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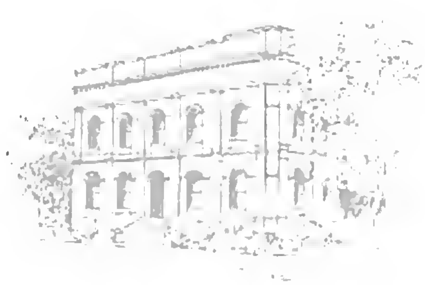

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OF THE

ROYAL SOCIETY OF VICTORIA

INCLUDING

TRANSACTIONS OF MEETINGS

Volume 114

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PROCEEDINGS

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PEER REVIEWED PAPERS

VASCULAR FLORA AND VERTEBRATE FAUNA OF THE DOOKIE BUSHLAND RESERVE, VICTORIA

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HAMILTON, S.D., HUNTER, D.K., COSTELLO, K., O'DWYER, C. & JONES, S., 2002:09:30. Flora and vertebrate fauna of the Dookie Bushland Reserve, Victoria. *Proceedings of the Royal Society of Victoria* 114(1): 1-20. ISSN 0035-9211.

The Dookie Bushland Reserve is a large grassy woodland remnant in northern Victoria that maintains considerable areas of high quality habitat. Despite significant numbers of introduced species of both plants and animals, particularly on the periphery of the area, it is of conservation significance because of the rarity and quality of its community associations, and the presence of many rare species on a regional, state and national scale. Management planning since 1991 has set the objectives for conservation management, and the area continues to be managed successfully in accordance with these guidelines.

Key words: grassy woodland, flora, fauna, northern Victoria

MORE THAN 90% of the remaining grassy woodlands in the Riverina bioregion in northern Victoria has been substantially modified due to clearing, grazing by stock and weed invasion: much of the remaining 10 % of the original grassy woodlands have been modified by direct and indirect impacts (Department of Conservation and Environment 1992; Davidson 1997; Department of Natural Resources and Environment 1998), and many areas continue to be utilised as an agricultural resource. The Dookie region, within the Goulburn-Broken catchment, is typically representative of this overall trend, with generally only small remnants of the original vegetation still present, with many of those remaining areas impacted and reduced in habitat quality (Land Conservation Council 1983; Davidson 1997; Hamilton 1999), however, there is one large area, the Dookie Bushland Reserve, hereafter referred to as the DBR.

The DBR is a 270 ha grassy woodland remnant found centrally on the Dookie College property, now a campus of the University of Melbourne, in northern Victoria. According to Ecological Vegetation Class (EVC) mapping undertaken by the DNRE, the majority of this area was grassy woodland prior to European settlement (Berwick 1999), and thus the DBR represents the last substantial area of this once common vegetation type within the Dookie region.

This report details the results of 9 years of both formal and informal information gathering on the vascular flora and vertebrate fauna of the DBR.

INTRODUCTION

Location

The DBR is an area of approximately 270 ha found approximately 8 km south of the township of Dookie in the centre of the Dookie College campus of the University of Melbourne (Dookie 8025 1:100,000 AMG 382 5970), some 35 km east of Shepparton and 35 km west of Benalla.

Land Status

The DBR is under the control of the University of Melbourne Limited (private land). The Campus was classified as reserved Crown Land for the purposes of agricultural education (Land Conservation Council 1983) until 1998, and was the responsibility of the now Department of Natural Resources and Environment. A conservation covenant is currently being sought for the area.

Climate

The climate of the DBR (based on the permanent weather station at Dookie College) is typically Mediterranean, with an average annual rainfall of 556 mm and 99 rain days, mostly in the winter months.

Approximately 330 mm of this rainfall falls in the period May to October, and there are on average 22 frosts annually, usually between April and September. Evaporation exceeds rainfall from September to April, and direct sunlight hours varies from 12 in the summer, to less than 7 in the winter. The maximum mean monthly temperature is 21.6 °C in February, and the minimum mean monthly temperature is 3.7 °C in July. Summer temperatures can exceed 41°C [Victorian College of Agriculture and Horticulture (VCAH) Dookie 1992].

Land Information

The elevation of the DBR ranges from 165 to 237 m above sea level, and contains thefull range of aspects. Flat, ridge areas occur at elevations greater than 200 m above sea level, and some areas of gentle slopes to flat topography occur at elevations of 165 to 180 m.

Two distinct soil types within the DBR area have been designated since 1949, known locally as Gowangardie Loam and Caniambo Loam by Downes (Downes 1949). The separation into two distinct soil types has been confirmed by recent survey, with these soils more appropriately referred to as a tenosol and brown chromosol (Isbell 1993), or as hard-setting alkaline brown duplex soils (Northcote 1983).

Land Management History

Considerably more detail on the land management history can be found in the summaries Hamilton (1993 & 1999), and reference should be made to these documents if further information on any aspect of the DBR is required.

In 1875, following a series of leaseholds over the present College area, the then Secretary for Agriculture requested that the undeveloped area now called Dookie College be reserved for the purposes of establishing an Experimental farm (Aldridge 1986). Much of the property was cleared by 1930, however, the DBR has had a relatively recent land use history, with no agricultural impact until the mid-1960s, when peripheral areas were incorporated into larger paddocks and utilised for domestic stock grazing (mostly sheep) and limited cropping, with significant areas fertilised aerially with superphosphate. A central area with little or no agricultural impact, referred to as the Timber Reserve, remained until 1992. Some areas were utilised for timber harvesting, and small areas for gravel extraction (rock for road surfacing, mostly during the 1960s and 1970s). Peripheral areas were re-combined with the minimally disturbed central area in 1992 to form the DBR. There is no record of wild fire within the DBR since European settlement.

The DBR area was historically not regarded as either an educational resource or an area of conservation value. Agriculturally, it was seen as mostly marginal and unprofitable, and was infrequently utilised as a source of timber and gravel, and was used only in extreme circumstances for grazing. It is the agriculturally "unproductive" view of the DBR area by management that more than likely saved it from clearing.

A management plan was written in 1993 and revised in 1999 (Hamilton 1993 & 1999), which has formed the basis of conservation management since 1992. At this time, domestic stock grazing was excluded, and the population of more than 700 Eastern Grey Kangaroos (*Macropus giganteus*) reduced to the estimated carrying capacity of 100. Domestic stock exclusion and kangaroo populations have been successfully managed to the present day.

The DBR has since been recognised as being of national significance for the quality and extent of now rare vegetation communities, and the presence of many species of regionally and state-wide threatened flora and fauna. The DBR is currently listed as an indicative site on the Register of the National Estate (Australian Heritage Commission).

METHODS

Vascular flora

The vascular flora of the DBR has been noted and recorded by many people using a variety of methods since spring 1991 to the present day. While the DBR has some 40 quadrats for long-term floristic monitoring that were established in 1991, the majority of the inventory has been accumulated from a mixture of casual observation and active searches, since 1991, mostly in spring-summer. Quadrats have also been established for the purposes of mapping by the DNRE (and its predecessors) at different times (e.g. Muir *et al.* 1996 and Clark 1996).

Identification of specimens has been undertaken through a mixture of the use of the works of Willis (1970 & 1972), Costermans (1994), and predominantly, Walsh and Entwistle (1994 & 1996).

Unidentified specimens were presented to the National Herbarium in South Yarra for confirmation of identification.

Lists of the identified flora present have progressively been compiled, with the nomenclature based variously on Hnatiuk (1990), Calder *et al.* (1994), Department of Conservation and Natural Resources (1994), Lunt *et al.* (1998) and Marriott & Marriott (1998).

Vertebrate fauna

As with the vascular flora, the vertebrate fauna of the DBR has been noted and recorded by several people using a variety of methods since Spring 1991 to the present day.

Mammals. An inventory of mammals was compiled through a variety of methods.

Active searching for mammals (or scats, burrows, diggings and other indirect indices) was conducted on multiple occasions annually for a period of at least 30 minutes. Scats were identified according to the guide by Triggs (1996).

Nocturnal spotlight searches (as transects) were conducted on at least 50 occasions over a variety of times and seasons, with a duration of at least 30 minutes per site per occasion. Transects were conducted by foot from both defined tracks and across sites.

Baited hair tubes were employed on an annual basis since 1996. The hair tubes used were a new plastic resin design provided by Faunatech® (hairfunnels; Ross Meggs personal communication). Hair samples obtained were identified according to Brunner & Coman (1974). A motion-sensitive camera (Faunatech®) has been employed for at least 30 nights at sites where cryptic fauna, such as the Brush-tailed Phascogale (*Phascogale tapoatafa*) were suspected of being present.

Birds. Data on the presence of birds was collected from at least 20 formal visits, of 20 minutes or more duration, since 1991, as well as information recorded during more casual observations. Visits have been made across all seasons and mostly either during early morning or late afternoon when species were most likely to be active. Formal censes were conducted by the gathering of visual and aural evidence of species across the whole site. Nocturnal transects have been conducted (usually simultaneously with surveys for mammals) to record species by sight or call.

Reptiles and amphibians. The DBR has been subjected to bi-annual active searches for reptiles and amphibians, for a duration of at least 20 minutes per visit, since 1994. Specimens of reptiles and amphibians are collected by hand when found and identified, and micro-habitats (logs, rocks, etc.) are also inspected for sheltering or cryptic species.

Frog calls were noted, and nocturnal transects by foot conducted to record nocturnal species, with a concentration on areas of prime habitat, such as dams. As many as possible of these transects were conducted on rainy nights when there was an increased likelihood of amphibian activity.

A large-scale survey involving pitfall trapping for herpetofauna in the Dookie Bushland Reserve by Hunter (1997) contributed significantly to the faunal inventory for this site.

Taxonomy. Lists of fauna present at each site were compiled, with the nomenclature based variously on the compilations of Hero *et al.* (1991), Menkhorst (1995), Cogger (1996) and Simpson and Day (1998).

RESULTS AND DISCUSSION

Vegetation structure and general ecology

The vegetation of the DBR is classified as Box-Ironbark Woodland and Low Rises Grassy Woodland (Ecological Vegetation Class, Berwick 1999; Muir *et al.* 1995) and the broad distribution of these vegetation types tends to follow soil type and topography (*E. albens* grassy woodland vegetation on the higher points, surrounded by *E. microcarpa* grassy woodland on the slopes).

The DBR is generally dominated by a box eucalypt canopy with projective foliage cover (pfc) between 25-40 %, and ranging between 7-25 m in height, the maximum height (and pfc) being strongly related to aspect, elevation and the depth of A horizon. The understorey is generally composed of two sparsely distributed shrub layers of *Acacia* spp. and/or *Cassinia arcuata* overlaying ground layers dominated by tussock forming grass species (particularly *Chionchloa pallida*), with a variety of herbs and forbs found between tussocks.

The lesser disturbed areas within the DBR are typically grassy woodlands with sparsely scattered shrubs, conforming well with descriptions of State I of a typical semi-arid eastern Australian woodland, according to the state-and-transition model outlined by Westoby *et al.* (1989). State I as described would be highly stable, and would only be transformed to State II (grassland with many shrub seedlings) or State III (dense shrub cover with little grass) by two or more very good rainfall years to stimulate shrub regeneration (Westoby *et al.* 1989). Examination of the rainfall records indicates that only one year in recent history (1974) produced rainfall significantly above average (VCAH Dookie 1992). It is unlikely that the DBR area has transformed from State III to II or I due to the exclusion/absence of fire, however, it is possible that grass competition has led to the reversion of a short-term State II after one year of good rainfall in 1974, back to State I. In summary, it is likely that the DBR has existed as a grassy woodland with sparsely scattered shrubs when remaining undisturbed by agricultural impact, for much of the recent past.

Therefore, while the lesser disturbed sites in the DBR are thought to retain a similar overall structure compared to pre-European times, there is no doubt that the current species composition in the understorey, particularly at ground level, is significantly different to the pre-European settlement composition and abundance. While no specific information is available, sufficient anecdotal evidence suggests that while all current indigenous understorey species were likely present, e.g. non-tussock-forming grasses, some were much less dominant, and others much more dominant, than they are now. The best example of this are *Themeda australis* (Kangaroo Grass), which is known to have once been the dominant tussock-forming indigenous species. Within the DBR, *Themeda australis* is still found in a very low abundance (not within the established quadrats however), but as a species that has a frequent requirement for fire to retain its abundance and dominance (Lunt 1990). With the deliberate exclusion of fire from the DBR and many of the other remaining minimally disturbed areas since European settlement, there has been a significant decline in the species. It is likely that other understorey species in the DBR have been similarly affected by this exclusion. Conversely, *Chionchloa pallida* (Red-anthered Wallaby Grass), a tussock-forming species, was thought to have been a common but not dominant species throughout this vegetation, but now is the most dominant grass species. Recent studies have indicated that this species (and others) has likely been promoted in abundance by agricultural activity, particularly low levels of stock grazing, while clearly other species have been reduced in abundance (Hamilton 2001).

In addition, at a number of times in the European history of the DBR, Eastern Grey Kangaroos have exerted a major endogenous grazing impact on the vegetation due to high population levels. The scale and extent of such endogenous grazing impact would have likely been very infrequent prior to European settlement. These periodic high population levels are likely to be a direct consequence of high vegetation clearance rates and increasing fragmentation, resulting in the increased pressure for shelter by the species on any remaining native vegetation. Such factors suggest that the DBR is an ecosystem already altered by significant periodic endogenous and exogenous grazing, and with a major endogenous disturbance agent (fire) excluded.

Current flora

There have been 164 species of indigenous plants identified as occurring in the DBR, and 81 species of introduced plants (Appendix 1). Most of the introduced species occur in a relatively low abundance, and most are more abundant around the periphery of the DBR (surrounding land utilised for cropping/grazing), or in areas previously utilised for agriculture.

The White Box (*Eucalyptus albeus*) woodland occupies areas of shallow, stony uniform textured brown soils. White Box is the dominant overstorey species. Other overstorey species, such as Yellow Box (*Eucalyptus melliodora*), Lightwood (*Acacia implexa*), Cherry Ballart (*Exocarpus* sp.), Drooping She-oak (*Allocasuarina verticillata*) appear to have once been widespread in this soil type, although their distribution throughout the DBR is now clumped, probably because of grazing and selective clearing pressures. Common understorey species currently include Golden Wattle (*Acacia pycnantha*), Chinese Scrub (*Cassinia arctuata*), Gorse Bitter-pea (*Daviesia ulicifolia*) and Slender Rice-flower (*Pimelia linifolia*).

The DBR contains a significant array of weeds, however those that cause the greatest management concern are Horehound (*Marrubium vulgare*), Spear Thistle (*Cirsium vulgare*), Paterson's Curse (*Echium plantigineum*) and European Olive (*Olea europeae*), the abundance of the latter being an artefact of the extensive olive groves maintained at the College until the 1970s. The distribution/extent of all of these species is being slowly reduced by continued management effort.

The Grey Box (*Eucalyptus microcarpa*) woodland occupies areas of brown duplex soils. Grey Box is the dominant overstorey species. Species such as Drooping She-oak were likely to have been common, while other species such as White Box and Yellow Box may have occurred irregularly.

There are 9 endangered, rare, depleted or vulnerable species (Gullan *et al.* 1990) within the precincts of the DBR (Appendix 1), including the Dookie Daisy (*Brachyscome gracilis*), Slender Tick-trefoil (*Desmodium varians*), Mallee Pellitory (*Parietaria cardiostegia*), Australia Piert (*Aphanes australiana*), Red Bird's-foot Trefoil (*Lotus cruentus*), and Small Psoralea (*Cullen australis*).

Fauna

There have been 116 species of indigenous birds, 5 species of amphibians, 14 species of native reptiles, and 26 native species of mammals identified as occurring in the DBR or its environs (Appendix 2). There have been 4 species of introduced mammals, and 5 species of introduced birds identified as occurring in the DBR or its environs (Appendix 2). Of the native species, 13 have been classified as having conservation status, a few of which have not been sighted in the DBR for a number of years.

The Squirrel Glider (*Petaurus norfolcensis*), Barking Owl (*Ninox connivens*), Brush-tailed Phascogale (*Phascogale tapoatafa*) and the Proximus Blind Snake (*Ramphotyhlops proximus*) have all been sighted in the DBR or its environs, and are considered to be rare and restricted in Victoria.

The Bush Thick-knee (*Burhinus grallarius*), Swift Parrot (*Lathamus discolor*), Grey-crowned Babbler (*Pomatostomus temporalis*), Square-tailed Kite (*Lophoictinia isura*), Bandy Bandy (*Vermicella annulata*), Regent Parrot (*Polytelis anthopeplus*) and Turquoise Parrot (*Neophema pulchella*) have all been sighted in the DBR, and are all classified as vulnerable in Victoria (Department of Conservation and Environment 1991). The Regent Parrot observation was likely a "one-off" sighting during the height of a drought. The sighting of the Bandy Bandy was an opportunistic sighting of one individual during a spotlighting tour in 1997 when observing Squirrel and Sugar Gliders.

The Regent Honeyeater (*Xanthomyza phrygia*) has not been seen in the DBR since 1964, and is currently considered endangered in Australia, and the Grey-crowned Babbler has not been observed since 1991. In recent times, Regent Honeyeaters have been sighted in Box-Ironbark woodlands north-east of Benalla (some 45 km east of the DBR), and Grey-crowned Babblers are resident at sites within 15 km north and south of the DBR. However, in all directions around the DBR, there has been significant clearing, with no continuous vegetation connecting to any of these regions for more than 30 years, and the lack of presence of both species is most likely due to this long-term loss of connectivity of the DBR to other bushland areas within the region

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APPENDICES

The Appendices contain lists of the flora and fauna of the DBR based on observations up to the end of 1999.

Flora lists contain a number of items of information: the scientific and common names of each species listed, according to the most recent taxonomic nomenclature (as listed in the Appendix captions), and the conservation status (if any) of species listed (Gullan *et al.* 1990). The scientific names of introduced plants are indicated with an asterisk. Total numbers are provided for vascular plant species, indigenous and introduced species, and vulnerable, rare or threatened (VROT) species.

Fauna lists contain: the scientific and common names of each species listed, according to the most recent taxonomic nomenclature (as listed in the Appendix captions), and the conservation status (if any) of species listed. The scientific names of introduced fauna are indicated with an asterisk. Total species numbers are provided for each faunal group, introduced species, and vulnerable, rare or threatened (VROT) species.

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Species name	Common name	Conservation status
Family Adiantaceae		
Cheilanthes austrotenuifolia	Green Rock Fern	
Cheilanthes distans	Bristly Cloak Fern	
Cheilanthes sieberi	Narrow Rock Fern	
Family Amaranthaceae		
Alternanthera denticulata	Lesser Joyweed	
Ptilotus spathulatus	Pussy-tails	
Family Anacardiaceae		
*Schinus molle**	Pepper Tree	
Family Apiaceae		
Daucus glochidiatus	Austral Carrot	
Hydrocotyle callicarpa	Small Pennywort	
Hydrocotyle foveolata	Yellow Pennywort	
Hydrocotyle laxiflora	Stinking Pennywort	
Family Asteraceae		
Actinobole uliginosum	Flannel Cudweed	
*Arctotheca calendula**	Cape Weed	
Brachyscome gracilis	Dookie Daisy	R v
Brachyscome perpusilla	Rayless Daisy	
Bracteantha viscosum	Shiny Everlasting	
*Carduus pycnocephalus**	Slender Thistle	
Cassinia arcuata	Drooping Cassinia	
*Centaurea solstitialis**	St. Barnaby's Thistle	
Chrysocephalum apiculatum	Common Everlasting	
*Cirsium vulgare**	Spear Thistle	
Cotula australis	Common Cotula	
Cymbonotus preissianus	Austral Bear's-ears	
Euchiton involucratus	Cudweed	
Gnaphalium indutum	Tiny Cudweed	
*Helminthotheca echioides**	Ox-tongue	
*Hypochoeris glabra**	Smooth Cat's Ear	
*Hypochoeris radicata**	Cat's Ear	
Isoetopsis graminifolia	Grass Cushion	
*Lactuca serriola**	Prickly Lettuce	
Lagenifera huegelii	Coarse Lagenifera	
Microseris aff. *lanceolata*	Foothills Yam-daisy	
Millotia tenuifolia	Soft Millotia	
Senecio hispidulis var. *dissectus*	Rough Fireweed	
Senecio quadridentatus	Cotton Fireweed	
Senecio tenuiflorus	Narrow Groundsel	
Solenogyne dominii	Solenogyne	
*Soliva sessilis**	Jo Jo	
*Sonchus asper**	Rough Sow-thistle	
*Sonchus oleraceus**	Sow-thistle	
Stuartina muelleri	Spoon Cudweed	
Triptilodiscus pygmaeus	Common Sunray	
Vittadinia gracilis	Woolly New Holland Daisy	
*Xanthium spinosum**	Bathurst Burr	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Boraginaceae		
Cynoglossum suaveolens	Sweet Hound's-tongue	
*Echium plantigineum**	Paterson's Curse	
Family Brassicaceae		
*Lepidium africanum**	Common Pepper-cress	
*Sisymbrium officinale**	Hedge Mustard	
Family Callitrichaceae		
*Callitriche hamulata**	Water Star-wort	
Family Campanulaceae		
Wahlenbergia communis	Tufted Bluebell	
Wahlenbergia luteola	Yellowish Bluebell	
Wahlenbergia multicaulis	Many-stemmed Bluebell	
Wahlenbergia stricta	Tall Bluebell	
Family Caryophyllaceae		
*Cerastium glomeratum**	Common Mouse-ear Chickweed	
*Moenchia erecta**	Erect Chickweed	
*Petrorhagia velutina**	Hairy Pink	
*Stellaria media**	Chickweed	
Family Casuarinaceae		
Allocasuarina verticillata	Drooping Sheoke	
Family Chenopodiaceae		
Einadia hastata	Saloop Saltbush	
Einadia nutans	Nodding Saltbush	
Rhagodia spp.	Saltbush	
Family Convolvulaceae		
Convolvulus erubescens	Pink Bindweed	
Family Crassulaceae		
*Crassula decumbens**	Spreading Crassula	
Crassula peduncularis	Purple Crassula	
Crassula sieberiana	Australian Stonecrop	
Family Cucurbitaceae		
*Cucumis myriocarpus**	Paddy Melon	
Family Cupressaceae		
Callitris glaucophylla	White Cypress Pine	d
Family Cyperaceae		
Carex inversa	Common Sedge	
*Cyperus eragrostis**	Drain Flat-sedge	
*Cyperus tenellus**	Tiny Flat-sedge	
Elaeocharis acuta	Common Spike-rush	
Isolepis hookeriana	Grassy Club-sedge	
*Isolepis hystrix**	Awned Club-sedge	
Isolepis marginata	Little Club-sedge	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Cyperaceae (coninued)		
Isolepis victoriensis	Victorian Club-sedge	
Lepidosperma laterale	Variable Sword-sedge	
Schoenus apogon	Common Bog-rush	
Family Dilleniaceae		
Hibbertia obtusifolia	Grey Guinea-flower	
Hibbertia sericea	Silky Guinea-flower	
Family Droseraceae		
Drosera glanduligera	Scarlet Sundew	
Drosera macrantha	Sundew	
Drosera peltata var. *auriculata*	Tall Sundew	
Drosera peltata var. *peltata*	Pale Sundew	
Family Epacridaceae		
Brachyloma daphnoides	Daphne Heath	
Melichrus urceolatus	Urn Heath	
Family Euphorbiaceae		
Chamaesyce drummondii	Flat Spurge	
Family Fabaceae		
Cullen parvum	Small Psoralea	E e
Daviesia leptophylla	Narrow-leaf Bitter-pea	
Daviesia ulicifolia	Gorse Bitter-pea	
Desmodium varians	Slender Tick-trefoil	r
Dillwynia cinerascens	Grey Parrot-pea	
Dillwynia sericea	Showy Parrot-pea	
Eutaxia microphylla	Common Eutaxia	
Glycine tabacina	Variable Glycine	
Hardenbergia violacea	Purple Coral-pea	
Hovea linearis	Common Hovea	
Indigofera australis	Austral Indigo	
Kennedia prostrata	Running Postman	
Lotus australis	Austral Trefoil	
*Medicago polymorpha**	Burr Medic	
Swainsona murrayana	Murray Swainson-pea	V e
Templetonia stenophylla	Leafy Templetonia	d
*Trifolium angustifolium**	Narrow-leaf Clover	
*Trifolium arvense**	Hare's Foot Clover	
*Trifolium campestre**	Hop Clover	
*Trifolium glomeratum**	Cluster Clover	
*Trifolium repens**	White Clover	
*Trifolium scabrum**	Rough Clover	
*Trifolium subterraneum**	Subterraneum Clover	
*Trifolium tomentosum**	Woolly Clover	
Vicia sativa ssp. *sativa**	Common Vetch	
Family Fumariaceae		
*Fumaria bastardii**	Bastards Fumitory	
*Fumaria muralis**	Wall Fumitory	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Gentianaceae		
*Centarrium erythraea**	Common Centaury	
*Cicendia quadrangularis**	Square Cicendia	
Sebaea ovata	Yellow Sebaea	
Family Geraniaceae		
*Erodium botrys**	Big Heron's Bill	
Geranium retrorsum	Grassland Crane's-Bill	
Family Goodeniaceae		
Goodenia pinnatifida	Cut-leaf Goodenia	
Family Haloragaceae		
Gonocarpus elatus	Tall Raspwort	
Gonocarpus tetragynus	Common Raspwort	
Family Hypericaceae		
Hypericum gramineum	Small St. John's Wort	
Family Hypoxidaceae		
Hypoxis glabella var. *glabbella*	Tiny Star	
Family Iridaceae		
*Romulea minutiflora**	Small Onion-grass	
*Romulea rosea**	Common Onion-grass	
Family Juncaceae		
Juncus amabilis	Hollow Rush	
Juncus australis	Austral Rush	
Juncus bufonis	Toad Rush	
*Juncus capitatus**	Dwarf Rush	
Juncus homalocaulis	Wiry Rush	
Juncus pauciflorus	Loose-flower Rush	
Juncus usitatus	Rush	
Family Liliaceae		
Arthropodium minus	Small Vanilla-lily	
Arthropodium strictum	Chocolate-lily	
Arthropodium sp. aff. *strictum*	Vanilla Lily	
Bulbine bulbosa	Yellow Bulbine-lily	
Burchardia umbellata	Milkmaids	
Dianella longifolia var. *longifolia*	Pale Flax-lily	
Dianella revoluta	Black-anther Flax-lily	
Thysanotus patersonii	Twining Fringe-lily	
Tricoryne elatior	Yellow Rush-lily	
Wurmbea dioica ssp. *dioica*	Common Early Nancy	
Family Lamiaceae		
*Lamium amplexicaule**	Henbit Dead-nettle	
*Marrubium vulgare**	Horehound	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Linaceae		
Linum marginale	Native Flax	
Family Loranthaceae		
Amyema miquelii	Box Mistletoe	
Family Lythraceae		
Lythrum hyssopifolia	Small Loosestrife	
Family Malvaceae		
*Malva parviflora**	Small-flowered Mallow	
Sida corrugata	Variable Sida	
Family Mimosaceae		
Acacia acinacea	Gold-dust Wattle	
Acacia dealbata	Silver Wattle	
Acacia genistifolia	Spreading Wattle	
Acacia implexa	Lightwood	
Acacia pycnantha	Golden Wattle	
Acacia verniciflua	Varnish Wattle	
Family Myrtaceae		
Eucalyptus albens	White Box	
Eucalyptus melliodora	Yellow Box	
Eucalyptus microcarpa	Grey Box	
Family Oleaceae		
*Olea europaea**	Olive	
Family Orchidaceae		
Caladenia carnea	Pink Fingers Caladenia	
Caladenia gracilis	Musky Caladenia	
Calochilus robertsonii	Purplish Beard-orchid	
Cyrtostylis reniformis	Mosquito Orchid	
Diuris pardina	Leopard Orchid	
Diuris sulphurea	Tiger Orchid	
Genoplesium sp.	Midge Orchid	
Glossodia major	Wax-lip Orchid	
Microtis parviflora	Slender Onion-orchid	
Microtis uniflora	Common Onion-orchid	
Pterostylis nutans	Nodding Greenhood	
Pterostylis longifolia	Tall Greenhood	
Thelymitra ixioides	Dotted Sun-orchid	
Thelymitra pauciflora	Slender Sun-orchid	
Family Orobanchaceae		
Orobanche cernua ssp. *australiana*	Australian Broomrape	
Family Oxalidaceae		
*Salvia verbenaca**	Wild Sage	
*Oxalis corniculata**	Creeping Wood-sorrel	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Oxalidaceae continued		
Oxalis exilis	Shady Wood-sorrel	
*Oxalis pes-caprae**	Soursob	
Family Poaceae		
*Aira caryophyllea**	Silvery Hair-grass	
*Aira elegans**	Elegant Hair-grass	
Amphibromus neesii	Southern Swamp Wallaby-grass	
Aristida behriana	Brush Wire-grass	
Austrodanthonia caespitosa	Common Wallaby-grass	
Austrodanthonia duttoniana	Brown-back Wallaby-grass	
Austrodanthonia eriantha	Hill Wallaby-grass	
Austrodanthonia racemosa	Stiped Wallaby-grass	
Austrodanthonia setacea	Bristly Wallaby-grass	
Austrostipa densiflora	Dense Spear-grass	
Austrostipa elegantissima	Feather Spear-grass	
Austrostipa nodosa	Knotty Spear-grass	
Austrostipa scabra ssp. *falcata*	Rough Spear-grass	
*Avena barbata**	Bearded Oat	
*Avena fatua**	Wild Oat	
*Briza maxima**	Large Quaking-grass	
*Briza minor**	Lesser Quaking-grass	
*Bromus diandrus**	Great Brome	
*Bromus hordeaceus**	Soft Brome	
*Bromus rubens**	Red Brome	
Chionchloa pallida	Silvertop Wallaby Grass	
*Critesion murinum**	Barley-grass	
*Cynodon dactylon**	Couch	
*Cynosurus echinatus**	Rough Dog's-tail	
*Ehrharta longiflora**	Annual Veldt Grass	
Elymus scabrus	Common Wheat Grass	
*Elytrigia repens**	English Couch	
*Lolium rigidum**	Wimmera Rye-grass	
Panicum decompositum	Hairy Panic	r
*Phalaris aquatica**	Toowoomba Canary Grass	
*Poa annua**	Annual Meadow-grass	
Poa morrisii	Soft Tussock-grass	
*Vulpia myuros**	Rat's-tail Fescue	
Family Pittosporaceae		
Bursaria spinosa	Sweet Bursaria	
Family Polygonaceae		
Rumex brownii	Slender Dock	
*Rumex crispus**	Curled Dock	
Family Portulacaceae		
Calandrinia calyptrata	Pink Purslane	
Family Primulaceae		
*Anagallis arvensis**	Pimpernel	

Appendix 1 continued next page

Species name	Common name	Conservation status
Family Ranunculaceae		
Ranunculus pachycarpus	Thick-fruit Buttercup	
R. sessiliflorus var. *sessiliflorus*	Annual Buttercup	
Family Rhamnaceae		
Cryptandra amara var. *longiflora*	Bitter Cryptandra	r
Family Rosaceae		
Aphanes australiana	Australian Piert	
*Rosa rubiginosa**	Sweet Briar	
Family Rubiaceae		
Asperula conferta	Common Woodruff	
*Galium divaricatum**	Slender Bedstraw	
Galium gaudichaudii	Rough Bedstraw	
*Galium murale**	Small Bedstraw	
*Sheradia arvensis**	Field Madder	
Family Santalaceae		
Exocarpus cupressiformis	Cherry Ballart	
Family Scrophulariaceae		
*Linaria pelisseriana**	Pelisser's Toad-flax	
*Parentucellia latifolia**	Common Bartsia	
*Verbascum virgatum**	Twiggy Mullein	
Veronica serpyllifolia	Thyme Speedwell	
Family Solanaceae		
*Lycium ferocissimum**	African Box-thorn	
*Solanum nigrum**	Black Nightshade	
Family Sterculiaceae		
Brachychiton populneus	Kurrajong	
Family Stylidiaceae		
Levenhookia dubia	Hairy Stylewort	
Family Thymeliaceae		
Pimelia curviflora	Curved Rice-flower	
Pimelia linifolia ssp. *linifolia*	Slender Rice-flower	
Family Urticaceae		
Parietaria cardiostegia	Mallee Pellitory	r
Family Xanthorrhoeaceae		
Lomandra filiformis	Wattle Mat-rush	
L. multiflora ssp. *multiflora*	Many-flowered Mat-rush	

Total number of vascular plant species = 246
Total number of indigenous plant species = 165
Total number of introduced plant species = 81
Number of VROT species = 9

Appendix 1. Vascular flora within the DBR. Taxonomy from Hnatiuk (1990), Calder and Calder (1994), DCNR (1996) and Lunt et al. (1998).

Species name	Common name	Last observation	Conservation status
Class Aves			
Family Accipitridae			
Accipiter fasciatus	Brown Goshawk	1999	
Aquila audax	Wedge-tailed Eagle	1999	
Hieraaetus morphnoides	Little Eagle	1998	
Lophoictinia isura	Square-tailed Kite	1992	V v
Milvus sphenurus	Whistling Kite	1980	
Family Aegothelidae			
Aegotheles cristatus	Owlet-nightjar	1993	
Family Alaudidae			
Cincloramphus cruralis	Brown Songlark	1993	
Cincloramphus mathewsi	Rufous Songlark	1999	
Mirafra javanica	Singing Bushlark	1991	
Family Alcedinidae			
Dacelo novaeguineae	Laughing Kookaburra	Resident	
Halcyon sancta	Sacred Kingfisher	1999	
Family Anatidae			
Anas superciliosa	Pacific Black Duck	1996	
Family Apodidae			
Hirundapus caudacutus	White-throated Needletail	1992	
Family Ardeidae			
Ardea novaehollandiae	White-faced Heron	1992	
Family Artamidae			
Artamus cyanopterus	Dusky Woodswallow	1999	
Artamus personatus	Masked Woodswallow	1995	
Artamus superciliosus	White-browed Woodswallow	1998	
Cracticus nigrogularis	Pied Butcherbird	Resident	
Cracticus torquatus	Grey Butcherbird	1999	
Gymnorhina tibicen	Australian Magpie	Resident	
Strepera graculina	Pied Currawong	1999	
Strepera versicolor	Grey Currawong	1951	
Family Burhinidae			
Burhinus grallarius	Bush Thick-knee	1992	V
Family Cacatuidae			
Cacatua galerita	Sulphur-crested Cockatoo	1999	
Cacatua roseicapilla	Galah	Resident	
Cacatua sanguinea	Little Corella	1993	
Cacatua tenuirostris	Long-billed Corella	1999	
Callocephalon fimbriatum	Gang-gang Cockatoo	1957	

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Species name	Common name	Last observation	Conservation status
Family Campephagidae			
Coracina novahollandiae	Black-faced Cuckoo-shrike	1999	
Coracina papuensis	Little Cuckoo-shrike	1999	
Lalage sueurii	White-winged Triller	1998	
Family Climaeteridae			
Climacteris picumnus	Brown Treecreeper	Resident	
Cormobates leucophaea	White-throated Treecreeper	1993	
Family Columbidae			
Geopelia placida	Peaceful Dove	1995	
Geophaps lophotes	Crested Pigeon	Resident	
Phaps chalcoptera	Common Bronzewing	Resident	
Family Coraciidae			
Eurystopmus orientalis	Dollarbird	1995	
Family Coreoraeidae			
Corcorax melanorhamphos	White-winged Chough	Resident	
Family Corvidae			
Corvus coronoides	Australian Raven	Resident	
Corvus mellori	Little Raven	1992	
Corvus sp.	Corvid	1992	
Family Cuculidae			
Chrysococcyx basalis	Horsfield's Bronze-cuckoo	1998	
Chrysococcyx lucidus	Shining Bronze-cuckoo	1998	
Cuculus flabelliformis	Fan-tailed Cuckoo	1999	
Cuculus pallidus	Pallid Cuckoo	1998	
Family Dieruridae			
Grallina cyanoleuca	Australian Magpie-lark	Resident	
Microeca leucophaea	Jacky Winter	Resident	
Myiagra alecto	Restless Flycatcher	Resident	
Rhipidura fuliginosa	Grey Fantail	Resident	
Rhipidura leucophrys	Willie Wagtail	Resident	
Family Falconidae			
Falco berigora	Brown Falcon	Resident	
Falco cenchroides	Nankeen Kestrel	1999	
Family Fringillidae			
Taeniopygia guttata	Zebra Finch	1993	
Family Hirundinidae			
Cheramoeca leucosterna	White-backed Swallow	1993	
Hirundo ariel	Fairy Martin	1991	
Hirundo neoxena	Welcome Swallow	1999	
Hirundo nigricans	Tree Martin	Resident	

Appendix 2 continued next page

Species name	Common name	Last observation	Conservation status
Family Meliphagidae			
Anthochaera carunculata	Red Wattlebird	1998	
Lichenostomus chrysops	Yellow-faced Honeyeater	1957	
Lichenostomus flavescens	White-plumed Honeyeater	1999	
Lichenostomus flavicollis	White-eared Honeyeater	1964	
Lichenostomus fuscus	Fuscous Honeyeater 1998		
Lichenostomus melanops	Yellow-tufted Honeyeater	1995	
Manorina melanophrys	Noisy Miner	Resident	
Melithreptus lunatus	White-naped Honeyeater	1998	
Melithreptus brevirostris	Brown-headed Honeyeater	1999	
Melithreptus gularis	Black-chinned Honeyeater	Resident	
Philemon citreogularis	Little Friarbird	1999	
Philemon corniculatus	Noisy Friarbird	1999	
Xanthomyza phrygia	Regent Honeyeater	1964	E
Family Meropidae			
Merops ornatus	Rainbow Bee-eater	1999	
Family Muscicapidae			
*Turdus merula**	Common Blackbird	1999	
Family Neosittidae			
Daphoenositta chrysoptera	Varied Sittella	1996	
Family Oriolidae			
Oriolus sagittatus	Olive-backed Oriole	1998	
Family Pachycephalidae			
Colluricincla harmonica	Grey Shrike-thrush	Resident	
Falcunculus frontatus	Crested Shrike-tit	Resident	
Pachycephala inornata	Gilbert's Whistler	1997	
Pachycephala pectoralis	Golden Whistler	1999	
Pachycephala rufiventris	Rufous Whistler	1998	
Family Pardalotidae			
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	Resident	
Acanthiza pusilla	Brown Thornbill	1980	
Acanthiza reguloides	Buff-rumped Thornbill	1992	
Acanthiza uropygialis	Chestnut-rumped Thornbill	1960	
Aphelocephala pectoralis	Southern Whiteface	Resident	
Gerygone fusca	Western Gerygone	1996	
Pardalotus punctatus	Spotted Pardalote	1996	
Pardalotus striatus	Striated Pardalote	1999	
Family Passeridae			
*Carduelis chloris**	Goldfinch	1996	
*Passer domesticus**	House Sparrow	1999	
*Passer montanus**	Tree Sparrow	1998	

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Species name	Common name	Last observation	Conservation status
Family Petroicidae			
Eopsaltria australis	Eastern Yellow Robin	1999	
Melonodryas cucullata	Hooded Robin	Resident	
Petroica multicolor	Scarlet Robin	1996	
Petroica phoeniciea	Flame Robin	1998	
Family Phasianidae			
Coturnix australis	Brown Quail	1996	
Family Plataleidae			
Threskiornis aethiopica	Sacred Ibis	1997	
Family Ploceidae			
Embleba guttata	Diamond Firetail	1998	
Family Podargidae			
Podargus strigoides	Tawny Frogmouth	1999	
Family Pomatostomidae			
Pomatostomus temporalis	Grey-crowned Babbler	1991	V
Family Psittacidae			
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	1999	
Glossopsitta pusilla	Little Lorikeet	1999	
Lathamus discolor	Swift Parrot	1998	V
Melopsittacus undulatus	Budgerigar	1995	
Neophema pulchella	Turqouise Parrot	1999	V
Nymphicus hollandicus	Cockatiel	1999	
Platycerus elegans	Crimson Rosella	1999	
Platycerus eximius	Eastern Rosella	Resident	
Polytelis anthopeplus	Regent Parrot	1997	V v
Psephotus varius	Red-rumped Parrot	Resident	
Family Strigidae			
Ninox connivens	Barking Owl	1957	r
Ninox novaeseelandia	Southern Boobook	Resident	
Family Sturnidae			
*Sturnus vulgaris**	Common Starling	1999	
Family Turnicidea			
Turnix varia	Painted Button-Quail	Resident	
Family Tytonidae			
Tyto alba	Barn Owl	1981	
Family Zosteropidae			
Dicaeum hirudinaceum	Mistletoe Bird	1999	
Class Amphibia			
Family Hylidae			
Litoria peronii	Peron's Tree Frog	1996	

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Species name	Common name	Last observation	Conservation status
Family Leptodactylidae			
Limnodynastes dumerili	Pobblebonk (Banjo) Frog	1996	
Limnodynastes tasmaniensis	Spotted Marsh Frog	1999	
Neobatrachus sudelli	Common Spadefoot Toad	1996	
Ranidella signifera	Common Froglet	1996	
Class Reptilia			
Family Agamidae			
Pogona barbata	Eastern Bearded Dragon	1998	
Family Elapidae			
Pseudonaja textilis	Eastern Brown Snake	1999	
Suta spectabilis ssp. *dwyeri*	Dwyer's Snake	1996	
Vermicella annulata	Bandy Bandy	1997	v
Family Gekkonidae			
Diplodactylus vittatus	Eastern Stone Gecko	1996	
Oedura marmorata	Marbled Velvet Gecko	1996	
Family Pygopodidae			
Delma inornata	Olive Legless Lizard	1996	
Family Scincidae			
Carlia tetradactyla	Southern Rainbow Skink	1998	
Cryptoblepharus carnabyi	Carnaby's Skink	1996	
Ctenotus robustus	Robust Ctenotus	1996	
Morethia boulengeri	Boulenger's Skink	1996	
Family Typhlopidae			
Ramphotyhlops nigrescens	Blind Snake	1996	
Ramphotyhlops proximus	Proximus Blind Snake	1996	r
Family Varanidae			
Varanus varius	Lace Monitor	1999	
Class Mammalia			
Family Canidae			
*Vulpes vulpes**	Red Fox	1999	
Family Dasyuridae			
Antechinus sp.	Antechinus	1992	
Phascogale tapoatafa	Brush-tailed Phascogale	1995	r
Family Felidae			
*Felis catus**	Cat	1996	
Family Leporidae			
*Lepus capensis**	Brown Hare	1999	
*Oryctolagus cuniculis**	European Rabbit	1999	

Appendix 2 continued next page

Species name	Common name	Last observation	Conservation status
Family Macropodidae			
Macropus giganteus	Eastern Grey Kangaroo	1999	
Wallabia bicolor	Black Wallaby	1999	
Family Molossidae			
Mormopterus planiceps (form 1)	Southern Freetail Bat (long penis)	1999	
Mormopterus planiceps (form 2)	Southern Freetail Bat (short penis)	1999	
Mormopterus sp.	Southern Freetail Bat (eastern form)	1999	
Tadarida australis	White-striped Freetail Bat	1999	
Family Muridae			
*Mus musculus**	House Mouse	1999	
Family Petauridae			
Petaurus norfolcensis	Squirrel Glider	1999	
Petaurus breviceps	Sugar Glider	1999	
Family Phalangeridae			
Trichosurus vulpecula	Common Brushtail Possum	1999	
Family Phascolarctidae			
Phascolarctos cinereus	Koala	1993	
Family Pseudocheiridae			
Pseudocheirus peregrinus	Common Ringtail Possum	1999	
Family Tachyglossidae			
Tachyglossus aculeatus	Short-beaked Echidna	1999	r
Family Vespertilionidae			
Chalinolobus gouldii	Gould's Wattled Bat	1999	
Chalinolobus morio	Chocolate Wattled Bat	1999	
Nyctophilus geoffroyi	Lesser Long-eared Bat	1999	
Scotorepens balstoni	Inland Broad-nosed Bat	1999	
Vespadelus darlingtoni	Large Forest Bat	1999	
Vespadelus regulus	Southern Forest Bat	1999	
Vespadelus vulturnus	Little Forest Bat	1999	

Total number of bird species = 116 (5 introduced)
Total number of amphibian species = 5
Total number of reptile species = 14
Total number of mammal species = 26 (5 introduced)
Number of VROT species = 12

Appendix 2. Observed fauna in the Dookie Bushland Reserve. Taxonomy variously from Hero et al. (1991), Menkhorst (1995), Cogger (1996) and Simpson and Day (1998)

THE ECOLOGY OF CLIFF-TOP HEATHLANDS AT PORT CAMPBELL, VICTORIA

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Vegetation on the uplifted coastal plain at Port Campbell is zoned parallel to the coast and is strongly influenced by the salt-laden winds from the southern ocean. On the most exposed cliff edges the lateritic sandy clays have been stripped off and open halophytic communities occur on the pitted limestone surface. For 200-400 m the vegetation is ground- water heath, the floristic composition of which changes from that dominated by *Leucopogon parviflorus-Poa poiformis* near the cliffs to that dominated by *Leptospermum scoparium- Gahnia trifida* with increasing distance inland. It is eventually replaced by low woodland and dry sclerophyll forest of *E. ovata*, *E. obliqua* and *Allocasuarina verticillata* . Clones of the latter species form emergent clumps on the heath where they regenerate to seaward by root suckering. Fruiting is very rare, due probably to damage of emergent feathery stigmas by salt aerosols. The occasional presence of halophytes in local microhabitats in the heathland may indicate an accumulation of cyclic salt in certain seasons. Close to the cliff edges duplex podzolic soil is overlain by a deposit of well-drained calcareous marl, which appears to have been blown up from the limestone cliff faces. The extent of this deposit is often indicated by severe chlorosis of a calcifuge shrub dominant, *Leptospermum scoparium*. In addition, the pH and exchangeable Ca^{++} content of the top soil decreases with distance inland from the cliffs suggesting a drift of fine loessic material. Most of the species on the heath regenerate vegetatively after fire, with the notable exception of *Leptospermum scoparium* which here is an obligate seeder. Since species richness of the heathland declines markedly with age, any management of biodiversity conservation using fire frequency needs to take into account the life-form and life history attributes of the major species.

Key words: Ecology, cliff-tops, heathlands, salt-spray, lime-chlorosis.

GENERAL ENVIRONMENT AND VEGETATION

PORT CAMPBELL National Park occupies a narrow strip 27 km long on the SW Victorian coast between Peterborough and Princetown (Fig.1). The Park is famous for its spectacular cliffs and rugged coasts, and is one of Victoria's most popular tourist destinations. Although its average width is only 0.7 km, it contains a rich flora of 641 species, of which 20% are exotic (Grant 1987). Much of the vegetation is heathland, which occurs in a broad band parallel to the cliff tops. Coastal heath is a common vegetation type in Victoria (Barson & Calder 1978), but cliff-top heaths are unusual. Coastal vegetation is also usually strongly zonal, in response to the influence of salt and wind. The survey of the Park by Grant (1987) described the broad vegetation types of the Park, but there have been no detailed studies of the ecology of the heathlands apart from that of McDonald (1989). The aim of this paper, therefore, is to describe the composition and structure of the heathlands, especially the zonation from the cliff-tops inland, along a stretch of the coast in the central section of the Park. We explore the distribution of plant communities in relation to soil types, saline aerosols, historical factors and vegetation dynamics. Species nomenclature is standardised on Walsh & Entwistle 1994, 1996 and 1999.

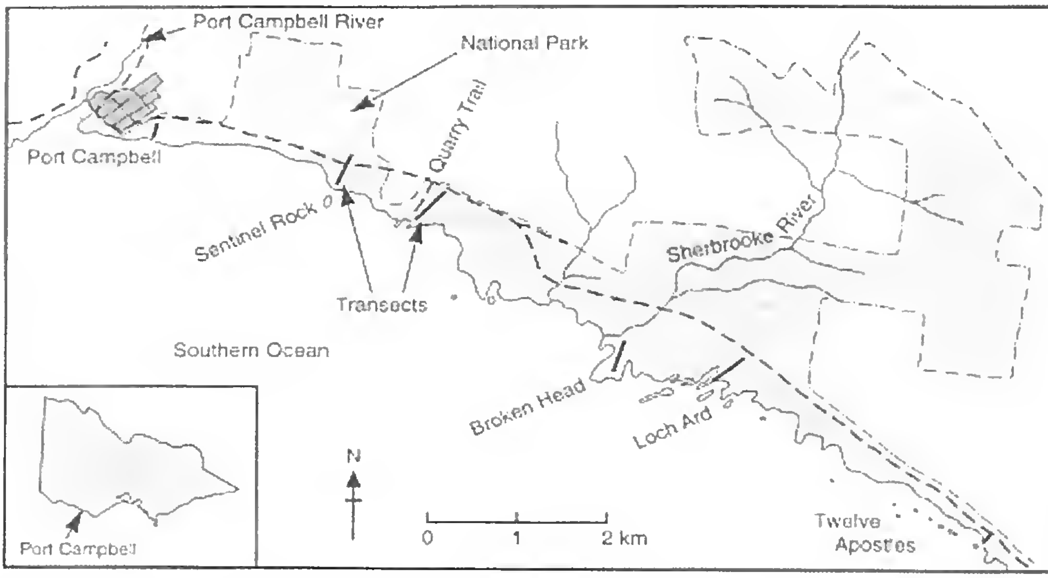


Fig. 1. Location map of the study sites at Port Campbell.

Fig. 2. General view of coast, east of Port Campbell

Physiography, Geology and Land Use

The Park occupies the seaward edge of an uplifted plain which terminates in high, spectacular cliffs of calcilutite (Port Campbell Limestone, Fig. 2) which, although relatively soft, stands in vertical cliffs and may be case-hardened by superficial carbonate precipitation (E.C.F. Bird, personal communication). Rock stacks and blowholes indicate the extent of the active marine erosion along this high energy coast (Bird 1976, 1993). The water table of the area seeps out of the cliffs about 40 m below the surface resulting in limestone shawls and malformed stalactites.

The hinterland is flat or gently undulating plain drained in this area by the two main streams, Port Campbell Creek and Sherbrooke River. Intermittent streams may reach the coast as hanging valleys. The land surface may either slope gently towards or away from the cliffs depending on the drainage systems present. The thick, fossiliferous marine Miocene limestones that underlie the whole region, have been uplifted 40-50 m and and exposed in the cliff faces, the cliff tops and inland along the deeper valleys. Most of the plain is covered with a 2-5 m veneer of non-fossiliferous Pliocene Hesse Clay, consisting of clays, sandy clays and current-bedded fluviatile sands (Gill 1965; Fig. 3).

In some places on the plain small lightly vegetated clay pans occur in the heath which may indicate an earlier dry period of soil deflation. The small tongues of Holocene sand which tend to infill surface irregularities in heathland at Loch Ard and Two Mile Bay, may also be a result of the same processes or may have been derived from beach sands further upwind to the west.

In general, the land surface has been stable since uplift and has revealed an important source of mid-Holocene extra-terrestrial australites (Gill 1965).

Prior to the gazetting of the National Park in 1964 the area was used for rough grazing by nearby farmers. Undoubtedly it was burnt many times both in pre and post European times. A small fire which occurred along the Quarry Trail in 1987 has provided valuable insights into the regeneration of heathlands in this area. However, the detailed fire history of the Park is unknown.

Climate

The climate is typically temperate and maritime with warm summers and cool winters and a general absence of severe frosts. The mean annual rainfall is about 908 mm with a winter maximum. Regional winds vary from predominantly NW in winter to SW in summer although in terms of strong–squally winds this generalization is reversed. Coastal sea breezes from the S-SE are an important component of the summer climate.

Soil

The soils of the area are closely correlated with parent material, topography and the age of the land surface. The predominant soil is a yellow to lateritic podzolic type (Stace et. al. 1968) with a humus-rich sand to sandy loam top soil 15-30 cm deep, above a sandy clay subsoil. Because of the sharp textural change at the A/B horizon boundary the soil type is clearly duplex (Northcote 1965). Buckshot gravel is com-

Fig. 3. Miocene limestone cliffs with an unconformable overburden of younger Pliocene sediments. The water table issues from the lower one third of the cliff face.

Fig. 4. Karst in stripped edges, Loch Ard area.

mon at this boundary and indicative of intermittent waterlogging (Leeper & Uren 1993). Nevertheless texture is variable, and is influenced locally by that of the parent marerial. In some places where sands predominate, subsoils are low in clay and show induration by coffee rock. In exposures at the cliff faces the deeper layers of sandy clays (2-3 m) are ferrugenized and show conspicuous red, yellow and white mottle. This material may be indurated with calcareous material along cracks for 1-2 m above the limestome disconformity.

Features of the cliff edge environment

On many exposed headlands, stripped cliff top edges (Baker 1958) may be 1-30 m wide and show local rugged erosional surfaces pitted with depressions and solution holes (Fig 4). In stormy weather in May 1987, waves were observed to break onto the cliffs and splash over onto one of the stripped zones. Backwash from such waves as well as run-off from heavy rains have contributed to the severe erosion of this zone.

In places along the near-vertical cliff edges, (such as opposite Sentinel Rock and at Quarry Trail), that are subjected to the full force of onshore winds, a 'berm-like' deposit of edging of undifferentiated yellowish brown marl up to 0.5 m deep resting on what appears to be a palaeosol on the Tertiary lateritized sandy clays (Fig.5). The marl is exposed at the top of cliff faces, thins out rapidly inland and cannot be distinguished after 100-150 m (Fig. 6). Occasional

Fig. 5. The upper section of the cliff near Quarry Trail, showing well structured Holocene marl deposit (1) above old soil profile (2) developed on lateritized Hesse Clay (3).

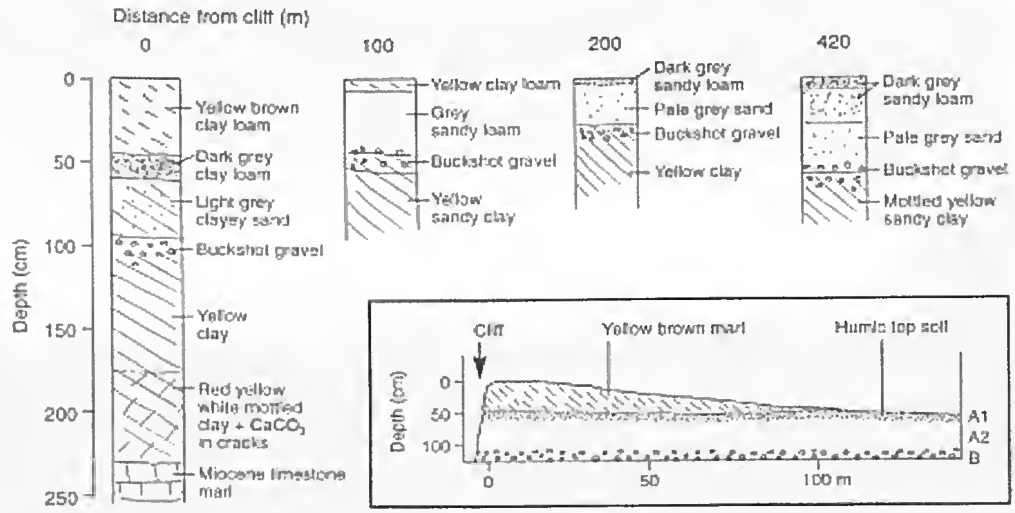


Fig. 6. The variation of soil profiles across the clifftop heathland and a schematic representation of the clifftop marl sediments opposite Sentinel Rock (inset).

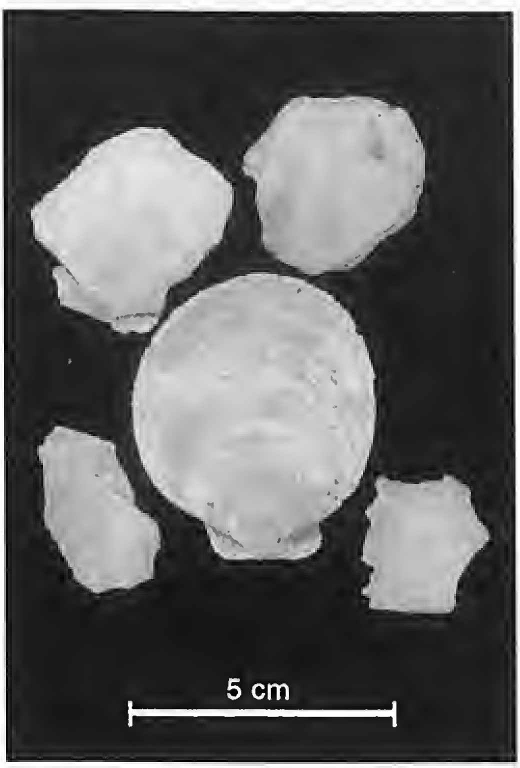


Fig. 7. Miocene fan shells from grass tussocks and shrubs at the cliff edge, Sentinel Rock.The largest specimen is *Hinnites* sp and the remainder, *Serripectin* sp

Miocene fossil fan shells (*Hinnites* sp and *Serripecten* sp) and shell fragments (Fig. 7) have been found on the soil surface or amongst grass tussocks at the cliff edge opposite Sentinel Rock. Marl has also collected in bark furrows and branch angles of shrubs of *Calocephalus* and *Leucopogon* in these sites. There seems little doubt that certain of the more aerodynamic fossils (1-5 cm in diameter and weighing 0.2-5.6 g) have been blasted out of soft limestone of the cliff face by squally on-shore winds and deposited on the cliff top. The coarser material (consisting of clay 30%, silt 14%, fine sand 41% and coarse sand 15%) has been deposited at the cliff edge whilst finer material is likely to have been blown inland over the heath in a somewhat analogous manner to loess or parna.

Vegetation

Vegetation is zoned parallel to the coast (Fig. 8). A broad scale survey of the plant communities of Port Campbell National Park by Grant (1987) emphasized the zonation from cliff-top tussock grassland and cushion heath (*Calocephalus brownii*) to different kinds of wet heath and to low, dry sclerophyll forest of *Eucalyptus obliqua* and *E.ovata* in the hinterland. Importantly, as suggested by Grant (1987), the wet, sedge-rich heathlands could be divided generally into

Fig. 8. General view of the grass and heath zonation, Sentinel Rock.

seaward communities characterised by *Leptospermum scoparium*, *Gahnia trifida* and *Baumea juncea* and landward communities characterised by *Leptospermum continentale*, and *Xanthorrhoea australis*. Occasional low bushes of eucalypts (*E. obliqua*, *E. ovata*) may merge with the general heath stratum 200-250 m from the cliffs, but further back these species become emergent with streamlined profiles. Throughout the heath zone conspicuous, widely scattered clumps of *Allocasuarina verticillata* emerge above the associated shrubs to heights of 6-9 m. Continuous low dry sclerophyll forest 5-8 m high, commences about 500 m inland beyond a broad ecotonal mosaic.

DETAILED ECOLOGICAL STUDIES

Methods

Detailed ecological studies were undertaken along a 12 km stretch of the coast, from Port Campbell to the Twelve Apostles (Fig. 1). We examined community structure and composition, soil properties, and plant-environment interactions. The major approach was to document environmental and vegetational changes along six transects up to 420 m long, laid out orthogonal to the coast.

Local climate. Thermohygrographs were set up one metre above ground at intervals along a transect near Sentinel Rock in late February-early March 1987-88. At the same time numerous salt traps, consisting of a tube of fine gauze 2 cm in diameter and 30 cm high, were set up at frequent intervals. After four days the traps were rinsed with distilled water and Cl^- concentration determined with an electrolysis chloride meter. Foliage of selected species at these locations was also collected, rinsed with distilled water, made up to standard volume and the concentration of Cl^- determined and expressed in terms of unit leaf area. Leaf anatomy of various species was also investigated in exposed and sheltered sites.

In a study of the root suckering regeneration of *Allocasuarina verticillata*, soil temperatures were measured by burying max-min thermometers at a depth of 2 cm around and inside clumps of *Allocasuarina verticillata*.

Soils. These were studied from soil pits dug at various intervals along the transects. Horizons were described and sampled for analysis of particle size distribution, ped structure, pH (1:5 soil:water), total N, HCO3- extractable P and exchangeable cations (Technicon Instruments 1977; Page et al 1972). In the winter of 1989, which in August was 46% wetter than average, the depth of the perched water table was measured in saturated heathland soils.

Vegetation

Community classification and structure. Quadrats (10 m x 2 m) were sampled every 10-20 m along each of 6 transects. The cover rating of all 113 species in 143 quadrats followed a Braun Blanquet scale (+= <1%, 1=1-5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=75-100%). The data set was subjected to a polythetic agglomerative classification which was truncated at the 11 group level. The groups were subsequently ordinated by non-metric multidimensional scaling. All analyses were undertaken using the PATN package (Belbin 1987).

The structure of various communities was depicted by bisect profiles. The density and height of trees and shrubs was assessed by the point-centred quarter method (Catana 1963). *Allocasuarina* clumps were analysed by a contiguous grid of 2x2 m plots in which species composition and density of stems was recorded. The litter layer of *Allocasuarina* clumps was collected from five quadrats (0.5 x 0.5 m) and compared with that from a similar number of plots under *E. obliqua* clumps and nearby heath of *L. scoparium*. The mean dry weights and concentration of total N and P were determined.

Chlorosis in Leptospermum scoparium. During the course of the vegetation survey, chlorosis in this species was observed where it was growing near many of the cliff edges. The growth, form and leaf colour of *L. scoparium* was studied in a pot experiment in the glasshouse at Melbourne University. Seed from both chlorotic and green bushes at Port Campbell were sown into plastic pots (n= 10) of marl collected from the cliff edge where chlorosis was apparent, and from top soil of heath 200 m inland, where chlorosis was absent. To test whether chlorosis could be alleviated by anoxic soil conditions, chlorotic plants, 2 months old and 10-20 cm high, were grown in drained marl then subjected to waterlogging to within 1 cm of the soil surface for several weeks. They were then re-aerated for a similar period and the results qualitatively assessed. To test whether chlorosis was due to iron deficiency, six month-old, chlorotic seedlings growing on free- drained marl were treated with iron chelate (2 p.p.m. Fe EDDHA) at a rate of 190 ml-over 14 days and the results qualiatively compared with control plants.

Results

Local climate and aerial salt collection. In late summer-early autumn on sunny days with sea breezes, cliff-top air temperatures were frequently 3-4 °C lower, wind speeds and relative humidities higher than those 300-400 m inland. The concentration of Cl^- in each year of study showed the marked effect of sea breezes on aerosol salt collection. The Cl^- concentration in the salt traps as well as Na^+ concentration in the top soil was high at the cliff edge and fell sharply with increasing distance inland (Figs. 9 a,b). The Cl- concentration on the foliage of various species generally followed the trend of that recorded from the traps. However, although it was greatest on the windward sides of dense-foliaged plants, this trend was reversed in plants with sparse foliage. Salt spray tolerant species had thick cuticles or surface mats of dead hairs (e.g. *Calocephalus brownii*) which would have prevented much of the salt from reaching the living leaf tissues. In general, salt was highest on foliage near the cliff edge and on emergent vegetation.

Soils. Typical profiles of various soil types on the Tertiary deposits are shown in Fig.6. The sandy loam top soils were of variable depth (20-40 cm), usually with a pale grey A2 horizon. The amount of buckshot gravel was also variable but often made up 10-40% by weight of the horizon sample.

During the very wet winter of 1989, holes dug in the heathland near Quarry Trail on a very gentle seaward slope showed a perched water table at depths of 0-2 cm. In places, where surface seepage occurred (Fig.10), bare soil surfaces were covered with strands of filamentous green algae oriented downslope as a result of water movement. In winter, many areas of soil in wet heath showed large patches of gelatinous blue-green alga, *Nostoc commune*, which no doubt contributed to the nitrogen status of the top soil. The structure of these soils showed less disaggregation in the top soils than sub soils. By contrast, the calcareous loam near the cliff edge was well drained and showed minimal profile development.

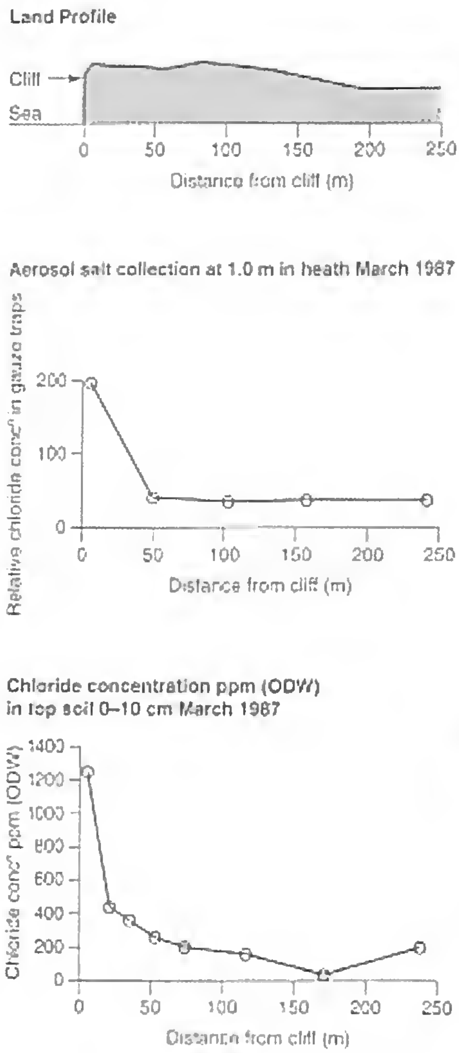


Fig. 9. A. Chloride concentration in aerosol traps at different distances from the cliff , Sentinel Rock transect, March 1987. B Chloride concentration in top soil, Sentinel Rock transect, March 1987

Depending on the particular site, the pH of top soils decreased from 7.5 - 8.5 near the cliff edge to 5.8 - 6.3 at a distance of 300-500 m inland (Fig. 11). The trend of the pH of the sub soils was generally similar to that of the top soils. Along two transects regression analysis showed that both the pH and the total of four exchangeable cations (Na,K, Ca, and Mg) decreased signi-ficantly ($p < 0.05$) with increasing distance inland. Calcium accounted for most of the exchangeable cations measured. At Quarry Trail the coastline is normal to the prevailing on-shore SW winds and exchangeable Ca showed a linear decline with distance inland from the cliffs. At the Sentinel Rock transect site however, the relationship is curvilinear, due probably to the large embayment of the coastline to the west (Fig. 1) which allowed SW winds undue influence on a large section of the transect (Fig. 12). The average concentration of Ca^{++} in top soils was twice that in the sub soil, whereas that for Mg^{++} this ratio was only about one third. Exchangeable Na^+ and K^+ as well as extractable Cl^- in both top soil and subsoil was higher near the cliff than inland. As expected, total nitrogen values paralleled those of organic carbon and were thus greater in top soil than sub soil and considerably greater under dense clumps of *Allocasuarina verticillata* than in adjacent heathland. Bicarbonate-extractable P in top soils was generally low and varied from 10 to 15 mg/kg and showed no trend over a distance of 420 m from the cliff.

Fig. 10. Seepage of perched water table from the soil surface, Quarry Trail July 1989

Plant Communities

Their composition, structure and zonation. The classification (not depicted) was truncated at the 11 group level, but was interpreted for the purposes of the ordination, at the five group level, A-E (Fig. 13). The species frequency of species arranged in these groups suggests a continuum (Table 1). The broadest groupings viz. A, B+C and D+E correspond approximately to the zonation described by Grant (1987). The zones varied considerably in width from one transect to another and not all groups were present in every transect. Axis 1 appears to be related to factors concerned with distance from the cliffs. Groups B and C appear to seggregate along Axis 2 which may be related to distance along the coastline. Groups D and E occur in the same zone and may be discriminated by local habitat factors which may be resolved by additional quadrats. Although there is a high degree of floristic similarity between groups B and C as well as between groups D and E there are sufficiently important differences in the frequencies of dominants and sub-dominants of shrub, forb and graminoid strata to suggest that they remain distinct

Profiles of the main communities are shown in Fig. 14. On many of the stripped cliff edges, such as those at Loch Ard, Broken Head and Quarry Trail, very open halophyte communities contain *Sarcocornia blackiana*, *Samolus repens*, *Selliera radicans* and *Wilsonia humilis* and *W. backhousei*. (Fig 14a). Where the original soil mantle persisted, the community present (Group A) was an open grassy heathland (Fig. 14 b) of *Poa poiformis* and cushion bush (*Calocephalus brownii*). This was similar to that recognized by Grant (1987), but it also contained *Olearia axillaris*, *Lepidosperma gladiatum*, *Tetragonia implexicoma* and *Samolus repens*. Further back on marl, up to 50-100 m from the cliff, the community (Group B) was a grassy heathland dominated by *Leucopogon parviflorus* and *Poa poiformis* with *Olearia axillaris*, *Acrotriche prostrata* and numerous forbs (Fig. 14c). Further inland, 100-200 m inland from the cliffs, the community (Group C) was heathland dominated by *Leptospermum scoparium* and *Hibbertia aspera* (Fig. 14d). Beyond this distance, 200-300 m inland, the community (Group D) was dominated by *Leptospermum scoparium* and *L. continentale* (Fig. 14 e,f). Groups A-D were distinguished by a change in the graminoid components: thus grasses were dominant in A and B whilst sedges (*Gahnia trifida* and

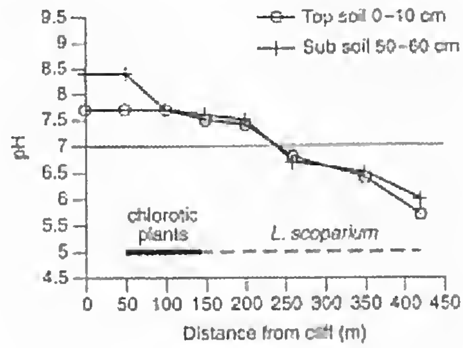


Fig. 11. pH in top soil and subsoil at different distances from the cliff at Quarry Trail.

Schoenus nitens) and rope rushes (*Baumea juncea*) were conspicuous in C and D. Furthest inland at 400-500 m, the community (Group E) was a low open woodland or forest 3-10 m tall, dominated by *E. obliqua* and *E. ovata* (Fig. 14 g). The understorey was heathy, and rich in those sclerophyll species, such as *Isopogon ceratophyllus*, *Allocasuarina paludosa* and *Xanthorrhoea australis*, that are typical of many other heathlands in southern Victoria.

Under the denser clumps of eucalypts, tangles of *Hibbertia aspera* were common and ground stratum species were suppressed. The humus horizon in such sites was commonly matted into a compact layer up to 10 cm thick, resembling fibrous mor in dry sclerophyll forests of southern Tasmania and parts of Wilsons Promontory.

In some heathlands within 200 m of the cliff,

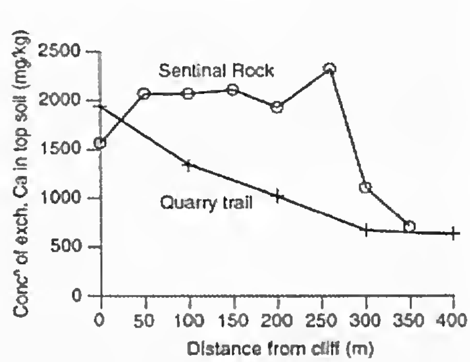


Fig. 12. Concentration of exchangeable calcium in top soil with increasing distances from the cliffs, Sentinel Rock and Quarry Trail.

Species Groups	A (n=9)	B (n=39)	C (n=65)	D (n=23)	E (n=7)
Shrubs-Trees:					
Calocephalus brownii	44 (33)	35 (17)	11 (6)	. .	. .
Olearia axillaris	44 (11)	35 (17)	48 (15)	. .	. .
Tetragonia implexicoma	33 (33)	22 ·	5 ·	. .	. .
Ozothamnus turbinatus	. .	17 ·	2 ·	. .	. .
Leucopogon parviflorus	. .	43 (9)	85 (53)	23 ·	43 ·
Leptospermum scoparium	. .	48 (39)	58 (49)	100 (97)	100 (86)
L. continentale	. .	35 (26)	2 ·	54 (31)	14 (14)
Bossiaea prostrata	. .	13 ·	2 ·	33 ·	. .
Hibbertia aspera	. .	. .	51 (34)	51 (44)	57 (57)
Banksia marginata	. .	. .	18 ·	49 ·	29 (14)
Astroloma humifusum	. .	. .	14 ·	38 (3)	14 ·
Acrotriche prostrata	. .	. .	37 (20)	8 ·	. .
A. serrulata	. .	. .	. .	23 ·	. .
Eucalyptus obliqua	. .	. .	. .	10 (8)	71 (57)
No. spp.	3	8	12	10	7
Graminoids:					
Poa poiformis	100 (55)	96 (78)	82 (60)	10 ·	43 ·
Tetrarrhena distichophylla	. .	61 (22)	3 ·	31 ·	43 ·
Baumea juncea	33 (11)	4 ·	60 (15)	61 (36)	14 ·
Gahnia trifida	. .	74 (22)	74 (58)	66 (51)	. .
Schoenus nitens	. .	48 (13)	65 (8)	64 (18)	14 ·
Carex breviculmis	. .	4 ·	29 ·	56 ·	29 ·
Isolepis nodosa	. .	48 ·	3 (2)	. .	. .
Themeda triandra	. .	. .	5 ·	18 ·	43 (29)
Lepidosperma filiformis	. .	3 (2)	13 ·	. .	. .
Danthonia spp. (3)	. .	. .	33 (4)	10 ·	. .
No. spp.	2	8	13	11	6
Forbs:					
Sarcocornia blackiana	55 ·	. .	. .	. .	. .
Samolus repens	55 ·	48 ·	42 ·	5 ·	. .
Selliera radicans	22 ·	35 ·	78 (21)	28 ·	14 ·
Senecio lautus	55 ·	43 ·	12 ·	. .	29 ·
Apium prostratum	55 ·	4 ·	11 (3)	. .	. .
Lobelia alata	22 ·	. .	29 ·	3 ·	14 ·
Oxalis 'corniculatus'	11 ·	70 ·	20 ·	10 ·	14 ·
Leontodon taraxacoides	11 ·	17 ·	52 ·	20 ·	43 ·
Brachyscome parvula	11 ·	. .	60 ·	5 ·	. .
*Centaurium erythraea**	. .	48 ·	77 ·	77 ·	14 ·
Dichondra repens	. .	. .	29 ·	18 ·	29 ·
No. spp.	9	7	10	8	7
Total number of spp.	14	23	35	29	20

Percent frequency of species in quadrat groups A-E zoned from the cliff inland for 300-400m. ( )=% Frequency of cover values ³ 5%. n = number of quadrats. * introduced.

Table 1. Species composition of vegetation groups

small areas of bare soil 50-100 cm in diameter may be partly vegetated by short turfs of *Schoenus apogon* and occasional prostrate halophytes, such as *Samolus repens* and *Selliera radicans*.

The dominant shrubs in Groups A-D varied in density with proximity to the cliff (Fig. 15). Vegetation decreased in height closer to the cliff edge where salt wind was strongest. In the cliff-top zone species were differentiated according to their tolerance to aerial salt. Thus, *Leucopogon parviflorus* and *Olearia axillaris* and the upper dead foliage of grasses and sedges overtop and partly protect low shrubs of *Hibbertia aspera* and *Leptospermum scoparium*. Dwarfed eucalypts in zones near the clÃiffs were pruned to the height of the heath but further back they formed emergent streamlined clumps or low forest. Emergent clumps of *Allocasuarina verticillata* were distinctly different.

Status of clumps of emergent Allocasuarina verticillata *and* E. obliqua. In each of Groups B to E, *A.verticillata* occured as dense, isolated clumps 5-25 m in diameter, and consisting of 100 or more stems 4-8 m tall. They occurred from the cliff edge sporadically through much of the heath zone and low eucalypt forest. *A. verticillata* also occurred in taller groves on shallow limestone soil on the sides of the Port Campbell creek valley, 1-2 km inland. Clumps of *A. verticillata* in the heath may be even aged with a compact profile or uneven aged with an uneven profile. Although *A. verticillata* is salt-wind resistant, it tended to lean away from the coast and, in the most exposed

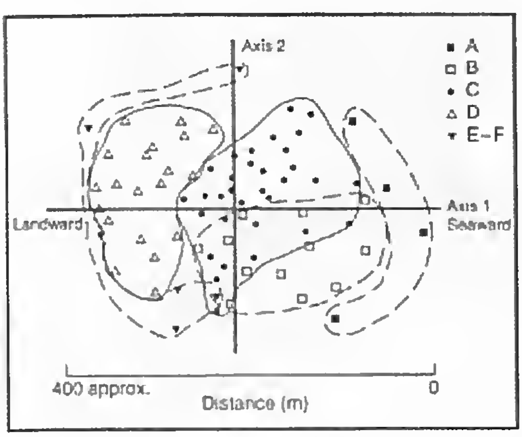


Fig. 13. Ordination of 5 major quadrat groups. Axis 1 correlates with distance from the cliff edge.

sites died back on the seaward side. Stress-affected plants commonly showed damage from wood boring larvae. Even-aged clumps (Fig. 16) were likely to have originated from past fires since charred remains of original stems were invariably present in the interior of the clumps. In uneven-aged clumps (Figs. 17, 18) a preponderance of dead and dying stems occurred in the centre of the stand and younger individuals occurred at the periphery. It appears that such clumps had not been burnt for a considerable time. *A. verticillata* regenerated principally by suckering from shallow roots at depth between 0.5 and 2.0 cm. and especially where the surrounding heath was low and bare soil exposed. Heath on the seaward side of clumps tended to be shorter than that flourishing in the wind shadow. The surface soil temperature on a warm autumn day was 3-4°C higher in the low heath on the immediate windward side than in the taller heath on the leeward sides of clumps (Table 2). This may be a reason for the stimulation of shoot development from shallow lateral roots on the seaward side of clumps. This type of regeneration has resulted in the clumps gradually extending seaward.

The taller, more salt-wind resistant *A. verticillata* may protect non-resistant species. Thus at Two Mile Bay, exposed *E. ovata* is wind pruned to the level of the heath (1 m) except in the immediate lee of *A. verticillata* when it equals the height of the protecting species (7 m).

The clumps tend to be dioecious, and about two thirds were male. No fruits were found in any female clumps exposed to onshore winds, although 300-400 m inland occasional fruits occurred on the lee side of the clumps. By contrast, along the valley of the Port Campbell creek 1 km inland, female trees are laden with fruits. The percentage of viable seed from cones in inland stands was 38% compared to 1.2% in heathand clumps. Mean seed weight from trees on the exposed sites was only 40 % of that on trees in protected sites. Associated species in the clumps were few -eg. *Rhagodia candolleana*, possibly due to low light intensity, root competition and a very thick, loose litter layer up to 20-50 cm deep.

The weight of loose litter on the floor of clumps of *A. verticillata* was 5.22± 3.45 kg m^{-2} or 9.7 times greater than that in adjacent *L. scoparium* heathland and 17.4 times greater than under clumps of dense *E. obliqua* (Table 2). Slow decay of the fibrous litter may be one of the reasons for the large differences in accumulation of material on the soil surface. The light intensity in *A. verticillata* clumps is considerably greater than

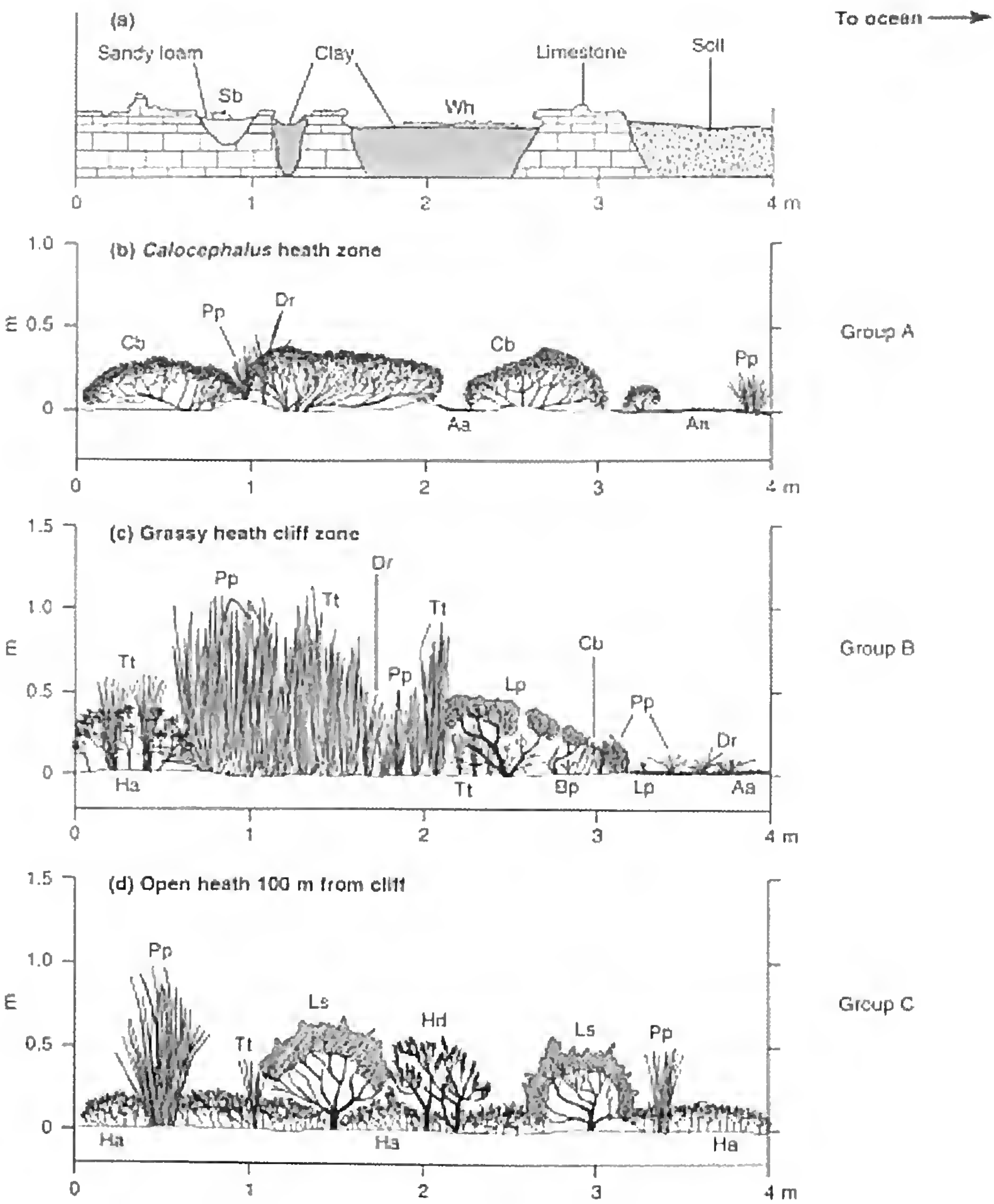
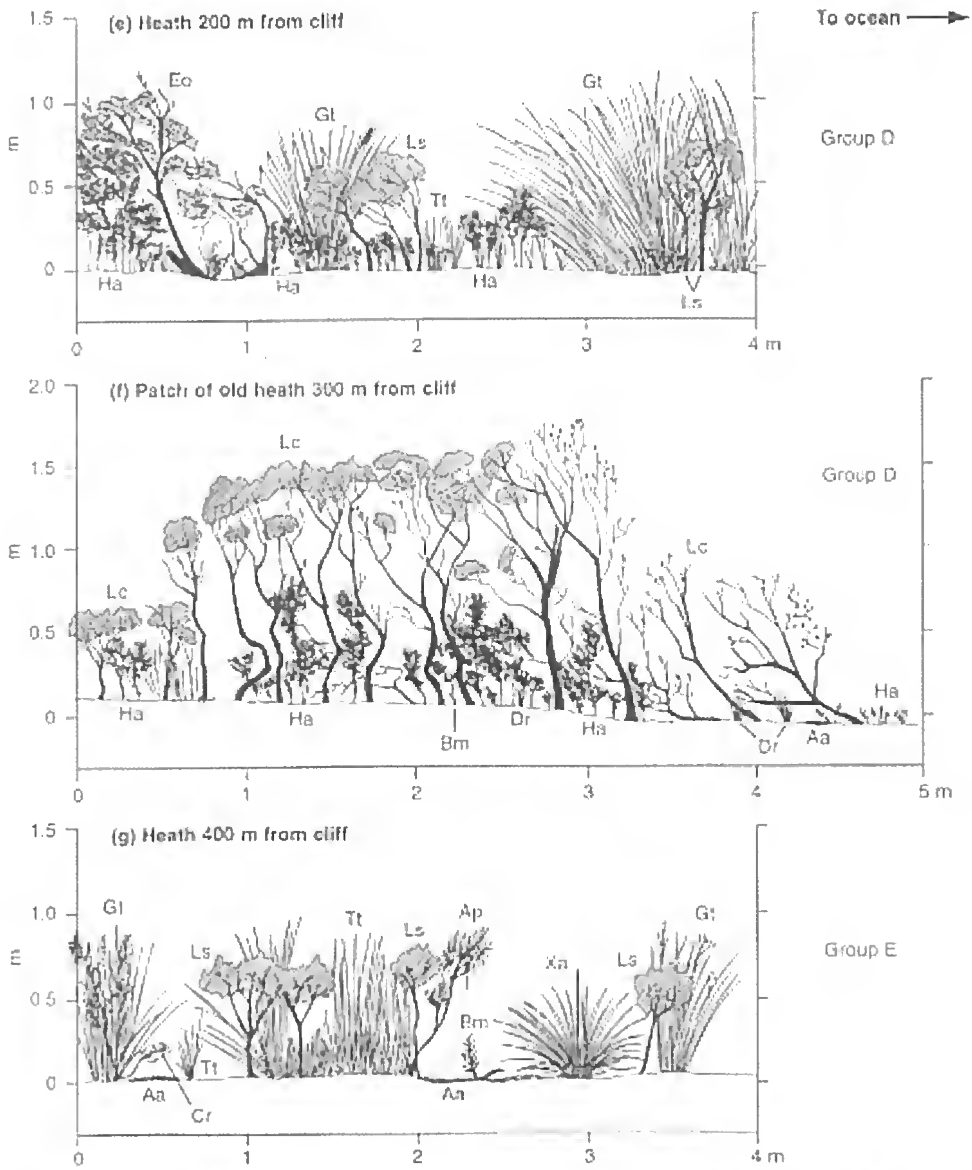


Fig. 14. (a)-(g). Profiles of various communities which conform to quadrat groupings A,B,C,D and E.



Key:

Aa	*Acrotriche affinis*	Eo	*Eucalyptus obliqua*	Pp	*Poa poiformis*
Ap	*Allocasuarina paludosa*	Gt	*Gahnia trifida*	Sb	*Sarcocornia blackiana*
Bm	*Banksia marginata*	Hd	*Helichrysum dendroideum*	Tt	*Themeda triandra*
Bp	*Brachyscome parvula*	Ha	*Hibbertia aspera*	Wh	*Wilsonia humilus*
Cb	*Calocephalus brownii*	Lc	*Leptospermum continentale*	Xa	*Xanthorrhoea australis*
Cr	*Correa reflexa*	Ls	*Leptospermum scoparium*		
Dr	*Dianella revoluta*	Lp	*Leucopogon parviflorus*		

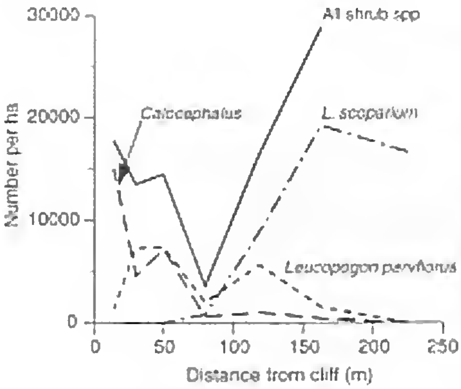


Fig. 15. Changes in density of major dominant shrubs with increasing distance from the cliff, Loch Ard area.

Fig. 16. Photograph of dense, emergent even-aged clump of *Allocasuarina verticillata*, Sentinel Rock.

under dense *E.obliqua* (Table 2). The number of associated understorey species is lower under *E. obliqua* than *A. verticillata*, although the effect of the cover of the latter species was only apparent when its cover exceeded 50-75%. The levels of N and P in the litter layer suggests that dense clumps of *C. verticillata* act as 'islands' of comparatively high nutrient accumulation in this heathland.

E. obliqua occasionally occurred as a wind-pruned component of the heath stratum (Fig. 14e) and became a wind-smoothed emergent beyond 250 m from the coast. Emergent clumps of *E. obliqua*, consisting of 10 or more trees form an aggregate smoothed profile 4-5 m high in the heath about 400 m from the cliff (Fig. 19) and with increasing distance are taller and coalesce to form low, dry sclerophyll forest. Eucalypt regeneration is very rare and probably restricted to post-fire periods.

Fire in heathland

Most of the heathland area shows at least some evidence of past fire.In the heathlands opposite Sentinel Rock, small patches of long unburnt *L. scoparium* and *Hibbertia aspera* heath were taller and denser than surrounding heath and less species-rich.

Where *Banksia marginata* occurred it was possible to provisionally age the vegetation since this species produces two nodes in the first year after a fire and one per year thereafter. Most of the heathland studied was at least 12-15 years old whilst the taller heath patches appeared to be about twice that age. A small fire of about 0.1 ha, in heathland dominated by *Leptospermum scoparium* and *L. continentale* occurred in March, 1987. This killed all above-ground parts but within a few weeks the fire resistant species had begun to resprout from lignotubers and under-

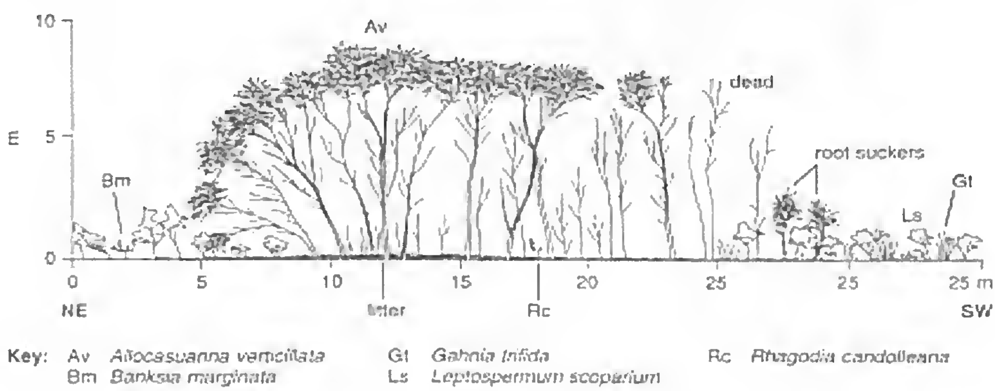


Fig. 17. Profile of uneven-aged clump of *A verticillata*, Sherbrooke River.

	Leptospermum spp. heath	*Allocasuarina verticillata*	*Eucalyptus obliqua*
Environment:			
Max. air temperature in March22.4°C			
Soil temp. 0-2 cm at midday, March	Seaward of *Allocasuarina* 27.2°C Landward of *Allocasuarina* 14.2°C	14.2°C	
Light intensity at 0.5 m			
Diffuse light (% sky)	62.8%	24.6%	17.8%
Direct light (% suntrack)	39.7%	15.5%	6.3%
(Mean of solstices & equinoxes)			
Litter floor			
Total d.wt. kg/m^2 ± SD	0.68 ± 0.28	5.22 ± 3.45	0.30 ± 0.04
N content g/m^2	36.83	479.65	17.66
P content g/m^2	1.23	8.66	0.77

Table 2. Environment and litter floor characteristics in *A verticillata* and *E. obliqua* clumps compared with adjacent mainly *L. scoparium* heath.

ground parts. Seedlings appeared in late autumn and in the following spring. The most important finding was that *L. scoparium* was not lignotuberous and not fire resistant (Fig. 20) and regenerated only from seed, whilst *L. continentale* (Fig. 21) and *Allocasuarina paludosa* regenerated vigorously from lignotubers as well as from seed. *Leucopogon parviflorus* sprouted from the lower stem and also regenerated from seed, whereas *Banksia marginata* sprouted mainly from shallow lateral roots.

Soil-plant interaction

Chlorosis in Leptospermum scoparium. Towards the cliff edge this shrub decreased in height and suffered severe pruning from salt wind. At about 20 m from the cliff edge it was prostrate, although protected to some extent by taller and more resistant species such as *Hibbertia aspera*. Where it encroached onto the calcareous marl deposits in this zone it was conspicuously yellow, particularly on the sunnier sides of the bush. The zone of chlorosis coincided with the zone of friable calcareous marl, indicating that this species is a calcifuge. Glasshouse experiments demonstrated that within a few weeks, chlorosis occurred only in seedlings raised in the calcareous top soils from near the cliff edge, irrespective of the seed source. Chlorosis was therefore not genetically based but environmentally determined. Morphological differences were also clear cut: chlorotic plants were very bushy and stunted, whilst normal plants at this stage under these conditions were tall with few axillary branches (Fig.22). The addition of iron chelate (Fe EDDHA) to seedlings over several weeks only partially removed chlorosis, however when chlorotic plants in calcareous soil were waterlogged they all rapidly turned green. This effect was rapidly reversed if such soil was allowed to aerate.

DISCUSSION

Vegetation Zonation

On-shore coastal winds laden with salt spray are probably the most important factors shaping the form and composition of plant communities in coastal environments. Communities are zoned parallel to the coast

Fig. 18. Photograph of a degenerate clump of *A.verticillata* near the cliff, Sentinel Rock, showing copious regeneration from root suckers.

Fig. 19. Wind-smoothed clump of 10 trees of *E. obliqua* 400 m from the cliff.

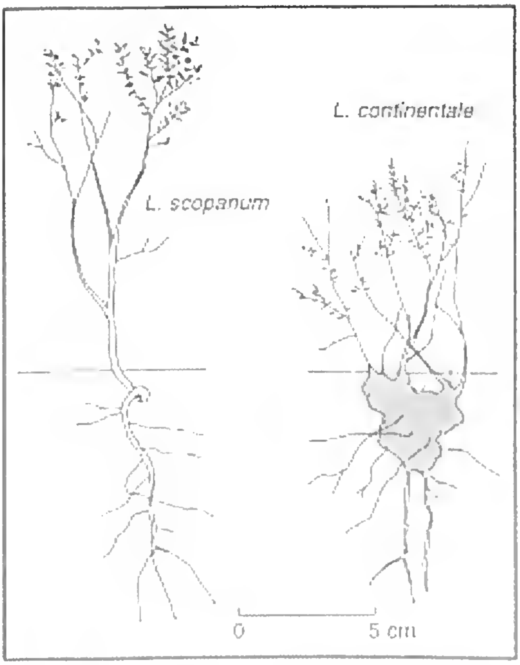


Fig. 20. Drawings of young *L .scoparium* and *L. continentale* showing absence and presence of lignotuber development

and any relief from such wind results in an increase in canopy height and a change in species composition, either from the reduction of saline aerosols *per se* or from the competition imposed by taller species. At Port Campbell, the zonation of vegetation ranges from short, grassy open heathland close to the cliffs to closed sedgey heathlands and woodlands further inland. The most rapid changes occur in the first 10-30 m from the cliff edge for it is here that winds are strongest and the concentration of deposited salt greatest. In general, the distance of species from the cliff edge is related to their relative resistance of aerial salt.

Salt intolerant species are severely wind-pruned where they extend above streamlined canopy profiles (Boyce 1954, Parsons and Gill 1968). However Parsons (1981) has pointed out that input of the major cations (K, Na, Ca, Mg) derived from rain is at least 50% of that recorded as 'dry fall out' and that the

Fig. 20. Recovery of heath in August 1989 following fire in March 1987 along Quarry Trail. Shrub on left is *Leucopogon parviflorus* coppicing from the base, shrub on the right is *Leptospermum scoparium* which has been completely killed.

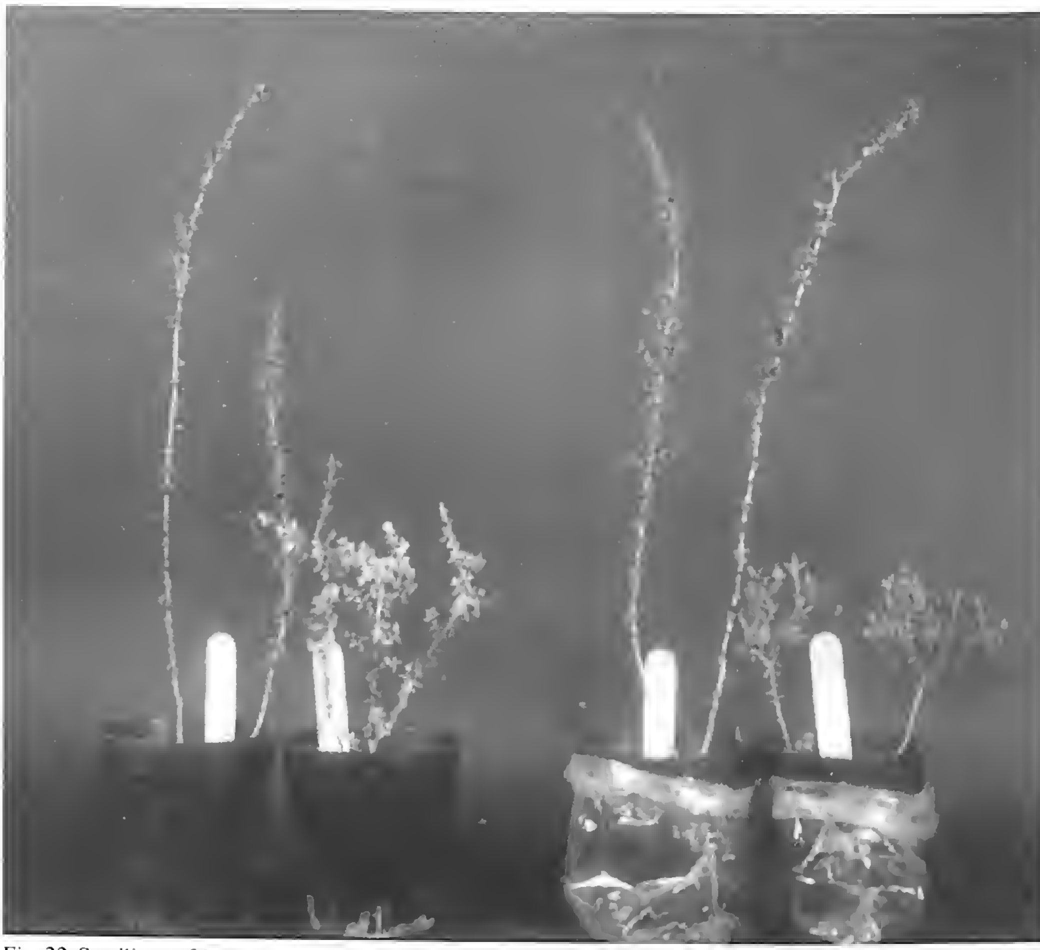


Fig. 22. Seedlings of *L. scoparium* (left) grown in drained marl soil (bushy chlorotic plant) and podzolic top soil (tall, unbranched non-chlorotic plant). Subsequent waterlogging of such plants after pots were encased in plastic bags (right), resulted in the full greening of plant in marl soil

canopy impaction of such elements may be 2.3-3.0 times higher. Boyce (1954) pointed out that in salt spray communities in North America, where there are strong onshore winds the whole of the foliage may intercept aerial salt. In many of the cliffs exposed to the strongest wave action, large storm waves splash onto the cliff top creating soil salinity and contributing to erosion of soil and limestone. The thin soils on these harsh sites are colonized by low halophytic plants forming very open communities.

The heathland along the Port Campbell clifftops is unusual due to the occasional presence of small, scattered halophytes such as *Selliera radicans* and *Samolus repens*. They occur on flat terrain associated with low swards of *Schoenus apogon* in small, slightly depressed gaps, 0.5-1.0 m in diameter, and are likely to indicate local accretion of cyclic salt, at least in some years.

One important feature of the cliff top vegetation at Port Campbell is the influence exerted by the limestone cliffs on the surface soil. Since calcilutite is relatively soft it is susceptable to considerable wind and water erosion. Dislodged heavier material is deposited close to the cliff edge whilst the finer material appears to be blown inland over some hundreds of metres. The calcareous marl deposit is well drained hence calcifuge species, such as *Leptospermum* *scoparium*, which encroach onto it, exhibit marked chlorosis. On this soil it is stunted and bushy, a feature which may he an advantage in a severe salt-wind environment. This species is also relatively tolerant of seasonal waterlogging and where this occurs, chlorosis is absent even though pH is relatively high. This suggests that anoxic conditions have led to the reduction of iron and an increase in its availability. The differences in soil pH between chlorotic and non chlorotic areas near Sentinel Rock may only differ by 0.5 units. Anderson & Ladiges (1978) however have shown at Cape Otway that relatively small differences in pH can be important in the development of chlorosis in *Eucalyptus* species on aeolianites.

Although Na+ from salt aerosols also decreases from the coast and may affect soil pH), exchangeable Ca is present in far greater amounts. It seems likely that much of the pH gradient across the heath is due to fine calcareous material carried from the cliff face by on-shore winds. Concentrations of exchangeable cations in the topsoil are greater than in the subsoil, a feature which could be explained by such aerial accretion or by nutrient enrichment derived from litter decomposition. The generally low P concentration in the soil is consistent with the general work of Specht (1979). Soils on the lateritized Pliocene sediments are markedly duplex and leached and are similar to soils of other ground water heaths in Victoria (Groves & Specht 1965). However, they differ from other coastal heath sites by their neutral to moderately acid pH. Intermittent perched water tables in such soils, which are indicated by the prevalence of buckshot gravel, create considerable stress to plants because of anoxicity, relatively impeded root systems and the subsequent occurrence of summer droughts (Groves and Specht 1965; Specht 1981). The presence of *Gahnia trifida* and *E. ovata* in the heath is often indicative of seasonal waterlogging, at least in the sub-soil.

Allocasuarina verticillata is a widespread small tree growing over a wide range of mostly dry habitats. Its conspicuous emergence in the Port Campbell heathland testifies to its extreme resistance to salt wind which to some extent, may be related to the tendency of its strongly xeromorphic foliage to 'flow in the wind'. *A. verticillata* is wind pollinated and the extreme paucity of fruiting in female plants on the exposed heathlands could be due to damage inflicted on the exposed, feathery stigmas by salt winds. The origin of the emergent clumps is somewhat enigmatic since they are clonal, propogate peripherally by root suckering and produce very little, if any seed. It seems likely that winged seed has been blown onto the heathland from fertile stands 1-2 km inland inland, probably as a result of a past fires associated with hot northerly winds. After fire, dense, vegetative regeneration of this species produces even-aged patches. Long unburnt clumps on the other hand, are uneven-aged. The litter layer is extraordinarily deep (20-50 cm), slow to decay and therefore represents considerable local accumulations of nutrients, such as N.

Most of the heathland area shows at least some evidence of past fire. From the morphology of associated *Banksia marginata* it was possible to provisionally age the vegetation, most of which was was at least 12-15 years old. A small fire in 1987 revealed that most heathland species recovered vegetatively by way of lignotubers, coppice, root suckers and rhizomes as well as by seedlings. Such observations were consistent with those of many others workers (Russell & Parsons 1978, Specht 1979, and Wark 1996). The most important finding was that *L. scoparium* was in this area is not fire resistant but regenerated copiously from seed after fire. Seedlings in unburnt heath are extremely rare. Preliminary observations suggest that the initial non-flowering period may be 4-5 years, hence if these heathlands had been burnt very frequently in the past, this species would have been eliminated.

Species richness (number per quadrat) across the heathland area varied between communities. It was least both at the cliff edge and inland under dense wind-pruned *E. obliqua* clumps. It reached a maximum in mixed heath on acid soils 200-300 m inland, but was markedly reduced in old patches of taller heath dominated by *Leptospermum scoparium* and *Hibbertia aspera*. Such reduction of species richness with age of heath is consistent with work on the Dark Island heaths of South Australia by Specht et. al.(1958) and ground water heaths of Wilsons Promontory by Russell & Parsons (1978). Fire within a particular frequency range is necessary to restore the biodiversity of heathlands dominated by obligate seeders and, to this extent the ecology of *L. scoparium* at Port Campbell is somewhat analogous to that of *Banksia ornata* in the drier heaths of Victoria and South Australia (Gill & McMahon, 1986).

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VEGETATION OF SAND DUNES AT WILSONS PROMONTORY, VICTORIA

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Two adjacent parallel dune systems on the west coast of Wilsons Promontory differ in their $CaCO_3$ content and therefore their soil pH. The calcareous dunes are more species rich than the siliceous dunes and although the major species on both dune systems are similar, at least one species, (*Swainsona lessertiifolia*), appears to be calcicolous. The scrub on the stable dunes mostly consists of even-aged stands as a result of numerous past fires. In most stands on Norman Bay *Leptospermum laevigatum* is dominant and *Leucopogon parviflorus* sub-dominant. The proportion of these species in the vegetation is likely to depend on the age of the stand and the frequency and severity of fires and droughts. In old stands, *L. laevigatum* is senescent with little or no regeneration due to seed harvesting by ants and persistent browsing by mammals. By contrast, *L. parviflorus* is rarely browsed, is more shade bearing and fire tolerant and although it remains vigorous in old stands it is damaged by sustained drought. It is likely to become the stand dominant in the presence of herbivores and in the continued absence of fire and severe drought, or any other disturbance. In severe SW storms fine calcareous beach sand at Norman Bay, is winnowed out over the dune scrub for up to 200 m inland, may delay normal processes of podzolization.

Key words. Sand dunes, calcareous, scrub, regeneration

THE COAST of Wilsons Promontory is characterised by granitic headlands and wide, curved sandy beaches. The junction of two sand provinces in Bass Strait occurs at Wilsons Promontory (Bird 1976), hence yellowish, calcareous sands and shell fragments from the continental shelf to the west are deposited on the west coast whist white quartzose sands derived from the east and southeast are deposited on the east coast. Similar patterns are also found on King and Flinders Islands (Bird 1976). However on the west coast of Wilsons Promontory (Fig.1) the siliceous sands at Leonard Bay are an exception which Bird (1993) suggests may be due to the deflection of the westward drift of calcareous material by the Glennie Group of islands off-shore The two adjacent, contrasted beaches at Norman Bay (Fig. 2a) and Leonard Bay (Fig. 2b) provided a convenient locale to compare the types of sand dune vegetation and to investigate stand dynamics on the calcareous system (van Gameren (1977).

The recent geological history of the Tidal River area is complex. Shell beds dated at dated at 6230+/-350 Yr BP. (Parsons 1966) occur at Tidal River 1.6-1.7 km inland under peats dated at 4960 Yr BP (G.S. Hope, personal communication) and indicate the existence of an estuary prior to the development of parallel dunes and swampy peats. Siliceous parabolic dunes and sand sheets of probable Pleistocene age occur on the surrounding granitic slopes at Tidal River (Parsons 1966) and behind Leonard Bay, indicating a period of considerable instability.

Norman Bay is broad and gently shelving and the wide beach is backed by up to six parallel calcareous dunes and one landward siliceous dune (Parsons 1966). Leonard Bay is narrower and steeply dipping and is backed by a single large siliceous dune which is under attack by large storm waves (Fig. 3). Although the Norman Bay front dune is occasionally eroded by storm waves it has been colonized by pioneer plants, such as *Thinopyrum junceiforme*, *Spinifex sericeus* and the exotic, *Euphorbia paralias*, forming embryo dunes. Further back, patches of scrub consist of *Olearia axillaris*, *Ozothamnus ferrugeneum*, *Correa alba*, *Leptospermum laevigatum* and *Leucopogon parviflorus*. The parallel dune system at Norman Bay extends 200-300 m from the beach and the extensive scrub shows considerable variation in age and species richness. By contrast the parallel dune at Leonard Bay extends only 80-90 m from the beach and the scrub on the lee side is restricted and relatively species poor.

Leptospermum laevigatum regenerates copiously after fire or disturbance (Parsons 1966; Hazard & Parsons 1977) and also vigorously invades adjacent, unburnt heathland (Burrell 1981). However its regeneration in stands of mature and degenerating scrub is meagre or absent. Its status was therefore studied in terms of autecology and field sowing trials.

The climate of the area is mild and maritime with a seasonally well distributed rainfall of about 1000 mm per annum. In spite of this, dry years occur which result in damage to vegetation and an increased chance of fires. Most of the northern half of the Norman Bay system beyond 90 m from the beach has been modified to various extents for the general development of tourism.

The nomenclature of vascular species follows The Flora of Victoria (Walsh & Entwistle 1994-99), that of bryophytes follows Scott & Stone (1976).

METHODS

Sand, soils and vegetation of Norman and Leonard Bays

Transects were set up at both bays and extended inland normal from the coast. At various distances, soils were sampled from soil pits, pH was determined by glass electrode using a 1:5 dilution with distilled water. The $CaCO_3$ content of beach sand in 1960 was determined by Ms Mary Todd using 0.1M HCl followed by back-titration with alkali (Piper 1950). In 1986 sand size spectra were determined by sieving sand collected from 0-10 and 30-40 cm to a mesh of 0.25mm. The dry weight of sand fractions was obtained after organic matter had been destroyed by H_2O_2.

Species cover was qualitatively assessed on the Braun Blanquet scale of +-5 (Kershaw 1964) in quadrats (10 x 1m) perpendicular to the transect. Quadrats did not extend to the heathland at either bay.

Even-aged scrub stands at Norman Bay

The structure of different even-aged stands of *Leptospermum laevigatum* and *Leucopogon parviflorus* were studied by bisect profiles in 1972. The species composition of mature and immature scrub was assessed from 5 random quadrats (10 x 1m). The demography of the two dominants was assessed from 50 distance measurements using the wandering quarter method of Catana (1963). The comparative regeneration of *L. laevigatum* scrub following the wildfire in NE Wilsons Promontory 1963, was assessed from 10 quadrats at intervals of 1, 9 and 28 years after the fire. The size of quadrats was commensurate at each time with that of the vegetation.

Accretion of beach sand by mature scrub on stable dunes

In the mature scrub at Norman Bay appreciable quantities of fine sand were found to have been collected in the flakey bark, furrows and notches of *L. laevigatum* trunks 90 m from the beach and also in epiphytic moss cushions of *Tortula papillosa* and *Zygodon intermedius* on the stems of *L. parviflorus*. Sand was collected from mature *L. laevigatum* trunks and passed through a series of sieves down to a mesh of 0.1 mm and compared with a similar sand spectrum of adjacent top soil (0-2 cm and 10-12 cm) in the mature scrub and

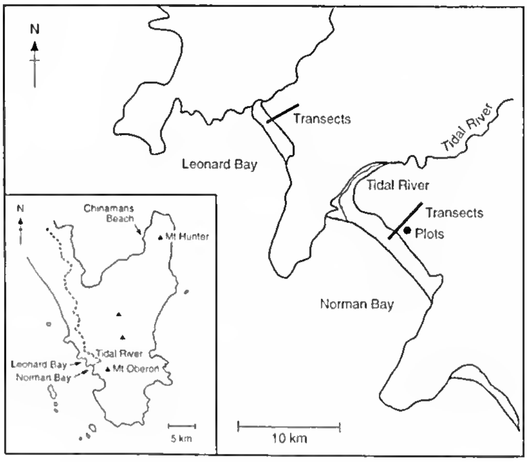

Fig. 1. Map of Wilsons Promontory, showing the location of the study sites.

(a)

(b)

Fig. 2. General view of dune systems. (a) Norman Bay and (b) Leonard Bay mid 1960s.

at intervals of 30 m as far as the beach. An indication of the rate of accretion of fine sand was obtained over a 7 month period from August 1999, by randomly placing nine plastic cups (9 cm diameter) on the soil surface in mature scrub 90-100 m from the beach, and in young scrub on the first dune 50 m closer the beach. After organic matter was destroyed, the dry weight of sand was expressed as g m^{-2} per month.

Regeneration of mature L. laevigatum scrub in the absence of fire

Sources of seed. In this area, abundant seed is stored in the canopy for up to one year after late spring flowering (Judd 1990) Seed fall was measured in suspended seed traps (Cunningham 1960); 5 being under canopy and 4 in gaps. Collections were made from April- October 1977, and seed counted and expressed as N° m^{-2}. Losses of seed from prepared soil surfaces (Ashton 1979) were assessed in May and August under mature scrub. In June 1977 the soil seed bank was investigated from ten plots (30 x 30 cm) at one cm intervals to a depth of 4 cm. Soil was sieved, moistened and incubated in a glasshouse for several months during which time all germinates were counted and identified. The germination of natural seed fall in eight random, 1 m^2 permanent quadrats under scrub canopy and in gaps was monitored from every 6 weeks from June-October 1977. The number of seedlings m^{-2} of both dominant species were calculated each month.

Fig. 3. Flakey bark of *Leptospermum laevigatum* where sand collects (right) and the rugose bark of *Leucopogon parviflorus* which supports epiphytic mosses which also collect fine sand (left).

Seed germination requirements. These were studied in the laboratory using a range of controlled temperatures (3-26° C), various light conditions (light, dark and a 12 hour photoperiod) and stratification storage periods of 4-8 weeks. In addition, seed was pricked with a fine needle to discover the existence of seed hardedness. Germination for each experiment was set up in 5 petri dishes using 0.25 g of seed for each treatment (1g contains 874 viable seed).

Fenced sowing trials. Natural gaps were deemed the most likely sites for successful regeneration. Three such gaps 5 m in diameter were found in the mature scrub area from crest to swale, 90-100 m from the beach. In June 1977 a plot (3.7 x 2.9 m) was fenced with wire mesh (2 cm diameter and 1.5 m high) in each gap. An adjacent unfenced plot acted as a control. Herbaceous material was removed and within each plot two blocks of of sub-plots (60cm^2) was set up in which the light litter layer was either removed or left intact. Seed sown at the rate 1 g per treatment. Germination and survival monitored at frequent intervals in the first year and at progressively longer intervals over the ensuing 20 years.

The effect of drought on scrub dominants

Following marked damage of dune scrub by drought in 1975, the degree of water stress of *L. laevigatum* and *L. parviflorus* was assessed in the field by determining the water potentials of shoots using the pressure-bomb method (Tyree and Hammel 1972). The relationship between water potential and relative water content of drying shoots was obtained in the laboratory.

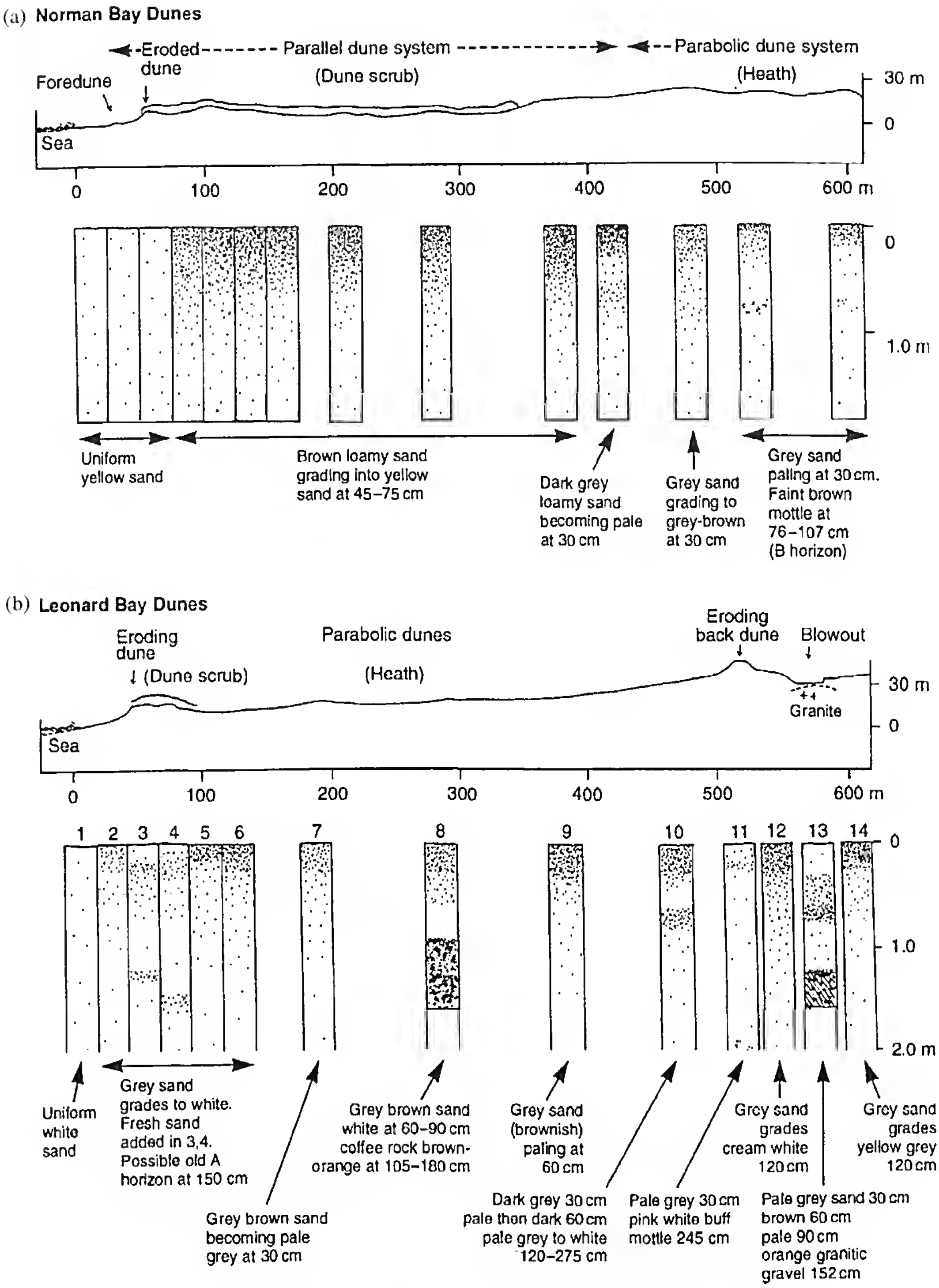

Fig. 4 Land profile of a) the Norman Bay dunes and b) Leonard Bay dunes.

RESULTS

Comparison of the two bay's dune systems

The most important difference in the two bays is the color and characteristics of the beach sand, the percentage of $CaCO_3$ and the consequent pH of the dunes that have been produced. At Norman Bay the pH of the beach sand is 8 and contains 34% $CaCO_3$ whilst at Leonard Bay the pH is 7 and contains only 0.4 % $CaCO_3$. The pH of dune soil at Norman Bay remains high and decreases slowly with distance inland for 200 m after which it falls to about 6. At Leonard Bay however the pH decreases quickly to 5.5 (Fig 5) The sand fraction data indicate that Norman Bay beach and parallel dunes are made of very fine sand (mostly 0.11-0.16 mm) whilst Leonard Bay the substrate is coarser fine sand (mostly 0.25-0.53 mm) (Fig. 6). The frequency spectrum of sand collected by vegetation was almost indistinguishable from that of dune and beach sand.

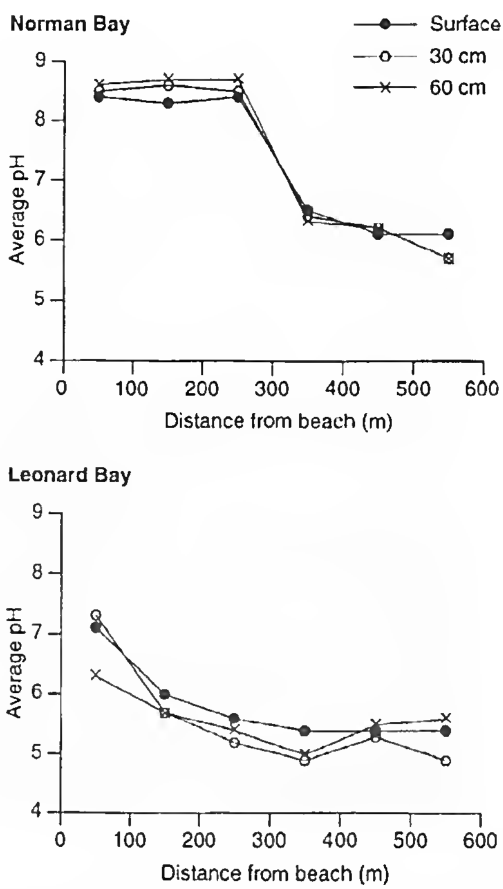

Fig. 5 The pH of soil with increasing distance from the beach at a) Norman Bay and b) Leonard Bay

The distribution of species on the two dune systems shows both similarities and differences (Table 1). The scrub on both dune systems is dominated by *L. laevigatum* and *L. parviflorus* and some *Allocasuarina verticillata* and *Correa alba*. The annual, *Daucus glochidiatus* is ubiquitous in winter. The species richness as indicated from transect quadrats, is much greater on the calcareous dunes (41 spp) than on the siliceous dunes (24 spp). The similarity index (2 x N° spp in common as a % of the sum of species in both stands) is 63%. Species restricted to the calcareous dunes include *Bursaria spinosa*, *Senecio biserratus* and *Swainsona lessertiifolia*, *Caladenia latifolia*, *Lagenophora stipitata* and the mat moss, *Thuidium laevinsculum*. Although *Exocarpos syrticola*, *Calocephalus brownii* and *Dianella revoluta* are common on the acid dumes at Leonard Bay, they may also be found elsewhere on calcareous soils. Occasional shrubs found more frequently on heath (*Grevillea lanigera*, *Hibbertia sericea*, *Spyridium parvifolius*, *Epacris impressa* and *Astroloma humifusum*) occur in more open areas of dune scrub at Leonard Bay and on the parallel, siliceous acid dune inland from Norman Bay.

Even-aged stands of dune scrub at Norman Bay

The vegetation on the stable dunes at Norman Bay ranging from dense, young *L. laevigatum* stands with little undergrowth and a trunk-space filled with criss-crossed dead branches, to old degenerating mature stands with gnarled, prostrate *L. laevigatum*, bushes of *L. parviflorus*, *Correa alba*, *Bursaria spinosa*, *Phyllanthus gunnii*, scramblers such as *Clematis microphylla and Muehlenbeckia adpressa* and *Rhagodia candolleana*. An herbaceous stratum of *Senecio biserratus*, *Swainsona lessertiifolia*, *Dichondra repens*, *Parietaria debilis* and numerous orchids and mosses is conspicuous, particularly in the moister swales. On the partially eroded front dune, the scrub is patchy and wind-contorted. Stringers of sand blown in from the beach through breaks in vegetation are colonized by foredune species such as *Spinifex sericeus*, and *Euphorbia paralias*.

The even-aged stands frequently have sharp boundaries (Fig. 7) and are almost certainly the result of post-fire regeneration. At Lawsons Creek, NE

Wilsons Promontory, a severe fire in 1962 killed mature stands of *L. laevigatum*. One year later, the seedling regeneration was exceedingly dense(1204 +/-138 m^{-2}) and compared with capsules of the fire-moss, *Funaria hygrometrica* both in size and density. Nine years later the mean height of the young stand was about 2 m and the density was reduced by 90%. After a further 11 years the density had reduced to less than one fiftieth (22.9 m^{-2}) of that in 1963, while the mean height of dominant plants had doubled to 4 m (Fig. 8).

At Norman Bay, the density of the woody species and the floristic composition in young and old stands is shown in Tables 2 and 3. In general, the number of species increased with age of the stand. In some places where the exotic grass *Ehrharta erecta* had established vigorously, the richness of the ground flora was diminished- affecting especially, small orchids, (*Caladenia carnea, C. latifolia, Acianthus caudatus*

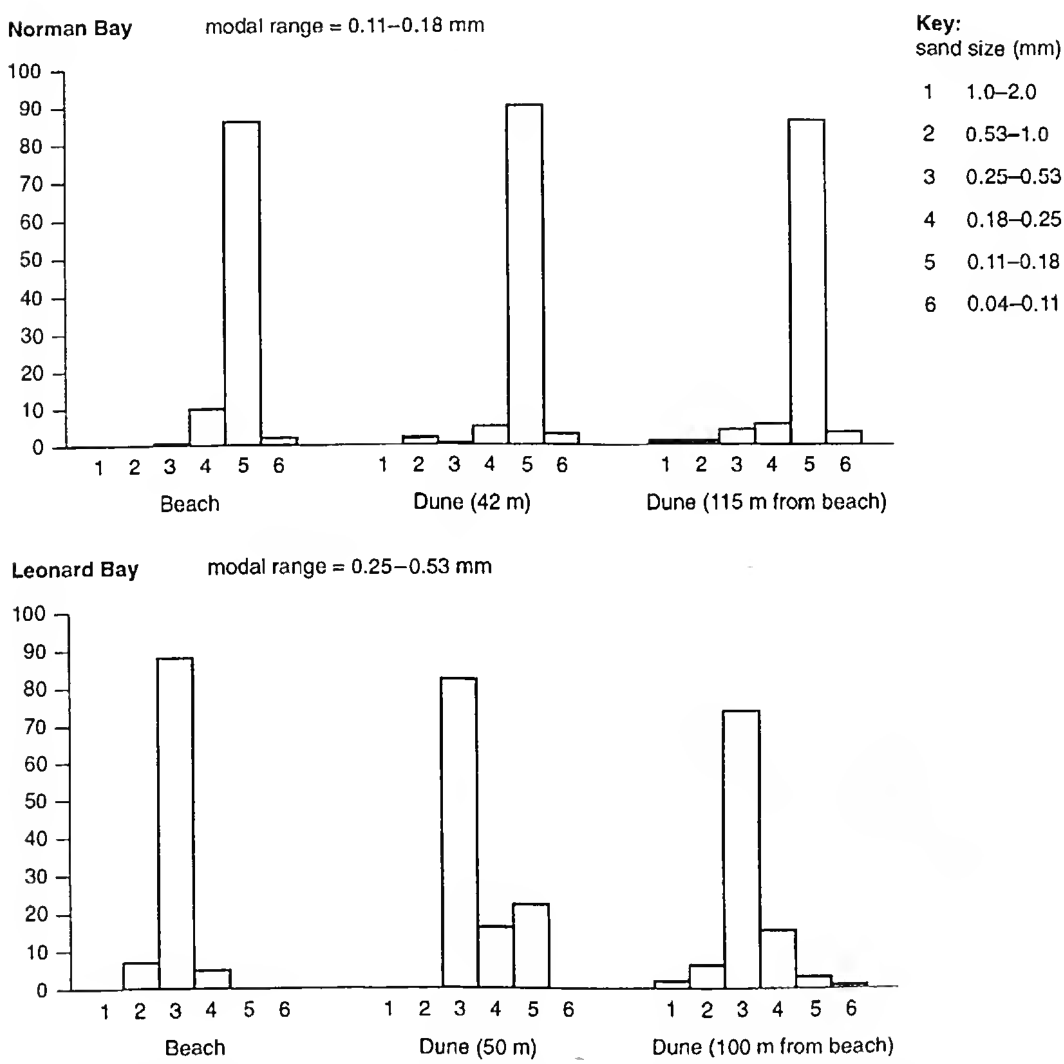

Fig. 6. Frequency histograms of sand size distribution of top soil with increasing distance from the beach at Norman Bay and Leonard Bay 1986.

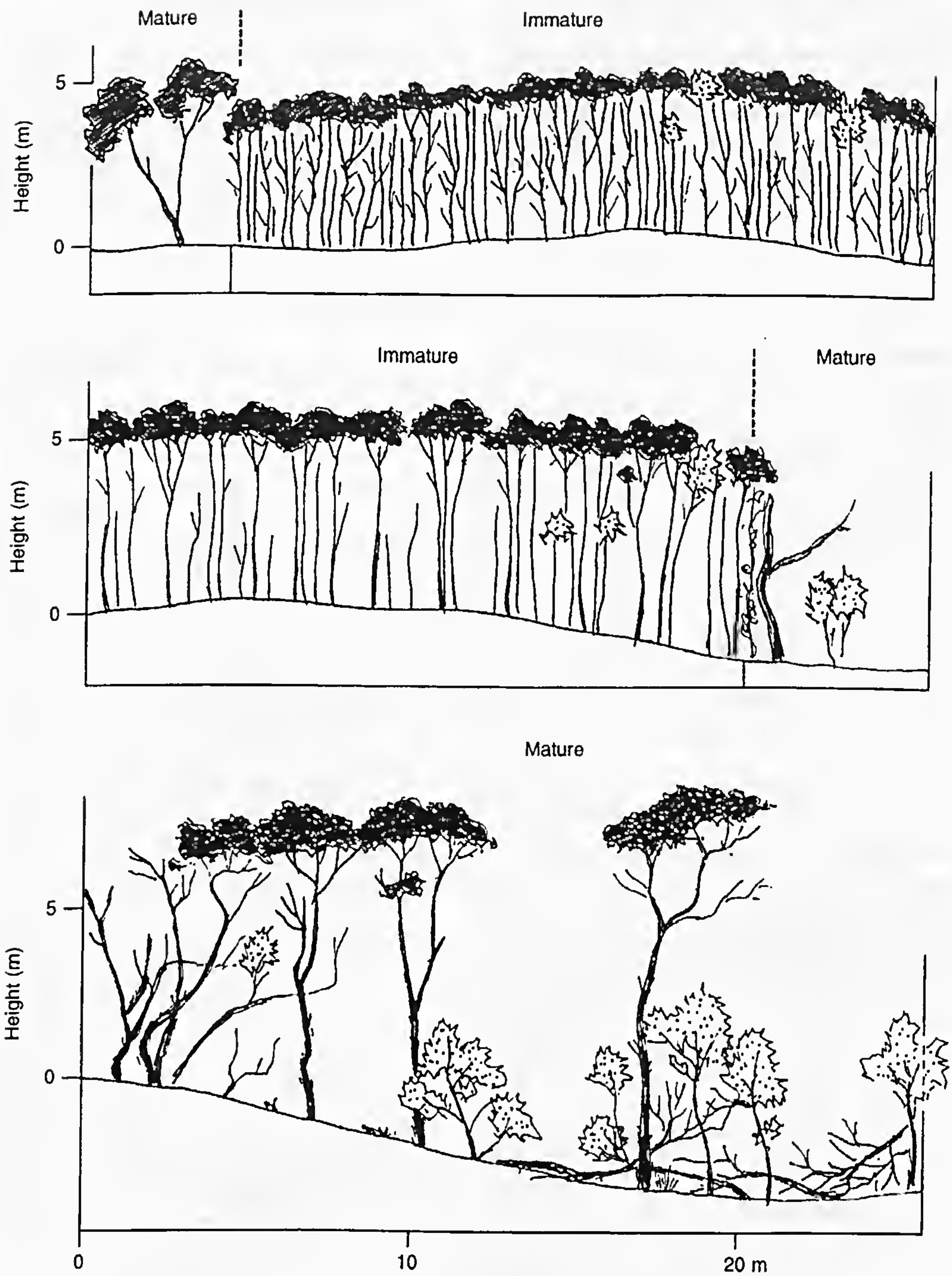

Fig. 7. Profiles of various even-aged stands of *L. laevigatum* at Norman Bay, 1972.

and *A. pusillus*) and ephemerals (*Daucus glochidiatus* and *Parietaria debilis*).

Although *L. laevigatum* is killed outright by fire, *L. parviflorus* resprouts from the butt or from buds below ground. Its growth appears to be slower than that of *L. laevigatum* and in immature stands it tends to be suppressed or subdominant. In old stands however, it becomes more vigorous as *L. laevigatum* senesces and is damaged progressively by severe storms. In contrast to *L. laevigatum*, *L. parviflorus* regenerates readily by seed in the mature stands and appears to be much less browsed.

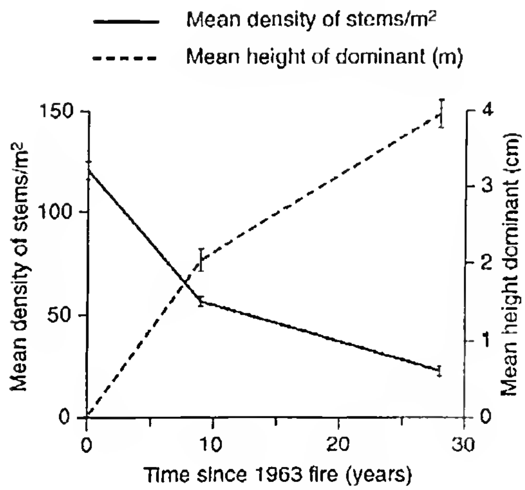

Fig. 8. Mean density and height of *L. laevigatum* regeneration at Chinaman Beach following the fire in NE Wilson's Promontory in 1962.

Regeneration of mature scrub in the absence of fire

Seed sources and germination requirements of L. laevigatum. The seed of *L. laevigatum* is small and fine (2.0 x 0.5 mm) with a potential viability of 91%. In the laboratory, germination is inhibited at 3°C and above 26°C but is optimal from 11°-16° C with 80% germination, when under a 12 hr photoperiod regime. The rate of germination is increased by pricking the seed coat and by stratifying for several weeks at 2-4°C. In the field, natural germination occurs between May and September when average maximum temperatures are in the optimal range.

In this area, capsules are stored in the canopy for up to 12 months from late spring flowering. Mean

Fig. 9. Photograph of fenced plot in a gap after 11 years, showing density and height of *L. laevigatum*. (Scale: Alan Andersen 1.9 m).

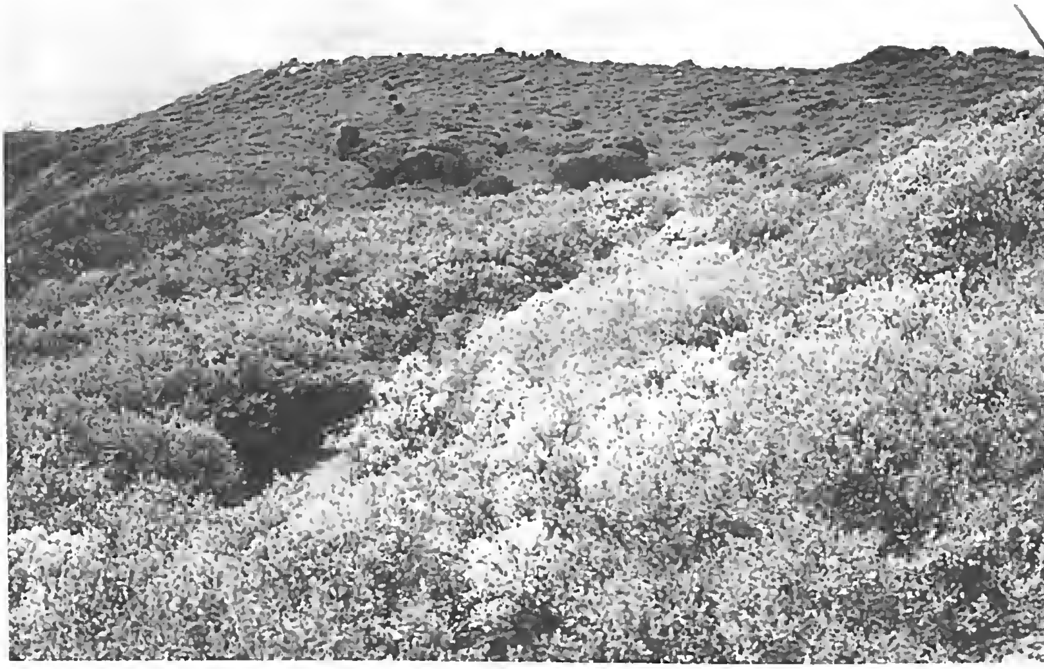

Fig. 10. Dead *L. parviflorus* (pale) amongst living *L. laevigatum* in the drought of summer 1976.

Species	Norman Bay (calcareous)										Leonard Bay (silicious)			
Distance from beach (m)	3	10	32	42	85	100	135	160	175	200	5	40	60	80
Shrubs, climbers														
Leptospermum laevigatum	·	·	1	1	+	1	2	2	1	2	·	+	3	3
Leucopogon parviflorus	·	·	+	1	1	1	1	1	1	1	·	·	2	2
Allocasuarina verticillata	·	·	·	·	1	·	·	·	·	·	·	·	·	·
Ozothamnus turbinatus	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Olearia axillaris	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Correa alba	·	·	2	+	+	·	·	·	·	·	·	1	·	·
Rhagodia candolleana	·	·	+	·	1	2	+	1	·	·	·	2	·	·
Tetragonia implexicoma	·	·	·	1	1	1	2	+	3	2	·	+	·	·
Clematis microphylla	·	·	+	1	1	+	+	+	+	+	·	·	·	·
Phyllanthus gunnii	·	·	·	·	·	·	1	·	·	·	·	·	·	·
Bursaria spinosa	·	·	·	·	·	·	+	+	+	·	·	·	·	·
Exocarpos syrticola	·	·	·	·	·	·	·	·	·	·	·	1	1	2
Calocephalus brownii	·	·	·	·	·	·	·	·	·	·	+	1	+	·
Grevillea lanigera	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Spyridium parvifolium	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Muehlenbeckia adpressa	·	·	·	·	·	·	·	·	·	·	·	1	·	·

Table 1. Species composition along transects normal to coast from high tide. Plots 10x1m at intervals (m). Cover estimated by Braun Blanquet scale: + (<1%), 1 (1-5%), 2 (5-25%), 3 (25-50%), 4 (50-75%), 5 (75-100%). * introduced.

Species	**Norman Bay (calcareous)**										**Leonard Bay (silicious)**			
Distance from beach (m)	**3**	**10**	**32**	**42**	**85**	**100**	**135**	**160**	**175**	**200**	**5**	**40**	**60**	**80**
Hibbertia sericea	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Forbs														
Euphorbia paralias *	+	3	·	+	·	·	·	·	·	·	·	·	·	·
*E. peplus**	·	·	+	·	+	+	+	+	·	·	·	·	·	·
Senecio elegans *	·	·	+	+	·	·	·	·	·	·	·	+	·	·
S. lautus	+	·	+	+	1	·	·	·	·	·	·	+	+	+
S. biserratus	·	·	·	+	+	+	+	+	+	·	·	·	·	·
Cakile maritima	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Sonchus asper *	·	+	·	·	·	·	·	·	·	·	·	·	·	·
S. oleraceus *	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Carpobrotus rossii	·	+	+	+	·	·	·	·	·	·	·	+	·	·
Galium sp.	·	·	+	+	·	·	·	+	·	·	·	·	+	·
Swainsona lessertiifolia	·	·	+	+	+	+	+	1	+	·	·	·	·	·
Daucus glochidiatus	·	·	+	+	+	+	+	+	+	+	·	1	+	+
Cynoglossum suaveolens	·	·	·	+	·	·	+	·	·	·	·	+	+	+
Dichondra repens	·	·	·	+	+	+	·	1	+	+	·	·	·	·
Parietaria debilis	·	·	·	+	+	+	+	·	+	+	·	·	·	·
Melilotus indica *	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Hydrocotyle sp.	·	·	·	·	·	·	·	+	1	·	·	·	·	·
Lagenophora stipitata	·	·	·	·	·	·	·	+	+	·	·	·	·	·
Centaurium erythraea *	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Oxalis corniculatus	·	·	·	·	·	·	·	·	·	·	·	+	+	·
Crassula sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Acaena anserinifolia	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Monocotyledons														
Thinopyrum junceiforme	2	+	1	+	·	·	·	·	·	·	+	·	·	·
Ammophila arenaria	·	·	1	·	·	·	·	·	·	·	·	·	·	·
Lepidosperma gladiatum	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Isolepis nodosa	·	+	+	·	+	+	·	·	·	·	·	1	+	+
Poa sp.	·	·	·	+	·	·	·	·	·	·	·	·	·	·
Lagurus ovatus	·	·	1	1	+	·	·	+	·	·	·	·	·	·
Carex inversa	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Caladenia latifolia	·	·	·	·	·	+	+	+	+	+	·	·	·	·
Dianella revoluta	·	·	·	·	·	·	·	·	·	·	·	+	+	·
Lomandra filiformis	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Cryptogams – Mosses														
Thuidium laeviusculum	·	·	·	1	+	2	3	2	1	+	·	·	·	·
Tortula princeps	·	·	·	+	·	·	·	·	·	·	·	·	·	+
Tortella calycina	·	·	·	·	+	+	·	+	·	·	·	·	·	·

Table 1. cont.

seedfall in May was 1400 m^{-2} under canopy and 25 m^{-2} in gaps 5 m in diameter, but in the ensuing four months this was reduced by 20-55%. Total yearly seedfall is likely to be adequate for regeneration. Long term storage of seed in the soil seems unlikely since in winter 1977, 91% of all germination was recorded from the upper 1 cm suggesting that it was derived from current seedfall.

Losses of seed from the soil surface were very high (90% in 24 hours) in May but were nil in August. Ants were observed taking *L. laevigatum* seed into their nests. The natural germination recorded from permanent quadrats over the period April to October 1977 was very low, viz: 1.0 m^{-2} under canopy and 0.75 m^{-2} in gaps.

Regeneration sowing trials. Initial germination 5 weeks after sowing was 84-100% of that predicted from the number of viable seed sown. After 4.5 months, mean survival inside fences was 15.1% of initial germination, whereas outside the fences it was 0.9%. Variability between blocks and plots was very high, hence although mean survival on bare soil and litter was 20.8% and 9.4% respectively, the difference was not statistically significant. Growth was slow and seedlings were only 1-2 cm tall at this time. After 3 years regeneration in the fenced plot was relatively

Species	Scrub	
Shrubs and climbers	Immature	Mature
Leptospermum laevigatum	*5 (4)*	*3 (2)*
Leucopogon parviflorus	*2 (+)*	*4 (+)*
Allocasuarina verticillata	*1 (+)*	*1 (+)*
Correa alba	*1 (+)*	*2 (1)*
Rhagodia candolleana	*3 (+)*	*2 (+)*
Tetragonia implexicoma	*2 (+)*	*4 (2)*
Clematis microphylla	*4 (+)*	*5 (+)*
Forbs		
Daucus glochidiatus	*4 (+)*	*5 (+)*
Parietaria debilis	*3 (+)*	*3 (+)*
Dichondra repens	*5 (+)*	*3 (+)*
Lagenophera stipitata	*2 (+)*	*2 (+)*
Senecio biserratus	·	*2 (+)*
Solanum *sp.*	*1 (+)*	·
Sonchus oleraceus *	*1 (+)*	*2 (+)*
Stellaria media *	·	*3 (+)*
Swainsona lessertiifolia	*2 (+)*	*2 (+)*
Viola hederacea	·	*5 (+)*
Caladenia latifolia	*4 (+)*	*4 (+)*
Centaurium erythraea *	·	*2 (+)*
Cynoglossum suaveolens	·	*1 (+)*
Graminoids		
Poa sp.	3 (+)	2 (+)
Lagurus ovatus	·	2 (+)
Bryophytes		
Thuidium laeviusculum	5 (+)	5 (1)
Tortula princeps	3 (+)	4 (+)
Lophocolea sp.	·	1 (+)
No. species	18	24

Table 2

Frequency and cover value(s) of species in immature and mature scrub, Norman Bay, 1984.

Five plots (10x1m). Cover values: + (<1%), 1 (1-5%), 2 (5-25%), 3 (25-50%), 4 (50-75%), 5 (75-100%). * introduced.

dense (up to 38 per plot), whereas outside the fences survival was nil. Two of the fenced plots were broken into after 4-5 years and all seedlings were stripped and killed. After 11 years the bushes in the remaining plot were capsule-bearing and vigorous (Fig 9), and after 22 years had reached heights of 8-9 m. Outside the were fences impenetrable thickets of *Bursaria spinosa* had developed- no doubt as a result of their effective physical defence against browsing to heights of at least 2 m. In the first year of the trial, it is likely that animal and/or bird scratching could have decimated unprotected germinates. Activity by wombats (*Vombatus ursinus*) was considerable around the plots. Browsing of larger seedlings could have been due to these animals as well as wallabies (*Wallabia bicolor*), European rabbits (*Oryctolagus cunnuculus*) or hog deer (*Cervus porcinus*). *Correa alba* and *Rhagodia candolleana* seedlings were also severely browsed but many other species such as *Leucopogon parviflorus*, *Phyllanthus gunnii* and the herbs, *Senecio biserratus* and *Swainsona lessertiifolia* were untouched and were probably unpalatable.

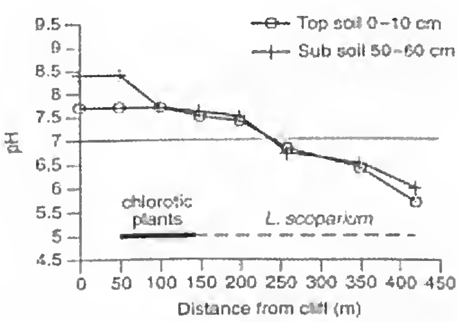

Fig. 11. Water potential (-bars) in shoots of *Leptospermum laevigatum* and *Leucopogon parviflorus* in relation to relative water content (% maximum uptake) in a severedrought, March 1976.

The effect of environmental stresses on the two dominant shrubs. *Leptospermum laevigatum* and *Leucopogon parviflorus* is different. In both 1975-76 and 1991-92 severe drought in this area resulted in yellowing and considerable foliage and branch death of both these species. In each case damage of *L. parviflorus* was considerably greater than that of *L. laevigatum* and sometimes resulted in the death of the whole shrub (Fig. 10). In early March 1976 the pre-dawn water potentials of shoots of *L. parviflorus* (-1.88 mPa) was significantly lower than that of *L. laevigatum* (-1.32 mPa)($t = 2.58$, $p<0.05$) for 5 replicates, indicating a greater degree of water stress in the former species. During a drying cycle of cut shoots the water potential of *L. parviflorus* was consistently lower than that of *L. laevigatum* for given relative leaf water contents (the water content as a percentage of maximum)(Fig. 11). Excavation of soil profiles revealed that in general, the roots of *L. parviflorus* were concentrated in the top half metre of soil whereas those of *L. laevigatum* were distributed more evenly and to a greater depth

DISCUSSION

The two adjacent dune systems are different in size, complexity and species composition. The beach sands are either very rich in $CaCO_3$ (yellowish) or very low (white) and the dunes which develop from them are therefore either acid or alkaline. Leonard Bay being steeply dipping, allows high energy waves at high tide to actively attack dunes. Norman Bay on the other hand shelves gradually and the beach is very wide and, although high tides and storms can result in dune attack, the recent environment has been conducive to foredune build up. Since air movement at ground level in dense

Scrub stage	Species	Density(No ha^{-1})	Mean Ht.(m)	Mean Girth at 30cm (cm)
Immature	*Leptospermum*	11991	4.6	16.3
	Leucopogon	3280	2.8	5.7
Mature	*Leptospermum*	5253	7.5	29.5
	Leucopogon	5016	2.5	9.2

Table 3. Comparitive stature of *Leptospermum laevigatum* and *Leucopogon parviflorus* in mature and immature scrub, Norman Bay dunes, 1984

dune scrub is slight- even during storms, it is considered that the very fine sand caught by bark and epiphytes 90 m inland has been derived from aerial transport from the beach Without doubt, the amount deposited in any year will be determined by the frequency and strength of onshore W-SW winds. It is possible that the fineness of the sand texture at Norman Bay is a major factor allowing such movement inland. Although the amount detected in cups in 1999-2000 was not great, a continual dusting of fine calcareous sand from the beach over decades or centuries could ameliorate normal podzolizing processes to some extent. The parallel dune systems are younger than the acid parabolic dunes and sand sheets in the hinterland where deep humus podzols are now developed (Parsons 1966).

In both dune systems the dune scrub of *L. laevigatum* and *L. parviflorus* is a relatively stable stage of development. The scrub on the Leonard Bay front dune is relatively poor in species and open areas are vegetated by conspicuous cushions of *Calocephalus brownii*. The more extensive scrub at Norman Bay is richer in species, certain of which (*Swainsona lessertiifolia*), are confined to the calcareous dunes. It appears to be a calcicole since it occurs on similar soils at both Yanakie Isthmus and Point Nepean. On the acid dune at Leonard Bay some of the heathland sclerophylls which occur in more open areas of scrub, may be calcifuges. The scrub on the Norman Bay dunes is composed of stands of different ages which are almost certainly related to past fires. Seedling regeneration of *L. laevigatum* following fire can be extremely prolific and thinning out of seedlings occurs very rapidly in the first few years. *L. laevigatum* eventually becomes senescent and prone to opening-up by storm damage. After 30 years the young stand studied in 1972 at Norman Bay had matured and the old stand had become moribund with many leaning and fallen stems of *L. laevigatum*. However the associated sub-dominant, *L. parviflorus*, had increased in both stature and cover and the diversity of the ground stratum had increased- probably as a result of increased light and soil moisture. Contrary to earlier years, occasional seedlings of *L. laevigatum* could be found in a few gaps, possibly as a result of the protection afforded by debris, tall herbs (such as *Senecio biserratus*), or from a decrease in the numbers of herbivores following rabbit control measures. The general lack of *L. laevigatum* regeneration in previous decades was not due to lack of seedfall but probably to a reduction of seed supply available for germination combined with summer droughts and severe browsing of established seedlings. It seems likely in previous decades, that the generally clear understorey and floor has enabled browsing animals to effectively control regeneration of palatable species. A corollary of this argument is provided by the massive invasion of dense heathland by *L. laevigatum* where the visibility of seedlings to herbivores such as swamp wallabies is impeded. *L. laevigatum* is fire-sensitive and easily killed. If fire occurs in its first 5 years, before seed has been produced, this species may be eliminated from a site. If fire does not occur for very long intervals and herbivore populations are high this species may not regenerate adequately. In some respects its ecology is similar to that of wet eucalypt forest species (Ashton & Chinner 1999).

Germination of *L. laevigatum* occurs in the cooler wetter months of the year but early growth is very slow and in dry years great losses could have occurred in spring and summer. After fire *Leucopogon parviflorus* usually regenerates from buds at or below ground level as well as from seed. It is dispersed actively by birds. As the stand matures *L. parviflorus* increases in prominence and in senescent stands may comprise much of the canopy. Without the intervention of fire stands of dune scrub at Wilson's Promontory are likely to become increasingly dominated by *L. parviflorus* -

Favouring factor			
Fire	*L. laevigatum*	¬	*L. parviflorus*
Very frequent fire < 5 yrs	*L. laevigatum*	®	*L. parviflorus*
No fire for 50-100 years	*L. laevigatum*	®	*L. parviflorus*
Very frequent severe drought	*L. laevigatum*	¬	*L. parviflorus*
No fires, no herbivores	*L. laevigatum*	+	*L. parviflorus*

Table 4. Suggested scenarios for oscillation of dominance between *Leptospermum laevigatum* and *Leucopogon parviflorus* in calcareous dune scrub, Norman Bay.

a scenario well documented by Hazard and Parsons (1977) at Western Port. However at both sites, the role played by *Allocasuarina verticillata* in the dynamics is not clear. Although at Norman Bay it occasionally regenerates from seed and root suckers, it does not appear likely to become a major species at that site - in marked contrast to the situation on some of the calcareous dunes on Yanakie Isthmus.

The oscillation of dominance of these two species may also be affected by drought, since *L parviflorus* may be more severely damaged than *L. laevigatum* and possibly killed. Following prolonged periods of drought therefore, the dominance of *L. laevigatum.* may increase.

In the Norman Bay area fire regimes would need to be delicately balanced to preserve the *status quo* of vegetation types. We know little of the past aboriginal activities in this area except that kitchen middens of shells and charcoal are common around the coastline. It seems likely therefore that coastal and sub-coastal communities were burnt more frequently than the inland slopes and mountain tops. Given the rapidity with which heathland is invaded and suppressed by *L. laevigatum* from the coast and by *Kunzea ambigua* from adjacent rocky outcrops, and given the ease with which both species are killed by fire (Judd 1986), it is not beyond the bounds of possibility that in the past much heathland was anthropologically maintained by fire frequency.

To conserve vegetation types we must know the controlling factors and we must decide what we want conserved. If nothing is done that is a management option; if we leave it to chance, that is also an option. If we want a certain type of dune scrub or a floristically rich heathland to remain as such, some intervention is necessary. To this extent conservation is frequently a value judgement. A scenario of factors affecting the dominance of overstorey in dune scrub is shown in Table 4.

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SHORT COMMUNICATION

A NEW DISTRIBUTION RECORD FROM VICTORIA FOR THE BLOWFLY, CHRYSOMYA INCISURALIS (MACQUART) (DIPTERA: CALLIPHORIDAE)

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Archer, M.S. & Wallman, J.F., 2002:09:30. A new distribution record from Victoria for the blowfly *Chrysomya incisuralis* (Macquart) (Diptera: Calliphoridae). *Proceedings of the Royal Society of Victoria* 114(1/2): 59-60. ISSN 0035-9211.

Key words: blowfly, Calliphoridae, *Chrysomya incisuralis*.

THERE IS SCANT knowledge about the basic biology of many Australian calliphorids, and this is especially true of species that are not implicated in livestock myiasis or utilised forensically. Due to the lack of available data on such species, it is important that any information collected is documented. Here we present the first recorded occurrence of the blowfly *Chrysomya incisuralis* (Macquart) in Victoria. Previously, the species was thought to be limited to Queensland and New South Wales (Kurahashi, 1989).

Two gravid female *C. incisuralis* were captured at Coranderrk Bushland, Healesville (37°40'59S, 145°31'07E). The habitat at this site is damp sclerophyll forest dominated by *Eucalyptus cephalocarpa* (silverleaf stringybark), *E. aromaphloia* (scent-bark), *E. obliqua* (messmate stringybark), and *Coprosma quadrifida* (prickly currant bush). Both specimens were sweep netted (15 Feb 1999 and 8 Feb 2001) at still-born piglet carcasses that had been exposed for two and three days, respectively.

In Australia, the subfamily Chrysomyinae, to which *C. incisuralis* belongs, is distributed predominantly in the north (Colless & McAlpine 1991). Previously, the only *Chrysomya* species known to occur in Victoria were *Chrysomya rufifacies* (Macquart) and *C. varipes* (Macquart). However, *C. incisuralis* is easily distinguished from these species by its unusual colouration. It has a yellow abdomen, with tergites 1+2 to 4 each with a black hind marginal band and central metallic green/blue markings. It also has yellow legs, black tarsi and a metallic green thorax (Bezzi 1927, Malloch 1927).

While almost nothing is known about its biology (Kitching & Voeten 1977), *C. incisuralis* is thought to be a carrion-breeder like the con-generic *C. rufifacies* and *C. varipes* (Kitching 1976). However, while it has been bred from meat in the laboratory (Kitching & Voeten 1977), it has never been reared from carcasses in the field. It was also apparently reared from cow dung on one occasion, however it is unclear whether the species identification was correct in this case (Hardy 1940).

In southern Victoria, *C. rufifacies* and *C. varipes* occur only in warm to hot weather. They do not overwinter as adults or juveniles, and instead re-populate the southernmost portion of their range between November and March (M. Archer, unpublished data). It is probable that *C. incisuralis* also does this, as both specimens were captured in hot weather; temperatures recorded at the site at the times of capture were 29°C and 24°C, respectively. This probably reflects a requirement of the species for warmth, similar to that of *C. rufifacies* and *C. varipes*.

The species also seems to be uncommon in the south of Victoria as it was trapped only twice in three years of intensive work at the Healesville site. It was also not seen elsewhere around Melbourne during these three years at other carrion baits or carcasses. Possibly, *C. incisuralis* is more common in the north of the state where temperatures tend to be higher for a larger part of the year. Alternatively, conditions in Victoria may be largely unsuitable for the species , thus making its appearance a rare event.

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PATTERNS OF ABUNDANCE AND HABITAT USE BY *NANNOPERCA OBSCURA* (YARRA PYGMY PERCH) AND *NANNOPERCA AUSTRALIS* (SOUTHERN PYGMY PERCH)

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WOODWARD, GREG M.A. & MALONE, BRIAN S., 2002:09:30. Patterns of abundance and habitat use by *Nannoperca obscura* (Yarra pygmy perch) and *Nannoperca australis* (Southern pygmy perch). *Proceedings of the Royal Society of Victoria* 114(1/2): 61-72. ISSN 0035-9211.

Nannoperca obscura (Yarra pygmy perch) and *Nannoperca australis* (Southern pygmy perch) appear to have undergone differential declines in abundance and distribution since European settlement. We examined patterns of abundance and habitat use of these species in allopatry and sympatry. While the pattern of habitat use by *N. obscura* was very similar to that of *N. australis* in allopatry, it was restricted to only a small proportion of available habitats and excluded from the floodplain when sympatric with *N. australis*. Habitats utilised by *N. obscura* when sympatric with *N. australis* were also occupied by relatively large numbers of *Perca fluviatilis* (Redfin). We speculate that the different patterns in abundance of pygmy perch among sites were largely due to interactions between size-fecundity relationships, habitat use sometimes mediated by interspecific competition, and predation intensity by *P. fluviatilis*.

Key words: Nannoperca obscura, N. australis

NANNOPERCA AUSTRALIS (Southern pygmy perch) and *Nannoperca obscura* (Yarra pygmy perch) are small, perch-like fishes endemic to south-eastern Australia. The two species are morphologically (Kuiter and Allen 1986) and ecologically similar (Backhouse & Gooley, 1979; Kuiter et al. 1996). While *N. australis* can attain a maximum size of 85 mm, *N. obscura* is slightly smaller, reaching a maximum size of 75 mm (Allen et al. 2002). Both species inhabit slow flowing or still waters with abundant aquatic vegetation and are often found together (Kuiter et al. 1996). Their diets are similar and include planktonic crustaceans, aquatic insects and their larvae (Kuiter et al. 1996). The breeding season of *N. obscura* (September – October) overlaps with that of *N. australis* (September – January) (Allen et al. 2002).

Nannoperca obscura has been recorded from only 24 localities in southwestern Victoria and southeastern South Australia and appears to have undergone large-scale reductions in its distribution and abundance since European settlement (Kuiter et al. 1996; DNRE 1998). It has been suggested that the decline is probably due to habitat loss and modification, and interactions with introduced species (Wager & Jackson 1993; Kuiter et al. 1996). The species is considered 'threatened' and currently listed as 'vulnerable' (Wager & Jackson 1993; Groombridge & Mace 1994).

While *N. australis* is still considered a common and widespread species in Victoria (Koehn & O'Connor 1990), it also appears to have suffered population declines, although not as severe as *N. obscura* (Kuiter et al. 1996). Although habitat loss and modification have been identified as probable causes of their declines, no detailed studies have been carried out on habitat use of *N. obscura* and *N. australis*. This study compares habitat use of these two species of pygmy perch during spring-summer, and hypotheses are proposed to explain the differential decline of *N. obscura* and *N. australis*.

METHODS

Site Selection

Habitat use by sympatric *N. obscura* and *N. australis* was investigated at two sites in Deep Creek. Deep Creek is a second order stream located in south central Victoria that flows south into the Maribyrnong River system. The upper reaches of Deep Creek contain slow moving water most of the year, with a silt and gravel substratum. The Deep Creek 1 site was located at Linehan's Bridge (37°15'S 144°42'W), and the Deep Creek 2 site was located approximately 2 km downstream at Mustey's Bridge (37°15'S 144°44'W). Habitat use by *N. obscura* in the absence of *N. australis* was investigated at Woady Yaloak River, which represents the only known allopatric population of this species (DNRE 1998). The Woady Yaloak River is a third order stream located in southwest Victoria that runs into Lake Corangamite. It is normally slow flowing, with a mud, sand and gravel bottom. The Woady Yaloak River site was located at the Hamilton Highway bridge (37°47'S 143°34'W). Deep Creek sites were sampled on four occasions, and Woady Yaloak River on two occasions.

Site Descriptions

The physical characteristics of the three sites used in the study were very similar. They were approximately 40 m long and 10 m wide and consisted of a number of well-vegetated, shallow (< 1 m) pools and sparsely vegetated, deep (1 m - 1.5 m) pools. At Woady Yaloak River and Deep Creek 1 low lying inset benches (mini-floodplains) were inundated throughout the sampling period. This created shallow (400 mm depth), low flow habitats containing both semiaquatic and aquatic vegetation. The land surrounding the sites is primarily used for grazing, and little native vegetation remains.

Fish Abundances

Preliminary sampling was conducted at both Deep Creek sites in September 1998. Subsequent sampling occurred once a month between October 1998 and January 1999 except for Deep Creek 1, which was not sampled in January due to low water levels, and Woady Yaloak River, which was not sampled in October and November.

Fish abundances were determined using unbaited funnel traps (commonly referred to as bait traps). Traps measured 500 mm x 250 mm x 250 mm, with 50 mm (diameter) openings located at both ends and a mesh diameter of 4 mm. Abundances were standardised (number of fish caught per trap per hour) in order to account for variation in trapping effort.

Habitat Use

To determine habitat use by fish species, a trapping regime using stratified sampling was employed (Schaeffer et al. 1996; Sutherland 1996). Previous observations indicate that both *N. obscura* and *N. australis* are closely associated with aquatic macrophytes (Backhouse & Gooley 1979; Humphries 1995; Kuiter et al. 1996). Four structurally different habitat types were recognised at each site: submerged and emergent plants with very fine or feathery leaves; emergent plants with narrow leaves; mixture of both types of plants and; open water (channel). Six funnel traps were placed randomly within each habitat. At Woady Yaloak River and Deep Creek 1 an additional 6 traps were placed in floodplain habitats to determine floodplain use by pygmy perch. Traps were always placed more than 2 metres apart. Traps were set for a 24-hour period, and fish removed at dusk and dawn. At the end of the sampling period fish were released immediately after being measured (standard length (SL) to the nearest 1 mm) back into the habitat in which they had been caught. Very light pressure on the belly of females was applied to determine if they were 'spawning' (Kesteven 1960).

Data were analysed using the statistical package JMP (SAS Institute 1995). The Shapiro-Wilk test for normality was performed on all the data, and equality of variances was tested using the O'Briens 0.5 test (Sokal & Rohlf 1995). Parametric or non-parametric statistical tests were used in the analysis, depending upon the outcome of these tests. Abundance data were square root transformed prior to analysis, as some were not normally distributed. Because individual trap success ranged from 0 - 80 individuals, individual traps were considered to be the sampling unit. Comparisons of the relative abundance of pygmy perch in the floodplain and river were made using standard t-tests or Kruskal-Wallis Chi-square tests. Probability values were tested using the sequential Bonferonni technique (Holm 1979) to eliminate bias of a single test significance value (Rice 1989). Habitats within sites were compared using one-way ANOVAs or Kruskal-Wallace Chi-square tests. All among group pair-wise comparisons were undertaken in conjunction with the Tukey-Kramer HSD test for all comparisons. The alpha level was set at 5%.

RESULTS

The same fish species occurred at the three study sites over the sampling period, except that *N. australis* was absent from Woady Yaloak River (Table 1). Additional species collected were *Anguilla australis* (Short-finned eel), *Perca fluviatilis* (Redfin) and *Gambusia holbrooki* (Eastern mosquitofish).

Our results indicate different patterns of temporal and spatial variation in abundance of pygmy perch

Study Site	Sample	*Nannoperca australis*	*Nannoperca obscura*	*Anguilla australis*	*Perca fluviatilis*	*Gambusia holbrooki*
Deep Creek 1	Sept.	15	5	0	0	2
	Oct.	68	18	0	0	5
	Nov.	1100	25	1	1	4
	Dec.	1162	28	2	0	8
Deep Creek 2	Sept.	39	3	0	0	1
	Oct.	74	7	4	0	5
	Nov.	356	20	6	0	7
	Dec.	396	11	2	15	5
	Jan.	314	4	6	27	5
Woady Yaloak River	Dec.	0	135	1	1	2
	Jan.	0	267	1	2	3

Table 1. Total number of fish collected in funnel traps during monthly sampling events between spring 1998 and summer 1999.

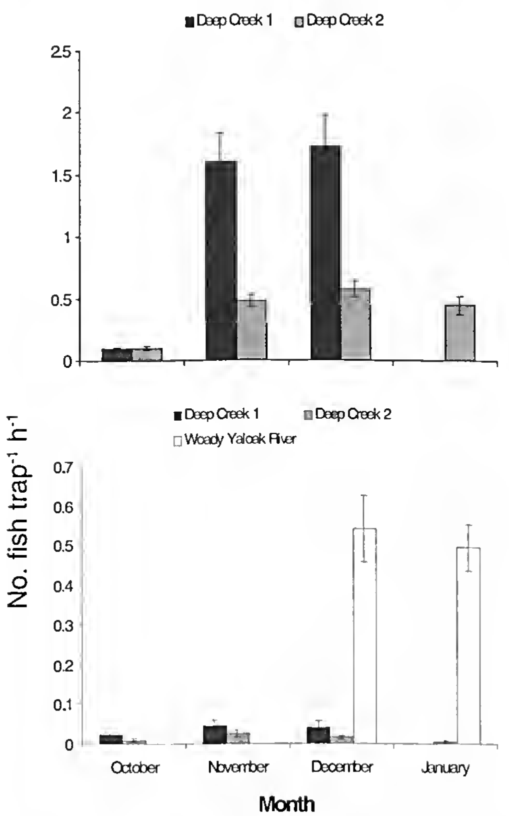

Fig. 1. Mean (± 1 SE) relative abundance (number of fish caught/trap/hour) during spring and summer of (i) *N. australis* at Deep Creek 1 and Deep Creek 2, and (ii) *N. obscura* at Deep Creek 1, Deep Creek 2 and Woady Yaloak River. Woady Yaloak River not sampled in October and November, and Deep Creek 1 was not sampled in January (see text).

populations (Fig. 1). While sizable increases in the relative abundance of *N. australis* occurred in November at both Deep Creek sites, the increase at Deep Creek 1 was substantially greater than at Deep Creek 2. In contrast, *N. obscura* showed little temporal variation at the Deep Creek sites. However, relative abundances of *N. obscura* at Woady Yaloak River were an order of magnitude larger than at both Deep Creek sites.

Length frequency data (Fig. 2) indicated that September samples of *N. australis* from both sites consisted of a small number of adults. Spawning *N. australis* females collected from Deep Creek 1 in September were significantly larger than those collected at Deep Creek 2 (Mean SL= 40.4mm vs. 32.9mm: Kruskal-Wallis Chisquare, X^2=10.31, d.f.=1, p=0.001). While substantial increases in its abundance occurred at both sites in November as a result of juvenile recruitment, the increase was much smaller at Deep Creek 2 despite similar aduult abundances two months earlier. Sample size was insufficient to compare size of *N. obscura* spawning females. The relatively small adult populations and low juvenile recruitment of *N. obscura* resulted in little change to abundances at both Deep Creek sites over the sampling period.

Significantly more *N. obscura* were trapped on the floodplain compared to the river at Woady Yaloak (Table 2). In contrast, larger numbers of *N. obscura* were trapped in the river at Deep Creek 1. Trapping success for *N. australis* at this site was significantly greater on the floodplain than in the river for all trapping episodes. These results indicate that *N. obscura* freely utilised the floodplain in allopatry but were seldom found there when sympatric with *N. australis*.

The patterns of habitat use by *N. australis* (Fig.

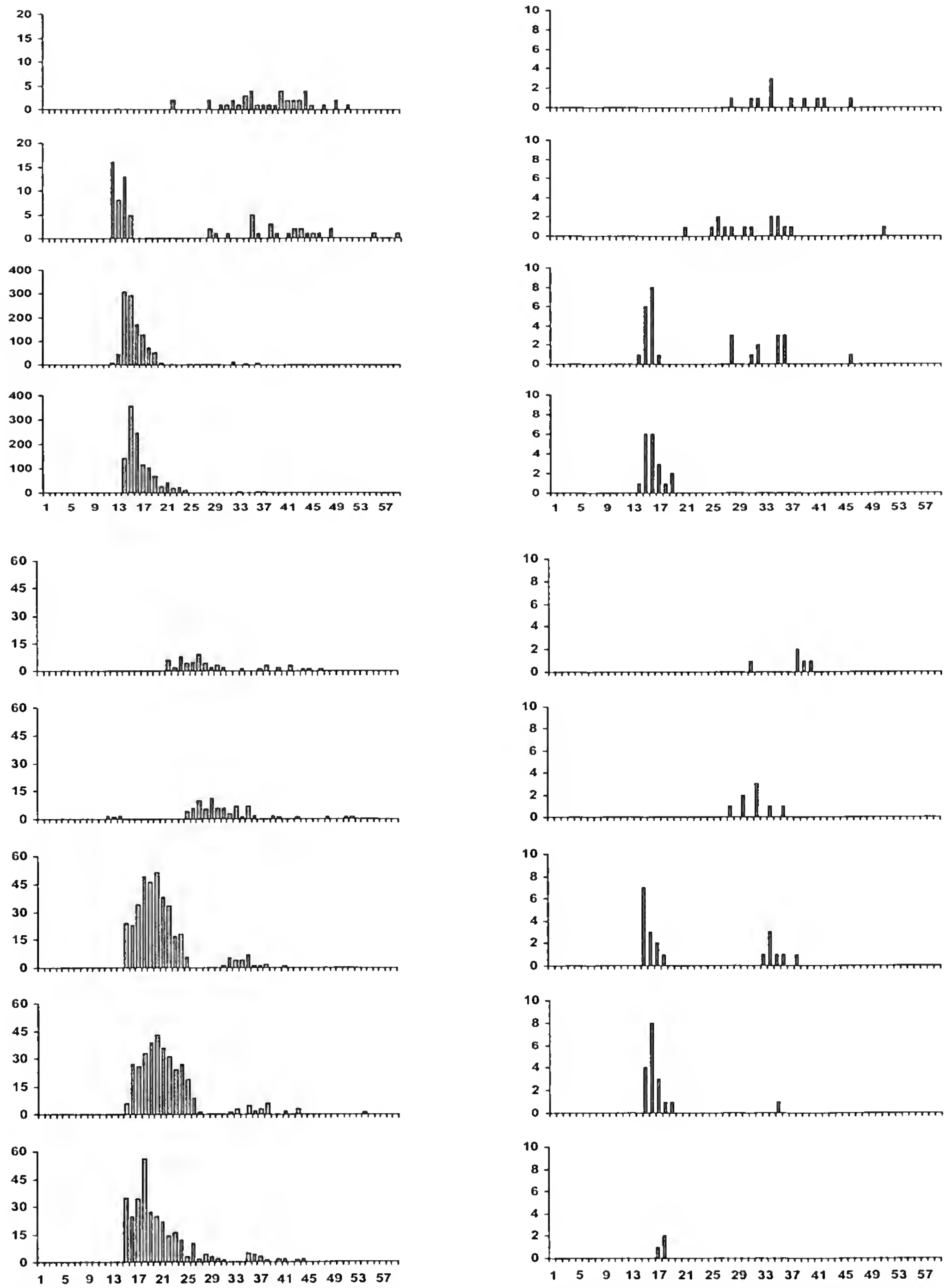

Fig. 2. Size variation (standard length in mm) of (i) *N. australis* and (ii) *N. obscura* individuals collected from (a) Deep Creek 1 and (b) Deep Creek 2 between September 1998 and January 1999. (Note the different scales on the Y-axis and that adult *N. australis* are not visible in November/December at Deep Creek 1 because of scale)

3) and *N. obscura* (Fig. 4) differed at both Deep Creek sites in that *N. australis* utilised all available habitats, but *N. obscura* was largely restricted to only two habitats (those with both submerged and emergent feathery plants and the channel). At Woady Yaloak River *N. obscura* used all available habitats (Fig. 5). While the types of habitats at the two streams were very similar, the pattern of habitat use by *N. obscura* differed when *N. australis* was present. *Nannoperca obscura* exhibited a similar pattern of habitat use to that of *N. australis* when in allopatry. All vegetated habitats were occupied, and relatively few individuals were trapped in the channel.

The number of potential predators of pygmy perch caught in each habitat is shown in Table 3. We recorded pygmy perch in stomach contents of a small number of *P. fluviatilis* and *A. australis* (unpublished data). While pygmy perch were not recorded from *G. holbrooki* in this study, it is likely to be a predator of only eggs and larvae. Relatively large numbers of *A. australis* and *P. fluviatilis* were collected at Deep Creek 2 compared to Deep Creek 1, suggesting that their abundance was greater at the former site. *Anguilla australis* was caught in all habitats except the channel. *Perca fluviatilis* was caught in all habitats, with the largest numbers occurring in channel habitats and those with submerged and emergent feathery vegetation. *Nannoperca obscura* was also largely restricted to these habitats at this site. Relatively small numbers of *P. fluviatilis* were caught at Woady Yaloak River.

DISCUSSION

Unbaited funnel traps proved to be an effective and non-intrusive way of capturing pygmy perch. Although variation in trapping success of pygmy perch may have been influenced by several factors, including fish density, fish activity, trapping effort and trap density, the sampling regime used in the study probably provided good estimates of the abundances of both species among sites and habitats. However, trapping success of funnel traps undoubtedly produced underestimates of predator abundances because of size bias.

The patterns of temporal changes in abundance of *N. obscura* and *N. australis* at the study sites may have been due to differences in fecundity, spawning success, mortality (particularly of juveniles) and/or emigration. Adult populations of *N. obscura* were much smaller than those of *N. australis* at Deep Creek, but juvenile recruitment was also substantially lower than expected based upon adult numbers in the spring, particularly at Deep Creek 2. Fecundity of a *N. australis* stream population was found to range from 78 to 679 (Humphries, 1995), depending upon female size. While the fecundity of *N. obscura* is not known, it may be similar to that of *N. australis* given the similar size and shape of the two species. Although *N. obscura* was not sampled from the Woady Yaloak River site in spring, samples collected in summer suggest that adult survivorship and juvenile recruitment was relatively high, resulting in summer populations that were an order of magnitude larger than the Deep Creek sites.

Abundance patterns of *N. australis* may have been largely determined by differences in fecundity and predator abundance at a site. The lower number of individuals at Deep Creek 2 may have been partly due to the smaller body size of spawning females. Fecundity in *N. australis* has been found to be correlated with body size (Humphries 1995). Intraspecific variation in fecundity is common in fish (Healy & Heard 1984; Humphries 1989) and may be due to factors such as variation in food supply (Bagenal 1969) and age/size dependent mortality (Reznick & Endler 1982).

The larger number of *P. fluviatilis* and *A. australis* caught at Deep Creek 2 also suggests that the lower numbers of *N. australis* at this site during spring-summer may have been due in part to larger populations of these predators of pygmy perch. While abundances of *N. obscura* among sites may have also been influenced by predation by these piscivores, competition with *N. australis* (see below) may have resulted in higher predation rates of *N. obscura* at Deep Creek (especially Deep Creek 2) compared to Woady Yaloak River.

The floodplain was utilised by both species of pygmy perch during late spring - early summer when available at Deep Creek and Woady Yaloak River. *Nannoperca australis* was found in significantly higher numbers on the floodplain compared to the main river at Deep Creek 1. *N. obscura* was also caught in significantly higher numbers on the floodplain at Woady Yaloak River however, it was virtually absent from this habitat at Deep Creek 1. While floodplain habitat does not appear to be essential for *N. australis* and *N. obscura*, the relative abundance of *N. obscura* was lower when absent from the floodplain (Deep Creek 1), or when a floodplain failed to develop because of channel characteristics (Deep Creek 2).

Floodplain habitat is important to many native fish, particularly as a nursery providing plentiful food (Geddes & Puckridge 1988). Floodplains also appear to be utilised by other species of pygmy perch as nurs-

Species	Site	Sample	Total Number of Fish (floodplain)	Relative abundance (floodplain)	Total Number of Fish (main river)	Relative abundance (main river)	t-test/X^2	d.f.	p value
N. australis	Deep Creek 1	Oct.	50	0.14 ±0.03	18	0.05±0.02	-2.99 [a]	70	0.004
		Nov.	766	2.25 ±0.39	334	0.95 ±0.23	-3.06 [a]	70	0.003
		Dec.	787	2.38 ±0.40	375	1.07 ±0.26	-2.79 [a]	70	0.007
N. obscura	Deep Creek 1	Oct.	0	0 ±0	18	0.48 ±0.02	11.37 [b]	1	<0.001
		Nov.	3	0.01 ±0.01	25	0.08 ±0.03	9.68 [b]	1	0.002
		Dec.	0	0 ±0	28	0.08 ±0.03	8.84 [b]	1	0.003
N. obscura	Woady Yaloak River	Dec.	104	0.84 ±0.11	30	0.24 ±0.06	-5.27 [a]	26	0.001

[a] =t-test [b] =X^2(Kruskal-Wallis Chisquare)

Table 2. Total number and comparison (t-test or Kruskal-Wallis Chisquare test) of the mean (±1 SE) relative abundance (number of fish caught/trap/hour) of *N. australis* and *N. obscura* on the floodplain and main river at Deep Creek 1 and Woady Yaloak River.

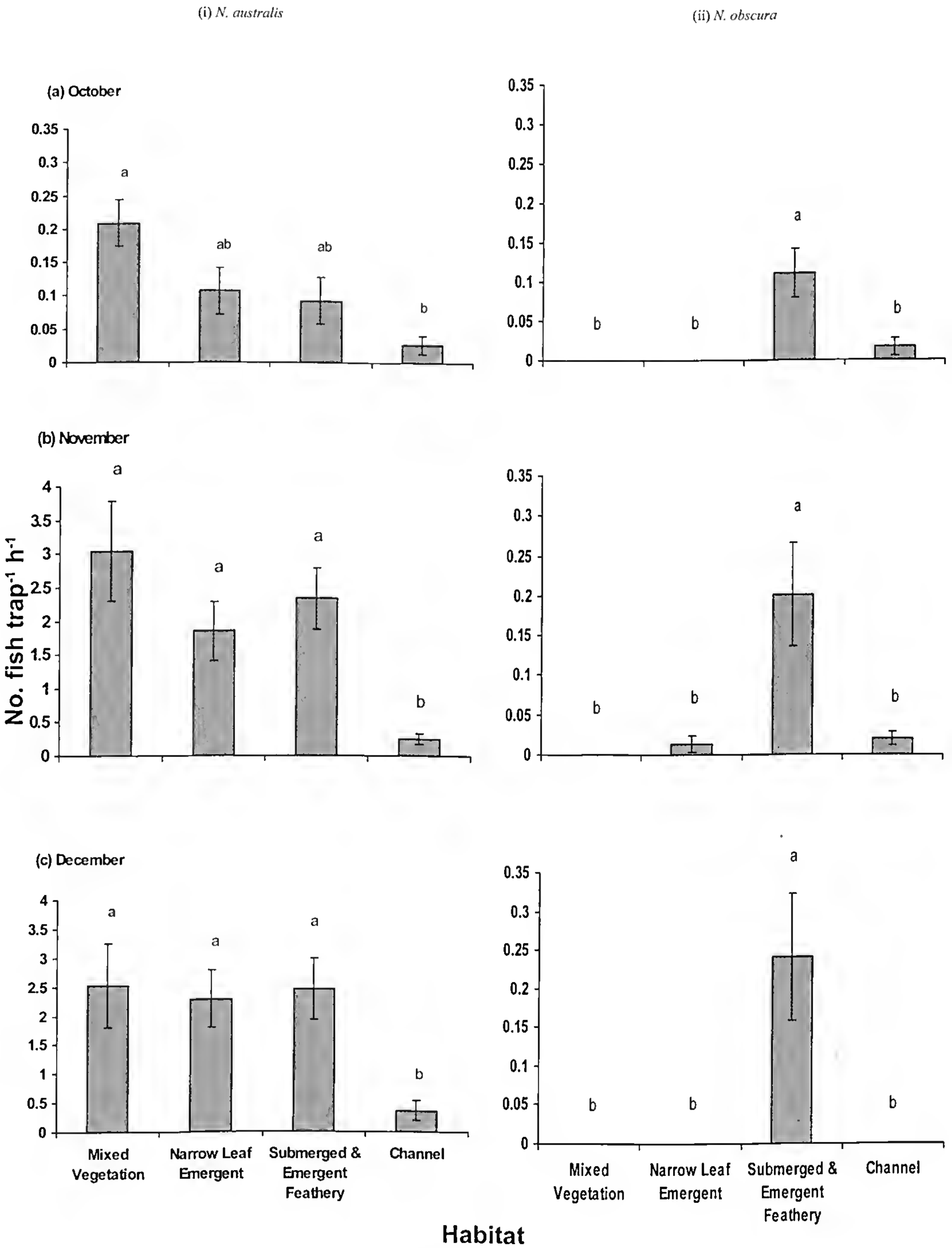

Fig. 3. Trapping success (number of fish caught/trap/hour) for *N. australis* and *N. obscura* at each habitat in Deep Creek 1. Tukey-Kramer tests were used to compare all habitat pairs. Means with the same letter are not significantly different ($p \geq 0.05$) for that graph. Note the different scales on the Y axes..

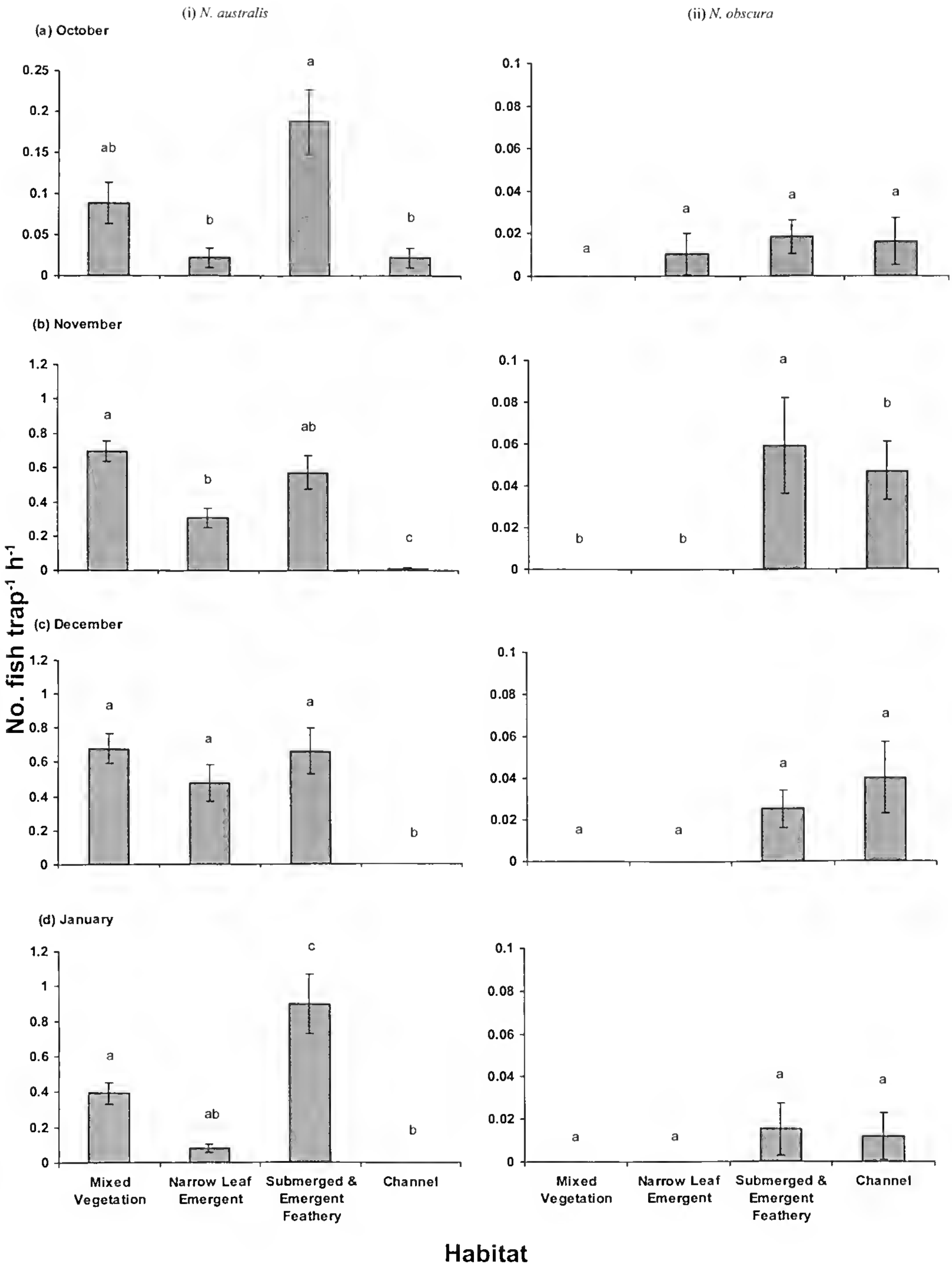

Fig. 4. Trapping success (number of fish caught/trap/hour) for (i) *N. australis* and (ii) *N. obscura* in each habitat at Deep Creek 2. Tukey-Kramer tests were used to compare all habitat pairs. Means with the same letter are not significantly different ($p \geq 0.05$). Note the different scales on the Y axes.

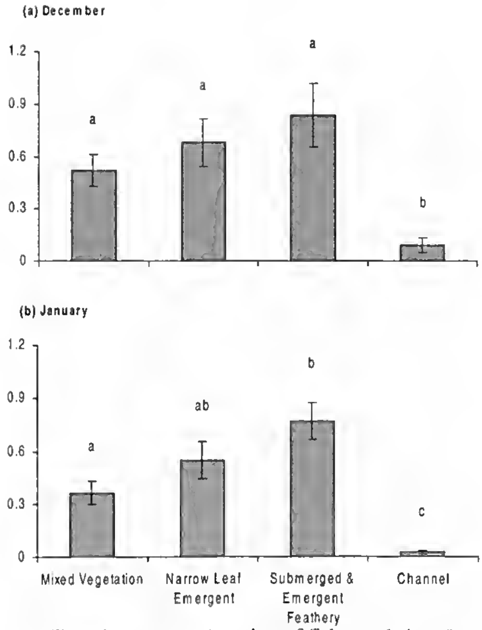

Fig. 5. Trapping success (number of fish caught/trap/hour) for *N. obscura* in each habitat at Woady Yaloak River. Tukey-Kramer tests were used to compare all habitat pairs. Means with the same letter are not significantly different ($p \geq 0.05$).

eries. *Nannatherina balstoni* (Balston's pygmy perch) (Morgan et al. 1995) and *Edelia vittata* (Western pygmy perch) (Pen & Potter 1991) move onto the floodplain after heavy flooding prior to spawning.

Nannoperca australis and *N. obscura* have been previously associated with aquatic macrophytes (Llewellyn 1974; Cadwallader 1979; Jackson & Davies 1983). This close association was also exhibited by both species in this study. While *N. australis* showed only an occasional preference for particular vegetated habitats, the channel habitat was generally avoided. Backhouse & Gooley (1979) and Humphries (1995) found *N. australis* has a strong preference for shallow water with low to zero velocity. The channel habitats at Deep Creek were characterised by deep water, little vegetation, and stronger current flows compared to other habitats, which probably accounts for the low number of *N. australis* recorded in this habitat.

While habitat floristics do not appear to be important, *N. australis* was trapped at relatively low numbers in areas containing *Myriophyllum*, despite the high density of macrophytes and shallow water. Relatively large numbers of *P. fluviatilis* were also caught in these areas, and some had been feeding on pygmy perch. Humphries (1995) indicated that *N. australis* is an important prey item for *P. fluviatilis*, and Hutchinson (1991) provided circumstantial evidence that *P. fluviatilis* was responsible for eliminating *E. vittata* (western pygmy perch) from many sites in the Murray River in Western Australia. While the relatively low numbers of *N. australis* trapped in this habitat may have been due to *P. fluviatilis* predation, fish are known to respond to predators by moving to habitats providing protection (Cerri & Fraser 1983; Werner et al. 1983).

While the pattern of habitat use by *N. obscura* was similar to that of *N. australis* in allopatry, it was essentially restricted to only one of the vegetated habitats and the channel habitat when sympatric. The habitat restriction of *N. obscura* at Deep Creek may be due to past or current interspecific competitive interactions (Connell 1980), habitat preferences of the species (Nilsson 1967; Wootton 1990) or predator avoidance (Cerri & Fraser 1983; Werner et al. 1983).

We speculate that the different patterns in abundance of pygmy perch among sites were largely due to interactions between size-fecundity relationships, habitat use sometimes mediated by interspecific competition, and predation intensity. Mortality rates due to predation will be influenced by predator abundance and encounter rates (Ware 1972). While abundances of *N. australis* may be influenced by overall predator abundances, predation rates on *N. obscura* may be higher when sympatric with *N. australis* because of its restriction to habitats with high predator abundances, in particular *P. fluviatilis*.

Observations of niche shifts and associated changes in mortality provide some of the best evidence that competition plays an important role in determining ecological assemblage and community characteristics. It appears that the competition for space between *N. australis* and *N. obscura* and predation by *P. fluviatilis* may influence habitat use and relative abundances of the two species. This suggests that the differential decline in *N. australis* and *N. obscura* populations since European settlement may be due to the competitive superiority of *N. australis* and habitat use by *N. obscura*, *N. australis* and *P. fluviatilis*. Stronger evidence that these biotic interactions underlie the differential decline of *N. obscura* and *N. australis* would require more replicate sites for each assemblage type, further sampling over time to establish assemblage stability, and/or removal experiments.

Site	Species	Mixed Vegetation	Narrow Leaf Emergent	Submerged & Emergent Feathery	Channel
Deep Creek 1	*Anguilla australis*	0.33	0.66	0.33	0
	Perca fluviatilis	0	0	0	0.33
	Gambusia holbrooki	1.33	1.0	2.33	0.66
Deep Creek 2	*Anguilla australis*	1.5	0.75	1.75	0
	Perca fluviatilis	1.0	1.0	4.75	3.75
	Gambusia holbrooki	1.75	1.75	1.75	1.0
Woady Yaloak	*Anguilla australis*	0.5	0	0.5	0
River	*Perca fluviatilis*	0	0	0.5	1.0
	Gambusia holbrooki	1.0	0	1.5	0

Table 3. Mean trapping success of pygmy perch predators (mean number of fish caught per trapping session) in different habitats at Deep Creek and Woady Yaloak River for all samples.

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CORRIGENDUM

References in Warne, 2001 (Fig. 2) to Hancock Museum registration numbers should be as follows. For the lectotype of *Ponticocythereis ichthyoderma* (Brady) the registration number should read 1.24.32. For the lectotype of *Ponticocythereis quadriserialis* (Brady) the registration number should read 1.40.10. This is in accord with the renumbering of these specimens by Davis and Horne, 1988 subsequent to the original designation of lectotype specimens by McKenzie, 1986.

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TRANSACTIONS

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PUBLIC TRANSPORT FLEET MANAGEMENT SYSTEMS A MELBOURNE EXPERIENCE

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THROUGHOUT the world there is considerable anecdotal evidence that suggests public transport usage improves with the on-time performance of the system. In particular, the Japanese and German networks are good evidence of higher usage rates as a result of the high level of customer service and the knowledge that the trains will always be on time. Whilst train management systems have been quite sophisticated for some time, as a result of the requirements for signaling, buses, trams and light rail have not had available to them the same degree of sophisticated fleet management systems.

Whilst Global Positioning Systems (GPS) technology provides great opportunities for the adoption of intelligent transport systems and even improved security for vehicles, particularly taxis, couriers and general freight transportation, these systems are quite expensive and are generally purely just what the title suggests - positioning systems which identify the location of the vehicle. Further add-on systems need to be developed to enable them to be used for public transport applications.

It is true there has been tremendously improved management of vehicles travelling randomly throughout the metropolitan road network by the use of GPS and one of the most striking examples is the use of GPS and additional hardware and software to monitor the location, load and position of liquid waste tankers. This was introduced in Western Australia by the Western Australian EPA to stop the illegal dumping of liquid waste and has now been extended to Queensland. It is also under consideration for use in some of the Asian countries and provides a very close monitoring of illegal dumping of liquid wastes. Similarly, GPS have been put to great use in South Africa where valuable cargoes and expensive cars are tracked regularly to prevent them being lost and stolen. These GPS systems are relatively expensive, being $4,000 to $5,000 per vehicle, plus require considerable post-processing and other hardware and software to build them into a total system as is used in the waste tankers or as is being promoted for the Melbourne taxi fleet.

A system installed here in Melbourne more than ten years ago, however, already offers many of the capabilities of the GPS systems. In fact the fleet management system introduced by the Public Transport Corporation is not only a positioning system but has also many other features, including dynamically counting passengers, identifying location of vehicles to within a 2 metre resolution, and providing output to the automatic ticketing machines as well as providing security to both the driver and passengers by way of direct transmission between the tram and the central control point.

This system has tremendous opportunities for further upgrading and is relatively inexpensive. It is particularly useful for those operations where the tram or bus is operating on a fixed route network. The Melbourne system comprises approximately 150 sign post receivers fixed to lamp posts which are triggered by a passing tram which resets the odometer and identifies the location of the tram. This information is then fed to the ticket machine to identify the zoning and provides outputs to identify to the central control operation where the trams are and whether they are bunched-up. On board the tram is equipment worth approximately $2,000 comprising receivers and transmitters with two voice and one data channel. These then transmit to six antennas located throughout Melbourne which are connected by landline to the tram control centre. In the tram control centre specific Windows-based software has been written by the Public Transport Corporation staff which is very sophisticated in its operation and well in advance of other similar systems in operation throughout the world.

Whilst the Melbourne system is relatively unique, there are two other systems based on the same sort of hardware operating in Saudi Arabia and San Antonio, Texas on bus fleets.

The system developed here in Melbourne and now available to the world through a marketing initiative of the PTC and Vipac Engineers (the manufacturers of the hardware) provides a low cost, very reliable fleet management system for the management of public transportation fleets where the infrastructure or budgets are not sufficient to support the high technology GPS. Proposals are already in place to export this system to the Vancouver Public Transport fleet in British Columbia and to the fleet of light rail vehicles in Prague, Czech Republic. Other interest has been shown through partners in the Tram Friendship Network signed by the Victorian Government.

The Melbourne system is truly a world class innovation and to this day is equivalent or better than those existing in other areas. It also offers opportunity for further expansion such as LED displays on board the vehicles to provide the latest news headlines, weather forecasts, or for commercial exploitation or subsidisation of the running costs by providing strategic advertisements such as "the next stop is McDonald's".

In summary, the fleet management systems developed by the PTC and Vipac Engineers and operating in the Melbourne public transport network is a world class transport management system greatly underestimated by the local population and under-marketed by its developers. Current efforts to export to the world may change this and open up further opportunities.

UNIVERSAL POINT TO POINT TRANSPORT OR SELFISH CONGESTION - SOLUTION OR IMPASSE?

Ros Trayford

Director, Easy Share Australia Pty Ltd

INTRODUCTION

In searching for universal and fundamental truths, physics and philosophy lie on either side of a contested boundary. In transport, physics assists us with technological change, but philosophy emphasises the overriding importance of asking the difficult questions to get to the glimmerings of a solution.

Today, in considering the role and the effects of the private car in our society, we have more questions than answers. However, these difficult questions should be faced if the idea of an equitable society is to prevail.

The omnipotence of the car

The universal desire to own and operate a car is seen by many as paramount in today's society. Three points of trivia are illustrative:-

- Dumped by his girlfriend a car owner formally marries his car (USA, The Age Odd Spot).
- The top of the line models, of the two prestige sports cars makes at the recent Melbourne Car Show, differed in two ways: in price $200,000, in performance to 100 km/h, 5.2 and 5.1 seconds - *a difference of just 0.1 of a second.*
- On the Eastern Freeway - a non-toll freeway - the tailback of traffic in the morning peak, in February, occasionally stretched as far as Bullen, more or less half the length of the freeway.

Demand on road space

Does it make sense to stand still in a traffic jam for half the morning commuting journey in a vehicle designed to cruise all day at 140 km/h or more?

Research suggests that commuters will spend up to half the journey time in stationary congestion before considering a move to another transport mode.

And with fuel costs being at an historically real low motorists would pay up to four times or more than the current price before changing to a more efficient vehicle or changing to another transport mode.

Demand on fuel usage

Private car use consumes a large fraction of the fuel consumed in Australia. This is inefficient in an energy sense and has a long term economic impact. The penalty on cruise performance imposed by the desire for high acceleration is one obvious inefficiency.

Pollution impact on urban communities

Despite improvements over the past two decades the fuel consumed by cars is a significant pollution contributor in urban areas. It accounts for at least half the airborne pollution.

Slow technological improvements in car effieciency

Monitoring of the performance of the on-road fleet shows that a given size of car has improved its fuel consumption 1% per year over the last decade.

However ....

The increasing use of larger automatics and air-conditioning has negated this increase in efficiency such that the now average Australian car (with its increased size, mass and accessories) consumes the same amount of fuel as the car of a decade ago.

Essentially fixed road space

Road building, especially near the centre of cities and in environmentally sensitive areas, is increasingly seen as unacceptable. The scope for augmenting road space on radial routes, where longer commuter routes then become feasible (thus attracting greater traffic), will be found increasingly politically difficult.

Is there a permanent solution?

The central issue in the transport debate is: What is society trying to achieve? Transport efficiency, planning issues, pollution and the application of taxes to roads, form the centrepiece of the argument. Equity, on the broadest scale, rarely gets a good hearing. With such diverse forces at work an enlightened approach seems unattainable so that the slow evolution of transport policy becomes the default process.

Is the solution technological or behavoiral?

While technological solutions can lower costs they can only succeed if they meet consumer needs and society objectives. These issues are well illustrated in the field of consumer electronics and the development of new software packages where history is littered with failed projects. In Melbourne this year both successful and less successful examples are unfolding before us.

Behavioral changes are even harder to bring about and the time scales for change are much longer. Twenty years is not unreasonable. Witness the slow adoption of seat belts, airbags, and the drink driving legislation. The typical division of transport lobbies into many competing interests also hinders new and even minor improvements. For instance, the public transport lobby tends to oppose car pooling, even when it can facilitate greater use of railway station car parks, thus increasing rail patronage. The reason given is that any encouragement of car usage is anathema to the cause of public transport.

CONGESTION PRICING, ITS HISTORY AND STATUS

Clumsy mechanisms (cordons and barriers, manual tollways) or wholesale technological implementation of electronically regulated road space (costly) posit an unwelcome future to many. Will the offered solutions be acceptable? Will the question of equity be resolved? The paucity of public transport for many cross-suburban and cross-city commuting trips means that low-paid commuters, relying on cars, will be discriminated against if simple congestion pricing is introduced.

Recently, at a lecture at ARRB, James Luk from Nanyang Technological University, Singapore, reported that the effect of universal application of automatic electronic gantry control to the inner city of Singapore has modified and lowered the number of cars entering the city each day. Now that day passes and longer term passes are not available the imposition of a this charge per passage has seemingly caused the above effect that is on going. However, the three freeways, effectively tolled by the same method, appear unaffected in terms of peak and total flows. The overriding issue for Australia and other democratic countries is however the acceptability of universal electronic congestion pricing. It is significant that Hong Kong appears likely to be the next adopter. Not to be ignored in this context is the extremely high import duty and associated, but separate, auctioned ten year usage fee, currently around $100,000, applicable in Singapore. This regulates the increase in private car numbers to some 3% per annum.

THE ALTERNATIVE COMBINATIONS

A different world view of transport becomes available when the allocation of demand is made on the basis of person occupant road space: The current possibilities are:

Busses: Three lanes @ 1000 per hour by 40 passengers = 120,000 per hour

Cars: Three lanes @ 2000 per hour by 1.1 persons = 6,600 per hour

Car pooling: Three lanes @ 2000 per hour by 4.5 persons = 27,000 per hour

Electronically Three lanes @ 4000 per hour by 1.1 persons = 13,200 per hour

Alternative Road Space Schemes

	Persons / vehicle	Nominal road capacity / hour
Busses	40	120,000
Cars	1.1	6,600
Car pooling	4.5	27,000
Car convoys	1.1	13,200

Car pooling

It is argued that car pooling is one equitable, good environmental, cost effective and sociably acceptable solution. Can car pooling be achieved efficiently by providing suitable technology?

[Car pooling (ride sharing in the U. S.) is not to be confused with *car sharing* where a fleet of cars is owned by a group, commercial or non-profit, and is time-shared at appropriate rates. The beginnings of this particular movement can be found in European cities and, like car pooling, it is too early to gauge the wider impact.]

A world first brought to fruition

The Sydney "Easy Share" car pooling operation. While concurrent mathematical, technical and psychological research was undertaken, market research was carried out in four cities, Melbourne, Kuala Lumpur, Bangkok and Sydney. In Melbourne, the proposed scheme was shown to be popular with younger people and females, predominately those in the professions, clerical occupations and students. Overall, some 44% of respondents indicated a high willingness to join. In Kuala Lumpur, a three language interview survey showed that over 60% of motorists would be interested in joining a scheme where passengers pay drivers two and a half times the bus fare or half the taxi fare. In Bangkok, a similar percentage responded equally positively but here the proposed scheme was mooted as requiring an indirect payment mechanism to comply with cultural concerns.

In Sydney, similar research, restricted to motorists, focused on willingness to join, willingness to pay and proposed frequency of usage. 18% expressed a willingness to join and 87% said they were prepared to pay the annual membership of $40 to $50. Some 40% expressed a desire to use the system three or more times a week. Given that there are over two million motorists, these results indicate sufficient support to launch the scheme.

The technical requirements for the system were dictated by the need for the system to respond to matching searches quickly. By using a 500 Mz processor, supported by a large volatile memory, searches on a large database could be completed in 30 seconds. The permanent database was held on a second machine. Interactive voice response units (IVR) were network mounted and connected to the requisite number of incoming phone lines.

The search algorithms used were a trade-off between brute force and more sophisticated algorithms, which gave higher matching yields. Postcodes were chosen as the prime location identity as they were publicly available and easily input by members into the IVR system.

The cost of making a match, because of the technology employed, was quite low, less than 10 cents. By comparison, the cost of a match under a manual system, even when supported by a personal computer, is known to be as high as $5 to $10.

To join the scheme the prospective member fills out a membership form, including a valid car driver's licence number, along with relevant personal details, i.e., address and home, office and mobile telephone numbers, gender and date of birth. Personal preferences are also checked on the membership application. These preferences are for age group, smoking and non-smoking, male and female and car radio music tastes.

The new member is sent a guide to using the scheme, a membership card with membership number and instructions on self selecting a Personal Identification Number (PIN) when first accessing the system. A wallet-sized list of postcodes and suburb and town names is included for the convenience of the member in identifying the origin and destination of proposed trips.

To make a trip request the member dials the Easy Share computer that has a menu driven IVR front end. The member is requested to input their membership number and PIN by touch-keying in the numbers. The member then inputs for the proposed trip, the origin and destination postcodes, and the time and date. The scheme allows multiple trip requests while minimising data input.

When a match is found the member is given the other member's name and phone numbers. They then contact that member to arrange a convenient pick-up point. Members are advised to make the pick-up point a public location, i.e., a street intersection, prominent building, etc., to preserve the privacy of their address if required.

At the pick-up point the two members view the other member's driver's licence and membership card. As an added precaution the intending passenger can assess whether the driver fits the criteria of the match, as well as using clues given by the prior phone conversation, before entering the vehicle.

The system operates 24 hours a day 7 days a week. It is in the process of being extended to cover the whole of Australia. At present it covers New South Wales and also covers trips to and from NSW to some 50 locations in other states.

Despite mass marketing with generous media treatment it soon became obvious that the technology alone was not sufficient. From investigation of prospective members who did not join, it was found that the perceived value of joining did not balance the expected loss of convenience involved in sharing a vehicle. In this situation it will be necessary for transport policy to change to provide both a "carrot" and a "stick" to get car-pooling to become accepted. While a direct and total congestion pricing policy in Sydney is at the moment not considered feasible, some measures can be considered.

POLICY QUESTIONS

The integration of transport policy is necessary to assure the successful operation of car pooling. A large degree of interdependence exists between market pricing (with fuel, cars, taxes, parking, tolls and other road user charges) and car-pooling as well as public transport. A number of policy reforms would be necessary for car-pooling services to be more widely used. The most effective policies would be those that reduce the hidden subsidies to motorists including car parking, and reward those who car-pool.

It is now recognised that when congestion pricing is presented in general terms as a way to manage traffic or reduce congestion, support tends to be low (Luk and Chung 1997). A package approach that returns the congestion toll revenue to the public in various ways is necessary to gain acceptance. When people see direct benefits, they are willing to pay for it.

The motorist's perception of the value of car-pooling needs to be altered. An attitudinal change should be caused which can result in a large expansion in membership and the active use of the scheme by those members. The attitudinal change necessary has similar parallels to the introduction of seat belt and drink-driving laws. But, because it is not so much safety related but more cost and community benefit related, it would require close diagnosis and action by government and support from the community, to achieve acceptable results. To be successful it must become an integral part of overall transport policy.

The two essential keys of a carrot and stick approach to encouraging wide-scale use of car pooling are the economic use of lanes, e.g. road congestion pricing and the cost of car parking. These two features have an immediate impact on the decisions associated with conducting a particular journey.

To maximise the use of lanes, ideally all lanes should be transit lanes, or at least as many as it is feasible to have. Additionally transit lane access can be hired out to single occupant drivers, thus placing a community price on the use of the lane. In California these lanes are known as HOT (High Occupancy Toll) lanes (Sullivan and Mastako 1997).

The restriction of all day parking, the removal of parking subsidies by employers and the taxing by local authorities of dedicated car park space is the other significant measure. The use of the company car (some 40-50 % of new car registrations in Sydney) (Schou 1982; Luk and Richardson 1997) for commuting into a subsidised car park thoroughly undermines the prospect of car sharing.

A future solution

The amalgamation of congestion pricing and universal chargeable car pooling can help to assure a future livable environment.

Radical solutions need to be considered if Melbourne is to live up to its "most livable city" status. One such solution is to encourage the capacity utilisation of passenger vehicles. This can be achieved by adopting a form of inverse pricing on bridges, tollways and inner city cordons. By charging half price for a vehicle carrying two persons, one third for three, a quarter for four etc., then a radical change in car occupancy would occur. Translated into a morning entry fee for the Eastern Freeway of Ten Dollars for a driver alone, this would scale down to Two Dollars for a car containing five persons. In a planned experiment, where provision of free parking and pick up zones near the ingress ramps were consciously provided, significant changes in the occupancy should soon occur. At present the automatic technology to achieve this pricing is not yet available, e.g., the need to reliably count the number of persons in the vehicle. This is an R&D challenge that should be taken up. Even so, the revenue raised in such an experiment would clearly pay for the manning levels needed on the ramps for the morning peak.

Other pricing schemes are being trialed, e.g., in California the "Hot Lane" fee allowing a lone driver to buy passage on a transit lane. However this particular economic probing may lead to conflicting ideas on the need to build more lanes, extend the transit lanes or simply to charge tolls, on what many may believe is already a highway paid for with public funds.

An even more radical approach to finding a universal solution is to regard cars as a universal transport option similar to public transport. People share public transport, why not cars through car pooling. No longer is public transport dominated by one operator, competition reigns. In this scenario every car becomes a public transport provider with a time-space electronic charging protocol to match (including the above inverse road passenger charge). The reservation and matching of requests is achieved by the same methods pioneered by Easy Share. Once social equity and the public good are recognised as the overwhelming concern then the arguments of lobbyists can be sidelined.

Providing the "hardware options" of transport to the community, whether public or private, is not however the end of the story. The public must be given the information - in real time - to make objective customised choices on all the transport options available. Our company is now beginning work to realise this objective.

The scheduled arrival of another million cars on Australia's roads in the next decade should make the universal car pooling option, at whatever level of sophistication, a most valuable part of this total solution.

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THE SUBURBAN BACKLASH

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SAVING OUR SUBURBS

The Save Our Suburbs movement has become a political force in a little over a year. What twelve months ago seemed a NIMBY - not in my back yard - movement amongst the residents of the leafy south-eastern suburbs is now the biggest single political force in Melbourne. Nor is it confined to Melbourne, for it extends from Mornington to Ballarat. Last Sunday *Save Our Sydney Suburbs* was formed at a meeting at Circular Quay. There is a related movement in Brisbane. There is even a *Save Our Noosa.*

This movement is concerned to control, if not to arrest, the spread of flats in suburban Melbourne. In this it is by implication opposed both to the orthodoxy of conventional planning and to the policies of the major political parties.

There are a number of false and objectionable assumptions integral to present planning system and to government policy-making:

- The assumption that ordinary suburban home owners do not count, and that the city should be planned to suit the views of profiteers, public servants and planning ideologues.
- The assumption that more intensive development of the suburbs is natural, desirable and inevitable.
- The assumption that existing neighborhoods are expendable.
- The assumption that existing residents should sacrifice their amenity to new multi-unit developments, and this without any compensation.

ORTHODOXY AND UNORTHODOXY

The planning orthodoxy is that the suburban sprawl - that is, the inexorable spread of housing and other development on the fringes of Melbourne - must be stopped. It is eating up fertile farming land and increasing travel distances - and hence it is wasting resources, polluting the atmosphere and increasing the cost of food. And aesthetically it is allowing Melbourne to expand into a giant dispiriting wasteland.

So it is hard to disagree with the proposition that this suburban sprawl must be stopped, and the orthodox view is that the only way to do this is to redevelop the existing built-up suburban area to much higher densities. Under the Kirner government in Victoria, supported by the Federal government's Better Cities program, this strategy was actively promoted, partly because it was also seen that the sprawl was creating ghettoes of disadvantage on the outskirts of Melbourne.

The present state Liberal government has gone along with this policy of consolidation, but perhaps more because of the business opportunities for flat developers which are implied by it. These motives may be suspect, and indeed entirely mercenary, but that does not mean that the policy itself wrong - or does it ? To quote T S Eliot: 'The last temptation is the greatest treason: to do the right deed for the wrong reason'.

THE APPROPRIATION OF PROPERTY

Let me now put to a you a proposition, which will at first seem quite irrelevant. It would be a very good thing if the richest people in Australia - the Packers and Pratts and so on - were to give all their money to the Salvation Army to assist the poor. That seems obvious enough. Well, if it's so obvious, why shouldn't the government do it for them - confiscate the money and hand it over.

The reason the government *doesn't* do so, is that it would infringe the property rights of the tycoons. It would also unleash a precedent, leaving nobody sure of their property. It would in principle be a simple and perhaps desirable form of communism, but in practice it would open the floodgates of anarchy.

How much more would this be the case if - in my example - we sought to confiscate the property of ordinary people, who were not rich.

That is exactly what is happening in Melbourne's suburbs. Ordinary people who have usually invested most of what they own in their houses, are having these houses devalued by the building of flats. The flats only sell because they are able to take advantage of roads and parking spaces, street trees and adjoining private gardens, light and views, and a pleasant ambience generally. So those advantages are worth real and substantial money to the developer.

Yet those advantages are taken, without payment, from the neighbours. The first block of flats does the greatest damage because it sets a precedent, and undermines the adjoining properties. Then those people next door find it unbearable and are likely to sell. It may be a wrench, but they may do all right financially - though this is not necessarily the case, for in many parts of Melbourne house sites are still more valuable than flat sites.

But what happens as more flats are built in this street? The traffic becomes clogged and parking becomes impossible. The appearance and ambience of the street is destroyed. Noise from the upper levels spreads unobstructed throughout the neighbourhood. The flats no longer look into other people's gardens but into each other's windows. The area is no longer desirable. The flats no longer command high prices. Like many parasites the flats have destroyed the host upon which they feed.

Spare a thought too for the last householders. They have suffered all this degradation, but they may occupy a site too small for flats, so they can't sell. They are literally trapped in a man-made nightmare.

Some years ago I used to sit on the Administrative Appeals Tribunal, and I heard a case where I had difficulty keeping a straight face. The residents of a multi-storey block of flats in South Yarra had enjoyed the view of the neighbouring house block, as well as the open air and light and privacy of their lofty situation. When the neighbour proposed to build flats they were full of righteous anger at the prospect of losing these things - which of course they had stolen in the first place.

LAISSEZ-FAIRE OR UNFAIR?

This may sound theoretical. Let me now give some hard figures which were calculated in 1997 using the cities of Melbourne and Stonnington as case studies. The impact of high density developments on residential amenity, devalue the adjacent residential properties by an average of 3% to 8% for properties within the City of Melbourne, and an average of 4% to 9% for properties within the City of Stonnington. That equates to an average loss between about $17,000 and $29,000 in Melbourne, (specifically $16,675.00 to $29,375.00) and $42,000 to $51,000 in Stonnington ($41,923.08 to $50,769.23).

The researcher, Michael Powell, pointed out that developments that reduce the value of adjacent properties are contrary to the objectives of the *Planning and Environment Act 1987.* He concluded 'The end result to this process is the erosion of the community's previously assumed confidence in the controls of the planning system. The loss of confidence is seen at the resident and developer levels.'

THE SPURIOS MARKET

Developers always respond - 'but there is a market demand for these units', and they are right. If flats were built in the Royal Botanic Gardens there would be a *huge* demand for them, because they would destroy the public's property and benefit the individual flat dwellers. Of course that would never be done. But when it is *private* property which is destroyed, *our* property, nobody cares.

So what I am saying to you is this. If the community believes that flat development is necessary in the public interest, the community must buy out existing property owners at a fair rate - not one by one, but street by street, so that nobody suffers. They must then design the flats to incorporate enough car parking, to maintain reasonable privacy, and generally to sustain a reasonable quality of life.

NEIGHBORHOOD CHARACTER

These effects upon land value are mainly to do with loss of amenity - that is, the sorts of things I have mentioned, like overshadowing, privacy and parking. But many residents have a more general, and arguably less selfish concern - not with their own personal comfort and convenience, but with the character of the neighbourhood. Every suburb has its own character and, we would argue, if the existing residents like it they should be allowed to keep it.

I am not talking heritage buildings and areas, but about more general characteristics. If your street has single storey buildings and deep gardens, and if the residents like this, why should they not be heard? Because this is not heritage control, it should not stop anybody pulling down or altering a house. It should simply ensure that what replaces it does not exceed the setback or height limits or breach any other such controls.

It is theoretically possible under the current legislation to look at 'neighbourhood character' and seek to preserve it by means of 'local variations' under the Good Design Guide.

But what is possible is not what happens. The City of Monash attempted it, but their recommendations were rejected by a panel appointed by the Minister, Mr Maclellan. The panel seemed to believe that neighbourhood character was just another sort of heritage control. It was to be assessed by experts, based upon state-wide standards, and not upon the wishes of local residents. The City of Boroondara's proposals are about to go on exhibition, but the probability is that they too will be rejected.

THE GOOD DESIGN GUIDE

The Government's development bible is the so-called *Good Design Guide,* which is now being attacked on all sides. A few months ago it was absolutely unassailable, but SOS has been hacking away at it, and now the rats are leaving the sinking ship. Even one of the original authors has come out and criticised it.

It is true that the Guide is in a principle an improvement on what preceded it - what was known as VicCode 1 and the dual occupancy provisions introduced under Labor. But this improvement is only in principle, for it is internally flawed, unenforcable, and creates so much uncertainty that the backlog of planning appeals is increasing exponentially.

The first thing to understand is that the title is deceptive. Most people think that 'good design' means that this is a document which will prevent more Neo-Georgian and Tuscan units. But it is not about that at all, it is about heights and setbacks, preventing overshadowing, retaining privacy and so on. And this is how it should be. It is impossible to legislate for good design, and it is not the role of government to do so (except in some extreme conservation situations).

The problem is not with the definition or scope of the guide but with its underlying principles. It is claimed in the public rhetoric to be based upon 'performance standards' as opposed to 'prescriptive standards' and therefore to be more flexible, and to promote better design. The argument goes that the old shoebox flats were the result of prescriptive standards, and that this guide will achieve something better

This is totally fallacious. They were prescriptive standards which controlled the streets of Paris, and once controlled the east end of Collins Street, so I don't think those results are necessarily bad. In fact the bad features of Melbourne flats were not due to *prescriptive* standards but to *low* standards. Sites which were too small were permitted to be developed with too many flats. As simple as that. If the standards are too low the result will be bad, whether they are prescriptive or they are performance standards.

A prescriptive standard is where you say that building must be of a certain maximum height and minimum distance from the boundary, so as to prevent overshadowing the neighbour. A performance standard is where the designer is allowed to achieve the same result by other means. He may be able to slope the wall so as not to increase the shading while he builds higher, or closer to the boundary .

I have no problem with such performance standards, but they are *not* in fact the basis of the Guide. For the most part the Guide says that certain things are desirable and others are undesirable. It is good to preserve trees on the site, and bad to look into your neighbour's bathroom window. But it is not *compulsory* to preserve the trees and it is not *forbidden* to look into the window. You can trade one off against another.

So the council planning officer, or the council itself, or ultimately the Tribunal, will have to decide whether preserving three trees gives you the right to look into a window. Every decision is subjective. Every decision is open to favouritism or corruption. Every decision has the potential to go to appeal. The cost and the uncertainty are horrific.

The other aspect of the Guide I want to mention is that the developer does the 'site analysis' which should determine things like whether the street can absorb the extra parking. But consider what follows. The development uses up the parking in the street, and the next development has no opportunity to do the same. In other words the neighbours - having had their own properties devalued, will not even be able to sell out to developers on the same basis. This is the principle of the devil take the hindmost.

FUNDAMENTAL QUESTIONS

It is hard to resolve the differences between those involved in the debate because all have, or purport to have, the same aspirations. All want to achieve 'good design', whatever that might be. All want to stop the urban sprawl. All want to make efficient use of the existing infrastructure. All want to conserve energy and resources.

Therefore certain questions must be asked:

1 Is it necessary or desirable that Victoria's population should expand unchecked?
2 If so, where should this increase be housed - country, country towns, Melbourne periphery or inner ring?
3 Is the provision of this accommodation most effectively done by stimulating private developers or by some degree of government intervention?
4 Will inner area redevelopment stop or significantly ameliorate the sprawl?
5 Should the costs be borne hy the development market or by existing residents?
6 Is it possible to ensure good design standards?
7 Does any of this really justify the destruction of Melbourne's character and liveability?

POPULATION

The first two of my questions relate to population. The State Government has not got a population policy. It has population predictions for the state and for individual areas. It has policies, or at least ideas, about how this population might be accommodated. But that is the reverse of planning. There is no policy as to how much population Victoria ***ought*** to have, where ***ought*** to go, and ***how*** you could bring that about.

Save Our Suburbs itself does not have a population policy, but it is strongly of the view that there should ***be*** such a policy. Until you have a policy you cannot make any rational decisions about suburban development. The argument that redeveloping the inner suburbs will relieve pressure on the periphery is completely meaningless if the inner suburban population merely acts as a magnet for more peripheral population.

If you increase the number of advertising executives living in South Yarra you will need ***more*** plumbers living in Dandenong, not less. In other words there is no ***known*** future population of Melbourne, such that if you encourage growth in one place you will slow it down elsewhere. What you do, in planning terms, will affect the market and will affect the total population. It's as bit like Heisenberg's Uncertainty Principle in physics.

However, for the sake of argument, let's assume that the population can be predicted. There is a law of diminishing returns in increasing densities. A large proportion of the suburbs is occupied by non-residential uses - roads, parks, retailing &c. So if you double the population on all the house sites, you nowhere near double the population of the suburb.

But it is much more serious than this. If you do double the population, then you have twice the population using these roads, parks, schools, public facilities and shops. Nobody is increasing ***them*** proportionately - certainly not the roads and the parks - so the proponents of increased densities are fact arguing for a reduction in the provision of public facilities. This is what I call the Calcutta solution, and if the planners were to come clean and admit it there would be a public outcry, just as there would if you halved the aged pension.

I then turn to the analysis of the late Professor Brian McLoughlin (p 154):

'... on the basis of severely pessimistic assumptions about the length of perimeter available and equally optimistic assumptions about the success of "smarter housing", some 600 metres of "sprawl" might be avoided over a ten year period. But if we also admitted to the calculation the innermost edges of the corridors - say about 20 kms more - the result would cast even greater doubt on the rhetoric of consolidation.'

This not makes the point that - after all the trauma and heartbreak of destroying the existing suburbs - the reduction in the diameter of Melbourne would be trivial. It also implicitly makes another point. If you succeeded in holding the sprawl in this way you would not have stopped it, only delayed it. The only way to actually ***stop*** the sprawl is to put permanent controls on the land affected.

Even more questions are raised when you turn to specific areas. Where you increase the number of dwellings you do not necessarily increase the number of inhabitants. If you replace a family home containing five people with two units containing one couple and bachelor, you have reduced the population. Something like this has happened in Richmond, where the new developments *have* increased the population, but only to a very marginal degree. Research by Belinda Boerkamp (p. 72) eighteen months ago concluded:

'... local and State government policy has been influential in raising dwelling densities within the City of Richmond. However, it has not been as successful in raising population densities. Falling household occupancy rates have meant that, for each additional dwelling constructed, there are declining benefits in terms of raising the total population. At the same time the municipality has experienced increased problems related to car parking provision and concerns related to neighbourhood character.'

POLICY RESPONSES

A sincere government would do a number of things:

- First, it would put a freeze upon the farmlands around Melbourne to prevent their redevelopment. Unfortunately, though this has been done in other countries, and has even been done here in the past, that is far too draconian a step for a Conservative government to contemplate.
- Secondly, it would ensure that all *new* development was multi-unit rather than single houses. It makes no sense at all to build houses in one place, and in another place to pull them down and build flats.
- Thirdly it would take positive measures to develop suitable flat sites in the existing suburbs, including acquiring the sites if necessary. They would be large sites, to allow the sort of coordinated rational design which is impossible when you cram flats onto a house block. They would be in locations which would not cause anguish to the neighbours - especially recycled industrial land, vacant government property and so on. They would be well-served by public transport and close to shops - indeed, where possible they would actually be in and above shopping centres.
- Fourthly, it would provide effective public transport to all existing nodes of flat development as well as future ones. Effective public transport is not the sort you get by standing on a tram stop at St Albans in the rain for forty minutes. It is the sort that is so frequent, comfortable and reliable

that even if you own a car, you are tempted to leave it behind. When did you last see Mr Kennett standing in the rain for forty minutes at St Albans?

Consider what it would be like if every suburban shopping centre - every Chadstone or Doncaster Shoppingtown - had three or four levels of flats above the shops. It would provide more custom for the shops. It would let the flat dwellers live a sophisticated life-style and dash downstairs for food, coffee or entertainment whenever they wished. It would provide enough demand to warrant a proper public transport service to the complex. It would make rational use of the parking space, which the residents and their visitors would mostly require after hours and on holidays when the shops were closed. It would keep population in the area, and make it safe to walk through at night. It would greatly minimise travel for residents who might not only shop, but actually work on the same site.

BONA FIDES

The fact that the government is not doing any of these things is proof that it is not sincere. To refer again to T S Eliot, it is in fact doing what is at best only *arguably* the right deed, for what is *certainly* the wrong reason. That reason is to allow developers to make profits at the public expense. And to be fair, the previous government was not much better, though its motives were a little more idealistic.

Now let me assume that you have been persuaded by my arguments. That is, there *are* ways of stopping the sprawl which do not involve degrading every single suburban street. The state government is *not* pursuing those avenues, and is not sincerely concerned about the sprawl. It is weeping crocodile tears while allowing its mates to make a fast buck.

But you may still ask me whether the Save Our Suburbs movement is any more sincere than the Government. Do they really care about the urban sprawl? Do they really care about saving resources, improving suburban amenity, or any of the other issues? Aren't they just protecting their own interests? Is it not, as I said at the outset, Nimbyism?.

You would be right to ask those questions, for indeed they *are* mainly concerned with their own interests and their own backyards. They've developed policies about urban sprawl and other issues only because they know that in the absence of such policies they will sooner or later be beaten.

But none of that means that they are wrong, *or* that their arguments are invalid, *or* that their policies are against the public interest. When I ring the local police station and say that there is a burglar climbing over my back fence, that is also nimbyism. But what is good for my security is also good for the neighbourhood security, and what is good for the neighbourhood is good for the community and for the state.

TO THE BARRICADES

And what Save Our Suburbs is doing is good for the community and the state. We are fighting to preserve some of the best residential accommodation imaginable in any city in the world, to preserve forms of housing which are fundamentally Australian, to preserve streets which we love and which our children will love, and to maintain an environment which is secure, and which fosters a true sense of community.

For too long have suburban householders been the forgotten people. Most Australians live in the big cities, and most of those people live in the suburbs. We, in our single and usually detached houses in the suburbs, are the backbone of Australia. Our yards, even where the Hills Hoist has been replaced by the pool and the barbecue, are the essence of Australian culture.

Why then are we attacked, criticised, patronised and made to feel guilty by the unholy alliance of politicians, public servants, planners and property developers? Somebody thinks we need greater densities - redevelop the suburbs. Somebody thinks we need a greater variety of housing stock - redevelop the suburbs. Somebody would like to make a fast buck - redevelop the suburbs.

Who says we need greater densities, and why? Aren't our streets already clogged with traffic and parking? Wouldn't it be far better to plan the sorts of development of which I have spoken, and to ensure that they are linked to a good public transport system?

Who says we need a greater variety of housing stock? Our exiting suburban houses accommodate young families, old couples, young families together *with* old people in granny flats, apartments, boarding houses, special accommodation houses and private hospitals. *That* is what I call variety in housing stock. How does it compare with the shoebox units which are replacing it? What variety do they offer? None. And what flexibility do they provide for alterations, as the family's requirements change? None.

And who says that we should let developers make a fast buck? Unfortunately that is implicitly the policy of the state, but I suggest that it is a totally immoral and cynical policy.

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PLANNING OR REACTING? - AN ANALYSIS OF LOCAL GOVERNMENT'S CAPACITY TO INFLUENCE A COMPLEX WEB OF SECTOR IMPERATIVES IN THE CITY OF PORT PHILIP

Councillor Liz Johnstone
City of Port Phillip

Port Phillip – which embraces suburbs of Port Melbourne, South Melbourne, Albert Park, Middle Park, St Kilda, Elwood, Ripponlea, Balaclava and East St Kilda with St Kilda Road – means many things to many people. For many Melburnians and visitors to Melbourne, Port Phillip is Victoria's premier playground, There's probably not a person in this room who hasn't been to Luna Park or the Palais, walked, cycled or roller-bladed along the foreshore, swum at one of our beaches or the new Melbourne Sports and Aquatic Centre, saited on the bay or Albert Park lake, or flown a kite at Elwood Beach, browsed at the Esplanade market, eaten at our many cafes or restaurants, ruined their diet in one of the Acland Street continental cake shops, been to our festivals or, dare I say, witnessed the Australian Grand Prix.

However, Port Phillip is also home to some 77,000 people and, unlike other inner-suburban municipalities, the numbers are rising, despite the decreasing size of households. The average household size in Port Phillip is now 1.9 compared to the Melbourne average of 2.69. Around 44% of our residents live alone. Our population continues to grow as more and more people – particularly in the 25 -49 age bracket – are drawn to Port Phillip's bayside attractions, its relaxed and cosmopolitan lifestyle, its many cafes and restaurants and its proximity to the city, The single greatest number are choosing to live in apartments or flats, as they used to be known.

This trend is especially evident in Port Melbourne where large tracts of former industrial estates are now available for residential development. One single development, at Beacon Cove, which is the biggest urban renewal project in Australia, will be home to more than 3,000 people by the time it's completed in 2002. All, in all, the population of Port Melbourne – currently around 8,000 – will have doubled within a few years

This prediction stands without taking account of the proliferation of high-rises touted in the State Government's recently-released document, *Gateway to the Bay.* If the State Government succeeds in imposing that particular vision on our municipality, the number of towers, not to mention the numbers of people and cars, will bring Port Phillip another step closer to being the Surfers' of the south – without, of course, the climate

The boom in property, population and the number of visitors has brought prosperity to Port Phillip – but it's also brought unprecedented traffic problems. Port Phillip is under siege by the private motor car.

The bones of the problem are in the stats. In 1991, there were 33,700 households and 30,000 cars but thirty per cent of households didn't own cars. The 1996 census figures show a significant change – there were 35,798 households and in excess of 34,000 cars. Only twenty-three per cent of households didn't own cars.

More and more residents, and they are more and more well-to-do, rely on private transport, rather than public transport, to move around. As of the last census, approximately, 69% of people went to work in cars – a 9% increase in just five years, The stats also show that the City of Port Phillip provides employment for about 55,000 people each day, most of whom travel to work by car.

What the stats don't show is the reality of the traffic gridlock on the ground. On the first warm Sunday in spring, it is not unusual to see a traffic jam stretching from the intersection of Carlisle and Barkly Streets, back around the Esplanade, up Fitzroy Street, across the junction, up Wellington Street to the Astor Theatre. During the weekday peak it takesup in tears after driving round and round the streets near their apartment blocks for forty- five minutes, looking in vain for a parking spot.

Adding to the traffic gridlock, are thousands of commuters and truck drivers. Port Phillip is intersected by three major commuter routes into the Melbourne Central Business District – Dandenong Road, Nepean Highway and Beach Road. The expansion of Webb Dock has added to traffic problems in Port Melbourne. CityLink is expected to exacerbate traffic problems in the future.

Yet Port Phillip has world-class public transport infrastructure:

- one railway line with two stations
- two light rails
- six tram lines offering 15 services
- twelve bus routes
- Two free Community Buses operated by the City in St Kilda and the South Melbourne Market Trader Association in South Melbourne

So why can't we cope with the increased population and its increased demand? The real reason lies in people's behaviour. The educated, more affluent people attracted to living in Port Phillip bring with them an expectation of a suburban, car-based life style. Every new dwelling brings in another 1.7 cars. Given that the overage household size across the City of Port Phillip is 1.9, that's nearly a car per person.

The City of Port Phillip has spent the last three years grappling with the transport needs of the municipality and last November adopted an *Integrated Transportation Strategy,* a first for the area,

After the episode of *Yes, Minister* on Monday night, you may be wondering if our new strategy is foolish or visionary. Certainly, Jim Hacker found an integrated transportation strategy – and it had exactly that title!- a political hot potato and quickly handballed it back to the Ministry of Transport. However, I prefer to see our strategy as visionary. It's certainty got the official imprimafur as a vision! Our three-year Corporate Plan states: Our Vision of the City of Port Phillip is for a City where the needs of residents, businesses and visitors are accommodated through proper planning and management of traffic and transport, including traffic flow, public transport, pedestrians and cyclists. Our traffic system is well-integrated and cyclists and pedestrians are a priority consideration. Parking facilities in our City s neighbourhood centres are balanced so that traffic congestion is minimised, public transport links are optimised, access to the City's facilities is enhanced and the use of cars is discouraged. *(Corporate Plan, 1998/99 - 2000/2001)*

The *Integrated Transportation Strategy is* holistic in approach, covering Port Phillip's strategic location, 'journey to work' data, existing road, public transport and cycle networks, parking issues, land use changes, transport accident data, existing policy framework, traffic management directions, environmental issues and a SWOT analysis of the ability of the transport infrastructure to meet future demand.

The key planks of our strategy travel a lot of ground. Firstly, let's look at our road network. The City of Port Phillip has a mature transport infrastructure system which has limited opportunities for growth. We are unlikely to build ease, beyond our direct control and necessitates continuing negotiations with State Government authorities over a number of issues:

- the immediate construction of Dockside Road to relieve traffic congestion caused by the expansion of Webb Dock
- a new Westgate Freeway access ramp between Graham Street and Todd Road and
- an alternative route for the Westgate Bridge traffic currently pouring down Williamstown Road and along Beach Road

We are also pressuring the State Government through the MAV to support the introduction of 50 km/h blanket speed limits for residential streets.

One of the more innovative strategies we have embraced centres on land use changes. You may remember the so-called 'McDonald's amendment' to the State Government's Planning and Environment Act. This restricted the ability of local government to limit the numbers of cafes, restaurants and bars. The result for Port Phillip has been the conversion of whole shopping centres to wall-to-wall cafes.

Take the case of Fitzroy Street. Over the past few years, it has lost a supermarket, two greengrocers, two butchers, the drycleaners and many other basic services to a proliferation of cafes, restaurants and bars. In 1997, when kerbside trading was first introduced in Port Phillip, 70 establishments applied for permits. Less than two years later, there are 570 establishments with permits and a total of 3830 seats, a third of which are on Fitzroy Street. Cafes, restaurants and bars, as we know, attract huge numbers of cars, cars which stay for hours – on just one Latte.

On last year's figures, Fitzroy Street was short at least 700 parking spaces at peak times at nights and on weekends – in the commercial precinct alone. While the expanded Prince of Wales car park provides an extra 160 spaces and the George Hotel Cinema offers 300 new public car parking spaces, this is insufficient to cope with the estimated 300 cars generated by kerbside dining alone or the demand generated by the Prince of Wales and the George at peak times.

A radical new plan for parking in Fitzroy Street, the first of our parking precinct plans, means that new bars, cafes and restaurants must provide their own car parking – one space for every two seats – or they will not be given a planning permit. No parking requirements will apply to existing buildings being converted into shops, offices or residences.

So while, the State Government's 'McDonald's amendment' to planning laws means that local councils no longer have the power to limit the number of cafes and restaurants, councils still have control over parking and in Port Phillip we intend to exercise it – not simply to contain parking pandemonium but to ensure that we have shopping centres where residents can actually shop. Similar parking precinct plans are being introduced in all our shopping centres to ensure some control over traffic generation as well as the maintenance of convenience shopping for residents and traders.

More generally, our approach to parking has been to ration and balance the supply between the competing needs of residents, traders, workers and visitors. The available space is maximised by our on-going program of installing angle parking, reinstating redundant cross-overs, allowing parking closer to intersections where it is safe to do so, line-marking individual spaces and enforcing parking breaches. We seek to recover costs from tourist and visitor parking.

In the case of Fitzroy Street, a special rate for parking to be paid by Fitzroy Street traders will apply from next financial year. Fitzroy Street traders have cooperated with this as they recognise that their businesses are suffering from the inadequate supply of parking. This special rate will enable the purchase of some new parking spaces, perhaps as part of the new development at the St Kilda railway station, or purpose built carparking in Jackson St.

The City of Port Phillip issues parking permits to residents and their visitors – a maximum of three per household unless genuine need can be demonstrated. No commercial permits are available. Residential permits exempt residents from 'time limited' or 'permit zone' parking restrictions abutting any residential property in their area and from paying fees on the St Kilda and Elwood foreshores. Under the *Integrated Transportation Strategy,* the City of Port Phillip plans to review the parking permit policy as a priority for the new Council. More permits than spaces currently exist.

We also use parking as leverage for better design outcomes in new developments. For instance, at the Central Equity complex on the old tram depot site in South Melbourne, we added a 'Section 173' covenant to the title. In return for improving the design of the complex, Central Equity was allowed to supply slightly less parking than the council policy dictates as St Kilda Road with its excellent public transport service is within easy walking distance. Under the Section 173 covenant, none of the residents will be entitled to resident parking permits. The parking demands of this development must be met on site. This principle will underpin the review and is also applied to small developments.

It is important to note that the *Integrated Transportation Strategy* recognises that the City of Port Phillip cannot and will not ever be able to provide sufficient parking for the number of cars in the municipality. It is simply not physically possible to provide a park for every car in Port Phillip at any one time. Besides, this would be an environmental disaster. Cars contribute seventy per cent of the pollutants in our air, deplete our scarce reserves of fossil fuels and add significantly to greenhouse gas emissions.

Under our new *Strategy,* Port Phillip will be striving for a better and more reliable public transport service and promoting alternative means of transport such as walking and cycling.

Public transport which, as I mentioned earlier, is well-supplied in Port Phillip, is perceived as slow and unreliable. Our research shows that 44% of workers travelling to and from Port Phillip are within a relatively short distance from their workplaces. Over short distances – 5 – 8 kilometres -in the inner suburbs, the tram is competitive with the car in terms of travel time. We need to get this message across.

However, there are many practical improvements to public transport needed to make it a more attractive alternative to the car. Timetabling needs to be better coordinated. For instance, the No. 16 tram and the No. 96 light rail service invariably leave for the city from the Acland Street terminus at the same time. Coming from the city, these two services usually leave from the Swanston Street/Bourke Street corner simultaneously. People are deterred from using Public transport if the wait exceeds 10 minutes.

To reduce the number of visitor cars coming into the main St Kilda tourist precinct – and 70% of visitors come by car – we need a St Kilda loop tram service, possibly a heritage tram, which runs from at least the St Kilda Junction to Carlisle Street, and preferably along the Bay to Port. We also want to explore park'n'ride schemes for the St Kilda foreshore which will also encourage people on the weekend to leave their cars in the empty St Kilda Road carparks and tram it for the rest of the journey.

Other public transport routes need attention and are subject to discussions with the PTC

- the extension of the tram line in Park Street between Eastern Road and Kingsway þ a public transport service along Beach Road

- improvement of public transport links across the city ie. Port Melbourne to Elwood and Elwood to the CBD

- reviewing a small number of strategically important routes to increase their competitiveness with the car

- in conjunction with the PTC, producing a consolidated timetable and map of public transport in the City for distribution with our regular Community Update. Already, thanks to our recently-launched homepage on the Internet, residents can directly access all PTC timetables.

In the last eighteen months, we have given a permit to AdShell to install 90 new tram and bus shelters. AdShell, actually cleans them on a reasonably regular basis, they are also well lit.

The single biggest unknown aspect to our campaign to increase public transport patronage – and to environmentally sustainable transport generally – comes from the planned privatisation of the public transport system. Who knows what will happen? If service declines or is perceived to decline, it will be almost impossible to wean residents away from their love affair with the private motor car.

Cycling and walking are real alternatives to the curse of the car. Currently, about over 30% of Port Phillip residents use public transport, cycle or walk to work. This is significantly higher than other municipalities and can be partially attributed to the relatively high proportion of people who both live and work within the municipality. Still, there is scope for improvement.

Port Phillip has a three year capital works program for cycling. Recent extensions to the bicycle and walking paths on Port Melbourne and Middle Park foreshores mean that cycling, walking or roller-blading along the nine kilometres of foreshore from Port Melbourne to Brighton is now a breeze. This project received an Award for Engineering Excellence in the Environment Category in 1997.

Work is also being undertaken to extend or upgrade other bicycle paths and provide bicycle racks in shopping centres across the municipality. The extension of bicycle lanes means that it is now possible to travel to and from the St Kilda Town Hall and the city via bicycle lanes. The State Government plans further extensions.

Last month, the City of Port Phillip convened a Bicycle Forum to hear from cyclists themselves about their priorities and what can be done in terms of education and publicity programs about cycling. Our efforts to improve bicycle paths and lanes have already won wide-spread support. Twelve satisfied cyclists recently wrote to the council, praising our initiatives. Given that we're most used to getting brickbats and not bouquets, this is an amazing response. The mayor of Port Phillip, Cr Dick Gross, has also done a lot to promote the benefits of cycling over the past year. He declined the offer of a mayoral car and instead cycled to most civic events.

The *Integrated Transportation Strategy does* not neglect pedestrians, commonly known as the 'forgotten' road users. Walking is and should be seen as a legitimate form of transport. As with cycling, walking is cheap (indeed free), healthy and environmentally friendly. Walking is also essential to creating safe communities. People – particularly women and older residents – hesitate to go out if the streets are deserted, especially at night, as they are in so many dormitory suburbs of Melbourne. Contrary to popular perception, most locals feel pretty safe walking around the streets of St Kilda at night because other people are doing the same.

Walking is integral maintaining a sense of community. Walking to and around your local shopping centre, for instance, means opportunities to meet with your neighbours, friends, other parents and traders – much needed social engagement.

Walking is not without its pitfalls, literally. Pedestrians can stumble into holes or over tree roots bulging up from the footpath so footpath maintenance and a tree root strategy are key adjuncts to a successful transportation strategy.

Pedestrian accidents from cars are even greater threats. Port Phillip has one of the highest incidence of accidents in Victoria which involve older people, many of whom were born overseas. A Senior Citizens' Forum held in March last year identified pedestrian safety as a key issue for older citizens. Our 'Walk with Care' program, funded by VicRoads, will concentrate on three areas in East St Kilda.

We are adopting an integrated approach to pedestrian education which involves council's traffic management and aged and disability services together with community groups such as Jewish welfare organisations, tenants' and senior citizens groups. We are actively surveying older residents to identify key issues and come up with appropriate traffic management and other solutions.

Solutions could involve more traffic lights, better positioned traffic lights, signs in languages other than English, railings to focus pedestrian access to crossings, more signals to assist those who are hearing impaired and better maintained, clearer footpaths. We will also identify whether it is up to VicRoads or the council to implement the solutions.

A similar program run in Port and South Melbourne in 1993 led to a massive reduction in pedestrian accidents. Obviously, with a more diverse population in East St Kilda, a significant proportion of senior citizens from non-English speaking backgrounds and generally more people on the street, the situation is a little more complicated but solutions will be found and implemented.

We are also campaigning for improved driver etiquette, especially at pedestrian crossings. Regrettably, too many drivers are indifferent to pedestrian crossings.

With VicRoads, the City of Port Phillip is also developing and implementing specific education programs aimed at younger pedestrians – Safe Routes to School and Walk Safe, funded by the State Government to the tune of $1.3 million.

In other initiatives to decrease dependency on the car, the City of Port Phillip is undertaking a feasibility study with Monash University's Institute of Transport Studies on a 'Flexicar' program. Based on experience in Europe and, to a lesser extent, the US, 'Flexicar' aims to reduce household ownership of a second car by offering alternative, competitive travel choices. These may include car lease/hire programs, taxis, cycling walking or public transport. Car sharing has grown rapidly in Europe over the past decade. One program in Switzerland involves over 20,000 people with a fleet of 900 cars, at 600 stations in 300 towns.

Initial research by Monash University points out that Australian motor vehicle users are very possessive of their right to own and drive a motor vehicle at their discretion. The Australian love affair with the car is long and enduring. Providing an attractive alternative to the ownership and operation of privately owned vehicles will require identifying and targeting factors which determine this habitual behaviour – a tall order. In the pre- feasibility stage, Monash University researchers have alerted us to the need for any 'Flexicar' scheme to involve savings – the old hip-pocket nerve – convenience and flexibility. Once the feasibility study has been completed, the City of Port Phillip will be in a better position to determine whether there is a scope to generate a demand for such a service within the city.

Additionally, we are exploring 'travel blending' – a tailor-made program for individuals which facilitates and suggests small changes in transportation which fit into their life style and give them personal benefits as well as benefits accruing to the broader community. To give you an example, I now drive my son to and from Elwood to secondary school in Brighton each day. I simply put a notice up at the school *8*, in the school newsletter and found another St Kilda parent doing the same thing and come to a mutually beneficial arrangement. Alternatively, I could have made him ride his bike – but I hope you get the general idea. One square kilometre in Adelaide is currently trialing this program.

Finally, I want to briefly discuss two other areas of transport planning – events management and traffic related to street sex work.

Port Phillip is home to a number of festivals, including the largest community suburban festival in Australia, the St Kilda Festival, marches like the annual Pride March and, rather more controversially, the Australian Grand Prix. We go to great efforts to maintain a balance between local and regional road access, the requirements of the event itself, the economic benefits to the community and the amenity of local residents. In the case of the Australian Grand Prix, managing the traffic in and out of area near Albert Park requires road closures, a complex system of permits for residents, traders, emergency services and service and delivery vehicles and close cooperation with the Australian Grand Prix Corporation.

Managing prostitution related traffic is even more of a challenge. Over the last fifteen years, the City of Port Phillip and the former City of St Kilda has attempted to alleviate the level of intrusion on local residents by traffic engineering means. A series of road humps and one-way street sections in Robe and Acland Streets simply shifted the main beat to the Greeves Street area which now experiences peak hour traffic between 11 pm and 4 am. In response to angry resident demands, nearby Blanche Street is now gated both ends between 6 pm and 6 am. For the past few months, the Blanche Street residents have been very happy but now other residents in other nearby streets are complaining about the noise, the traffic and the hoons. As our traffic department is fond of telling us, Councilors, you can't use an engineering solution for a social problem. Our greatest hope in resolving this particular traffic problem lies in radical solutions to the heroin problem, decriminalising street sex work and realistic alternatives such as sex hotels or safe houses.

Through its *Integrafed Transportation Strategy*, the City of Port Phillip is determined to confront our traffic and transportation problems head on. I would like to say Port Phillip has a magic wand which will make all these problems disappear but we don't. In fact, other agencies – VicRoads, the PTC, Melbourne Ports Corporation, City Link and the State Government – hold the magic wand. What the City of Port Phillip can do is to negotiate with these different agencies for the best possible outcomes and to implement our three- year plan to provide a sustainable, safe and equitable transportation system. The one thing that is for sure is, that if we don't get it pretty right, the lifestyle which attracts both residents and visitors to Port Phillip will soon lose its allure in traffic gridlock and parking pandemonium.

MOBILITY, TECHNOLOGY & THE ENVIRONMENT

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INTRODUCTION

Mobility is an integral part of the Australian way of life. While there are many modes of transport available to suit varying mobility needs, the fact is that the motor car is the mode of choice for most Australians in meeting most of their transport needs. Australia has one of the highest rates of vehicle ownership in the world (606 vehicles /1000 population) (ABS, 1997). In Melbourne, cars account for 75% of all person trips, public transport 5%, cycling 2%, walking 16% and others 2% (Department of Infrastructure, 1996).

These figures reflect the inherent technological characteristics of the respective modes. Consumers expect, and will use, a mode of transport which is direct, reliable, quick, safe and secure, comfortable and affordable. In many ways, this has favoured the automobile over other transport options. Consumers will continue to demand the mobility and access benefits the car provides.

This is not to say that public transport modes, walking, and cycling are unimportant. To the contrary, they are vital, and in many cases dominate the market to which they are technologically and spatially suited (e.g. public transport accounts for half of all trips to Melbourne's central business district). Sensible transport policy must therefore be based on a concept of an integrated, multi-modal transport system where each mode plays the role to which it is best suited.

It is also important to acknowledge that transport technologies are evolving. Vehicle manufacturers are presently engaged in extensive research and development programs into various refinements of existing technologies and new motive sources. More importantly in the longer term, the convergence of information technology, vehicle based technology and infrastructure-oriented technologies will see the evolution of what amounts to a new transport mode where the energy and space efficiencies of public transport can be combined with the flexibility and convenience of the private vehicle.

This paper presents a consumer perspective on the automobile and new transport technologies. It summarises current developments in the automobile industry, and outlines a possible progression of transport technology which will combine the best features of current motor vehicle and mass transport modes. It also reviews consumer attitudes to technological change, and the role of the consumer in affecting change.

TRANSPORT AND LAND USE

The theme of this symposium in planning, and the Melbourne lifestyle.

Melbourne has numerous forms of transport technology, each occupying a market niche in reflection of the needs which the technology satisfies.

Melbourne has a very extensive public transport system. Most of Melbourne's fixed rail and tram network was in place by 1890, 110 years ago. These networks are thus quintessential 19th century technologies. It is salutary, however, in the context of this symposium, to note that these networks were built not as a result of enlightened planning, which foresaw the need to provide mobility and access to the growing metropolis, but rather to provide a profit through land speculation to the so called 'land boomers' - the owners of land on the urban fringe, who benefited when a rail or tram line was built near their property (Cannon, 1966).

Notwithstanding their motives, the land boomers gave Melbourne an invaluable resource - a very extensive suburban rail and tram network. Today, this network comprises 336 route kilometres of rail serving 197 stations, and 341 route kilometres of tram and light rail. (Department of Infrastructure, 1996). These are enormous networks by world standards. We do not appreciate well enough in Melbourne what an extensive asset this fixed rail public transport legacy is. It will be interesting to see if the new private sector franchisees can revitalise this invaluable asset in the way that their private sector forebears did when the network was laid down.

Moreover, for several decades after this network was laid down, it was in harmony with, and well served by, the land use patterns which it helped to produce. It was a strongly radial transport system, with a highly centralised city. The two were mutually reinforcing. This pattern existed up until the 1950s when the rapid growth of automobilisation began to take off in earnest. This was driven by the essential technological features of the motor car, as outlined in the introduction to this paper.

The motor car, and also the truck, both produced and made possible a different form and structure of Melbourne, one that was characterised by a lower density, a multitude of trip generators, a diverse pattern of trips, and a much less strong orientation towards travelling any particular corridor or direction. Once again, we have a situation where the technology and the urban structure are in harmony.

Indeed, looking back, it could be said that Melbourne has accommodated the post-World War II development remarkably well, based essentially on the old one mile (1.6 kilometre) rural farm grid of arterial roads and, compared with other comparable cities, very few higher order roads (eg, freeways). Melbourne's 231 kilometres of freeway, shortly to become 253 kilometres with the opening of CityLink, is only about one-third of what comparable North American cities have. But, in the context of this paper, the important point to note is that the Melbourne associated with the suburbanisation of jobs and other activities, together with the mobility provided by the motor car, bore little relationship to the earlier Melbourne associated with centralised activity and public transport mobility.

However, these two land use patterns continue to co-exist to this day. A useful way of visualising Melbourne is to think of it as these two urban forms superimposed one on the other.

It is implicit in the above discussion that cities are constantly changing and that one of the key factors affecting change is transport technology. It is much more complex than a simple cause-effect relationship. Cities can and do adapt to different transport technologies and they change as those technologies change. Conversely, when new technology is introduced it only survives if there is a market for it. Let us turn then to consider technological developments in transport.

CURRENT TECHNOLOGICAL DEVELOPMENT IN THE AUTOMOBILE

Today's automobile is an extremely sophisticated device which embodies advanced technology in materials, engines, safety features, emissions performance, ergonomics and information systems. All these facets are combined to produce a functional and aesthetic vehicle which must meet requirements for safety and environment as well as motorists expectations of performance, affordability and comfort.

Major advances are being made in vehicle materials. The use of ultra light steel, aluminium, composite alloys, plastics, rubber, paints, cloth and glass are examples of a range of materials used in vehicle design and which are currently undergoing major refinement and change. Materials are used to meet precise performance requirements.'In striving for improvements in terms of vehicle weight, production costs, safety, comfort and the like, manufacturers look to advanced materials.

When buying a car, safety emerges after monetary considerations in consumer choice, and is on a par with comfort (ANOP, 1996). Safety features such as anti-lock braking systems, seat belt pre- tensioning systems, vehicle structures and crash responses, head restraint designs, airbags, yaw sensors and crash avoidance systems have been designed to improve aspects of vehicle safety. These technologies are also currently undergoing enhancement and major change.

Significant advances are also being made in engine design and engine management. Each of the manufacturers have major research and development programs to refine the existing internal combustion engine to extract the best performance with the lowest emissions and reduced fuel consumption. Advanced computing and control systems are now an integral part of these developments.

Similarly, the major vehicle manufacturers are investing in research into electric vehicles, alternative

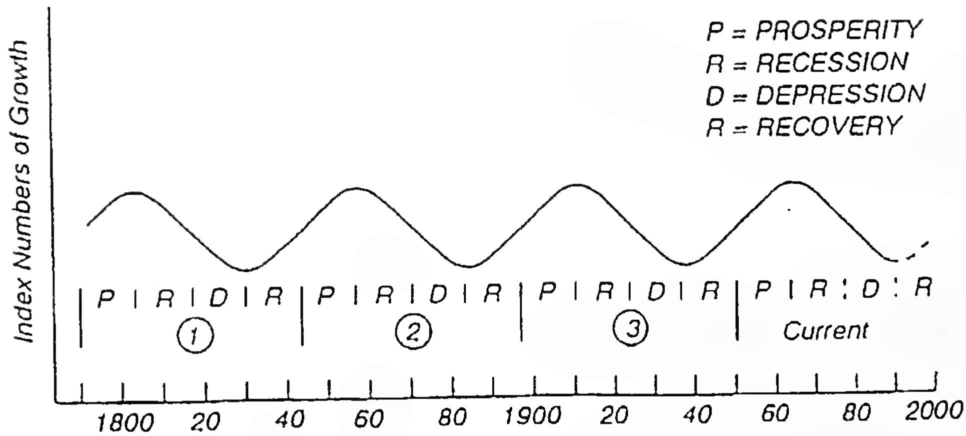

Figure 1 - Kondratieff Waves

fuels (natural gas, liquefied petroleum gas, oxygenated fuels like methanol and ethanol) and hybrid systems (which combine motive sources including ultimately methanol and eventually hydrogen fuel cells).

A final aspect of developments in the motor vehicle relates to the concept of "whole of life". This embodies the manufacture, use and ultimately the recycling or disposal of vehicles. Manufacturers like BMW

Application	User Services
Traffic Management	Transport Planning Support Traffic Control Incident Management Demand Management Policing/Enforcing Traffic Regulations Infrastructure Maintenance Management
Traveller Information	Pre-trip Information On-trip Driver Information On-trip Public Transport Information Personal Information Services Route Guidance and Navigation
Vehicle	Vision Enhancement Automated Vehicle Operation Longitudinal Collision Avoidance Lateral Collision Avoidance Safety Readiness Pre-crash Restraint Deployment
Commercial Vehicle	Commercial Vehicle Pre-clearance Commercial Vehicle Administrative Process Automated Roadside Safety Inspection Commercial Vehicle On-board Safety Monitoring
Public Transport	Commercial Vehicle Fleet Management Public Transport Management Demand Responsive Transport Management
Emergency	Shared Transport Management Emergency Notification and Personal Security Emergency Vehicle Management Hazardous Materials and Incident Notification
Electronic Payment	Electronic Financial Transactions
Safety	Public Travel Security Safety Enhancement for Vulnerable Road Users Intelligent Intersections

Table 1 Intelligent Transport Systems Applications and User Services (Source: PIARC, 1999)

and Volvo have vehicle-part recycling systems. Current generation vehicles are designed with these recycling systems in mind. In future such systems will become more common place as pressure mounts on the availability of certain resources.

THE NEXT TRANSPORT WAVE?

Technological change has been observed to comprise two elements, a gradual change over time as technologies refine and adapt, and a periodic revolutionary change. It can be argued that in transport we are entering an era featuring the latter, as our existing technology nears its limits. In the 1920's, the Russian economist Kondratieff observed that over the previous two centuries, economic performance had moved in cycles, or waves, or a period of about 55-65 years. Each cycle had four phases; prosperity, recession, depression and recovery. We are entering a recovery phase at the moment! (Freeman, 1982). This may be represented as shown in *Figure 1*.

The key point to make here is that in the past, the "prosperity" phase of each cycle has been associated with the introduction of revolutionary new technologies including transport technologies. The transport innovations of the previous cycles have been canals, railways, motor vehicles and aircraft.

Moreover, these technologies arose from research and development during the previous "depression" phase. Indeed, the prosperity phase occurred when the goods and services derived during the depression phase became readily available. Thus if there is any value in this analogy, it is only necessary to look at what research and development has been underway in recent years, to provide a hint not only about short term adoption of existing transport technology, but maybe a glimpse of the long term radical change.

In fact, there has been a very large research and development effort underway in areas of direct interest over the last decade. Japan, the US, and Europe have had major research programs in what is now generally referred to as Intelligent Transport Systems. (Table 1 summarises ITS applications and user services). The European effort is perhaps the most interesting, because in the early 1980's, they very deliberately began a major research effort, known as Eureka, in a number of areas where they deduced (or hoped) that they could become world leaders in key 21st century technologies. One of the major areas identified was transport technology. Two programs were developed. One, PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety) was vehicle oriented, whilst the other DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) was infrastructure oriented.

Vehicle related technologies developed in the PROMETHEUS program and comparable research and developments efforts elsewhere, feature such things as hybrid engines, route guidance systems, on-board navigation systems, on-board engine diagnostics, congestion avoiding systems, vehicle location systems, in-vehicle information and reservation systems, light-weight vehicles, freight vehicle systems, public transport vehicle management and information systems, etc. Several of these systems are beginning to find commercial application in Australia and overseas, and there is little doubt that there will be an explosion in the use of these types of technologies and applications over the next few years.

Infrastructure oriented technologies feature such things as adaptive traffic control, crash avoidance, automated highways, vision enhancement, and the potential for charges to be levied in real time using electronic license plates and roadside sensors. Eventually they will likely lead to driver-less cars and perhaps in-pavement energy sources. In 1997, a research and demonstration project on a 13 kilometre stretch of a freeway in California featured driver-less vehicles travelling in a platoon at up to 105 km/h with cars virtually bumper to bumper. They were steered through a system which recognised magnetic markers embedded in the roadway, whilst the spacing was maintained by radar and radio communication between the vehicles, without driver involvement.

In the long run, we can envisage that logical development of these technologies will see the evolution of what amounts to a new transport mode, one that combines the best features of both public and private transport. That is, it will still permit a door-to-door mobility and the ready access which the private car provides, whilst having the energy efficiency, space efficiency and low levels of environmental impact associated with high density mass public transport systems. The challenge will be to maximise energy efficiency and fuel conversation whilst at the same time keeping the attractive features of the private vehicle.

MOTORISTS' ATTITUDES

What do motorists know about the radical technology changes ahead? The answer is not very much at present. The motoring clubs and the Australian Automobile

Association monitor member views, and have explored many issues important to Australian motorists. In a 1996 survey (ANOP, 1996) the topic of Intelligent Transport Systems (ITS) was investigated.

When asked about their expectations of technology in new cars in 5 years time, only 35% of motorists thought that it would be "very different". Of this 35%, nearly half saw major change as merely an enhancement of the existing product. While some anticipated increased computerisation, only a small minority mentioned ITS applications.

When asked about their initial reactions to 12 applications, the most favourably received were:

- satellite tracking of stolen cars,
- controlling and managing traffic flows and congestion, and
- providing traffic information for drivers.

Thus the reaction to these new applications relate primarily to motorists' existing concerns of security and traffic congestion.

The main concerns expressed in this survey were:

- the possible increased cost of buying and maintaining cars;
- the potential for governments to start charging drivers for road usage; and
- invasion of privacy.

What was clear was that Australian motorists are wary of applications that have the potential to affect the hip pocket. In particular, they expressed reservations about electronic tolls, primarily because of the possibility that they could be used to measure drivers' road usage and charge them for it - precisely what economists and other argue for in the context of congestion pricing! This research suggests that congestion pricing may have an uphill battle for consumer acceptance, unless there are clear trade-offs to the consumer in terms of reduction in other road user taxes and charges.

The general acceptance of ITS will depend on whether the fear of government raises itself as an issue – in particular, the fear of government using ITS to raise revenue. There is a role for an independent voice positioned between the vehicle manufacturers and government to speak on behalf of motorists.

There is clear support for the motoring clubs to undertake this role and, indeed, RACV has been active over the past year in ensuring that Transurban has a comprehensive privacy code in place when CityLink opens for business.

The 1996 ANOP survey concluded that the uptake of new technology was likely to be slow and very much related to the current paucity of knowledge, understanding and experience. The speed of adoption is likely to depend on perceived need, price and whether motorists judge the benefits as outweighing their concerns.

Motorists' attitudes towards the environment are also ambiguous. Austroads (1997) report an international comparison undertaken by the Australian Bureau of Statistics which found that Australia had the highest percentage of people who believe that economic growth and environmental protection are both possible (71%) and the lowest percentge of people who placed environmental protection above economic growth (18% compared with 30% – 50% in Japan and Europe).

The 1995 ANOP survey (ANOP, 1995) for the Australian Automobile Association asked respondents to list their main concerns about transport issues. The most important issues, in order, were public transport (36%), condition of roads (29%), motoring costs (29%), safety (25%), followed by air pollution (16%). When asked about issues specifically related to cars, the response indicated that "environmental concerns" were the second highest ranked concern (25%), behind safety and driver behaviour (42%).

Despite their environment concern, surveys consistently indicate that motorists will not or cannot readily reduce their car usage. The 1995 ANOP survey found that less than half of motorists would personally do something to reduce the environmental problems caused by their cars and, for many, the action that they nominated would not represent significant changes in their behaviour. For example, only one of ten of those who were prepared to do something would consider using public transport more - and most of these were already public transport users!

The 1996 ANOP survey had an open-ended survey question about what reduces the environmental impact of a car. Just over half mentioned the type of fuel used (especially unleaded fuel), and about 40% nominated exhaust and emission controls. Less than 20% referred to fuel efficiency or the condition of the car. Only a tiny minority of motorists (4%) suggested less use of the car as a way of reducing its effects on the environment.

There is a potential role for motoring organisations in this area because of motorists' concern on the one hand and lack of information on the other. However, the theme of an environmental education campaign would have to be relevant to motorists' behaviour and take into account their dependence on the car and their desire to fix the car rather than fix the way they drive it. Motoring clubs have in fact responded to this demand. The RACV, for example, sponsors the 'Aircare Victoria' campaign jointly with the Victorian Environment Protection Authority, with its theme of 'Stay Tuned'.

CONCLUSION

The automobile has evolved over the last 100 years and in the short term we are likely to see continued refinement and change in this technology. In the longer term, opportunities for new technologies will arise. The motor vehicle is the mode of choice for most Australians and they will be unwilling to give up or do without the mobility and access benefits that the motor vehicle provides.

We may need to consider that we are on the verge of a new radical form of transport with the convergence of information systems and infrastructure and vehicle technologies, one that combines the best features of both private and public transport. Ultimately, transport solutions should be more sustainable, more equitable, safer, more efficient, and have less adverse environmental effects.

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It will assist reviewers if related papers recently published or submitted elsewhere accompany the submitted manuscript.

FORMAT

All manuscripts should be written in clear and concise English. Use double spacing throughout; leave 30 mm margins around the text; number all pages. All measurements are to be expressed in SI units (eg μm, mm, m, km but not cm) and standard symbols and abbreviations used. Note, Ma refers to a date (eg 25Ma) not a time interval, which is written as 5 million years. When a number does not refer to a measurement it should be spelt out except when it is greater than nine. Wherever possible fractions should be written in the form x/y.

Geological papers must follow the Australian Code of Stratigraphic Nomenclature and should cite geological maps in the text with italics for the 1:63 360 series and full caps for the 1:250 000 series. New stratigraphic names should be registered with the Geoscience Australia (GA) Australian Stratigraphic Names Database. The GA website "How to define a lithostratigraphic unit" (http://www.ga.gov.au/minerals/strat_names/) is a useful guide.

The Proceedings uses Australian spelling according to the latest edition of the *Macquarie Dictionary* and where there is optional spelling for words we use the form used by Victorians traditionally. For example we use the following spelling; color, honorary, program.

Authors should follow the layout of headings, tables and illustrations as presented in a recent issue of the *Proceedings*.

Papers should be organised as follows:

1. *A brief title*, capitalised and, if possible, beginning with a key word.
2. *The name and address of the author(s)*, with numerical superscripts to distinguish addresses of multiple authors.
3. *A full reference to the paper*, leaving space for the printer's additions.
4. *A short abstract* of not more than 200 words describing the results (rather than the contents) of the paper.
5. *Up to 5 key words.*
6. *The main text.* Capitalise the first word of the introductory paragraph; do not use the heading 'Introduction'. Within the text up to three grades of headings may be used, typed as follows:

GRADE ONE HEADING

Grade two heading

Grade three heading. Followed by running text on the same line.

Refer to illustrations of the paper in the text as 'Fig. 1A, B', 'Figs 1, 2' or Figs 1-4', and indicate in the margins where the illustrations should be placed. Refer to references in the text as Archbold (1998), (Archbold 1998) or (Archbold 1998: 2, fig. 1); multiple citations of references should be arranged chronologically. All references cited in the text must be listred at the end of the paper. Footnotes in the main text are not allowed.

In taxonomic works, synonymies should be of the same format as the following examples, with a dash preceding authors' names except in the case of reference to the original description.

Eudendrium generalis Lendenberg 1885: 351, pl. 6. — Lendenberg 1887: 16.

Eudendrium generale. — Hartlaub 1905: 515.—Watson 1985: 196-200, figs 40-52.

non *Eudendrium generale.*—Watson 1982: 89, pl. 10, fig. 3.

Eudendrium lendenfeldi Briggs 1922: 150.—Rosler 1978: 104, 120, pl. 20, figs 1-3.

Note that plate and figure numbers, etc. originally given in Roman numerals should be transliterated into Arabic figures; this is also the case in the main text and in the references.

7. *Acknowledgements.* The source of finacial grants and other funding as well as the contribution of colleagues or institutions should be acknowledged. These should follow the main text and be as brief as possible.
8. *References.* These should conform in arrangement to the examples below. Journal titles must be cited in full as they appear on the title page.

CURTIS, N. P., 2001. Germination of *Xanthorrhoea australis* using treatments that mimic post-fire and unburnt conditions. *Proceedings of the Royal Society of Victoria* 113(2): 237-245.

BERGSON, H., 1928. *Creative Evoltion*. MacMillan and Co., Limited, London, xv+425 pp.

ROSEN, B.R. & TURNŠEK, D., 1989. Extinction patterns and biogeography of scleractinian corals across the Cretaceous/

Tertiary boundary. In *Proceedings of the Fifth International Symposium on Fossil Cnidaria including Archaeocyatha and Spongiomorphs*, P.A. Jell & J.W. Pickett, eds, Association of Australasian Palaeontologists, Brisbane, Queensland, 355-370.

Personal communications and unpublished data are not to be listed in the reference list but should be mentioned in full in the text (eg P. Brown pers. comm. 2002).

9. *Tables and Figures.* Each table with its title should be typed on a sperate sheet. A separate sheet should also be used to list captions to figures in numerical order.

ILLUSTRATION

These must be designed for one or two column width (67 mm or 140 mm); maximum length is 193 mm. Composite Figures should be lablelled A, B, C, etc. (not a, b, c). Oversized illustrations, tables or maps may be accepted for publication as foldouts only if the author meets all costs involved in their production. Maximum size for foldouts is 193x285 mm.

Final submission of black and white figures electronically is encouraged as long as it is in a readily acceptable format (JPEG, TIFF, emf, wmf, pcx, pct, wpg, cdr). These can be supplied on 3.5" floppy disks, zip disks or CD (especially for figures with any grey shades) and accompanied by a high quality hard copy. Digital files must be supplied at a resolution of at least 300 d.p.i. at full size.

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Authors will normally receive an 'Adobe Acrobat PDF' version of the mock page proofs; this is for the purpose of correcting printer's errors and not for altering the wording or substance of the paper. This should be returned to the editor within 72 hours. If absent, authors should arrange for a collegue to check and return proofs to the editor on their behalf. Authors will be charged for excessive alterations at this stage.

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