa					0.3	0.3			
Cephalotus follicularis					10.3	0.6	0.3		1.5
Chorizandra cymbaria									
Comesperma flavum									
Comesperma virgatum									
Corybas abditus						0.3			
Cosmelia rubra		2.7			0.9	0.3	2.1		0.3
Cryptostylis ovata						0.3	0.3		
Cyathochaeta teretifolia									
?Baumea sp Blackwood Tauss pn									
Dampiera hederacea			1.5						
Dampiera leptoclada				0.6			1.2		
Dampiera linearis	1.5								
Dasypogon bromeliifolius	1.55								
Daviesia flexuosa									
Diaspasis filifolia		4.65	0.9				0.9		
Diplopogon setaceus									
Drosera binata		1.5							
Drosera roseana									
Drosera erythrogyna									
Drosera hamiltonii		1.5			2.1				0.6

	PR1	PR2	PR3	SB2	SB2A	SB3	SB4	SHE1	SHE2
Drosera menziesii					2.4		2.4		
Drosera myriantha									
Drosera pulchella									
Empodisma gracillimum		4.25	1.2		11.2	9.35	6.2		2.4
Eucalyptus marginata								8.75	
Evandra aristata	17.8			3.95				17.5	
Gompholobium confertum									
Gompholobium sp.									
Gonocarpus diffusus			1.55						
Gonocarpus simplex					0.9				
Gymnoschoenus anceps				20.4			6.8	0.3	1.85
Haemodorum sp.									
Hibbertia perfoliata			0.3						
Histiopteris incisa									
Homalospermum firmum		6.8	3.1	9.1	15.7	38.2	20.7		30.4
Hypolaena exsulca	3.65								
Hypolaena fastigiata									
Jacksonia horrida	1.55								
Johnsonia lupulina	0.6								
Kunzea sulphurea									
Lepidosperma Floodplain Tauss pn									
Leptocarpus sp.									
Leptocarpus tenax		0.9		1.2	4.25		4.25		
Leptomeria scrobiculata									
Leucopogon alternifolius									
Leucopogon australis			0.3	0.9	0.6		0.6		1.2
Leucopogon glabellus	3.35								
Leucopogon gracilis					0.3				
Logania serpyllifolia	0.3								
Lomandra sonderii									
Lycopodiella serpentina		2.1			3.2				0.3
~~*Maeboldina decipiens*~~ Sporodanthus strictus		1.5							
Melaleuca microphylla			2.15						
Mesomelaena graciliceps	2.1								
Microtis sp.									
Platychorda rivalis									
Platysace pendula	2.1								
Podocarpus drouyinianus									
Pimelia hispida									
Pimelia longiflora									
Pteridium esculentum									
Pultenea reticulata	0.6			0.9				1.85	
Reedia spathacea		9.25			30.7	31.3			18.5
Scaevola BR									
Scaevola calliptera	0.9								
Schoenus cruentus					0.6		2.1		
Schoenus multiglumis		11.8	1.5	1.55	1.5	0.9	8		14.4
Schoenus sp.									
Schoenus sublateralis									
Schoenus sublaxus —							0.3		
Schizaea fistulosa							0.3		
Schizaea rupestris									
Sphaerolobium BR									

[illegible]
did not occur in [illegible] floodplain but [illegible]

	PR1	PR2	PR3	SB2	SB2A	SB3	SB4	SHE1	SHE2
Sphaerolobium sp. Chudelup Tauss pn									
Sphaerolobium fornicatum		1.8	0.9						
Sphaerolobium sp. nov. Butcher				2.1			2.1	0.3	
Sphaerolobium rostratum					1.8	2.1			1.8
Sphenotoma gracile	1.8		0.3			0.3			
Sphenotoma squarrosum									0.3
Sporodanthus rivularis			5.5						
Stylidium glaucum		0.9			0.9	0.3			
Stylidium laciniatum									0.3
Stylidium scandens			2.4	0.9					1.8
Stylidium squamosotuberosum			0.3				0.9		
Taraxis grossa		3	4.25						3.95
Tetratheca filiformis				3	2.1			0.3	1.2
Thelymitra cucullata									
Thelymitra flexuosa									
Thelymitra mucida							0.9		
Thysanotus pauciflorus									
Thysanotus pseudojunceus									
Thysanotus tenellus									
Triglochin huegelii.									
Utricularia paulineae									
Velleia trinervis									
Villarsia lasiosperma									
Xanthorrhoeaea preisii	4.95							5.35	
Xanthosia rotundifolia									
Xyris flexifolia		0.6	2.45		2.1		2.15		
Xyris gracillima									
Xyris lacera									
Xyr lanata									
Xyris maxima									
Xyris roycei									

	SHE3	*WB2*	*WB3*	*WB4*
Acacia hastulata		0.9	1.5	2.1
Acacia myrtifolia				
Acacia pulchella var. goadbyi				
Acidonia microcarpa				
Actinotus glomeratus				
Actinotus laxus		3.05	1.85	2.75
Actinotus omnifertilis				
Adenanthos obovatus				
Agonis sp. Coarse Agonis Wheeler pn			0.9	0.6
Agonis linearifolia			0.9	
Agonis parviceps		4.6		7.8
Amperea protensa				
Anarthria prolifera				
Anarthria scabra		0.9		
Aotus cordifolia				
Aotus genistoides				
Aotus intermedia				
Aotus passerinoides				
Astartea aff. fascicularis	11.2	0.3	4	5.35
Banksia quercifolia				
Baumea rubiginosa			2.7	
Baumea vaginalis				
Baxteria australis				
Beaufortia sparsa		2.75	0.3	1.85
Billardiera varifolia				
Boronia fastigiata				
Boronia spathulata				
Boronia stricta		0.9		0.3
Bossiaea praetermissa				
Burchardia muliflora				
Callistemon glaucus				
Cassytha racemosa				
Cephalotus follicularis				0.9
Chorizandra cymbaria				
Comesperma flavum				
Comesperma virgatum				
Corybas abditus				
Cosmelia rubra				
Cryptostylis ovata				
Cyathochaeta teretifolia				
?Baumea sp Blackwood Tauss pn				
Dampiera hederacea				
Dampiera leptoclada				
Dampiera linearis				
Dasypogon bromeliifolius				
Daviesia flexuosa				
Diaspasis filifolia				
Diplopogon setaceus				
Drosera binata				
Drosera roseana				
Drosera erythrogyna				
Drosera hamiltonii			0.9	

	SHE3	WB2	WB3	WB4
Drosera menziesii				
Drosera myriantha				
Drosera pulchella				
Empodisma gracillimum			18.75	0.6
Eucalyptus marginata				
Evandra aristata		7.6	1.5	
Gompholobium confertum				
Gompholobium sp.				
Gonocarpus diffusus				
Gonocarpus simplex				
Gymnoschoenus anceps		7.8		
Haemodorum sp.				
Hibbertia perfoliata				
Histiopteris incisa				
Homalospermum firmum	48	29.35	9.95	6.9
Hypolaena exsulca				
Hypolaena fastigiata				
Jacksonia horrida				
Johnsonia lupulina				
Kunzea sulphurea				
Lepidosperma Floodplain Tauss pn				
Leptocarpus sp.				
Leptocarpus tenax		0.3	0.3	
Leptomeria scrobiculata				
Leucopogon alternifolius				
Leucopogon australis	4.95			
Leucopogon glabellus				
Leucopogon gracilis				
Logania serpyllifolia				
Lomandra sonderii				
Lycopodiella serpentina			2.6	
Meeboldina decipiens				
Melaleuca microphylla				
Mesomelaena graciliceps				
Microtis sp.				
Platychorda rivalis				
Platysace pendula				
Podocarpus drouyinianus		1.55		
Pimelia hispida				
Pimelia longiflora				
Pteridium esculentum	3.7			
Pultenea reticulata		1.85		1.2
Reedia spathacea			32.05	13.45
Scaevola BR				
Scaevola calliptera				
Schoenus cruentus				
Schoenus multiglumis	3.35	3.65	0.9	7.1
Schoenus sp.				
Schoenus sublateralis				
Schoenus sublaxus				
Schizaea fistulosa				
Schizaea rupestris			0.3	
Sphaerolobium BR				

	SHE3	WB2	WB3	WB4
Sphaerolobium sp. Chudelup Tauss pn				
Sphaerolobium fornicatum				
Sphaerolobium sp. nov. Butcher	0.9	0.9		
Sphaerolobium rostratum			0.3	
Sphenotoma gracile		0.9		
Sphenotoma squarrosum	0.9			
Sporodanthus rivularis				
Stylidium glaucum			0.9	
Stylidium laciniatum				
Stylidium scandens	2.4	0.3	0.3	
Stylidium squamosotuberosum				
Taraxis grossa	72.9			
Tetratheca filiformis	3	2.4		2.1
Thelymitra cucullata				
Thelymitra flexuosa				
Thelymitra mucida				
Thysanotus pauciflorus				
Thysanotus pseudojunceus				
Thysanotus tenellus				
Triglochin huegelii.			0.9	
Utricularia paulineae			0.6	
Velleia trinervis				
Villarsia lasiosperma				
Xanthorrhoeaea preisii				
Xanthosia rotundifolia				
Xyris flexifolia				
Xyris gracillima				
Xyris lacera				
Xyr lanata				
Xyris maxima				
Xyris roycei			0.3	