Surveying Western Australia's Land Edge

Reference transects in coastal vegetation at Geraldton, Port Kennedy, Bunbury and Esperance, Western Australia.

C.Tauss 2002

The Western Australian Herbarium (W.A. Department of Conservation and Land Management); Volunteers of the WA Herbarium's Regional Herbaria; and Coastwest/Coastcare.

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COASTCARE
GOVERNMENT OF WESTERN AUSTRALIA
DEPARTMENT OF Conservation AND LAND MANAGEMENT Conserving the nature of WA
Coastwest

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Preface

The mission of the Department of Conservation and Land Management (DCLM) stresses the need to develop partnerships with the wider community to conserve Western Australia's biodiversity. The WA Herbarium as part of the Department's Science Division has placed particular importance on community partnerships in order to extend knowledge of the flora especially of the south west of the state, one of the world's biodiversity hotspots.

The Western Australian Herbarium is the custodian of names and all information about the state's flora and it aims to extend knowledge of plants through the collection of well-documented plant specimens. There are currently just over a half million specimens in the collection, all of their details have been captured electronically and the information made available to any user through access to a comprehensive online information system. However, to maintain and enhance its effectiveness as a conservation tool the collection needs to be much more comprehensive and representative of the WA flora .To assist this aim the WA Herbarium has developed collaborative programs that now provide valuable information backed by well-annotated herbarium specimens.

The Western Australian Herbarium developed these innovative programs in partnership with the community to maximize the impact of the state's small taxonomic taskforce to ensure that up-to-date information is available to regional community groups. It is the task of herbarium taxonomists to ensure that correct names are used for the flora and that a classification framework is available to ecologists, conservationists and other users of plant information. Ahead of most biological collections in Australia and elsewhere, the WA Herbarium adopted computer technology to offset the dwindling supply of trained taxonomists and to make critical biodiversity information accessible in corporate electronic information systems. The entire half million specimens in the state-managed collection are databased, and Latin and common names, short descriptions, maps and images are available for each of the 13 000 species recorded in the state to date. These data are presented in a comprehensive plant identification and information system available on Internet. Electronic data capture and the online delivery system, FloraBase, have enabled the development of the Regional Herbaria Project that now empowers 74 regional groups by providing access to up-to-date information about the WA flora.

The SWALE Project is operated as an adjunct to the Regional Herbaria Project. The already established Regional Herbaria provided considerable support to the SWALE Project that depended on the identification and specimen processing systems developed by the WA Herbarium in Perth. The Western Australian Herbarium has regularly presented training courses to community groups to enable them to conduct and document flora surveys. Groups are taught how to collect and preserve herbarium specimens, record field details and to access and utilize FloraBase. The necessity to collect voucher specimens and the ongoing value of these is a central theme in the training sessions. The Regional Herbaria are the foci for local information. Every specimen in a Regional Herbarium is represented by a barcoded "parent specimen" which has been incorporated into the main herbarium in Perth and which can be scrutinized by any users including national and international taxonomic experts. The databasing system in the WA Herbarium has revolutionized the management of ancillary collections. In the 74 Regional Herbaria in WA a single specimen of a species offers access to all available information about that particular species.

The SWALE project soon became a leading light in the Regional Herbarium program. The enthusiasm of the Project Officer, Cate Tauss, complemented that of the numerous participants. The results presented at a seminar in Perth in November 2002 were outstanding. The contribution to knowledge of Western Australian coastal flora is remarkable in that the results are thoroughly documented and available to build on in the future. The voucher collections are now housed and curated in the WA Herbarium collection. The methods and results of the SWALE Project will be made available as a special part of the Herbarium's information delivery system FloraBase so that it can be readily accessed as a vitally important base-line study and model for similar studies of our unique and fascinating flora.

Dr Neville Marchant
Director, Western Australian Herbarium

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Cover photo

A close-up look at the coastal flora - discoveries at the scale 1m x 1m.

Calandrinia sp.1 Becher. F.Littleton 66. An undescribed species of Portulacaceae with bright pink flowers first collected by a volunteer at the Port Kennedy Scientific Park growing with *Senecio lautus* subsp. *maritimus,* a widespread yellow coastal daisy.

Photo: C.Tauss

"The summer air is white with blowing sand. We live morning and night the way I did as a boy in Greenough. Thank God we don't outlive all of our childhood fancies."

Tim Winton (1993). Land's Edge.

1. Introduction

There are many layers of value and meaning inherent in the coastline of Western Australia and many scales at which it can be explored, described, enjoyed and cared for.

To many of its inhabitants, the land's edge has little significance beyond its recreational opportunities, high real estate value and a slowly dawning awareness of the need to protect property from coastal erosion. There are also many West Australians who resonate with local novelist Tim Winton when he describes the coastal forces of wind, sand and sun which fill their senses in summer. They feel nostalgic when he describes the coastal settings in which urban rites of passage take place and where urban myths grow. There are also a few who follow Tim when he ventures onto more spiritual planes and articulates the identity-shaping influence of the coastal environment on his life and on his vocation as a writer. Some return their debt to this environment in the form of practical conservation projects. A tiny minority of West Australians are involved in scientifically exploring coastal environments and the international scientific community sometimes knows and values this exploration more than their compatriots. A deeper level of meaning (which can only be glimpsed as an idea and not truly experienced by Western Australians of non-Aboriginal descent) is that of the Aboriginal coastal heritage built up over many thousands of years of vital interaction with the coast, its creatures and its plants. If the coast is identity-shaping over the life of an individual like Tim Winton and evokes a large response in his readers, what does it mean to have inherited an identity, culture and spirituality shaped by an environment for over 40,000 years? In this context most of the current inhabitants of the coast could be considered as truly living superficially on the land's edge, remote from the deeper layers this land can offer.

An important aspect of human cultural evolution is that names are given to physical entities (or ideas) as an almost obligatory step in developing a relationship with those entities or as a prelude to deeper exploration of ideas. Conversely, the range and richness of names which a culture holds is indicative of the depth and complexity of its relationship with a particular entity or idea. One of the underlying aims of Surveying Western Australia's Land Edge (the SWALE project) was to establish at the local community level (with the aid of the science of taxonomy and electronic information-sharing tools) some name-based foundations, traditions and resources to promote deeper appreciation and ongoing care for the unique and beautiful flora of our coastal environment.

The SWALE project thus brought together scientific and community efforts to record floristics and vegetation structure in the form of reference transects in coastal areas of high conservation value. Natural processes such as climatic fluctuation and human-mediated factors such as weed invasion, increase in fire frequency and recreational use of coastal areas all produce readily observable change in coastal environments, even in the short term. The transect survey was designed so that vegetation condition and floristics could be monitored in the future and compared to the baseline data obtained by SWALE in 2002. Thus insights to inform future management of natural coastal resources could be amassed. The project also provided training for community volunteers of the Regional Herbarium in each of the project areas to support and promote their work in collecting the Western Australian flora for scientific purposes. Lodging voucher specimens is a particularly important activity to validate the scientific value of any study and in this regard the project aimed to be an example of how this should be done. This project carried the expertise of the volunteers into the realm of ecological survey and vegetation monitoring in recognition of the fact that it is often the volunteer sector which provides continuity in many long-term projects (such as vegetation monitoring and bush regeneration) which are essential in managing and conserving biodiversity.

The SWALE project focussed on fine detail at the scale of flora genera, species and the state of individual plants in small quadrats. It was also preoccupied with the practical details of establishing permanent reference transects for vegetation monitoring and lodging voucher specimens to validate botanical studies. These small scale activities are very relevant to the present task of conservation and management but were informed by a large body of previous research which places the vegetation within a broader context. A framework of botanical, geological, stratigraphic, hydrological, Palaeogeographic and biogeographical studies have preceded SWALE and many of these will be referred to in the description of the setting of individual transects below. Early botanical and biogeographic studies were reviewed by Beard (1990a). A comprehensive checklist of the coastal flora of the South West Botanical Province was also compiled from these sources (Beard, 1990b). These studies included Sauer (1965), Nelson (1974), Semeniuk *et al.,* (1978), Bridgewater & Zammitt (1979), Marchant and Abbott (1981), Cresswell & Bridgewater (1985), Smith (1985) and later Semeniuk *et al.*, (1989), Hesp (1991), Keighery & Keighery (1993) and Rippey & Rowland (1995). More recently there has been a renewal of interest in coastal vegetation and conservation with Pen *et al.,* (2000), Semeniuk *et al.,* (2000), Harvey *et al.,* (2001), O'Connor (2001), Rippey (in prep) and Semeniuk (in prep).

The coastal flora is important in issues of Australian historical biogeography such as recruitment of new taxa to Australia, dispersal trends around the perimeter of Australia and the movement and speciation of the flora between the coast and the inland in response to fluctuating climate. Plant propagules arrive from overseas and from other coastal regions of Australia under the influence of forces such as weather, ocean currents, human and animal migration. Over the longer term, sea levels changes in the past have, at times, enabled migration of coastal plants laterally around the coast along expanded terrestrial corridors or alternatively have isolated coastal areas from plant migration. The coastal flora patterns preserve some of the evidence of these fluctuations. There is also a hypothesis that many elements of the present day arid zone flora of Australia (e.g. members of the families Aizoaceae, Amaranthaceae, Asteraceae, Brassicaceae, Chenopodiaceae and Portulacaceae) may have originated from coastal ancestors (Burbidge, 1960 and Schodde, 1989). The pre-adaptation of the coastal flora to harsh coastal habitats during the Tertiary, when there is strong evidence that much of the rest of the continent experienced more humid conditions, would have been advantageous to their radiation into the inland habitats as arid conditions became widespread later in the Pliocene and Pleistocene eras. Such questions are becoming more amenable to study with the development of molecular genetics and other technology but adequate description of the coastal flora and adequate collections of the flora underlie further progress.

Sauer (1965) established the belt transect method as useful in describing coastal vegetation in a geographic reconnaissance of Western Australian seashore vegetation between Port Hedland and the Albany region. The linear belt transect effectively captures variation of vegetation as a function of distance from the shoreline. The methods used by Sauer were adapted for the SWALE project. The latter differed however in that permanent transects were established, quantitative data (abundance of taxa) were collected as well as qualitative data, local volunteers were involved in the study and all specimens were lodged as vouchers with the WA Herbarium. The SWALE project also focussed on the abundance of indigenous and alien taxa seedlings recruiting as this is an important factor in assessing vegetation condition. Quantitative data were collected in this project because measures of vegetation abundance can be compared by multivariate statistical analysis to detect changes in the vegetation and floristics over time. It is equally important to have an abundance measure when comparing vegetation at one site with that at another site (at the same point of time) because relative abundance of taxa in an assemblage can be an important indicator of vegetation type.

The SWALE project established monitoring transects at Geraldton, Bunbury, Perth (Port Kennedy) and Esperance (Cape Le Grand National Park). These areas were chosen primarily because of interest expressed by the respective Regional Herbarium groups, the high conservation value of the project areas and the wide variety of coastal landforms and vegetation present (Table 1 and Fig 1). The Greenough Dunes in the Geraldton area are of State-wide conservation significance (Fig 1a) with characteristically large, perched dunes encroaching northwards over scrub and heath towards the Greenough River. This type of landform is not found elsewhere in Western Australia. The Port Kennedy Scientific Park (Fig 1b), encompasses part of the Becher cuspate foreland. This is composed of an extensive series of low-relief beach ridges and swales. Subtle vegetation patterns include grassland, sedgeland and open heath and these reflect the developmental history of the landforms and the groundwater levels. The area is of international significance and this is recognized in its Ramsar convention listing. At Dalyellup Beach, south of Bunbury (Fig 1c), eastward-trending dunes of high relief are fixed with closed scrub and low closed forest of Peppermints in deep parabolic dune bowls and valleys. Tuart woodland is present within a stone's throw of the beach in some of these valleys. This area is of regional significance being representative of the northern part of the poorly-conserved Quindalup to Leschenault sector of the Quindalup Dunes. At Cape Le Grand National Park (Fig 1d) species-rich coastal vegetation inhabits a great variety of landforms such as granite hills, islands and headlands, plateaux, dunes and coastal wetlands. The area also holds a rich human history associated with early European coastal exploration and the investigation of natural science.

The study areas lie within the 400 –900 mm annual rainfall zones (Fig 2) and thus encompass a large range of climatic conditions found along the coastline within the boundary of the South West Botanical Province (Beard, 1980) except that of the more humid south west corner of the state where the summer drought is the least pronounced.

Table 1: Natural heritage values of SWALE transect areas

	Heritage values
Geraldton	
Greenough Dunes	State significance as a representative landform. Shire Reserve.
Drummonds Cove	Regional significance as a representative landform.
Port Kennedy	
Port Kennedy Scientific Park including Becher Point	International significance, listed under the Ramsar Convention due to the natural history record preserved in the sediments and the temporal series exhibited by the wetlands. The wetlands are also listed as an endangered ecological community by DCLM and the Federal Dept of Environment on criteria of representation, rarity and demonstrable threats.
Bunbury	
Dalyellup Beach	Regional significance as Quindalup Dunes of the (poorly conserved) Quindalup to Leschenault sector with vegetation in good condition.
Preston River Delta	State significance as the most southerly population of mangroves in W.A. and insights it provides into the Leeuwin Current.
Esperance	
Mt Le Grand & Hellfire Beach	State significance for geoheritage and flora. Part of the Cape Le Grand National Park.

a. Geraldton

b. Port Kennedy

c. Bunbury

d. Esperance.

Figure 1: Contrasting landforms and vegetation in the four project areas

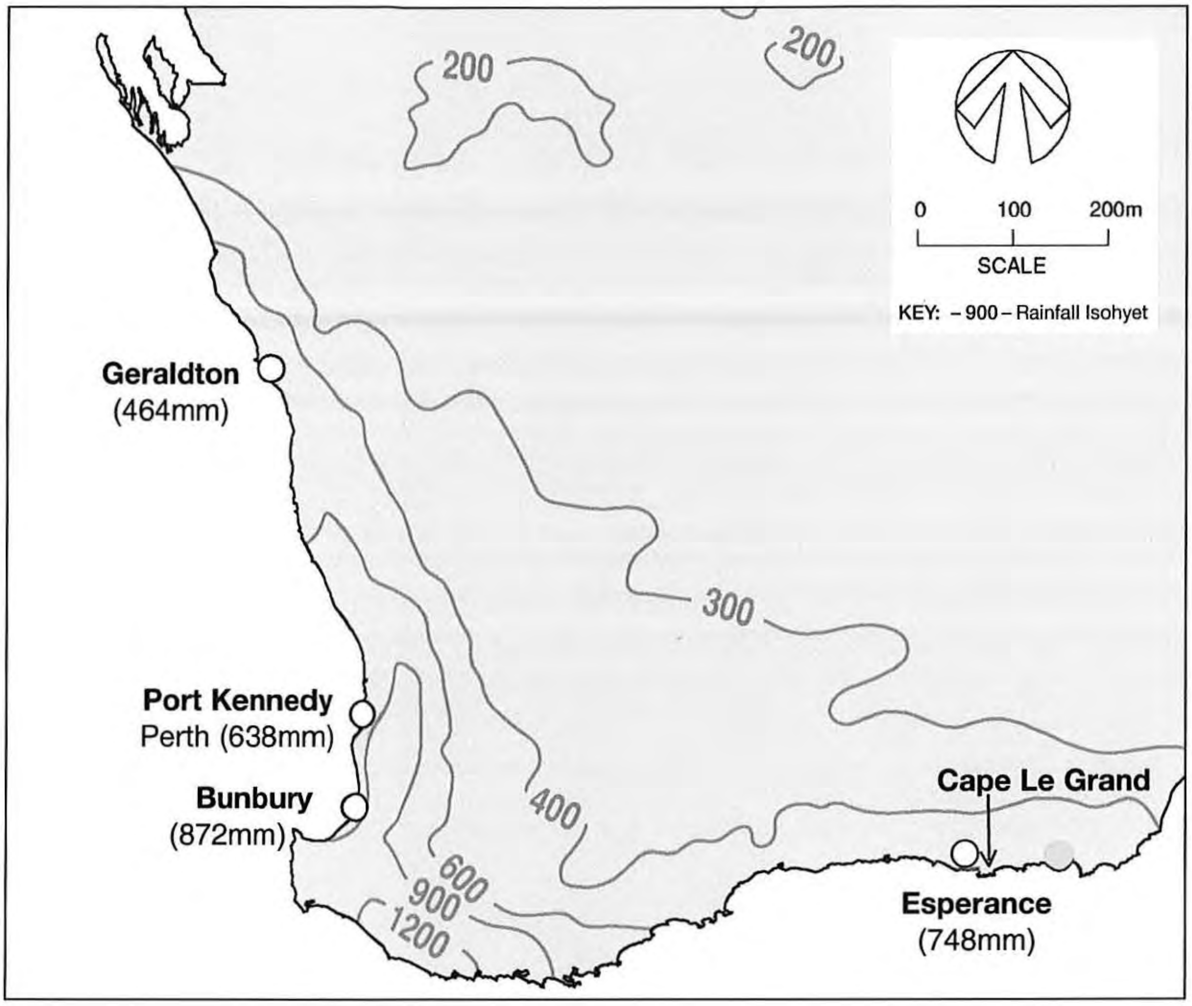


Figure 2: **Mean annual rainfall in the four project areas and isohyets in South Western Australia. Figure adapted from Bureau of Meteorology (2002) with isohyets based on a standard 30 year record (1960-1990).**

2. Methods

Location of transects

Transect locations and transect length were determined by the unique features and style of coastal vegetation in each region as well as a need to record a standard sample of the interface between the ocean and the land at each site. Originally it was proposed to limit the transects to the foredune vegetation alone. However this proved less than satisfying to enthusiastic volunteers and was also not applicable due to topography and vegetation in some areas. For example foredunes were not present at the Cape Le Grand granite slope and deltaic shoals at Bunbury. At the low relief Becher Plain at Port Kennedy, there was a very wide zone of recently accumulated sediments and to illustrate some of the subtle patterns of the coastal vegetation here required a very long transect. In contrast to this, at Hellfire Beach a very short transect was surveyed due to the difficulties involved in traversing extremely thick vegetation and the need to limit damage to disturbance-sensitive *Banksia* vegetation. Selection of locations for transects (Table 2) was carried out on the following criteria:

Proximity to the respective Regional Herbarium, number of volunteers involved, their local resources and level of ownership felt for the particular site;

Conservation value of the vegetation and landforms;

Vegetation condition; and

Contrast of habitat types, within the limited budget and time of the project, to maximize the sample of diverse south west Western Australian coastal flora captured by this project.

Vegetation and flora

Colour aerial photographs (from the Department of Land Administration, flown in 2000) at a scale of 1:5000 were used to map vegetation units and select sites for transects. These aerial photos will remain with the Regional Herbaria groups for use in interpretive displays and as part of the reference resources to be used in assessment of vegetation changes over time. Vegetation structure terms used for describing vegetation mapping units (Table 3) were modified from Specht (1981). Safety of participants was an issue at Port Kennedy since the area is known to contain unexploded shells from Army firing range activity in the past. Therefore the Fire and Emergency Service was asked to scan the sites chosen by their standard process using appropriate metal detector equipment. Fortunately no shells were detected.

Table 2: Transect locations and lengths

Transect Name & Code	Location GPS	Length m
Hellfire Bay E2	34^{0}00’ 02” S 122^{0} 09’ 09” E Cape Le Grand National Park, SE of Esperance	72
Mt Le Grand E1	33^{0}59’ 00” S 122^{0}05’ 04” E Cape Le Grand National Park, SE of Esperance	116
Preston River Delta B2	33^{0}19’ 26” S 115^{0}38’ 55” E Koombana Bay, Bunbury townsite	123
Dalyellup Beach B1	33^{0} 19’ 24” S 115^{0} 36’ 05” E Southern suburb of Bunbury	125
Drummonds Cove G2	28^{0} 41’ S 114^{0} 37’ E 7 km N of Geraldton	145
Becher Point PK2	32^{0}22’15”S 115^{0}42’59”E Port Kennedy Scientific Park south of Perth	149
Greenough Dunes G1	28^{0} 57’ S 114^{0}44’ E South of Geraldton	181
Port Kennedy PK1	32^{0}22’ 54” S 115^{0}43’ 50” E Port Kennedy Scientific Park south of Perth	500

Table 3: Vegetation structure classification (adapted from Specht 1981).
Note: Three layers were used to describe the distinctive perennial monocotyledenous vegetation in this study: 1.Grasses and other monocots such as *Lomandra*; 2.Sedges and rushes; and 3.*Borya* mats with associated herbs and low cushion shrubs.

	Foliage projective cover of tallest layer			
Tallest layer	**100-70%**	**70-30%**	**30-10%**	**<10%**
trees 10-30m	closed forest	open forest	woodland	open woodland
trees < 10m	low closed forest	low open forest	low woodland	low open woodland
shrubs > 2m	closed scrub	scrub	open scrub	tall open shrubs
shrubs < 2m	closed heath	heath	open heath	low open shrubs
Perennial grasses and *Lomandra*.	closed grasses	grasses	open grasses	sparse grasses
Perennial sedges & rushes	closed sedges	sedges	open sedges	sparse sedges
Perennial *Borya* mats		monocot mats	open monocot mats	sparse low monocots

Transects were marked out using a 50m tape measure, aluminium pegs and flagging tape. The number of permanent markers used were kept to a minimum for aesthetic and safety reasons. Geographic positioning system (GPS) readings were taken to provide location information for the voucher specimen database and as the main method of permanently locating transects.

The first activity carried out at each transect, once the transect location had been marked out with flagging tape, was to collect small samples of every taxon in the vicinity (both mature and seedling specimens). These were used to make two copies of a temporary field herbarium on site in which all taxa were represented, each labeled with a standard field name. The field herbarium activity served as informal botanical training to familiarize participants with the flora of each area prior to commencing the survey and allowed everyone to contribute information (Fig 3c). It also enabled consensus to be reached about standard field names for each taxon and these were then strictly adhered to on the transect data sheets in the survey. The field herbaria were thus used as a basic reference text to accurately score taxa in the field. As the survey proceeded, the field herbaria were updated as soon as any of the data recorders came across any further unnamed taxa. Any changes thus made were circulated to the whole group. However at most sites, such running updates were generally minimal as the participants had made very comprehensive initial collections. After the field work further informal plant identification training sessions were held at the Regional Herbarium headquarters in Geraldton, Bunbury and Esperance using the resources the groups have assembled including specimen collections, microscopes, reference libraries and Florabase on line.

Each transect was surveyed as a 1m wide belt recording flora from a continuous series of $1m^2$ quadrats over a 50m measuring tape (Fig 3b) after Sauer (1965). Presence of all flora taxa in the quadrats was recorded using field names from field herbariums, projected foliage cover class and height of plant. A modified Braun-Blanquet (1951) system was used to group projected foliage cover of each taxon encountered in the quadrat in the following classes.

Cover Class: **1.** < 5%

2. > 5% and <25%

3. >25% and <75%

4. > 75%

Both adult and juvenile forms of all the flora were recorded and phenological notes were kept (eg. seedling, flowering or fruiting states).

Voucher specimens are an essential component of the natural sciences because all studies following the scientific method must, by definition, have their results and conclusions backed up by evidence. The voucher specimens are this evidence in material form. Moreover, since the scientific pursuit of knowledge is a dynamic, evolving process the availability of the voucher specimens in a Herbarium is an important element allowing researchers in the future not just to check on the veracity of a study but review the evidence supporting its conclusions in the light of any further evidence as this becomes available. Standard protocols developed by the WA Herbarium for the Regional Herbarium Program were used for collection of flora voucher specimens, recording collection notes and specimen processing, curation, databasing and incorporation. Collecting notes accompanying each specimen included: collectors name and number, date, field identification name, habit, size, flower colour, landform, soils, vegetation structure, associated taxa, condition of vegetation, locality statement and GPS coordinates. Specimens were labeled with the collector's name and number and then pressed, dried and delivered to the WA Herbarium with labeled duplicate specimens and collecting notes retained at the respective Regional Herbarium. Each batch of specimens received by the WA Herbarium were frozen to destroy any insect contamination. Identification of the specimen by the Regional Herbarium volunteers in Perth was the next task with all names verified by Herbarium botanists. Specimens meeting the Herbarium criteria with regard to quality of specimen and accompanying notes were then mounted on standard sheets and databased. The databasing process assigned each specimen with a unique database number and this, with all relevant data about the specimen from the collecting notes was incorporated into the electronic database and onto a printed label to be affixed to the specimen sheet. Duplicate labels were sent to the respective Regional Herbarium. The specimens were then physically incorporated into the Western Australian Herbarium collection to be stored under controlled atmospheric conditions.

Landforms, soils and water

Topographic survey of landforms for each transect was undertaken using either a dumpy level or a laser level depending on availability of equipment.

Stratigraphy at selected sites was investigated by shallow manual augering or digging and materials were subsequently examined using a stereoscopic microscope. Surface sediments were described directly in terms of grain size, texture, colour and presence of organic matter without resort to soil classification systems. The terms used for grain size were according to the Wentworth scale (Krumblein & Pettijohn, 1938), (Table 4). 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 (Table 5).

Table 4: Sediment grain size (Wentworth Scale)

Size class of grains (μm)	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	mud or peat

Table 5 : Sediment texture terms

Descriptor	Definition
sand	Sand-sized particles dominant (>90%).
humic sand	Sand grains coated with a thin layer of fine organic particles dominant (>90%).
muddy (or peaty) sand	Sand particles form the frame (>60%) with some interstitial mud-sized particles (or peat) also present.
sandy mud (or peat)	Mud (or peat) sized grains dominant (>60%) and support some sand grains.
mud (or peat)	Mud sized grains dominant (>90%).

Groundwater levels at the Port Kennedy Scientific Park were monitored at three sites to illustrate the relationship of plant assemblages to ground water levels. These sites were the Becher Point saltmarsh (Fig 3a), a shallow swale near the beginning of the Port Kennedy transect and a linear wetland at the end of the same transect. Piezometers made of PVC pipe were installed at these three sites and the water table was monitored (at various intervals) for one year. Weekly rainfall data for the area were also obtained from the Bureau of Meteorology nearest weather station at Medina. Wetlands in this study were described using the geomorphic classification of wetlands of Semeniuk & Semeniuk (1995), (Table 6).

Table 6: Geomorphic classification of wetlands (adapted from Semeniuk & Semeniuk, 1995).

Landform	Permanent inundation	Seasonal inundation	Seasonal waterlogging
Basin	lake	sumpland	dampland
Flat		floodplain	palusplain

a. Felicity Littleton monitors groundwater levels. *Photo: Deanne Pember*

b. Diana Hitchin and Andrew Motherwell record flora data in a quadrat on transect PK/1. *Photo: Deanne Pember*

c. Meeting to share information, reach consensus about field names and make temporary field herbarium notebooks after a first foray into the field. *Photo: Deanne Pember*

Figure 3: Research by Rockingham Regional Herbarium volunteers at Port Kennedy Scientific Park.

3. The S.W.A.L.E. transects

A total of eight transects were established in the survey (total length = 1412m) with individual transects ranging in length from 72m (Hellfire Bay) to 500m (Port Kennedy). This involved recording vegetation data from a total of 1292 x 1m^2 quadrats.

The transects were first described below in the context of the physical setting of each region with regard to climate, geology and landforms (Table 7). This information was mainly sourced from the literature and definitions of the terms used are listed in the glossary (Appendix 1). Results from the surveys were then presented using various ways to summarize and depict the data:
Aerial photos showing mapping of broad scale vegetation assemblages in each project area (Figs 4, 5, 9,14,15,18 &19);
Field data sheets for the entire length of each transect (Appendices 3-6) listing quantitative data of presence/absence, abundance (% cover class) and height of taxa recorded in the field and some phenological notes;
Transect diagrams (Figs 6,10,16 &20) illustrating the relationship of topography to dominant species and vegetation structure in at least the first 100m or so of each transect; and
An inventory of all flora specimens collected at the various transects and lodged in duplicate with the WA Herbarium and the respective Regional Herbarium with verified names and database numbers (Appendix 2).
The data is organized in this way to enable it to be used for various purposes such as monitoring condition of vegetation in the area over time (aerial photographs), monitoring flora in transects (field data sheets), creating interpretative or educational material (transect diagrams) and researching aspects of taxa recorded such as their geographical range, ecology, taxonomy updates and botanical literature (flora inventory using Florabase).

Table 7 : Summary of physical setting of the SWALE transects.

	Climate	Geology & stratigraphy	Landforms	Surface sediments or soils
Geraldton	Semi arid	Extreme north of Perth Basin. Holocene sands over Pleistocene Tamala Limestone	Northern sector of Quindalup Dunes **Greenough** Wave cut rocky shore (erosional system). Slope of large scale perched barrier dune with shore-parallel mobile parabolic dunes. **Drummonds** Cuspate foreland (accretionary system) with overprint of shore-parallel parabolic dunes	Calcareous and quartz sand Calcareous and quartz sand
Port Kennedy	Sub humid	Rottnest Trough of Perth Basin. Holocene Safety Bay Sand over seagrass bank Becher Formation over Bridport Calcilutite	Pt Bouvard to Trigg Island sector of Quindalup Dunes. **Pt Kennedy** Cuspate foreland-series of low-relief relict beachridges, swales and freshwater damplands. **Becher Point** Barred lagoon wetland at tip of cuspate foreland. Saltmarsh.	Calcareous and quartz sand, humic sand, peaty sand, sandy peat.
Bunbury	Sub humid to humid	Bunbury Trough of southern Perth Basin. Holocene Safety Bay Sand over Pleistocene Tamala Limestone. Holocene alluvium over Safety Bay Sand over Pleistocene Leschenault Formation	Quindalup to Leschenault sector of the Quindalup Dunes **Dalyellup Beach** High relief shore- normal perched parabolic dunes **Preston River Delta** Tide-oriented shoals of a microtidal delta. Salt marsh and tidal flats between mean sea level and highest tide and slightly higher dune crests.	Quartz and calcareous sand Organic matter and mud over sand
Esperance	Sub humid	Proterozoic granite and gneiss colluvium Holocene aeolian sand	**Mt Le Grand** Steep rocky shore and headland. **Hellfire Beach** Pocket beach and dunes between two rocky headlands.	Catena down the slope of boulders, cobbles, pebbles, gravel, coarse sand to peaty sand and mud Pure quartz sand

3.1 Geraldton: Greenough Dunes and Drummonds Cove

a. Setting of the transects

Geraldton has a climate classified as semi arid (Gentilli 1972) or dry warm mediterranean (Beard, 1990a). It is situated in the Irwin Botanical District (Beard, 1980) or the Geraldton Sandplains Biogeographical Region (IBRA, 2000). Mean annual rainfall is 464 mm with an annual evaporation of 2468 mm (Bureau of Meteorology, 2002). Winter rain is generally reliable with a growing season (i.e. the months when precipitation is high compared to evaporation) of about four months (Beard and Burns, 1976). There is a daily land and sea breeze pattern of strong winds (20-40 km/hr) from the SEE and SSW respectively in summer (Semeniuk *et al.* 1989).

The coastal areas of Geraldton are situated at the northern end of the Perth Basin in a geological unit known as the Abrolhos Sub-Basin (Playford *et al.*, 1976). A Pleistocene age aeolianite, (Tamala Limestone, Playford *et al.,* 1976) forms several extensive, shore-parallel ridges along the entire length of the coast in the region and outcrops at the coast as tall sea cliffs north of Horrocks Beach. Most of the aeolianite immediately adjacent to the ocean is however flanked by calcareous and quartz Holocene dunes on its seaward side or is overlaid by perched dunes. These coastal dunes can be considered as a correlative of the Quindalup Dunes although the latter has been formally described only between Quindalup and Dongara. Geomorphic terms used by Semeniuk *et al.* (1989) for the northern sector of the Quindalup Dunes are applicable in describing the coastal landforms and associated plant habitats in the Geraldton region (see Appendix 1). The Geraldton coastline shows evidence of Quaternary sea level changes. Some of the coral-algal reefs at the Houtman Abrolhos Islands are thought to have formed when Pleistocene sea levels were at least 7.61 m higher than at present. The islands have been connected to the mainland during periods of low sea levels in the Quaternary (Playford *et al.* 1970).

The Holocene dunes of the area are best developed south of the Greenough River mouth. The Greenough dunes are continuous, large-scale, perched barrier dunes of high relief overlying a shore-parallel ridge of Tamala limestone. Inland lies the extensive floodplain of the Greenough

River, with the river transgressing the barrier dunes just north of Cape Burney. A sand bar is generally present at the river mouth and this is only breached by infrequent floods. At mean sea level along the coastline there is a wave-cut platform of aeolianite. The inner platform is covered by sand forming a continuous ribbon of beach and a low foredune. This type of Pleistocene rocky shore sequence is described in Semeniuk and Johnson (1985). The foredune adjoins a steep, gently undulating slope to the top of the ridge (which is over 50m in height in some places). Here, the semi-arid climate and the intensity and direction of the winds in summer contribute to the development of distinctive large, northward-mobile parabolic dunes. The Greenough dunes transect (G1) (Fig 4) is located about 1km south of the Greenough River mouth and extends from the rocky shore about 150 m up the slope. The area is a Shire of Greenough Reserve.

North of Geraldton, the coastal dunes are thin ribbons except for the cuspate foreland at Drummonds Cove. This is an accretionary system (in contrast to the erosional wave-cut shore at the Greenough dunes) with a taller foredune and a series of inland, shore-parallel Holocene beachridges. The regularity of the beachridges is disrupted over much of this area by aeolian processes producing shore-parallel blowouts and parabolic dunes which are now fixed with vegetation. Sandy Hill (the highest point of the area at about 30m) occurs at the north end of the largest parabolic dune of the area. The eastern boundary of the dunes is marked by a narrow alluvial flat known colloquially as the "Rum Jungle". This is probably a palusplain (seasonally waterlogged flat) maintained by rainfall, surface drainage from the Moresby Range via Dolby's Gully and seepage from the coastal dunes. The entire cuspate foreland north of the Geraldton Water Treatment Plant (with the exception of a narrow coastal reserve about 100m or so in width) is zoned for future urban development. The Drummonds transect (G2), (Fig 5) is located in the southern part of the cusp, west of the treatment plant and thus is expected to be incorporated into a coastal reserve.

b. Results of transect surveys

Surface sediments of the Geraldton transects were largely unaltered parent material with, at most, a thin weakly humified surface. At Greenough, (Table 8) they were generally cream-coloured, medium to coarse calcareous sands with some quartz also present. Large marine mollusc shells and very coarse shell fragments were common on the ocean side slope of the dunes well above the beach and foredune. In shallow swales this sand was grey and humic in the surface 10 cm. At Drummonds the surface sediments were similar to Greenough in grain size and texture except that quartz predominated over calcareous grains and there were no humic soils in the area sampled.

Table 8: Geraldton transect surface sediments.

Position of sample site on transect	Description
Greenough foredune	Cream, medium to coarse, calcareous and quartz sand with some larger shell fragments.
Greenough lower slope	"
Greenough mid slope- a shallow swale	Grey, humic, medium to coarse calcareous and quartz sand to about 10 cm over cream sand as above.
Drummonds foredune	Cream, medium to coarse, quartz and calcareous sand.
Drummonds first swale	"
Drummonds second crest	"
Drummonds second swale	"

Vegetation habitats at the Greenough Dunes study area (Fig 4) correspond with the following small scale landforms:

The foredune and associated swale;

Perched dune slopes (seaward or landward);

Mobile parabolic dunes; and

River flats.

An overprint of human usage on the natural landscape of the area is also evident in the flora and vegetation. A total of 41 indigenous and 13 alien flora taxa were recorded in and around the Greenough transect G1 (Appendix 2& 3) with the most numerous families being Poaceae (8 spp.), Asteraceae (5 spp.), Euphorbiaceae (4 spp.) and Aizoaceae (4 spp.)

At the cusp south of Drummonds Cove (Fig 5) the vegetation units vary in structure with a series of shore-parallel landforms. However the floristic composition of assemblages inhabiting these landforms does not exhibit a great deal of variation except for the distinctive assemblage of the seaward slope of the foredune which is very different to vegetation of the secondary beachridges. The landforms comprise (from west to east): the foredune and adjoining swale; a secondary beachridge with another swale in its lee; an attenuated arm of a large parabolic dune forming a narrow ridge running north/ south; the vegetated bowl of a parabolic dune; the eastern arm of the parabolic dune forming another ridge; and a wetland marking the border between the Holocene dunes and the Pleistocene ridge east of the North West Coastal Highway. A total of 37 indigenous and 11 alien flora taxa were recorded in and around the Drummonds transect (Appendix 2& 3) with the most numerous families being Asteraceae (6 spp.), Chenopodiaceae (4 spp) and Poaceae (4 spp.).

The low foredune at the Greenough transect (Fig 6) is sparsely vegetated with *Angianthus cunninghamii* and *Scaevola crassifolia* (Thick-leafed Fanflower) about 20cm in height, *Carpobrotus virescens* (Native Pigface) and *Spinifex longifolius*. This is augmented by *Isolepis nodosa, Lotus australis* (Australian Trefoil) and occasionally *Carpobrotus modestus* (Inland Pigface) in the adjacent swale. Apart from **Bromus diandrus* (Greater Brome) at low frequency, there are few weeds in the Greenough foredune zone and none of the cosmopolitan taxa usually associated with foredunes except an occasional plant of **Tetragonia decumbens* (Sea Spinach). In some areas, one or two shrubs of the *Atriplex isatidea* (Coast Saltbush) over 2m in height inhabits steeper foredune peaks.

Much of the lower seaward slopes (Fig 7a) are dominated by a closed and almost prostrate heath of *Scaevola crassifolia* less than about 30cm in height with *Lotus australis*, the grass *Poa poiformis* and herbs *Parietaria debilis* (Native Pellitory), *Senecio lautus* subsp. *maritimus* (Coastal Groundsel), **Euphorbia peplus* (Petty Spurge) and **Reichardia tingitana* (False Sow Thistle). The succulent **Mesembryanthemum crystallinum* (Ice Plant) occasionally occurs near tracks. Near Cape Burney, the pink flowering *Thryptomene baeckeacea* forms an attractive closed, wind- pruned heath on lower slopes (Fig 4). The main disturbance on the lower slopes and foredune is due to off-road vehicles.

Further up the western slope, the heath becomes more open, taller and more species-rich. It grades into scrub and heath dominated by *Acacia rostellifera* (Summer-Scented Wattle) and *Olearia axillaris* (Fig 7d). Associated taxa include: *Alyxia buxifolia* (Dysentery Bush), *Austrostipa flavescens, Diplolaena leemaniana, Logania litoralis, Melaleuca depressa, Opercularia spermacocea, Pimelea microcephala* subsp. *microcephala, Pittosporum ligustrifolium, Stylobasium spathulatum* (Pebble Bush) and *Templetonia retusa* (Cockies

Tongues). Numerous lax or twining plants supported by the shrubs include: *Austrostipa elegantissima* (Feather Speargrass), *Clematis linearifolia, Commicarpus australis* (Perennial Tar Vine), *Muehlenbeckia adpressa* (Climbing Lignum), *Ptilotus divaricatus* subsp. *divaricatus* (Climbing Mulla Mulla), *Tetragonia implexicoma* (Bower Spinach) and *Zygophyllum fruticulosum* (Shrubby Twinleaf). *Parietaria debilis* is abundant in the shade.
The condition of the vegetation on the mid to upper slope varies from very good to fair. In the more degraded areas, the shrubs are very open and often limited to hardy taxa such as *Threlkeldia diffusa, *Euphorbia terracina* (Geraldton Carnation), *Euphorbia tannensis* subsp. *eremophila* (Desert Spurge) and *Acanthocarpus preissii.* Here the woody weed **Lycium ferocissimum* (African Boxthorn) is more common and the understorey consists largely of naturalized alien tax such as **Ehrharta longiflora* (Annual Veldt Grass) and **Reichardia tingitana.* It is probable that grazing and frequent fires have contributed to this degradation of the indigenous vegetation. Natural regeneration is slowly occurring. Numerous seedlings of a wide range of indigenous taxa were recorded along the entire length of the transect during the survey in July 2001.

The bowl of the large mobile parabolic dune at the top of the Greenough dunes slope is largely unvegetated. However the arms and inner face of the dune are colonized by sparse **Ammophila arenaria* (Marram Grass) *Spinifex longifolius* and *Olearia axillaris.* The outer slopes of the parabolic dune are edged on both the seaward and landward sides by closed scrub to low closed forest of *Acacia rostellifera* and *Melaleuca cardiophylla* (Tangling Melaleuca) respectively. The latter grades into a lower, more open scrub that includes *Acacia rostellifera* as a co-dominant on the eastern slopes towards the Greenough River. The bush north and north-east of the mobile dune, (the area onto which the dune is encroaching) comprises open scrub to open heath including *Pittosporum ligustrifolium*, *Acanthocarpus preissii, Alyxia buxifolia*, *Scaevola tomentosa, Pimelea gilgiana* and *Solanum oldfieldii* and with occasional small trees of *Melaleuca cardiophylla. *Lycium ferocissimum* is very common and the understorey herbs and grasses are almost exclusively naturalized alien taxa including **Euphorbia terracina* (Geraldton Carnation). The area appears to have been subjected to considerable disturbance from human use and grazing. Other serious weeds include **Tamarix aphylla* and **Agave* sp. and indicate a dwelling on the site in the past.

The Greenough River floodplain, which is quite narrow in this area, is fringed with low zoned halophytes including *Sarcocornia quinqueflora* (Beaded Glasswort), *Halosarcia indica* subsp.

bidens, Sporobolus virginicus (Saltwater Couch) and *Atriplex amnicola* (Swamp Saltbush) with low open *Casuarina obesa* (Swamp Sheoak) woodland.

The foredune at the Drummonds transect (Fig 6 & Fig 7b) is colonized by sparse *Spinifex longifolius*, **Tetragonia decumbens, Angianthus cunninghamii* and *Olearia axillaris*. A distinctive linear scrub of the silver-foliaged *Atriplex isatidea* fixes the crest of the foredune in an acute ridge (Fig 7c). In the swales, *Acacia rostellifera* and *Myoporum insulare* (Blueberry Tree) form a heath to scrub which supports twining plants including *Tetragonia implexicoma, Zygophyllum fruticulosum* and *Rhagodia preissii* over herbs including *Parietaria debilis* and *Calandrinia brevipedata.* An undescribed taxon of the family Portulacaceae, *Calandrinia* sp. Drummonds A.A. Brooker 110, previously not collected from the Geraldton region, also occurs in these swales and the slopes of adjacent dunes. The dune crests are dominated by a lower and less dense assemblage including *Acacia rostellifera* with *Acanthocarpus preissii, Santalum acuminatum* (Quandong), *Austrostipa elegantissima* and P*tilotus divaricatus* subsp. *divaricatus.* **Lycium ferocissimum* is common at low frequency throughout the area forming isolated shrubs of 3-4 m in height. Other naturalized alien taxa common at the Drummonds transect include **Bromus diandrus*, **Brassica tournefortii* (Mediterranean Turnip), **Dischisma arenarium*, **Ehrharta longiflora*, **Euphorbia terracina*, *Reichardia tingitana and **Sonchus oleraceus* (Common Sowthistle). As at Greenough, indigenous taxa seedlings were recorded at a high rate along the transect. The vegetation inland from the foredune throughout the Drummonds cusp (Fig 5) is relatively homogeneous in floristic composition with swale and beachridge crest assemblages very comparable to the swale and secondary beachridge of the transect described above. Structural differences are present however with crests of beachridges inhabited by lower and more sparse vegetation compared to that of swales. The large parabolic dune bowl in the east (Fig 5.2c) in particular, forms an *Acacia rostellifera* closed scrub which is much taller and thicker than vegetation elsewhere in the area. A vegetation formation which is not common in the vicinity of the Geraldton occurs on the alluvium of the "Rum Jungle" (Fig 5.4). Here there is a well- developed low closed forest of *Casuarina obesa* with a sparse but weedy understorey.

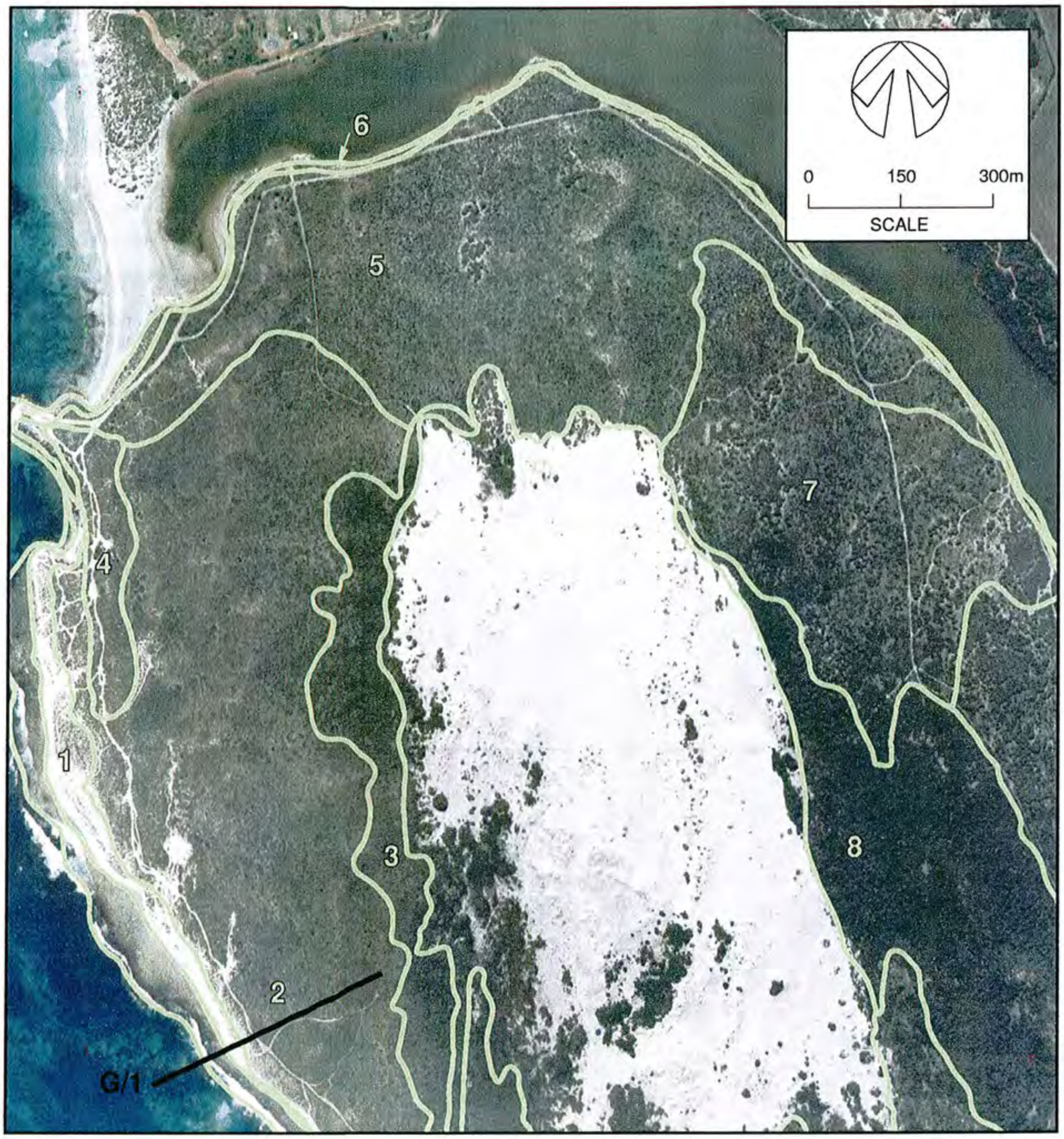


Figure 4: Aerial view of the northern end of the Greenough Dunes with transect G/1 .

The Greenough River curves around the dunes in the north. The sand bar across the river mouth can be seen near the top left of the photo just above Cape Burney. The bare area in the centre is a large mobile dune vegetated sparsely at its edges by **Ammophila arenaria, Spinifex longifolius and Olearia axillaris.*

Key:

1. Low open shrubs, grasses and herbs of foredune.
2. Closed heath to scrub on seaward slopes.
3. Closed *Acacia rostellifera* scrub.
4. *Thryptomene baeckeacea* closed heath.
5. Open heath to scrub.
6. River fringe- low heath of halophytes with sparse *Casuarina obesa.*
7. Open heath to scrub of *Acacia rostellifera* and *Melaleuca cardiophylla* with understorey of naturalized alien grasses and herbs.
8. Closed scrub of *Melaleuca cardiophylla.*

Figure 5: Aerial view of foreland south of Drummonds Cove with location of transect G/2.

Key:

1. Foredune with scrub of *Atriplex isatidea* on the crest.

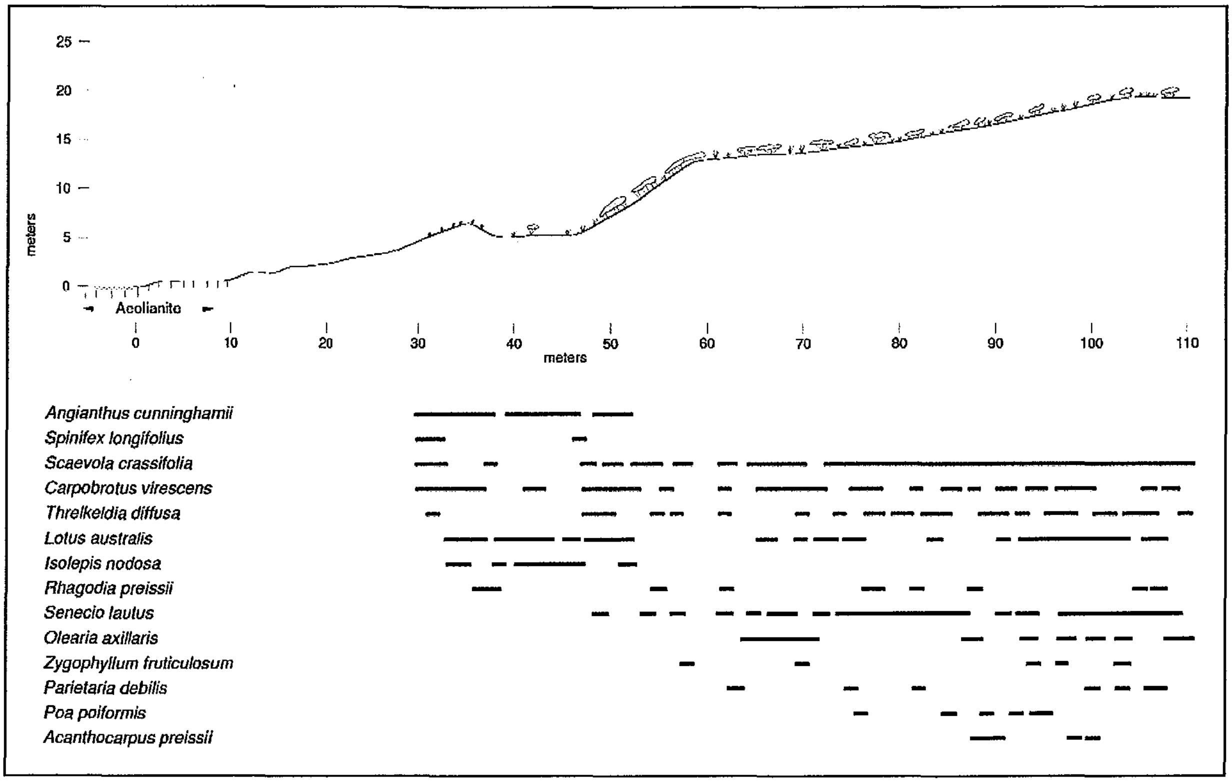
2a & 2b. Swales: *Acacia rostellifera/Myoporum insulare* heath to scrub.

2c. Bowl of large parabolic dune: *Acacia rostellifera* scrub to closed scrub.

3a, 3b & 3c. Ridges: *Acacia rostellifera/ Acanthocarpus preissii* open heath.

4. Low closed forest of *Casuarina* obesa over alien grasses and herbs- the "Rum Jungle".

a. Greenough



b. Drummond

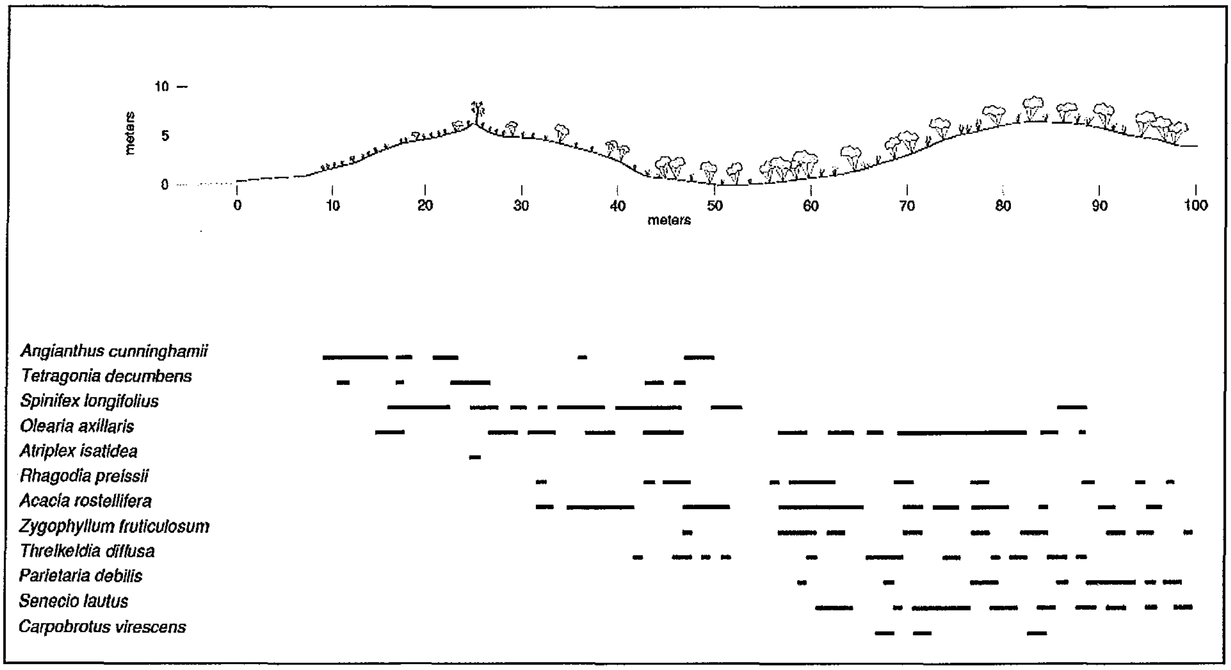


Figure 6: The Geraldton transects.

a. Geraldton Regional Herbarium volunteers Jenna Brooker, Ena McNamara and Julie Firth prepare to survey the Greenough transect. *Photo: Tony Brooker*

b. Drummonds foredune with *Angianthus cunninghamii* and *Spinifex longifolius*.

c. Acute crest of foredune at the Drummonds transect with narrow zone of *Atriplex isatidea*.

d. Upper slope at the Greenough Dunes: heath to closed scrub dominated by *Acacia rostellifera* and *Olearia axillaris*.

Figure 7: Vegetation of the Greenough Dunes and Drummonds Cove.

3.2 Port Kennedy Scientific Park

a. Setting of transects

Port Kennedy, in the south of Perth, is located in the Drummond Botanical Subdistrict (Beard 1980) or the Swan Coastal Plain Biogeographical Region (IBRA, 2000). It has a climate which can be classified as sub-humid (Gentilli 1972) or warm mediterranean (Beard, 1990). Mean annual rainfall at the nearest weather station, Medina, is 638 mm with an annual evaporation of 1733 mm (Bureau of Meteorology, 2002). Winter rain is generally reliable with a growing season of about six months. There is a land and sea breeze pattern of winds of 20 km/hr (and occasionally to 40 km/hr) from the SE to NE and SW respectively in summer (Semeniuk *et al.* 1989).

Many aspects of the natural history of the Rockingham and Port Kennedy area are described in the literature including: geomorphology, stratigraphy and paleogeography and these are reviewed in Searle *et al.*(1988) and Semeniuk *et al.*(1989); floristics (Keighery & Keighery,1995); and hydrology and ecology (Semeniuk C.A., in prep.). The following brief description of the area is summarized from Searle *et al.*(1988).

The Port Kennedy Scientific Park encompasses the western end of the Becher cuspate foreland in the south of the extensive Rockingham-Becher Plain: a large accumulation of Holocene sediments in the Warnbro-Cockburn Depression between two shore-parallel Pleistocene aeolianite ridges. The latter are the Garden Island Ridge offshore (visible as a series of islands between Cape Bouvard and Rottnest) and the Spearwood Ridge in the hinterland (east of Lake Walyungup and Lake Cooloongup). The stratigraphy of the plain is generally the Holocene sequence comprising Safety Bay Sand, Becher Sand (submarine bank seagrass sediments) and Bridport Calcilutite (deepwater basin mud deposits) overlying Pleistocene Tamala Limestone.

The age structure of the Rockingham-Becher Plain has been determined by radiocarbon dating of shell (Fig 8) by Searle *et al.*(1988). This, with other data, has enabled a reconstruction of the paleogeography of the area from about 7000 yrs BP to the present. At the beginning of this period, the Garden Island Ridge was a continuous linear ridge from Rottnest to near Cape

Bouvard. Between the Garden Island Ridge and the Spearwood Ridge was an elongate valley. Subsequent to sea level rise and inundation of the valley, marine erosion of the Garden Island Ridge aeolianite produced a series of breaches in the ridge. Westward movement of sediments from this erosion initiated the submarine deposits of the Rockingham Bank at the coastline (which was then situated at the base of the Spearwood Ridge near to the present site of Lake Cooloongup). The Becher Bank commenced prograding in the same manner approximately 4000 years BP. Littoral drift of sediments from the south and further erosion of the Garden Island Ridge, into a series of small islands, built up the submarine banks into two cuspate forelands. At about 2500 years BP the tip of the Rockingham cusp had prograded westwards sufficient to make contact with the remains of the Garden Island Ridge. The latter remnant is discernible as the Tamala Limestone at the end of Point Peron. To the south of this, Becher Point is thought to have continued prograding for a further 1000 years. The remains of the Garden Island Ridge off Becher Point can be seen as small islands some distance off shore (see Fig 11a). The Becher cusp is currently thought to be undergoing a phase of erosion.

The Rockingham-Becher Plain is part of the Cape Bouvard to Trigg Island sector of the Quindalup Dune System (Semeniuk *et al.*,1989). The plain lies approximately 2 to 5m above the water table and its surface is marked by a clear pattern of shore-parallel, low-relief, linear beachridges and swales. Some aeolian modification of this pattern is evident in places with the formation of blowouts, chaots and parabolic dunes. The carbonate sediments preserved in the Rockingham-Becher Plain contain an unbroken depositional history from 7000 yrs BP to the present. This constitutes an invaluable resource for understanding the climatic and eustatic (sea level) changes which took place in the Quaternary.

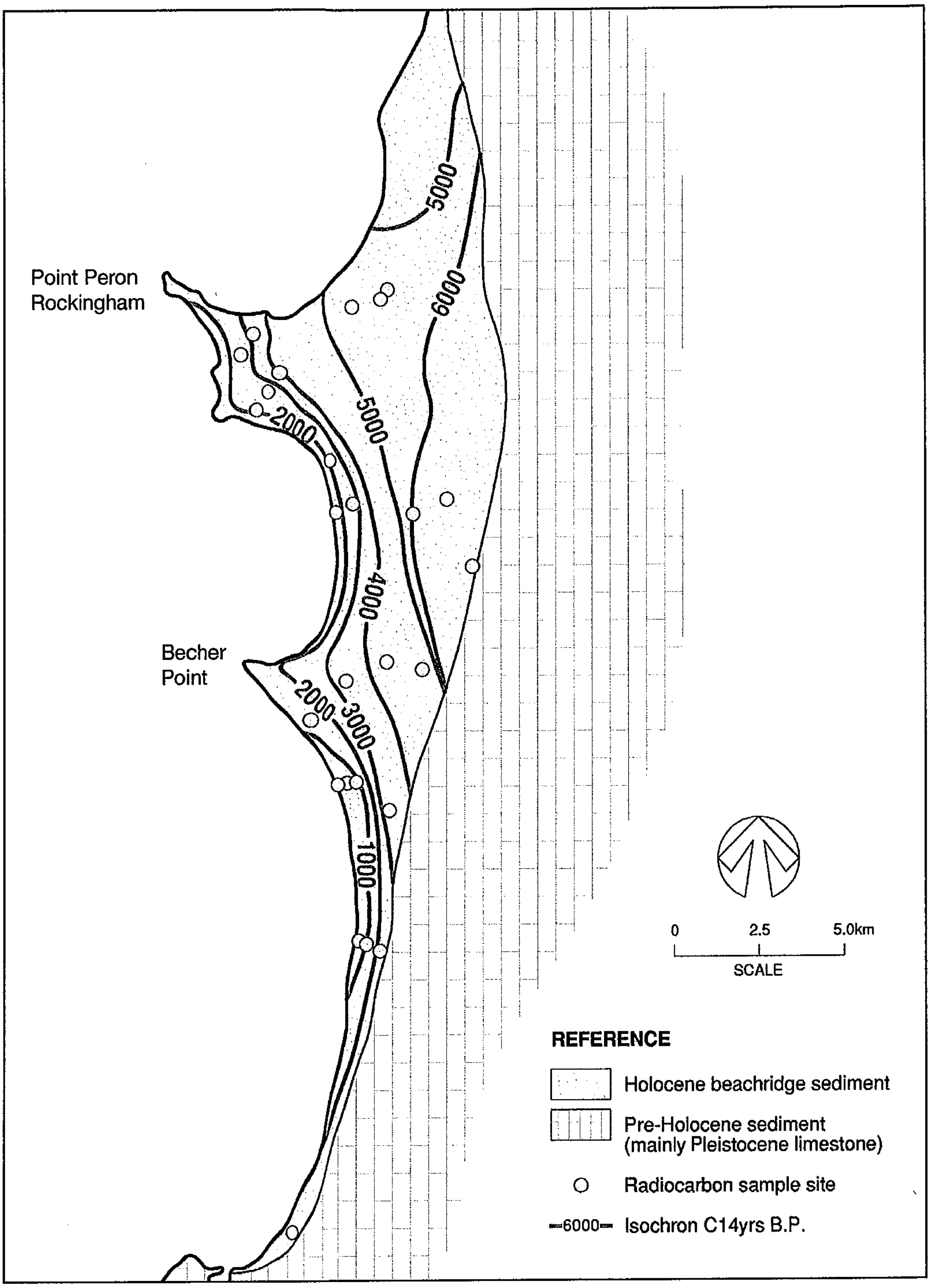


Figure 8: Age structure of the Rockingham-Becher beachridge plain.
(Figure adapted from Fig 8A in Searle et. al., 1988, with permission).

The wetlands of the Rockingham–Becher Plain have been classified by Semeniuk (1988) into two consanguineous suites.

1. Quindalup Suite 1. These wetlands originated as oceanic basins and were barred by a prograding shore. They are now recharged by freshwater. The stratigraphic sequence of Cooloongup Mud over Becher Sand characterises these wetlands. The Becher Point wetland (transect PK2) and Lake Richmond (near Point Peron) are members of this suite, unified by a common mode of origin and stratigraphy whilst superficially they appear very different..

2. Quindalup Suite 2. These wetlands are a series of depressions between the relict beachridges with humic sand or peat and thin carbonate mud over Safety Bay Sand. The linear wetland at the end of transect PK1 is a member of this suite.

b. Results of transect surveys

Surface sediments of the Port Kennedy transects were generally very calcareous grey and cream medium to coarse sands on the foredune. In shallow swales, this material was overlaid by a dark grey peaty sand or humic sand to 15 cm in depth. In the deeper swale, the top layer contained more humified organic matter in the form of 10-20 cm of sandy peat to peaty sand over humic sand to about 30cm in depth and subsequently cream calcareous sand to the water table.

On crests of dunes the surface sand was slightly finer in texture with more quartz over medium to coarse calcareous cream sand.

At Becher Point the foredune sand was the same calcareous and quartz sand as that found further south along the shore at the PK1 transect The surface sediments in the wetland consisted of about 10 cm of coarse black partially-decomposed organic matter over cream, medium to coarse, calcareous sand.

Table 9: Port Kennedy surface sediments.

Port Kennedy PK1 transect	
Foredune	Grey and cream-coloured medium to coarse calcareous sand with some quartz.
Shallow swale	Dark grey, peaty, medium to coarse calcareous sand to 15 cm over cream calcareous sand.
Low dune crest	Grey, fine to medium calcareous sand with some quartz. to 15 cm over cream-coloured, medium to coarse calcareous sand.
Deep swale at end of transect	Dark brown sandy peat to 10 cm. Calcareous peaty sand to 30cm. Cream- coloured, medium to coarse, calcareous sand to the water table at approx. 1m.
Becher Point PK2 transect	
Foredune	Grey and cream-coloured medium to coarse calcareous sand with some quartz.
Wetland basin	Black peat to 10 cm over cream coloured medium to coarse calcareous sand.

Vegetation habitats at the Port Kennedy beachridge plain transect and Becher Point transect (Fig 9) can be seen to correspond with the following small scale landforms: foredune and associated swale; a basin wetland; shallow swales; beachridges; a deep linear swale; and inland swales. A total of 62 indigenous and 14 alien flora taxa were recorded in and around the Port Kennedy beachridge plain transect and 13 indigenous and 17 alien flora taxa at the Becher Point transect (Appendix 2 & 4). The most numerous families were Poaceae (9 spp.), Cyperaceae (7spp.) and Asteraceae (7 spp.) at PK1 and Asteraceae (6 spp.), Chenopodiaceae (5 spp), Cyperaceae (4spp.) and Poaceae (4 spp.) at PK2.

The vegetation assemblages traversed by the transects in the south of the beachridge plain (PK1) and at Becher Point (PK2), (Fig 10) will be described first followed by a general description of other plant assemblages in the area. The foredune assemblage at the Becher Point transect and that at the start of the Port Kennedy beachridge plain, consists of co-dominant cosmopolitan species **Cakile Maritima*, **Tetragonia decumbens* and **Arctotheca populifolia*. At the beach and the very low foredune (which, at its crest is less than 2m above sea level) of Becher Point (Fig 11a), the sparse **Cakile maritima* and **Tetragonia decumbens* zone is a remarkable 69m in width. Seedlings were noted recruiting as close as 6m to the shoreline and constituted the only vegetation present until the 53m mark along the transect. Here the first mature specimens of **Cakile maritima* and **Tetragonia decumbens* (with flowers and fruit) in this transect were recorded. No other taxa are present right up to the edge of the wetland. Here *Sarcocornia* *quinqueflora* subsp. *quinqueflora, Suaeda australis, Sporobolus virginicus* and *Juncus kraussii* (Sea Rush) are present. In contrast to this, at the PK1 transect, the beach is steeper, the foredune is taller and the bare beach is about 25m in width. **Tetragonia decumbens,* often forming dense mats, dominates the incipient foredune. It can still be found, however at low frequency 70m from the shoreline. However, from the landward slope of the foredune and into the fist swale there is a much more diverse swale assemblage that at PK2 including *Olearia axillaris*, *Lepidosperma gladiatum* (Sword Sedge), (*Hardenbergia comptoniana* (Native Wisteria) *Acacia saligna* (Orange Wattle) and *Acanthocarpus preissii.*

The Becher Point wetland (Fig 11a) is a brackish environment and is dominated by a closed formation of *Juncus kraussii* over 1m in height. Associated with this are: *Lobelia alata* (a tall delicate herb with small blue flowers supported by the rushes), and two robust Asteraceae species both up to 1.2m in height: *Sonchus hydrophilus* (Native Sow Thistle) with its distinctive leathery leaves and the sparsely-leafed naturalized alien **Symphyotrichum subulatum* (Bushy Starwort). There is a low sand bar in the centre of the wetland and the transition to this is marked by a zone of *Sarcocornia quinqueflora* subsp. *quinqueflora*, *Suaeda australis, Sporobolus virginicus, Triglochin mucronata* (Prickly Arrowgrass), **Atriplex prostrata* (Hastate Orache) and **Polypogon maritimus* (Coast Barbgrass). The drier, sandy conditions on the bar itself are host to an assemblage which largely comprises naturalized alien taxa including **Cyperus tenuiflorus* (Scaly Sedge), **Melilotus indicus* (King Island Melilot), **Isolepis marginata*, **Anagallis arvensis* var. *caerulea* (Blue Pimpernel), **Sonchus oleraceus* and **Dischisma arenarium*. Also present here are *Senecio lautus* subsp. *maritimus* (Coastal Groundsel) and *Sporobolus virginicus*. At the eastern edge of the *Juncus kraussii* sumpland, there is another zone of transition to sand dune vegetation which is truncated by an old vehicle track and a fence. A low dune rises to a crest of about 5m in height east of this and this coincides with the end of the Becher Point transect. The vegetation of the area disturbed by the track is dominated by **Lagurus ovatus* (Hare's Tail Grass), **Pelargonium capitatum* (Rose Pelargonium) and **Trachyandra divaricata* with the **Cuscuta epithymum* (Lesser Dodder) preferentially parasitizing the latter two weeds. On the dune slope, an open heath (in degraded condition) also includes *Scaevola crassifolia*, *Ozothamnus cordatus*, *Hibbertia cuneiformis* (Cut leaf Hibbertia), *Lepidosperma gladiatum*, *Hardenbergia comptoniana*, and *Acanthocarpus preissii.* The crest of the dune and beyond is a closed scrub of *Acacia rostellifera*.

The beachridge plain transect at Port Kennedy (PK1), (Fig 12) traverses 500m of the beachridge plain. Here the vegetation, beyond the foredune and the first swale, displays subtle and somewhat repetitive patterns generally correlating with a series of low, shore-parallel, relict beachridges and shallow swales. The eastern slope of the second swale from the coast is dominated by *Acacia saligna*, *Lomandra maritima* and *Acanthocarpus preissii,* with occasional *Conostylis pauciflora* subsp. *pauciflora* and *Lepidosperma gladiatum*. The latter sedge does not reappear until the rather steep slope at the end of the transect some 400m east. *Lomandra maritima*, a monocotyledenous tussock to about 50cm in height, dominates the vegetation of beachridges and swales alike for the next 350m. *Acanthocarpus preissii* is most common close to the start of the transect but is also associated with crests of inland beachridges. *Acacia saligna* occurs sporadically throughout the transect, being somewhat more common on lower slopes.

Beyond the blowouts, chaots and low parabolic dunes immediately adjacent to the coast, the indigenous vegetation of the first wide swale has been disturbed by a vehicle track and, in common with most tracks in the reserve, is dominated by naturalized alien taxa including **Trachyandra divaricata*, **Romulea rosea* (Guildford Grass) and **Lagurus ovatus*. East of the track, the relatively low-lying area retains some of its indigenous flora elements apart from the hardy *Lomandra maritima*, notably *Lepidosperma squamatum*, *Baumea juncea* and occasionally the delicate *Pelargonium littorale* (Native Pelargonium).

Open heath to low open shrubs, seldom greater than 1m in height, over diverse grasses, sedges and herbs characterise the beachridges over the next 275m of the transect. This assemblage includes *Melaleuca systena* (Coastal Honeymyrtle), *Olearia axillaris*, *Leucopogon parviflorus* (Coastal Beard Heath), *Acacia lasiocarpa* (Panjang), *Jacksonia furcellata* (Grey Stinkwood) and *Spyridium globulosum* (Basket bush). Also present are *Lomandra maritima*, the grasses *Poa poiformis* and *Austrostipa flavescens*, sedges *Carex preissii*, *Schoenus grandiflorus* and *Lepidosperma squamatum*, the rush *Desmocladus flexuosus* and a colourful assemblage of annual herbs. The latter are dominated by *Senecio lautus* subsp. *maritimus* but also include *Lobelia tenuior* (Slender Lobelia), *Leptorhynchos scaber*, *Rhodanthe citrina*, *Calandrinia* sp.1 Becher F.Littleton 66 and *Calandrinia* sp.2 Becher F.Littleton 68, *Daucus glochidiatus* (Native Carrot) and **Dischisma arenarium*. Shallow swales in the same interval of the transect can be described as grasslands with open sedges and sparse low shrubs. This assemblage is dominated by *Lomandra maritima, Lepidosperma squamatum, Poa poiformis, Austrostipa flavescens* and

Baumea juncea. Herbs include *Hydrocotyle tetragonocarpa, Triglochin trichophora* and **Heliophila pusilla.* Small plants of *Pelargonium littorale* are also common.

The deep swale at the end of the transect exhibits a sharp change in floristics and vegetation structure (Fig 9.6 and Fig 11c). The open heath of the preceding beachridge abruptly changes on the lower eastern slope to a closed scrub of *Spyridium globulosum* with *Clematis linearifolia* draped over the shrubs. The hitherto ubiquitous *Lomandra maritima,* is replaced in the understorey by the sedges *Lepidosperma squamatum* and *Baumea juncea.* The centre of the swale is a closed sedgeland of *Isolepis nodosa,* and *Baumea juncea* (Fig 11c) with *Centella asiatica,* occasional *Loxocarya pubescens,* sparse columnar shrubs of *Logania vaginalis* (White Spray) and some **Trachyandra divaricata.* Seedlings of **Euphobia terracina* (not recorded west of this swale) are encroaching from the east into this area.

Vegetation over the remainder of the area was not mapped in detail in this study (Fig 9) but is comprehensively described in Semeniuk (in prep). It includes: assemblages of sedges in the swales (including *Baumea articulata, Baumea preissii* and *Typha* sp. in some of the deeper swales); beachridges with low open shrubs over grassland; and linear wetlands with closed scrub to low open forest of *Melaleuca rhaphiophylla* (Swamp Freshwater Paperbark) and *Melaleuca viminea* (Mohan) further inland. An extensive closed scrub of *Acacia rostellifera* and *Spyridium globulosum* over *Lepidosperma squamatum* covers wetlands and ridges over much of the area.

Groundwater levels at the Port Kennedy Scientific Park were monitored as often as practicable from March to November in 2002 at three sites:
The Becher point wetland (Fig 11a);
A shallow swale 125m from the shoreline at the Port Kennedy transect (Fig 11b); and
A linear wetland at the end of the same transect (Fig 11c).

The Becher Point wetland was the only site where standing water was observed. This concave, shallow depression is vegetated with closed *Juncus kraussii* rushes and lies just above sea level. A very low foredune (less than 2m above sea level) bars the wetland from the ocean. Water levels at this site were, in general, much higher than those at the other sites, with overall highs and lows correlated with the general trend of increased rainfall in winter (Fig 13). However they showed considerable fluctuation between late autumn and mid winter. Standing water was recorded on several occasions between early May and mid July. Water level in this period fluctuated between a minimum of 16 cm below the ground in late May to an overall maximum for the whole monitoring period of 16 cm above the ground in mid July. The overall minimum for the monitoring period was 44 cm below the ground in late March. Based on the seasonal inundation and the concave topography of the inundated area this wetland was classified as a sumpland.

The deep linear swale at the end of the Port Kennedy transect (Fig 11c) showed a regular rise in groundwater from a minimum of 130 cm below the ground surface at the end of April (when readings commenced) to a maximum of 100 cm below the ground surface in mid August (Fig 13). A slow decline was observed until the end of the monitoring period. The groundwater pattern mirrored the rainfall trend much more closely than that of the sumpland at Becher Point. The sand between the water table and the surface was constantly waterlogged from early winter to the end of the monitoring period in late spring at this site despite periods of scanty rain. The concave topography and seasonal waterlogging exhibited here qualified this site for classification as a dampland.

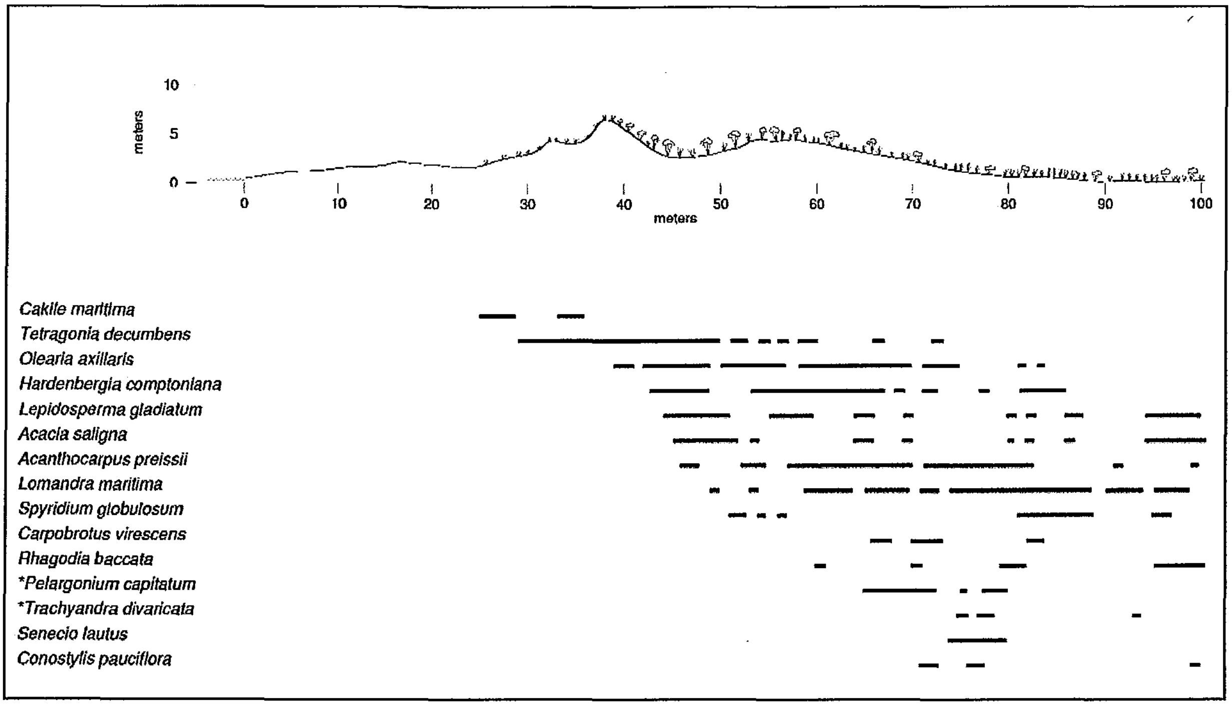
Shallow swales along transect PK1 (Fig 11b) were vegetated by *Lomandra maritima* and sedges and rushes including *Baumea juncea, Lepidosperma squamatum* and *Hypolaena pubescens* along with diverse native grasses and herbs such as *Hydrocotyle tetragonocarpa* and *Pelargonium littorale.* This contrasted with adjacent low relict beachridges which had a more dense cover of low shrubs such as *Melaleuca systena, Olearia axillaris, Leucopogon parviflorus* and *Hibbertia cuneiformis.* Swales such as these were not waterlogged in winter (Fig 13) during the monitoring period. The ground water level showed a similar pattern of increase and decline to that of the dampland described above but water levels were in general about 1m lower than the latter varying between 164 cm to 149 cm below the surface.

Key:

1. Foredune and blowouts.
2. *Juncus kraussii* sumpland
3. *Acacia rostellifera* / *Spyridium globulosum* closed scrub.
4. Series of shallow swales and linear damplands approximately parallel to the coast.
5. Series of beachridges between swales.
6. Linear dampland fringed by a closed scrub of *Spyridium globulosum*.
7. Linear wetlands with *Melaleuca rhaphiophylla*/ *Melaleuca viminea* closed scrub to low closed forest.

Figure 9: Aerial view of part of the Port Kennedy Scientific Park project area with locations of transects PK/1 (in the south of the beachridge plain) and PK/2 at Becher Point.

a. Port Kennedy



b. Becher Point

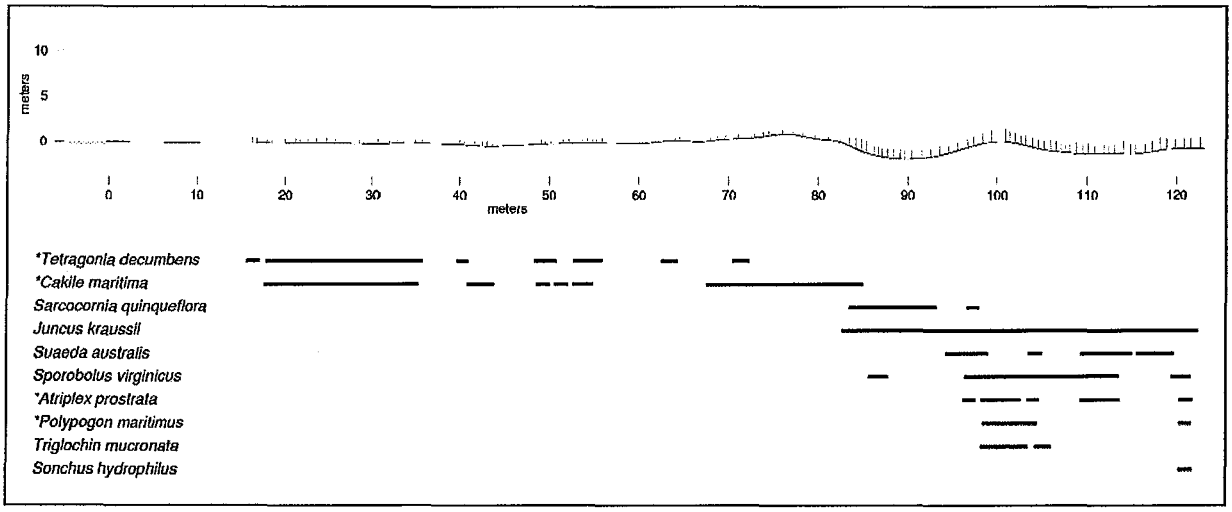


Figure 10: Port Kennedy Scientific Park transects.

a. Becher Point sumpland PK/2.

b. Shallow swale PK/1.

c. Linear dampland PK/1.

Figure 11: Wetlands at Port Kennedy Scientific Park.

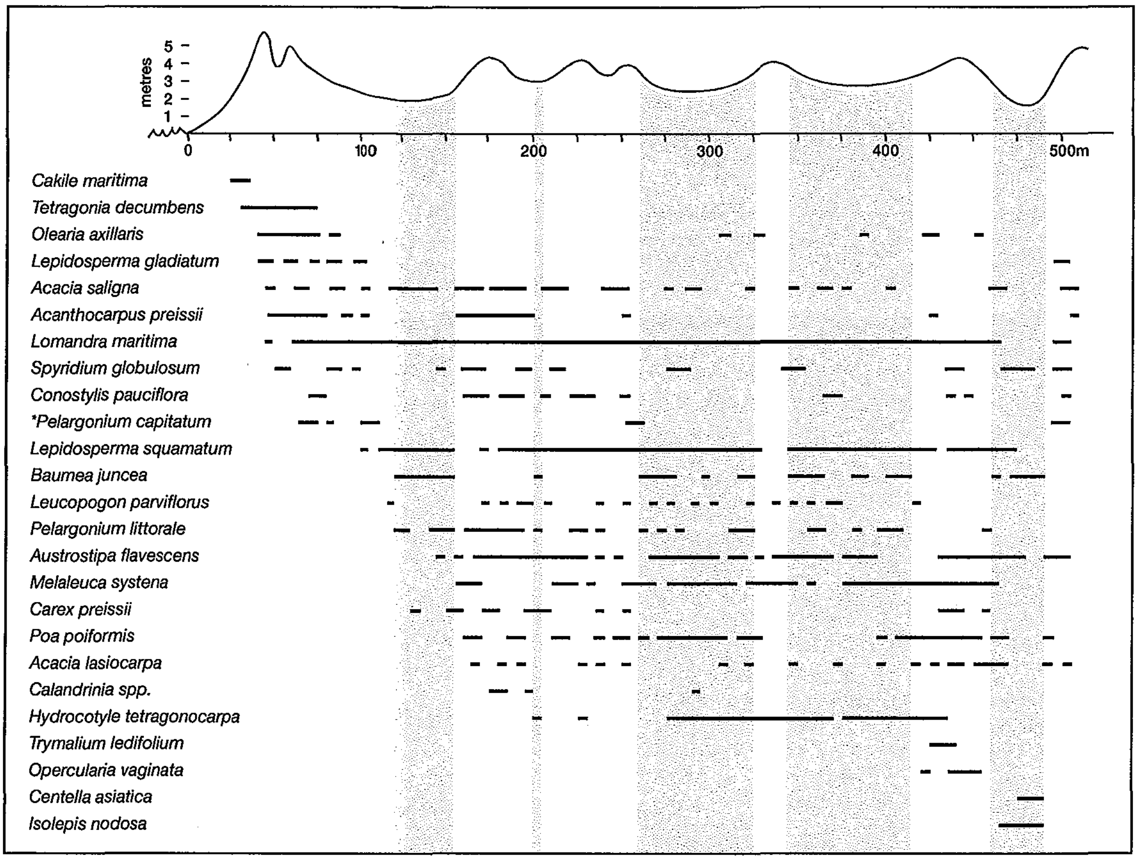


Figure 12: Transect PK/1 (Port Kennedy Scientific Park) at a scale encompassing the full length of the surveyed transect from sea level to the first linear dampland.

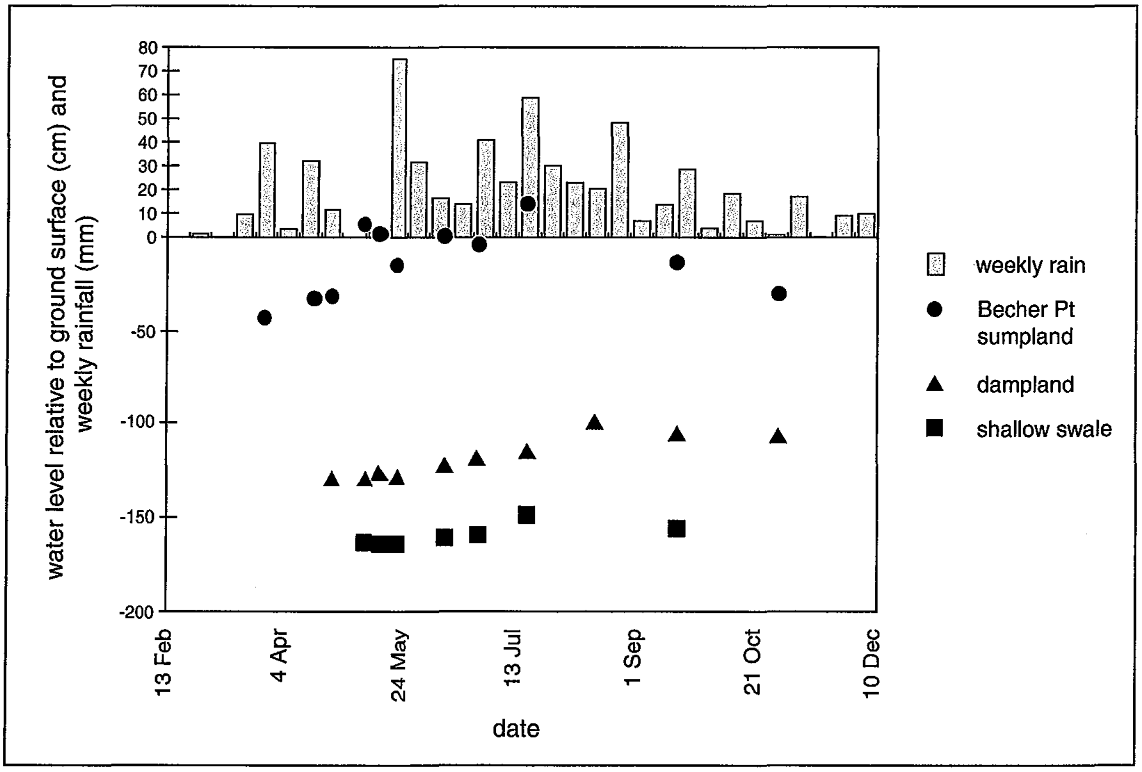


Figure 13: Groundwater levels at three monitoring sites at the Port Kennedy transects compared with total rainfall (Medina, Bureau of Meteorology) each week.

3.3 Bunbury: Dalyellup Beach and the Preston River Delta

a. Setting of transects

Bunbury has a climate which can be classified as sub-humid, warm mediterranean (Wilde&Walker,1982). It is located in the south of the Drummond Botanical Subdistrict (Beard 1980) or the Swan Coastal Plain Biogeographical Region (IBRA, 2000). The mean annual rainfall is approximately 872 mm with an annual evaporation of 1554 mm (Roelands weather station, Bureau of Meteorology, 2002). Winter rain is generally reliable and the growing season averages about seven months (Beard, 1990a). There is a land and sea breeze pattern of winds up to 20 km/hr from the SE to NE and SW respectively in summer (Semeniuk *et al.,* 1989).

The project area lies in the southern region of the Perth Basin (Playford *et al.*, 1976) on the Swan Coastal Plain. The Holocene beachridges and shore-normal, high relief parabolic dunes immediately adjacent to the coast at Dalyellup (transect B1) are part of the Quindalup to Leschenault sector of the Quindalup Dunes (Semeniuk *et al.*,1989) and consist of Safety Bay Sand. The Spearwood Dunes adjoining the latter inland (and often underlying the Quindalup Dunes closer to the shoreline) are largely Pleistocene aeolianite (Tamala Limestone) with some quartz and calcareous sands.

The Preston River Delta (transect B2) is situated adjoining Koombana Bay in the City of Bunbury (Fig 15) and was once part of the Leschenault Inlet Estuary (see Fig 1 of Semeniuk, 2000 for an aerial view of the original delta). Natural landforms of this area have been extensively modified in recent years by local industry. What was once the tide-dominated delta of the Preston River, draining freshwater from the hinterland (including the Leschenault Inlet) to the ocean, is now a marine embayment cut off from the river and the inlet by landfill.The Leschenault Inlet now drains to the ocean by a man-made channel colloquially know as "The Cut".

The habitat, physiognomy and biogeographical aspects of the mangrove population on the site are described in (Semeniuk *et al.,* 2000) and this information is summarized below. The tides in the area are generally diurnal and microtidal with a mean spring range of 0.5m and maximum range of 0.9m. Tidally-aligned shoals and emergent islands occur amongst the channels with emergent surfaces located between mean sea level to just above the highest astronomical tide. The shoals and islands of the delta are comprised of shelly and quartz deltaic sands, with sandy crests flanked by deltaic mud to about 50cm in depth. There is a large accumulation of vegetation detritus in the bioturbated mud of the mangrove-inhabited zones. The ground water is generally in the order of marine salinity in the mangrove zones and brackish in the centre of islands where sandy crest elevation is sufficient to allow rainfall recharge. Hypersaline soil conditions occur on some shoals and high tidal platforms which are isolated from regular marine flushing

b. Results of transect surveys

Surface sediments at Dalyellup Beach, (Table 10) were cream-coloured, medium to coarse quartz and calcareous sands (with a little more quartz than calcareous grains). The stratigraphy and water salinity of the Preston River Delta is comprehensively described elsewhere (see above) and was not further investigated in this study.

Table 10: Dalyellup transect surface sediments.

Position on foredune	Description
Incipient foredune	Cream and white, medium to coarse, quartz and calcareous sand.
Break of foredune slope (midslope)	Humic, medium to coarse quartz and calcareous sand.
Crest of foredune.	Cream and white, medium to coarse, quartz and calcareous sand.

At Dalyellup Beach, the vegetation comprises heaths and scrub of tall, Holocene dunes adjacent to the coast juxtaposed in a mosaic with a woodland of *Eucalyptus gomphocephala* (Tuart) on the Pleistocene hinterland (Fig 14). The recent dunes have encroached inland for variable distances over the older ridges but their vegetation has a floristic composition very similar to the understorey of the latter. The incipient foredune is the only unit which has significantly different floristic elements. Otherwise, most taxa (notably *Spyridium globulosum, Diplolaena dampieri, Acacia cochlearis* and many native herbs) are present throughout the vegetation from the foredune to the hinterland ridges. Vegetation structure (*i.e.* heath, scrub and woodland) generally correlates with topography and distance from the shoreline. The Holocene dune vegetation was surveyed in detail at the Dalyellup transect and variations in this correspond with small scale landforms comprising the incipient foredune, seaward lower slopes, the break of slope (mid slope) and the upper slope and crest of a tall dune. A total of 48 indigenous and 17 alien flora taxa were recorded in and immediately adjacent to the Dalyellup transect (Appendix 2 & 5) with Poaceae (9 spp.), Asteraceae (5 spp.) and Papilionaceae (4 spp.) being the best represented families.

The vegetation of the Preston River Delta (Fig 15) comprises low closed forest to low open shrubs of the *Avicennia marina* (White Mangrove), *Juncus kraussii* closed rushes, halophyte assemblages, a sand bar assemblage and degraded sand dune flora of the hinterland dunes. These assemblages vary with subtle changes in height above sea level which corresponds with substrate type (from mud in the lowest lying areas through to sand on the highest crests), soil and groundwater salinity and frequency of marine inundation. The mangroves form a well-developed, low closed forest to closed scrub along with *Sarcocornia quinqueflora* subsp. *quinqueflora* in the zone between mean sea level and mean high tide where they receive daily marine flooding. In high tidal platform, muddy settings where there is no fresh water seepage the mangroves are confined to small scattered shrubs amongst halophytes such as *Halosarcia halocnemoides* subsp. *halocnemoides*. *Juncus kraussi* generally proliferates on higher ground such as the slopes or crests of low shoals where groundwater is brackish. Cliffed shorelines of the channels are inhabited by a woodland of *Casuarina obesa* with an understorey of *Melaleuca viminea, Gahnia trifida, Halosarcia indica* ssp. *bidens* and *Atriplex* sp.. Tidal pools are generally bare of vegetation and fringed by prostrate *Sarcocornia quinqueflora* subsp. *quinqueflora*. Serious weeds have invaded some areas with **Schinus terebinthifolia* (Japanese Pepper Tree) and **Asparagus asparagoides* (Bridal Creeper) forming dense isolated stands . The sandy crests of shoals above the highest tide are inhabited by an assemblage typical of beachridges of the area including *Olearia axillaris*. The hinterland of the saltmarsh has been developed with picnic facilities and sculpture displays however the beachridge vegetation is severely degraded and consists largely of **Avena barbata, *Lupinus consentii* and *Acacia saligna*. A total of 41 indigenous and 16 alien flora taxa were recorded in and around the Preston River Delta transect (Appendix 2& 5) with the most numerous families being Poaceae (8 spp. including 6 alien spp.), Asteraceae (6 spp.) and Chenopodiaceae (5 spp.).

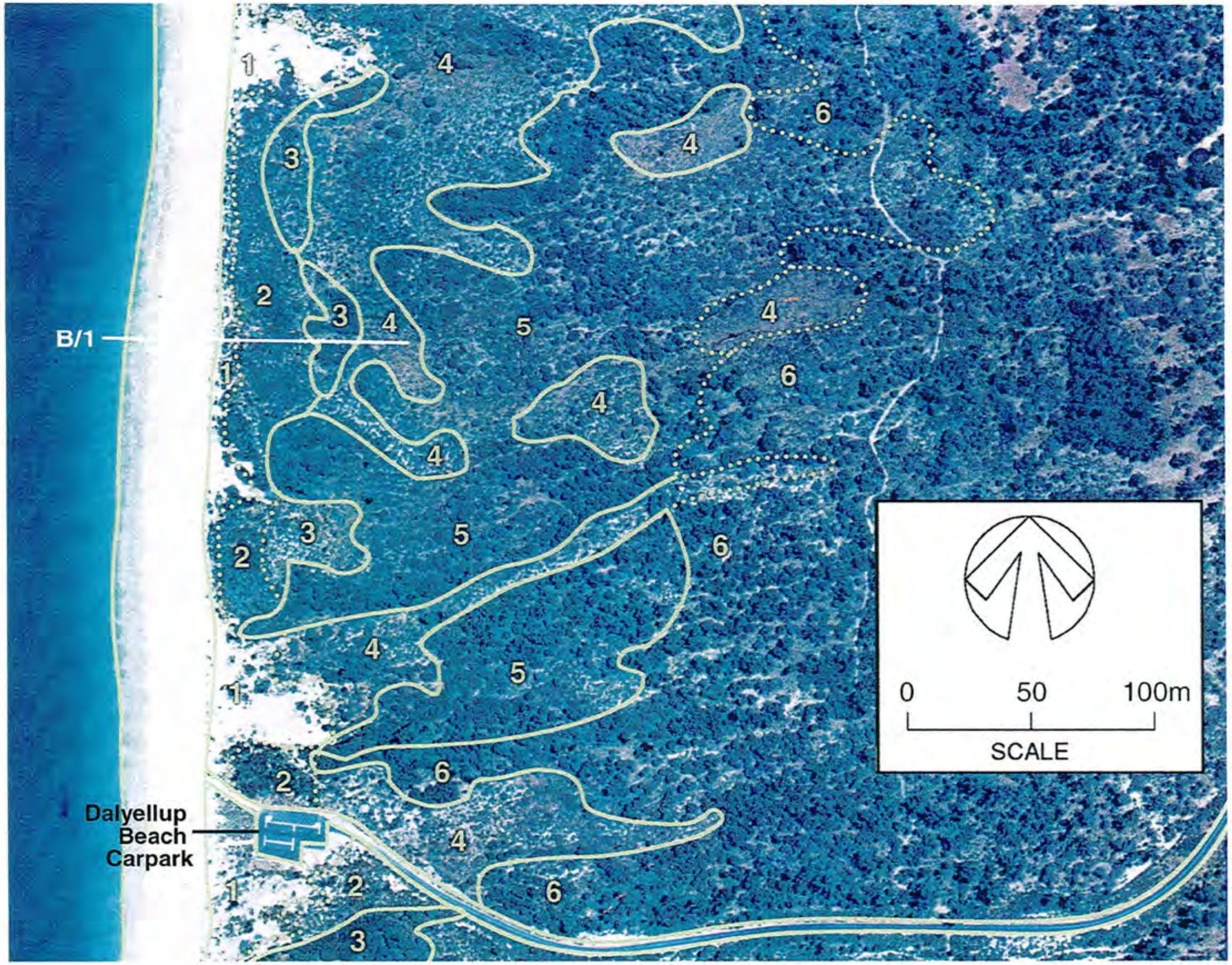
At Dalyellup Beach, **Euphorbia paralias, Spinifex longifolius* and **Cakile maritima* are the major components of the incipient foredune and the blowouts near the shore (Fig 16 and Fig 17a). **Vulpia fasciculata, *Pelargonium capitatum, *Trachyandra divaricata, *Bromus diandrus* and

**Tetragonia decumbens* inhabit the narrow swale at the base of the foredune. The steep lower slopes of the foredune are subject to erosion in places but are generally covered by a diverse and attractive closed heath including *Scaevola crassifolia, Acacia cochlearis, Olearia axillaris, Diplolaena dampieri, Spyridium globulosum, Hibbertia cuneiformis* and *Lepidosperma gladiatum* with the grasses *Poa poiformis, Austrostipa flavescens* and *Bromus arenarius* and herbs *Calandrinia brevipedata* and *Parietaria debilis.* This heath is generally in very good condition with few weeds except the occasional **Erharhta longiflora, *Dischisma arenarium* and **Trachyandra divaricata.*

The mid slope zone of the transect is a closed scrub of *Agonis flexuosa* var. *flexuosa* (Peppermint) with *Spyridium globulosum, Rhagodia baccata* subsp. *dioica* and *Diplolaena dampieri* (Fig 17b). This has a mesic understorey of indigenous herbs and grasses including *Parietaria debilis, Daucus glochidiatus, Caladenia latifolia* (Pink Fairies), *Triglochin* sp.B, *Calandrinia brevipedata, Hydrocotyle pilifera* var. *glabrata, Pterostylis brevisepala* ms and *Austrostipa flavescens.* The flatter areas of this zone appear more degraded (possibly due to grazing). Here the Peppermint canopy is disrupted and there is a high cover of **Trachyandra divaricata* and **Erharhta longiflora* as well as the indigenous herbs and grasses.

An open heath of *Olearia axillaris, Scaevola crassifolia* and *Acacia cochlearis* inhabits the upper slope and crest of the dune (Fig 17c). Associated with these are: *Acanthocarpus pressii, Carpobrotus virescens, Conostylis aculeata* subsp. *preissii, Jacksonia furcellata, Opercularia vaginata, Scaevola anchusifolia* and *Senecio lautus* subsp. *maritimus.*

At the Preston River Delta transect (Fig 16), *Avicennia marina* inhabits the edges of the shoals where it forms low, open columnar shrubs which grade into a low closed scrub to low closed forest with little understorey except occasional sparse *Sarcocornia quinqueflora* subsp. *quinqueflora, Suaeda australis* and *Samolus repens*. Inland of the mangroves, a high tide platform is inhabited by *Halosarcia halocnemoides* subsp. *halocnemoides, Halosarcia indica* subsp. *bidens* , *Sarcocornia quinqueflora* subsp. *quinqueflora, Suaeda australis, Frankenia pauciflora* with some sparse *Juncus kraussii* and *Sporobolus virginicus.* A bare tidal pool nearby (Fig 17) is fringed by *Sarcocornia quinqueflora* subsp. *quinqueflora* and occasionally *Lawrencia spicata.* A low sand dune emergent from the wetland is fringed by *Isolepis nodosa, Triglochin mucronata, Apium prostratum* var. *prostratum* (Sea Celery), *Cotula cotuloides, Myoporum* *caprarioides* and occasionally the orange-flowered **Romulea obscura*. The sandy crest flora comprises the shrubs *Olearia axillaris, Exocarpus sparteus* (Broom Ballard), the lemon-yellow flowered *Eremophila glabra* subsp. *albicans* and *Hibbertia cuneiformis* as well as *Sporobolus virginicus* and an assemblage of herbs, including **Melilotus indicus*, **Sonchus oleraceus* and *Senecio lautus* subsp. *maritimus*. The remainder of the wetland is generally closed rushes of *Juncus kraussii* with some patchy small closed stands *of Poa poiformis* (both to about 1.1m in height), *Lobelia alata* and **Symphyotrichum subulatum* to 1.2m in height.



Key:

1. Foredune and blowouts with **Euphorbia paralias, *Cakile maritima,* and *Spinifex longifolius.*
2. Steep seaward slopes: closed heath to heath including *Scaevola crassifolia, Lepidosperma gladiatum, Hibbertia cuneiformis, Spyridium globulosum, Poa poiformis* and *Diplolaena dampieri.*
3. *Agonis flexuosa* closed heath to scrub over herbs including *Parietaria debilis* and **Trachyandra divaricata* in the more sheltered sites beyond the break of the steep seaward slope.
4. Upper slopes and crests: heath to open heath of *Acacia cochlearis, Scaevola anchusifolia,* and *Olearia axillaris* often with emergent tall shrubs of *Agonis flexuosa* and *Spyridium globulosum.*
5. Valleys and lower slopes: Low closed forest to tall open shrubs of *Agonis flexuosa* with *Spyridium globulosum* and *Diplolaena dampieri.*
6. Deep valleys near the beach and in the hinterland: *Eucalyptus gomphocephala* (Tuart) woodland to open forest over scrub of *Agonis flexuosa, Spyridium globulosum, Diplolaena dampierii* and *Acacia cochlearis.*

Figure 14: Aerial view of Dalyellup Beach, Bunbury with location of transect B/1.

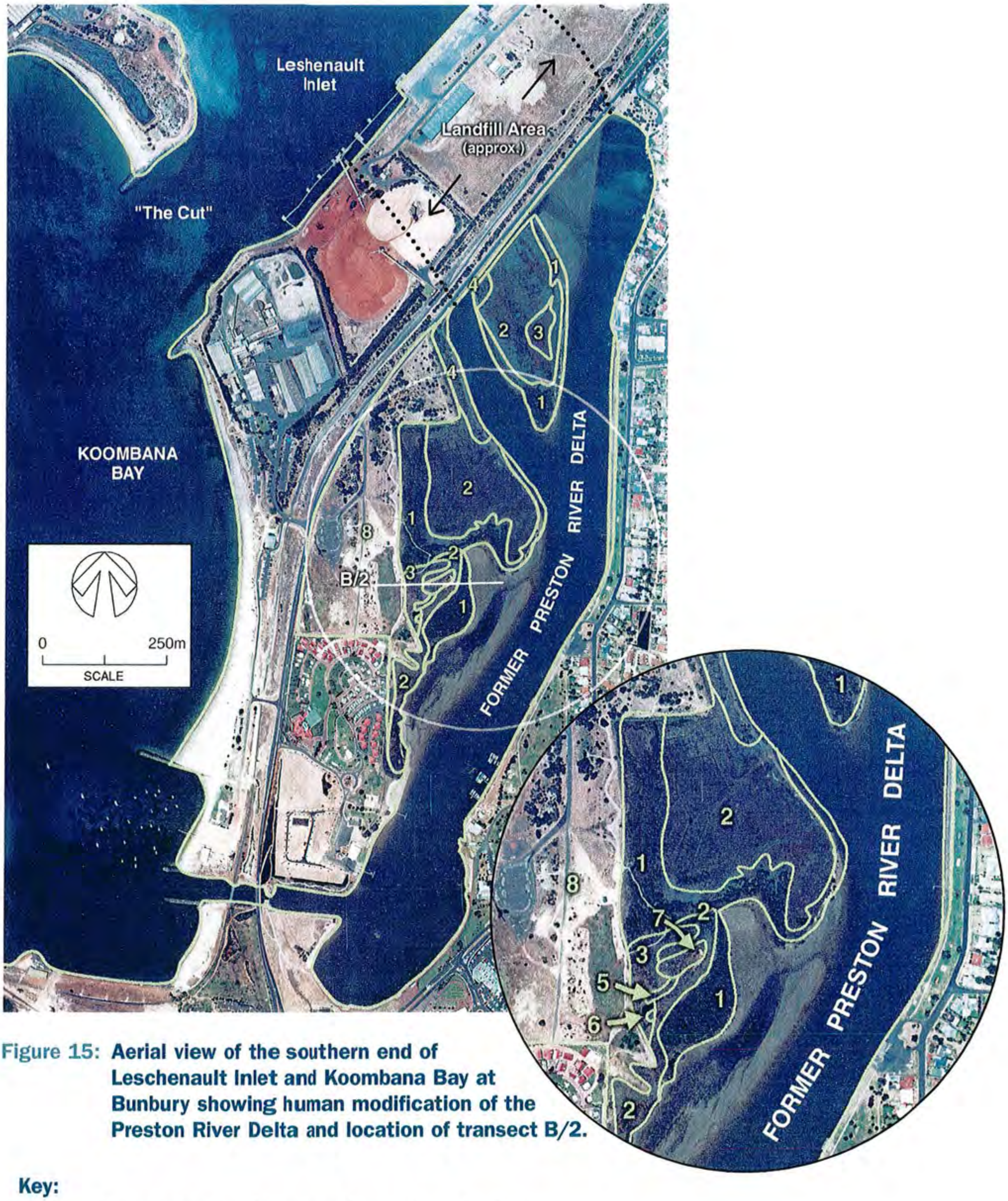
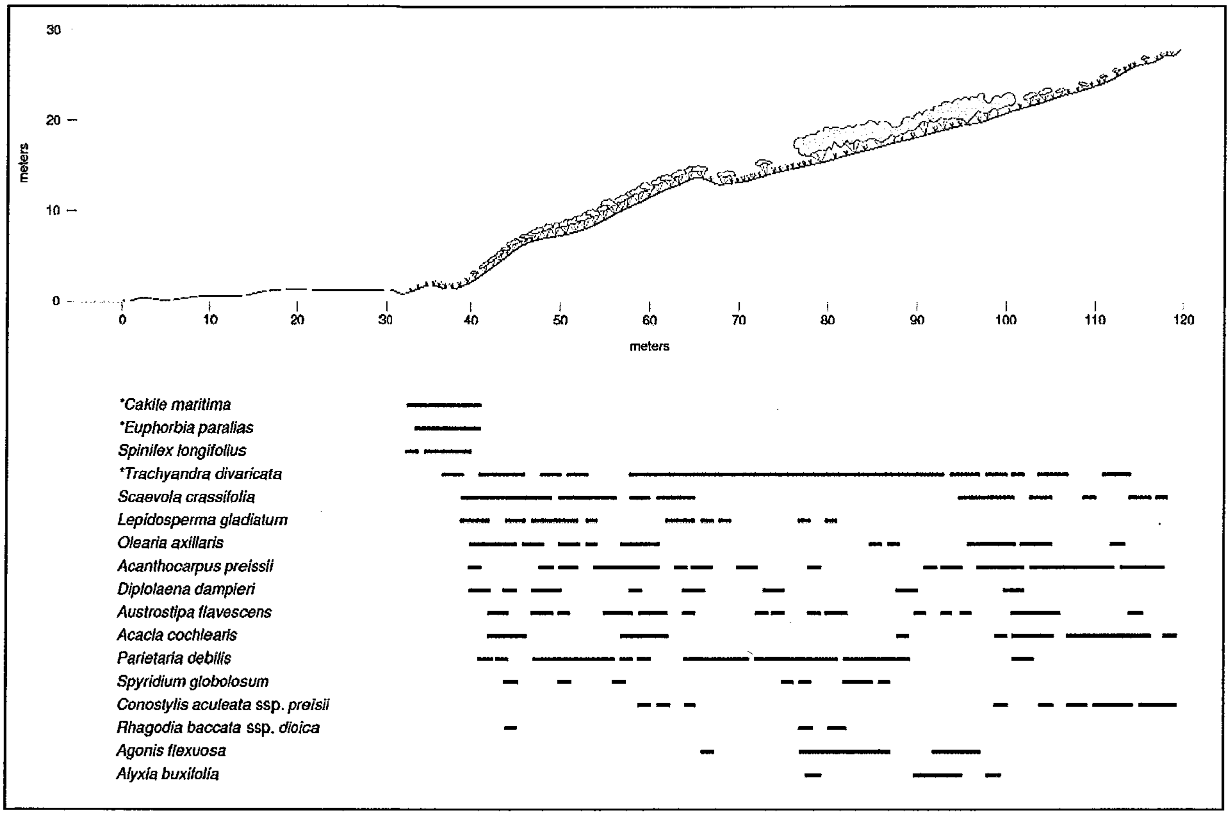


Figure 15: Aerial view of the southern end of Leschenault Inlet and Koombana Bay at Bunbury showing human modification of the Preston River Delta and location of transect B/2.

Key:

1. *Avicennia marina* low closed mangrove forest to open heath.
2. Various halophyte assemblages (e.g. *Sarcocornia quinqeflora, Halosarcia halocnemoides ssp halocnemoides, Wilsonia humilis, Frankenia pauciflora*) sometimes with low open shrubs of *Avicennia marina*.
3. *Juncus kraussii* closed rushes with *Poa poiformis*.
4. *Casuarina obesa* woodland.
5. Tidal pool.
6. Alien taxa (**Schinus terebinthifolia/ *Asparagus asparagoides*).
7. Sand bar with *Olearia axillaris, Eremophila glabra ssp albicans ms, Hibbertia cuneiformis, Isolepis nodosa.*
8. Degraded dune vegetation dominated by alien taxa.

a. Dalyellup



b. Preston River Delta

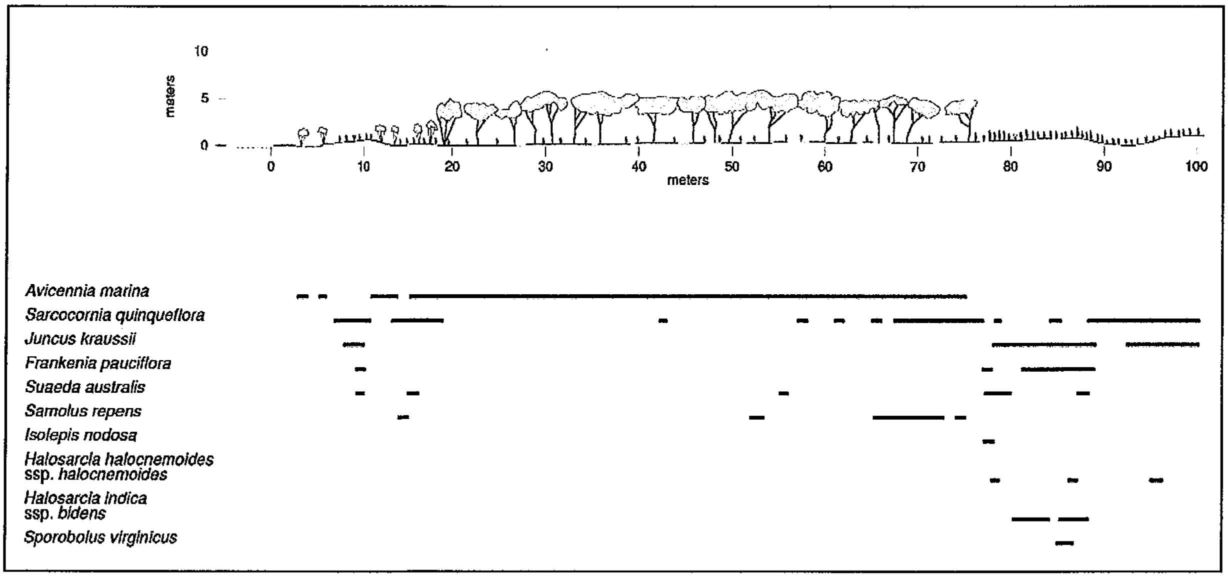


Figure 16: Bunbury transects.

a. Dalyellup Beach foredune.

b. Crest of hill at the Dalyellup transect.

c. Closed scrub of the mangrove *Avicennia marina* and salt marsh at the Preston River Delta transect.

d. *Agonis flexuosa* closed scrub on the slope above Dalyellup Beach.

Figure 17: Vegetation of Dalyellup Beach and the Preston River Delta.

3.4 Esperance: Mt Le Grand and Hellfire Bay, Cape Le Grand National Park.

a. Setting of transects

Esperance has a climate which can be classified as sub humid (Gentilli, 1972) or as warm Mediterranean (Beard, 1990a). It is located in the east of the Eyre Botanical District (Beard, 1980) or the Esperance Plain Biogeographical Region (IBRA, 2002). Mean annual rainfall is 748 mm with an annual evaporation of 1712 mm (Esperance town weather station, Bureau of Meteorology, 2002). Winter rain is generally reliable. Approximately 50 mm p.a. more rain is received at Cape Le Grand than at the town of Esperance (Beard, 1973). The growing season at Cape Le Grand probably also exceeds the mean of 6 months expected for Esperance. Cloud cover and southerly winds moderate summer temperatures whilst severe southerly winds and gales can occur in winter.

The geology of Esperance is described by Morgan and Peers (1973). The area lies within the Albany Fraser geological province with Proterozoic bedrock of mainly granite and gneiss. During the Eocene, after the Australian continent separated from Antarctica, there is evidence that sea level was at times several hundred metres above the present and marine transgressions extended inland to the Dundas Hills. Marine sediments (e.g. Pallinup Siltstone) were deposited during this time and form the basis of an extensive plateau in the hinterland. This plateau was overlaid by later sediments forming what is generally known as the Esperance Sand Plain. The southern margin of this inland plateau is evident as a low scarp about 7 km north of the town of Esperance. Emergent Proterozoic hills inland include landmarks such as Mt Merivale, Mt Ridley and Frenchman's Peak. This granitic material is also present as rugged headlands such as Mt Le Grand (345m) along the coast and the islands of the Recherche Archipelago. The near coastal Esperance Bay area is a low plain of Holocene dunes and many wetlands. The recent coastal dunes are generally composed of white quartz sands very low in calcium carbonate. Aeolianite is generally of limited occurrence in the district, being restricted to areas west of Esperance (including Dempster Head). The granite and other hard rocks of the coastal headlands erode very slowly forming thin layers of skeletal soils.

b. Results of transect survey

At Mount Le Grand, (Table 11) the summits are mostly bare rock and boulders. A range of colluvial materials ranging in size from cobbles to coarse sand, sand and mud has accumulated on the slopes in complex patterns depending on factors such as position on the slope, steepness of the slope, cracks and crevices in the rock surfaces and surface flow patterns. Fine sand, mud and organic matter are trapped by mats of low prostrate vegetation and a thin layer of sandy peat to peaty sand is present in some areas on the lower slopes of the hill.
The surface sediments of the Hellfire Beach foredune are largely unaltered parent material and consist almost entirely of siliceous materials *i.e.* quartz sands. These sands are somewhat humified in the swale beyond the crest of the foredune.

Table 11: Esperance transect surface sediments.

Position of sample site on transect	Description
Mount Le Grand lower slope (monocot mats)	Dark brown, medium to fine, peaty, quartz sand to sandy peat.
Mount Le Grand mid slope closed heath)	Dark brown, very coarse to medium, peaty, quartz sand with lateritic pebbles.
Mount Le Grand upper slope (open scrub)	Light brown, very coarse to medium, quartz sand with lateritic cobbles and pebbles over saprolite.
Hellfire Beach (incipient foredune)	Pure white, medium quartz sand.
Hellfire Beach (mid slope)	Pure white, medium quartz sand.
Hellfire Beach (swale)	Deep litter layer of *Banksia* leaves underlaid by peaty, medium quartz sand.

Vegetation habitats in the Mt Le Grand area (Fig 18) are patchy and complex but generally vary with their position on the slope and thus soil texture, depth and its water-holding capacity. At the base of the granite hill, small pockets of sand deposited by the highest tides provide habitat for an assemblage akin to the foredune of the nearby Cape Le Grande Beach. Species-rich assemblages associated with monocotyledenous mats proliferate in moist conditions on peaty sand, sandy peat and mud of the lower slopes. Heaths and closed scrub predominate further up the slopes where the skeletal soils are thinner and consists of drier, coarse rocky sand. Beyond the foredune of

Cape Le Grand Beach, *Melaleuca cuticularis* heath and scrub borders wetlands amongst sand dune vegetation typical of the Esperance Bay area. A total of 84 indigenous and 7 alien flora taxa were recorded at the Mt Le Grand transect (Appendix 2 & 6) with the most numerous families being Poaceae (9 spp.), Myrtaceae (7 spp.), Stylidiaceae (6 spp.), Cyperaceae and Apiaceae (5 spp. each).

The Hellfire Bay area is notable for the variety of landforms and vegetation assemblages present in the coastal zone (Fig 19). A small pocket beach lies between two rocky granitic headlands. Slopes of granitic hills are host to monocot mat, diverse heath and closed scrub assemblages similar to those found at the Mt Le Grand transect. The foredune of the pocket beach consists entirely of white quartz sand. The incipient foredune, which forms a low cliff on its seaward edge, is vegetated by a diverse assemblage dominated by **Ammophila arenaria*. The seaward slope of the foredune is covered by a prostrate, species–poor, low closed heath which rises into a closed scrub in the adjoining swale. The hinterland is a mosaic of vegetation assemblages including *Banksia speciosa* scrub on dune crests and *Anarthria scabra* closed rushes with low open heaths including *Melaleuca thymoides*, *Beaufortia* sp. and *Adenanthos* sp. on gentle slopes and flats. The coastal dunes bar extensive freshwater basin wetlands where closed sedges are fringed with closed heath to closed scrub of *Agonis* aff. *linearifolia* and *Callistachys* aff. *lanceolata.* A deeply-incised narrow channel drains the wetlands to the beach. A total of 20 indigenous and 6 alien flora taxa were recorded in the Hellfire Bay transect (Appendix 2&10) with the most numerous families being Asteraceae (5 spp.) and Poaceae (4 spp.).

At the Mt Le Grand transect (Fig 20 and 21), sand accumulates in crevices and shelves in the rocks near sea level and supports an assemblage mainly consisting of naturalized alien taxa (Fig 21a). These include **Euphorbia paralias*, **Parapholis incurva,* **Pelargonium capitatum* and **Bromus diandrus*. (It is notable that few alien taxa are present further up the slope on the granite rocks except for one small clump of **Vulpia myuros* var. *myuros,* **Anagallis arvensis* var. *caerulea* and several plants of **Avena barbata* on the lower slope). Also present on these sandy shelves are *Isolepis nodosa, Apium annum* and the shrubs *Hakea clavata* and occasional low shrubs of *Acacia cyclops*.

The lower slopes of the transect are largely bare of vegetation except for patchy mats of the monocotyledenous *Borya nitida* (Pincushions) and other dwarf perennial herbs and shrubs (Fig

21b). *Borya* is commonly known as a resurrection plant since it can tolerate extreme drought in a dormant state with its leaves appearing dry, orange-coloured and lifeless. However with the onset of rain it quickly rehydrates. Its matted habit traps water, soil and organic matter and provides a niche for a species-rich assemblage of small shrubs, and herbs. These include the sedge *Lepidosperma tuberculatum,* small cushion plants such as *Andersonia sprengelioides*, *Asteridea nivea*, *Pelargonium australe* subsp. *drummondii, Xanthosia tasmanica, Stylidium breviscapum* (Boomerang Triggerplant) and *Stylidium piliferum* (Butterfly Triggerplant). Also found here are many annuals and geophytes including *Chamaescilla corymbosa* (Australian Bluebell), *Stylidium inundatum* (Hundreds and Thousands), *Stylidium mimeticum, Gnephosis drummondii, Siloxeros filifolius, Wurmbea cernua, Thelymitra benthamiana* (Cinnamon Sun Orchid) and *Plumatichilus* aff. *plumosus* (Esperance Bird Orchid). Larger but almost prostrate shrubs growing in rock crevices in this zone include *Melaleuca globifera, Hakea clavata, Platysace compressa* (Tapeworm Plant) and *Anthocercis viscosa* subsp. *caudata.*

Further up the slope the assemblage becomes even more species- rich (Fig 21c) with many more shrubs including *Baeckea tetragona, Calothamnus quadrifidus* (One-sided Bottlebrush), *Dampiera fasciculata, Dillwynia pungens, Eutaxia obovata, Sollya fusiformis* and *Verticordia vicinella.* Grasses and sedges include *Amphipogon strictus, Neurachne alopecuroidea, Spartochloa scirpoidea, Lepidosperma* aff. *costale* and *Schoenus subflavus* subsp. "long leaves" (K.L. Wilson 2865). *Acacia pinguiculosa* subsp. *teretifolia* forms a closed heath over some parts of this midslope zone excluding most other taxa (Fig 21d).

In the upper part of the transect where the soil is rocky and dry, there is an open heath to scrub of *Melaleuca fulgens* subsp. *fulgens, Calothamnus villosus, Grevillea concinna* subsp. *concinna, Dryandra armata* and *Hibbertia ulicifolia. Borya* mats are no longer present and a variety of tufted grasses, sedges, rushes and herbs make up a sparse understorey. These include *Neurachne alopecuroidea, Amphipogon turbinatus, Amphipogon strictus, Lepidosperma* aff. *costale, Desmocladus flexuosus, Lepyrodia monoica, Mesomelaena stygia* subsp. *stygia, Stylidium rupestre* and *Conostylis bealiana.* A closed scrub of *Allocasuarina trichodon* (Fig 21d) is also present amongst boulders over much of the upper slopes with occasional *Dryandra armata* and *Lepyrodia monoica.* The ground is generally covered with a deep litter layer excluding most other understorey taxa.

At the pocket beach at Hellfire Bay the transect (Fig 20 & 22) traverses a steep foredune and the adjacent swale. The incipient foredune is dominated by **Ammophila* arenaria and the silver-foliaged *Leucophyta brownii* (Fig 22a). Otherwise it supports a species-rich assemblage including **Cakile maritima, Calandrinia granulifera, Carpobrotus virescens, Crassula colorata, *Isolepis marginata, Poa poiformis, Senecio lautus* subsp. *maritimus, *Sonchus oleraceus, Sporobolus virginicus, Triglochin minutissimum* and **Vulpia myuros* var. *myuros*. Naturalized alien taxa are not present in the extremely thick heath and scrub beyond the incipient foredune.

The seaward slope of the steep foredune is inhabited almost exclusively by four taxa which are wind pruned into a dense closed heath less than 50cm in height. These are *Ricinocarpus tuberculatus* (Wedding Bush) which otherwise grows to over 3m in height in the lee of the foredune, *Bossiaea dentata, Darwinia diosmoides* and *Asteridea nivea* (Fig 22b). Apart from occasional shrubs of *Pimelea ferruginea* and *Leucopogon obovatus,* few other taxa are found on this slope. *Banksia speciosa* lines the crest of this dune in what appears to be a closed heath less than 50cm in height. However this is actually a gnarled, prostrate formation with the thick branches and trunks of the individual *Banksia* plants extending over 3m in length along the ground and merging with those of adjoining plants in a sturdy labyrinth.

In the lee of the foredune, *Banksia speciosa* and *Ricinocarpus tuberculatus* form a closed scrub which rapidly rises to about 2.5m in height. Beyond this, the transect traversed about 50m^2 of dead *Banksia speciosa* which originally formed a closed scrub to over 4m in height. A sparse understorey of *Leucopogon obovatus*, *Ricinocarpus tuberculatus* and *Lepidosperma gladiatum* is present in this zone with a deep litter layer. In the swale and on its eastern slope, live *Banksia speciosa* forms a closed scrub to over 5.2m in height exclusive of all other taxa. A closed heath and scrub of *Ricinocarpus tuberculatus* and *Melaleuca globifera* dominates the leeward slopes of the secondary dune (Fig 22c). Coastal wetlands adjoining the dunes (Fig 22d) are rich in endemic sedges and rushes and uncommon taxa however because of the difficulties of the terrain, limited resources and time the transect was not continued into these habitats and only opportunistic collections were made.

Key:

1. A large proportion of this area is bare rock. Low open shrubs (including *Melaleuca globifera, Andersonia sprengelioides* and *Calothamnus quadrifidus*) inhabit rock crevices. *Borya nitida* mats provide habitat for a diverse assemblage of geophytes and other annual herbs. *Acacia pinguiculosa* forms a closed heath in some places.
2. Closed diverse heaths (e.g. *Calothamnus quadrifidus* and *Grevillea concinna*) to closed scrubs (e.g. *Allocasuarina trichodon, Melaleuca globifera* and *Eucalyptus* spp.)
3. Foredune vegetation including **Euphorbia paralias, *Pelargonium capitatum, Sporobolus virginicus* and *Senecio lautus.*
4. *Melaleuca cuticularis* heath to closed scrub bordering wetlands.
5. Fixed dunes with *Acacia cyclops, Spyridium globulosum, Olearia axillaris* and *Pimelea ferruginea*.

Figure 18: Aerial view of the lower western slope of Mt Le Grand and location of transect E/1.

Figure 19 : Aerial view of Hellfire Bay and location of transect E/2.

Key:

1. Granite headlands: *Melaleuca globifera/ Eucalyptus* spp. closed scrub on upper slopes and *Melaleuca globifera* low open shrubs with *Borya nitida* and diverse geophytes on lower slopes.
2. Incipient foredune: open grasses/ sedges/ herbs (**Ammophila arenaria, Sporobolus virginicus, Isolepis nodosa, Leucophyta brownii, Senecio lautus subsp. maritimus*).

3a. Foredune seaward slope: closed heath less than 0.5m in height of *Bossiaea dentata, Ricinocarpus tuberculatus, Darwinia diosmoides.*

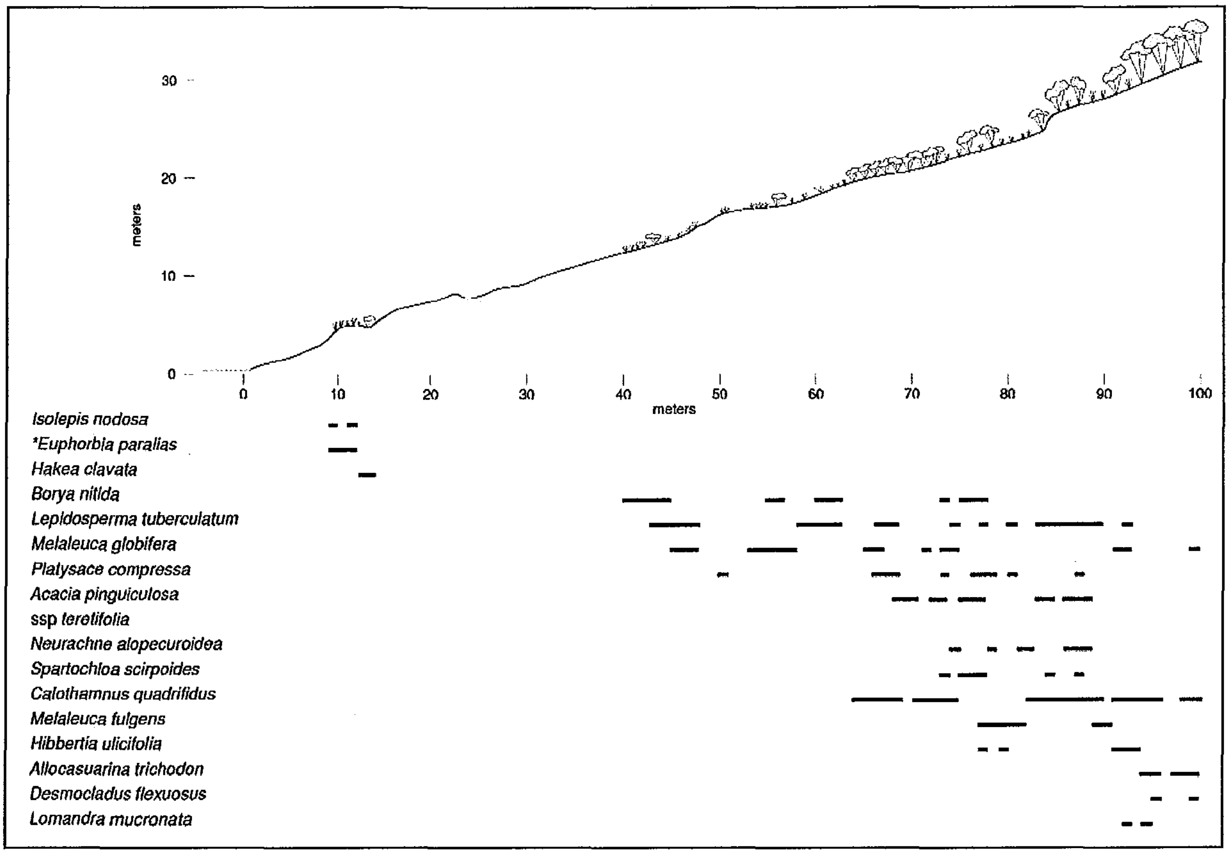
3b. Foredune crest: closed heath less than 1m in height of *Banksia speciosa* grading into a closed scrub of *Banksia speciosa* to 6m in the swale.

4a. Gentle slopes: species rich low closed heath including *Melaleuca thymoides* and *Anarthria scabra.*

4b. A mosaic of dunes (with *Banksia speciosa/ Ricinocarpus tuberculatus* scrub on crests) flats and gentle slopes (vegetated by *Anarthria scabra* and diverse low open shrubs including *Melaleuca thymoides)* and wetlands.

5. Sumplands and linear wetlands: closed sedges *Baumea articulata, Baumea juncea, Baumea acuta* with an outer zone of closed heath to scrub of *Agonis aff linearifolia* "Cape Le Grand" and *Callistachys sp.*
6. *Allocasuarina trichodon* scrub.

a. Mt Le Grand



b. Hellfire Bay

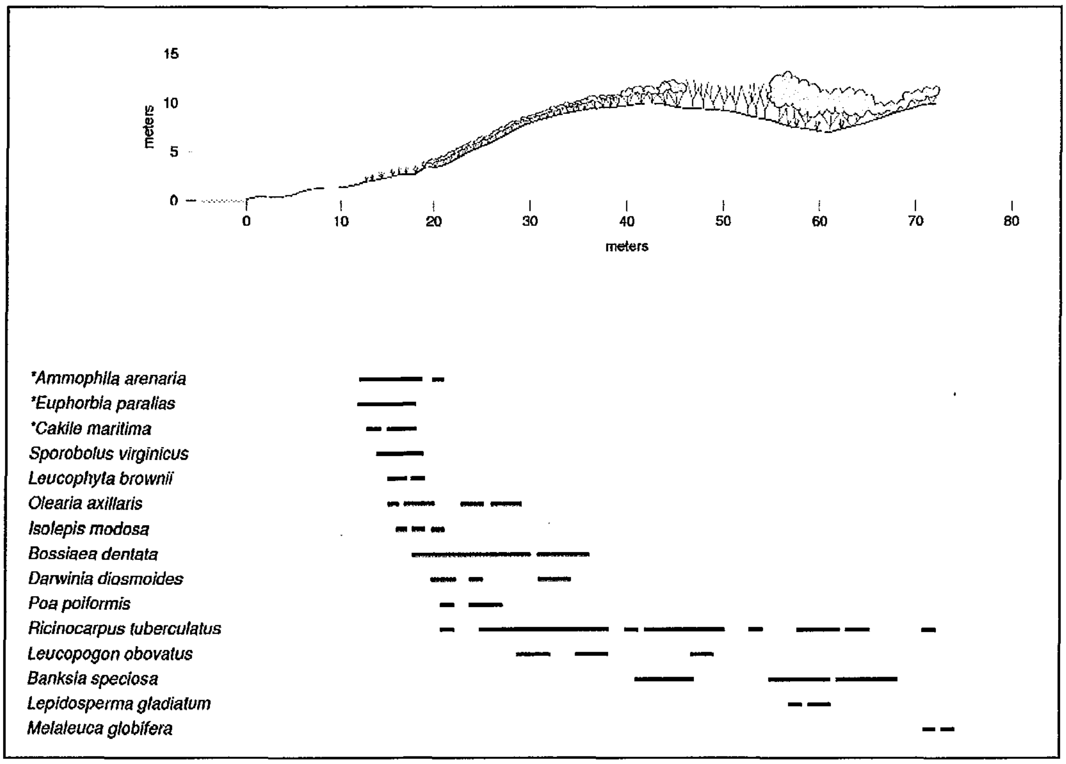


Figure 20: Esperance area transect diagrams

a. Sandy shelf on rock just above high tide dominated by naturalized alien taxa e.g. **Euphorbia paralias* and **Pelargonium capitatum.*

c. Mid slope: a diverse heath dominated by *Melaleuca globifera* and *Calothamnus quadrifidus.*

b. Lower slope: *Borya nitida* mats with diverse geophytes and other annuals.

d. Upper section of transect: closed heath of *Acacia pinguiculosa* and above this a closed scrub of *Allocasuarina trichodon.*

Figure 21: Vegetation at Mt Le Grand.

a. Foredune at Hellfire Beach with **Ammophila arenaria* and *Leucophyta brownii* dominating the lower slope.

b. Midslope closed heath of *Ricinocarpus tuberculatus, Bossiaea dentata, Darwinia diosmoides* and *Pimelea ferruginea* is replaced by wind pruned *Banksia speciosa* less than 1m in height at the top of the dune.

c. Leeward side of the foredune. *Banksia speciosa* closed scrub on the dune grades into *Anarthria scabra* rushes with sparse low shrubs such as *Melaleuca thymoides*.

d. Coastal wetlands behind the dunes at Hellfire Beach. Closed sedgelands of *Baumea articulata, B. juncea* and *B. acuta* are fringed by closed heath to scrub of *Agonis aff. linearifolia* "Cape Le Grand".

Figure 22 : Vegetation at Hellfire Bay.

4. Summary and discussion

The SWALE project described eight sites that displayed some of the very wide range of physical settings found in the South West region of Western Australia. The variety of physical settings surveyed corresponded with large floristic and structural differences in the vegetation between sites. A number of taxa poorly represented in the WA Herbarium collection, undescribed taxa, new populations of DCLM Priority Species and range extensions were recorded. This was so not only in the vegetation of the Quindalup Dunes, that has received the most attention from previous researchers, but particularly in the vegetation of Cape Le Grand National Park. It is clear that many elements of the coastal flora of this region are not well known and considering the intense pressures on coastal vegetation due to development and recreation, it is a priority that coastal vegetation be surveyed more adequately to ensure adequate conservation of this diversity in reserves. The methods used by the SWALE project with Regional Herbarium volunteers were effective in surveying the flora and vegetation and establishing a baseline for monitoring change. These methods can be used in the future at various levels ranging from qualitative assessment of vegetation to multivariate analysis of quantitative trends to both assess diversity of vegetation between sites and inform management decisions. In addition, management issues were identified during the course of the SWALE project which should be addressed in the near future to protect these high conservation areas.

A total of 243 taxa were recorded from the eight SWALE transects and another 23 taxa were collected opportunistically nearby.The transects were repeatedly visited for the purposes of flora collection over about 18 months. The total recorded exceeded the 110 taxa of Sauer (1965) from 50 transects in a larger survey from Port Hedland to Albany. The latter probably involved only one visit to each site and the survey was carried out in late summer therefore transects would probably have been devoid of many winter and spring-flowering geophytes and annuals. Apart from the season and intensity of survey, it is also probable that the inclusion of the species-rich Cape Le Grand area and its complement of south coast siliceous (quartz) sand endemics in the SWALE project also contributed to the large number of taxa collected. The SWALE flora inventory also contributed 76 taxa above those known to inhabit the coast by Beard (1990b) (whose list was sourced from all published records to 1990). Most of these additions were taxa from the Cape Le Grand area, thus again underscoring a relative paucity of floristic survey in coastal habitats of this region.

The Mt Le Grand transect was by far the most species-rich of the transects and most taxa from this site did not occur elsewhere in the study (Table 12). It was also the transect with the most numerous undescribed and DCLM Priority Species and a very low proportion of naturalized alien taxa. The transect encompassed a catena of soils developed on the rocky slope colluvium and thus a wide array of plant habitats. The Hellfire Beach transect was the least alien-invaded transect, had an average species richness and a high proportion of taxa found only in this transect of the study. The very thick, undisturbed heath occurring on the slope was probably not conducive to invasion by the relatively low pool of alien taxa occurring in the area. The uniformity of edaphic conditions on the slope (deep siliceous sands throughout the transect) contrasted with the complexity of the Mt Le Grand slope and this could explain the comparatively low species richness and high distinctiveness of the flora. The Dalyellup Beach transect was significantly more species-rich than all the other Quindalup Dunes in the survey and was second in this attribute only to Mt Le Grand. However it had a higher proportion of alien taxa than many of the other Quindalup Dunes transects (e.g. the Port Kennedy plain transect PK1) and a relatively low rate of taxa which did not occur elsewhere in the survey. The Port Kennedy beachridge plain transect was notable as the Quindalup Dunes transect with the most undescribed taxa, its relatively low rate of alien taxa and the numerous taxa which did not occur in other transects. The latter was probably due to the freshwater wetland habitats of this transect which were not present elsewhere in the survey. The Becher Point transect was considerably more invaded by alien taxa and less species-rich than the saltmarsh at the Preston River Delta. The number of weeds is not surprising considering the large swathes cut through this transect by vehicle tracks. One of the tracks is currently being rehabilitated by the manager of the Port Kennedy reserve (DCLM). The low species richness probably reflects the relatively uniform edaphic conditions over the saltmarsh compared to the complex tide-related habitats of the delta and perhaps the relative youth of the Becher Point wetland (see Fig 8). The Greenough Dunes and Drummonds Cove were similar to each other in floristics, with average species richness and proportions of alien taxa. They were however sharply differentiated from the southern Quindalup Dunes transects on floristics.

Table 12: Summary of floristic characteristics of the SWALE transects.
* This transect varies considerably in species richness and vegetation condition. The figure below was calculated from the section between 200-300m along transect PK1 as this did not include any vehicle tracks.

Transect	Total taxa	% alien taxa	% taxa in this transect only	Taxa/m^2	Total priority & undescribed taxa
Mt Le Grand	91	8	71	0.85	6
Hellfire Bay	26	2	38	0.44	-
Port Kennedy plain	76	18	32	*0.43	3
Drummonds Cove	48	23	6	0.32	1
Greenough Dunes	54	24	22	0.40	-
Dalyellup Beach	65	26	15	0.71	2
Preston River Delta	57	28	33	0.46	-
Becher Point	30	57	13	0.21	-

Over 500 voucher specimens were databased and incorporated into the WA Herbarium by the SWALE project and the names assigned to these specimens are now constantly updated and available on line. Unfortunately all but one of the specimens from Sauer's collection were lodged with herbaria in the United States of America. About 29% of the names assigned to taxa in the latter inventory are no longer valid due to taxonomic revisions and other scientific reasons. It would therefore be a relatively specialized task to research vegetation changes of the Sauer transects over time compared to conducting similar studies of the SWALE transects in which name changes are available on line to volunteers without need to refer to taxonomic journals. With the assistance of the distribution records of flora now available via Florabase, a number of significant range extensions of coastal taxa were determined from the SWALE project collections (Table 13). Seven new populations of DCLM Priority Taxa were also found (Table 14). (Note: some of the latter were collected opportunistically from Cape Le Grand coastal wetlands not included in transects).

There were no CALM Priority taxa collected in the Geraldton transects however a significant collection from the Drummonds transect was *Calandrinia* sp. Drummonds AA Brooker 110. This is a previously undescribed taxon and appears to have affinities with *Calandrinia remota* and *Calandrinia polyandra* (neither of which have been collected at Geraldton before). It differs however in several diagnostic character states from the latter taxa.

Table 13 : SWALE flora taxon range extensions

Taxon	Previous records	Extension
Platysace haplosciadia	Margaret River area	East to Mt Le Grand
Sphaerolobium pubescens	Albany area	East to Cape Le Grand
Zygophyllum fruticulosum	Claremont-Cottesloe, Perth	South to Dalyellup
Xanthosia tasmanica	West of Ravensthorpe	East to Mt Le Grand
Logania litoralis	Horrocks Beach north of Geraldton	South to Greenough Dunes

Table 14: DCLM Priority Taxa new populations found in the SWALE project.

Taxon	Priority	Location
Dampiera decurrens	P2	Mt Le Grand transect
Goodenia quadrilocularis	P2	Cape Le Grand coastal wetlands
Lepyrodia fortunata ms	P2	Cape Le Grand coastal wetlands
Leucopogon rotundifolius	P3	Mt Le Grand transect
Sphaerolobium pubescens	P3	Cape Le Grand coastal wetlands
Verticordia vicinella	P3	Mt Le Grand transect
Conostylis pauciflora subsp. *pauciflora*	P4	Port Kennedy both transects

Many taxa collected in the Geraldton transects were at the southern end of their coastal range including *Ptilotus divaricatus* var. *divaricatus*, *Rhagodia latifolia, Rhagodia preissii* subsp. *obovata, Euphorbia tannensis* subsp. *eremophila, Logania litoralis, Commicarpus australis* and *Lotus australis*. Therefore the importance of the Geraldton coastal vegetation is not based on the rarity of constituent taxa but on its embodiment of ecological and biogeographical trends.

Unfortunately coastal vegetation in the immediate vicinity of the town of Geraldton has effectively all been cleared for the installation of the port, the town centre and the expanding suburbs. A railway line runs immediately adjacent to the beach along much of the urban shoreline. Fringing the beach-side suburbs there is, at most, a narrow and often degraded ribbon of foredune vegetation. The large Southgate Dunes on the southern outskirts of the city are in the process of being homogenized into a suburban precinct. North from the city, the Drummonds Cove suburban development is destined to consume almost all the remaining coastal scrub. The loss of indigenous vegetation is compounded by a major invasion of the coastal scrub throughout the area by **Lycium ferocissimum* (African Boxthorn), which spreads rapidly forming massive prickly stands excluding all indigenous plants. Other serious weeds are also rampant. The Greenough Dunes faces serious threats from indiscriminant use of off-road vehicles in the reserve as well as weed invasion. Two distinctive landform and vegetation features are encompassed by the project areas at Geraldton transects which have considerable conservation value as landscape features and embody some of the sense of place which make Geraldton different to other coastal towns. These are the unique Greenough Dunes and the acute foredune crests vegetated by *Atriplex isatidea* scrub in the Geraldton suburb of Drummonds Cove. Unfortunately, it seems almost certain that Geraldton will lose most of its remnant indigenous vegetation unless local awareness is raised. Major funding directed to the management of weeds, revegetation and the reservation of larger areas of coastal vegetation would be required in the near future to reverse current trends and this seems unlikely in the social and economic climate of the region which favours development over conservation.

At Port Kennedy Scientific Park, the SWALE project was part of a long-term and committed effort by local volunteers to conserve and manage the Port Kennedy Scientific Park and it provided floristic and hydrological data in a form useful for public education and ongoing management of the reserve. A number of flora taxa previously not recorded from the area were collected by the SWALE project (Table 14). These additions probably reflected the difference in sampling strategies between the SWALE study, which intensively sampled near-coastal areas, and previous extensive sampling of the entire reserve (Keighery and Keighery, 1993). Two previously undescribed taxa of *Calandrinia* (F. Littleton 66 & 68) were of particular significance amongst the new flora records from Port Kennedy Scientific Park. These have affinities with *Calandrinia polyandra* and *Calandrinia eremaea* respectively (both of which have never been collected from the Perth Coastal Plain and are generally plants of the arid zone) but differ significantly from the latter taxa. The Port Kennedy *Calandrinia* spp. also differ from *Calandrinia* sp. Drummonds Cove A.A. Brooker 110 which was collected at Geraldton. *Calandrinia* is a genus of the family Portulacaceae, whose constituents are usually succulent plants with very delicate, ephemeral flowers. Material of these taxa is difficult to collect and preserve in a condition that retains essential features for taxonomic study. This difficulty is partly responsible for these taxa being poorly known by botanists. Trained volunteers in the SWALE project have thus made a large contribution in their skillful and patient collection of these specimens.

Table 14 : New flora records for the Port Kennedy Scientific Park

Taxon
**Atriplex prostrata*
Calandrinia sp. 1 Becher. F Littleton 66
Calandrinia sp. 2 Becher. F.Littleton 68
Conostylis pauciflora subsp. *pauciflora* P4
Hydrocotyle tetragonocarpa
Lepidosperma squamatum
**Polypogon maritimus*
Rhodanthe citrina
Sarcocornia quinqueflora subsp. *quinqueflora*
Scaevola anchusifolia
Suaeda australis
Threlkeldia diffusa
Triglochin mucronata
**Vulpia fasciculata*

The indigenous vegetation of the Port Kennedy Scientific Park was generally in good condition and species-rich over much of the reserve. However this fact is not always obvious to the casual observer because much of the area's diversity resides in assemblages of poorly-known native grasses, sedges and herbs. There were few serious invasive weeds in the area surveyed except for **Euphorbia terracina* (present at a low rate) and small localized infestations of **Asparagus asparagoides* (Bridal Creeper). The latter has now been eradicated. The SWALE survey showed these two weeds were by no means widespread at present in the western parts of the reserve. However **Euphorbia terracina* does have the potential to be invasive as a consequence of frequent fires. Fire control is thus an important issue in park management along with controlling illegal use of the park by visitors in off-road vehicles. Revegetation of numerous poorly-sited tracks which currently abound in the area is also a priority.

The subtle patterns displayed by near-coastal plant assemblages with regard to groundwater levels is a distinctive feature of the Port Kennedy Scientific Park. To investigate this aspect of the reserve was largely beyond the resources available to the SWALE project. However due to interest and support from the volunteers, a rudimentary hydrological study was conducted over one year at three sites along the flora transects. The level of monitoring employed was sufficient to classify these wetlands according to hydroperiod and gain some insight into hydrological factors maintaining the wetland conditions. It became apparent however that whilst the wetland swales were largely maintained by rainfall, the Becher Point wetland showed a more complex pattern of groundwater fluctuation. More intensive sampling would be necessary to explain the latter. It is probable that perching of rainwater by organic matter in the basin and the proximity of the wetland to the ocean and thus tidal influence may be implicated in this pattern. Groundwater levels in the area are potentially subject to serious change due to nearby urban development and ground water abstraction by bores. The baseline hydrological data collected by SWALE will be useful in monitoring for such effects and in understanding vegetation change due to climatic fluctuations over time.

The Bunbury transects were located in a rapidly developing urban area. The vegetation of the transects and surrounding areas has high conservation value and use of the transects to monitor change over time in these areas may be crucial, even in the short term, in alerting management authorities with regard to threats to the biodiversity and local character of the vegetation. The vegetation is composed mainly of common taxa however it is in good condition and remarkably species-rich for Quindalup Dunes vegetation. Such vegetation is now becoming scarce in the area. The Dalyellup transect is immediately adjacent to the Dalyellup Beach urban development zone and since the transect was established, much of the hinterland of the transect has been cleared of indigenous vegetation and associated landforms have been modified beyond recognition by large scale earth-moving equipment. It is a hoped that the SWALE data will be used to raise awareness of the need to reserve more of the attractive vegetation of the Quindalup to Leschenault sector of the Quindalup Dunes for conservation reserves.

The Preston River Delta mangrove population is of State-wide conservation significance being the southernmost outlier of *Avicennia marina* in Western Australia. There is evidence to suggest that mangroves have only been present at this site in relatively recent times (*i.e.* for less than 2000 yrs) (Semeniuk *et al.,* 2000). This is thought to be related to climatic change and the variable influence of the Leeuwin Current on the south west coast of Western Australia during this period. A slow expansion of the mangrove population and increase in height of the formation has been documented since the massive anthropogenic alteration of the delta. This proliferation is thought to be linked with the increased salinity of the waters subsequent to human diversion of freshwater drainage. The vegetation assemblages observed (apart from the mangrove formations) and their fine-scale correlation with height above sea level were in accord with the conclusions of a quantitative study of halophytes at the Peel Inlet and Harvey Estuary by Backshall and Bridgewater (1981). The detailed vegetation monitoring baseline established in the SWALE transect was of particular importance at the Preston River Delta to enable future assessment of flora dispersal in relation to climate change and human intervention. The mangrove and salt marsh vegetation was in good condition but it is unfortunate that the hinterland of the saltmarsh was virtually devoid of indigenous taxa and has a very sparse, low structure. Infrastructure installed in recent years, such as boardwalks and paths protects mangrove and saltmarsh vegetation. A buffer of indigenous vegetation in the degraded hinterland to provide habitat for the indigenous bird fauna attracted to the biologically productive mangrove zone would enhance the picnic area and conservation value of the area. Other issues not successfully addressed at present include weed control and control of litter from boats which floats into the mangroves and can interfere with mangrove seedling recruitment.

Cape Le Grand National Park was impressive by any standards in its biodiversity and the pristine nature of its coastal vegetation. The SWALE project proved inadequate to describe all but a small fraction of the varied coastal landforms and vegetation of the area. It is important that vegetation types in the coastal areas and particularly the coastal wetlands are more adequately surveyed and monitoring systems are established before further pressure from tourist operations and the growing population of the area make adverse impacts. There are few natural bushland areas in the state where weed invasion is at such a low rate as Cape Le Grand National Park. However nearby along the Esperance Bay, serious infestations of invasive weeds (such as **Asparagus asparagoides* and **Leptospermum laevigatum*) are present and these will inevitably disperse to the national park in the very near future unless comprehensive, well-funded controls are implemented. Feral horses are also a growing problem on the fringes of the park. The Hellfire Bay transect set a baseline for collecting information over time regarding the regeneration of small patches of dead *Banksia* vegetation observed in the area and potentially an assessment of the importance of dieback in coastal areas. Dedicated and capable efforts have been made by the community and park managers DCLM to document the local flora. The Esperance region remains however a largely unexplored botanical frontier with many undescribed species and thus potentially lacking the essential data and resources for effective long term management.

5. Acknowledgements

WA Herbarium

All staff and numerous volunteers who contributed to the project with their taxonomic, curation, databasing and bookkeeping skills. In particular:

Neville Marchant for his unreserved support and encouragement;
Jan Gathe who developed the original idea to survey coastal flora as an adjunct to the Herbarium's Regional Herbaria Program, coordinated volunteers, edited text and helped in many other creative and kind ways; and
Mike Hislop for verifying specimen names.

Regional Herbaria, Regional DCLM and other volunteers in the project areas

Geraldton

Geraldton Regional Herbarium. The Residency, Marine Terrace, Geraldton.

Jenna Brooker, Tony Brooker, Julie Firth, Ian Morris, Andrew Lang, Jason Smith (Coastwest/Coastcare), Indra Kristen, Ena McNamara, Greg Burrows, Jack Burrows, Sally Vigilante, Alana Chant.

Port Kennedy

Rockingham Regional Herbarium. Narragebup Environment Centre. Safety Bay Rd, Rockingham.

Felicity Littleton, Lorin Tauss, Elizabeth Rippey, John Rippey, Anne Bellman, Deanne Pember (DCLM), Andrew Motherwell, Diana Hitchin, Bronwen Hyde, Norm Poulter, Vicki Bresnan, Andrew Arnold (FESA).

Bunbury

Bunbury Regional Herbarium. Department of Conservation and Land Management, cnr South West Highway and Dodson St, Bunbury.

Shirley Fisher, Olga Green, Lyn Clarke, Gordon Paine, Rita Watkins, George Watkins, Lorin Tauss, Mike Webster, Kip Webster, Frank Forrest.

Esperance

Esperance Regional Herbarium. Department of Conservation and Land Management, Dempster St, Esperance.

Coral Turley, Noel Blyth, Jan Gathe, Klaus Tiedeman (DCLM), Geoff Passmore (DCLM), Wayne Smith (DCLM).

Graphics

Tiffany Aberin (DCLM Graphic Design Unit, Crawley) design and layout of posters: Coastal Flora of Geraldton, Coastal Flora of Port Kennedy, Coastal Flora of Bunbury Coastal Flora of Esperance.
Drafting of illustrations: Colin Reeves, Nyunkia Tauss.

Photographs

Photos where not otherwise acknowledged - Cate Tauss.
Poster photographs:
Babs and Bert Wells Collection (DCLM)- *Pittosporum ligustrifolium, Clematis linearifolia, Thelymitra benthamiana, Kennedia prostrata, Banksia speciosa, Chamaescilla corymbosa.*
WA Herbarium Florabase collection (DCLM): Coralie Hortin (Albany Regional Herbarium) (*Scaevola crassifolia*), Eddie Wajon (*Lobelia tenuior*).
Gordon Roberts DCLM(*Diplolaena dampieri, Senecio lautus, Caladenia latifolia*).
Jiri Lochman (*Thysanotus patersonii, Agonis flexuosa*), Marie Lochman (*Calothamnus quadrifidus*), C. Garnett DCLM (*Pimelia ferruginea*), M. James DCLM (*Carpobrotus virescens*).

Quote from the novel "Land's Edge" by Tim Winton (1993) with permission of the publisher Pan Macmillan. Figure 8 is adapted from Searle, Semeniuk & Woods (1988) with kind permission of Dr Vic Semeniuk.

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Appendix 1: Glossary of Terms*

Aeolian (eolian). Pertaining to wind-driven processes.

Barrier dune. Shore parallel narrow dune complex forming a barrier to lagoon or estuary.

Blowout. Small to large trough shaped depression or scour formed by wind erosion.

B.P. Before present.

Chaots. A chaotic system of sand hills mostly conical in shape and of various sizes and relief and associated, mostly circular, depressions.

Cuspate beachridge plain. Low relief accretionary plain of parallel sand ridges. The coastal margin of the plain is cuspate and the plain is the result of coalescence of adjoining cusps.

Cuspate foreland or cusp. Isolated accretionary sedimentary body triangular in plan composed of a low relief to high relief dune complex.

Dampland. Seasonally waterlogged basin.

Aeolianite (eolianite). A cemented, wind-blown sediment. The cement is derived from calcium carbonate (originally as grains in the sand) which is dissolved by infiltrating rainwater and subsequently re-precipitated.

Floodplain. Seasonally inundated flat.

Fluvial. Pertaining to river or stream processes.

Foredune. Shoestring deposit of sand developed by aeolian (wind mediated) processes usually as a low ridge immediately landward of beach and seaward of the first high relief-medium relief dune complexes further landward.

Holocene. The youngest epoch of the Quaternary, from 10,000 yrs ago to the present (0.01 Ma-present).

Palusplain. Seasonally waterlogged flat.

Parabolic dunes. Sand dunes, u-shaped or spathulate in plan and convex in a downwind direction.

Perched dunes. Shoreward encroaching dune complex of parabolic dunes and sand sheets perched upon and transgressing the upland hinterland limestone terrain.

Pleistocene. An older epoch of the Quaternary from 164 million years to 10,000 years ago. (164-0.01 Ma).

Saprolite. A fine grained clay material formed by in situ deep weathering of bedrock particularly crystalline igneous and metamorphic rocks under humid conditions.

Sumpland. Seasonally inundated basin.

Tamala Limestone. A Pleistocene age aeolianite found throughout the coastal areas of the Perth Basin.

Tertiary. A period in the Cenozoic 65.0-1.64 Ma.

Proterozoic. The youngest epoch of the Pre-Cambrian, 2500-570 Ma.

*Quindalup Dune landform term definitions from Semeniuk *et al.,* (1989).
Wetland terms from Semeniuk & Semeniuk (1995).
Other geological terms from Kearey (2001).

APPENDIX 2. SWALE Project Flora Inventory

Information recorded below for each voucher specimen in the SWALE collection can be used to search for further information on taxonomy, ecology and biogeography on line at: www.calm.wa.gov.au/science/florabase.html
Western Australian Herbarium (2002). *Florabase. Information on the Western Australian flora.* Department of Conservation and Land Management.

Transect names and abbreviations:
G1 Greenough Dunes, Geraldton
G2 Drummonds Cove, Geraldton.
PK1 Port Kennedy, Perth
PK2 Becher Point, Perth.
B1 Dalyellup Beach Bunbury.
B2 Preston River Delta, Bunbury
E1 Cape Le Grand, Esperance.
E2 Hellfire Bay, Esperance.
op opportunistic collection in study area but not directly on transect.
* naturalized alien taxon
P CALM Priority Taxon
(Note: taxa without a database number in the list below have been identified in the field but have not to date been lodged as vouchers with the Herbarium).

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
AIZOACEAE									
Carpobrotus modestus	05623855							*	
Carpobrotus virescens	06144500								*
Carpobrotus virescens	06221149			*					
Carpobrotus virescens	05933137					*			
Carpobrotus virescens	06191932						*		
Carpobrotus virescens	05623863							*	
Carpobrotus virescens	06145426		*						
**Mesembryanthemum crystallinum*	05623820							*	
**Tetragonia decumbens*	05948851							*	
**Tetragonia decumbens*	06077323					*			
**Tetragonia decumbens*	06077374			*					
**Tetragonia decumbens*	06192009						*		
**Tetragonia decumbens*	06077374			*					
**Tetragonia decumbens*	05948851							*	
**Tetragonia decumbens*	06144314								*
**Tetragonia implexicoma*	05623723							*	
**Tetragonia implexicoma*	06144470								*
AMARANTHACEAE									
Ptilotus divaricatus var.*divaricatus*	05623715							*	
Ptilotus divaricatus var.*divaricatus*	06145701								*
Ptilotus villosiflorus	06145728								*
ANACARDIACEAE									
**Schinus terebinthifolia*	06197949				op				
ANTHERICACEAE									
Chamaescilla corymbosa var.*corymbosa*	06020771	*							
Lomandra mucronata	05995892	*							
Lomandra maritima	05933358					*			
Lomandra maritima	06196101							*	
Thysanotus patersonii	05948436	*							

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
Thysanotus patersonii	06197965			*					
Thysanotus dichotomus	06020690	*							
Thysanotus pauciflorus	06020720	*							
APOCYNACEAE									
Alyxia buxifolia	05948746							*	
Alyxia buxifolia	06221130			*					
Alyxia buxifolia	06192770					op			
APIACEAE									
Apium annuum	06021018	*							
Apium annuum	06058922		*						
Apium prostratum var. *prostratum*	06077382				*				
Centella asiatica	06191762					*			
Daucus glochidiatus	06019528					*			
Daucus glochidiatus	06197744			*					
Hydrocotyle alata	06020747	*							
Hydrocotyle pilifera var. *glabrata*	06255450			*					
Hydrocotyle tetragonocarpa	06019285					*			
Platysace compressa	06020917	*							
Platysace haplosciadia	06077161	*							
Trachymene pilosa	06197752			*					
Trachymene pilosa	06019358					*			
Xanthosia tasmanica	05948533	*							
ASPARAGACEAE									
**Asparagus asparagoides*	06077560				*				
**Asparagus asparagoides*	06191789						op		
ASPHODELIACEAE									
**Trachyandra divaricata*	06191940					*			
**Trachyandra divaricata*				*					
**Trachyandra divaricata*	05933315					*			
**Trachyandra divaricata*							*		
ASTERACEAE									
Angianthus cunninghamii	05623804							*	
Angianthus cunninghamii	06144306								*
**Arctotis stoechadifolia*	05933013						op		
**Arctotheca populifolia*							*		
**Arctotheca populifolia*						op			
Asteridea nivea	06020658	*							
Asteridea nivea	06020607		*						
**Conyza albida*	06077528				*				
Cotula cotuloides	06197825				*				
Gnephosis drummondii	06020798	*							
**Hypochaeris glabra*	05933234					*			
Leptorhynchos scaber	06019536					*			
Leucophyta brownii	06021085		*						
Olearia axillaris			*						
Olearia axillaris	06078044			*					
Olearia axillaris	06077706				*				
Olearia axillaris	06191800					*			
Olearia axillaris	06191959						*		
Olearia axillaris	06196071							*	
Olearia axillaris	06144322								*
Ozothamnus cordatus	06077471			*					
Ozothamnus cordatus	06191967						*		
* *Reichardia tingitana*	05623758							*	
* *Reichardia tingitana*	06145647								*
Rhodanthe citrina	05933153					*			

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
Senecio lautus subsp. *maritimus*	06077552			*					
Senecio lautus subsp. *maritimus*	06077676				*				
Senecio lautus subsp. *maritimus*	06019668					*			
Senecio lautus subsp. *maritimus*							*		
Senecio lautus subsp. *maritimus*	05948878							*	
Senecio lautus subsp. *maritimus*	06145450								*
Siloxeros filifolius	06020852	*							
**Sonchus oleraceus*	06020593		*						
**Sonchus oleraceus*	06221203			*					
**Sonchus oleraceus*	06077579				*				
**Sonchus oleraceus*	06019722					*			
**Sonchus oleraceus*	06019404						*		
**Sonchus oleraceus*								*	
**Sonchus oleraceus*	06145531								*
**Sonchus tenerrimus*								*	
**Sonchus tenerrimus*									*
Sonchus hydrophilus	06019374						*		
**Symphyotrichum subulatum*					*				
**Symphyotrichum subulatum*							*		
AVICENNIACEAE									
Avicennia marina var. *marina*	06077870				*				
BORYACEAE									
Borya nitida	06020755	*							
BRASSICACEAE									
**Cakile maritima*	06077293					*			
**Cakile maritima*	05623790							*	
**Cakile maritima*	06077811			*					
**Cakile maritima*	06020526		*						
**Cakile maritima*	06019498						*		
**Brassica tournefortii*	06077641			*					
**Brassica tournefortii*	06144497								*
**Heliophila pusilla*	06019692					*			
**Heliophila pusilla*	06077331					*			
CARYOPHYLLACEAE									
**Polycarpon tetraphyllum*	06145361	*							
**Polycarpon tetraphyllum*									*
CASUARINACEAE									
Allocasuarina trichodon	06020429	*							
CENTROLEPIDACEAE									
Centrolepis aristata	06020968	*							
Centrolepis polygyna	06020976	*							
Centrolepis strigosa subsp. *strigosa*	06020941	*							
CHENOPODIACEAE									
Atriplex amnicola	06144659							op	
Atriplex isatidea	06144330								*
**Atriplex prostrata*	06019390						*		
Halosarcia halocnemoides subsp. *halocnemoides*	06077617				*				
Halosarcia indica subsp. *bidens*	06196055							op	
Halosarcia indica subsp. *bidens*	06145213				*				
Rhagodia baccata subsp. *baccata*	06020534		*						
Rhagodia baccata subsp. *baccata*	06191916					*			
Rhagodia baccata subsp. *baccata*	06191976						*		
Rhagodia baccata subsp. *dioica*	06077463			*					
Rhagodia latifolia	05948959							*	
Rhagodia latifolia	05948886							*	

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G/2
Rhagodia latifolia	06145493								*
Rhagodia preissii subsp. *obovata*	05623782							*	
Rhagodia preissii subsp. *obovata*	06144489								*
Sarcocornia sp.	06077765				*				
Sarcocornia quinqueflora	06191983						*		
Sarcocornia quinqueflora	06144667							op	
Suaeda australis	06077757				*				
Suaeda australis	06019315						*		
Threlkeldia diffusa	06221181			*					
Threlkeldia diffusa	06019323						*		
Threlkeldia diffusa	06144454								*
Threlkeldia diffusa	05623677							*	
COLCHICACEAE									
Wurmbea cernua	05952654	*							
CONVOLVULACEAE									
Wilsonia humilis	06078001				*				
CRASSULACEAE									
Crassula colorata var. *colorata*	06020585		*						
Crassula colorata var. *colorata*	06197957			*					
Crassula colorata var. *colorata*	05933242					*			
**Crassula glomerata*	06019439						*		
**Crassula glomerata*	05933226					*			
CUSCUTACEAE									
**Cuscuta epithymum*	06019617					*			
**Cuscuta epithymum*	06192017						*		
CYPERACEAE									
Baumea juncea						*			
Carex preissii	05933285					*			
**Cyperus tenuiflorus*	05933080						*		
**Isolepis marginata*	05933161						*		
**Isolepis marginata*	06058906		*						
Isolepis nodosa	05995876		*						
Isolepis nodosa	06221238			*					
Isolepis nodosa		*							
Isolepis nodosa	06077625				*				
Isolepis nodosa	06191835					*			
Isolepis nodosa	06192041						*		
Isolepis nodosa	05623685							*	
Lepidosperma gladiatum	06077285					*			
Lepidosperma gladiatum	06192068						*		
Lepidosperma gladiatum	06197817			*					
Lepidosperma tuberculatum	06077196	*							
Lepidosperma aff. *costale*	06020704	*							
Lepidosperma squamatum	06019587					*			
Lepidosperma squamatum	06019331					*			
Mesomelaena stygia subsp. *stygia*	05996015	*							
Schoenus grandiflorus	06191843					*			
Schoenus subflavus subsp. "long leaves" KL Wilson 2865	05996074	*							
Schoenus sublaxus	06145302	*							
DASYPOGONACEAE									
Acanthocarpus preissii	05948711							*	
Acanthocarpus preissii	06191797					*			
Acanthocarpus preissii	06144543								*
Acanthocarpus preissii	06197779			*					
DILLENIACEAE									
Hibbertia cuneiformis	06077242					*			

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
Hibbertia cuneiformis	06192076						*		
Hibbertia cuneiformis	06077773			*					
Hibbertia cuneiformis	06077927				*				
Hibbertia cuneiformis	06077587				*				
Hibbertia aff. *rhadinopoda*	06020623	*							
Hibbertia ulicifolia	05948487	*							
DROSERACEAE									
Drosera glanduligera	06145248	*							
EPACRIDACEAE									
Andersonia sprengelioides	06020933	*							
Leucopogon obovatus	06020542		*						
Leucopogon obovatus	05952182		*						
Leucopogon parviflorus	06077269					*			
Leucopogon parviflorus	06077609			*					
Leucopogon rotundifolius **P3**	05952670	*							
EUPHORBIACEAE									
**Euphorbia paralias*	06020887	*							
**Euphorbia paralias*			*						
**Euphorbia paralias*	06077730			*					
**Euphorbia terracina*	06145620							*	
**Euphorbia terracina*	06145655								*
**Euphorbia peplus*	06144551								*
Euphorbia tannensis subsp. *eremophila*	05623839							*	
Phyllanthus calycinus	06077633			*					
Phyllanthus calycinus	06191851					*			
Phyllanthus calycinus	06196128							*	
Phyllanthus calycinus									*
Ricinocarpus tuberculatus	06077188		*						
FRANKENIACEAE									
Frankenia pauciflora					*				
GERANIACEAE									
* *Erodium cicutarium*	06077358					*			
* *Erodium cicutarium*	05933218					*			
* *Erodium cicutarium*	06255442			*					
Geranium solanderi	06197981			op					
Geranium retrorsum	06019307					*			
Pelargonium littorale subsp. *littorale*	05933188					*			
Pelargonium australe subsp. *drummondii*		*							
Pelargonium australe subsp. *drummondii*	06021026		op						
**Pelargonium capitatum*				*					
**Pelargonium capitatum*	06191878					*			
**Pelargonium capitatum*	06192092						*		
GOODENIACEAE									
Dampiera fasciculata	06020674	*							
Dampiera decurrens **P2**	06145272	op							
Goodenia quadrilocularis **P2**	06130887	op							
Lechenaultia formosa	05948509	*							
Scaevola crassifolia	05948797							*	
Scaevola crassifolia	06145639								*
Scaevola crassifolia	06077749			*					
Scaevola crassifolia	06021042		*						
Scaevola anchusifolia	06020488					op			
Scaevola anchusifolia	06197922			*					
Scaevola tomentosa	06196047							op	
Velleia trinervis	06020844	op							

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
HAEMODORACEAE									
Conostylis aculeata subsp. *preissii*	06077099			*					
Conostylis bealiana	05952719	*							
Conostylis pauciflora susp. *pauciflora* **P4**	05933307					*			
HALORAGACEAE									
Glischrocaryon aureum var. *angustifolium*	06020992	*							
IRIDACEAE									
**Romulea rosea*							*		
**Romulea rosea*	05933277					*			
**Romulea obscura*	06198538				*				
JUNCACEAE									
Juncus kraussii subsp. *australiensis*	06077900				*				
Juncus kraussii subsp. *australiensis*	05933064						*		
JUNCAGINACEAE									
Triglochin minutissima	06020577		*						
Triglochin mucronata	06019420						*		
Triglochin mucronata	06197833				*				
Triglochin trichophora	06077366					*			
Triglochin sp. B Flora of Australia (P.G.Wilson 4294)	06197973			*					
LAURACEAE									
Cassytha racemosa forma *pilosa*	05952190	*							
Cassytha racemosa forma *racemosa*	06077668			*					
Cassytha racemosa forma *racemosa*	06144632								*
Cassytha racemosa								*	
Cassytha racemosa	06020445	*							
Cassytha racemosa	06191886					*			
LOBELIACEAE									
Lobelia alata	06020836	*							
Lobelia alata	06021034		op						
Lobelia alata	06077935				*				
Lobelia alata							*		
Lobelia tenuior	05933048					*			
Lobelia tenuior	06197736			*					
LOGANIACEAE									
Logania litoralis	05948649							*	
Logania vaginalis	06019641					*			
MALVACEAE									
Lawrencia spicata	06077978				*				
MIMOSACEAE									
Acacia cochlearis	06019633					op			
Acacia cochlearis	06197809			*					
Acacia cyclops	06078036			op					
Acacia cyclops	05995868		op						
Acacia lasiocarpa var. *lasiocarpa*	06019625					*			
Acacia myrtifolia	06145329	*							
Acacia nigricans	05952174	*							
Acacia nigricans	06058892		*						
Acacia pinguiculosa subsp. *teretifolia*	05948479	*							
Acacia rostellifera	06196039							*	
Acacia rostellifera									*
Acacia saligna	06077889			op					
Acacia saligna	05933390					*			

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
MYOPORACEAE									
Eremophila glabra subsp. *albicans* ms	06077684			*					
Eremophila glabra subsp. *albicans* ms	06221211				*				
Eremophila glabra subsp. *albicans* ms	05948800							*	
Eremophila glabra subsp. *albicans* ms	05933293					*			
Myoporum caprarioides	06078133				*				
Myoporum insulare	05948827							*	
Myoporum insulare	06020437	*							
Myoporum insulare	06144624								*
MYRTACEAE									
Agonis flexuosa var. flexuosa	06077536			*					
Agonis aff. *linearifolia* "Cape Le Grand"	06020453	*							
Baeckea tetragona	06058914	op							
Calothamnus quadrifidus	06077145	*							
Calothamnus villosus	05995949	*							
Darwinia diosmoides	05995906		*						
Eucalyptus angulosa	05952557		op						
Eucalyptus ligulata subsp. *ligulata*	05995914		op						
Melaleuca cardiophylla								op	
Melaleuca depressa	05948762							*	
Melaleuca fulgens subsp. *fulgens*	06077153	*							
Melaleuca globifera	05996031	*							
Melaleuca globifera	06145434		*						
Melaleuca systena	06191908					*			
Melaleuca viminea subsp. *viminea*	05933021					op			
Thryptomene baeckeacea	06182356							op	
Verticordia vicinella **P4**	05948541	*							
NYCTAGINACEAE									
Commicarpus australis	05948738							*	
Commicarpus australis	06145698								*
ORCHIDACEAE									
Caladenia latifolia	06197728			*					
Diuris concinna	06020666	*							
Eriochilus dilatatus subsp. *dilatatus*	06020879	*							
Eriochilus scaber subsp. *scaber*	05952697	*							
Plumatichilus aff. *plumosus*	06221114	*							
Pterostylis brevisepala ms				*					
Oligochaetochilus vittatus	05952689	*							
Thelymitra benthamiana	06145345	*							
Thelymitra cucullata	06020909	*							
PAPILIONACEAE									
Bossiaea dentata	06145396		*						
Dillwynia pungens	06020682	*							
Eutaxia obovata	05948495	*							
Gompholobium tomentosum	05995930	*							
Gompholobium tomentosum	05933323					*			
Hardenbergia comptoniana	06077277					*			
Hardenbergia comptoniana	06192084						*		
Hardenbergia comptoniana	06077714			*					
Hovea trisperma	05996058	*							
Jacksonia furcellata	06077722			*					
Jacksonia furcellata	05933331					*			
Lotus australis	05948940							*	
**Medicago polymorpha*	06077102				*				
** Melilotus indicus*	06077501			*					
** Melilotus indicus*	06077986				*				

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
* *Melilotus indicus*	06019447						*		
Sphaerolobium pubescens **P3**	06130836	op							
**Trifolium* sp.	06077838				*				
**Trifolium hirtum*	06255418			*					
* *Trifolium campestre* var. *campestre*	06077919				*				
**Vicia sativa*	06078028				*				
PITTOSPORACEAE									
Sollya fusiformis	06020801	*							
Pittosporum ligustrifolium	06196098							*	
PLUMBAGINACEAE									
**Limonium sinuatum*	06144640							op	
POACEAE									
**Ammophila arenaria*	06020496		*						
Amphipogon strictus	06020631	*							
Amphipogon turbinatus	05995981	*							
Austrodanthonia occidentalis	06019412					*			
Austrodanthonia setacea	06020763	*							
Austrostipa elegantissima	05623650							*	
Austrostipa elegantissima	06145523								*
Austrostipa flavescens	05948665							*	
Austrostipa flavescens	06078052			*					
Austrostipa flavescens	05933382					*			
**Avena barbata*	06145337	*							
**Avena barbata*	06197841				*				
Bromus arenarius	06019366					*			
Bromus arenarius	06197787			*					
* *Bromus diandrus*	06145353	*							
* *Bromus diandrus*	06019595					*			
* *Bromus diandrus*	06078087			*					
* *Bromus diandrus*	06197914				*				
* *Bromus diandrus*	06145663								*
* *Bromus diandrus*	06145566							*	
**Bromus madritensis*	05948789							*	
**Ehrharta longiflora*	06197795			*					
**Ehrharta longiflora*	05948703							*	
**Ehrharta longiflora*	06078079				*				
**Ehrharta longiflora*	06145671								*
**Lagurus ovatus*	06078184			*					
**Lagurus ovatus*	05933374					*			
**Lagurus ovatus*							*		
**Lagurus ovatus*	06197892				*				
**Lolium rigidum*	06078109			*					
**Lolium multiflorum x perenne*	06078117				*				
**Lolium multiflorum x perenne*							*		
**Lolium multiflorum x perenne*	06019560					*			
**Lolium rigidum*	06078109			*					
**Lolium multiflorum x perenne*	06078117				*				
**Lolium multiflorum x perenne*	06019560					*			
**Lolium perenne*	06197868				*				
Neurachne alopecuroidea	06145280	*							
**Parapholis incurva*	06021069		op						
**Parapholis incurva*	06145299	*							
Poa poiformis	06078095			*					
Poa poiformis	06020178		*						
Poa poiformis	06197906				*				
Poa poiformis	06019552					*			

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
Poa poiformis	06019382					*			
**Polypogon maritimus*	06192114						*		
Spartochloa scirpoides	06145310	*							
Spinifex longifolius	06077862			*					
Spinifex longifolius	05623812							*	
Spinifex longifolius	05948835							*	
Spinifex longifolius	06144349								*
Sporobolus virginicus	06020569		*						
Sporobolus virginicus	05933072						*		
Sporobolus virginicus	06145590							*	
**Vulpia fasciculata*	06019293					*			
**Vulpia fasciculata*	06078060			*					
**Vulpia fasciculata*	06145418		*						
**Vulpia myuros* var. *myuros*	05933056					*			
**Vulpia myuros* var. *myuros*	05996023	*							
POLYGONACEAE									
Muehlenbeckia adpressa	06145736							*	
PORTULACACEAE									
Calandrinia brevipedata	05948460		*						
Calandrinia brevipedata	06077544			*					
Calandrinia brevipedata	06144519								*
Calandrinia granulifera	06020615		*						
Calandrinia sp. Becher 1. F. Littleton 66	06019269					*			
Calandrinia sp. Becher 2. F. Littleton 68	06019714					*			
Calandrinia sp. Drummonds A.A. Brooker 110	06145515								*
PRIMULACEAE									
**Anagallis arvensis* var. *arvensis*	05933145					*			
**Anagallis arvensis* var. *caerulea*	06221157			*					
**Anagallis arvensis* var. *caerulea*	05948819							*	
**Anagallis arvensis* var. *caerulea*	06020828	*							
**Anagallis arvensis* var. *caerulea*	05933196					*			
Samolus repens	06077943				*				
PROTEACEAE									
Banksia speciosa			*						
Dryandra armata var. *armata*	05952565	*							
Dryandra armata var. *ignicida*	06029493	*							
Grevillea concinna subsp. *concinna*	06145264	op							
Hakea varia	06077595				op				
Hakea clavata		*							
RANUNCULACEAE									
Clematis linearifolia	06019684					*			
Clematis linearifolia	06144608								*
RESTIONACEAE									
Desmocladus flexuosus	06077218	*							
Desmocladus flexuosus	06077226					*			
Hypolaena pubescens	06019544					*			
Lepyrodia monoica	05952573	*							
Lepyrodia fortunata ms **P2**	06130798	op							
RHAMNACEAE									
Spyridium globulosum	06077307					*			
Spyridium globulosum	06077692			*					
Cryptandra mutila	06077234					*			
Trymalium ledifolium						*			

Voucher Specimen	PERTH Database No	E1	E2	B1	B2	PK1	PK2	G1	G2
RUBIACEAE									
**Galium aparine*	06197701			*					
Opercularia spermacocea	05948517	*							
Opercularia spermacocea	06196063							*	
Opercularia vaginata	06019463					*			
Opercularia vaginata	06197930			*					
RUTACEAE									
Diplolaena dampieri	06077854			*					
Diplolaena leemaniana	05948630							*	
SANTALACEAE									
Exocarpus sparteus	05948754							*	
Exocarpus sparteus	06191924					*			
Exocarpus sparteus	06077803				*				
Exocarpus sparteus	06078125			*					
SAPINDACEAE									
Dodonaea ceratocarpa	06077129	*							
STACKHOUSIACEAE									
Stackhousia monogyna	06019706					op			
STYLIDIACEAE									
Levenhookia pusilla	05995957	*							
Stylidium piliferum	05996007	*							
Stylidium breviscapum	06020739	*							
Stylidium inundatum	06020860	*							
Stylidium mimeticum	06020895	*							
Stylidium rupestre	06020984	*							
SCROPHULARIACEAE									
**Bartsia trixago*	05933110					op			
**Dischisma arenarium*	06077994			*					
**Dischisma arenarium*	06019501					*			
**Dischisma arenarium*									*
**Parentucellia latifolia*	06019455					*			
**Parentucellia viscosa*						*			
SOLANACEAE									
Anthocercis littorea	05933005					op			
Anthocercis littorea	06221076			*					
Anthocercis viscosa subsp. *caudata*	05952662	*							
**Lycium ferocissimum*	06195938							*	
**Lycium ferocissimum*	06144594								*
Solanum oldfieldii	06196020							op	
SURANIACEAE									
Stylobasium spathulatum	05948843							*	
THYMELIACEAE									
Pimelia gilgiana	06196012							op	
Pimelia ferruginea	06020518		*						
Pimelia microcephala subsp. *microcephala.*	05948657							*	
URTICACEAE									
Parietaria debilis	06077897			*					
Parietaria debilis								*	
Parietaria debilis	06144527								*
ZYGOPHYLLACEAE									
Zygophyllum fruticulosum	06255426			*					
Zygophyllum fruticulosum	05948908							*	
Zygophyllum fruticulosum	06144462								*