Natural History of Kangaroo Island

SECOND EDITION

Editors: M. Davies, C. R. Twidale & M. J. Tyler

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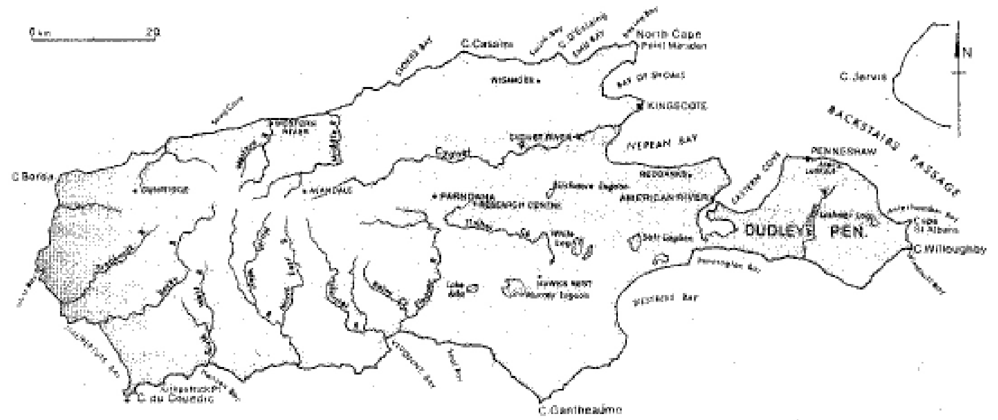

LOCALITY MAP

SATELLITE PHOTOGRAPH

DEDICATION

This volume is dedicated to the memory of the late Emeritus Professor W. D. (Bill) Williams, A.O., long-time Fellow of the Society, Verco medallist, and one-time President; valued contributor and ardent supporter of the Natural History series.

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Preface to First Edition

On the first visit to almost any island a visitor is likely to experience a variety of emotions. It certainly would be an insensitive person who is not stirred by a feeling of isolation, and perhaps there may be slight unease at the apparent vulnerability of a coastline exposed to the awesome destructive power of the waves generated on the surrounding seas.

Against such a background it is easy to view an island both as a refuge and, given sufficiently long isolation, a potential area for evolution. In the case of Kangaroo Island only the former assumption is correct. Thus some animals are far more abundant on Kangaroo Island than on the adjacent mainland, and at least some of the pests on the mainland (e.g. the rabbit) are absent. Understandably the island has a special attraction for anyone interested in natural history.

'Natural History of Kangaroo Island' is an accurate and highly informative guide to the physical environment and the fauna and flora, and to the Aboriginal people who formerly inhabited the island. This book is a companion volume to the Society's successful 1976 publication, 'Natural History of the Adelaide Region'.

Most regional natural histories treat the subject superficially, simply because it is impossible for one author to possess the necessary depth of knowledge to do justice to such a broad topic. In this new volume 24 authors have collaborated to produce 15 chapters, and by this means accuracy and a reasonable degree of detail have been produced. Certainly most of the authors indicated that they could have achieved a more comprehensive coverage of their particular specialities if they had been given twice the number of pages actually allotted! However, to have done so would have increased the cost of the volume considerably and, despite extra pages, it would still be incomplete simply because so much remains to be discovered. For example, in his chapter, 'Native Vegetation', R.T. Lange writes ' ... the keen observer on Kangaroo Island can rapidly list many simple questions for which there are no published answers. This should encourage students who think opportunities for pioneering research are gone'. Similarly Inns, Aitken and Ling report several mammals known on the island from only one or two records; the reptile list is probably incomplete, and the checklists of birds and fishes will no doubt be modified as informed observers study the fauna. The checklists have been produced as a result of considerable effort by the respective authors; they constitute a positive contribution to stimulate residents and visitors to examine the fauna more closely.

Gross, Lee and Zeidler point out in their chapter on invertebrates that there is only one record of earthworms being found on kangaroo Island; taken at Rocky River the species was new to science and had not yet been found anywhere on the mainland (or elsewhere on the island). Every gardener will appreciate that such a deficiency is probably more apparent than real; it serves to focus attention upon the inadequacy of modern knowledge.

At various times in the past the lowering of sea levels has resulted in Kangaroo Island being connected to the mainland by a land link. As a result the flora and fauna there has been shared with the mainland, and that is the case there today. The absence of a unique Kangaroo Island fauna is simply because the present period of separation from the mainland of 10 000 years represents an insufficient span for the isolated populations to evolve into distinguishable species.

From the turn of the nineteenth century Kangaroo Island received numerous visitors, and the island was a significant focus for the attention of sealers and whalers in that period before the Proclamation of South Australia. A description of this fascination history is beyond the scope of the present volume, but we have include, as a concluding chapter, a translation of the observations made by the French zoologist Francois Peron in 1803.

On the behalf the co-editors I express thanks to the authors who co-operated to produce this volume. We are also indebted to Margaret Davies for valuable assistance with the reading of galley proofs, and to Ian Murray of Graphic Services for his valuable advice and ever ready assistance with this venture.

MICHAEL J. TYLER,
AUGUST,1979

Preface to Second Edition

The word 'history' implies an account or record of past events, but here is used in its original sense in the term 'natural history'. Derived from the Greek word *historia,* natural history is concerned with an enquiry or research into the natural world and hence with understanding and explanation.

The last 20 years have seen dramatic changes in our knowledge and perceptions of some aspects of the natural history of Kangaroo Island. For example, the structure of the Island remains as it has been for some 500 million years, but the way we see it has been revolutionized by detailed mapping and the application of fresh concepts.

This sort of change, taken together with the high level of interest in the natural history of the Island, has motivated the revision of the first edition of 'Natural History of Kangaroo Island' (1979).

Kangaroo Island has a special place in both human and natural histories of the State. It witnessed some of the earliest encounters made by visitors from Europe and North America with our environment, leading both Flinders and Baudin, for example, to wonder at its scenery and wildlife. It was briefly considered as the site of the capital city of South Australia. The geology of the Island epitomizes many aspects of the geology of the entire State, and its high plain is claimed to be amongst the oldest land surfaces known. Its location at the edge of the Australian continent has rendered it susceptible to the worldwide changes in sea level of the past twenty millions of years, so that it has at times been an integral part of the mainland but at others isolated by the ocean, with all that that implies for the evolution of plants and animals.

Its fauna and flora is increasingly challenged by introduced species - some purposeful, others by accident. We hope that the management issues discussed in this volume will increase awareness of potential disaster faced by this unique Island, and that such issues are acted upon quickly. Increased numbers of visitors enjoying this wonderful habitat bring their own ecological problems which need to be recognized and prevented before they become further management issues.

Several contributors to the first volume are now deceased or retired, yet their original contributions remain the major body of knowledge of Island natural history. The nomenclature in the works of the late S. J. Edmonds and Ifor Thomas have been updated by Scoresby Shepherd, that of the work of the late John Glover has been updated from the work of Gomon *et al.* (1994) whilst the Soils chapter of K. H. Northcote has been updated by Malcolm Wright and Bob Bourman. We thank them for their contributions. Most of the Chapters in this volume, however, are newly written reflecting the massive increase in our knowledge of the Island's natural history. The addition of an Index should make the volume more user friendly.

We hope that this volume will, like its predecessor, continue to engage the interest of inhabitant and visitor alike. May there be many more encounters of a stimulating kind!

Margaret Davies
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July 2002

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The editors wish to thank Jennie Bourne for meticulous proofreading of the earth science chapters and Ian Murray and Graphic Print for care and support in the production of this and others in the Natural History Series.

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2.

1: Geology

by P. R. JAMES and I. F. CLARK

INTRODUCTION

Although Kangaroo Island is currently isolated from the mainland by Investigator Strait it essentially reveals a microcosm of the geology of South Australia. Through much of geological history Australia was joined to Antarctica as part of the Rodinian Supercontinent (Figs 1.,2). Many of the elements of the geology of South Australia can be found and are indeed displayed on Kangaroo Island, where cratonic and orogenic elements are juxtaposed and where structures critical to the understanding of the geological evolution of southern South Australia have been identified and studied. It is suggested that the geological history of the island cannot be divorced from that of Fleurieu Peninsula (Daily *et al*. 1979).

The structural architecture of the island and its specific relation to the Adelaide Geosyncline and Delamerian fold belt was synthesized initially by Mancktelow (1990) and subsequently by Flottmann *et al.* (1995). Kangaroo Island is currently being remapped for a new Kingscote Sheet (Belperio & Fairclough in prep.). Other recent publications appearing in association with this mapping, (Belperio & Flint 1992; Belperio 1995) and with the allied geophysical and drilling

Fig. 1. Kangaroo Island at the centre of the Rodinian Supercontinent 1,000,000.000 years ago (after Li *et al*. 1996)

studies (Van der Stelt *et al.* 1992) also provide valuable insight to the geology which underlies and, in many cases, forms features which make Kangaroo Island one of the principal tourist destinations in South Australia.

Apart from the name, isolation, and rugged bush scenery, which provide the mystique to lure tourists from allover the world, and the spectacular coastline dominated by scenic cliffs, rocky headlands and pristine beaches, many of the most appealing tourist locations are fundamentally geological in nature (e.g. Remarkable Rocks, Kelly Hill Caves, Cape Willoughby, Admirals Arch, Little Sahara etc. Fig. 3). Many of these are recognised as such and are registered as geological monuments under the National Estate programme.

METAMORPHIC BASEMENT

Although poorly exposed, except on the coast, the subsurface geology of most of Kangaroo Island is dominated by uniform, immature clastic metasediments belonging to the Cambrian Kanmantoo Group, deposited in the Kanmantoo Basin, and exposed throughout the Fleurieu

ERA	Period	Time in years from present	KI Events
CAINOZOIC	QUATERNARY	2,000,000	
	TERTIARY	50,000,000	Australia-Antarctic Separate
		65,000,000	Laterite Plateau
MESOZOIC	CRETACEOUS	140,000,000	
	JURASSIC	205,000,000.	Flood Basalt
	TRIASSIC	251000000	
PALAEOZOIC	PERMIAN	298,000,000	Glaciation
	CARBONIFEROUS	354,000,000	
	DEVONIAN	410.000.000	
	SILURIAN	434,000,000	
	ORDOVICIAN	490000000	S Coast Granite
	CAMBRIAN	545,000,000	Mountain Building Cambrian & Adelaidean Sediments
PRECAMBRIAN	PROTEROZOIC	800,000,000	
		2,500.000,00C	
	ARCHAEAN	4 000 000 000	

Fig 2. Geological Time Scale including timing of events recognised on Kangaroo Island

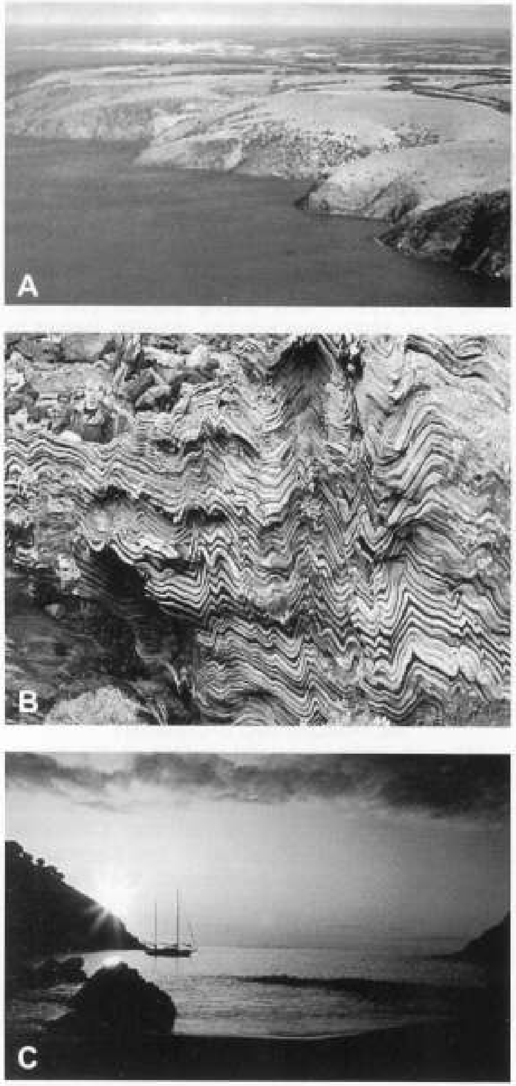


Fig. 3. Examples of spectacular geological features around Kangaroo Island; (a) oblique aerial view across eastern Dudley Peninsula. The deeply dissected plateau forms steep-sided inlets in the foreground, which are controlled by faults and shears of the Sprigg Inlet Shear Zone. Cape Willoughby is visible in the background across Antechamber Bay, (b) 'zebra' folds in schist at Harveys Return, (c) sunset at Snug Cove.

Peninsula and the eastern Mt Lofty Ranges. This Kangaroo Island - Fleurieu Arc is a segment of the much larger Adelaide Fold-Thrust Belt (Fig. 4).

The basement rocks of the Island comprise three stratigraphically and structurally distinct domains. In the south, basinal and moderately metamorphosed Cambrian Kanmantoo Group strata consist of simply deformed packages of regional northeast-southwest trending folds and thrusts. In stark contrast, the Kangaroo Island Shear Zone forms a broad east-west trending sheared and folded zone, which consists primarily of anastomosing coarse and fine-grained cataclastic metamorphic rocks known as mylonites and phyllonites. Lithologies and stratigraphy cannot be correlated with any degree

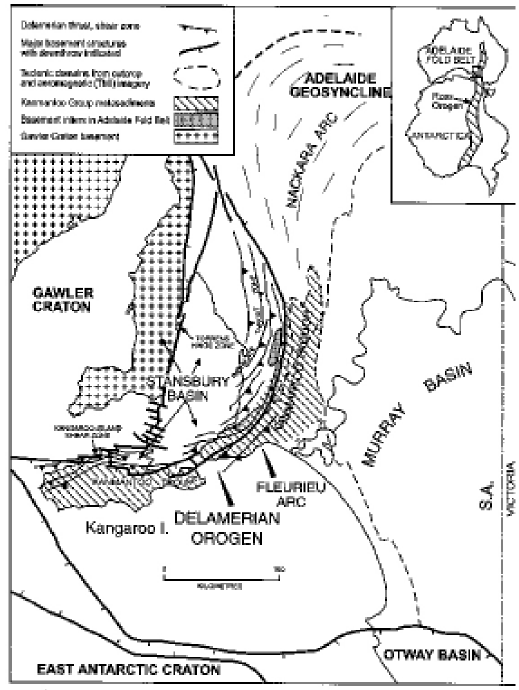


Fig. 4. Location map of Kangaroo Island in relation to the adjacent tectonic elements of South Australia (modified after Belperio & Flint 1993).

of confidence across this major tectonic boundary. Along the shear zone, the Kanmantoo sediments have been metamorphosed, compressed and displaced towards the northwest, creating an overturned anticline against its southern boundary. The third and most northerly crustal zone forms a 15 km-wide thrust belt incorporating a relatively thin veneer of Cambrian platformal sediments known as the Kangaroo Island Group, that unconformably overlie the southernmost extension of the Gawler Craton in South Australia. The Kangaroo Island Group rock types, which are absent on the Fleurieu Peninsula, are displaced along discrete thrusts and reverse faults. These three lithological and tectonic domains of Kangaroo Island reflect a basin geometry and associated sedimentological architecture distinct from the mainland.

Palaeo/Mesoproterozoic basement

The northern platformal zone of Kangaroo Island lies at the very southern margin of the Gawler Craton which is exposed on the adjacent south coast of Yorke Peninsula and on several islands in

Investigator Strait, and is composed of deformed Palaeoproterozoic granites and gneisses (Rankin *et al.* 1991).

The eastern margin of the Gawler Craton is considered to be located along a marked linear feature known as the Torrens Hinge Zone which trends north-south from northern South Australia to a few kilometres offshore of northern Kangaroo Island (Fig. 4). Recent geophysical work allied with seafloor sampling led Belperio & Flint (1993) to place the southern margin of the Craton onshore, on northern Kangaroo Island, approximately along the trace of the Snelling-Cygnet fault system. Subsequent drilling 5 km west of Pt Marsden intersected 313 metres of the platformal Cambrian Kangaroo Island Group sediments overlying crystalline basement including quartz feldspar gneiss, pegmatite and amphibolite (Belperio & Hibburt 1994).

Adelaidean - Stratigraphy

On Dudley Peninsula, a narrow wedge of highly deformed metasediments was originally identified as part of the Kanmantoo Group. However, Daily &

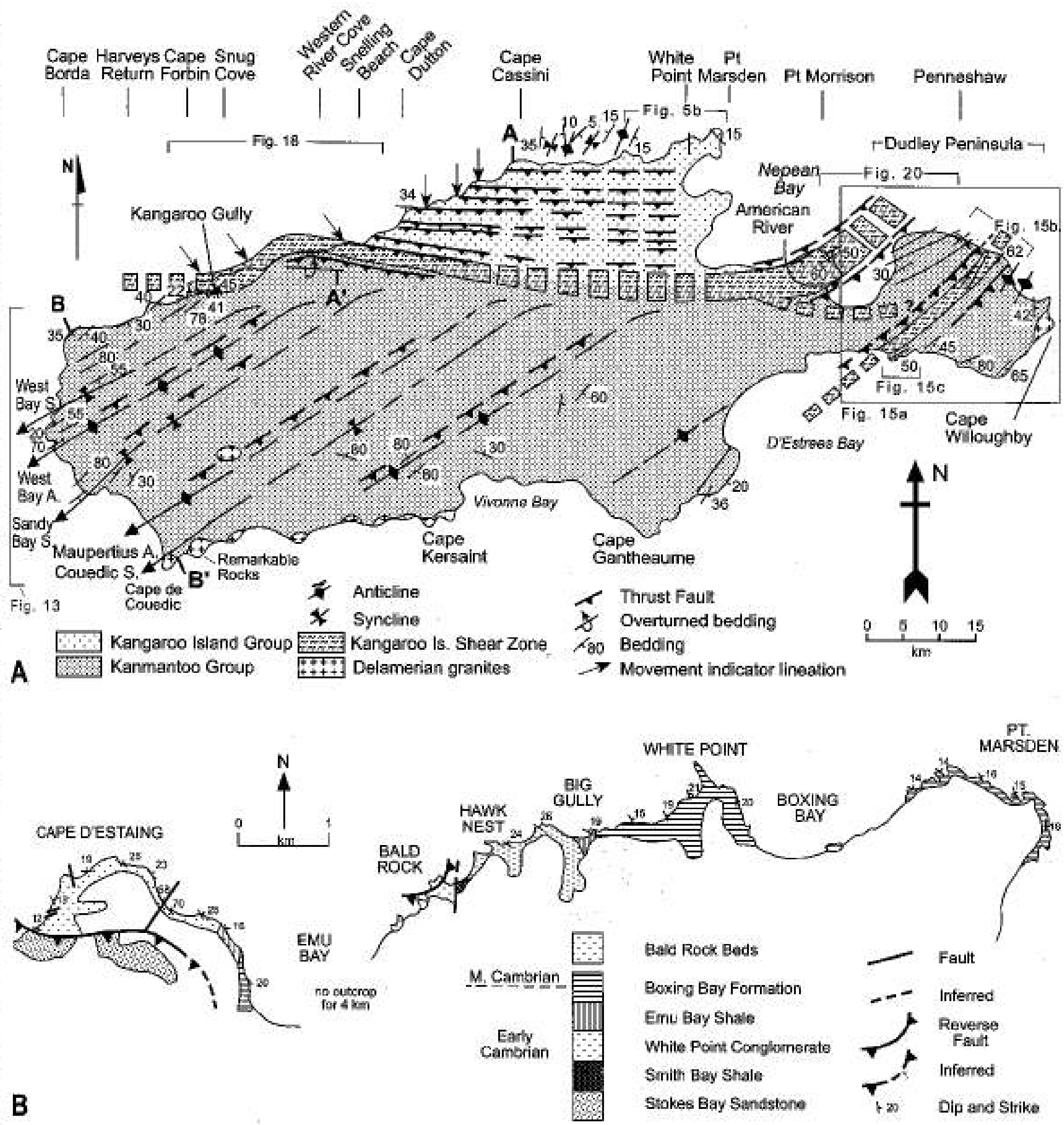


Fig. 5. (a) Principal geological features of the pre-Permian basement of Kangaroo Island (after Flottmann *et al.* 1995), with locations of more detailed maps; (b) Sketch map of formations and structures along the north coast between Cape D'Estaing and Point Marsden (after Nedin 1995)

Milnes (1971) reinterpreted these as belonging to the underlying Adelaidean succession (Fig. 5). These lie in a thrust fault and shear-bounded wedge on the eastern coast of the Dudley Peninsula and were suggested to include both glacial and interglacial deposits. These lie to the north of what is now identified as the Sprigg Inlet Shear Zone, as well as in the core of the adjacent Cuttlefish Bay Anticline and are bounded to the north by the major Dudley Fault. These strata are considered to include from base to top, the Sturt Tillite, the Tapley Hill Formation, the Brighton Limestone and the Marino (Hallett-) Arkose, and are the oldest rocks exposed on Kangaroo Island, although all are intensely deformed and moderately metamorphosed, making stratigraphic correlation difficult.

The Sturt Tillite within the core of the Cuttlefish Bay Anticline is a pebbly sandstone with clasts of quartzite and igneous rocks up to 40 cm across, randomly dispersed amongst smaller pebbles and granules in a sandy and phyllitic matrix. These were interpreted by Daily & Milnes (1971) as subaqueous dropstones, released by the melting of floating ice and incorporated in gritty and sandy deeper-water sediments. Daily *et al. (1979)* regarded the granitic character of many of the larger clasts to indicate the Gawler Craton as the source of much of this glacial debris. Overlying the tillite, dark-coloured well-laminated mudstones and siltstones of the Tapley Hill Formation, are now represented by phyllites with conspicuous thick bands of red- and brown-stained sulphide (pyritic) rich horizons. These presumably indicate deeper water conditions typical of this horizon throughout the Adelaide Rift and likely to represent eustatic rise due to melting of the Sturtian icecap. Towards the top there is a gradation to more calcareous siltstones with thin marble interbeds, probably indicating shallower water conditions before the gradation to a thinly-bedded, coarsely-crystalline marble sequence correlated with the Brighton Limestone Formation. This unit is severely affected and thinned by deformation in this section. Above the metamorphosed Brighton Limestone there is a transition to grey to green laminated meta-siltstones with thin light-coloured calcareous bands, correlated by Daily *et al.* (1979) with the basal Umberatana Group of the Adelaidean succession. Metamorphism and deformation have destroyed all original sedimentary features other than highly transposed bedding, and the correlation is based on 'gross characteristics as seen in the (type) Adelaide region' (Daily *et al.* 1979, p. 8). Most of the Umberatana Group is represented by grey-coloured metasediments with prominent andalusite porphyroblasts, and with upwardly increasing numbers of thin, pale-coloured quartzite.

For most of these rocks, lithostratigraphic classification remains tentative. The strata are clearly highly metamorphosed, strongly

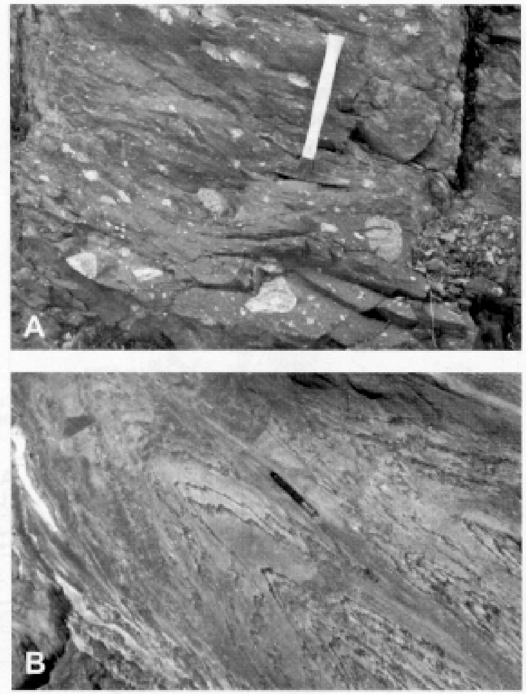


Fig. 6. Possible Adelaidean lithologies occurring on the NE coast of the Dudley Peninsula (a) Assorted pebbles from Sturt Tillite(?) in the core of the overturned Cuttlefish Bay Anticline (photograph # 035633 courtesy of Office of Mineral and Energy Resources, SA) (b) Sheared and folded Talisker Calc-siltstone, on the overturned limb of the Cuttlefish Bay Anticline

transposed, sheared and foliated. They are grey coloured, fine-grained rocks, which on lithologic grounds are difficult to discriminate from the bulk of the monotonous Kanmantoo strata (especially the highly-sheared varieties of the western Kangaroo Island Shear Zone). Similarly, the 'Brighton Limestone unit', which consists of repeated thin layers of coarse-grained pink-white marble, is lithologically very similar to marbles of the basal Cambrian Normanville Group found elsewhere and in particular they are identical to highly strained marbles at Rapid Bay, on the Fleurieu Peninsula. Finally, the presumed Sturt 'Tillite' is a deformed diamictite with a fine-grained matrix and strongly elongated clasts (Fig. 6a). These clasts in their present deformational state do not readily reveal their presumed glacial origin, but could be analogous to pebble-beds in the Tappanappa Formation, or potentially even to those of the White Point Conglomerate.

Thus until more conclusive evidence is forthcoming (possibly geochemical or isotopic), the presence of a stratigraphically intact Adelaidean sequence on Kangaroo Island must remain equivocal. Even Daily *et al.* (1979, p. 9) recorded that 'lithologically, the metasiltstones (of the Marino Group) are indistinguishable from the meta-

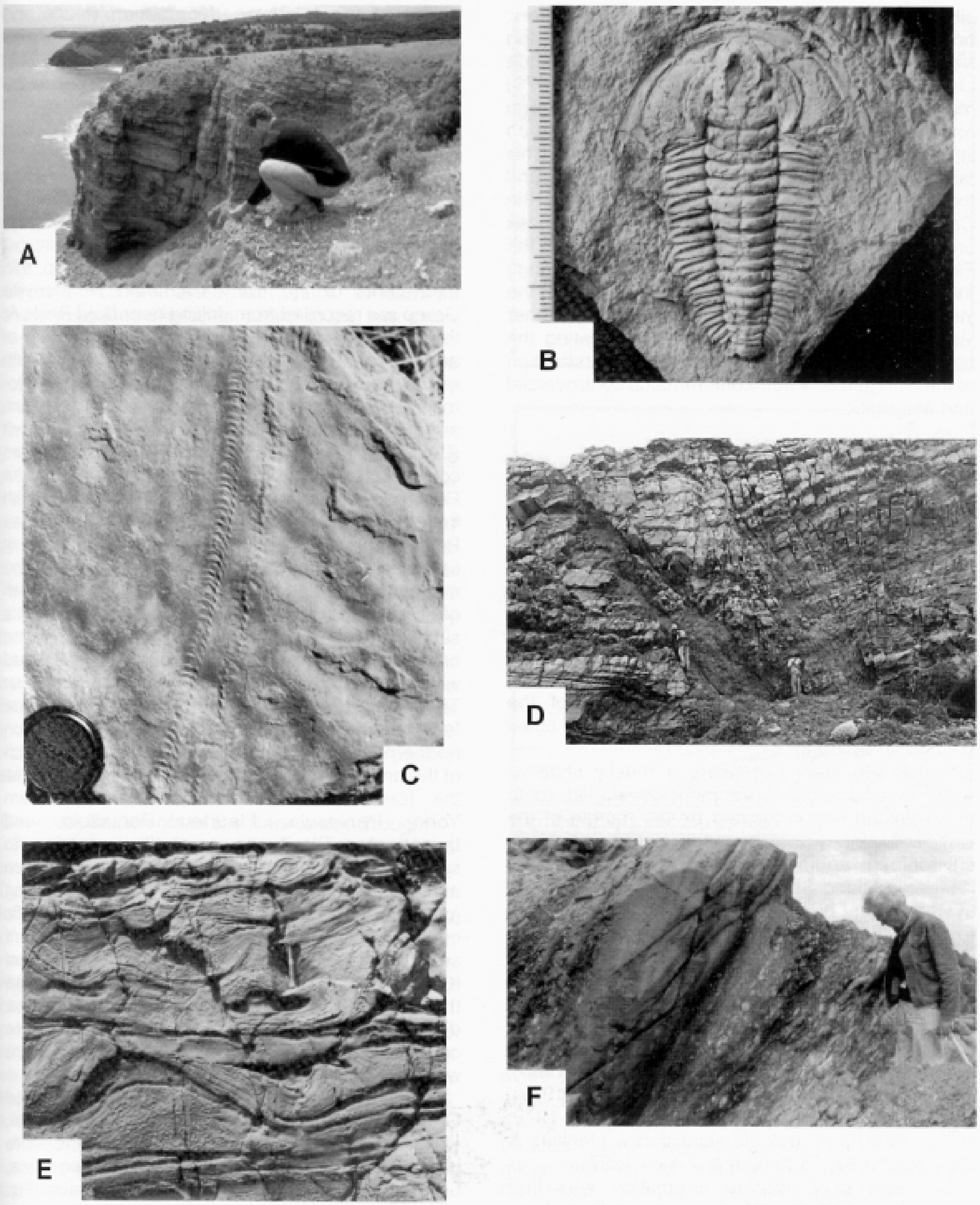


Fig. 7. Rock types and fossils found in the Cambrian Kangaroo Island Group of the northern Kangaroo Island Platform, (a) Cliffs southwest of Cape Cassini (far headland) showing shallow dipping Stokes Bay Sandstone overlying Mt McDonnell Formation (lower one-third of cliffs), (b) Near complete specimen of the trilobite *Redlichia*, Emu Bay Shale, east of the mouth of The Big Gully. Scale in centimetres, (c) Trilobite trackway seen on the base of a loose sandstone slab from the upper part of the Emu Bay Shale, east of the mouth of The Big Gully. Lens cap is 53 mm in diameter, (d) Subhorizontal bedding of coarse cross-bedded sandstone of the Boxing Bay Formation near The Big Gully. Note the steep west-dipping fault and intense jointing, (e) Contorted bedding in red-brown arkose near the base of the Boxing Bay formation, east of the mouth of The Big Gully. Contorted bedding is a feature of many Cambrian sandstones found on Kangaroo Island (photograph by P.S. Moore). Hammer is 31 cm long, (f) Outcrop of plane-bedded White Point Conglomerate from near to The Big Gully showing the variation in clast size and associated coarse-grained calcareous sandstones (photograph courtesy of Vic Gostin).

siltstones of the Carrickalinga Head Formation', only being 'recognised' by the distinctive, overlying Mount Terrible Formation and Wangkonda Limestone (now marble). Daily *et al. (1979)* mapped a disconformity between the Marino Group and the overlying basal Normanville Group limestones within the Sprigg Inlet Fault Zone. This feature is not exposed on the coast however, and the characteristic shelly fauna which confirm the Cambrian age of supposedly equivalent sequences on the north coast of Kangaroo Island, and on the Fleurieu Peninsula, is not evident within the Sprigg Inlet Fault Zone. These features, together with the intensity of the deformation in this area, further lessen the strength of arguments correlating the units here with confidence, and the understanding of the Sprigg Inlet Fault Zone remains controversial and enigmatic.

Fossiliferous Cambrian Platformal Sediments of *the North Coast*

The rocks, which make up the northern part of Kangaroo Island, are part of the Kangaroo Island Group (Daily *et al.* 1980). All of the units of this Group are well exposed in cliffs up to 80 m high, and on shore platforms along the north coast of the Island east from Snelling Beach and west from Point Marsden (Figs 5, 7a). Outcrop is almost continuously exposed in cliffs from several beaches (Fig. 7). The eastern section of the northern zone is not exposed on the western coast of Nepean Bay (Fig. 5).

During the early Cambrian, a mostly shallow water coastal shelf environment developed south of an upland region located by the margin of the Gawler Craton, with a deeper water basinal or rift environment south of the then active east-west Kangaroo Island Shear Zone/Cygnet-Snelling fault system. On northern Kangaroo Island, this excellently exposed sequence of deltaic coarse to fine clastics and minor carbonates, with its spectacular array of Cambrian fossils was first briefly described by Sprigg (1955) (Fig. 7b,c), but has been the subject of much subsequent study concerning its sedimentology and depositional environment (Moore 1979; Daily *et al. 1980),* stratigraphy and correlation (Daily *et al. 1979),* palaeontology (Pocock 1970; Glaessner 1979; Nedin 1995) and tectonic significance (Jenkins & Sandiford 1992; Flottmann & James 1997).

Evidence of Cambrian deposition was first reported by Wade (1915) and confirmed by Madigan (1928), with the recognition of archaeocyathans at Cape D'Estaing and trilobite tracks inland from Smith Bay. Sprigg (1955) began mapping and correlation of the stratigraphic units which were described in detail as the Kangaroo Island Group by Daily *et al.* (1980). This work subdivided the Kangaroo Island Group into six stratigraphic units, with mostly shallow-dipping and gently-tilted or folded strata repeated by narrow zones of more intense deformation (faults and thrusts), making more complex outcrop patterns and structural repetitions along the coast, from Snelling Beach in the west to Point Marsden in the northeast. Mapping demonstrated an overall composite thickness of 2500-2700 metres, with some lower units not outcropping and only found in stratigraphic bores and the whole sequence resting with marked non-conformity upon Palaeoproterozoic metamorphic basement which is not exposed.

Below the exposed Kangaroo Island Group, thin equivalents of the Early Cambrian Normanville Group are recorded from drilling near Bald Rock. At the base of the Kangaroo Island Group, 40 m of arkosic sandstone and calcareous sandstone with minor mud laminae, follow an arkosic conglomerate with crystalline gneissic pebbles, which directly overlies the Proterozoic basement (Belperio & Fairclough in prep.). This unit has been correlated with the Winulta Formation of the Yorke Peninsula which is considered to intertongue with the overlying Wangkonda Formation of the Fleurieu Peninsula, recognised in the drill hole as 16 m of calcareous sandstone, burrow-mottled lime mudstone and glauconitic limestone. A further 55 m of algal and dolomitic laminated calcareous siltstone with slumping, vuggy and solution breccias, and glauconite interbeds is correlated with the Parara Limestone of the Yorke Peninsula. These sequences represent the basal strata of the fault-bounded Lower Cambrian Stansbury Basin on northern Kangaroo Island. This basin covers much of the area of the current Gulf St Vincent, as well as the Torrens Hinge Zone, the adjacent eastern Yorke Peninsula, Fleurieu Peninsula, and Investigator Strait, as a shallow, marine to subaerial, platform marginal to the Gawler Craton and was open to the east with a ramp sloping gradually eastwards towards the Palaeopacific continental margin. However, in their recent summary of the early Cambrian stratigraphy of Kangaroo Island, Belperio *et al.* (1998) emphasise that current correlations between these discontinuous and marginal sequences are confusing and may only be improved in the future with possible drilling from within the Gulf.

Exposed formations of the Kangaroo Island Group begin with the Mt McDonnell Formation, which outcrops extensively in high cliffs and shore platforms at the western end of this sequence, between Snelling Beach and Cape Cassini (Fig. 7a). This unit (- 650 m - 1300 m) is predominantly greyish-green shale, siltstone and fine sandstone with finer parts displaying fine laminations, lenticular and flaser beds and ripples. A sharp but gradational contact occurs one kilometre west of Hummocky Point with overlying Stokes Bay Sandstone, which comprises up to 700 m of red-brown weathering feldspathic sandstone, outcropping between Cape Cassini and Cape D'Estaing. Generally gentle northerly and easterly dips reveal the remainder of the Kangaroo Island Group younging progressively from Emu Bay east to Point Marsden. The Smith Bay Shale represents a thin (100 m) shallow marine prodeltaic facies with well-laminated grey-green shale and siltstones containing minor trace fossils and trilobite fragments. The White Point Conglomerate is a spectacular unit outcropping at Cape D'Estaing and west of White Point, which consists of coarse conglomerate beds with thin interbedded coarse sandstone (Fig. 7f). The White Point Conglomerate (550 m), is a polymict poorly-sorted matrix supported conglomerate with basal sandstones and interbedded siltstones. Lower in the formation, large (0.5 - 1.5 m) cobbles and pebbles are dominated by grey-cream archaeocyathic limestone, indicating initial unroofing of presumably platformal carbonate sheets to the north (Fig. 8). The eventual unroofing and exposure of basement gneisses is demonstrated by increasing proportions of gneissic and granitic clasts higher up the sequence (thus showing a reversed stratigraphy of younger clasts at the base and progressively older ones towards the top). The Emu Bay Shale is found both at Emu Bay and at The Big Gully, where thin (55 m) brown, laminated shales and siltstones, with intertidal sedimentary features (mudcracks), reveal a spectacular fossil assemblage including trilobites, annelids and hyoliths (Nedin 1995). Towards Point Marsden, the Boxing Bay Formation (550 m) consists of thick interlayered laminated micaceous and feldspathic sandstones, flaggy siltstones and pebbly sandstones (Fig. 7).

Cambrian Sediments of the Kanmantoo Trough

The basement substrate to the majority of the southern portion of Kangaroo Island and the Dudley Peninsula display only extremely limited inland outcrop, and is composed almost exclusively of uniform grey, impure massively-bedded metasandstones and metapelites of the Kanmantoo Group regionally metamorphosed to biotite grade. Lack of contiguous outcrop, in particular along the south coast of Kangaroo Island, inhibits substantiated correlation of the stratigraphic units of the Kanmantoo Group with those established on Fleurieu Peninsula *(cf* Daily & Milnes 1973).

Recently, stratigraphic correlatives of all formations found on the adjacent type sections of the Fleurieu Peninsula and eastern Mt Lofty Ranges have been presented by Belperio *et al*. (in press). At the base, the deeper-water Carrickalinga Head Formation and shallower-water Backstairs Passage Formation are thick sequences of rapidly deposited, poorly-bedded to thin laminated and cross-bedded sandstones which crop out south of the Sprigg Inlet Shear Zone on Dudley Peninsula. The Talisker Calc-siltstone (Fig. 6b) is a thin overlying sheared unit

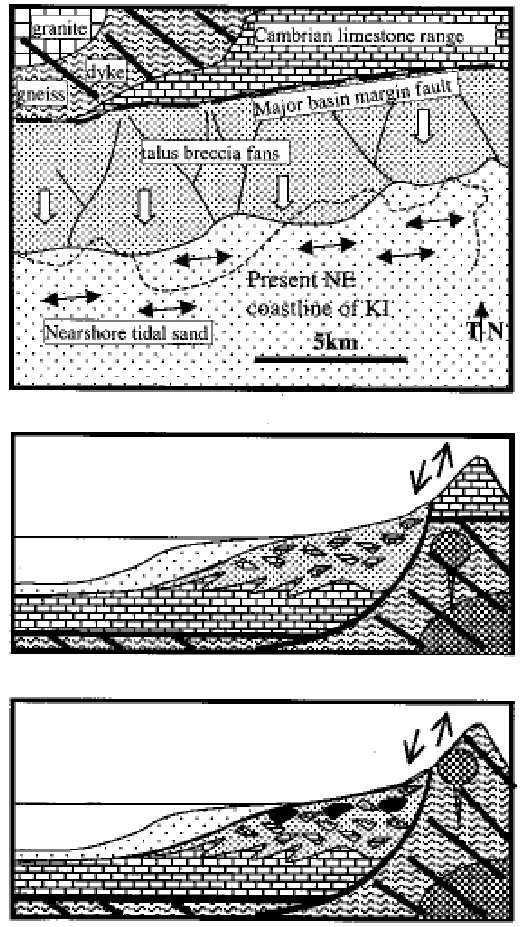


Fig. 8. Cartoon sketch (a) of Cambrian palaeogeography with alluvial and tidal current directions (after Daily *et al.* 1980). Sections show the effects of (b) early and (c) late uplift of Gawler Craton to north showing progressive unroofing of limestone followed by gneiss, granite and amphibolite, showing thus a reversed stratigraphy of younger clasts at the base and progressively older ones towards the top of the stratigraphy in the White Point Conglomerate.

on Dudley Peninsula and comprises well-laminated calcareous phyllites with minor marble bands and sulphidic "rusty" stained units. Much of the remainder of the Kanmantoo Group on Dudley Peninsula is formed by thick bedded, dirty metasandstones and thinner metasiltstones of the Tapanappa Formation. Deformed pebble conglomerates (Fig. 9) sporadically occur and are best preserved on the foreshore at Penneshaw, with pebbles and cobbles of mainly marble, quartzite, gneiss and metasandstone. Similar units also occur at Point Morrison and near Castle Gully. At Middle River and again at Castle Gully the overlying Tunkalilla Formation comprises highly deformed blue-grey phyllites with goethite and jarosite staining and pyrite moulds. The Balquhidder Formation occurs in Antechamber Bay, around Middle River and just

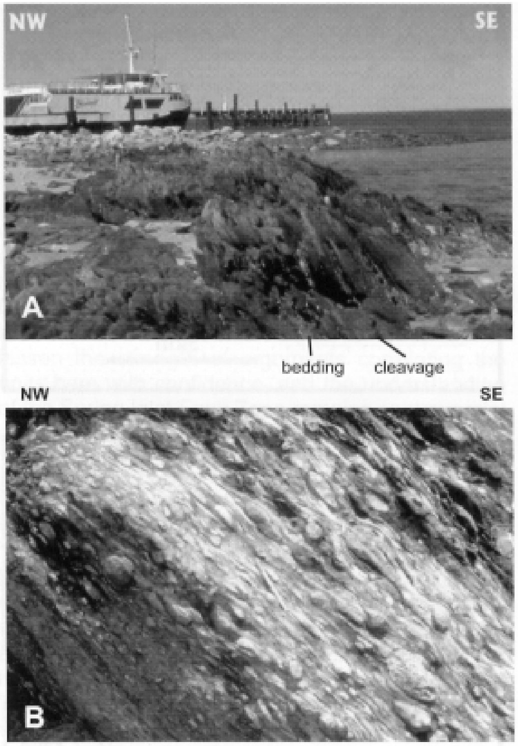


Fig. 9. (a) Bedding-cleavage relations in Tapanappa Formation at the Penneshaw boat ramp. Bedding dips very steeply to the SE and is overturned (younging to the NW), while cleavage is moderate to shallow SE dipping. This shows the tectonic forces must have pushed the layers in a northwesterly direction. (b) Stretched pebbles in Tapanappa Formation from headland at Penneshaw - (photograph # 042491 courtesy of Office of Mineral and Energy Resources, SA).

south of the Kangaroo Island Shear Zone on the north coast, west of Snelling Beach. It consists of thick massive metasandstones and interbedded metasiltstones with plentiful sedimentary structures such as scours, cross beds, graded beds, climbing ripples and flame structures (Fig. 10). The Petrel Cove Formation is only recognised from the North East River of the central plateau and comprises fine-grained and laminated dirty cyclic sandstones and siltstones. Over much of the remainder of the southern Dudley Peninsula and over most of the southern and western parts of the Island, the topmost Kanmantoo formation of the Middleton Sandstone occurs as medium- to fine-grained grey feldspathic sandstones with thin biotite laminations. Thick bedding with tabular cross beds, slumped and convolute bedding and dewatering features are common, and this formation is characterised by its typical orange weathering crust and distinctive magnetic signature.

In terms of sedimentary environments, the laminated units of the Kanmantoo Group (Fig. 11)

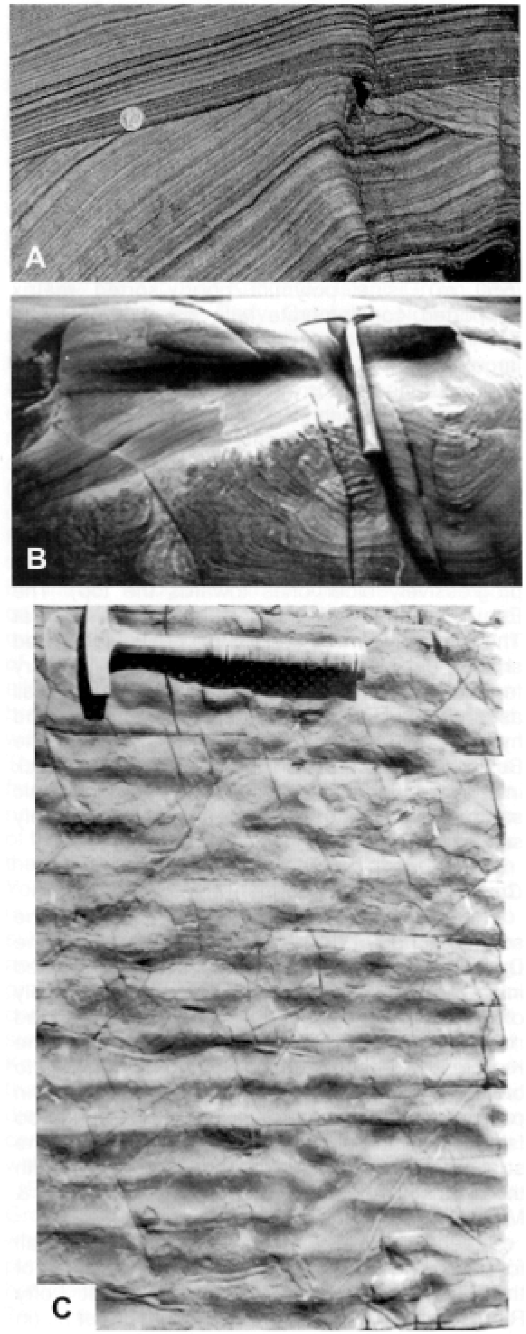


Fig. 10. Sedimentary structures from within Cambrian metasediments. (a) Cross-bedding in biotite quartz metasandstone from Harveys Return. (b) Soft sediment slumping and folding in coarse metasandstone of the Stokes Bay Sandstone near Cape Cassini. (c) Straight-crested asymmetric ripple marks on bedding surface, with bifid trails made by an unknown mollusc as it moved across the sea floor. Carrickalinga Head Formation, coast west of Hummocky Gorge. Hammer is 33 cm long.

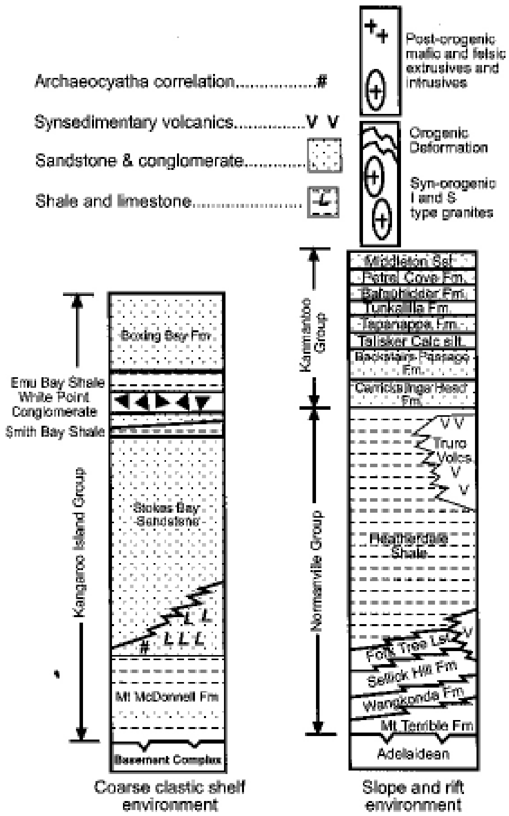


Fig. 11. Generalised stratigraphic columns and correlations of the Kangaroo Island Group and Kanmantoo Group sediments from the north coast of Kangaroo Island (after Belperio *et al.* 1998).

are interpreted to have been formed by the reworking of originally homogeneous beds, resulting in a differentiation into coarse and fine grained constituents, the latter of which were most likely deposited from suspension. The massive quartzite units are commonly erosive into the laminated sequences resulting in ball and pillow structures (Belperio & Fairclough in prep.). Daily & Milnes (1973) considered the overall deposition to have been in a shallow water environment, as is evident in particular in the Backstairs Passage and Middleton Formations. There is also clear evidence of finer-grained deeper-water deposition in the Carrickalinga Head Formation.

DEFORMATION AND METAMORPHISM DURING THE DELAMERIAN OROGENY

The Northern Platformal Zone

The northern Kangaroo Island platformal zone is 40 km wide (east-west) and extends north-south for 20 km from Snelling Beach in the south to the latitude of Point Marsden in the north (Fig. 5). The structural record across this northern zone shows a general northerly waning of deformation intensity. In the Snelling Beach area the Snelling Thrust marks the southern boundary of the Kangaroo Island platform. Between the Snelling and Middle River faults the strata of the Mt McDonnell Formation are intensely folded over an across strike outcrop width of about one kilometre (Fig. 12). The folds are tight, north-verging, asymmetric chevron-folds, which plunge at 10-30° both to the east and west. Fold limbs are strongly sheared along the pervasive biotite and chlorite cleavage, which dips at 70-80° south and is also marked by abundant quartz veining. A down-dip mineral lineation which plunges towards 150° is commonly developed on the cleavage planes and demonstrates the direction of Delamerian transport which is south block upwards and towards the northwest.

North of the Middle River Thrust (Figs 5, 12) the Stokes Bay Sandstone and Mt McDonnell Formation form a regional syncline in the hanging wall of the Winston Bell Thrust, which dips 40° - 45° to the south. This displaces the lowermost known strata of the Mt McDonnell Formation south of the fault against the uppermost known strata of the same Formation, which crop out to the north of the fault. The constructed stratigraphic thickness of the Mt McDonnell Formation in this area is about 1300 m, and hence the displacement along the structure must be in excess of 1000 m vertically. The 500 m thick interval of the Mt McDonnell Formation between the Winston Bell Thrust and the Blue Head Point Thrust is intensely folded.

Pervasive deformation in the northern zone occurs in a ductile shear zone adjacent to the Cape Dutton Thrust. This is a steeply south dipping zone of intense bedding-parallel deformation, which over a width of about 100 m crosscuts the moderately south-dipping strata of the Mt McDonnell Formation at Cape Dutton. The shear zone is characterised by abundant boudinage of either quartz veins contained in the foliation or entire domains of the foliation itself. In the phyllitic interlayers of the Mt McDonnell Formation kink bands are commonly developed (Fig. 12).

North of the Cape Dutton Thrust deformational style changes markedly. South of this structure strata dip moderately to steeply to the south, but north of the Cape Dutton Thrust layering in general dips only shallowly (5-10°) to the south or south-southwest. The principal structural elements of the northern part of the foreland zone are the widely spaced Stokes, Hummocky and Cassini thrusts. In the hanging wall of these thrusts, layering steepens and is parallel to the 45°-55° south-dipping thrust planes. The Cassini Thrust is accompanied by an imbricate fan, in which five reverse faults spaced at about '100 m from each other bring into juxtaposition slabs of Stokes Bay Sandstone against shallowly west-northwest dipping Stokes Bay Sandstone at Cape Cassini (Fig. 12).

All deformational movement indicators of the

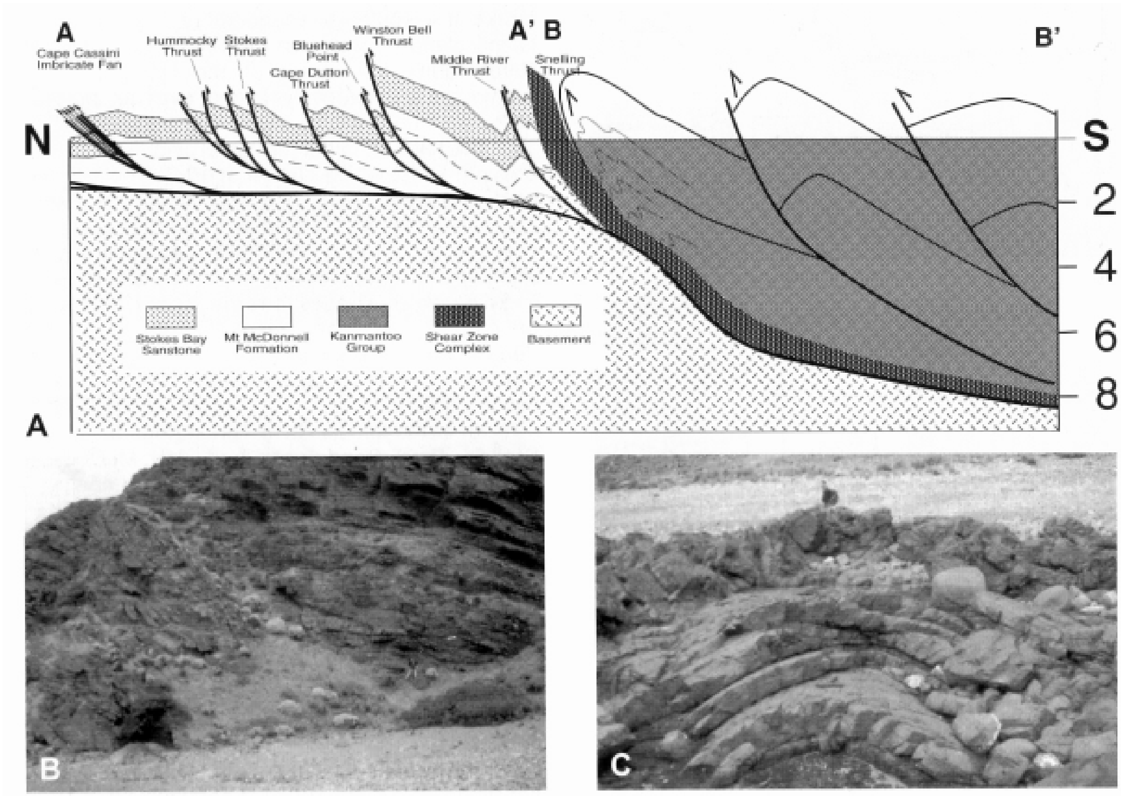


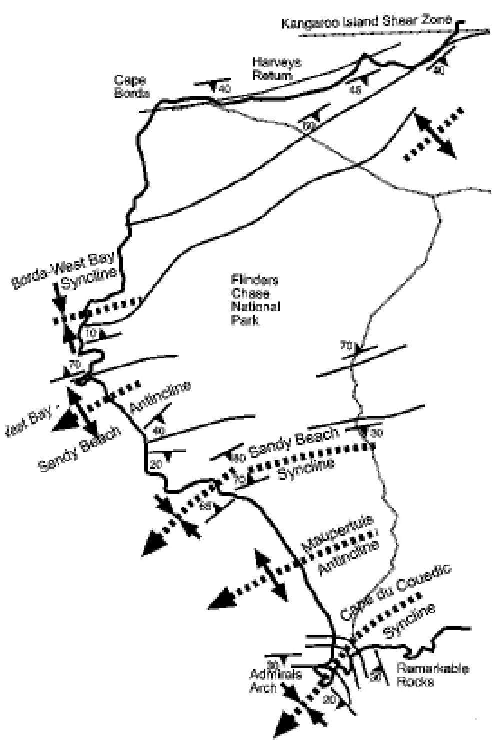
Fig. 12. (a) Geological cross-section constructed from N to S across Kangaroo Island. The northern part traverses south from Cape Cassini and the southern section approximately parallels the west coast of the Island (see section lines A-A' and B-B' on Fig.5a). (b) Major fault with Mt McDonnell Formation thrust up and over Stokes Bay Sandstone, south of Cape Cassini headland. (c) Minor hangingwall anticline formed above the thrust shown in Fig. 12b and exposed on the adjacent shore platform.

northern Kangaroo Island platformal zone give north to north-northeast directed displacement directions, which are indicated by fibres, slickensides and mineral slip lineations. The consistent downdip orientation of these displacement vectors indicates the absence of oblique displacement components in the northern zone. The overall deformational shortening of the northern zone from restoration of the cross-section is 30%.

The Southern Kanmantoo Trough Fold-Thrust Zone

Where exposed, the structure of the southern zone appears to be dominated by a single generation of tens of metre- to km-scale ENE-WSW trending folds, separated by occasional poorly exposed fold-related parallel thrust faults (Figs 5, 13). Fold sequences like these have been documented from the west coast in Flinders Chase (Flint & Grady 1979), from the north coast (Flottmann *et 81.* 1995) and from the north (Menpes 1992) and south (Buick 2000) coasts of the Dudley Peninsula it appears that the major structure is dominated by anticlines with 4-8 km wavelength, but with synclines of shorter (2-4 km) wavelength. This geometry suggests that the folding may be related to reverse faults, with probably only minor displacement, as shown in Fig. 12.

Fold style, geometry and kinematics and their relations to the associated thrusts have only been documented in a few isolated localities due to the paucity of inland outcrop and the geographic limitations of coastal cliff and shore platform localities. The most classic examples of folds related to this style and sequence of deformation occur at Harveys Return on the far western end of the north coast (Figs 3b, 14b). Harveys Return is a narrow northwest-facing inlet 4 km east of Cape Borda accessible by a short but steep track down the cliffs. Massive interbedded grey turbiditic metasandstone-pelite sequences (0.5-1.0 m beds) dominate, with prominent bedding planes and strong compositional contrasts displaying copious primary structures, including ball and pillow, load casts, flutes, flames and grossly discordant and remobilised small-scale dewatering piercement structures. Overall the bedding trends uniformly northeast-southwest, is right way up and dips steeply southeast. On the northeast side of the



ig. 13. Geological map and basement summary of the western end of Kangaroo Island (after Major & Vitols 1973 and Flint & Grady 1979).

inlet, the massive psammitic turbidites give way to regular black and white interlayers of biotite-rich and quartz-rich units which form the spectacular 'Zebra' folds well known from tourist pamphlets (Figs 3b, 14b). These minor symmetric and asymmetric folds are often convolute, disharmonic and intrafolial. Some folds have truncated upper surfaces and may represent slumps, but most have consistent internal geometries and are clearly tectonic. Within individual beds the minor folds are regular, planar and cylindrical. Fold axes are consistent within individual beds, but due to major dip variations caused by large cross-bedded foresets, plunges vary from 20°-60° SE. Fold styles vary from rounded to chevron depending on thickness and type of layering, with interlimb angles typically of 70°-90°. All folds die out rapidly across the layering suggesting significant interbed slip. Fold axial surfaces dip steeply south to southeast parallel to a pervasive axial plane foliation and prominent quartz-rich veins.

South of Western River Cove, the strata reveal in detail the transition from the inherited southern zone structural style to the obliquely imposed Kangaroo Island Shear Zone (Fig. 5). The less deformed country rocks in the shear zone are deformed by north-verging, open upright to inclined folds, which plunge shallowly to the east. The fold size and types change depending on the deformed rock types. In more massive units fold amplitudes are around one metre with wavelength between 1.5 and 3 m (Fig. 14), whereas in less competent layers folds are very regular and fold

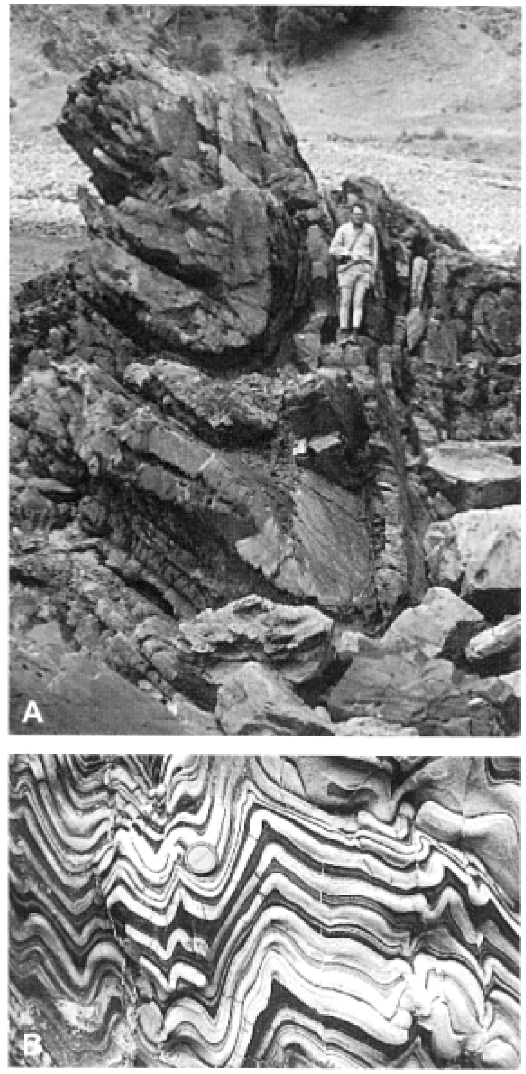
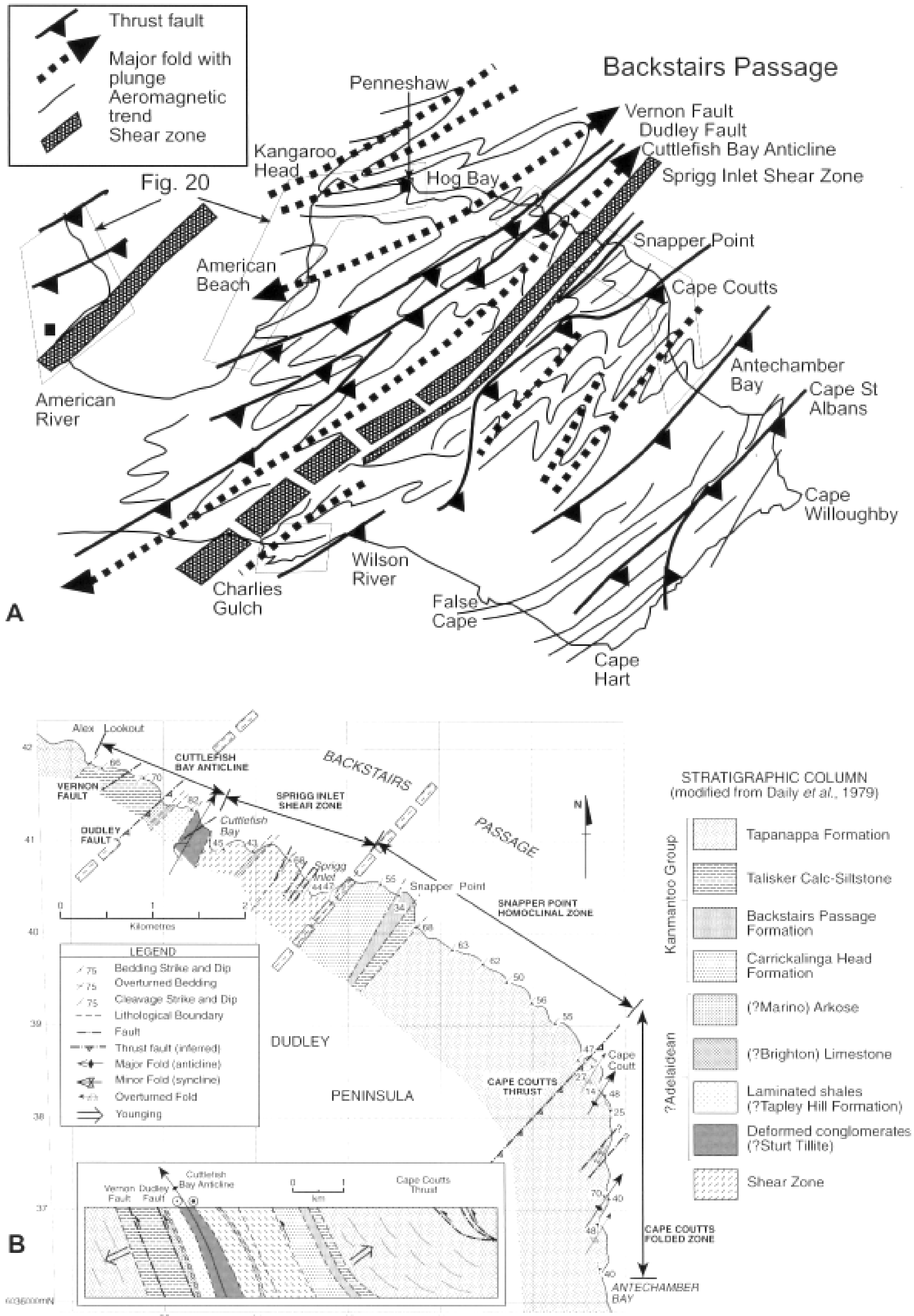


Fig. 14. (a) Down-plunge view towards the east of inclined–overturned asymmetric minor syncline from Western River Cove. Northerly overturning shows main tectonic Delamerian push was from the south. (b) Spectacular 'Zebra Rock' folds with axial plane quartz veins from Harveys Return.

wavelengths are in the decimetre range. Axial surface foliations related to the folds dip on average steeply to the south, but fan markedly and dip between 20°-60° SE in more competent layers. Many folds show the development of conspicuous quartz veins along their axial planes (Fig. 14). Rib-like and rodded (mullion) structures are commonly developed at the


Thrust fault
Major fold with plunge
Aeromagnetic trend
Shear zone
Backstairs Passage
Penneshaw
Vernon Fault
Dudley Fault
Cuttlefish Bay Anticline
Sprigg Inlet Shear Zone
Kangaroo Head
Hog Bay
Fig. 20
Snapper Point
American Beach
Cape Coutts
Antechamber Bay
Cape St Albans
American River
Cape Willoughby
Wilson River
Charlies Gulch
False Cape
Cape Hart
A
Alex Lookout
CUTTLEFISH BAY ANTICLINE
VERNON FAULT
DUDLEY FAULT
BACKSTAIRS
PASSAGE
SPRIGG INLET SHEAR ZONE
Cuttlefish Bay
Sprigg Inlet
Snapper Point
SNAPPER POINT HOMOCLINAL ZONE
Kilometres
LEGEND
Bedding Strike and Dip
Overturned Bedding
Cleavage Strike and Dip
Lithological Boundary
Fault
Thrust fault (inferred)
Major Fold (anticline)
Minor Fold (syncline)
Overturned Fold
Younging
DUDLEY
PENINSULA
CAPE COUTTS THRUST
Cape Coutt
CAPE COUTTS FOLDED ZONE
ANTECHAMBER BAY
Vernon Fault
Dudley Fault
Cuttlefish Bay Anticline
Cape Coutts Thrust
km
STRATIGRAPHIC COLUMN
(modified from Daily et al., 1979)
Kanmantoo Group
Tapanappa Formation
Talisker Calc-Siltstone
Backstairs Passage Formation
Carrickalinga Head Formation
?Adelaidean
(?Marino) Arkose
(?Brighton) Limestone
Laminated shales (?Tapley Hill Formation)
Deformed conglomerates (?Sturt Tillite)
Shear Zone
B

contact of competent psammitic layers with less competent pelitic units. The mullion long-axes, fold axes and the intersection lineation between cleavage and bedding are oriented parallel to each other with an easterly trend.

On the Dudley Peninsula, both north and south of the major Sprigg Inlet Shear Zone (Fig. 15), the Kanmantoo rocks are dominated by major and minor folds (Flottmann *et al.* 1995). North of the zone, the folds have kilometre-scale wavelengths and are major folds with steep to moderate southeast limbs and overturned northwest limbs (e.g. Kangaroo Head Syncline, Lincoln Green Anticline) and moderate east to northeast plunges. From Penneshaw south to the Sprigg Inlet Shear Zone the whole sequence of Tapanappa Formation is overturned and dips steeply southeast while younging to the northwest. South of the Sprigg Inlet Shear Zone and into Antechamber Bay, a nearly complete stratigraphic sequence of the Normanville Group and overlying Kanmantoo Group is exposed in a major homoclinal and moderately-folded section (Fig. 15). The sequence is interrupted at Cape Coutts by one of the fold-related thrusts considered to have formed by contractional Delamerian deformation. The Cape Coutts folded zone extends from Antechamber Bay in the south to the Cape Coutts thrust in the north and is characterised by biotite grade metamorphic Tapanappa Formation which is openly folded around shallowly northeast-plunging folds with wavelength of 200 to 300 m. Northwest directed tectonic transport is indicated by the northwesterly fold vergence. Fold axial planes dip to the southeast and contain an oblique-dip mineral elongation lineation (orientation) marked by retrogressed andalusite porphyroblasts. The Cape Coutts Zone locally contains moderately boudinaged pegmatites which display a northwest trending lineation defined by tourmaline.

Another interesting feature of the fold-thrust development in the Kanmantoo Trough is the trend of the major structures. Although they have been previously interpreted to turn around the Fleurieu Arc from northerly trends around Adelaide, through northeast trends on the southern Fleurieu Peninsula and into a more westerly trend on Kangaroo Island (Marshak & Flottmann 1996), from both outcrop mapping of smaller scale structures and from recently obtained airborne geophysics, it appears that although the structures of the Island are dominated by the E-W trending Kangaroo Island Shear Zone, south of this zone the folds and thrusts largely retain their NE-SW trends

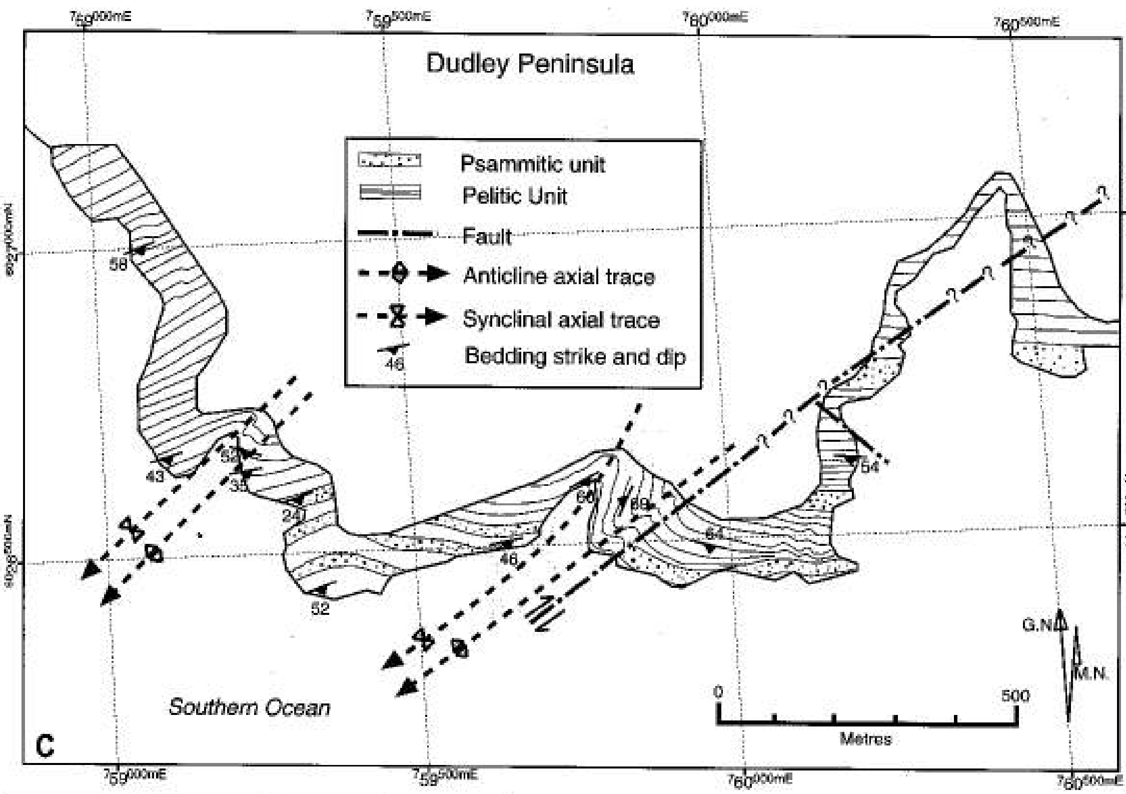


Fig. 15. (a) Geological interpretation and location of detailed geological maps of the Dudley Peninsula (after Daily *et al.* 1979 and Buick 2000). (b) Geological map and cross-section of the NE coast of the Dudley Peninsula. (c) Coastal outcrop map, west of Charlies Gulch, on the south coast of Dudley Peninsula, showing the orientation of bedding, and the outcrop traces of parasitic folds and faults.

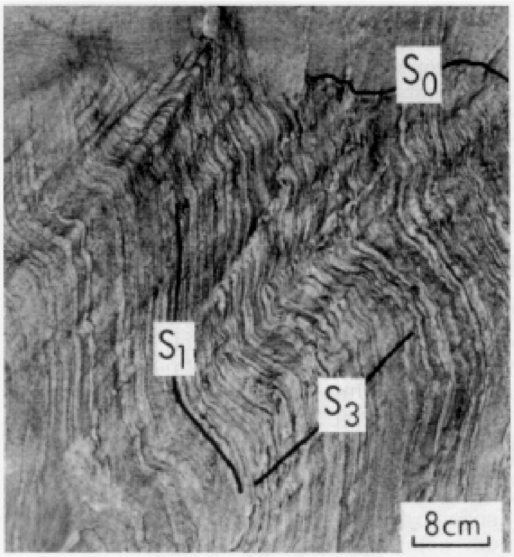


Fig. 16. Evidence of multiple deformation events from Kanmantoo metasediments 2 km south of West Bay. S_0 represents bedding, S_1 represents a first schistosity with a new metamorphic layering parallel to it and S_3 are axial surfaces of overprinted folds (from Flint & Grady 1979).

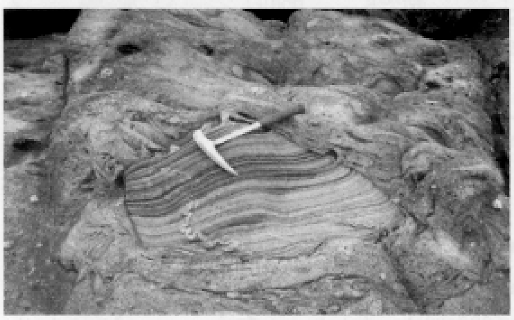


Fig. 17. Layered Kanmantoo metasedimentary biotite gneiss xenolith with ptygmatically folded vein enclosed in migmatite and granitic melt from Vivonne Bay (photograph courtesy J. Foden).

parallel with those on the Fleurieu Peninsula (see also Thomson 1969). On the south coast of Dudley Peninsula for example around Charlies Gulch, Buick (2000) has demonstrated that rather than showing westerly fold trends, the Kanmantoo rocks are folded about northeast trending and northwest verging major inclined fold trains (Fig. 15c).

Flint & Grady (1979) have described an unusually complex deformation sequence on the west coast of the Island (Fig. 13). The structure of the Breakneck River area of the southern fold-thrust zone exhibits three distinct phases of deformation. First phase folds are interpreted to be of kilometer scale wavelength and are expressed at the microscale by quartz-veins, and a planar anisotropy evidenced either by a schistosity or differentiated layering. The second deformational event formed mesoscopic folds and the third phase produced crenulations (Fig. 16). Peak metamorphic grades were attained during the first deformation and progressively waned during the subsequent deformations. It is noteworthy that the Kangaroo Island Shear Zone cuts the west-southwest trending fold axes obliquely.

Another much more complexly deformed zone outcrops on the south coast of the Island west of Vivonne Bay. The elevated shore platform on the southwest side of Point Ellen comprises an excellently exposed coastal strip, which is unusual for the Island in that it is dominated by high grade metamorphics and migmatised equivalents of the Kanmantoo Group metasediments. These rocks are intensely folded and net veined, originally massive to variably layered psammites, with layering folded and warped on a variety of scales (Fig. 17). The layering changes orientation dramatically on the outcrop scale in an apparently non systematic manner, which is further complicated and confused by the presence of drag associated with large ductile shear zones. Many of the rocks contain a strong fabric dominated by a rodding lineation frequently parallel to tight minor folds (Fig. 17). The lineation and folds vary from southerly to southwest plunges and at least two phases of ductile fold overprinting are present, with an early reclined tight angular phase overprinted by a more open rounded later upright phase (Fig. 17). The migmatitic character is caused by a profusion of mostly granitic and pegmatitic veins and bodies. Vein types include early layer-parallel isoclinally folded varieties, narrow discontinuous parallel sets of axial plane lensoidal "sweat" veins, long continuous planar veins and randomly oriented thicker bodies with discordant apophyses and rafted-off host-rock xenoliths. The migmatitic rocks gradually increase in complexity and degree of melting until about 2kr;n to the west they are eventually cut by a major granitic pluton (Mitchell 1990).

The Kangaroo Island Shear Zone

The Kangaroo Island Shear Zone (Fig. 18) has only recently been recognised as a major long-lived tectonic boundary and crustal deformation zone in South Australia (Flottmann *et al.* 1995). Recent movement is attested by minor displacements on the Snelling and Cygnet faults (Sprigg *et al.* 1954), which are geographically coincident with the Shear Zone, and which develop a north facing scarp, which separates the northern low plain from the central lateritic plateau. However, this is a minor reactivation of a much more ancient, fundamental and deep-seated crustal discontinuity. In scale, structural and lithologic complexity and displacement, it can be compared with other major tectonic sutures or plate boundaries around the world such as the ancient Brevard Zone of the Appalachian chain or the still active San Andreas fault system in the USA, the Caledonian Moine

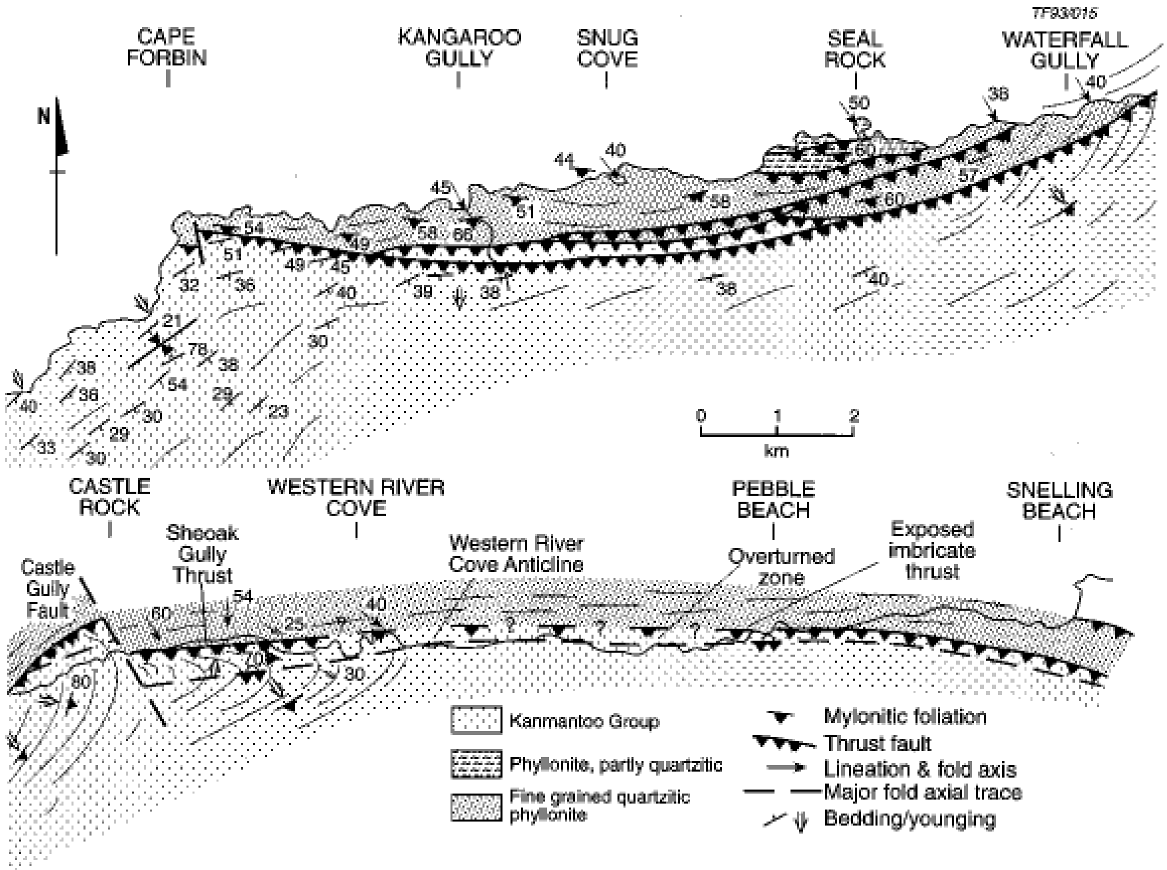


Fig. 18. Detailed geologic map of the western part of the Kangaroo Island Shear Zone. Lower map is the eastern continuation of the upper map (after Flottmann *et al.* 1995).

Thrust in Scotland or the Himalayan Main Boundary Fault Zone. Thus the Kangaroo Island Shear Zone represents an ancient plate margin that now forms a fundamental Delamerian displacement zone on Kangaroo Island (Fig. 18) and separates the northern platformal, from the southern basinal, part of the Island. Intensely deformed tectonites of about 2 km thickness in the Cape Forbin/Kangaroo Gully area form the westernmost outcrops of the shear zone (see Fig. 18). The eastern portion of the Kangaroo Island Shear Zone crops out in the Point Morrison/American River area and in a southeastern branch on Dudley Peninsula (Fig. 15).

The influence of progressive deformation from little deformed country rock to highly deformed tectonites is best observed in the Kangaroo Gully and Snug Cove area (Fig. 18). On the map scale the shear zone is characterised by lozenges of intensely deformed country rock of uncertain stratigraphic position, which are surrounded by highly strained schistose and mylonitic rocks (Fig. 19). In cross section the less strained lozenges define stretched quartz boudin trains enclosed in highly strained schists, phyllonites and mylonites (Fig. 19). The tectonic foliation is commonly folded into small, tight to isoclinal asymmetric folds (Fig. 19), the limbs of which are normally cut by the mylonitic foliation. The axes of these folds in zones with strongly planar mylonitic foliations are oriented subparallel to a well-developed mineral elongation/stretching lineation, which plunges very consistently to the southeast (Fig. 19). In strongly mylonitic zones the foliation defines wavy composite 'oyster shell' fabrics, typical of such high strain zones

East of Snug Cove the Kangaroo Island Shear Zone bends seaward and goes offshore about one kilometre east of Waterfall Gully and it reappears onshore east of Western River Cove, where at Pebble Beach, the shear fabric and associated thrusts occur on the coastal platform and the whole thickness of the zone is exposed trending along the coast to Snelling Beach. In this section isoclinally folded and transposed layered grey black schists and mylonites are intensely veined.

The Kangaroo Island Shear Zone has not been recognised to the east across the interior of the Island, where its trace is represented by the scarp of the Cygnet/Snelling fault system. At the eastern end of the Island it is characterised by two separate branches. It first reappears on the

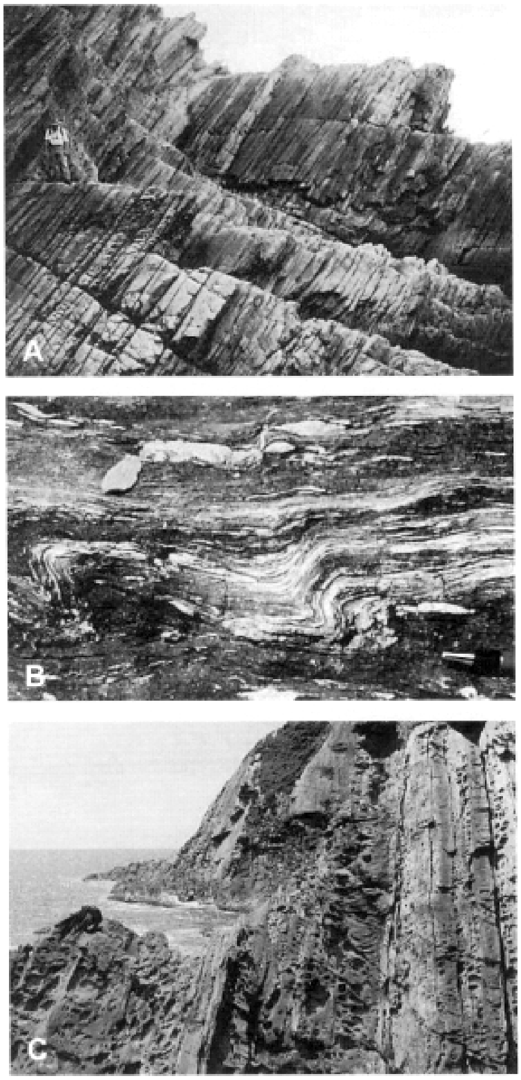


Fig. 19. Field examples of rocks and structures from the Kangaroo Island Shear Zone including strongly foliated Kanmantoo phyllonites at Snug Cove Cliff. (a) Platform section viewed to the west parallel to the shearing direction shows parallelism of layering and foliation due to intense shearing. (b) Complex folds and refolds and dismembered veins in section perpendicular to lineation (view to SSE). (c) Intense mineral and fold axis lineation as seen lying on the foliation planes of the shear zone indicates tectonic movement overthrusting towards the NW.

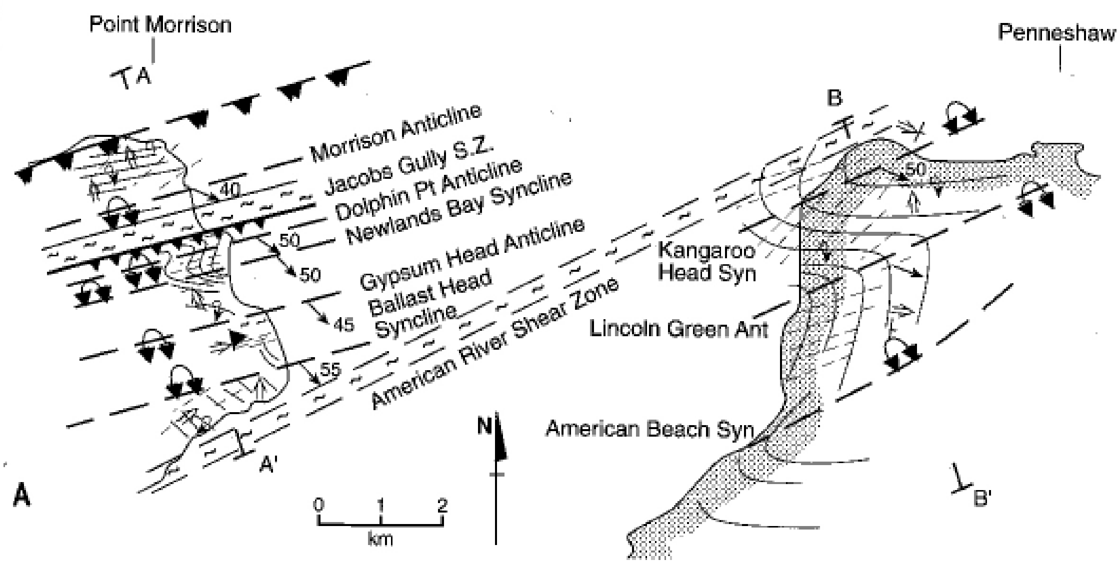
headland between Point Morrison and American River (Fig. 15a), where it differs slightly from the western end as a more widely distributed high strain zone, with less intensely developed mylonites and more discrete thrusts and large-scale complex overfolds. Structures here include the Jacobs Gully Shear Zone comprising pervasively mylonitised quartzitic arkoses of the Stokes Bay Sandstone *(cf* Thomson 1969) and a series of northerly overturned major folds, viz, the Morrison Anticline at Point Morrison the Dolphin Point and Gypsum Head anticlines and the Newlands Bay and Ballast Head synclines (Fig. 20). Deformation within this folded zone occurs only in discrete zones and is characterised by an intense pervasive cleavage.

A similar style of intense deformation continues to the east on Dudley Peninsula. Here, however, northwestward overturned folds (Kangaroo Head and American Beach synclines and the Lincoln Green Anticline) with northeasterly trending inclined axial surfaces and oblique east-southeast plunges deform Kanmantoo Group strata (Fig. 20). The contrast in rock type and stratigraphic thickness between the platformal Stokes Bay Sandstone and the basinal Kanmantoo Group of Dudley Peninsula suggests the existence of a former major normal fault between the two domains. This structure, which was presumably reactivated during the Delamerian, now forms the American River Shear Zone, which is largely concealed, but crops out west of American River.

On the Dudley Peninsula, the easternmost portion of the major overturned zone is marked by the Cuttlefish Bay Anticline, which is bounded to the south by the Sprigg Inlet Shear Zone (Fig. 20). This separates an overturned and highly deformed zone to the north from lesser deformed Kanmantoo strata of the southern zone. Flottmann *et al*. (1995) considered that this zone curved to the east into the Kangaroo Island Shear Zone, but recent high resolution aeromagnetic imagery shows that this zone in fact forms a linear trace to the SE across the Peninsula (Buick 2000). The Sprigg Inlet Shear Zone is thus a structurally higher shear zone in its own right, and is also important as it may be traced onto the mainland Fleurieu Peninsula where it may outcrop as the Talisker Shear Complex. The direct evidence for this conclusion is structural but it also finds some support in geophysical evidence.

Structurally the regional Cuttlefish Bay Anticline consists of a right-way-up southeastern limb and an overturned northwestern limb. Andalusite grade metasediments are exposed within the core and are in sheared contact with the Sprigg Inlet Shear Zone to the southeast, and in faulted contact with Kanmantoo Group metasediments via the Dudley Fault to the northwest. The Kanmantoo Group metasediments north of the Dudley Fault are overturned, and are hence interpreted to have been affected by the same folding event that formed the Cuttlefish Bay Anticline. Within the Cuttlefish Bay Anticline the style and degree of deformation changes depending on lithology and location within the Anticline. Near the contact with the marble horizon reclined intrafolial folds display dextral vergence, and the predominant shear sense associated with vein deformation is also dextral, but the sense of shear is not consistent.

The strongly sheared diamictite (Sturt Tillite?)



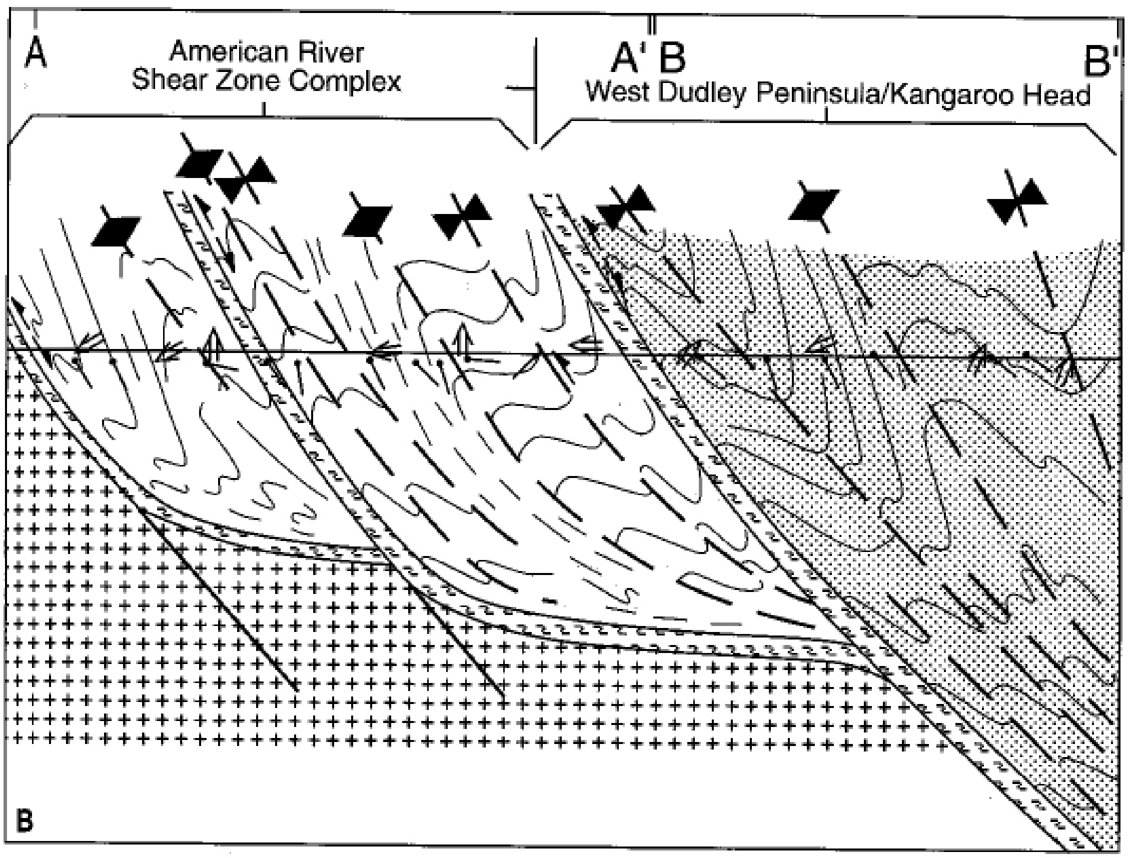


Fig. 20. (a) Structural map of the Point Morrison-Penneshaw area, with (b) interpreted cross section (after Flottmann *et al.* 1995). See Fig. 20a for section line.

forms the core of the Cuttlefish Bay Anticline. The contact between the pebbly horizon and the surrounding rocks is sheared and the boudins are subhorizontally stretched and asymmetrically deflected in a dextral sense, indicating predominance of dextrally transcurrent displacement in this zone. On the overturned limb of the Cuttlefish Bay Anticline, the strata appear more intensely folded than on the upright limb, with both sinistral and dextral mesoscopic chevron folding, disrupted folds, and a strongly transposed foliation. The folds within the laminated, calcareous metapelites are tight, long limbed, and display a fairly consistent axial planar cleavage. Immediately adjacent to the Dudley Fault are refolded folds within quartz veins. The Talisker Calc-siltstone on the overturned limb of the Cuttlefish Bay Anticline is dramatically shortened by intense mesoscopic chevron folding. These folds are cut by calcite and quartz veins which are strongly boudinaged. This folded Talisker Calc-siltstone section is repeated by the low angle Vernon reverse fault, south of Alex Lookout. The Talisker Calc-siltstone is overlain by the (overturned) Tapanappa Formation, which constitutes the northernmost (overturned) part of the Cuttlefish Bay Anticline, and extends to the west of Penneshaw. Here the structure of Dudley Peninsula is characterised by a succession of large-scale overfolds, the American Beach Syncline, the Lincoln Green Anticline and the Kangaroo Head Syncline (Fig. 20) which all deform Cambrian Kanmantoo strata and all have overturned northwest younging limbs.

The Sprigg Inlet Shear Zone is a wide zone of variably intense shearing and folding very similar to that seen at Second Valley on the adjacent Fleurieu Peninsula, which extends from Sprigg Inlet to Cuttlefish Bay (Figs 6b, 15b) and is characterised by intensely transposed folding on all scales. The fold axes are oriented parallel to an elongation lineation which plunges moderately to the southeast. At Sprigg Inlet a number of minor faults lead to imbrication of the transposed strata within the shear zone.

Igneous Rocks

Three distinct groups of igneous rocks are exposed on Kangaroo Island. Early Palaeozoic pre- to syntectonic granitoids form prominent outcrops around the southern coastline. These granitoids are intruded by at least two varieties of Early Palaeozoic basic igneous rocks that take the form of dykes and dykes swarms. During the Mesozoic the tensional regime associated with the separation of Australia and Antarctica resulted in the formation basalts which now outcrop as a fragmented sheet on the northeastern part of the Island near Kingscote and Penneshaw.

EARLY PALAEOZOIC IGNEOUS ROCKS

Igneous rocks associated with and post-dating the Cambro-Ordivician Delamerian Orogeny can be seen around the southern coast of Kangaroo Island. Granitic rocks crop out at Cape Willoughby, at intervals along the south coast between Vivonne Bay and Cape du Couedic, along the Stuns'l Boom River, and inland near the southeastern corner of Flinders Chase National Park. Basic igneous rocks in the form of post-orogenic dykes are prominent between Cape Hart and Cape Gantheaume, (Sprigg *et al.* 1954; Foden in press). The coastal exposures are especially good, but access to them is often difficult and dangerous.

Granitic Rocks

Foden *et al.* (in press) have identified three different styles of granite magma production during the 514 Ma - 485 Ma period of the deformation history. These include I-type magmas from lower crustal mafic magma chambers that are contaminated by and mingled with melts of the local metasediments, S-type magmas formed as crustal melts in the heated zones around the upwelling mantle or close to mafic or I-type granite intrusions and A-type granite produced by fractionation of upper crustal mafic intrusions.

Cape Willoughby

The granite at Cape Willoughby (Fig. 21) has been studied by Tilley (1919a, 1919b) and Milnes (1973). Foden (in press) describes the granite as a sheet-like layer-parallel intrusion into the Kanmantoo clastic sediments. The main variety is a medium-grained biotite granite with distinctive opalescent-blue quartz and pink to grey megacrysts of K-rich microcline, xenoliths of Middleton Sandstone metasediments are common, particularly near the northern exposure of the contact. Other granite varieties in the Cape Willoughby area include a red aplite, and a dark grey diorite. Transformation of all granite varieties to cream albite-rich rock and grey muscovite-rich rock has occurred along two different sets of joint fractures.

Similar granitic rocks outcrop at Cape Kersaint, along Stuns'l Boom River, and at Remarkable Rocks. At Cape Kersaint, a coarse-grained pink biotite-granite containing opalescent-blue quartz is exposed along the base of the cliffs in four prominent headlands. It contains large potash feldspar crystals together with irregularly distributed xenoliths of metasedimentary rocks through the granite. There is also a distinct alignment of biotite crystals outlining a crude layering.

Vivonne Bay - Stuns'l Boom River

The granites and migmatites at Vivonne Bay and Stuns'l Boom River on the south coast of Kangaroo Island exhibit features that have been used by Foden *et al.* (in press) to interpret the origin of the granites in the Delamerian Fold Belt as a whole. At these locations they recognise three different types of intrusives. A transitional I- to S-type K-feldspar

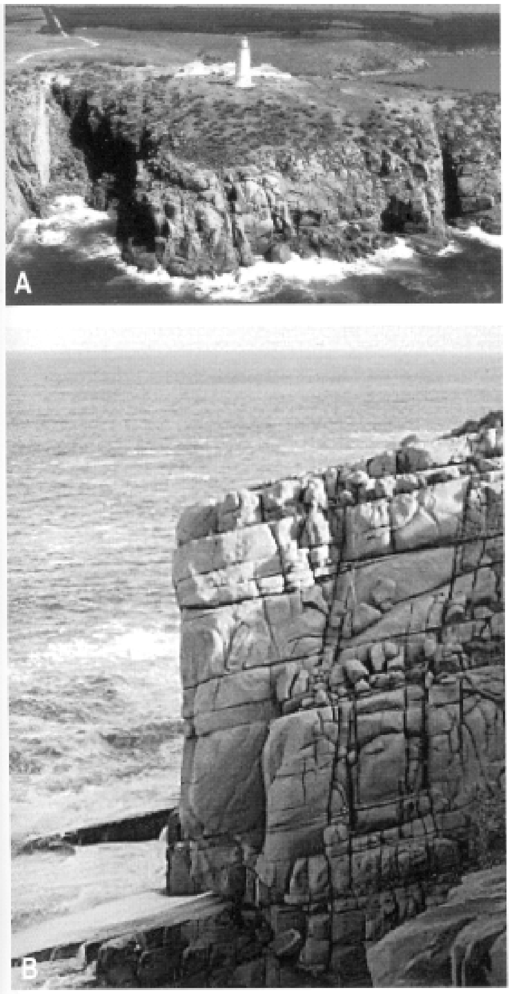


Fig. 21. (a) Coastal cliffs of Cape Willoughby granite. (b) Joint sets in the Cape Willoughby granite.

megacrystic biotite granite outcrops at a series of headlands between Vivonne Bay and Remarkable Rocks. In this region the Kanmantoo metasediments have been metamorphosed to upper amphibolite facies and partial melting has produced a diatexitic biotite granodiorite. It is a biotite-rich rock, which contains numerous enclaves of unmelted Kanmantoo Group metasediments. Mingling of fingers of the megacrystic granite and the biotite granodiorite indicates that they are contemporaneous (Foden *et al.* in press)

A third type of granite is found in this area. It is a highly leucocratic granite composed of quartz, K-rich microline and muscovite and is notable because it contains numerous patches of almandine-rich garnets. These are thought to represent extracted and fractionated near minimum-temperature melts because of their proximity with the biotite granodiorite (Foden *et al.* in press).

Basic Igneous Rocks

At least two varieties of Early Palaeozoic basic rocks occur on Kangaroo Island. Metadolerite dykes composed of amphibole and plagioclase have intruded Kanmantoo Group metasediments immediately east of the farmhouse in Antechamber Bay (Howchin 1903) and on the 'Greenslopes' property on the northern side of the South Coast road near Southwest River (Sprigg *et al.* 1954). Swarms of dykes of variable composition, but including metadolerites contaminated by metasedimentary rock material, have intruded the Middleton Sandstone and are conspicuous at Cape Hart and Cape Gantheaume. Here a series of northwest-southeast trending vertical dykes cut through the Kanmantoo metasediments. They vary in width from 0.5 to 4 metres and are interesting because most are composite with mafic and felsic components although a few are one or the other. The mingling of the felsic and mafic components in the composite dykes indicates that the two melts were contemporaneous. The felsic components are porphyritic with quartz, plagioclase and K-feldspar phenocrysts set in a fine dark-coloured matrix. The mafic component contains plagioclase intergrown with augite (mostly replaced by amphibole).

Pegmatites

Pegmatites of igneous and metamorphic origin also occur on Kangaroo Island. Metamorphic pegmatites containing large crystals of minerals such as andalusite, micas, scapolite, amphiboles and calcite, in addition to quartz and feldspar, are common within the metasedimentary rock sequences, especially on Dudley Peninsula, and were emplaced during the Delamerian metamorphism. In many localities very coarsegrained pegmatites of granitic origin and of a similar age to the Encounter Bay Granites (Milnes *et al.* 1977) have intruded Kanmantoo Group metasediments. They contain large crystals of quartz, feldspar and muscovite, with tourmaline and garnet. Gem-quality tourmaline has been mined from one of these pegmatites, which outcrops about 12 km southeast of Penneshaw.

PERMO-CARBONIFEROUS GLACIATION AND THE PERMIAN RECORD

During the late Palaeozoic the Australian landmass was part of Gondwana, the ancient super-continent comprising South America, Africa, Madagascar, peninsular India, Australia and Antarctica. Palaeomagnetic studies show that during this time Gondwana drifted across the South Pole which resulted in widespread glaciation across parts of the super-continent. Evidence of the youngest phases of this glaciation, scattered across the Australian continent, is provided by striated, grooved and polished rock pavements and other glacial landforms (Fig. 22). More commonly, evidence for the glaciation is provided by the numerous faceted and striated pebble to boulder

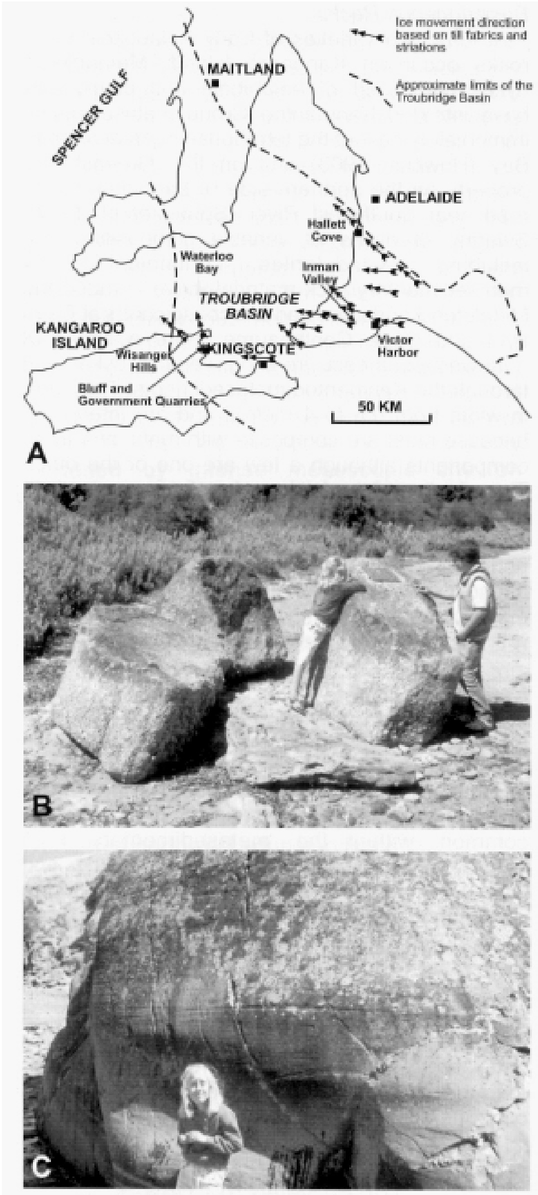


Fig. 22. (a) Location of the Permian Troubridge Basin and general ice movement directions (after Bourman and Alley 1990), (b) Granite erratic, Christmas Cove, Dudley Peninsula (photograph # 036216 courtesy of Office of Mineral and Energy Resources, SA), (c) Granite erratic, Christmas Cove, Dudley Peninsula (photograph # 036217 courtesy of Office of Mineral and Energy Resources, SA).

size granites erratics found within and weathered out of the Permian sediments. The presence of granite indicates that up to 10 km of rock was eroded from the fold belt between the end of the Delamerian Orogeny and the Early Permian exposing the Late Cambrian Encounter Bay Granites at Cape Willoughby, and the surrounding Kanmantoo Group metasediments (Milnes *et al.* 1977). This is further indicated by the smoothed and striated glacial pavements cut on Kanmantoo Group metasediments which underlie the glacial sediments, for example the partially exhumed Permian glacial depression in Christmas Cove at Penneshaw (Ward 1922; Bourman & Alley 1999).

Fig. 23. Columnar jointing in basalt, Bluff Quarry Kingscote, (photograph # 044137 courtesy of Office of Mineral and Energy Resources, SA).

The significant thickness of glacigene sediments left behind when the ice sheet retreated in the Early Permian was referred to as the Cape Jervis Beds (Ludbrook 1967), but later named the Cape Jervis Formation (Bourman & Alley 1990). The basin of deposition for these sediments is referred to as the Troubridge Basin (Wopfner 1972) and stretched from the northern Coorong across Fleurieu Peninsula and Kangaroo Island to Yorke Peninsula. The sediments were dumped on to the glaciated land surface as the onset of a warmer climate caused the ice-caps to recede. Vast amounts of debris were also rafted by floating ice to be deposited beyond the margins of the ice sheets. On

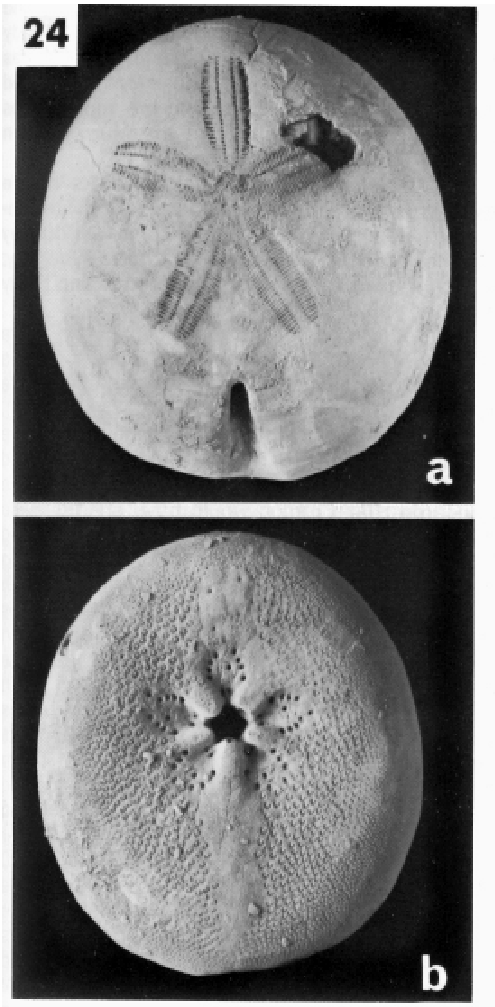


Fig. 24. The echinoid (sea-urchin) *Australanthus longianus*, a characteristic fossil found in the Upper Eocene deposits of the St Vincent Basin, and found in the Eocene sediments at Kingscote. a, aboral view; b, oral view. Natural size.

Kangaroo Island the Cape Jervis Formation is overlain by either Tertiary sediments or the Jurassic Wisanger Basalt. About 300 m of glacigene sediments were intersected in the Kingscote Bore (Howchin 1929; Ludbrook 1967) and up to 450 m are believed to fill a deep north-south trending trough eroded in bedrock along the western side of Dudley Peninsula. Seismic evidence suggests that the Cape Jervis Formation may be around 2000 m thick on the continental shelf east of Kangaroo Island (Alley & Bourman 1995).

Scattered outcrops of the Cape Jervis Formation occur along the northern coast of Kangaroo Island between Dudley Peninsula and Smith Bay and in the Wisanger Hills. At Christmas Cove, the Permian consists of a few metres of fluvioglacial and glaciolacustrine silt, sand and brown, bedded claystones carrying erratics up to 3 m long. The sediments display primary dips of up to 30^0 parallel to the slope of the underlying glaciated bedrock. Pavements, in part grooved, are also developed on the fossiliferous Cambrian sediments at Smith Bay and can also be seen in the intertidal zone on the western side of Boxing Bay.

Glacial sediments also outcrop in the coastal cliffs at Kingscote and to the west of the town in road cuttings and quarries. An 8 m thick deposit of horizontally-bedded to cross-bedded coarse sand in the disused Government Quarry was considered to be younger and of fluvial origin (Belperio & Flint 1992), but is now considered to be part of the proglacial succession, probably the distal sandy part of an outwash plain (Alley & Bourman 1995).

In Smith Bay, more than 15 m of green, sandy and clay-rich unbedded till rest directly on glaciated Cambrian sedimentary rocks. Erratic boulders, many of which are faceted, polished and striated, include red Cambrian sandstone of local derivation, but more commonly dark grey Kanmantoo Group metasediments and Encounter Bay Granites, and minor Adelaidean quartzites. Some erratics are up to 3 m long.

In Boxing Bay, up to 20 cm of till rests directly on the grooved and glaciated surface cut on Cambrian sandstone. The occurrence of till-filled fractures in strongly shattered and jointed sandstones in this locality is notable since such structures have not previously been reported from beneath glacial deposits in Australia. Where the till is absent because of erosion during the Early Permian, subaqueously deposited green-grey varved claystone and siltstone rest upon the glaciated surface. The varves contain erratics rafted by ice, which, upon melting, dropped its load into the bedded deposits.

Backstairs Passage, the stretch of water separating Kangaroo Island from the mainland is thought to be of glacial origin. The Passage is a narrow strait, 12 km wide and more than 70 m deep in places, though the deepest areas lie close to the opposing coasts at Cape Jervis and Cape St Albans, rather than in the centre of the feature. It is thought to be a pre-existing topographic low that was exploited by glacial ice.

THE MESOZOIC RECORD

Following deposition of the Permian sediments, a further phase of erosion cut a planate surface across the Late Precambrian and Early Palaeozoic bedrock and the poorly consolidated Permian Cape Jervis Formation sediments. Prolonged weathering of this surface has produced a ferruginised capping that forms the dominant feature of the main plateau on Kangaroo Island. The nature, origin and age of this capping are discussed in the 'Land Surface' chapter of this book.

Mesozoic Igneous Rocks

The most significant feature of the Mesozoic record on Kangaroo Island is the Wisanger Basalt that crops out as an eroded sheet westwards from Kingscote. The sheet is the remains of an extrusion of the Middle Jurassic tholeiitic basaltic lavas (Tilley 1921; Wellman 1971). These basalts flowed across the irregular surface cut into the deeply weathered glacigene sediments (Daily *et al.* 1974). They presently crop out between Kingscote and The Bluff, and occur as a cap-rock on the distinctive mesas in the Gap Hills between Rettie Bluff and Smith Bay (Howchin 1899; Daily *et al.* 1974). The best exposures can be seen in quarries near the northern outskirts of Kingscote and at The Bluff, where the basalts display the typical columnar jointing (Fig. 23). The near-surface zones of the basalts are fractured and contain root-channels infilled with calcium carbonate precipitated from downward percolating groundwaters. A less conspicuous outcrop occurs below the laterite-capped summit surface near Alex Lookout, on Dudley Peninsula. A K-Ar date of 170 Ma (McDougall & Wellman 1976) and other evidence suggests that the Wisanger Basalt can be attributed to the tensional regime that resulted in the separation of Australia and Antarctica (Milnes *et al.* 1982). The basalts were probably extruded in response to the widespread rifting prevalent across the southeastern part of the Australian continent during the Middle Jurassic. This rifting was associated with the initial dismemberment of Gondwanaland which eventually led to the separation of Australia and Antarctica in the Early Eocene.

THE TERTIARY RECORD

Tertiary strata are widespread in South Australia, occupying gently downwarped cratonic basins around the southern margin, down faulted basins, palaeochannels and extensive thin deposits inland (Alley & Bourman 1995).

Very little is currently known about the geological conditions on Kangaroo Island during the Tertiary. However, a consequence of the separation of Australia and Antarctica was the initiation of marine transgressions on to the southern margin of South Australia resulting in thick deposits in a series of basins referred to as the Southern Marine Basins (Alley & Bourman 1995). The St Vincent Basin is represented by the Kingscote Limestone which outcrops in coastal cliffs, adjacent to the jetty at Kingscote and southwest to Rolls Point (Fig. 24). These limestones are the same age as the Tortachilla Limestone and Blanche Point Marls exposed in the coastal cliffs at Christies Beach and Maslin Bay, south of Adelaide, and were deposited in the southern part of the extensive Tertiary St Vincent Basin. At Cygnet River, the transgressing sea deposited carbonate-rich sediments with the same stratigraphic relationships (intersected in bores in the area) on a surface dissected across deeply weathered Permian sands and clays. About 18 m of Tortachilla Limestone equivalents have also been intersected in a bore near Flour Cask Bay on the southeast coast of Kangaroo Island (Ludbrook 1969). On southern Kangaroo Island fossiliferous calcareous sandstone and sandy limestone containing Early Pliocene microfaunas occur at several localities. These are correlated with the basal Loxton Sand and are regarded as the southwestern extremity of the Murray Basin (Alley & Bourman 1995).

Other isolated outcrops of Tertiary rocks include exposures of bryozoal limestones in the Kingscote/Cygnet Basin, on top of the Cape Willoughby Granite; Porky Flat, 9 km west of Cape Willoughby; and on the western end of Kangaroo Island (Daily & Milnes 1982).

As in other parts of the St Vincent Basin, there appears to have been a regression of the sea in the Middle Miocene, due to the widespread uplift of the continental margins (Daily *et al. 1979).* Compressive earth movements slightly folded the Tertiary sediments of the Adelaide region, and block faulting disrupted the land surface. The Kangaroo Island region would have shared these events. Movement along the Cygnet and Snelling faults resulted in the fault block to the south being elevated with respect to that of the north, and each block being tilted slightly to the southeast. This resulted in a period of erosion until deposition recommenced in warm shallow seas in the Late Pliocene during a widespread transgression which resulted in the deposition of the fossiliferous calcareous Hallett Cove Sandstone equivalents near Gum Creek (Ludbrook 1959, 1963). Other outcrops of Upper Pliocene limestones are located in Section 172, Hundred of Haines, at Mount Taylor and Kelly Hill, and in Section 20, Hundred of Seddon. The latter outcrop is exceptional for it occurs more than 120 m above sea level, just below the top of the laterite plateau, and, together with the Mt Taylor occurrence which is at a similar height, suggests that a large part of Kangaroo Island was inundated during the Late Pliocene (Daily *et al.* 1979). At Vivonne Bay, shell-beds are exposed in the coastal cliffs and represent stranded marine deposits Large and complete thick-shelled molluscs, including *Anodontia,* dominate the older parts of the deposit and represent a warm-water fauna of possible Pliocene age (Daily *et al. 1979).*

Immediately following a regression of the sea in the Early Pleistocene in the Adelaide region, major uplift took place along the bounding faults of the Mt Lofty Ranges and disrupted the Late Pliocene marine deposits. As a consequence of this uplift, thick wedges of alluvial outwash were spread northwestwards across the Willunga, Noarlunga and Adelaide Plains embayments of the St Vincent Basin, and buried the Tertiary and basal Pleistocene marine deposits. In contrast with the Adelaide region, there is no evidence of movement along the Cygnet and Snelling faults on Kangaroo Island after the Middle Miocene. However, this does not preclude uplift of the Kangaroo Island region as a whole during Pleistocene times, as seems to have been the case.

2: The Land Surface

by C. R. TWIDALE & J. A. BOURNE

INTRODUCTION

Kangaroo Island is essentially a dissected high plain or plateau that extends about 140 km east-west and 55 km north-south (Fig. 1). It has been incised by rivers and streams on both its northern and southern flanks, but because of the ironstone or lateritic capping the valleys are narrow and the rather featureless high plain remains intact over large areas. In the valleys, and especially on the coast, are exposed the Proterozoic and Palaeozoic rocks which underlie the island and on which the laterite has developed. Prominent mesas or table like hills are associated with basaltic cappings in the Wisanger area. A linear fault scarp runs parallel with the north coast from just west of American River westward to the longitude of Parndana (Fig. 1a). Most of the north-flowing rivers reach the sea uninterrupted, but those draining to Antechamber Bay and those running to the south are blocked by relic coastal dunes of calcareous composition. Prospect Hill (Mt Tisby, or Mt Thisby, as it is now and perhaps unfortunately, more commonly known: see Cockburn 1984, p. 219) a local high spot standing about 101 metres above sea level, is also an old dune accumulated by south and north blowing winds. Some contemporary dunes, like one at Smith Bay are active, but others are stabilised by vegetation.

It is on the coast that the most spectacular scenery is to be found, with rocky cliffs and promontories and intricately sculptured granite domes and boulders interspersed with embayments, backed by beaches of shingle or white sand (Fig. 2 a, b and c).

How and when did this landscape evolve? Indeed, how and when did the island form?

THE HIGH PLAIN OR PLATEAU

The lateritised high plain or plateau which occupies much of Kangaroo Island (Figs 1a and 2a) slopes down to the south and to the east. It stands between 50 m above sea level in the east and south and 250 m further to the west and north, attaining its highest point of 320 m near the intersection of the West End and Playford highways. The Cygnet fault scarp separates a lower, from the main, higher, lateritic plateau.

Origin of *the laterite*

The plateau is upstanding by virtue of faulting but is preserved by a protective capping of laterite. On Kangaroo Island the laterite comprises a sandy Ahorizon up to a metre thick, overlying a ferruginous zone one or two metres thick and consisting of irregular spheres or pisolites of iron oxide. This is underlain by a kaolinised zone. Ferruginous red, brown and yellow mottling is typical, and in places there are siliceous bands. This mottled and pallid zone is a few tens of metres thick and merges below with the country

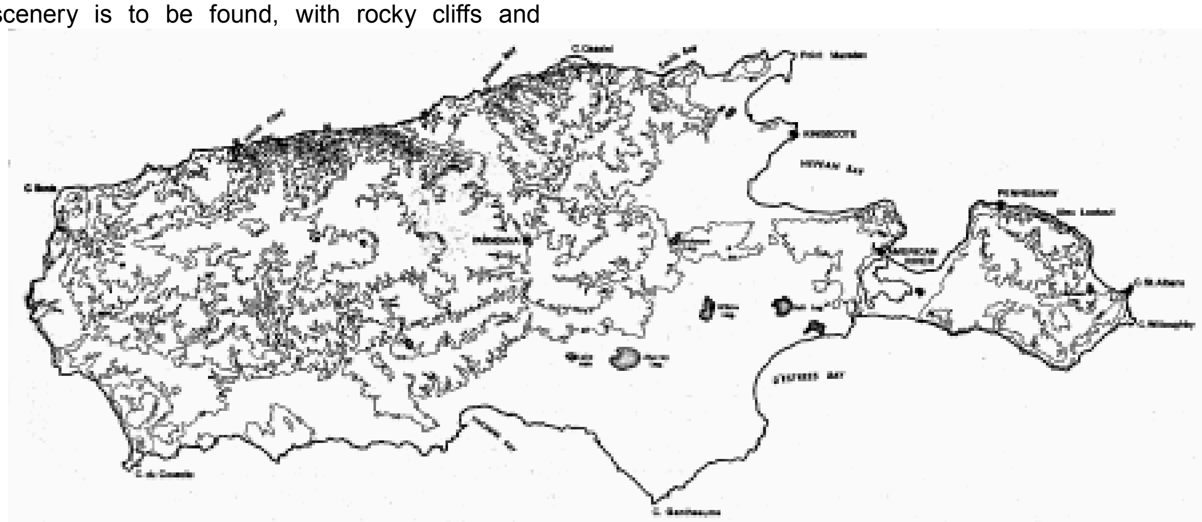


Fig. 1.(a) Kangaroo Island, topography. Contours in metres.

Fig. 1.(b) Kangaroo Island drainage.

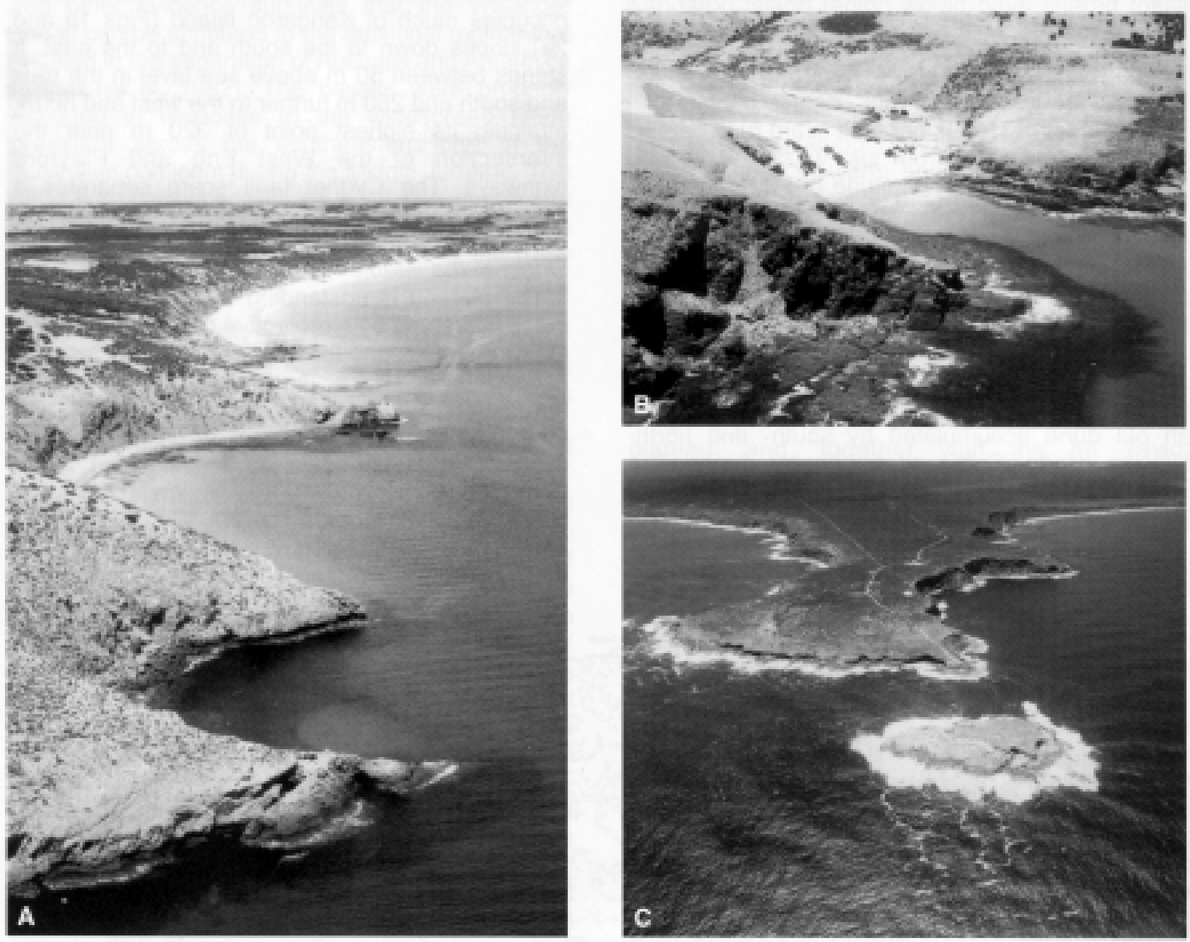


Fig. 2. (a) Part of the north-central coast of Kangaroo Island, with rocky headlands and, in the middle distance, the long beach of Emu Bay, backed by vegetated sand dunes. In the distance is the fault scarp leading up to the lateritic plateau which occupies most of the Island. (Coast Protection Board, S. A.). (b) Small bayhead beach backed by active dune, Hummocky Gorge, near Cape Cassini (Coast Protection Board, S. A.). (c) Low aerial oblique shot of Cape du Couedic, with one of the Casuarina Islets (also known as The Brothers) in the foreground, Admirals Arch (with track leading to it) at right of promontory, and the lateritic plateau in the distance. Note the featureless lateritic surface and the steep dip of strata exposed on the coast on the islet and promontory. (Environmental and Geographic Information, DEHA, South Australia).

rock. Laterite is due to rock weathering. Such soils are at present developing in humid tropical and especially monsoonal areas (Maignien 1966), though ferruginous weathering of later Cainozoic age is reported from cool climate areas of southeastern Australia (Taylor *et al.* 1992; Young *et al.*1994).

Age of *the laterite*

When the laterite formed is controversial. Early workers such as Northcote (1946) and Sprigg *et al.* (1954), not unreasonably in light of the data then available, considered it to be latest Tertiary (Pliocene) in age, and this view was accepted for many years. A much greater age, however, is suggested by the relationship of the lateritised surface and basalts extruded in the northeast of the Island, though the nature of the lateritisation process must also be taken into consideration.

The oldest possible age for the laterite is indicated by the age of the youngest rocks affected by the lateritic weathering, and the youngest by the age of any materials resting upon it. Laterite developed on Precambrian and Cambrian rocks folded during the Delamerian Orogeny. Late Palaeozoic glacigene strata also show signs of lateritic weathering. About 270 Ma when Australia was still part of Gondwana, and located in high southern latitudes (e.g. Embleton 1984), and with what is now Antarctica located immediately south of South Australia, huge ice sheets pushed northwestwards (in contemporary terms) over the continent. On Kangaroo Island this ice age is evidenced not only by widely distributed glacial sediments, but also by polished and striated pavements reported from Christmas Cove, near Penneshaw (e.g. Bourman & Alley 1999). Though no ferruginous zone has been located developed on Permian glacigene rocks, they are deeply weathered. For example, Howchin (1903) described a section at Beares Point, near Queenscliff (the original name for Kingscote) where contorted glacigene sediments include numerous discrete irregular masses of iron oxide. Either any ferruginous capping has been stripped from the readily eroded unconsolidated strata; or such an iron-rich horizon never developed due to lack of ferruginous salts; or the water table in the permeable, weakly-lithified rocks fluctuated widely. Though iron oxides were precipitated, they did so at scattered sites rather than in a definite horizon. In any event, the weathering of the Permian strata and the position of the laterite over these rocks shows that the laterite is younger than Permian.

The post Permian age of the laterite was appreciated by Sprigg *et al.* (1954) who also realised that it was older than the basalts extruded at various sites in the northeast of the Island. At that time, however, the absolute age of the basalts was not known, and correlations were made between this volcanism and that of Late Cainozoic age evidenced in the South East and in western Victoria. The reality is very different, for K-Ar dates on the rock give ages of around 174 my or a

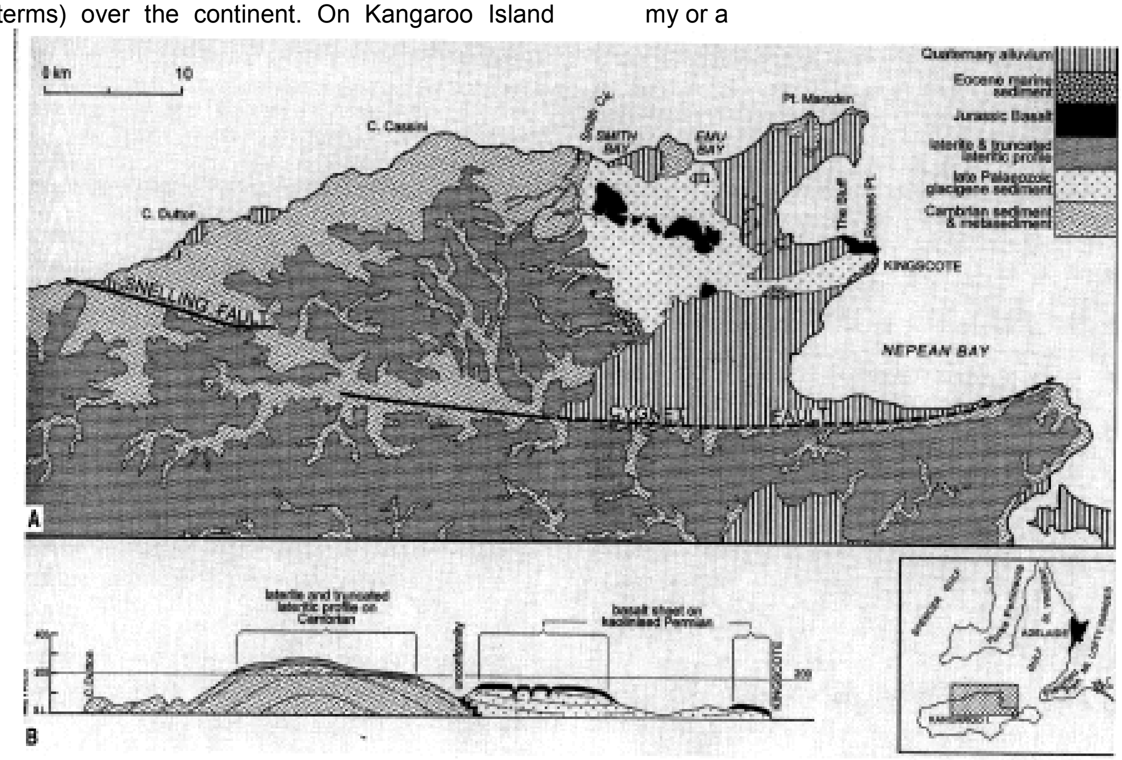


Fig. 3. (a) Map and (b) section showing relationship of basalt and laterite on northwestern Kangaroo Island.

Fig. 3. (c) Basalt-capped plateau near Wisanger.

Middle Jurassic age (Wellman 1971; McDougall & Wellman 1976).

In Middle Jurassic times, the separation of Australia and Antarctica began with the development of a tensional rift, into which welled the basaltic lavas now exposed in Tasmania, in the southwest of Western Australia and on Kangaroo Island. In the latter area, some were extruded in the Wisanger area, west of Kingscote (Fig. 3), and in lesser measure at various sites to the east, near Penneshaw and at Alex Lookout. Sections exposed in Grahams Quarry, northwest of Kingscote, show that the lava is subdivided by innumerable vertical joints of columnar systems developed normal to the cooling surface, so that the rock effectively consists of myriads of thin elongate columns, slivers, or laths (Fig. 4); meteoric waters can readily infiltrate the rock mass yet the basalt remains surprisingly fresh; which indicated youthfulness to Sprigg and his colleagues.

At Wisanger and at Penneshaw the basalts rest upon kaolinised Permian glacigene strata and at Penneshaw on a ferruginous zone (see also Tilley 1921). On this evidence, the basalts are younger than both the laterite or weathered mantle and the surface on which it is developed.

Thus the lateritic surface appears to be younger than Permian but to predate the Middle Jurassic basalt. Oxygen isotope analysis of kaolinised Permian sediments located beneath the Wisanger Basalt suggests that the laterite predates the Late Mesozoic (Bird & Chivas 1989), though palaeomagnetic work produced a younger date (Schmidt *et al.* 1976). Assuming that the laterite and associated surfaces predate the Middle Jurassic, the palaeoclimate of the period between Permian and Middle Jurassic was warm, with cool indicators at higher latitudes not appearing until the later Jurassic and Cretaceous (Frakes *et al.* 1992). Thus if lateritic development under a torrid climate is implied, regional stratigraphy suggests a Triassic age for the duricrust (Daily *et al.* 1974, 1979). At this time Kangaroo Island evidently stood in high latitudes (Embleton 1984), which is difficult to reconcile with a warm climate.

Fig. 4. Basalt subdivided into slim columns or laths and exposed in Grahams Quarry north of Kingscote.

Problems attaching to putative great age

This interpretation has been much disputed and has been termed unreasonable (e.g. Bourman 1989, 1995), on the grounds that such an old surface could surely not have survived the elements for a period of some 200 Ma. It has been suggested that the kaolinised materials may have formed by sub-basaltic weathering, by waters percolating through the basalts and into the underlying country rock (Schmidt *et al.* 1976), but if this were so the basal zone of the basalt ought to be altered, whereas the basalt shows little or no sign of weathering. Moreover, this does not account for the ferruginous zone preserved beneath the basalt west of Penneshaw. Even if the suggestion that laterites develop continuously is accepted (e.g. McFarlane 1986; Bourman 1993), it does not clarify the stratigraphic relationships of the regolith and basalt exposed on Kangaroo Island.

The freshness of the basalt also poses problems, exacerbated by the belief (Goldich 1938) that rocks of basaltic composition ought to be especially susceptible to moisture attack. On the other hand old basalts underlie and evidently conserve basaltic plateaux in cold conditions in the high Drakensberg of Natal and the Snake River basin in aridity in the Columbia Plateau, and in the monsoonal Victoria River basin of northern Australia. Is it the perviousness of basalt due to the common development of hexagonal and pentagonal fracture sets (columnar jointing), combined with a position high in the local relief, that has saved the rock from intense alteration?

Milnes *et al.* (1982) suggest that any regolith developed on it has been stripped away, or that its freshness is due to burial by post Jurassic sediments and recent exhumation. It is difficult to accept that the stripping of any regolith would have been complete, and that kaolinised material did not survive in pipes and other negative irregularities in the weathering front. It is equally unlikely that burial could have caused preservation. It would have prevented erosion but unless extraordinarily deep (groundwaters are commonplace in the upper 800 m of the crust and are known to occur as deep as 10 km) any cover would have retained moisture and ensured alteration of the basalt.

The Miocene was a period of high sea level. About 20 Ma, during the Early Miocene, a rise of sea level caused substantial areas of southern South Australia, especially the Murray and Eucla basins, but including the southern part of what is now Kangaroo Island, to be inundated. Evidence of this marine transgression takes the form of marine sediments preserved at a height of about 130 m above sea level southwest of Parndana, at Mt Taylor, and Mt Stockdale, and at about 50 m in the southeast of the Dudley Peninsula. There is no suggestion that the marine transgression covered the whole Island. Moreover, it would be imprudent to extrapolate from the known height of preserved remnants of Miocene strata, for there is clear evidence of late and continuing tectonism in the Gulfs region (e.g. Glaessner & Wade 1958; Greenhalgh *et al.* 1994) so that the present details of topography almost certainly do not reflect the situation in Miocene times.

All that the Miocene transgression implies is that the seas then lapped up against the edges of the lateritised plain. The laterite plateau was not washed by the sea. But it then stood close to sea level and this may have served to protect the surface, for streams at or near base level tend to corrade laterally. Given the small volume, low gradients and rough rocky channels of most of the rivers, and also the resistance to erosion afforded by the ferruginous capping of the laterite, this would have been a slow process.

The basic stratigraphic relationships between the older bedrock and the volcanic rocks that were established by Sprigg *et al.* (1954) have been reexamined, and are not disputed. The radiometrically determined Middle Jurassic age of the basalt has been reproduced many times. Tilley (1921) noted, and Daily *et al.* (1974) confirmed, that west of Penneshaw ferruginous zone laterite is overlain by basalt so that the laterite and the surface on which it evolved predate the Jurassic volcanicity and the separation of Australia from Antarctica; and conventionally, and as with strata, the age attributed to a surface is that of its origin. There is now a measure of agreement that some duricrusted surfaces may be of great antiquity (e.g. Benbow *et al.* 1995). Wright & Bourman (this volume, addendum to Soils chapter), however, assert that the Mesozoic age attributed to the lateritic high plain of the island is "tenuous", on the grounds that oxygen isotope dating of clays from the lateritic surface indicate a Middle Tertiary age. Yet if, as has been demonstrated (e.g. Ludbrook 1980; Veevers & Eittreim 1988; Parker 1993), the Australian continent, including Kangaroo Island, has migrated northward during the present plate cycle, surely one would expect a younger age for presumably altered and reconstituted surficial clays deposited in valleys and depressions?

Asymmetrical Valleys

The lateritic high plain is broadly rolling but otherwise featureless. At the margins it is dissected by valleys some of which are asymmetrical. Many of the lower reaches of valleys cut by rivers like the Harriet and Curley, which run southwards from the lateritic plateau have been blocked by coastal dunes. The valleys have aggraded upstream from the obstacles. Rivers like the White Tree, Western and Breakneck, flowing to the north or western coasts have excavated short, deep and narrow valleys and one of them, Middle River, has been dammed.

Some of the plateau valleys are of particular interest because they are asymmetrical in cross-section, with a steeper south-facing or northern valley-side slope (Northcote & Tucker 1949). They include the headwaters of Timber Creek, an unnamed stream located south and southwest of Parndana, another to the west of Macgillivray, and one west of Antechamber Bay. All are aligned east-west. They could reflect structure, and in particular a consistent latitudinal strike and northerly dip of cleavage or bedding in the local Kanmantoo bedrock, but this is not borne out by the field evidence.

Valleys of a similar asymmetry have been reported from the Mt Lofty Ranges (Woods 1962, 1989; Grear 1988) and other parts of the world (e.g. Le Fevre 1931; Ollier & Thomasson 1957). Many occur in cold or cool areas and are readily understood in terms of different rates of freeze-thaw and mass movement on contrasted aspects. Some asymmetrical valleys owe their morphology to structural control, but that can be ruled out on Kangaroo Island for there is no consistent relationship between form and dip of bedrock. Le Fevre suggested an explanation for asymmetry in non-nival areas based in contrasted rainfall regimes on opposed slopes.

For the sake of discussion consider a symmetrical valley. In terms of the Gulfs region, including Kangaroo Island, it was suggested that as

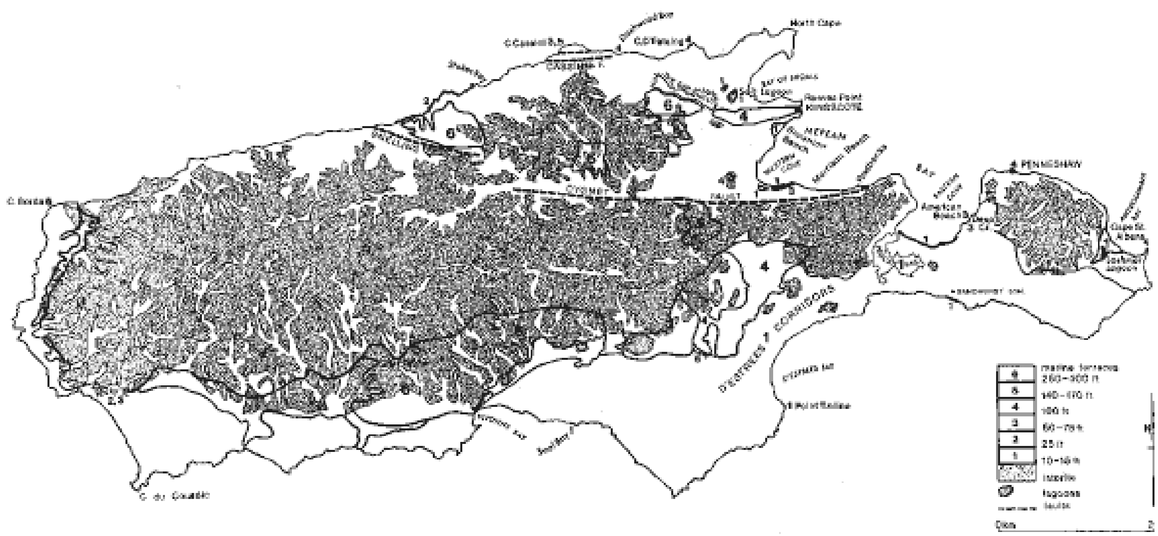


Fig. 5. The distribution of various marine terraces recognised by Bauer (1959).

rainfall originated in the southwest, south-facing slopes would receive direct rainfall impact and runoff would be rapid and coincident with river flow, so that eroded debris would be evacuated from the base of the slope. The sheltered southern slope, on the other hand, would receive seepage rather than direct rainfall. Runoff would be slow and eroded detritus would arrive at the base of the slope when the main or trunk stream has either ceased to flow or is at a low ebb. The debris would tend to be deposited so that the base of the slope would be built out, and the river diverted northwards, undercutting and steepening the northern or south facing slope. Such wedges of colluvial material have indeed been located at the base of the gentler valley-side slopes in asymmetrical valleys such as Pedlars Creek, south of Noarlunga (Grear 1988), providing corroboration for Le Fevre's working hypothesis.

Lagoons on the lateritic surface

Lagoons occur in several valleys. Those in the south may have been impounded by coastal foredunes (q.v.). But those in the north, and particularly Birchmore Lagoon, are surrounded by the lateritised surface, suggesting they are of a different origin. They may be partly infilled sinkholes comparable to those such as Frew's (Ironstone) Pond described by McDouall Stuart (1863, pp. 16, 17 and chart) from the Sturt Plateau of the Northern Territory, where they are of later Cainozoic age and are still developing (see Twidale 1987). These sinkholes are due to solution of silica from the underlying sediments, and occur preferentially along fractures and in valleys. Their dissolution may have been assisted by the spread of the eucalypt-dominated woodlands, for litter from these trees produces chemicals (polyphenols) that aid silica solution. The lagoons have not been investigated geologically, but there is suggestion of deep weathering involving mobilisation of iron oxides in a narrow pipe in the granitic coast west of Cape Willoughby, and construed as the bottom of a doline inherited and extended from the calcarenite that formerly covered the granitic headland.

SOME QUATERNARY EVENTS AND FORMS

Sea level changes

There is no evidence of post-Permian marine inundation of Backstairs Passage, and hence the separation of Kangaroo Island from the mainland, until the Late Eocene. Throughout the rest of the Tertiary, isolation must have occurred each time the seas flooded into Gulf St Vincent.

During the Quaternary, which commenced about 1.8 million years ago, the Island was intermittently part of the mainland due to stands of the sea much lower than at present. Such regressions were caused by periodic glaciations during the Pleistocene, at which times water was extracted from the oceans and accumulated in the ice caps. Aboriginal Man reached the Island during the latest Pleistocene (Pretty 1977) when a crossing could have been effected on foot. However, the Island was uninhabited when the first American and European whalers arrived in 1802.

The world-wide sea level changes consequent upon the waxing and waning of the ice sheets in high latitudes have affected the landscape of Kangaroo Island. The general theory is that there were four major glacial phases and four interglacials during the Quaternary Period, the last of which we are still experiencing. During each of the glacials, water became frozen and locked up in ice sheets. It was taken out of the hydrological cycle so that sea level was lowered. During the interglacial phases the ice sheets melted, or partly melted, so that large quantities of water were returned to the ocean basins and sea level rose, though probably not to preglacial levels.

The effects of Pleistocene low sea levels around Kangaroo Island are only fragmentarily known and this side of the story awaits further underwater exploration by marine scientists. The impact of higher Pleistocene stands of the sea was studied by Bauer (1959) and some of the difficulties encountered are outlined in a later publication (Bauer 1961; see also Daily *et at.* 1979; Milnes *et* al. 1983). Comparable studies of Pleistocene stands of the sea as they have affected the Adelaide region and Fleurieu Peninsula are summarised in Twidale (1976). Bauer's studies were handicapped in particular, and crucially, by a lack of adequate topographic maps.

Nevertheless, he amassed a vast amount of information which allowed him to postulate a Late Pliocene sea level at the present altitude of 122 m (400 ft), and five Pleistocene to Recent stands of the sea between 52 m (170 ft) and 3 m (10 ft) *above* present sea level (Fig. 5). On the basis of their elevations above present sea level he tentatively correlated these various postulated strandlines.

It is fair to state that the lower features are better substantiated than those at higher elevations, though some storm beaches and benches (around high tide level) and high level solution benches confuse the picture. Platforms related to high-tide or storm levels (Fig. 6) are well developed at several sites. The lowermost 'raised beach', the 3-5 m (10-15 ft) level, appears to be well founded, for beach deposits with fossil shells, mainly molluscs (including *Anadara trapezia),* are found extensively around the periphery of the Island. A shingle beach at this level is preserved beneath dune calcarenite at Admirals Arch (Fig. 7), and at Cape Willoughby a stack stands on such a granitic platform at a similar level (Fig. 8); showing that age does not necessarily correlate with height. A 6-8 m (20-25 ft) level is represented by probable shore platforms or narrow coastal plains, as for example at Cape du Couedic (Twidale *et at. 1977).*

On the other hand, a platform standing between 15-23 m (50-75 ft) above present sea level on many parts of the coast is more difficult to interpret. It is not associated with marine deposits and is not as flat as shore platforms commonly

Fig. 6. High, or storm-tide shore platform in calcarenite at Pennington Bay.

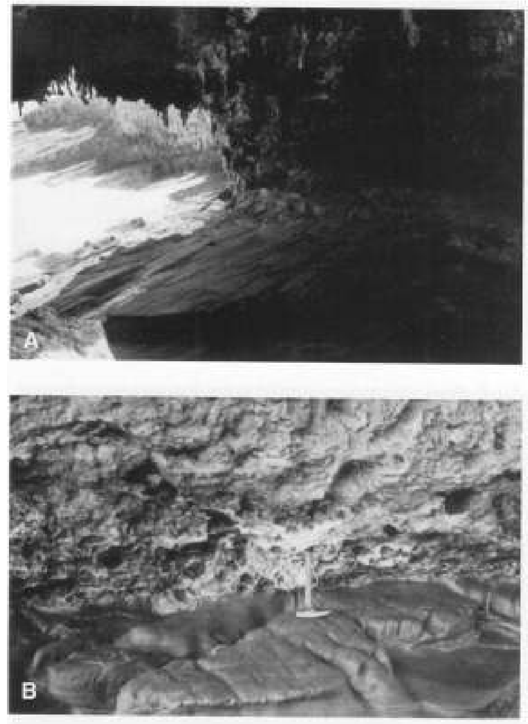


Fig. 7. (a) Admirals Arch, Cape du Couedic. Showing dipping Cambrian rocks overlain by dune calcarenite, the latter giving rise to numerous stalactites. (b) Unconformity between Cambrian rocks below and calcarenite above, with a shingle beach, cemented by carbonate, preserved at the junction.

are. It may be of marine origin but could alternatively be a coastal plain cut by rivers, possibly graded to a higher stand of the sea; though not necessarily at 15 m or thereabouts, for the position and elevation of the then coastline are unknown. The evidence concerning a platform that stands 30-34 m (100-110ft) above sea level is also equivocal. Because of its extensive development it was regarded by Bauer as a marine abrasion platform, but its extent in fact argues against such an origin for true shore platforms are inherently narrow features (King 1963), and again we may be dealing with preserved fragments of a riverine coastal plain. A good example of this level can be seen behind the lighthouse on Cape St Albans. At higher elevations a possible 43-52 m (140-170 ft - Fig. 9) platform is regarded by Bauer as of questionable marine origin; and we agree.

In summary, there are definite Pleistocene marine terraces at 3-5 m and 6-8 m but the higher platforms at present lack positive evidence to support their marine origin.

A further difficulty is that Kangaroo Island has not been tectonically stable through the Pleistocene, as Bauer supposed. The platforms have probably

Fig. 8. Stack in granite preserved some 3 m above sea level at Cape Willoughby.

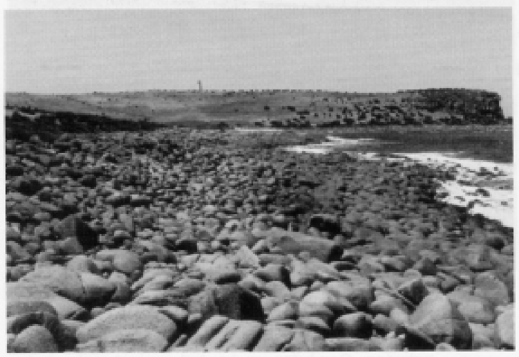


Fig. 9. A remnant of a 50 m platform at Cape Willoughby with a shingle beach of released corestones (q.v.) bordering Windmill Bay, and the granite cliffs of Cape Willoughby at right middle distance.

been raised by Pleistocene faulting which elevated but also tilted the Island. Thus the present altitude of the Late Pliocene marine features does not necessarily indicate the true altitude of the sea at the time of their formation.

Coastal dunes

One important effect of the ice ages was that at these times of low sea level, wide expanses of what is now the sea floor were exposed. The sediments and shells, broken by weathering and waves, were blown by onshore winds to form huge fields of beach and backshore sand deposits (Sprigg 1979), consisting predominantly of calcium carbonate. In time these calcareous dunes became consolidated through cementation of the constituents by downward-percolating rain water charged with calcium. The consolidated Pleistocene calcareous dune-rock was widely known as aeolianite (Crocker 1946) but is now more commonly referred to as dune calcarenite. Fields of such largely relic Pleistocene consolidated calcareous dunes are widely developed along the coasts of Western Australia, Victoria and South Australia, and they are especially well developed along the western and southern coasts of Kangaroo Island. The calcarenite dune fields developed on the west coast of Eyre Peninsula have been dated as Middle-Late Pleistocene (630,000-180,000 years: Wilson 1991); and those of Kangaroo Island may

Fig. 10. Stalactites, with helictite (growth defying gravity) right of centre, and on the floor, flowstone and stalagmites, Kelly Hill Caves. (Grant Gartrell and Cave Exploration Group, S. A.).

be of similar age-range.

These dune areas are characterised by a lack of surface drainage. Other limestone (or karst) forms include several dolines, or sinkholes, and shallow, comparatively short cave systems, many decorated with stalactites, and other speleothems (Matthews 1985). Fossil bones have been found in several (see Chapter 12), providing valuable evidence of former life and climates. Of these caves, those at and around Kelly Hill, near the southwestern .coast of the Island, are the best known (Fig. 10). The main cave there is about 30 m deep and extends laterally for about 200 m. Its speleothems include helictites, and bone deposits are also found there.

Soils developed on the dunes as a result of weathering at times of stability, and these can be seen as buried red-coloured palaeosols (fossil soils), with associated calcrete, in dune complexes. Submarine consolidated shoreline dunes marking lower stands of the Pleistocene seas, as low as 100 m below present sea level, occur offshore from Kangaroo Island, the Coorong in southeastern South Australia, and elsewhere (Sprigg 1979). Sprigg (1979) has shown that in the Cape Gantheaume area along the southern coast of Kangaroo Island, the Pleistocene dune drifts were laid down under the influence of westerly winds. This contrasts with the unconsolidated and vegetated more recent dunes, which, together with the presently active and unvegetated sandblows, formed ahead of southwesterly winds and cut across the pre-existing fossil dune trends.

Lagoons and lunettes

One effect of the spread of calcarenite dunes along the south coast of Kangaroo Island was that the normal drainage from the plateau was impeded. Alluvial plains were formed between the high dunes and the southerly slope of the tilted fault block, and also spread up river valleys. In some areas, shallow lakes or lagoons formed, the largest examples being White Lagoon, Murray Lagoon and Lake Ada.

Lagoons also developed in other settings, for example behind bars and beaches (Pelican Lagoon, Lashmar Lagoon), in sinkholes or dolines in the calcarenite (near Vivonne Bay), as well as on the lateritic plateau (q.v.). They may also occupy abandoned river loops (ox-bow lakes), particularly on the Cygnet River floodplain.

During the Late Pleistocene, prevailing westerly winds scoured the land surface to the level of the local water table, thus forming additional shallow lakes or lagoons. Sand, silt and gypsum were blown a short distance from the dry beds of lagoons, and from beaches accumulated at the eastern shores, before being trapped by vegetation. The wind-blown materials were deposited in distinct ridges of arcuate shape in plan and hence called lunettes at the edges, and particularly the eastern margins, of many of the lagoons (Hills 1940; Stephens & Crocker 1946; Bauer 1959; Campbell 1968; Bowler 1968; Sprigg 1979). Multiple lunettes (i.e. ridges formed in parallel, one with another, around the lake edge) are found, e.g. White Lagoon. The lagoons are now only seasonal lakes and tend to be dry during summer.

Present coastal forms

As has been mentioned previously, the coastline is Kangaroo Island's greatest scenic asset. The coast is predominantly rocky, though there are some flat aggradational areas, as for example around Nepean and Antechamber bays. Cliffy headlands separated by magnificent sandy beaches are, however, more characteristic (Fig. 2). Shore platforms are well developed at the bases of the cliffs, especially those eroded in the calcarenite. They are also prominent where the unconformity between the calcarenite and bedrock is coincident with present sea level, as at Stokes Bay. At Cape du Couedic the unconformity between calcarenite above and the dipping Kanmantoo rocks below has been exploited to produce the well-known opening and arch.

The detailed form of the cliffs is closely controlled by the nature of the rock. For example, characteristically large-scale cross-bedding and calcrete layers are expressed in detail in the calcarenite cliffs. On the other hand, ridges and clefts are typical of the older folded sediments and metasediments. Ledges and clefts are well developed in areas of flat-lying rock, as at Cape Cassini, where the sandstone displays alveolar or honeycomb weathering (Fig. 11**).** Several small batholiths and stocks of granitic rocks of Delamerian age and notably those at Cape

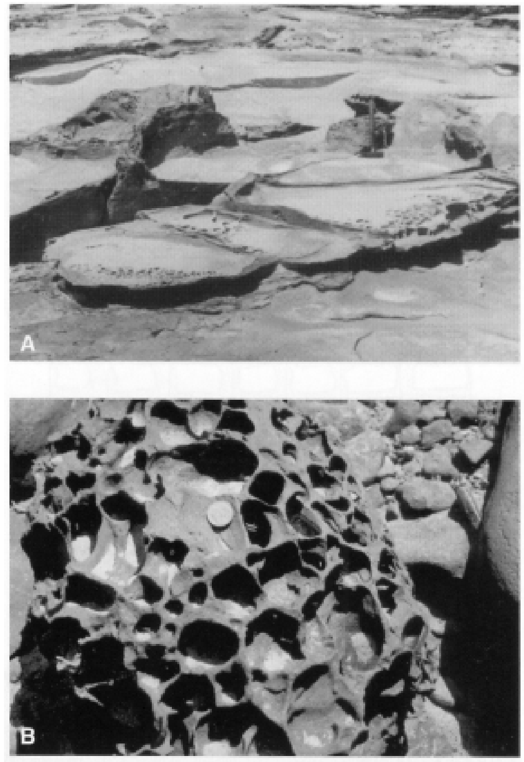
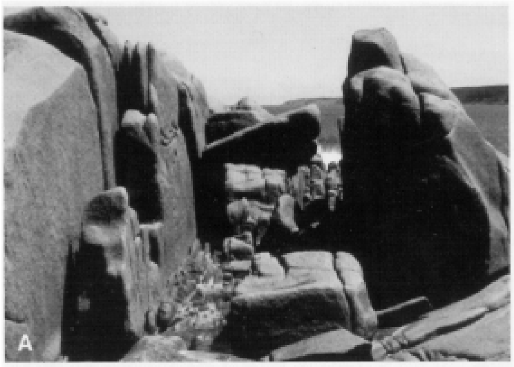


Fig. 11. (a) Flat-lying sandstone exposed in shore platform at Cape Cassini, north coast. Note alveolar or honeycomb weathering at the edges of slabs. (b) An example of the alveolar weathering at Cape Cassini. The scale is given by the 20 cent piece.

Willoughby and Remarkable Rocks are exposed along the south coast of Kangaroo Island. They are analagous to the outcrops well known from the eastern Mt Lofty Ranges (including the Victor Harbor area) and adjacent sectors of the Murray Basin. The outcrops were covered by dune calcarenite in the Middle Pleistocene and have since been exhumed as the sand has been stripped away by waves and wind.

Granite cliffs, like those at Cape Willoughby, are blocky and reflect the orthogonal jointing of the bedrock (Fig. 12). Conversely, at Kirkpatrick Point, the well-named Remarkable Rocks consist essentially of a broad dome (Fig. 13) scored by widely-spaced shallow gutters. Several blocks stand partly covered by soil at the lower edge of the dome and several of these have concave or flared sidewalls. Standing on the crest of the dome are several large angular weathered blocks (Fig. 14a). The steep external walls of some are scored by grooves or *Rillen* (Fig. 14b) but the most spectacular features found on the blocks are the numerous hollows or tafoni which have produced intricate fretting, mamillated ceilings, and unusual shapes (Fig. 14).



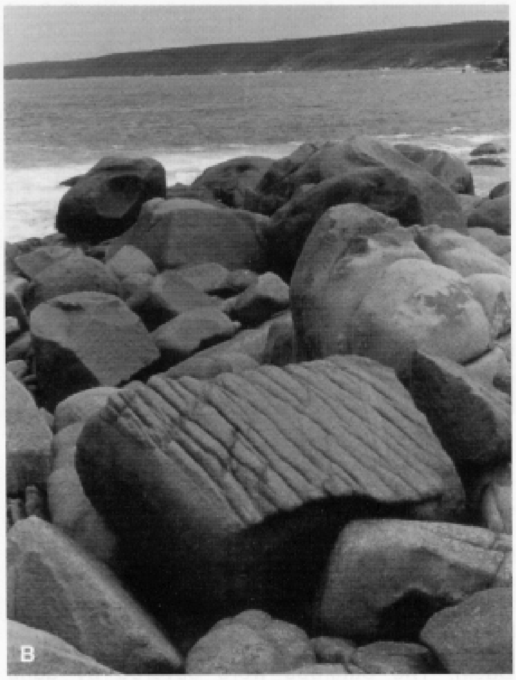


Fig. 12. (a) Size and shape of granite blocks at Cape Willoughby determined by spacing of fractures. (b) Grooves or *Rillen* on face of block at Cape Willoughby.

The formation of alcoves and tafoni and of the smaller alveoles are both due to salt crystallisation, or haloclasty (e.g. Bradley *et al.* 1978). Seawater or spray lodged in basins or depressions, or on rough surfaces, percolates into the rock with which it comes into contact. The water evaporates and the contained salts, especially common salt or halite, crystallise out. In so doing the salts exert a pressure sufficient to rupture the rock, so that the hollows are enlarged to form first mamillae a few centimetres across and then tafoni, some of which are several metres in diameter. Good mamillation is to be seen on the ceiling and interior walls of tafoni at Remarkable Rocks (Fig. 14c). Once initiated, tafoni grow upwards and outwards and eventually breach the outer shell of the block or boulder in which they are sited. Small hollows, or alveoles, grow and coalesce until, either the host block is destroyed or a tafone is formed. Very good examples of alveoles are developed in amphibolite at Emu Bay and Stokes Bay, in schist and gneiss at Penneshaw, as well as, and as already

Fig. 13. Low oblique aerial photograph of Remarkable Rocks from the southwest. Apart from the cluster of sculptured blocks preserved on the crest of the dome, the rest of the granite surface is essentially smooth. Note the traces of steeply-dipping fractures, the slabby remnants of thin sheets of rock, the concave slopes or flares at the near left margin of the dome; also the blocks and boulders, some released corestones (q.v.), on the shore platform; and the virtually unbroken line of calcarenite cliffs stretching into the distance.

mentioned, in quartzite and granite.

Evidence from Eyre and Yorke peninsulas suggests that many of the minor features - basins, gutters, clefts, flared slopes - found on these granite exposures originated through moisture attack beneath the surface, at the junction between soil and bedrock (Twidale 1962; Twidale & Bourne 1975). That they predate the deposition of the dune calcarenite, is demonstrated at several sites where the carbonate has filled basins and grooves. They developed at the base of the soil or regolith as a result of weathering by moisture attack. Certainly they have developed further after exposure but originated much earlier, possibly at the base of the ?Early Mesozoic lateritic weathered mantle. Subsequently the forms at the weathering front were exposed as the regolith was stripped. They are two-stage forms (Twidale 1982; Fig. 15a). Corroboration for this suggestion is found in the corestones still enclosed in grussy regolith exposed in cliffs at the eastern end of the Island (Fig. 15b) and adjacent to Remarkable Rocks. Once the matrix of weathered rock is stripped the corestones will emerge as boulders like those scattered over the adjacent slopes.

Water has penetrated along the partings, and weathered the bedrock, leaving kernels, or corestones, of fresh rock within the blocks. The palaeosol is preserved beneath the calcarenite, e.g. at Cape Willoughby, where the mean diameter of the kernels tends to increase with depth below

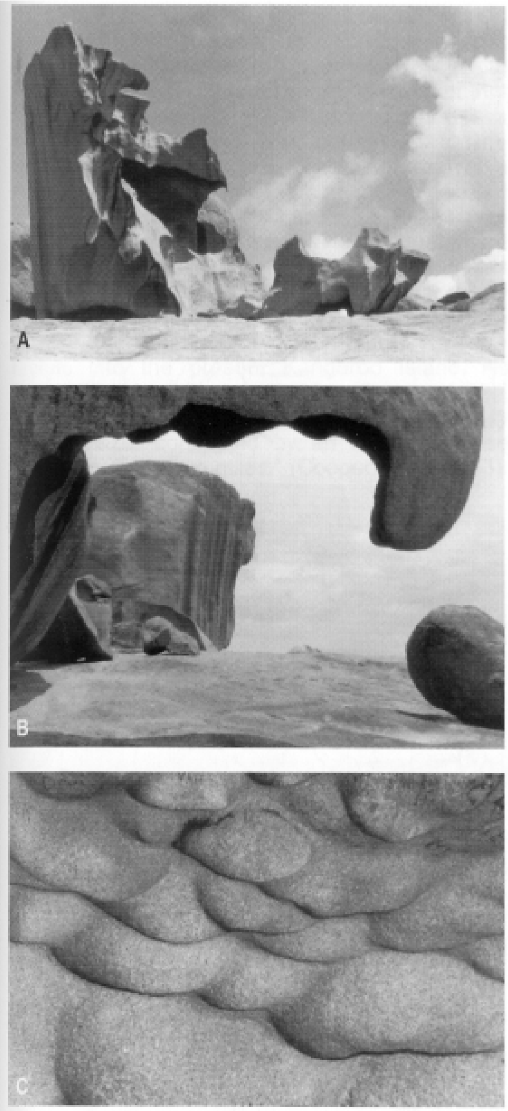


Fig. 14. Remarkable Rocks: (a) Block hollowed, weakened and broken by the development of hollows or tafoni due to salt weathering. (b) Grooved side of block. (c) Mamillated ceiling of tafoni.

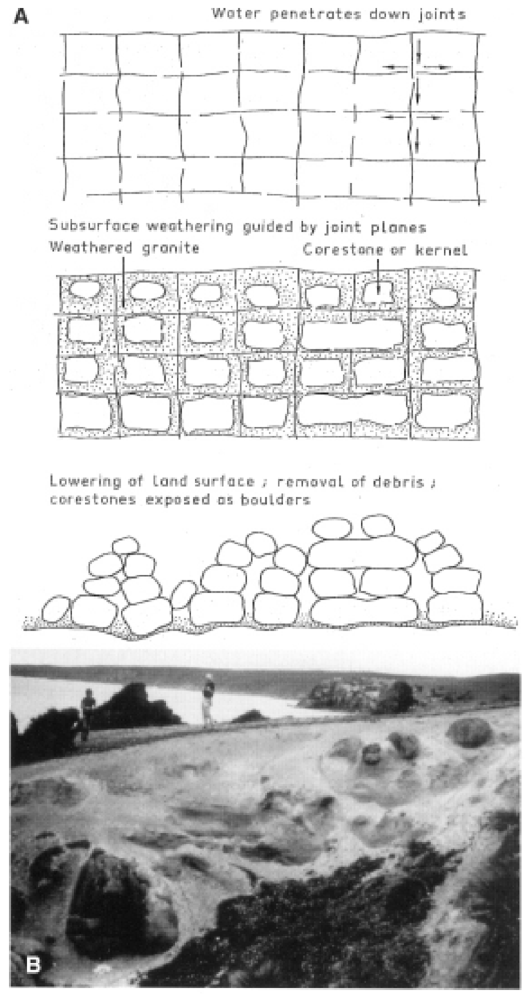


Fig. 15. (a) Diagrams showing the two-stage development of corestones and boulders. (b) Corestones set in weathered granite or grus and partly exposed in a cliff near Cape Willoughby. (W. C. Bradley).

the surface. Much of the weathered granite, or grus, has been evacuated by wash and waves, and many corestones, released from the matrix of weathered granite, are exposed as boulders accumulated in coarse shingle beaches like that on Windmill Bay (Fig. 9), where the granite cobbles and boulders display splitting as a result of powerful waves hurling the boulders against other boulders or against blocks *in situ,* fitting (Hills 1970; Fig. 16), and a prominent storm ridge. For the most part, the beaches of Kangaroo Island are calcareous, except where the local bedrock has weathered to produce shingle, as for instance at Stokes Bay where the material is quartzitic, at Admirals Arch where it is composed of gneiss and schist, and west of Cape Willoughby where granitic cobbles and boulders comprise the beach.

Human occupation

The most obvious impact of human occupation is the clearance of vegetation and concomitant soil erosion, commonly in the form of gullying, but including also sheet wash and scalding. Burning by indigenous peoples must have had similar effects. Furrows delineating 'lands' or strip fields in paddocks south of Kingscote (Fig. 17) serve as reminders of the early days of farming when single-share ploughs were used to prepare the soil for cereal cultivation (Twidale *et al.* 1971; Twidale & Bourne 1978).

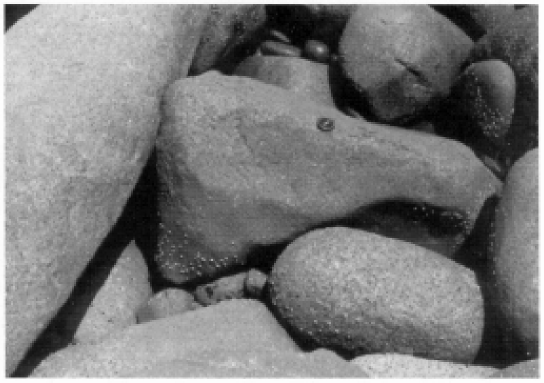
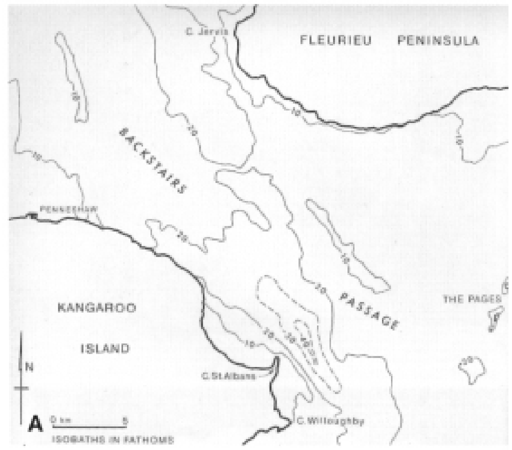


Fig. 16. Fitted and scalloped boulders in the shingle beach at Windmill Bay.

Fig. 17. 'Lands' preserved in field south of Kingscote.

THE ORIGIN OF THE ISLAND

At present Kangaroo Island is separated from the mainland by Backstairs Passage, a strait some 12 km wide and over 70 m deep. Curiously, the deepest parts of the sea floor lie not in the centre of the strait but close to the opposed headlands in Cape Jervis on the mainland and Cape St Albans (Fig. 18a). There is general agreement that Late Palaeozoic glaciers passed through the Passage and that the ice followed a pre-existing depression or valley. During Late Cainozoic glacial periods of low sea level the strait was followed by the former St Vincent River which drained much of the area between Yorke Peninsula and the Mt Lofty Ranges and which is now occupied by Gulf St Vincent (Fig. 18b). This much is clear: it is the origin of this topographic low that is puzzling. As pointed out elsewhere (Daily *et al.* 1979), the Kanmantoo strata exposed on opposite sides of the strait can be matched and appear not to have suffered major dislocation. This does not however rule out vertical faulting, and the associated possibilities of the Passage occupying a fault zone, or of it being a rift valley or graben. In this connection it is interesting that the Passage is seismically active (Sutton & White 1968; Greenhalgh *et al.* 1994), and that the lateritised surface which dominates the Island landscape tilts down toward the strait. Most significantly, the Passage is developed normal to a



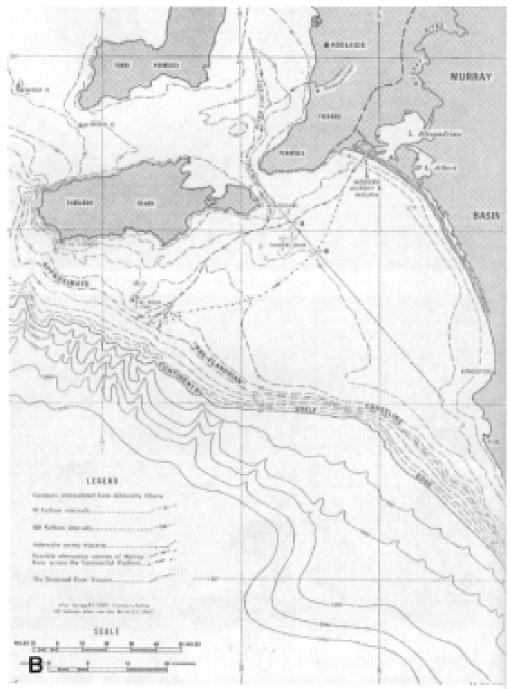


Fig. 18. (a) Bathymetric map of Backstairs Passage. (b) Th course of the former St Vincent River throug Backstairs Passage and showing also the topograph of the sea floor around Kangaroo Island. (After Firma 1969).

pronounced bend in the structural alignment of the Cambrian strata, suggesting the possibility of compression (and crushing?) in the northern sector, and tension in the southern: stress conditions, both of which are conducive to preferential weathering and erosion.

During the Quaternary pronounced global climatic changes caused, among other effects, major glacioeustatic changes in sea level with stands of the sea 100 m, or more, lower than that of the present. During glacial periods of low sea level Kangaroo Island was connected to the mainland both in Fleurieu Peninsula and Yorke Peninsula (see seafloor topography in Fig. 18b). At times of high stands of the sea the Island was isolated, as at present. Also, during the Quaternary periods of low sea level, huge coastal dunes formed, especially along the south coast. They remain important landscape features. They also effected the linking of two (or more) separate islands into the present Kangaroo Island. As Flinders observed, on climbing Prospect Hill, "Kanguroo Island is separated into two parts of very unequal size, connected by an isthmus whose breadth is about two miles." (Cooper 1953, p. 63).

The dunes form the whole of the narrow (6-7 km) isthmus which separates Eastern Cove from Pennington Bay and links the Dudley Peninsula with the remainder of the Island. They accumulated mainly under the influence of southerly or southwesterly winds, but with some contributions from the north.

CONCLUSION

Kangaroo Island has much to offer the geologist and the geomorphologist. Until comparatively recently, much of the interior of the Island was covered by dense natural scrub, making geological and geomorphological studies difficult: almost all of the significant exposures occur in the precipitous coastal zones. A considerable body of knowledge is summarised here but it must be remembered that this is by way of a preface or introduction: the substantial chapters are still to be written.

3: Soils

by K.H. NORTHCOTE

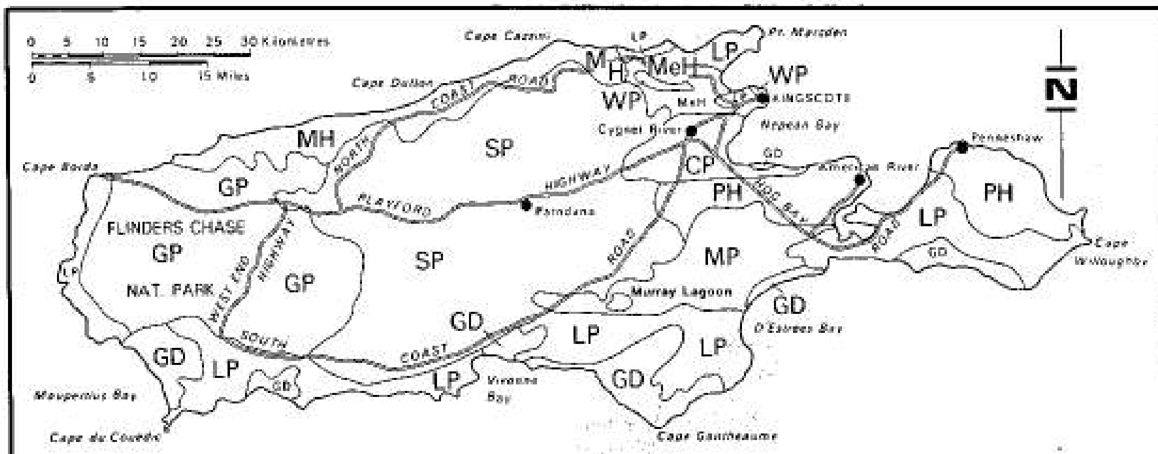
INTRODUCTION

The small town of Parndana, situated in the central eastern portion of the lateritic plateau or high plain that covers the greater part of Kangaroo Island, is the first of only two new country towns created in South Australia since 1945, the second being Roxby Downs. This distinction is due in no small measure to the difficulties attending the development of the ironstone gravelly soils common to the plateau. All the other island towns and villages such as Kingscote, were sited near the coasts where the soils were easier to develop; even so, the productive areas were recognized to be 'limited and detached' (Tate 1883).

Of all the islands in the southern Australian system, Kangaroo Island with an area of about 3890 km^2, is second in size only to Tasmania. The climate is of a Mediterranean type with a generally reliable winter rainfall and a growing season favourable for agriculture. However, difficult soils have held back its development even from the very early days of settlement (Tate 1883). Indeed, developments over the years have been largely consequent upon advances in soil science. This pattern is likely to be continued.

THE SOIL-LANDSCAPES OF THE ISLAND

Ten broad soil-landscapes, Fig. 1, based on the Atlas of Australian Soils (Northcote 1960), occur in Kangaroo Island. Two of these, the Seddon and Gosse plateau units, dominate the island covering about three-quarters of its total area. Together, they form a low-level plateau underlain by sedimentary rocks of Cambrian and Precambrian age that have been deeply weathered, with the development of laterites and kaolinitic clays. Related deeply-weathered profiles (DWP) are found also in the adjoining Adelaide region (Northcote 1976). This low plateau rises to between 100 and 300 m, above present sealevel,



UNIT		LANDSCAPE	DOMINANT SOILS
SP	Seddon plateau	undulating upland with valley sideslopes,swamps,lakes	duplex soils containing ironstone gravels: Dy3.61,Dy5.84
GP	Gosse plateau	hilly upland with valley sideslopes,swamps,lakes	acid duplex soils: Dy5.41,Dy3.41 plus soils of unit SP
MH	McDonnell hills	steep hilly upland	shallow grey-brown sandy soils: Uc6.11 with some duplex soils
LP	Lincoln plains	rough, broken calcarenite lowlands	pockets of shallow red - brown sandy soils: Uc6.13
GD	Gantheaume dunes	hilly uplands	deep calcareous sands: Uc1.11
WP	Wisanger plateau	upland plains	cracking clays: Ug5.2, .3 and alkaline duplex soils: Dy3.43
MeH	Menzies hills	undulating uplands and plains	alkaline duplex soils: Dy5.43, Dy5.83, Dy3.43, and cracking clays Ug5.2
PH	Penneshaw hills and ridges	hilly uplands with lateritic remnants	alkaline duplex soils: Dy5.43, Dy3.43, and acid duplex soils: Dy5.61, Dy3.61
CP	Cygnet plains	subcoastal, riverine lowlands	alkaline duplex soils: Dy5.43
MP	Macgillivray plains	subcoastal lowlands with swamps, lagoons, lunettes	alkaline duplex soils: Dy5.43 and leached sands: Uc2.2

Fig. 1. Soil-landscapes of Kangaroo Island.

but is tilted from north to south, so that the plateau is now highest in the northwest (307 m near Snug Cove) and in general slopes down to the east and south. This has resulted in a more dissected and hilly landscape with generally sandier surface soils in the Gosse unit of the western plateau as compared with the Seddon unit. Small areas of a fossil soil, known as Eleanor Sand (North cote 1946), occupy the least truncated and dissected portions of the plateau. These soils (Dy5.84 on The Factual Key of Northcote 1971) are notable for the presence of nodular laterite about 30-40 cm thick between the sands of the surface soil and the clays of the subsoil. The fossil Eleanor Sand has provided the parent materials for many of the other plateau soils by processes of truncation, dissection and transport (Northcote & Tucker 1948; Stephens 1946).

Such derived soils include the most widespread of the soils of the plateau, namely, the yellow-brown coloured Seddon series (Dy3.6I). This soil series was derived from a breakup of the laterite into pisolitic, ironstone gravels and their subsequent admixture with the sands of the former Eleanor A horizons, probably involving some slope transport, but leaving the clays of the Eleanor B horizons essentially intact to become the clay B horizons of this 'newer' soil, the Seddon series. The ironstone gravels range up to 75% of the content of Seddon surface soils. Their surface soil textures range from dominantly sandy loams to loamy sands in the Seddon unit, but become dominantly sands in the Gosse unit.

On the valley sideslopes and valley bottoms of the Gosse unit, surface soils are more commonly sands, whereas they are more often sandy barns in the Seddon unit. Bleached sands (Uc2.2 and Uc2.3) often present in valleys cover larger areas in the Gosse unit. These bleached sands (Uc2.2 and .3) are correctly named as 'Podzols' in Great Soil Group terminology (Table 1). They have a bleached subsurface and an underlying (illuvial) horizon with an accumulation of coloured substances, e.g. iron oxides and humus. These are the hallmarks indicating that the process of podzolization has taken place (Peterson 1976). Now, in the Seddon soil series, Dy3.61, none of these features occurs and I agree with Peterson that soils like the Seddon should not be classified as 'podzolic' let alone as 'podzol', which can happen if the Great Soil Group system is used (Table 1). That is, Dy3.61 soils like the Seddon, which have subsoils inherited *in situ* from a pre-existing soil, the surface soils derived by truncation, mixing and slope transport from a pre-existing soil, have not been formed by the process of podzolization. The properties of these soils, as their factual key notation shows, are quite distinctive to those of the bleached sands or true podzols.

The new Playford Highway is located along the drainage divide of the plateau between the north and south-flowing streams, respectively. Small lakes and swamps are found commonly, but solely in this vicinity. Some of the lakes contain fresh water, e.g. Kangaroo Lagoon, but all probably have high salt-water tables below the lake floor. Both lakes and swamps are usually floored with clays, below which there are sands which pass into highly weathered Cambrian rocks at depths exceeding one metre. Although lateritic materials, including block laterite are common on the encircling country, none is present in the lake or swamp floors, suggesting the possibility of a free water-surface there during the period of laterite formation. On the other hand Bourman (1989) reported the sporadic occurrence of vesicular ferricrete or bog iron ore on the Kangaroo Island summit surface, which was interpreted as indicating the presence of former freshwater swamps into which iron oxides were transported in solution to replace the organic matter in the swamp. Such ferricretes have high total iron contents (60% and greater) and an iron oxide mineralogy dominated by goethite, which displays very low aluminium substitution.

Along the northern margin of the uplifted and tilted plateau, and between it and the north coast of the island, is the steep hilly upland of the McDonnell hills unit. Mt McDonnell itself rises to nearly 300 m. Dissection of this unit generally removed the lateritic materials. Soils formed on the exposed sandstones, schists and other rocks of Cambrian to Precambrian age on the steep valley side-slopes. Many of the soils are shallow (Uc6.11), but may contain some transported ironstone gravels. Rock outcrops are common and associated soils include mainly acid duplex soils (such as Dy3.41) but some ironstone gravelly soils (Dy3.61) may occur too. The soils of the valley bottoms have not been recorded.

The southern margins of the plateau gently give way to the Linois plains. These rough, broken, lowlands consist of calcrete-capped calcarenite (the aeolianite of Crocker 1946) that represents the consolidated remains of old Pleistocene calcareous dunes. Not only does the Linois unit margin the plateau, but it forms the cuffed margins to the coast or coastal beaches elsewhere on the Island (Fig. 1). Small salt lakes are present in some depressions. Shallow red-brown sandy soils (Uc6.13) cover small pockets between bare calcretes, while soil materials from nearby soil landscapes have spilt over on to the calcretes locally to give a variety of mostly shallow soils over calcrete (Northcote & Tucker 1948).

Deep calcareous sands (Ucl.11) have developed on dunes of Recent calcareous materials, consisting largely of comminuted shell fragments, and designated the Gantheaume unit. Such formations are common along the southern Australian coast and the occurrences on Kangaroo Island are no exception. Sand drift is usual where the dunes are not vegetated.

In the north-eastern part of the island, the Gap Hills and the Bluff are included in the Wisanger unit.

Table 1. SOME PROPERTIES OF KANGAROO ISLAND SOILS

Soils		*Usual Occurrence*			*Morphological Properties*		
PPF[1]	*GSG*[2]	*Soil-landscape*	*Topographic situation*	*Generalized Parent Material*	*Profile*	*A horizon*	*B horizon*
Uc1.11	CS	Gantheaume e.g. Gantheaume series[3]	Dunes	Calcareous sands	U	A_1	—
Uc2.2	P	Gosse, Seddon, Macgillivray e.g. Snaky Creek series[3]	Valleys, plains	Siliceous sands	U	A_1, A_2	Colour B
Uc2.3	P	Gosse, Seddon, Macgillivray e.g. Type 17[3]	Valleys, plains	Siliceous sands	U	A_1, A_2	Cemented colour B (coffee rock)
Uc6.11	L	McDonnell	Hill-slopes	Siliceous rocks	U	A_1, pedal	—
Uc6.13	T	Linois	Plains	Calcrete	U	A_1, pedal	—
Um6.24	T	Macgillivray	Lunettes	Aeolian deposits	U	A_1, pedal	—
Ug5.2 Ug5.3	GB	Wisanger, Menzies	Plains	Clays from basalt weathering	U	Grey and Brown deep, cracking clays	
Dr2.23	RB	Macgillivray	Lunettes	Aeolian deposits	D	Hardsetting	Red pedal clays
Dy3.41	S	Gosse, Seddon, Penneshaw, McDonnell	Slopes of hills and ridges	Coarser-grained quartz-rich	D	Hardsetting	Mottled yellow, pedal clays
Dy3.43	SS	Menzies, Macgillivray Penneshaw	Plains and slopes	as above	D	Hardsetting	as above but calcareous at depth
Dy3.61	LP, YP	Seddon, Gosse, Penneshaw, e.g. Seddon series[3]	Undulating ridges and their slopes	Deep weathering profile (DWP)	D	Hardsetting	Mottled yellow clays
Dy5.41	S	Gosse, Seddon	Slopes of ridges and hills	Coarser-grained quartz-rich + DWP	D	Sandy	Mottled yellow clays
Dy5.43 Dy5.83	SS	Cygnet, Menzies Macgillivray Penneshaw	Plains and slopes	Coarser-grained quartz-rich	D	Sandy	Mottled yellow clays pedal = .43 non-pedal = .83
Dy5.84	LP	Gosse, Seddon e.g. Eleanor series[3]	Ridge crests	Deep weathering profile (DWP)	D	Sandy	Laterite →Mottled yellow clays

Notes: 1. Principal profile forms of the Factual Key (Northcote 1971; Northcote *et al.* 1975).
2. Nearest equivalent Great Soil Group (Stace *et al.* 1968): CS = Calcareous Sands; GB = Grey, Brown and Red Clays; L = Lithosols; LP = Lateritic Podzolic Soils; P = Podzols; RB = Red-brown Earths; S = Soloths; SS= Solodized Solonetz and Solodic Soils; T = Terra Rossa Soils; YP = Yellow Podzolic Soils.

	Physical Properties			Chemical Properties			
Below B horizon	*Moisture Regime*	*Shrink-Swell Capacity*	*Bearing Capacity*	*SRT*	*Ex.Cats.*[4]	*Sodicity*	*Deficiencies Reported*
—	Highly permeable	nil	stable after compaction	Alkaline	—	—	N, P, K, Cu, Co, Zn, B, Fe, Mn
Sands or clays	Highly permeable to seasonal waterlogging	nil	depends on material below B	Acid	low	Nil but clays may be sodic	N, P, K, Ca, Mg, Cu, Zn
various	seasonal waterlogging	nil	unstable when wet	Acid	low	Low but clays below may be sodic	N, P, K, Ca, Mg, S, Cu, Co, Mo
Country rock	Permeable	nil	stable	Acid	3-4	Nil	N, P, K, plus
Calcrete	Permeable	nil	stable	Neutral	—	Nil	Cu, Co, N, P, K
Aeolian deposits	Permeable	nil	stable	Acid-Neutral	—	Nil	Cu, Co, N, P, K
Clays	Low Permeability	Large	High[5]	Alkaline	>20	Sodic	P, N, Zn, Mo, S, Mn
Aeolian deposits	Permeable	Moderate in B	Moderate to high[5]	Alkaline	15-30	Nil	N, P, Zn
Sandstones quartzites, schists (Cambrian)	Seasonal waterlogging	Moderate in B	High	Acid	5-20	Weakly sodic	N, P, K, Ca, Mo, Cu, Zn
Permian and Pleistocene to Recent sediments	as above	as above	as above	Alkaline	15-30	Sodic to strongly sodic	N, P, Mo, S, Cu, Zn
Mottled and pallid clays over weathering Cambrian rocks	Severe seasonal waterlogging	small in B	as above	Acid	5-10	Nil to weakly sodic	P, N, K, Mo, Cu, Zn, Mn
Weathering sandstones etc. plus DWP	Seasonal waterlogging	small in B	as above	Acid	5-15	Weakly sodic	N, P, K, Ca, Mo, Cu, Zn
Permian and Pleistocene to Recent sediments	Seasonal waterlogging	small to moderate in B	as above	Alkaline	10-30	Strongly sodic	N, P, K, Ca, Mo, Cu, Zn
Mottled and pallid clays over weathering Cambrian rocks	Seasonal waterlogging	small in clays	as above	Acid	5-6	Nil	N, P, K, Cu, Mo, Zn, Ca

3. Named soil series from Northcote & Tucker (1948).
4. Total metal cations (Ca + Mg + K + Na) in m.e. per 100 g of soil for upper clay B.
5. Calcareous layers where soft and powdery have low bearing capacity.

This small upstanding array of steep-sided plateau remnants is of immense interest because it is capped by basalt, dated as being of Middle Jurassic age (Daily *et al.* 1974). The steeper, upper slopes of these plateau remnants are composed of bare, prismatic basalts and their weathering products. Below, calcretes are often found on their middle to lower slopes, on what appear to be benches. These could mark the remains of former land surfaces but, as yet they have not been studied. On the flat, plain-like tops of the plateau remnants, grey and brown cracking clays (Ug5.2, Ug5.3) often with alkaline duplex soils (Dy3.43) have developed from the weathering of the basalts. These cracking clay soils that most often have a self-mulching characteristic are similar to soils developed from the clays produced by weathering of basalts of differing geologic ages elsewhere in southern Australia.

The basalt sheet that forms the Wisanger plateau unit rests on deeply weathered and kaolinized glacigene sediments of Permian age which, in turn, have probably received a more recent cover of alluvial, colluvial or even aeolian deposition as evidenced by the presence of calcium carbonate in many subsoils. Pillans & Bourman (2001) identified the BrunheslMatuyama polarity transition (780 ka) in ferruginous Pleistocene sediments at Redbanks on the north coast of Kangaroo Island as well as several mainland localities. This iron oxide dominated weathering regime is overlain by a carbonate-dominated weathering regime, attributed to a major arid shift in regional climates, estimated to have occurred at about 500-600 ka, and may have played an important role in the development of duplex (texture contrast) soils. The undulating to hilly area of the Wisanger Plateau in which alkaline duplex soils (Dy5.43, Dy3.43) are common, together with smaller areas of grey cracking clays (Ug5.2), has been designated the Menzies hills unit. A small area of coastal sands and swamps bordering the Bay of Shoals is included for ease of mapping at the present scale.

The remaining upland soil-landscape is that of the Penneshaw hills and ridges which is a worn-down eastwards extension of the Gosse-Seddon plateau. Here, the soils have formed from remnants of the old lateritic materials and exhumed rocks of the underlying Cambrian and Precambrian for-mations. The soil pattern is varied and complex. While many of the soils contain ironstone gravels and boulders, it seems that most are alkaline duplex soils (Dy5.43, Dy3.43) but both neutral (such as Dy5.42, Dy3.42) and acid forms (such as Dy3.61) occur, as do smaller areas of grey cracking clays (Ug5.2) and bleached sands (Uc2.2).

Both the remaining soil-landscapes, the Cygnet and the Macgillivray plains, are subcoastal formations largely derived from Quaternary alluvium, possibly with some contribution from Tertiary marine sediments. Transported ironstone gravels are found in some of the soils. Alkaline duplex soils (Dy5.43, Dy3.43) are most common. In the Cygnet Plain which is largely confined to the lower reaches of the Cygnet River, small areas of a wide range of other soils are likely also. The Macgillivray Plains are characterized by numerous swamps and lagoons many of which are saline, and some of which have associated lunettes. Bleached sands (Uc2.2) occur on these plains, and there are shallow red friable barns (Um6.24) and alkaline red duplex soils (Dr2.23) on lunettes. Small areas of other soils are likely.

SOME PROPERTIES OF KANGAROO ISLAND SOILS

The more usual occurrence of the chief island soils together with some of their morphological, physical and chemical properties are listed in Table 1. Generally, these and related properties result from the natural history of soil formation, and provide an insight into soil management and use, including the way soils may react to various future human activities.

The foregoing brief descriptions of soil landscapes, and the statement of soil properties in Table 1, lead to the conclusion that there are four or five particular soil-environments on the island worthy of special comment and discussion. They are the alkaline, sodic duplex' soils (Dy5.43, Dy3.43), the cracking clays (UgS.2, .3), the shallow red-brown sandy soils on calcrete, and the acid duplex soils (Dy3.61, Dy5.41, Dy3.41). The shallow soils (Uc6.11) of the northern coastal hills may be a fifth, but is much less extensive than are the other four.

Alkaline, sodic duplex soils (Dy5.43, Dy3.43)

It was in the eastern, mostly subcoastal soil landscapes now designated as Menzies, Cygnet, Penneshaw and Macgillivray that early agricultural settlement began on Kangaroo Island. For example, the locality known as Cygnet River figured prominently in the production of wheat and barley in the early days of South Australia (Tate 1883). The natural vegetation of mal lee (such as *Eucalyptus cneorifolia),* broombush *(Melaleuca uncinata)* and attendant sclerophyllous shrubs, was not as dense as were the low forests of stringybark *(E. baxteri* and *E. obliqua)* further west. The soils were considered to be more responsive too, as early wheat and barley yields of 30 and 60 bushels, respectively, showed. However, such yields could not be sustained without adequate fertilizers. Even today, with fertilizers, growers are still virtually using only the top 30 em or less of soil! These sandy (Dy5.43) and hardsetting (Dy3.43) duplex soils mostly have greyish sands to sandy

1 Duplex soils have a marked change in texture between their A and B horizons - sand, sandy loam or loam A horizons (surface soils) overlying clay B horizons (subsoils).

loams overlying white (bleached) subsurface sands to sandy loams, which in turn overly the solid, coarsely-structured clay subsoils. These contain calcium carbonates in their deeper layers. Soil reaction trends are alkaline with surface pH of 6-7 and subsoils of pH 8.5-9.5. Because these soils have developed in subcoastal regions largely from. sediments derived from marine deposition, or from saline-rich alluvia derived from the plateau to the west, all subsoils contain sodium on their clay particles. That is, they have sodic subsoil clays that disperse when wet, preventing the downwards movement of water by sealing up natural cracks. Hence, the bleached subsurface layer often contains free-flowing water during late winter and spring. This condition not only means a loss of water laterally out of the soil system - water that should have been stored in subsoils for summer use by plants-but also decreases the vigour of plant roots and allows pathogens to invade them. The result is decreased production. A stalemate has been reached since the chemical fertilizers that have improved the low nutrient levels of these soils will not correct their physical shortcomings. Improvement of their low subsoil permeability depends on deep-ripping of the clay sub-soils with the incorporation of gypsum as an amendment into the ripped furrow to keep the soil open and friable. A lift in agricultural production in these areas of earliest settlement depends on economic means being found to improve the physical character of these sodic duplex soils.

Cracking Clays (Ug5.2, Ug5.3)

Cracking clays are present chiefly in the Wisanger and Menzies soil-landscapes. In terms of the area they occupy, they are relatively unimportant soils, but they are outstandingly different to any other soils on the Island and deserve mention for this reason. In the physical sense their difference is epitomised by the great capacity of their clay minerals to shrink and swell during drying and wetting cycles, so that when dry, large cracks develop in the soil. They close up again on wetting. In terms of plant nutrients they are probably better supplied than any other island soils. These, and their other soil conditions and properties, are directly related to the derivation of their parent clays from the weathering of basic igneous rocks, namely, basalts. This is a very good example of the importance of parent material, and especially of its mineralogical composition, in determining the character of the soil. The importance of parent material as a controlling factor in soil distribution in southeastern Australia (North cote 1976) is once again emphasized by this occurrence of cracking clay soils.

Shallow red-brown sandy soils (Uc6.13)

The Linois soil-landscape includes mostly shallow sandy soils. Some have formed from sandy materials deposited over the calcrete, others, such as Uc6.13, may have formed largely from weathering of the calcrete, or be part of the weathering process that produced the calcreted surface on the underlying calcarenites. In any case the Uc6.13 soils are characteristic for the area, and again underline the importance of parent material. Limestones, here specifically calcarenite, do provide a special kind of parent material. Small areas of natural grasslands of *Danthonia* sp. and *Stipa* sp. found within the more general mallee *(E. diversifolia-E. rugosa)* vegetation of the Linois soil landscape, were used as natural pasturage in the earlier part of this century. Included were parts of the southern portion of the Macgillivray soil landscape, as near Murray Lagoon, and the more hospitable edges of the Gantheaume soil landscape. Unfortunately, stock did not prosper due to what became known as coast disease which subsequent research showed to be a dual deficiency of copper and cobalt (Lines 1935; Marston *et al. 1938).*

Acid duplex soils (Dy3.61, Dy5.41, Dy3.41)

By the late 1930s to early 1940s, some agricultural development had taken place in most of the soil landscapes of Kangaroo Island. However, there were two notable exceptions, namely, Gosse and Seddon. Not only were their acid duplex soils, and especially the ironstone gravelly kind, difficult, but their low, shrubby, often dense, stringy-bark forests *(E. baxteri, E. cosmophylla, E. remota, E. obliqua)* were inhospitable and clearing was a problem. It took the combined, co-operative efforts of officers and research scientists from the South Australian Department of Lands, the Waite Agricultural Research Institute of the University of Adelaide, the CSIRO Division of Soils and the then South Australian Department of Agriculture to create productive pasture suitable for grazing stock, where no sheep or cattle had been able to survive previously (Northcote & Tucker 1948). These and subsequent researches established that good subterranean clover pastures could be grown on the Seddon series of ironstone gravelly soils (Dy3.61) providing the total dressing of superphosphate is adequate, and the micronutrients copper and molybdenum are included in the fertilizer dressing (Carter 1958a). Under certain conditions responses are obtained also to zinc and manganese. Furthermore, when the soil has been developed to pasture for a time, more than 80% of residual phosphate is tied up in an organic form so that pasture renovation involving cultivations becomes important (Carter 1958a, 1958b)

Yet another feature of these soils is their winter-spring waterlogging which is related to their relatively impermeable clay subsoils (Table 1). One consequence is that agronomic practice has concentrated on using varieties of subterranean clover adapted to growing in waterlogged soils. An alternative aimed at creating a more permeable subsoil does not seem to have been considered to date. From the pedological standpoint, research directed towards developing techniques to create more friable and permeable subsoils and thus lessening seasonal waterlogging, would allow a wider range of pasture, and other plants, with deeper root systems to be grown. Such a result could have an ameliorative effect on the ever increasing areas of soil salinity - a development predicted by the early soil surveys (Northcote & Tucker 1948) - by decreasing the volume of seepage waters. The volume of seepage is related directly to subsurface waterlogging. The subsurface waters perched on the clay subsoils help bring salts stored deep in the weathered profile to the surface in seepage spots, usually on slopes to stream valleys. Research is a continuing requirement in the Seddon and Gosse soil landscapes, and especially on the sandier soils of the latter which may have other problems.

CONCLUSION

The work briefly described above permitted the establishment of the new town of Parndana in 1945, more than a century after the first settlers arrived at Kingscote. This late development can be attributed directly to the nature of the soil landscape there: a soil landscape with a very long history that has not yet been fully elucidated. The deep weathering that led to the formation of the Eleanor Sand (Dy5.84) from which the Seddon series (Dy361) developed, is an ancient phenomenon going back millions of years in geological time. Many researchers have considered the deep weathering to be of mid to late Tertiary age, 2-30 million years old (Northcote 1976). However, there is evidence presented by Daily *et al.* (1974) based on the occurrence of Middle Jurassic basalts overlying kaolinized Permian clays in the Gap Hills that laterite formation on Kangaroo Island (development of Eleanor Sand) could have occurred in the late Triassic to Early Jurassic, about 200 million years ago! One original unresolved consideration was whether the kaolinization of the Permian clays could be correlated with the kaolinization of the pallid zone of the Seddon and Gosse soil· landscapes. Subsequent oxygen isotope data ranging in value between $+11.1^{0}/_{00}$ to $+14^{0}/_{00}$ on kaolinite collected from beneath the Middle Jurassic basalt contrast sharply with data derived from the summit surface clays ($+18^{0}/_{00}$ to $+20^{0}/_{00}$). The former results are compatible with Early Mesozoic weathering, but the latter is characteristic of Middle Tertiary times (Bird 1988) suggesting thai equating the sub-basaltic clays with those of the summit surface is tenuous (Bourman 1993). A great deal of value and interest is still to be obtained from further studies of the natural history of the soils of Kangaroo Island.

APPENDIX 1.

Approximate correlation of PPF (Northcote 1971) with The Australian Soil Classification (Isbell 1996) (To be read in conjunction with Table 1)

PPF	Aust Soil Classification	PPF	Aust Soil Classification
Uc1.11	Arenic Rudosols	Dr2.23	Red Chromosols
Uc2.2	Aeric Podosols	Dy3.41	Yellow Kurosols
Uc2.3	Aeric Podosols	Dy3.43	Yellow Sodosols
Uc6.11	Arenic Rudosols	Dy3.61	Yellow Kurosols
Uc6.13	Hypocalcic Calcarosols	Dy5.41	Yellow Kurosols
Um6.24	Orthic Tenosols	Dy5.43	Yellow Sodosols
Ug5.2	Grey Vertosols	Dy5.83	Yellow Sodosols
Ug5.3	Brown Vertosols	Dy5.84	Yellow Kurosols

4: Giant Submarine Canyons

by CHRIS C. VON DER BORSH

INTRODUCTION

Some of Earth's most spectacular scenery has never been seen by human eyes. It is difficult to imagine, when standing on the cliffs of southern Kangaroo Island, that some of the world's largest canyons dissect the continental slope a mere 60 km south (Sprigg 1947, 1963; von der Borch 1968; van der Borch *et al.* 1970). These huge clefts (Fig. 1), some of which are considerably larger than the Grand Canyon of the Colorado River in the U.S.A., wind their way from the outer continental shelf to oceanic depths of the order of 2500 fathoms (4600 m). It was not until the advent of the marine depth recorder, however, that the existence of these features was known. Only now are they being mapped in detail, using newly developed precision aids such as satellite navigation.

The group of canyons situated directly south of Kangaroo Island was named by Sprigg (1947) the Murray Submarine Canyons. Such continental slope canyons are common to all continents, and provide information on the origin of the continental margin, and on large-scale sea level changes that have occurred over the past 1.8 or so million years of earth history during the Pleistocene ice ages.

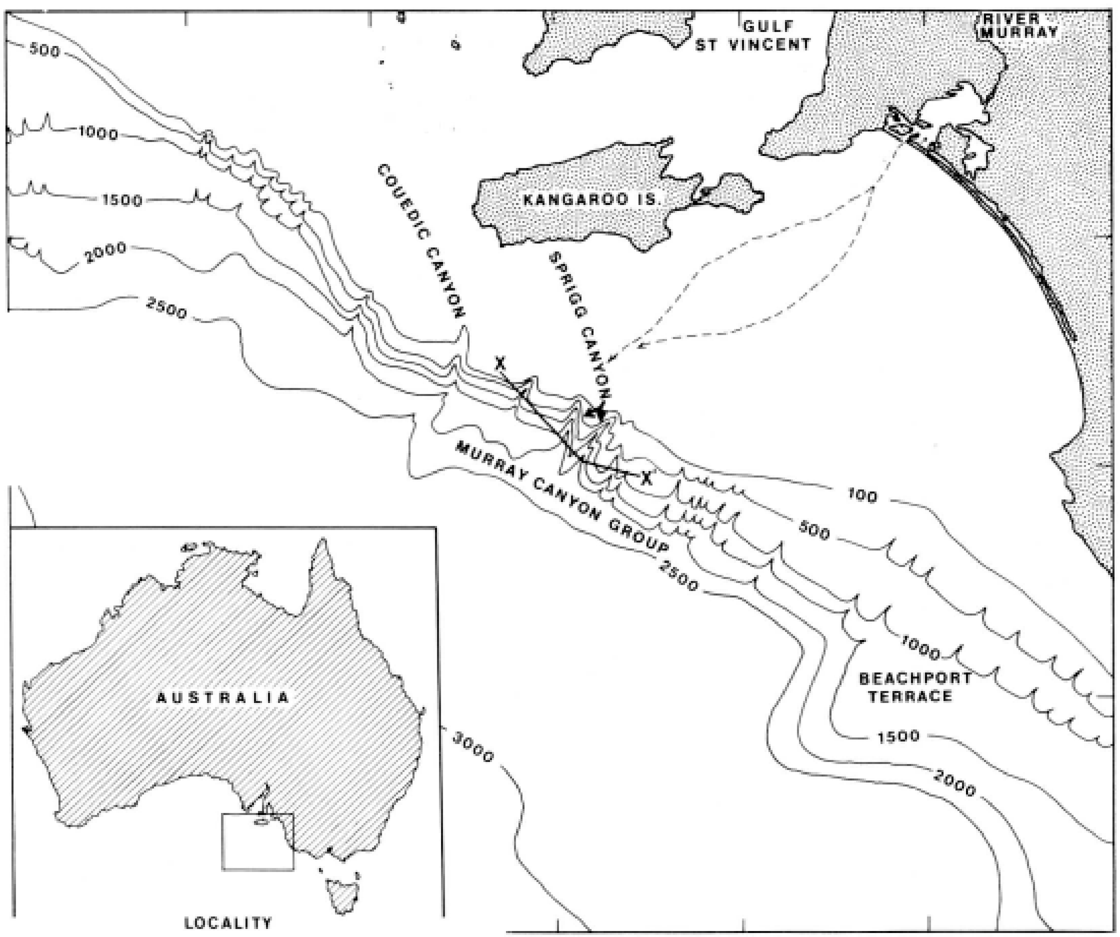


Fig. 1. Bathymetry of the ocean south of Kangaroo Island, showing continental slope marine canyons; location of echo-sounder profile XX' across Sprigg Canyon (Fig. 4) shown; possible low sea level courses of River Murray after Sprigg (1947); depth contours in fathoms.

BIRTH OF THE SOUTHERN OCEAN

Like all of earth's oceans, the Southern Ocean (the southern portions of the Indian, Atlantic and Pacific oceans), geologically speaking, is a very youthful feature. In fact 40 millions years ago that portion that lies south of Australia did not exist, and Australia was joined to Antarctica along a line now approximately defined by the continental slope. This ocean has in fact existed only for about 1 % of geological time and the well-documented sequential stages of its birth (Deighton *et al. 1976)* are shown in Fig. 2.

It is suspected that the earth's upper crust is being rafted about by massive convection cells deep in the semi-fluid mantle. New oceans, for example the Red Sea, are created where upwelling convection cells cause rifting and rupturing of pre-existing continental crust. Ocean basins then widen by the accretion on their floors of cooling basalt (oceanic crust) along linear mid-ocean ridges. Older ocean basins are continually being destroyed by the oceanic crust being 'subducted' or forced back into the mantle around the earthquake and volcanic belts of the globe, for example beneath the Indonesian islands of Java and Sumatra. When two buoyant continental masses ultimately collide (incidentally producing a mountain range and destroying an ocean), the sub-crustal convection cells are thought to switch locality to produce a new rift. This is the accepted reason for the splitting of Australia from Antarctica 100 million years ago. Remarkably enough, it is thought that the collision of what is now India with Eurasia, which formed the Himalayas,

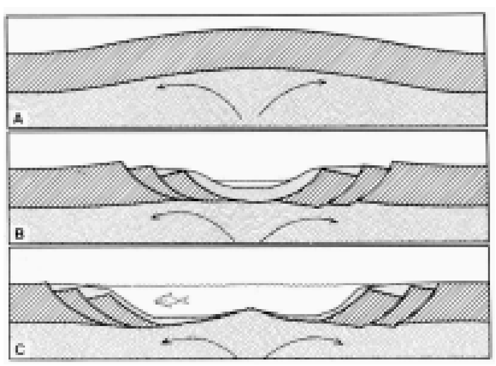


Fig. 2. Stages of rifting of southern Australia and Antarctica. After von der Borch *et al. (1970).*

A. Initial thermal dome, developed in continental crust by sub-crustal convection cell prior to 100 million years ago.
B. Initial rifting between ancestral Australia and Antarctica around 100 million years ago, caused by gravity collapse of domed crust (Red Sea stage); submarine canyon formation probably initiated at this stage.
C. Upwelling along mid-ocean ridge of mantle to form oceanic crust, causing progressive separation of Australia and Antarctica: submarine canyons increased in size during this stage, particularly during low sea level stands of the Pleistocene ice ages.

modified the global stress field enough to trigger the rift between Australia and Antarctica. This emphasises how geological events around the globe are often inter-related.

It is apparent from Fig. 2 that the two continents were tending to split apart as far back as the Mesozoic Era, around 100 or more million years ago. During this phase, thermal expansion followed by tensional forces resulting from pulling apart of the continental crust caused huge fractured fault blocks of crust to elevate and then subside along a linear down-faulted zone similar to contemporary Africa's Great Rift Valley. As rifting proceeded a stage was reached analogous to the present young basin of the Red Sea, and a narrow, deep ocean basin formed parallel to the shorelines of Australia and Antarctica.

Ultimately, in the Eocene (40 million years ago), the birth pains of the Southern Ocean ceased, basaltic magma welled up along a median fracture in the deepest portion of the rift, and accretion of oceanic crust began with consequent widening of the ocean (Fig. 2). The boundary between the ruptured outer portion of the Australian continental crust and first-accreted oceanic crust now exists 80 km south of Kangaroo Island, beneath the lower continental slope of southern Australia approximately parallel to the 2000 fathom isobath (Fig. 1).

EARLY FORMATION OF THE SUBMARINE CANYONS

In all probability, as rifting proceeded, massive blocks of continental crust first rose and then subsided up to 5 km to oceanic depths. As they subsided, these blocks carried with them the scars which resulted from their exposure to the elements, in particular riverine valleys, which in turn were almost certainly controlled by major structural features such as basement faults. It is likely that this process generated early stages of many of the submarine canyons south of Kangaroo Island, particularly the notably large examples in the vicinity of and including Sprigg Canyon, the largest canyon of the Murray Submarine Canyon group and so named after its discoverer (Fig. 1). Unlike smaller ones to the east and west, these large gashes occur in a region of shallow basement where the primeval continental margin has not been deeply buried by subsequent sediments (von der Borch 1968; von der Borch *et al.* 1970). As such they may indeed represent somewhat modified former sub-aerial canyons which subsided to their present depths as the continental margin readjusted to the new stress regime after rifting.

SUBSEQUENT HISTORY OF THE CANYONS

Some of the canyons south of Kangaroo Island may well be modified river valleys developed on raised crustal blocks prior to subsidence. As such

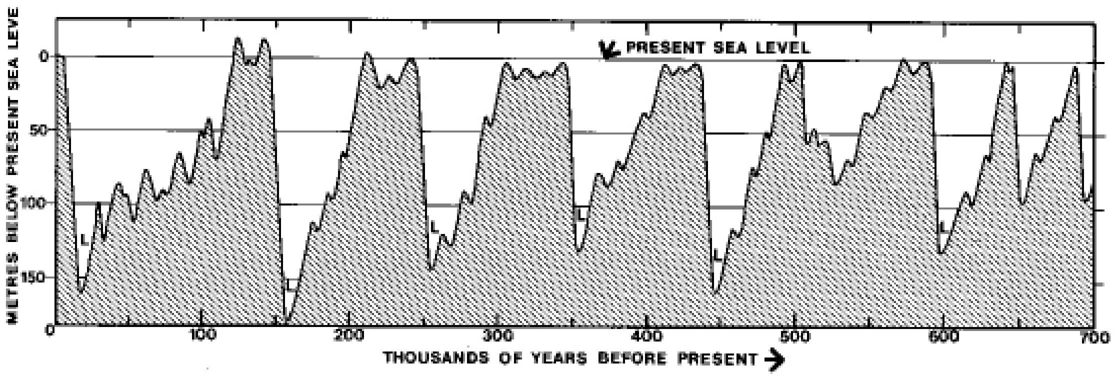


Fig. 3. Approximate sea level variations of the past 700 000 years modified from Bloom *et al.* (1974) and deep sea core isotope data (Shackleton *et al.* 1976); note the several major low sea level stands (L) at approximate 100 000 year intervals, when sea level was 100-150 m (55-82 fathoms) below its present level.

they may be older than the Southern Ocean itself. However, later events have significantly modified canyon morphology. The canyons may even have been subsequently enlarged. The most significant process which can cause an increase in canyon size is the sediment input from rivers which flow directly into emerged canyon heads during times of glacially lowered sea level. Turbidity currents (Daly 1936; Kuenen 1938, 1950; Heezen 1956) and slow sediment creep (Shepard & Dill 1966) are processes which can erode and deepen canyons.

Figure 3 shows how sea level fluctuated during the current ice age. Poorly understood mechanisms, possibly related in part to continental drift, have caused the present ice age, which we see mainly as the massive ice sheets which cover Antarctica and Greenland. Geologically speaking this is an unusual situation, though it has existed for the past 10 or 20 million years. For reasons that are poorly understood, the last 1.8 million years of this ice age have witnessed large rhythmic fluctuations of climate. **It** has changed repeatedly from the present interglacial (although still ice age) situation, to one of massive glaciation of North America and Europe, with extremes recurring with a period of about 100 000 years. These changes are possibly related to rhythmic variations in earth's orbital parameters.

The last glacial period occurred around 18 000 years ago. During this and other glacial episodes, vast volumes of water from the reservoir of the oceans became locked into the ice sheets and accordingly sea level fell by as much as 150-200 m below its present level. As ice sheets receded during intervening warmer phases, sea level returned to about its present level, causing amongst other things the development of great shoreline sand dune deposits. Today these form the cliffs of Kangaroo Island's south and west coast and the parallel dune ranges of the lower southeast of South Australia.

It is, however, the low sea level phases of these oscillations (Fig. 3) which are of particular relevance to submarine canyon processes. As can be seen from Fig. 1, the shoreline would then

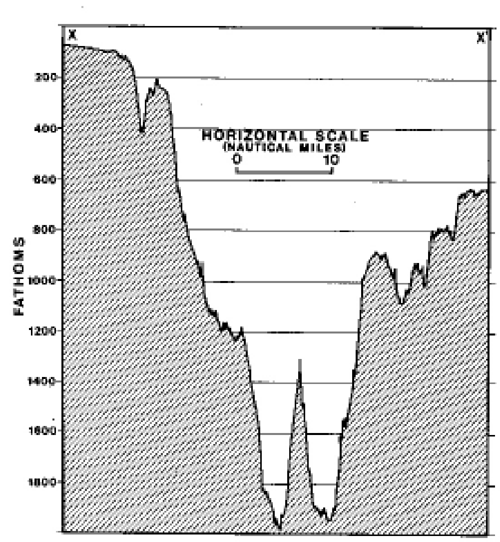


Fig. 4. Precision depth recorder profile of Sprigg Canyon, after von der Borch *et al.* 1970; note the double axis and sharp interfluve of the main canyon, possibly due to the existence of two coalescing tributaries; note also the flat floors of both the main canyons and higher level tributary canyons, due to sand deposits which are moving down-canyon.

have been close to the break-in-slope and associated canyon heads at the outer edge of the continental shelf. The last time this occurred was in fact only 18 000 years ago. The River Murray would then have followed a course across the flat, rather featureless continental shelf which would have been a subaereal coastal plain. The likely course of the River Murray across this exposed shelf, as suggested by Sprigg (1947) is indicated on Fig. 1. Here it is shown to have discharged into Sprigg Canyon which seems the one most likely related to this river. It has been proven elsewhere that river and beach sediment, particularly abrasive bed-load material of sand grain size, has the capability of deepening submarine canyons, and in some cases even initiating them by a glacial-like scouring action and possibly by turbidity current erosion (Shepard & Dill 1966). Concurrently, margins of canyons can be built up by addition of layers of pelagic (oceanic) or terrigenous (land-derived) sediments (von der Borch 1969). These processes, acting in concert, can notably increase a canyon's vertical dimensions.

The result has been the production of perhaps the world's largest submarine canyon (Sprigg Canyon) south of Kangaroo Island. The size of this canyon can be gauged from the tracing of an echogram collected during an oceanographic cruise by the U.S. Coast and Geodetic Survey vessel 'Oceanographer' (Fig. 4). As with all such records vertical exaggeration is rather high, in this case approximately 30:1. However, slope steepness is comparable to that of major large land canyons of spectacular dimensions and the Grand Canyon of the Colorado River would nestle inside Sprigg Canyon with considerable elbow room. It is of interest to note the double valley and sharp interfluve, representing two coalescing tributaries. The narrow flat floors of the deepest portions are also remarkable and are due to sand which is possibly creeping slowly down-canyon to the abyssal fans at the base of the continental slope. Seismic reflection profiles across this canyon collected by the Bureau of Mineral Resources, Canberra, clearly show truncated horizontal sediment layers, deeper ones of which almost

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certainly represent rift valley strata laid down in the proto-Southern Ocean prior to 40 million years ago.

OCEANOGRAPHIC IMPLICATIONS

The canyons south of Kangaroo Island are virtually unexplored. They nevertheless represent what may in the future be a valuable resource. It is known elsewhere that upwelling water from deeper oceanic levels finds its way up submarine canyons into shallower shelf regions and there contributes nutrients to the food chain. Notable concentrations of sperm whales occur around large canyon heads off southwestern Australia, obviously attracted by a rich food source related to these nutrients. It is quite possible that a comparable situation exists around the Kangaroo Island canyons because dense deep-scattering layers caused by organisms have been noted around canyons heads by Sprigg (1963). Important deep-trawl fisheries may one day begin in this region, although ironically the rough seafloor terrain in the vicinity of the canyons will make conventional trawling methods difficult or even impossible. From a geological viewpoint, dredging of outcropping rock samples from canyon walls would provide a relatively low-cost (compared with offshore drilling) method for studying the composition and history of the sediment layers which, like the pages of a book, contain a record of the major geological changes that occurred during evolution of our continental margin

5: Climate

by PETER SCHWERDTFEGER

One of the first organised groups of European colonists intending to participate in the then novel colonial experiment represented by the privately planned but government-endorsed establishment of the colony of South Australia assembled near Kingscote on Kangaroo Island in 1836, to await the arrival of the appointed Surveyor-General, Colonel William Light. Their location and opinions con-sequently demanded some consideration as to the possibility of it being selected as the capital of the new settlement. Through his subsequently demonstrated cognisance of climatic factors and their relationship to essential water resources, Light quickly concluded that Kangaroo Island would be unable to support a substantive city as well as the activities, mainly agricultural, then foreseen for the infant colony (Elder 1984). However, some elements of the settlement remained on the Island while the capital, more appropriately, became established on the mainland. That step alone has contributed to an interest in comparing the c1imatologies of Adelaide and Kingscote. While more than 160 years of climate data have consistently confirmed the correctness of Light's decision, the Island is now known to have an interesting range of climatic environments, in some of which the degree of exposure to the Southern Ocean has a major influence.

Kangaroo Island is separated from the mainland by the about 12 km wide Backstairs Passage. The bulk of the island lies between the latitudes of 35°30' and 35°S. Its maximum dimensions are about 55 km from north to south and 140 km from west to east. The map which summa rises the mean annual rainfall (Fig. 1), also shows topographical features as well as the principal locations referred to in this chapter.

AIR TEMPERATURES

There are four stations on the Island which have been selected to illustrate the main factors which determine local temperature regimes. Because the maximum elevation is only about 300 m, with only 16% of the total land area being above 200 m, altitudinal variations would usually contribute less than 1 SC to local air temperature differences except for pockets of nocturnal cold air ponding in some valleys. While it would be interesting to have this assertion confirmed, in common with most other isolated topographically extreme locations in Australia, no long term temperature records are available either for the Island's highest points or

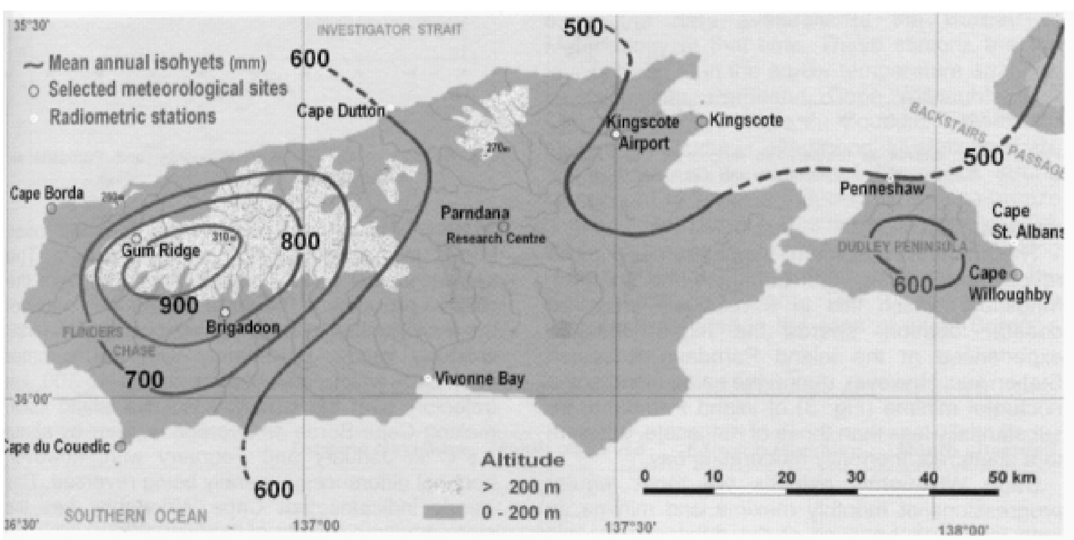


Fig. 1. Map showing contours of mean annual rainfall as well as locations of temperature, wind and irradiance observations for Kangaroo Island referred to in the text.

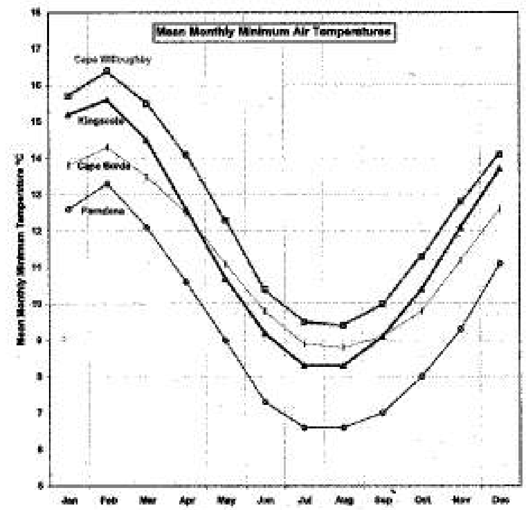


Fig. 2. Mean monthly minimum air temperatures for Cape Borda, Cape Willoughby, Parndana and Kingscote.

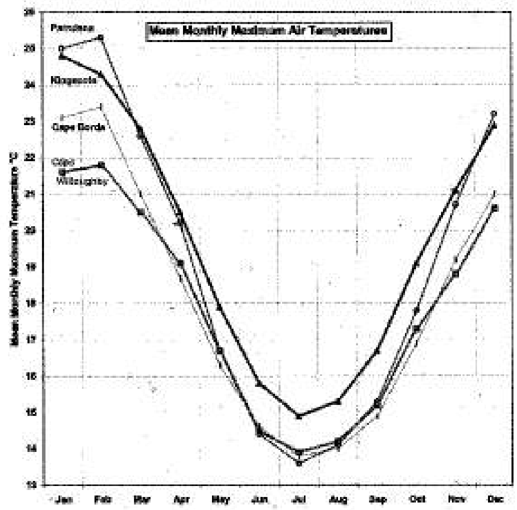


Fig. 3. Mean monthly maximum air temperatures for Cape Borda, Cape Willoughby, Parndana and Kingscote.

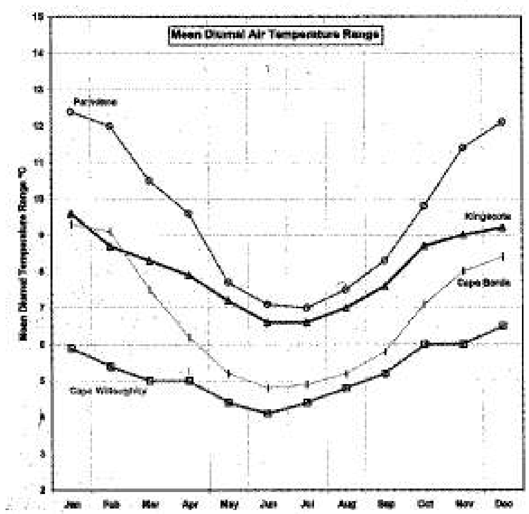


Fig. 4. Mean diurnal air temperature ranges for Cape Borda, Cape Willoughby, Parndana and Kingscote.

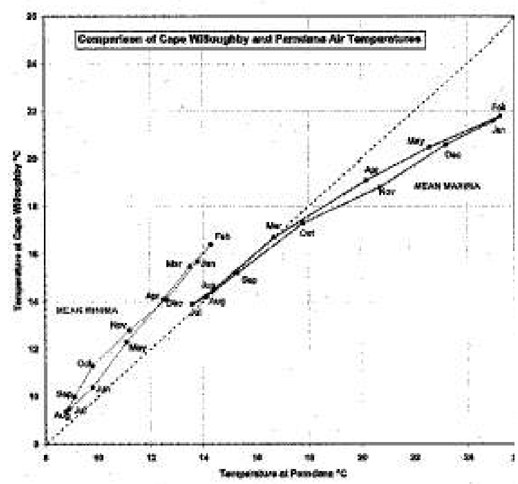


Fig. 5. Comparison of Cape Willoughby and Parndana air temperatures.

deepest valleys.

The monthly maximum temperatures (Fig. 2) reveal that during the summer and autumn, Kingscote, which lies in a relatively sheltered coastal location, shares the higher maxima experienced at the inland Parndana Research Station site. However, during the same months, the nocturnal minima (Fig. 3) of inland Parndana are substantially less than those of Kingscote, adjacent to a sheltered, thermally moderating bay.

Cape Willoughby exhibits the most regular progressions of monthly maxima and minima, in both instances because of the dominant oceanic surroundings. It might well be asked why Cape Borda does not share these thermal features in summer, while it does so in winter. The wind roses shown in the next section are helpful here. The answer almost certainly lies in small part with the relative proximity of the large heated land mass of the Eyre Peninsula, coupled with occasional north westerly winds, but mainly with the summer easterlies which are heated during a 100 km trajectory over the land mass of the Island itself, making Cape Borda on average warmer by about 1.5°C in January and February with, however, noctural differences generally being reversed. This clearly indicates that Cape Willoughby has the more maritime climate of the two.

The mean diurnal temperature range has been estimated simply by considering the differences between mean monthly maxima and minima for the various stations (Fig. 4). These data confirm that of the four locations, the inland Parndana site experiences the most continental thermal regime and the exposed coastal Cape Willoughby the most maritime. Kingscote is the most sheltered from extremes, while Cape Borda shares Cape Willoughby's characteristics in winter.

The essential differences between the mean monthly temperature regimes have been developed further between the most maritime and the most continental stations in Fig. 5. This shows that for each month of the year the minima at Cape Willoughby are higher than those experienced at Parndana, while, with the rather minor exceptions for the winter months, the reverse holds true for the maximum temperatures.

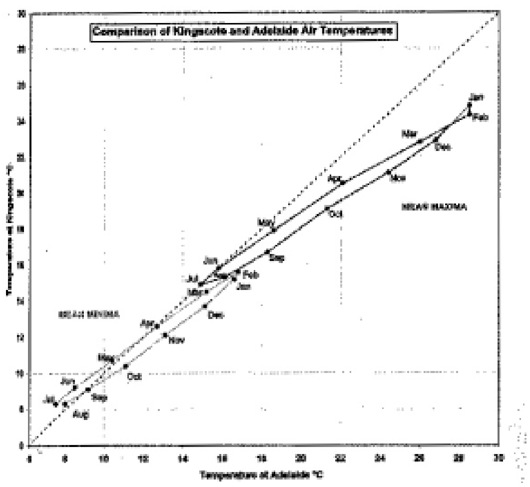


Fig. 6. Comparison of Kingscote and Adelaide air temperatures.

In view of the, in part, historically based climatic rivalry between the State's capital Adelaide and Kingscote, a similar analysis has been presented for these two locations (Fig. 6). These data support Kingscote's claim of having a more favourable "holiday" climate. In all months except June and July, Kingscote's maximum temperatures are significantly less than Adelaide's, particularly so at the height of summer, when Kingscote's maximum can be expected to be a welcome more than 4°C below that of Adelaide. In winter, however, Kingscote has the more favourable, higher, minima. The data presented so far have all related to long-term mean values. Table 1, below, summa rises extreme values for maximum and minimum air temperatures recorded at the five locations, including Adelaide for comparison, which have been discussed earlier.

The values below represent significant departures from the simple averages discussed earlier and demonstrate the importance of further investigation when the consequences of extreme temperatures come to be appreciated. In agriculture, the question of frost frequency is probably the most important.

The Parndana Research Station has an average of 7.6 days a year when grass temperatures fall below -O.9°C. Undoubtedly there are other similar, or even more extreme, but unmonitored, locations. On the other hand, apart from well-sheltered sites such as exemplified by Kingscote, frosts would not usually be anticipated near to the coast.

WINDS

Because South Australia's coastal environments are all located within a relatively narrow latitudinal band, substantially similar winter wind regimes are experienced by most coastal stations. As the sub-tropical ridge, characterised by large slowly eastward moving high atmospheric pressure systems, shown in the four seasonal charts due to Grace & Curran (1993) which comprise Fig. 7, gradually drifts southward in summer, Kangaroo Island's exposure to a more summery wind regime comes later than at stations like Ceduna on the Great Australian Bight, but a little earlier than in the South East district at coastal locations like Beachport and Port MacDonnell.

In the previous edition of this volume, Burrows (1979) presents a useful diagram which summa rises the wind directions for five stations, using the data available to the Bureau of Meteorology at that time. These stations are the four referred to in the earlier temperature analysis, i.e. Kingscote, Parndana, Cape Willoughby and Cape Borda, plus Cape du Couedic. These data show that in summer afternoons, all stations share a similar south to southeast breeze, a strong component of which is induced by the sea-breeze or ocean-wind drawn by the larger continental land-mass to the north as well as by the prevailing regime of higher atmospheric pressure over the Great Australian Bight. This phenomenon is somewhat reduced in the case of Cape Borda, a

Table 1. EXTREME VALUES OF RECORDED AIR TEMPERATURES IN °C, FOR ADELAIDE AND FOUR STATIONS ON KANGAROO ISLAND

Station	Extreme Maximum	Month observed	Extreme Minimum	Month observed
Adelaide	46.1	January	-0.4	June
Kingscote	41.0	February	-1.1	June
Parndana (Research	43.0	January	-2.5	July
Cape Borda	39.0	January	2.2	July
Cape Willoughby	41.5	January	3.3	September

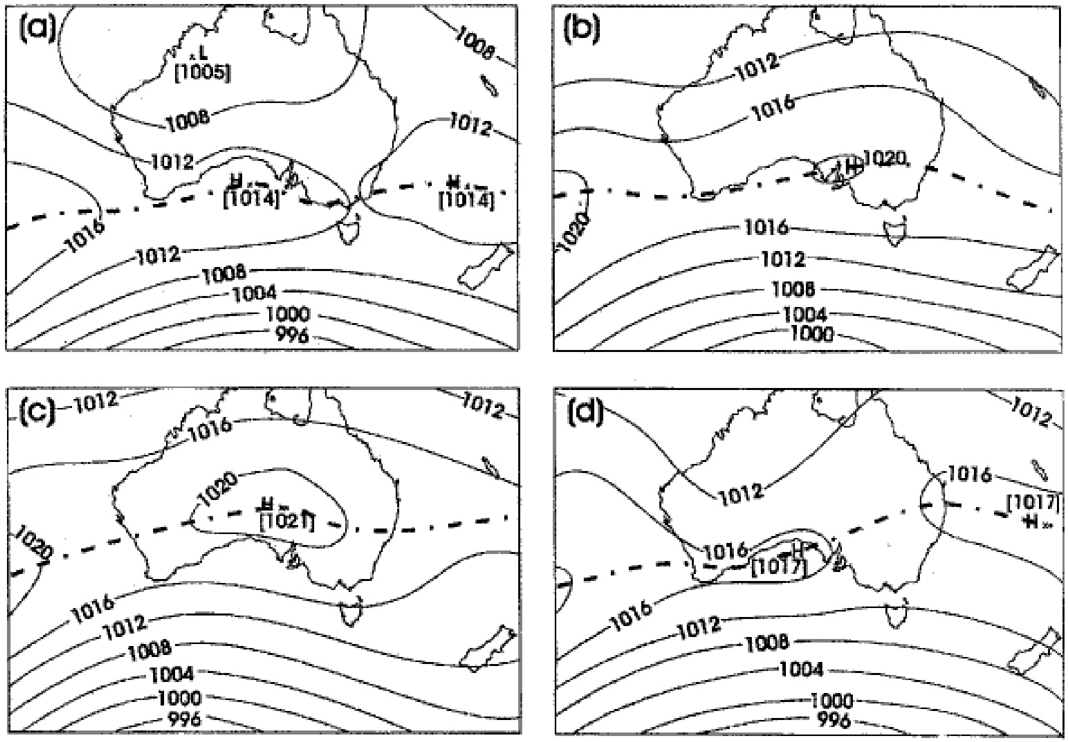


Fig. 7. Climatological mean sea level atmospheric pressure charts, showing the mean position of the sub-tropical ridge in the mid-season months of January, April, July and October.

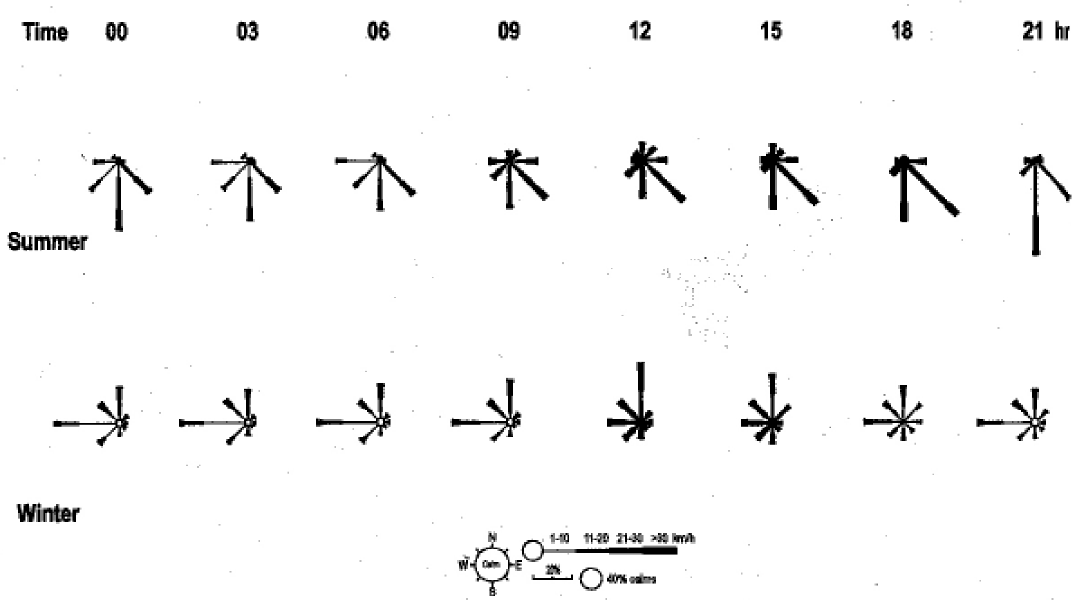


Fig. 8. Wind roses for summer and winter at three-hourly intervals for Kingscote Airport (Bureau of Meteorology).

fact which is almost certainly ascribable to the mildly elevated island topography in that direction.

In winter, wind directions are also rather similar for all parts of the Island, with again, the minor exception of Cape Borda. In this season, the dominant winds are influenced by the tendency for low pressure systems over the Bight, thereby favouring a northwest surface air-flow.

Bureau of Meteorology records of 9 a.m. and 3 p.m. wind speeds at the five stations listed by Burrows (1979) as might be expected, show the three more exposed coastal locations at the three 'Capes" to be windier in all seasons, with Cape Willoughby being the windiest of these in summer, when on 5% of all occasions, the wind speed exceeds 50 km h^{-1}. In winter, all three "Capes" report such speeds for 8% of the time.

Following the installation of an A.W.S. (automatic weather station) at Kingscote Airport excellent wind data have become available for this site. Fig. 8 shows mean wind roses at three hourly intervals for both summer and winter with not only directions, but a resolution into four ranges of wind velocity as well as calms. It is readily seen that in both summer and winter, the strongest winds are reached during the warmest daylight hours. The dominating effect of the continent to the north drawing a southerly wind as part of a large scale ocean wind system is evident. In winter, the most energetic direction is reversed to northerly. During this season, however, the Island is more exposed to westerlies.

It can be expected that locations on the south coast of Kangaroo Island experience mean wind speeds at least as high as those recorded at Cape Thevenard on the Great Australian Bight, where the annual mean value at 10m height is about 5.7 m S·l (National Tidal Facility). Indeed it would be surprising if at a location such as Cape du Couedic this figure were not significantly in excess of this. The Island should thus be regarded as a prime location for the harnessing of wind power, particularly since any excess electricity generated could be transmitted to the mainland via the existing cable, because under these conditions the cable link to the mainland would otherwise be idle.

Kangaroo Island's topography, reaching a maximum altitude of about 320 m, and most areas well below 200 m, is too low to modify greatly the synoptic wind regime, although it should be noted that passage over a land surface with its surface aerodynamic roughness, generally results in a reduction of wind speeds when compared to similar effects over the ocean. Because of the relative proximity to the mainland, the sea and land breezes generated by the latter tend to overshadow the smaller scale developments on the Island. In summer afternoons, for example, the northward moving sea breeze over South Australia can reach Leigh Creek, some 200 km inland from Port Augusta, thereby assuming continental dimensions. It is thus little wonder that

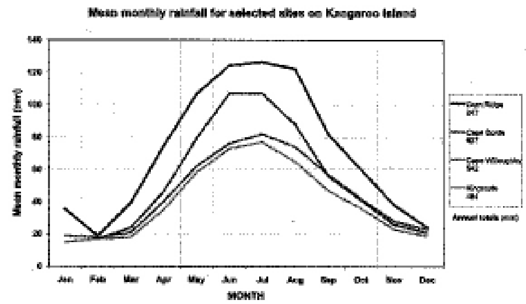


Fig. 9. Mean monthly rainfall for selected sites on Kangaroo Island (Bureau of Meteorology and *Australian Rainman*).

the January 3 p.m. wind-rose reveals strong southerly components for all five stations.

RAINFALL, DROUGHTS AND EVAPORATION

All of Kangaroo Island experiences a Mediterranean type of rainfall regime, i.e. most rain falls during winter with one or two months in summer showing an unmistakeable minimum, as is clearly seen in Fig. 9, which shows the distribution for four sites, ranging from the highest to the lowest gauging stations. In the Island's west, at Cape Borda the summer to winter rainfall ratio is about 0.18, a figure only matched in the southwest of the Eyre Peninsula, but this gradually increases for stations to the east and reaches 0.26 at Cape Willoughby.

When viewed in the context of the overall distribution of rainfall in South Australia, the small expanse of water separating the mainland from the Island does not markedly influence the general characteristics exhibited for mean annual rain, rainfall reliability and the summer to winter ratio. These three parameters are all substantially influenced by both latitude and proximity to the broad arc of the continental coastline. This gives the western parts of the Island a similar rainfall to that experienced in the southeast of the State. Because the highest point of Kangaroo Island at 320 m has less than half of the altitude of the 720 m Mount Lofty on the mainland, the orographic rainfall is significantly less, even though the former site is one degree of latitude further south. The mean annual rainfall map (Fig. 1) shows Kangaroo Island's 800 mm rainfall contour to coincide with the higher terrain in the west, with nearly all areas receiving more than 500 mm annually. Kingscote's slight rain-shadow is a consequence of it lying in the lee of the higher topography to its west, where precipitation is extracted from winter moisture bearing frontal systems. A minor elevation just west of Cape Willoughby accounts for the slight increase in rainfall over the centre of the Dudley Peninsula.

If the reliability of annual rainfall is defined as the ratio of the mean annual rainfall to its standard deviation, then this factor is found to be greater

Table 2. KANGAROO ISLAND DROUGHTS RECORDED AT KINGSCOTE (BUREAU OF METEOROLOGY).

Drought No.	Period	Duration (months)	% of time as severe drought	Total rain during drought period (mm)	Normal rain for drought period (mm)	% of normal rain received in period
1	Jun 1877 to Jun 1878	13	50	413	557	74
2	Feb 1881 to Jul 1882	18	14	605	762	79
3	Jul 1885 to Jul 1886	13	100	376	561	67
4	Dec 1887 to Mar 1889	16	40	393	553	71
5	Nov 1890 to Nov 1891	13	0	380	507	75
6	May 1896 to Oct 1899	42	29	1286	1808	71
7	Sep 1900 to Feb 1903	30	58	787	1125	70
8	May 1907 to Apr 1908	12	0	351	484	73
9	Oct 1913 to Jul 1915	22	82	653	856	76
10	Mar 1919 to Apr 1920	14	67	373	519	72
11	May 1922 to Apr 1923	12	0	350	484	72
12	May 1928 to May 1929	13	0	393	542	73
13	Sep 1943 to Jul 1945	23	0	688	903	76
14	Mar 1946 to Apr 1947	14	0	406	537	76
15	Aug 1958 to Mar 1960	20	0	633	724	87
16	Aug 1960 to Sep 1962	26	47	794	1080	74
17	Jan 1967 to Mar 1968	15	50	405	534	76
18	Nov 1975 to Jun 1978	32	57	875	1227	71
19	Sep 1981 to Jun 1983	22	73	624	826	76
20	Jan 1994 to Dec 1994	12	0	357	484	74
21	Sep 1996 to Aug 1997	12	0	351	484	73

than 5 for most of Kangaroo Island. This compares favourably with the range of 4.5 to 5 for the South Mount Lofty Ranges and 5 to 6 for the Southeast of South Australia. However, droughts constitute an ever looming risk in all of South Australia, with the Kingscote record showing 21 of these, ranging from 12 to 42 months in length, identified by the Bureau of Meteorology in a 120 year period, being summarised in Table 2.

From the stand-point of rainfall alone, the Island is well suited for a wide range of agricultural pursuits. In the past, exploitation of the land resources has been tempered largely by problems of transportation to and from the mainland rather than environmental concerns. It is perhaps fortunate that 'Flinders Chase', an important National Park in the southwest includes a significant section of the higher rainfall zone. The map reveals that almost all of Kangaroo Island's streams and rivers drain this area, a fact which assumed greater significance during the early 1980s when problems of salinisation began to manifest themselves, particularly in those areas which had been subjected to intensive land clearance. In connection with the region then known as the 'Gosse Unallotted Crownlands', now fortunately incorporated with Flinders Chase, a major struggle developed, when less enlightened local interests attempted to secure the area for farming because it included even more of the coveted higher rainfall zone. Land clearance would have resulted in yet further disastrous salinity problems of the type now being regarded with belated seriousness in much of southern Australia.

In a part of the World where water resources must be treated conservatively and with respect, the mean annual potential evaporation of probably just under 1000 mm is as low as found anywhere in South Australia. The potential evaporation is the rate at which water would evaporate if its supply to the surface at any particular location were unrestricted. It depends on the saturation moisture deficit of the air and its temperature as well as the wind speed. As such, this parameter offers a useful guide to irrigation requirements. There is nowhere in South Australia where the annual potential evaporation does not exceed the mean annual rainfall.

It must be appreciated that the magnitude of the potential evaporation at any location and time is strongly influenced by the local atmospheric humidity. The mean annual value of the potential evaporation therefore depends on proximity to other, neighbouring, evaporation sources as well as on the prevailing natural moisture regime. Hence this fickle figure would also be expected to increase during droughts.

SUNSHINE AND RADIATION

Mean monthly values for daily total solar irradiances have been obtained by the Bureau of Meteorology for six stations on Kangaroo Island. In preparing a plot of these data, it was found that the values for Cape Dutton, on the north coast of the Island and Brigadoon, in the central southwest, formed an envelope for the observations at the other four sites. In order to preserve clarity, only the Cape Dutton, Brigadoon and Kingscote values have been shown (Fig. 10).

As might be expected, in all seasons, the north coast experiences the highest mean irradiance levels. These generally fall off in the southwest but less so toward the east. Kingscote, Cape St Albans and Penneshaw all experience similar radiational

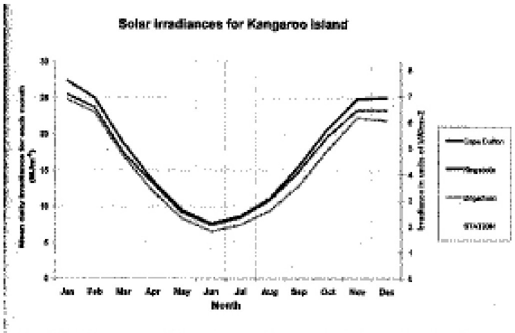


Fig. 10. Mean monthly observations of daily solar irradiance totals (Bureau of Meteorology).

regimes. Vivonne Bay and Brigadoon are similar in summer, but the former tends to emulate Kingscote, Cape St Albans and Penneshaw in mid-winter.

The data from all available stations reveal an interesting phenomenon in December, when the trend of increased irradiance from winter to summer either pauses or falls before climbing to a maximum in January. This can only be explained by a seasonally persistent cloud development, but one which is nevertheless not associated with significant rain. This irradiance feature is mirrored in the number of sunshine hours tabulated by Burrows (1979).

Because of the developing interest in solar power conversion, not only for hot water generation, the daily irradiance totals (Fig. 10) have been shown not only in the conventional units of MJ, but also in the commercially familiar units of kWh, in each case per square metre. Economically, it cannot be ignored that the mean annual irradiance at Kingscote exceeds 1600 kWhm-^{2}

SUMMARY

Kangaroo Island's relatively benign, Mediterranean climate accommodates a wide range of activities. Separated from the mainland by Investigator Strait, the Island's non-avian wildlife, as well as some insects such as bees, are effectively quarantined. Strong winds, frequently bearing some salt from the surrounding seas, demand a cautious approach to land clearance if agriculture and natural water resources are to remain sustainable. Both wind and solar radiation represent potentially valuable self-renewing sources of environmentally friendly power.

6: Vegetation

by D.BALL

Stephen Jay Gould, the noted American palaeontologist, has described evolution as the most misunderstood concept in biology. If this is true then it follows that ecology is equally misunderstood; for evolution is the product of ecological processes when spread out over a long period of time. What probably underpins the widespread misconceptions about ecology and evolution is the lack of appreciation of the dynamic nature of living systems which poets have always interpreted to reflect the very essence of peace and tranquility. Modern humans live increasingly in urban settings remote from all but the most dramatic forces of nature such as floods, fire and drought. The tourist visits Kangaroo Island for a day, maybe two, but rarely longer and departs with a snapshot of a natural world frozen in time. This merely reinforces the notion that to know a natural system it is merely enough to see it in an instant.

Had the early European settlers who cleared the landscape of Australia for farmland seen their actions in the context of a hugely dynamic system they may have foreseen the scourge of salinity that now blights so much of their enterprise. By the end of the 20th century ecologically sustainable development had become a catch cry. Inherent in this belief is the notion that we can increase both our numbers and our economic activity while all around us the ecosystem remains stable. No modern belief so starkly demonstrates the widespread failure of humans to appreciate the dynamic processes of natural systems.

In this description of the vegetation of Kangaroo Island there is deliberate bias toward placing the whole structure in the context of a dynamic continuum which has led to its current state rather than a simple inventory of what is now on the shelf.

Vegetation systems are a product of three main factors:

1: The physical, such as soil and underlying geology combined with landform and the attendant features of altitude, slope and aspect.

2: The climatic, such as temperature and rainfall, in both quantities and distribution as well as extremes, wind, cloud cover and proximity to the coast.

3: The temporal, involving the past history of events which has impacted on any or all aspects of the first two categories. It includes everything from yesterday's weather to the last rain, or fire, through to continental drift.

The vegetation of Kangaroo Island is a text book example of these factors at work. The pre-eminent factor defining the distribution and form of the island vegetation today is soil nutrient status and pH. In broad terms there are three major provinces on the island, the raised plateaux, the low lying plains and the coastal formations. For a full description of the physical structure and geology of the island see Chapters 1 and 2. The island itself is an elongate wedge, highest in the north and sloping to the south. The Cygnet fault runs longitudinally from Nepean Bay to Western River. North of this fault the underlying bedrock is Cambrian sandstone while south of it are Ordovician sandstones. Both these rock types weather to relatively fertile soils with a range of mineral nutrients present. However, in the past, a prolonged period of intense weathering occurred to produce a laterite surface under rainfall measurable more in metres than millimetres. This laterite cap overlies the bedrock over most of the upland plateaux. During this period any soluble minerals were washed out to sea, leaving only the insoluble fraction, the heavy clays, the iron and aluminium as laterite reefs and rubble and the silica as quartz sand. As a result the island was left with some of the poorest soils in Australia. More recent tectonic movement has meant that north of the Cygnet fault the landform is much more deeply dissected. As a consequence these soils are often derived from more recent weathering of the original bedrock as well as the laterite phase.

The island today has 25% of its area in National Park and 46% of its surface under tree or shrub cover (Ball & Carruthers 1998). This is largely a direct result of poor soils which were agriculturally useless until the advent of trace element fertilisers in the mid 20th Century. Even after trace elements, significant areas of the island remained beyond economic worth. These areas are now largely national parks.

What prevented crops and pastures from growing also precluded weeds. The single most characteristic feature that differentiates the island from the mainland is the native vegetation along the roadsides. That legacy is a direct result of the paucity of the soils. There is no better demonstration of this than shown by the rampant weed Bridal Creeper *(Asparagus asparagoides),* introduced in the late 19th Century. Bridal creeper cannot *survive* stock grazing. Where cleared pasture meets naturally-vegetated road verges the spreading of fertiliser through the fence onto the verge creates a fertile and sunny, grazing-free, environment, immediately outside the fence. It is here that bridal creeper thrives. Further into the verge the levels of infestation drop away markedly. On the opposite *verge,* if no pasture directly adjoins the road and the soils are therefore unchanged, there will be little or no bridal creeper *even* after 30 years of rampant growth just 20 metres away.

However, over time the trees along the roadsides extend their roots out into the paddock and withdraw nutrients which are then incorporated into the falling leaves and bark. Even where fertiliser applications do not directly cross the fence the verges will become increasingly more fertile. As a consequence they will become more degraded and weed infested. This process has been speeded up considerably in recent times with the advent of tourism. The need to cater for vastly more traffic and higher speeds has seen the central carriageways widened at the expense of native vegetation along the *verge.* This has thinned the line of trees dramatically and with bigger trees utilising fertilised pasture land, their inability to withstand the ferocity of the winds means that the trees progressively fall over exposing the understorey to more light. The weeds then take over.

Because of the prevailing winds in the southern hemisphere, the island has accumulated, *over* millions of years, a northward migration of beach sands derived almost entirely from shell fragments. This has formed large areas of limestone and alkaline dunes along the south coast. Small pockets of limestone are also found along the north coast. Where this coastal province, with its high pH, meets the laterite with its acid soils the windblown sand tends to neutralise the acid clays. This produces an intergrade zone along the line where the stringy barks *give* way to the mallee to the south. Without this influence the domain of the stringy barks would *very* likely extend to the south coast.

In between these two pH extremes is the province of the low lying plains, the Menzies, east of Kingscote, and the MacGillivray, south of the Cygnet fault and west of American River. In part sedimentary in origin, this province also abuts the Wisanger Hills which are a geological oddity made up from volcanic lava flows. The MacGillivray Plain is home to a much higher level of plant diversity than any other part of the island.

One other factor that has preserved the native vegetation is the absence of rabbits. For this we can thank the intelligence of the goanna rather than humans. Rabbits were introduced more than once (Waite & Wood Jones 1927). If there had been a resident Aboriginal population on Kangaroo Island at the time of European contact the rabbit may well *have* survived. There would have been far fewer goannas and much greater availability of open grasslands. Because the last Aboriginal presence on Kangaroo Island was in excess of 400 yr BP and may have been much longer (Draper 1999), the fire regime on the island from then until European settlement was solely a product of lightning strikes. This makes Kangaroo Island unique in relation to the nearby mainland and has doubtlessly played a major part in shaping the plant communities of the modern day.

While the island escaped the scourge of the rabbit, it was not so fortunate with the introduction of the Koala *(Phascolarctos cinereus).* When any species of plant, insect, other animal or other organism is released into a new environment it must, and will, take over whatever undefended resources it finds available, until it is stopped by a contrary predator, like a goanna, or a resource limitation, like defended nest sites. The Koala has no natural predator on the island and no need of nest sites, so the only resource limitation it can encounter is starvation. At the time of writing the Koala had entirely eliminated many localised populations of Manna gum *(Eucalyptus viminalis* ssp *cygnetensis)* to the point where it is probable that half the Manna gums on the island are now dead. The phenotypes of all the modern eucalypts evolved on Kangaroo Island without koalas. They have therefore not been selected for resistance to browsing impact by incorporating unpalatable structures or compounds in their leaves. The most highly preferred species, like Manna gum, will be systematically destroyed by the Koalas as they aggregate in high numbers around such trees.

It is not possible to *have* a wild population of Koalas on Kangaroo Island, with the capacity to undergo a 500-1000-fold increase in numbers inside the 75 years since they were first introduced, while still maintaining a population of Manna or SA Blue gums, nor a healthy population of Brown Stringy Barks. Nor is it possible to artificially create new food sources at the rate at which these animals can breed. Added to which, the replacement of wild Manna gums by plantation stocks merely aggravates the problem by further increasing the population.

One other major *event* in the island's past that has a direct bearing on the distribution of vegetation is that the Dudley Peninsula could easily have been the Dudley Island. Except for the sediments around the isthmus created between Pelican Lagoon and Pennington Bay there would be two islands. In the past two islands existed, as is demonstrated by the fact that four of the main species of eucalypts west of American River are not present on the Dudley Peninsula. The general soil types and rainfall near Parndana and Penneshaw are not dissimilar but the former is covered by stringy barks, and the latter by narrow leaf implying that the stringy barks either never got to the Dudley Peninsula or disappeared prior to the last land-bridge. On the peninsula, the SA Blue gum occupies the domain normally held by Sugar gums which, like the Cup gum, is absent from the peninsula even though present at American River.

A final factor that has an obvious bearing on the distribution of vegetation is rainfall. Broadly the islands' rainfall is directly correlated with altitude with the maximum rainfall centred in the NW plateau (Chapter 5). The woodland and shrubland systems are in the higher rainfall areas of the western plateau, also extending into lower rainfall areas along water courses across the whole Island. The mallee systems cover the medium to low rainfall areas with a mix of mallee and heath around the coastal perimeter. Before European entry it is unlikely that there would have been any significant development of grasslands. In addition to these major categories there are recent coastal dunes mainly along the south coast, as well as samphire swamps mainly along the eastern end of the north coast. A few freshwater lagoons, some vegetated, occur on the island. A larger number of salt lagoons, some apparently once fresh, are also found. These lagoons have assemblages of shrubs, mainly *Melaleuca* species, in which some are fringing as well as ephemerally submerged.

Fig 1. *Eucalyptus cladocalyx* beside Stokes Bay road

THE WOODLANDS

This category includes the areas of the island dominated by stringy barks or tall, single bole trees. The tallest tree species on the island is the Sugar gum *(Eucalyptus cladocalyx).* This smooth, grey to mottled-barked tree with its characteristic lollypop canopy on the end of long sinuous limbs, can grow to over 35 m (Fig. 1). It occurs from American River through to the west coast, most commonly in areas where the laterite crust has been cut through along water courses, or on the slopes of the more fertile hills of the north coast. It often forms near monocultures on slopes, usually with a poor understorey but in the base of water courses it can be found with a range of other species and a more diverse understorey. In permanent creeks the white-barked Pink gums *(E. fasciculosa)* and SA Blue gums *(E. leucoxylon* ssp.*leucoxylon)* are not uncommon although the latter does not occur in Flinders Chase west of the West End Highway. Less common is the Manna gum which requires the development of substantial alluvial deposition in order to survive. In the Western Plateau the. Messmate *(E. obliqua)* is frequently found under sugar gums while at the tops of dry water courses the Brown Stringy Bark *(E. baxteri)* is more common. The Cup gum *(E. cosmophylla)* is usually present under Sugar gums while in the lower Cygnet River the Red gum *(E. camaldulensis)* is prominent. This species is well represented in Flinders Chase National Park and, due to its commanding size, has probably been preferentially spared in past clearing operations. It is favoured by apiarists for honey and its hollows are used by the Glossy Black Cockatoo for nesting. The Koala browses this species but does not appear to cause other than trivial defoliation.

The River Red gum is common on the flood plain of the Cygnet River; although never far from the actual river course. It occurs from Bark Hut Road bridge down. A few also occur in the bottom of the Middle River. The requirement for flood waters in propagation appears to determine this distribution. Salinity and periodic insect attack are major impacts on this species, as is Koala browsing. Tree deaths are becoming more common in its lower reaches and are likely to increase as time goes on. There is a very big problem looming for the Red gums and the Blue gums that line the actual river bank. They are under considerable stress and recruitment in the river channel appears non-existent. The huge volumes of water that the lower Cygnet River now carries in flooding rains as a result of agricultural land clearance makes restoration of this habitat very difficult. It goes without saying that it will not happen by itself.

The SA Blue gum is the second tallest species on the island. It occurs from Antechamber Bay through to the West End Highway but is absent west of there. It is almost indistinguishable in form from a Pink gum excepting for its large dark fruit occurring in ones, twos or three per elongate peduncle with pink or white flowers set back inside the canopy. By contrast, the Pink gum has small, white only, flowers set on the extreme outside of the canopy in extensive clusters which litter the ground with intact staminal rings after flowering. The Blue gum is largely restricted to water courses or more fertile deep soils, although near Antechamber Bay it has a population of almost bonzai proportions on a stony slope. Around Pioneer Bend, through to the Bark Hut Road bridge, it covers quite a wide area on and off the river. It is highly-favoured by Koalas and where the trees are only small or in low numbers, high mortalities are found. As Koalas preferentially eat out the upper central canopy of a tree the extent of damage inflicted on this species with its white limbs is more obvious from the air than the ground. The same is true for Manna gums.

The Manna gum *(E. viminalis* ssp. *cygnetensis),* so named as the type specimen was collected from near Cygnet River, is the primary choice of koalas for browse. It is almost entirely restricted to water courses and, in particular, to areas of deep alluvial deposition such as occur when creeks meander or are forced into pinched loops. As a consequence, the entire population of Manna gum is highly fragmented with at best no more than 20% of the total in anyone area. In Scotch Thistle Flat in Flinders Chase, upwards of 600 trees were once found in one area. Once, because over 50% are now dead. Another major centre for this species is Pioneer Bend, north of Parndana in the middle Cygnet River, where Manna gums extend out of the river onto the hillslopes. In the main, the remaining population is, or was, in clumps of 1 to 50 trees scattered throughout the upper river systems of the south-flowing Eleanor, Harriet, Northwest and Southwest rivers, the upper and lower Cygnet and the north-flowing Middle, Western and De Mole rivers. A small outlier population is found on the Dudley Peninsula, on the Chapman River and on the Cape Hart Road. Apart from the Dudley Peninsula where Koalas never established, these small populations have suffered from 30 to 100% mortality (Fig. 2).

Fig. 2. Not one *Eucalyptus viminalis* var. *cygnetensis* remains alive out of the original 59 trees in this group in the middle Cygnet River on Peter MacGill's "Henderson's Farm". The koalas have moved on.

The Messmate *(E. obliqua)* is a stringy bark characterised by its hollow wine-glass fruit. No other "rough bark" on the island has hollow fruit. It prefers the more fertile areas of the plateau being found preferentially in water courses rather than hillslopes but it does occupy slopes in better soils. Its range is west from a line projected due north of Murrays Lagoon, including an outlier population on the lower Birchmore Road, and a continuous range running from Margries Road to the far west coast. Its southern boundary is a line from the mouth of the Stuns'l Boom River to the bottom of Margries Road. It represents the most common residual tree in the agricultural areas along uncleared water courses. It appears to handle Koala browse without too much ill effect although some isolated deaths may be Koala related.

Fig. 3. *Eucalyptus baxteri* woodland with dense understorey. Gosselands. Flinders Chase National Park.

The same cannot be said for the more ubiquitous Brown Stringy Bark *(E. baxteri)* (Fig. 3). This species occupies an identical range to the Messmate but is preponderantly found on hilltops and slopes and much less so in water courses. As a consequence it is often the predominant roadside tree over much of the plateau. For this same reason it was preferentially cleared in the post-1950 days of agricultural development and is the major species found in shelter belts on farm slopes. Its role in ameliorating the effect of wind over the agricultural areas cannot be overstated. This species is in a serious state of decline over much of the agricultural area. Increasingly, dead limbs are showing in the upper canopy. The possible causes of this decline are many. Excessive growth through access to fertiliser leading to higher water stress in dry summers, salinity, rising water tables, compaction by stock of the root zone, aging, beetles and caterpillars, or an undetected disease are all possibilities. Koalas are definitely involved as the mortality rate for this species when in close proximity to Manna gums is higher than for the Manna itself. As this is the second or third most common tree on Kangaroo Island there will be major implications for biodiversity if it cannot be sustained.

One ominous sign that this species is in a downward spiral is the number of stringy barks that have been killed in the most recent bushfires. This species, unlike mallees, is dependent on withstanding the ferocity of the fire by insulating its epicormic buds inside the thick fibrous bark which preferentially chars rather than burns. Once the fire has passed, the tree shoots again from the existing trunk and major branches (see Fig. 4). When large numbers of Stringy Barks die in a fire it is a sure sign that the trees were already under stress before the fire.

The Peppermint gum *(E. odorata)* probably has suffered a greater proportionate population loss than even the Brown Stringy Bark because it favours the slopes and hilltops of the more fertile soils north of the Cygnet Fault. These were more readily convertible to farmland. Its domain has

Fig. 4. *Eucalyptus baxteri* recovering from a fire six months earlier. Sprouting of new growth occurs along the entire trunk. Gosselands, Flinders Chase National Park.

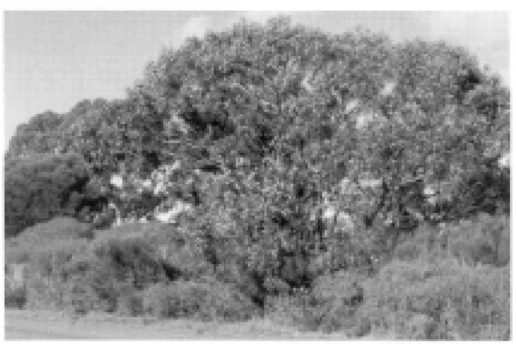


Fig. 5 *Eucalyptus odorata* flowering in August along the Playford Highway east of Branch Creek.

shrunk to pockets of remnant vegetation only. It is common on the Bark Hut Road near Millers Road and in patches along the Playford Highway (Figs 5 & 12), but is not well represented in any National Park. It is eaten by Koalas to the point of severe defoliation and death when found near Blue gums suffering a similar fate.

The Pink gum *(E. fasciculosa)* has the widest range of any tree species on the island. It is, however, rarely a dominant species. Apart from the high pH coastal areas it is found allover the island, albeit in small numbers. It is best represented in the better rainfall areas and is the principal white· barked paddock tree south of the Playford Highway. It is usually displaced by Blue gums in the major rivers except in the Rocky and Breakneck rivers where Blues are absent. It is very common on the road to West Bay in Flinders Chase. This species is not at all favoured by Koalas and rarely shows any sign of being used or abused by them. As a consequence its future is more than assured. In time it will entirely displace all the Blue gums and Manna gums throughout Kangaroo Island wherever Koalas occur. This process has already happened at the original Koala release site where the Manna gums are only to be found on fading photographs and Pink gums have replaced them. It is currently happening in Scotch Thistle Flat further up the Rocky River.

The Cup gum *(E. cosmophylla)* putatively contains within its ranks the oldest living thing on Kangaroo Island. It is a slow-growing, sprawling tree with a wood that is much favoured for turning and which is remarkably impervious to fungal attack and fire. It too shares the characteristic of reshooting from epicormic buds, post fire (Fig. 4). There are specimens in the upper Cygnet River with butts in excess of 2 m diameter; albeit they are reduced to smaller trunks, like broken teeth, poking up from the original stump. These trees must be well in excess of 300 years old and could be far older than that. This species is at home in a swamp and yet manages to occupy some of the stoniest slopes as a near bonzai tree, often accompanied by a dense near monoculture of Bulloaks *(Allocasuarina meulleriana* ssp. *notocolpica).* It is used by Koalas but it is as yet difficult to assess the impact on this species because it is so highly variable in general appearance.

Two minor, probably related, woodland species of eucalypts occur in the far west. The Swamp gum *(E. ovata)* and a recently named species *E. paludicola* are found in Flinders Chase and Kelly Hill Conservation Park. The Swamp gum is also present in very low numbers in the Western and Middle rivers. Koalas rate the Swamp gum relatively highly and would have destroyed a small population at Grassdale around an ephemeral lagoon were their numbers not recently reduced. However they show a clear preference for the Brown Stringy Bark when the two are together.

There is one non eucalypt in the woodland group, the Drooping Sheoak *(Allocasuarina verticillata)* (Fig. 6). It is predominantly a north coast species with some major occurrences inland. Typically this tree is found where there is bedrock near the surface; Nepean Bay being an odd exception. Being the principal food source of the Glossy Black Cockatoo (Crowley 1997), it has an obvious conservation significance. As it does frequent areas with stone outcops and surface flagstones it has probably been spared preferentially in past

Fig. 6. *Allocasuarina verticillata* beside Pelican Lagoon.

clearing. In sheoak dominant areas the understorey is usually very limited (Fig. 6).

Throughout the eucalypt woodland systems the understorey is remarkably uniform, the same basic species occurring in varying proportions, with a range of less common species being either present, absent or even dominant. The Vacca *(Xanthorroea semiplana* ssp. *tateana)* is all but ubiquitous over the entire system. Its down-folded dead leaves form a grass skirt that ultimately reaches to the ground. Inside this is an insulating and dry refuge for a multitude of fauna from large to small. The Yacca is also commonly present in the mallee associations when away from the coastal limestones and lime sands. Four members of the family Proteaceae are also commonly found as prominent in the woodland understorey: *Banksia ornata,* B. *marginata, Hakea meulleriana* and *H. rostrata.* Where surface sandstone occurs *A. meulleriana* ssp. *notocolpica* is often very dominant, otherwise it is variably present, as is the related *A. striata.* In permanent creeks *Leptosperrnum lanigerum* is not uncommon in shaded areas while *Acacia retinodes* var. *retinodes* prefers more open spots. In swampy habitats *Melaleuca gibbosa* and *Hakea rugosa* with *L. continentale* and *Callistemon rugulosus* var. *rugulosus* often predominate.

The range of medium-sized shrubs is too numerous to name but many are quite common and widespread. They include *Phyllota pleurandroides* in the western half, the *Acacia myrtifolia* group, *Platylobium obtusangulum, Calythrix tetragona, Adenanthos terminalis, Isopogon ceratophyllus, Petrophile multisecta, Leptospermum myrsinoides* and *L. continentale, Davesia asperula* ssp. *asperula* and *D. brevifolia,* to which can be added a larger number of small to miniscule shrub and forb species. Native grasses are more common in near creek locations. Despite the extensive nature of the woodlands they contain very few examples of rare or endangered shrubs. The majority of these species occur in mallee or coastal heaths.

The ferns are most commonly present in the form of Bracken *(Pteridium esculentum),* both

Fig. 7. *Eucalyptus remota* in a low whipstick form surrounded with shrub heath. Gosselands, Flinders Chase Nationa

along water courses and on slopes. In disturbed land it often recolonises to blanket the area totally. On more steep and rocky slopes, Maiden Hair fern *(Adiantum aethiopicum)* is common. In the permanent creeks the Coral fern *(Gleichenia microphylla)* and two *Blechnum* species are found although some older local residents suggest that these ferns, living right on the waters' edge, may have suffered from the introduction of the Yabby *(Cherax destructor).* The flow rates in floods from areas that have been cleared are much higher than naturally vegetated surfaces and with crustaceans possibly tunnelling under the ferns this has seen them torn out and rolled up like carpet in strong flood currents. As this waters-edge habitat is the only one available to these ferns they are largely absent from creeks in agricultural areas.

THE SHRUBLANDS

In the higher rainfall areas on slopes and ridges, usually with skeletal soils covering near surface bedrock, a number of shrub associations has developed. These shrublands are often accompanied by a scattering of stunted Cup and Pink gums never much higher than the shrubs. The main species is more often *A. meulleriana* ssp. *notocolpica,* although in places *Melaleuca uncinata* provides a totally different hue to the rusty red of the bulloak. Both species form dense almost monocultural thickets to 2.2 m. A much more diverse shrub system or heath is found in areas where *E. remota* is located. The occurrence of this mallee species coincides frequently with very poor soils and a typical heath structure develops between widely-spaced, low, stunted mallees (Fig. 7). A thin ribbon of shrubland is usually found around the coastal perimeter on windswept cliff tops. Where this is on limestone surfaces the shrubs are dominated by ground-hugging forms of *Melaleuca lanceolata* var. *lanceolata,* sometimes with depauperate *E. diversifolia.* One other lesser recognised shrubland which serves a vital role in the interface between the terrestrial and marine environments is the Samphire swamps with their

Fig. 8. Samphire swamp near Nepean Bay. In the late afternoon sun the area lights up with a deep pink from the leaf colour of the shrubs. The trees are Paper Barks *(Melaleuca halmaturorum* var. *halmaturorum)*.

Paper Bark *(Melaleuca halmaturorum* spp. *halmaturorum)* fringes. They are prominent both north and south of Kingscote, near Nepean Bay and around Pelican and Lashmars lagoons. These hardy members of the Salt Bush family *(Chenopodiaceae)* are often fully submerged in very high tides by sea water. Like the Mangrove, which is absent from the island, these plants have to extract both their nutrients and water from sea water itself (Fig. 8).

THE GRASSLANDS

There are no naturally occurring grasslands on Kangaroo Island that could be said to have predated European settlement. However, off the coast, there are extensive sea grass meadows comprising true members of the Grass family (Graminaea). These grasses grow in relatively shallow waters where they cannot be exposed at low tides and are not normally subject to high levels of turbidity such as in high wave-action surf zones. Being true grasses they photosynthesise just like terrestrial grasses. However they are placed under significant duress by sediment from land-based streams which not only blots out light through turbidity but also, when the silt settles on the leaves, acts as a sunlight barrier. Significant loss of sea grass meadows has occurred around the outfall of the main island river the Cygnet (Edyvane 1997). These sea grasses are of paramount significance as nursery and feeding sites for a multitude of marine species.

THE MALLEE

The mallee is a multistemmed tree in which each stem emanates from a common root. Like all attempts by humans to impose order on the natural world, there are many components that refuse to fit in one box. The mallee form is a product of both genes and environment. At least eight local eucalypt species adopt both tree and mallee forms. In good soils and water regimes they tend to a tree form with a single trunk. In poorer soils, and particularly lower rainfall the multistem form prevails. Where it does, it is the root that represents the tree more than the stems. In a fire, the aerial component is often sacrificed and the plant reshoots from the base. In this sense a mallee root may be many times older than the stems. There are four major mallee associations on the island, the low lying plains, the coastal dunes and limestones, the outer perimeter of the plateaux and the western mallee ash.

The Kangaroo Island Mallee Ash *(E. remota)* is the only eucalypt restricted entirely to the island. It is also the only mallee restricted to the plateau. It occurs inside an area west of Mt Taylor Road and north of the South Coast Road. Much of its existing domain lies within the Gosselands and Northern Flinders Chase parks system. It varies from being a low whipstick mallee (Fig. 8) to a 12 m high tree in fertilised soil. In bark and leaf it is not unlike the Messmate but its fruits are flat-topped, inverted cones, not hollow. In poor areas it often occurs as an isolated, low, stunted, whipstick mallee in a sea of shrub heath surrounding clumped islands of much taller stringy barks.

A most interesting aspect of this species is why it occupies an area mainly devoid of Blue gums in the major rivers, which would normally be expected to have them. Cape Borda, on recent historical data, has a high incidence of fires from lightning strike. It may be that this species owes its very existence to a long history of repeated fires that have, over time, favoured the Mallee Ash over Stringy Barks and defeated the Blue gums.

Potentially the most common tree on the island, certainly since agricultural clearing, is the White Coastal Mallee *(E. diversifolia)*. It occupies the outer perimeter of the Western Plateau where it competes with the stringy barks and similarly on the Dudley Peninsula where it competes with the narrow leaf *(E. cneorifolia)*. It is ubiquitous over the coastal limestones and dunal systems and intermingles variably with narrow leaf in the low-lying Menzies and MacGillivray plains.

This species can be found in hollows, in sheet limestone, on windswept cliff tops as a 1 - 2 m shrub perpetually pruned by the force of the wind, or, in good conditions, as impressive 15 m mallees or trees. Along the south coast it is ubiquitous but only intermittent along the north. Because the coastal dunes and limestones were not considered good agricultural land, a high proportion of the original population remains intact and most is in reserves. Away from the coast, when on clay or more neutral sands, this species is often associated with the Port Lincoln Mallee *(E. lansdowneana* ssp. *albopurpurea)* and east of Vivonne Bay with the less common, Narrow-leafed Red Mallee, *(E. foecunda)*. On high pH soils it is usually associated with the Kingscote Mallee *(E. rugosa)* and *E. oleosa* and occasionally on limestone ridges with the relatively rare *E. gracilis*. Over much of the southern limestone areas the landscape is a mosaic of stony ridges and fossil clay horizons formed into pocket flats. In these flats *E. cneorifolia,* at times with *H. meulleriana,* is better suited. In the far west this species intermingles with *E remota.*

The understorey accompanying *E. diversifolia* depends on two major factors. The first is soil type. In clay or neutral sands the understorey is usually complex and not unlike that of the stringy barks, with Yaccas, Banksias and Hakeas prominent. In coastal dunes, Black Tea Tree *(Melaleuca lanceolata* ssp. *lanceolata), Acacia longifolia* var *sophorae, A. retinodes* var. *uncifolia, Correa reflexa* and *Pomaderris paniculosa* are often present with *Leucopogon parviflorus, Acacia leiophylla* and *Adriana klotzschii* being particularly prominent when the area has had a history of human disturbance. In limestones the understorey is highly variably from open but complex to nonexistent (Figs 9, 10). Black Tea Tree is usually present with *Acrotriche patula* also persistent.

Fig. 9. *Eucalyptus diversifofia* mallee scrub with mainly twig and litter understorey. Dudley National Park.

Fig. 10. *Eucalyptus diversifolia* with *E. rugosa* mallee scrub with mainly twig and litter understorey. Dudley National Park.

The second factor determining the understorey is longevity since the last fire. This is particularly so away from coastal dunes. Mallees are long-lived plants and as time advances, the shorter-lived shrubs die out. By the time this occurs the root zone is fully utilised and the tree canopy fully spread. Seedling shrubs are unlikely to survive when germinating into such a hostile regime. As a consequence, shrubs set long-lived seed which will only be activated by the next fire. Immediately after a fire the water in the soil is available for any and all, as the trees have lost their canopy and therefore draw little for themselves. This, in turn, leads to a profusion of seedling input. It is not uncommon to find mallee scrub on the island with just twig and litter understorey. The tendency to see this as a state of decline or senescence, given the contrast to the vigour and colour of a post fire recovery, is natural. However this is not senescence unless and until the trees start dying or the viability of the shrub seed reserves declines.

In the normal course of events, fires on Kangaroo Island would be erratic and in pre-settlement times, determined solely by dry lightning strikes. Bauer (1959) postulated a very high fire intensity from 1880 to 1940, which raises the question as to how much of the existing native vegetation is a modern day artifact. In the various states of cycling from fire recovery to mature stands the resources the vegetation provides to fauna are quite different. It is this difference that maintains faunal diversity. Fire diversity is equally as important as plant diversity. Because humans equate vigorous flush vegetation with healthy crops or' gardens there is a tendency to equate a mature, understorey-poor mal lee with an unhealthy state. This would be so if the same mallees on the island were all in a similar mature aged condition.

The species that most people equate with the island is the Kangaroo Island Narrow Leaf *(E. cneorifolia).* While *E. foecunda* has narrower leaves and *E. odorata* equally narrow leaves, what makes this species the 'Island' tree is its dominance of the immediate hinterland of the older population centres of Kingscote, American River and Penneshaw. It is the dominant species covering the low-lying Menzies and MacGillivray plains which are neutral to alkaline clays and sands and the Dudley Plateau which is acidic. Long term agricultural use of much of its domain has seen it preferentially cleared. However the practice of leaving hedge rows, in earlier times, creates an appearance of a far greater residual presence. It is not well represented in reserves where it is a dominant, although it is included as a common associate in the Dudley and Cape Hart parks. In more clay-based areas there is a minor sporadic occurrence of *E. phenax,* with its characteristic broad but pale yellow-green leaves, and where limestone occurs, *E. rugosa.* South of the Playford Highway *E. lansdowneana* ssp. *albopurpurea* and *E. diversifolia* occur in varying amounts.

The understorey is, as with *E. diversifolia,* highly variable from twig and litter (Fig. 11) to quite complex associations (Fig. 12). In the MacGillivray Plain there is a much higher level of diversity and a significant number of the island's rare species are found there. Typically, Broombush (M. *uncinata), Thryptomene ericeae* and *Choretrum glomeratum*

Fig. 11. *Eucalyptus cneorifolia* with typically dense upper canopy. Dudley National Park.

Fig. 12. *Eucalyptus cneorifolia* with *E. odorata* and a complex understorey. Playford Highway east of Branch Creek ..

and X. *semiplana* ssp. *tateana* are common understorey species.

The Kingscote Mallee *(E.* rugosa) is not restricted to Kangaroo Island (Fig. 13). It grows to a 15 m tree in better areas and while not often a dominant, it is so near Hanson Bay and on rockier limestone ridges. Predominantly it is a mallee with a smooth ruddy bark above the rough base and produces distinctly ribbed, medium-sized, fruit. Usually it is found in association with the White Coastal Mallee, the Narrow Leaf, and less commonly, *E. oleosa,* with which it shares a very similar upper canopy form, but very dissimilar fruit, the latter being quite small. It is most often found on sheet or broken limestone surfaces which makes it common along the south coast but only intermittent along the north. The understorey is much the same as for the White Coastal Mallee.

The Port Lincoln Mallee *(E. lansdowneana* var. *albopurpurea)* mainly occupies the intergrade zone between the pH extremes of the coastal limestones and the acid clays of the plateaux. It occurs from the eastern to western ends of the island principally in the southern half. It is almost always associated with *E. diversifolia* and, in the eastern half, with *E. cneorifolia.* In the low-lying MacGillivray Plain this species is often associated with a very diverse understorey and along its southern flank the small Narrow-leafed Red Mallee *(E. foecunda)* is not uncommon. Like the Kingscote Mallee, the trunk, above the rough base, is smooth and quite often rusty brown with prominent peeling ribbons of bark. Where it is the tallest species in the area, its twisting upper limbs provide near horizontal perching which is favoured by large birds like Currawongs. As a consequence it accumulates a disproportionate aggregation of bird-borne weeds like Bridal Creeper and Bridal Veil at its base.

The role of non vascular plants on the island is not well documented. The most obvious are the vivid orange lichens which adorn Remarkable Rocks, and other exposed granite intrusions, and are being worn off by countless tourist hands and feet. As agents to protect soil surfaces they are undoubtedly highly important. They can be found on all rock surfaces across the island in wet and dry habitats. Mosses are also common across the island and playa major role in soil stabilisation in the consolidated coastal dunes. They are both also prominent in the water courses and more shaded slopes. The fungi are similarly little documented. Without fungi, of course, there would hardly be any vegetation on Kangaroo Island as the larger part of the nutrient cycle would not be possible. The role of fungi in breaking down fallen bark and leaves underscores their crucial significance to the standing vegetation.

Fig. 13 *Eucalyptus* rugosa with *Melaleuca gibbosa* and M *lanceolata* var *lanceolata* near Pennington Bay.

WEEDS, PESTS AND PATHOGENS

Because of its poor soils, Kangaroo Island is remarkably free of weeds. This is, however, purely a legacy of chance. It will not persist without increasing human involvement. The major weeds that cause concern are those that invade native vegetation, almost all of which are former, or worse, modern, garden escapees. The genus *Aparagus* has contributed three species including the nationally significant Bridal Creeper as well as Bridal Veil *(A. declinatum).* The family Leguminosae includes Lucerne Tree *(Chamaecytisus palmensis)* and Cape Leeuwin Wattle *(Albizia lophantha)* which are spreading aggressively into roadside vegetation as is New Zealand Mirror Bush *(Coprosma repens)* and the recently introduced West Australian species, the Australian Blue Bell *(Sollya heterophylla).* The common feature which characterises the woody weeds, including boxthorns *(Lycium ferocissimum),* is a fruit or seed pod that attracts birds. These propagules are then taken from home gardens or horticultural plantings and deposited in nearby vegetation. This erratic distribution can take place over very long distances where large birds are involved. Once a shrub with long-lived seeds, like a wattle, invades an area it will be a continuous problem for up to 50 years or more, even if subject to constant regular removal.

Horne gardeners on Kangaroo Island, no more than anywhere else in Australia, are yet to take on board the responsibility to refrain from planting species that have bird-borne seeds that are invasive of natural vegetation. Once again, our inability to see biological systems as dynamic structures, preferring instead to see them as just pretty backdrops to human life, places the viability of natural systems under a cloud.

While Blackberry *(Rubus disclor)* is a weed on the island, it is, to date, quite benign compared to the Adelaide Hills. Fennel *(Foeniculum vulgare)* and Onion Weed *(Asphodelus fistulosus)* are major weeds in sandy areas and are being spread more widely by road maintenance machinery. With the advent of increased cropping since the early 1990s, roadside weeds like Evening Primrose *(Oenethera stricta)* and Wild Mustard *(Sysimbrium officinale)* are now becoming significant. Similarly, just as in Canada, Canola is now becoming a weed on roadsides.

Non-woody weeds come in the form of grasses, bulbs, annuals and perennials. A number of these, particularly grasses, is seriously degrading roadside vegetation, and bulbs like *Freesias* are a major concern in water courses. A weed of island beaches that has taken hold around the whole coastline in the last 25 years is Sea Spurge *(Euphorbia paralias).* This species is spreading inland from the foredunes and has presumably spread by sea from beach to beach. A more recent invader, which is now expanding explosively, is Purple Pin Cushion *(Scabiosa atropurpurea).* This species very likely has come onto the island adhering to tourist vehicles approaching Cape Jervis. The seed heads grow on the very edge of the bitumen at bumper height. Road maintenance is a major spreading agent for weeds where seeds are transported in slashers, graders or road material. The prognosis for roadside vegetation is not good. Only concerted, integrated management practices and resources directed at this area can preserve them. This is not happening at the moment.

Major plant pathogens introduced to Kangaroo Island include the devastating root rot fungus or Dieback *(Phytophthora cinnamomi)* and four other related *Phytophthera* species (Vickery 1997; Furner 1998). In a more biologically-literate culture this would never have happened as the most outstanding feature of the native vegetation on the island, distinguishing it from the rest of SA, is the extensive Proteaceae flora. It has long been known that this group is particularly vulnerable to this pathogen. There is legislation protecting the Koala and the European Honey Bee, both of which are having a negative impact on the vegetation but no attempt was deemed necessary to quarantine the island from Dieback. Nor is there any serious concerted attempt being made to prevent its spread around the island by forestry or farm machinery or tourist traffic. Additionally the extreme vulnerability of the Yacca to this pathogen group creates a long term knock on effect to fauna which don't actually feed on the vulnerable species but use the Yacca as a refuge. In most areas where Dieback is present it is the dying Yaccas that provide the first indication of its presence.

A more recent, presumed pathogen, is Mundulla Yellows. It has been recorded on the island in three areas. If this eventuates as a pathogen that attacks healthy as well as stressed trees then there is little that can be done until some antidote is developed. The Sugar gum is regarded as a vulnerable species. If stress is implicated in the spread of this condition then the spreading salinity scourge and the Koala become even more problematical.

Feral pigs, goats and deer are mainly present in the western half of the island. Their impact on native vegetation is difficult to determine as they are not yet in such numbers as to create more than localised damage. The pigs in particular are likely to be major vectors for speading P *cinnamomi* as they favour rooting in creeks. Their rooting up the ground is also a serious erosion problem and could be expected to mitigate against those species that occur predominantly in the alluvium of water courses.

The impact of the European Honey Bee on the island is currently being studied (see Chapter 10). The competition between native bees, honeyeaters and pigmy possums must inevitably impact on those plant species, like *Cheirantheras,* that are solely or preferentially pollinated by native species. One lesser-known problem relates to the ring barking of some of the largest trees in the lower

Cygnet River presumably by Galahs, Corellas or Cockatoos. The bark removal progresses over some years until it fully encircles the trunk and kills the tree. This, yet again, reflects an unstable natural system with a major bird population imbalance.

RELATED ISSUES

Forestry has recently taken off on Kangaroo Island. A very strong case can be mounted for replanting deep-rooted perennials on the high rainfall areas to decrease the winter runoff that is having a major deleterious impact on the internal drainage systems like Murrays Lagoon and potentially also the Nepean Bay sea grass meadows. The freshwater lagoons can only progressively turn into eutrophic salt swamps under existing farming processes as the nutrients washed down the streams in winter accumulate, while the water itself evaporates off in the summer. However the species being planted on the island is predominantly Tasmanian Blue gum *(E. globulus).* This species is second only to Manna gum as a preferred browse of the Koala. The defoliation of farm driveways lined with earlier plantings of *E. globulus* is stark testimony to this. The potential exists to provide an enormous food resource for the Koala which will then add further pressure to failing native tree species from an even larger and faster growing population. The forestry industry maintains that it can contain this food resource inside electrified fences. As this is a new venture on the island the long term continual maintenance of these fences is crucial through both good and bad economic times.

The progressive subdivision of the island to cater for a wave of retired or wealthy urban people wanting a weekender lifestyle will potentially generate large areas of small, probably unproductive land parcels, with a high potential for weed development once the usual controls that stock grazing pressure provide are gone. It will lead to a proliferation of exotic garden plants, many with weed potential, being widely scattered all over the island. Maintaining the current integrity of the natural vegetation of the island will become increasingly more difficult in the future. The dynamics of current trends do not inspire confidence that future generations will be as fortunate as those at the turn of the 21 st century in having such access to natural biodiversity.

One lesser considered problem that has real potential to degrade the vegetation in agricultural areas is the very high numbers of native animals like wallabies and possums that feed on crops and pasture during the winter and spring. This extensive food reserve allows them to build up their numbers. When the pastures have dried off in the summer these animals are forced back onto browsing native species in the remnant vegetation along creeks and windbreaks. The first plants to succumb are the shrub and tree seedlings which effectively chokes off the regeneration process. Excessive numbers of Corellas and Galahs which

Fig. 14. The vegetation map of Kangaroo Island showing the remaining areas of natural vegetation divided into woodlands and mallee.

feed on fallen crop seed are also killing tree canopies by stripping the outer twigs when roosting. Biological systems are hugely complex and dynamic structures which rely on a myriad of checks and balances to work properly. The attempt by Humans to simplify "Nature" is the root cause of the ecological problems, not just on Kangaroo Island, but across the globe.

TAXONOMY

The island has a total of 1179 plant species of which 45 are endemic (occur only on Kangaroo Island), while seven are only found in SA because they occur on Kangaroo Island (Kinnear *et al.* 1999). The taxonomy of the island's vegetation has attracted many contributors both from the point of simply naming species to the obvious contrasts and comparisons to nearby mainland areas. Ida Jackson, a long term island resident, did much to foster an interest in taxonomy among the local residents in the post war era. Much recent work has been done by Davies (1986, 1992, 1996) and Overton (1988, 1990, 1992, 1995) on the rare and endangered plants on the island. For those interested in general taxonomic issues see Robinson & Armstrong (1999) for a full listing of the taxa. For a field guide to the flowering plants see Prescott (1995).

VEGETATION MAPPING

A number of attempts has been made to map the vegetation of Kangaroo Island from the 1930s onward (Kinnear *et al.* 1999). The most comprehensive map was drawn up by Bauer (1959), just at the time of major land clearing. In that map 13 classifications were used. It is a fascinating commentary on changing perspectives that Bauer made the comment on p. 190 with respect to the stringy bark and mallee associations that "Economically this vegetation has been more of a liability than an asset". Salinity was not a problem back then.

A more recent map of the vegetation of Kangaroo Island (Ball & Carruthers 1998) (Fig. 14), was drawn up using a primary classification based on the tallest stratum. As with all attempts to simplify biological systems, this has both pluses and minuses. The tallest stratum is not necessarily the dominant species and dominance itself is rarely uniform across a landscape. Within any given unit it is a gross simplification to lump together north and south facing slopes, ridges and gullies as though this is a uniform structure. Vegetation maps are a guide to general occurrences within which considerable variation has to be expected. Given the limited resources applied to such compilations they are also best seen as permanent works in progress.

The map divides the vegetation into 37 major groupings based on the tallest species and divides these into 132 subgroups. The level of subgroupings would make little sense in a pre-computer age, at least from a cartographic viewpoint. However as computers are designed to sift and select, the data fields provided in the subgroups become usable when searching the fields of vegetation types for minor tree and understorey species and their relationships.

7: Aborigines

by R. J. LAMPERT

INTRODUCTION

Kangaroo Island is, with the exception of Tasmania, the largest Australian off-shore island, yet it was uninhabited by Aborigines at the time of its discovery by Europeans. Matthew Flinders, approaching from the northwest, first saw Kangaroo Island as a long piece of land to the south notable for the absence of smoke from fires. Elsewhere explorers of Australia from Cook onward described smoke-filled skies caused by constant Aboriginal fire pressure on the vegetation (Jones 1969). The absence of smoke reinforced a belief among Aboriginal people dwelling on the mainland opposite that Kangaroo Island, or Karta as they called it, was "the island of the dead", a place visited by their mythical ancestors but unoccupied by living people. This view is borne out by Flinders who noted the extraordinary tameness of kangaroos grown accustomed to the absence of men, and concluded that the island was completely without a human population (Flinders 1814).

Not long after its discovery, Kangaroo Island was settled by Europeans, sporadically at first by sealers who brought with them Aboriginal women abducted from both the nearby mainland and from Tasmania. The island was officially settled in 1836 and clearing of the natural vegetation began at that time. None of the early settlers realised that the island had once been the habitat of another human population. Indeed it was almost exactly a century after Flinders' discovery of Kangaroo Island that the first prehistoric stone tools came to light. The South Australian geologist Howchin (1903) recognised the work of humans on several beach pebbles, pitted through having been used as hammers, and found out of geological context on Hawks Nest Station near the shore of Murrays Lagoon. This discovery aroused considerable interest among ethnologists at the South Australian Museum, and the Hawks Nest site was visited by Tindale & Maegraith (1931) who found more hammer stones together with large pebbles that had been flaked along one side to give them a sharp cutting edge. When Tindale visited the island again he found more sites with the large pebble tools, and he also recognised other forms of tool made on heavy blocks of stone originating from outcrops inland (Tindale 1937). Tindale named the stone industry Kartan after the Ramindjeri name Karta for Kangaroo Island. However, the most prolonged earlier study of the Kartan industry was by H. M. Cooper, who between 1934 and 1939 collected more than 1500 Kartan tools from at least 47 sites. Reconnaissance and collecting by Cooper, and also by the geographer Bauer, continued until by 1958 more than 120 Kartan sites had been located on the island (Cooper 1943, 1960; Bauer 1970). Sites with similar large tools were found also on parts of the nearby mainland, including Cape Jervis, Hallett Cove, Wakefield River and the southern Flinders Range (Cooper 1943, 1959, 1960,1961) (Fig. 1).

LOCATION OF KARTAN SITES

Although the term 'surface site' is used to describe nearly all the sites on which Kartan tools are found, the tools generally lie about 20 cm below the surface at the base of the top soil, and are brought to the surface by ripping, ploughing and other activities concerned with the clearance and sites are largely dependent on disturbance of the soil. Most of the sites examined by archaeologists in the 1930's are in parts of the island where settlement was early, whereas reconnaissance by Bauer in the 1950's and by me in the 1970's (Lampert 1981) extended the range of sites to the main plateau in the western half of the island, which was cleared only after World War II (Fig. 2). Enough Kartan sites have now been discovered to assess the locational requirements of the people who used the large tools. The following locational characteristics appear significant. Most sites lie within 200 m of fresh water, distances of more than 500 m being very rare. Major sites, with large concentrations of Kartan tools, are on the shores of prominent lagoons and along main stream courses.

Smaller sites are more scattered, but lie principally along streams, around swamps and on lagoon shores. The majority of sites are on slopes with a northerly aspect, the resultant of 41 sites examined in detail being north-northwest. This aspect offers both protection from westerly and southwesterly weather and efficient use of the sun's warmth. Sites are most prolific on dissected plateau slopes where streams are common and behind the coastal dunefields on sandy flats which also contain nearly all of Kangaroo Island's lagoons. Sites are notably absent on the undissected central core, the main plateau, on the Cygnet River flat and on the coastal

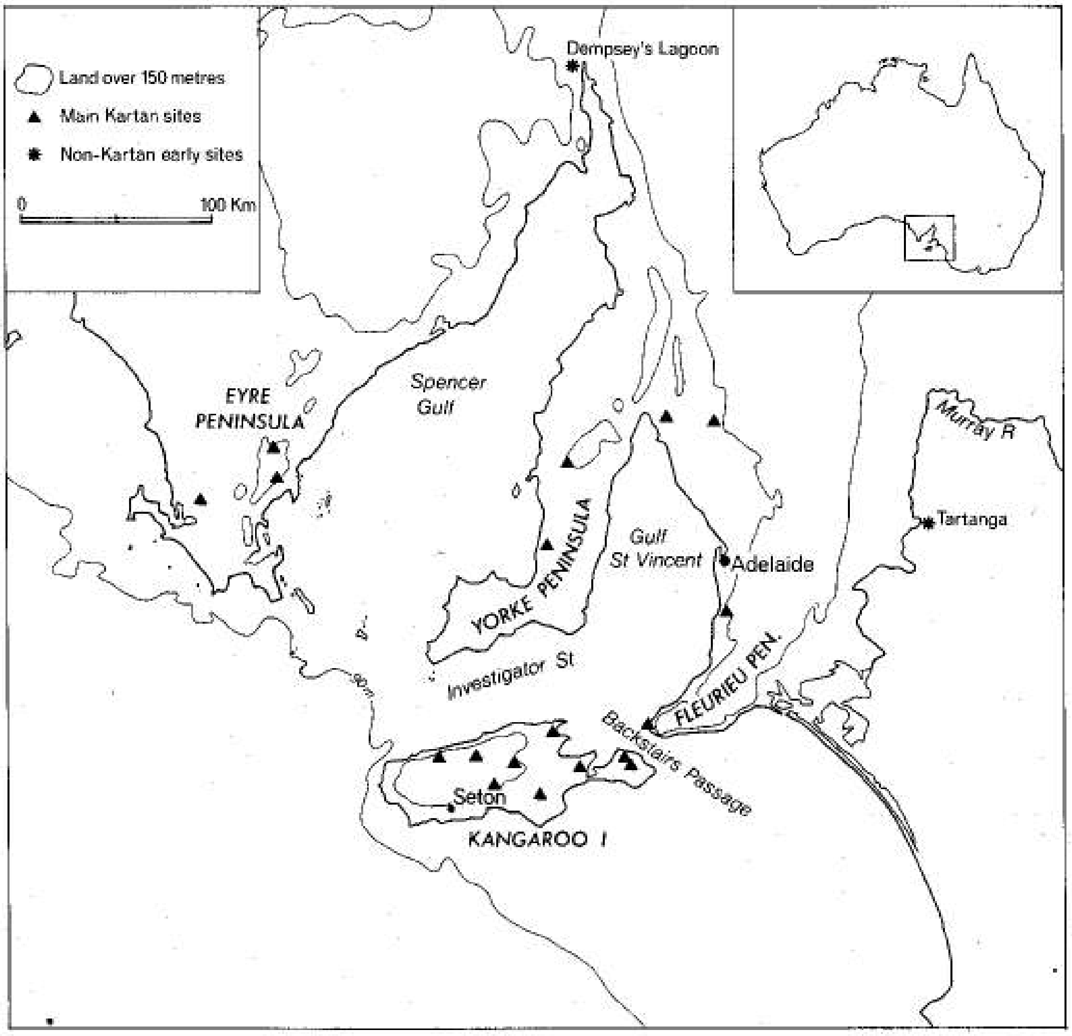


Fig. 1. Distribution of main Kartan sites on Kangaroo Island and nearby parts of the mainland. The 90 m submarine contour indicates the position of the shoreline 17000 years ago.

dune fields themselves. Sites are not concentrated along the present shoreline as for example are recent sites in several other Australian Coast regions.

KARTAN TOOLS

The tools that typify Kartan assemblages are core tools, made either on quartzite beach pebbles, or on blocks of quartzite obtained from exposures that occur over much of the island surface, particularly on the plateau.

Both forms of stone originate in the Kanmantoo Series. Compared with Australian tool assemblages generally Kartan tools are large, being described by Mulvaney (1975). The following different kinds of tool have been recognised:

Pebble tools. These are pebbles on which a sharp cutting edge has been formed by the removal of flakes along one side (Fig. 3). Pebble tools have a mean weight of just over 500 g.

Horsehoof series tools. These are basically loose blocks of stone on which a cutting edge has been formed by the removal of flakes (Fig. 3). They vary considerably in shape from tools flaked merely on one side to those flaked around the entire margin. Among the latter, two types are recognizable: a high-domed, steeply-trimmed tool known as the 'horsehoof core' and a flatter discoidal tool known as the 'karta'. However, the two sub-groups merge with each other and appear part of the same tool series. The mean weight of horse hoof tools is slightly less than 900 g.

Hammerstones. These are pebbles which are pitted around the edges through having been used as hammerstones (Fig. 3). Some have deeply pitted depressions indicating they were used also as anvils.

Steep-edged scrapers. Scrapers, made of flakes of quartzite or small blocks of quartz, are

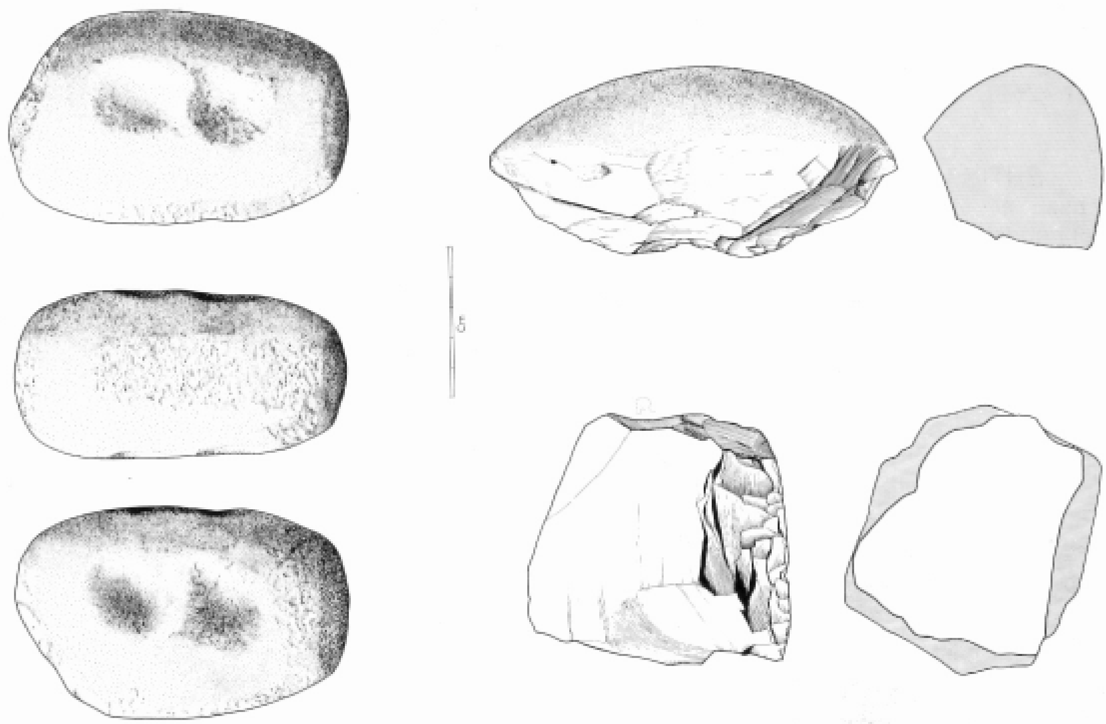


Fig. 3. The three main types of Kartan core tool: left, hammerstone; lower right, horsehoof core; top right, pebble tool.

overshadowed numerically by the much larger core tools described above. On some sites scrapers make up as much as 30% of flaked tools, but less than 10% is more usual, none having been found on several sites.

Waisted tools. These are large axe-like tools, with two opposed notches made presumably to facilitate hafting. They are made of flat slabs of quartzite on which the two main flat surfaces are natural fracture planes. The tools are found scattered near rather than actually on Kartan sites, the majority being loosely grouped around two major sites at Snug Cove and King George Creek.

Relative popularity of the principal tool form.

Pebble tools predominate numerically at most Kartan sites on Kangaroo Island, with horsehool tools being next in order of popularity. The relationship changes according to the distance inland. For sites lying near the coast, where beach pebbles are plentiful, pebble tools frequently outnumber horsehoof tools by more than five to one, whereas on some sites towards the centre 01 the island, pebble tools are outnumbered by horse hoof tools by more than two to one. This variation reflects the use of local stone as raw material for the heavy tools. It shows also that beach pebbles must have been the more popular form of stone, because pebbles had been carried up to at least 17 km inland, even though outcropping rocks of quartzite are plentiful near the sites on which the pebble tools were found. Further this pattern of distribution suggests that the two types of tool, being related to the form of local stone, replace each other in the tool kit and are therefore functionally the same.

Function of Kartan tools

Studies of stone tools among living Aborigines elsewhere in Australia suggest that the large pebble and horsehoof tools were used for heavy woodworking tasks, such as chopping. Probably their role in the economy was in manufacturing the wooden weapons, utensils, and possibly huts, necessary for sustaining life among nomadic hunters and gatherers on Kangaroo Island.

Geographical limits of the Kartan industry

As already noted, the pebble tool is the typical heavy implement of Kangaroo Island, although horsehoof tools made of large blocks of outcropping stone are also fairly common. On nearby parts of the mainland, pebble tools are rare and are numerically overshadowed by horsehoof tools, this variation probably resulting from differences in the forms of raw material available. As well as the mainland Kartan sites already mentioned, on the Fleurieu Peninsula and north of Adelaide, others have been found on both the Yorke and Eyre peninsulas.

The visual similarity of these tools across the region has been tested by comparing statistically between large samples of the tools, drawn from various localities, in terms of such characteristics as length breadth, height, weight and angle of the cutting edge. No significant differences were found despite a wide variety in the types of rock that had been used for tool making. The implication of these results is that Kangaroo Island and the nearby peninsulas of the mainland formed a single cultural unit at the time Kartan tools were in use (Lampert 1980).

Further afield, several Kartan sites have been noted in the northern Flinders Ranges. One of these is Hawker Lagoon, a stratified site in shoreline deposits of a small ephemeral lake, where excavations revealed a sequence of two industrial traditions (Lampert & Hughes 1980). Large core tools made on blocks of local quartzite, and with characteristics identical to those of Kangaroo Island horsehoof tools, predominate in the earlier occupation level, dated to c.15 000 B.P. Above this is a stratigraphic disconformity indicating an erosional phase before deposits of the upper horizon began to accumulate. This later phase of deposition began around 5000 B.P. and continued into the early years of European contact, after which pastoral activity induced a new erosional regime. The upper horizon is characterised by a suite of small tools that includes tula adze, pirri, geometric microlith, thumbnail scraper and reniform slate scraper; small tools typical of this part of the Australian mainland.

Hawker Lagoon exemplifies a change in stone tool technology that occurred over much of Australia around 3500 - 5000 years ago, in which an earlier core-tool and scraper tradition was followed by one characterised by small tools. Usually the small tools augment rather than replace the earlier tools, which continue in use though in declining numbers. At Hawker Lagoon this change appears unusually abrupt because of an absence of material falling between the dates of 15 000 and 5000 B. P.

The Northern Flinders Ranges are on the fringe of the inland desert region and some 400 km to the north of Kangaroo Island. Despite this distance, Lampert & Hughes (1988) suggest a relationship between the two regions which may explain the typological similarity of their Kartan tools. The regions lie at opposite ends of a continuous chain of uplands that begins north of Hawker, extends through the Flinders Ranges, through the Mount Lofty Range, and continues south along Fleurieu Peninsula to Kangaroo Island. The identical nature of Kartan core tools over this upland chain suggests a cultural linkage along which techno-logical ideas freely passed. This view is supported by the absence of such tools from the surrounding plains and the dissimilarity between them and core tools from more distant parts of Australia and beyond.

EXCAVATED SITES

In an attempt to find the age of the Kartan industry, and to seek associated faunal and plant remains that might indicate the kind of economic life of people who used the tools, several occupation deposits were excavated.

Seton Site

The first of these deposits was below a small overhang at the mouth of Seton Cave, which stands on the shore of a small semi-permanent lagoon (Lampert 1972, 1978; Hope *et al*. 1977). Deposits nearly 2 m deep revealed two phases of human occupation separated by a period when the sole use of the cave appears to have been as a carnivore's den (Dasyuridae). The early occupation phase which took place about 16 000 years ago, was merely a fleeting visit to the cave by people who left behind only one small scraper and a few tiny flakes of flint to mark their brief residence. They might have preyed upon the now extinct kangaroo Sthenurus sp., the bones of which were found in and around the level that contained flaked stone.

The late phase of human occupation, which occurred around 11000 years ago, was much more intensive, being denoted by several thousands of pieces of flaked flint and quartz and numerous smashed and fire-blackened bones of animals, mostly of the modern grey kangaroo, *Macropus* *fuliginosus*, which were the prey of humans. Marine molluscs, which must have been carried to the site from a shore then 16 km away, and numerous fragments of emu egg shell, show that the economic pursuits at Seton were not confined solely to the hunting of large animals. Despite the large amount of flaked stone recovered by excavation, not one of the large Kartan tools was found in the deposit. All the finished tools from Seton are small scrapers and adzes made on flint and quartz.

Pigs Water Hole

This site is an occupation deposit within a sheet of quartzite sand surrounding a small, permanent water hole. No charcoal to indicate antiquity, bone to reveal the economy, nor other organic remains were found, and the interpretation of human activity at the site depends solely on the stone tools recovered. Most of these are small scrapers and adzes of quartz and flint and are indistinguishable therefore from the tools found at Seton. However, Pigs Water Hole also yielded a suite of pebble tools that are significantly smaller than those of Kartan industries in the same level as the adzes and scrapers.

Rowells

Rowells is an extensive site on a bank of the Cygnet River, dated to about 5300 B.P., and characterised by scrapers and adzes like those found at Seton and Pigs Water Hole.

Sand Quarry

This site consists of an occupation level buried within the Holocene shore deposit of a formerly extensive lake, represented today by two shrunken remnants, White Lagoon and Rush Lagoon. A carbon date from the basal beach deposit beneath the occupation level shows that the lake was full more than 7000 years ago. These conditions persisted until at least 4300 years ago which is the date obtained from charcoal in the occupation horizon and marks also the end of the accumulation of beach sand. The Sand Quarry site is important not only because it contains evidence for a wetter climate in early Holocene times (ct. Bowler et al. 1976), but also because it provides the latest definite date for Aboriginal occupation on Kangaroo Island. Within the occupation level was a stone industry consisting of small scrapers and adzes indistinguishable from those found at the sites discussed above.

Coastal sites

There are shoreline sites, with marine shellfish, at Cape Cassini, West Bay, Cape du Couedic, Bales Bay and Pennington Bay. This evidence for the exploitation of marine foods also indicates that the sites have an antiquity postdating the arrival of the sea at about its present level, 6000 years ago (ct. Thom & Chapped 1975). Where flaked tools are present they consist of small scrapers and adzes, as found at the sites already described.

A few years after my research further investigation on the island by Draper (1987, 1988) produced the following results.

Cape du Couedic

The site is a spacious rockshelter in a coastal cliff that overlooks a narrow beach at the western end of Kangaroo Island. In two seasons of excavation Draper unearthed a rich and extensive human occupation deposit dating from 7500 B.P. to 6800 B.P. Food remains include those of Grey Kangaroo, Tammar Wallaby, Sea Lion and several species of marine shellfish. Of the several thousands of flaked stone artefacts recovered from the site, most are simple flakes of quartz, limestone breccia and quartzite. Other artefacts include scrapers and adzes made of flakes, and two Kartan pebble tools.

The time of occupation appears to be related to the post-glacial rise in sea level. Occupation began some 7500 years ago, when rising seas brought such marine resources as fish, Sea Lion and shellfish within reach of the site, and ceased around 6800 years ago when a further rise in sea level made the beach at the foot of the cliff too narrow for access to the shore.

RELATIONSHIP BETWEEN THE KARTAN AND THE SMALL TOOL INDUSTRIES

Archaeological association

At only one site, Cape du Couedic, was an apparent association found between the two industries, two large pebble tools being present among a number of small tools. At all other excavated sites on Kangaroo Island (Seton, Rowells, Pigs Water Hole, Sand Quarry, Rainy Creek) numerous small tools were found without a single Kartan tool in association, despite the presence of many Kartan tools on surfaces sites not far away. From this evidence it would appear that the two kinds of stone industry were not closely related, an explanation for which will be sought by examining a range of models of human behaviour. Further afield on the other hand, Kartan tools are clearly older than small tools at Hawker Lagoon.

Chronology

Small tools have been dated to 11000-4000 B.P. on Kangaroo Island, and possibly date back to 16000 B.P. at Seton, although there is insufficient stone in the early level to identify the industry conclusively.

The Kartan dates back to c. 15000 B.P. at the mainland site of Hawker Lagoon, where horsehoof tools are a dominant component of an excavated assemblage. Two Kartan pebble tools were excavated from levels dated to c. 7000 B.P. at Cape du Couedic but have a low numerical representation within an assemblage of thousands of stone artefacts. The close similarity between

Kartan tools on Kangaroo Island and the nearby mainland, and the c. 15 000 B. P. date for Hawker Lagoon, together suggest that this industrial tradition reached the island before it was isolated by rising post- glacial seas about 9500 years ago.

Explaining the different industries.

From studying both living hunter gatherers and broadly-based archaeological evidence, several models of human behaviour were examined. Of these, two alternatives each provide a possible explanation for the division between Kartan and small tool sites on Kangaroo Island.

The first postulates a group of people occupying the two kinds of site for different activities which consequently require different stone tools. An example (Hayden 1979) comes from central Australia, where Pintubi people were observed using large, hand-held chopping tools (for which a parallel may be seen in those of the Kartan) to procure pieces of wood from groves of suitable trees. The wood was then taken back to the main camp and shaped into a weapon or utensil with such smaller tools as hand-held scraper and hafted adze, both of which are comparable to the small tools in question. The activities left two kinds of site: camp sites in which small tools were clustered among other occupational debris, and wood procurement sites where heavy chopping tools were spread thinly among groves of trees.

Given the high probability that Kartan core-tools were also heavy woodworking implements and the small tools were used for lighter work, this could be seen as an adequate model for Kangaroo Island in broad general terms. Indeed it is the kind of explanation favoured by Draper (1988) who sees in the evidence from Kangaroo Island a single Aboriginal adaptation with varied patterns of land use and technology. It must be noted however that the Pintubi model does not allow an exact explanation for Kangaroo Island where the heavy tools are concentrated in favourable camp site locations rather than the more scattered distribution to be expected from wood procurement.

If confronted with only the evidence from within Kangaroo Island, I too might favour the explanation above. However, reference to the more widespread Australia evidence prompts me to give greater consideration to an alternative explanation, namely that most of observed variation results from a difference in age. Indeed the evidence from Kangaroo Island fits neatly into the pattern of change, from core-tool tradition to small tool, found at a number of Australian sites.

Apart from the difference between the two traditions, the process of change provides some telling evidence. As has been generally noted (Lampert 1980; Lorblanchet & Jones 1979), the change was gradual, with incoming small tools arriving at varying dates to augment rather than replace the heavier tools, which continue in use albeit in lesser numbers. Also, a gradual reduction in average tool size was already taking place in the earlier tradition before the more noticeable and easily recognisable formal types of small tool arrived.

Under this hypothesis, the Kartan industry with its predominance of the core-tools, is a regional variant of the core-tool and scraper tradition and dates back into Pleistocene times. At Cape du Couedic, where two heavy core-tools were found within an industry in which small tools predominate, the transition is well on the way. At Pigs Water Hole which, arguably, is of early Holocene age, core tools have become smaller and diminish in number later in the sequence to be replaced by small flake artefacts. At Rowells, Sand Quarry and Rainy Creek, all late Holocene sites, only small tools are present. Formal types of small tool, which appear only during the mid to late Holocene at mainland sites, did not reach Kangaroo Island because it was by then isolated.

This is seen as the process of change which produced the main industrial variation on Kangaroo Island. However, it is a view that does not seek to deny that there were also differences between sites, where at anyone time the technology of the day was adapted to take account of such local environmental concerns as availability of raw materials and the types of food being exploited. To give one example, these factors are seen to account for the difference in technology between Cape du Couedic and Pigs Water Hole, sites which appear to be broadly contemporary but are located in different environments.

WIDER AFFILIATIONS OF THE KARTAN INDUSTRY

At a broad level of comparison the Kartan industry of Kangaroo Island and adjacent areas on the mainland is part of the more widespread Australian core tool and scraper tradition. However, when compared more closely, the industry shows enough individuality in its greater emphasis on heavy core tools to mark the region as a distinct culture area within the early Australian tradition.

Beyond Australia, Kartan pebble tools, as well as pebble tool industries in northern New South Wales had been likened by some archaeologists to the Hoabinhian I industry of Southeast Asia, in which pebble tools also predominate. This view became less acceptable after detailed studies of the tools showed no close resemblance between Australian and Hoabinhian pebble tools (Matthews 1966). However, the more recent discovery of waisted tools on Kangaroo Island raises again the possibility that links beyond Australia are indicated, since waisted tools were found associated with pebble tools at the Hoabinhian site of Sai Yok in Thailand (Van Heekeren & Knuth 1967), and, moreover, are known from such intervening regions as north Queensland and New Guinea, where the earliest examples so far directly dated were found in 26 000-year-old levels at Kosipe in the Papuan Highlands (White et al. 1970).

The geographical distribution and probable antiquity of waisted tools suggest that they may represent an early migration of people from Southeast Asia through New Guinea into Australia during low sea level times of the last glaciation. If waisted tools do have this association, we might ask why the migration of people into Australia from a northerly point of origin is evidenced so strongly on a part of the southern fringe of the continent, and concentrated particularly on what it is today an off-shore island. An answer to this question may be seen in the locational characteristics of Kangaroo Island. During the time of Pleistocene low sea level, the Aborigines were probably concentrated along the now submerged ancient shore line, just as the densest Aboriginal populations at the time of European contact were found on the present day littoral. Kangaroo Island was once a high piece of land on the ancient coastal shelf and today is one of its few remnants still above sea-level. Also, and perhaps more importantly, Kangaroo Island was situated near the mouth of the ancient Murray River, the lower course of which during glacial times extended about 70 km further to the southwest, passing less than 10 km from the eastern tip of Kangaroo Island and-meeting the sea 20 km south of Cape Gantheaume the island's most southerly point (Sprigg 1963; Parkin 1969). Moreover, as a result of more effective precipitation during glacial times, the discharge rate of the Murray appears to have been several times greater than it is today (Pels 1964; Bowler *et al*. 1976). Just as today's Murray mouth and lower reaches of the river are a rich resource zone, supporting a high Aboriginal population in recent years, so too must the ancient mouth have been an important focal point, perhaps relatively more important because of the river's higher rate of discharge.

Studies of recent Aborigines suggest that the highest population would have been along the shores of the estuary and lower reaches of the river, with the immediate inland being exploited economically through forays by people more regularly domiciled on the shoreline. Because Kangaroo Island in glacial times was a high area of the coastal shelf adjacent to the Murray estuary, the Kartan industry is most likely the archaeological expression of such inland forays, conducted to exploit land resources that supplemented those of the estuary and its shores. One pursuit during these expeditions might have been the hunting of such game as the larger marsupials, perhaps including 5thenurus which was extant locally as recently as 16000 years ago.

THE DEMISE OF THE ABORIGINES

Dating.

Despite having been a particularly favourable human habitat during the late Pleistocene, Kangaroo Island was entirely bereft of an Aboriginal population when the first Europeans arrived on its shores. As has been noted already, the island was isolated from the mainland some 9500 years ago, and archaeological sites show that Kangaroo Island was occupied at several dates during isolation until as recently as 4300 years ago. Evidence from a pollen core at Lashmars Lagoon shows that a marked change in the burning pattern of the island's vegetation occurred about 2250 years ago (Clark 1976; Clark & Lampert 1977). Before that date there was a low but regular accumulation of carbonised particles, consistent with the Aboriginal practice of maintaining constant fire pressure on the bush (ct. Jones 1969). After 2250 years ago there are enormous fluctuations in the rate of deposition of charcoal at Lashmars Lagoon, evidencing a change in the burning regime which Clark & Lampert (1977) interpret as having occurred through the release of Aboriginal fire pressure on the vegetation. A regime of relatively infrequent fires with natural causes would have allowed an alternation of huge accumulations of forest litter, which were consumed periodically by immense fiery holocausts. Thus the change in burning about 2250 years ago could mark the end of Aboriginal life on Kangaroo Island.

Was the island revisited?

The question of whether the recent archaeological sites on Kangaroo Island result from an isolated Aboriginal population, or from sporadic visits by watercraft from the mainland, cannot be answered conclusively on present evidence. On the one hand, as Jones (1977) points out, there are social and demographic arguments against such a small population, perhaps less than the theoretical estimate of 450, maintaining itself in physical and cultural isolation for at least 5000 and possibly as long as 7000 years. On the other hand, the arguments against crossings to Kangaroo Island from the mainland include: the absence of suitable watercraft among recent Aborigines; unfavourable winds and currents throughout most of the year and indications that these conditions have not changed significantly within Holocene times; evidence from the Lashmars Lagoon pollen core for continual Aboriginal pressure on the vegetation 7000-2250 BP and, perhaps more significantly, the complete absence of any of the new types of small tool (pirri, tula, backed blades) that appear, often profusely, on the mainland around 5000 years ago, or even of a single fragment of the specially transported fine grained stone on which these tools were often made.

On balance the evidence is weighted slightly in favour of a relict population rather than visits to the island since isolation. However, accepting this hypothesis as being more likely entails the introduction of new propositions to explain the extinction of Aborigines on Kangaroo Island.

Environmental deterioration.

Other writers who have faced the problem of extinction of the Kangaroo Islanders suggest a number of alternative explanations that include warfare, drought, bushfires, disease, and trace element deficiency. Any of these is possible, but all are based on conjecture rather than real evidence. However, the following evidence points to a deterioration in Kangaroo Island as a human habitat during the Holocene, which might have been a contributing factor in the proposed extinction.

With the post-glacial rise in sea level, the Murray mouth retreated northeast-wards across the continental shelf until, by about 9500 years ago, the sea invaded the Backstairs Passage and separated the Kangaroo Islanders from the richest resource zone within their ambit. Probably by then a reduction in the island's population towards a new equilibrium had already taken place, since many people would have followed the retreating Murray mouth. For those who remained on the island some compensation was offered by a lengthened coastline (proportional to land area) and an increase in the productivity in the land itself that must have accompanied the onset of warmer and wetter conditions evidenced from the period 7000-4000 B.P. However, around 4000 years ago a more arid regime began, as shown on Kangaroo Island by falling water levels at White Lagoon and a change in vegetation towards drier shrubs at Lashmars Lagoon. Conditions became pro- gressively drier until about 2000 B.P., that is, not long after the times for which Carbonised particle counts from Lashmars Lagoon indicate a change in the burning regime, due to the cessation of Aboriginal fire pressure on the vegetation.

Because the cessation of Aboriginal activity on Kangaroo Island appears to coincide with climax of arid conditions, it seems likely that deterioration of the environment played a part in the extinction of the island's putative relict population. However, other factors such as demographic imbalance of sex and age ratios, and perhaps shorter term environmental disaster, may have also played a role, particularly if coincident with the period of greatest aridity.

To give an example, the following course of events may have taken place. With the onset of aridity the productivity of the land diminished, causing the population size to be adjusted downward. A smaller population is more likely to be adversely affected by the usual fluctuating demographic imbalances, that occur randomly through time, notably in sex and age ratios. Under such conditions there must have been a time when females of child-bearing age were fewer than usual. A catastrophe, not insurmountable to a larger population, may then have occurred, such as a group of younger women being swept off the rocks and drowned while fishing. With numbers of such women already reduced this could well have caused the population to drop below survival level.

8: Terrestrial Mammals

by ROBERT W. INNS

There are currently eighteen species of native terrestrial mammals on Kangaroo Island: two species of pygmy possum, one marsupial mouse, two kangaroo species, three native rats, a bandicoot, the Common Brushtail Possum, Echidna and seven bats. A further six native species have been introduced to the island of which three, the Platypus, Koala and Ring-tail Possum, became established and are still present today. The other three species, the Burrowing Bettong, Hairy-nosed Wombat and the Wallaroo or Euro were only released in very small numbers and did not become established.

Five species of non-native mammal have also become established on the island, the Goat, Cat, House Mouse, Black Rat and Pig. In addition, feral deer have also been reported recently as having escaped from deer farms (Willoughby *et al*. 2001).

Two species of native mammals have become extinct since European settlement, the Native Cat or Quoll (*Dasyurus* spp) and the Brush-tailed Phascogale (*Phascogale tapoatafa*) (Robinson & Kemper 1999). On the basis of accounts from wallaby trappers Wood Jones (1925) believed that the Eastern Quoll (*Dasyurus viverrinus*) was still present on the island at the time of European settlement. However, as no specimens were collected and because bone material from cave deposits of both the Eastern Quoll and the Tiger Quoll (*0. maculatus*) have been found, the actual species that was present remains unknown. While the presence of the Brush-tailed Phascogale is based on only one report of a sighting in 1839, bone material of this species has been found in cave deposits suggesting that it could well have been part of the mammal fauna at the time of settlement.

A new addition to the mammal fauna was found recently when a specimen of the Heath Rat (*Pseudomys shortridgei*) was identified in January 2000 after reexamination of a sample of Swamp Rats (*Rattus lutreolus*) collected in 1967. Further survey work is required to determine if this species is still extant on the island. The Heath Rat occurs in western Victoria and the south west of Western Australia and the specimen identified from Kangaroo Island is the first record of this species for South Australia. Further specimens have now been found on the mainland just inside the State border in the Glenelg River region (Mark Bachman pers. comm. 2001). This species was once more widely spread in South Australia as it is also known from undated sub-fossil material from the Nullarbor, Eyre and Yorke peninsulas, Kangaroo Island and the South East.

The first European encounter with Kangaroo Island mammals occurred during Matthew Flinders' voyage of exploration of the southern coast of Australia in the Investigator. He sighted a large island situated across the entrance to Gulf St Vincent on 21 March 1802 and the next morning, on approaching the shore, several kangaroos were seen. Flinders (1814) recorded that ' ... a number of dark-brown kanguroos [sic] were seen feeding upon a grass flat by the side of the wood; and our landing gave them no disturbance. I had with me a double-barrelled gun, fitted with a bayonet, and the gentlemen my companions had muskets. It would be difficult to guess how many kanguroos were seen; but I killed ten, and the rest of the party made up the number to thirty-one, taken on board in the course of the day; the least of them weighing sixty-nine, and the largest one hundred and twenty-five pounds. These kanguroos had much resemblance to the large species found in the forest lands of New South Wales; except that their colour was darker, and they were not wholly destitute of fat. .. '.

It was in gratitude for such a plentiful supply of fresh meat that Flinders named this southern land Kangaroo Island. These animals were Kangaroo Island Grey Kangaroos, *Macropus fuliginosus fuliginosus*, an island subspecies of the Western Grey Kangaroo. Flinders and his crew were not the only Europeans exploring the southern coast at around this time as the Frenchman Nicolas Baudin in the Geographe also briefly visited the island after meeting with Flinders at Encounter Bay on 8 April 1802. Baudin visited the island again in January 1803 and this time the French captured twenty seven kangaroos alive and some of these eventually made the journey to Paris arriving on the Geographe in March 1804 (Brown 2000). A few years later in 1817 one of these animals was used as the type specimen for the scientific description of this species at the Museum of Natural History in Paris.

While little is known about the ecology of *M fuliginosus fuliginosus* on the island, their reproductive biology has been studied by Poole (1976). Males and females become sexually

Fig. 1. Kangaroo Island Wallaby, Macropus eugenii (photo: P. Aitken).

Fig. 2. Echidna or spiny anteater, Tachyglossus aculeatus (photo: P. Aitken).

mature at around 20 months of age. The gestation period is 31 days and births occur in all months of the year, although they are more frequent during the summer. The young remain in the pouch for 40-45 weeks. These animals are seldom seen during the day because of their rather shy and retiring nature. However, in Flinders Chase National Park some of the kangaroos have become accustomed to people visiting the park and they are quick to gather around buses and cars seeking food from the tourists.

During Flinders' visit to the island several other smaller Kangaroos were also shot and it was noted that these appeared to be a different species. These animals are now known to be the Tammar Wallaby, *Macropus eugenii*, the only other kangaroo species present on the island (Fig. 1). The Tammar Wallaby was once quite common on the mainland of South Australia, particularly on the Adelaide Plains, Mt Lofty Ranges and on Eyre Peninsula (Finlayson 1927). It also occurs in the south-west of Western Australia and on some off-shore islands but its distribution and abundance have been considerably reduced. Habitat destruction and predation by foxes has had a considerable impact on this species and it is now extinct on the mainland of South Australia. However, it has recently been confirmed that it was the South Australian mainland form of the Tammar Wallaby that was introduced to Kawau Island, New Zealand, where it is still so common that numbers are controlled (Taylor & Cooper 1999). There are plans now being developed by the South Australian Government to reintroduce this animal to the South Australian mainland.

The Tammar Wallaby has an interesting reproductive cycle. There is a distinct breeding season with most young being born in late January and early February (Andrewartha & Barker 1969). Following the birth the females mate again and the fertilised egg resulting from this mating develops only to the stage of a hollow sphere of cells, called a blastocyst, which then lies dormant in the uterus (Berger 1966). If the pouch young is lost or removed this dormant blastocyst will resume development immediately and another young is born 26-27 days later. However, this will not occur if the pouch young is lost between June and December. Usually, the first pouch young is reared successfully and remains in the pouch for 8-9 months, emerging around October. The dormant blastocyst does not resume development at this time but recommences a few days after the summer solstice, or longest day on 22 December (Berger 1970). The cycle is completed by the birth of another pouch young about a month later.

Some aspects of the ecology of this animal have been investigated on Kangaroo Island. The daily and seasonal movements of a group of wallabies was studied within Flinders Chase National Park using small radio-transmitters attached to collars (Inns 1980). The movement patterns of all the wallabies studied were very similar. They sheltered within dense scrub during the day, remaining fairly stationary, but at around dusk they began to move towards the edge of the scrub emerging just after dark to feed on more open grassed areas. Each wallaby radio-tracked had a well-defined home range which overlapped with the home ranges of other wallabies. There was no difference in the size of the home ranges of males and females but there was a seasonal variation with home ranges being larger in summer than in winter. Within each home range there was usually a core-area where more time was spent, especially during the day. The average size of the home range in summer was 42 hectares and in winter it was 16 hectares. It is believed that this difference is related to seasonal changes in the availability and quality of their food. Studies of marked animals revealed that these wallabies have a high reproductive rate with more than 90% of females producing young each year, although there is also a quite high mortality rate of juvenile animals over their first year after emerging from the pouch (Inns 1980). Once they survive their first year, however, they fare much better and can be quite long lived with some females reaching 14-15 years and males to around 11-12 years (Poole *et al*. 1988).

While both species of monotreme occur on the island, only the Echidna or Spiny Ant-eater (*Tachyglossus aculeatus*, Fig. 2) is native. Augee *et al*. (1975) studied the movements of echidnas, fitted with radio transmitters, in Flinders Chase. They found that echidnas are solitary animals for most of the year but did have a definite home range, of about 800 m diameter, which could overlap with the home-range of other individuals. More recent work has shown home ranges varying in size from around 40 hectares to 150 hectares (Rismiller 1999). Nest sites range from purpose dug burrows to shallow depressions beneath bushes or fallen debris and occasionally a hollow log. Activity seemed to be influenced by temperature, the animals often being inactive during cold, wet periods. The Echidna breeds once a year (Griffiths 1972) with courtship and mating occurring between May and September. During this time males actively search for sexually active females and several males may follow the female and compete to mate with her. These mating groups of echidnas are known as 'trains'. About three weeks after mating a single egg is laid directly into the pouch that has formed on the animal's ventral surface just before the end of the gestation period. The egg takes around ten days to hatch and the young remains in the pouch for a further 50 days suckling on milk excreted from milk patches located on the mother's abdomen and within the pouch (Rismiller 1999). After this time the young are left in a nursery burrow while the female is out foraging for food. She returns for about two hours, every five to seven days to feed her young (Rismiller 1999). The young are weaned at about seven months of age by which time they have developed the characteristic spines of the adult and are able to forage for themselves.

In 1969, two specimens of a marsupial mouse or dunnart were collected in the north-central region of the island (Aitken 1972). This animal was a new record for the island and it was initially described as the Common Marsupial Mouse (*Sminthopsis murina*, Fig. 3). Subsequent studies of this species across Australia have revealed that the Kangaroo Island specimens are a separate species and it was renamed the Kangaroo Island Dunnart Sminthopsis aitkeni, after the late Peter Aitken, Curator of Mammals at the South Australian Museum (Baverstock *et al*. 1984; Kitchener *et al*. 1984). Since then only a few other specimens have been collected and little is known of its habitat requirements and conservation status. On current information it is regarded as endangered at both the State and National level.

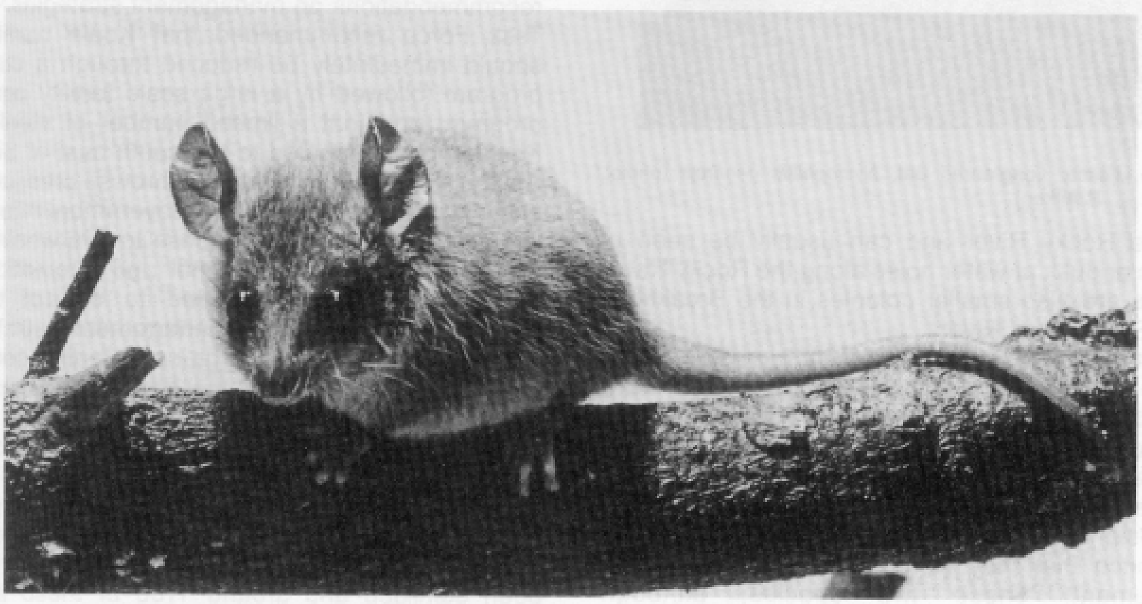
The Southern Brown Bandicoot (*Isoodon obesulus*) is considered to be a vulnerable species in South Australia but due to the lack of foxes on the island it is probably far more secure there than on the mainland. Little is known of these animals, although Wood Jones (1925) made some observations on them. Their teeth are adapted for an omnivorous diet, having flat molars as well as sharp canines. However, insects, arachnids and earthworms appear to be their main food and they scratch holes in the soil, particularly around the base of plants, to obtain them. The breeding season begins in winter, around June, and two or three litters of two to four young may be produced, As well as requiring areas of fairly dense scrubby vegetation with low ground cover the bandicoot also needs a mosaic of habitats created by fire, as this appears to provide more abundant food resources than areas which have not been burnt for a long period (Stoddart & Braithwaite 1979).

Two species of Pygmy Possum occur on Kangaroo Island. The Western Pygmy Possum (*Cercartetus concinnus*) is common throughout the island while the Little Pygmy Possum (*C. lepidus*, Fig. 4) is uncommon. Up until 1964 Little Pygmy Possums were thought to survive only in Tasmania but then a specimen was collected by Mrs I. Davis during burning-off operations near Karratta at the western end of the island (Aitken 1967,1974), Since then they have also been found in mallee-heath vegetation of southern South Australia and adjacent areas of Victoria and New South Wales. Pygmy Possums are insect and nectar-feeders and when food is abundant they can store fat in their tails and utilise this when food is scarce or during cold conditions. An interesting aspect of the physiology of Pygmy Possums is their ability to become torpid when exposed to low temperatures, or when food is scarce. Torpor is a means of conserving energy and involves a lowering of body temperature and heart rate, similar to the physiological changes that occur in hibernating animals. Because it is not as prolonged as hibernation they are able to spontaneously arouse from the torpid state. Little is known of their reproductive biology, but the Western Pygmy Possum can have up to six young (Ride 1970).

The Common Brushtail Possum (Trichosurus vulpecula*)* is extremely abundant on Kangaroo Island and, like the Kangaroo and Wallaby, it is probably one of the few native species to have benefited from agricultural development. These animals are larger than the mainland form and also spend considerably more time feeding on the ground due to the absence of foxes. Despite being largely vegetarian Common Brushtail Possums will eat a variety of foods and have been found to be a major predator of the threatened Glossy Black Cockatoo, taking both eggs and chicks. To prevent this, cockatoo nest sites are now being protected using sheets of iron on the tree trunks to prevent the possums from reaching the nests.

Of the placental mammals, the Bush Rat (*Rattus fuscipes*) is the most common and is widespread

3. Common Marsupial Mouse, *Sminthopsis murina* (photo: P. Aitken).



4. Little Pygmy Possum, *Cercartetus lepidus* (photo: P. Aitken).

across the island. A study of the ecology of the Bush Rat by Wheeler (1970) found that population numbers declined over the winter months during which time fungi and leaves were the main items of diet. The population increased rapidly and reached a peak in late summer and at this time the diet changed to mainly seeds with some insects. Breeding began at the end of October and continued until March or April. The Swamp Rat (*R. jutreolus*), another native rodent, has only been recorded from a few sites on the western end of the island where suitable swampy conditions occur (Taylor & Horner 1973; Robinson & Kemper 1999).

While there are records of eight species of bats on the island one of them, the Little Red Flying-fox (*Pteropus scapulatus*) is regarded as only an occasional vagrant (McKean & Simpson 1967). The other species found on the island are Gould's Wattled Bat (*Chalinolobus gouldii*), Chocolate Wattled Bat (*Chalinolobus moria*), Southern Forest Bat (Vespadelus regulus), Large Forest Bat (*Vespadelus darlingtoni*), Southern Freetail-bat (*Mormopterus planiceps*) and the Lesser Longeared Bat (*Nytophilus geoffroyi*, Fig. 5). There is also one record of the White-striped Freetail-bat (*Tadarida australis*) from Kangaroo Island (Reardon & Flavel 1987).

As mentioned earlier, three species of native Australian mammals introduced to Kangaroo Island have successfully established. The Platypus (*Ornithorhynchus anatinus*) was introduced into the Rocky River in Flinders Chase National Park with 12 animals being released in the period between 1928 and 1947. They have formed a viable colony

Fig. 5. Lesser Long-eared Bat, Nyctophilus geoffroyi (photo: P. Aitken).

in the Rocky River and can usually be seen at dawn or dusk at water holes along the Rocky River. There are also smaller colonies in the Breakneck and South West Rivers.

Ring-tail Possums (*Pseudocheirus peregrinus*) were introduced in 1926 when 15 animals were released in Flinders Chase National Park. They are now distributed throughout suitable habitat over the western half of the island but only in low numbers. While it is possible that the Ringtail was present on the island before this introduction there is no evidence that they were present at the time of settlement. These two species, although introduced, do not appear to have had any obvious adverse environmental impact. However, this is not the case for the other introduced native species the Koala (*Phascolarctos cinereus*).

Between 1923 and 1925 eighteen Koalas, plus some young, were taken to Flinders Chase where they formed a thriving colony. Later some animals were taken from this colony and established along the Cygnet River. Eberhard (1972) found that in Flinders Chase Koalas were distributed mainly around areas where the Rough-barked Manna gum (*Eucalyptus viminalis*) were growing. It was apparent that although they fed on other species of eucalypts such as South Australian Blue gum (*Eucalyptus leucoxylon*) and Swamp gum (*Eucalyptus ovata*) they preferred to eat some manna gum more or less regularly. The introduction of Koalas was prompted over concerns about a decline in numbers of Koalas in the south east of South Australia, the only part of this State where they occurred naturally. While the Koalas on Kangaroo Island flourished those in the south east of the State continued to decline and by the late 1930s they were considered to be extinct

Koalas now occur in all riverine habitats on Kangaroo Island where there are suitable food tree species and because of the high density of animals in some areas there are concerns that their browsing is having a devastating impact on trees such as Manna gum and Blue gum. In the mid 1990s surveys by National Parks and Wildlife SA indicated that Koala browsing was leading to increasing tree damage and the death of some trees. It was recognised that if the Koala population was not managed over-browsing would not only continue to kill trees and cause degradation of the riparian habitats but could also result in food shortage for the Koala population leading to starvation for many animals.

The South Australian Government established a Koala Management Task Force in 1996 to provide recommendations on management strategies. The Task Force recommended that Koala numbers should immediately be reduced through a culling program followed by a large scale fertility control program; and that a limited number of sterilized Koalas be translocated to the south east of South Australia to immediately reduce browse pressure in severely impacted areas. The Government rejected the option of culling in response to overwhelming public concerns, both national and international, that Koalas would be killed to control their population size. The management strategy approved was based on large-scale fertility control and the re-location of some koalas to areas of suitable habitat in the south east of the State. The management program, known as 'Koala Rescue', began in January 1997. The main focus of the management program has been in the Cygnet River area as this has been heavily impacted by Koala browsing. By 2001 nearly 3500 koalas have been sterilised and around 1100 of these have been relocated to the south east of South Australia. In the Cygnet River area where the program has been mainly focused there has been a reduction in Koala density and birth rate and the vegetation has shown some signs of recovery. However, this program would need to continue for some time and be expanded into other areas on the island if the impact of Koalas on the vegetation is to be successfully managed.

Unfortunately a number of introduced mammals have become feral on the island. Both the Pig (*Sus scrofa*) and the Goat (*Capra hircus*) are common and cause damage to native vegetation. Cats (*Felis catus*) occur as feral animals and have probably had a considerable impact on the numbers and distribution of the smaller native mammals. Studies in the eastern states have shown that they prey upon marsupial mice, native rats and possums (Coman & Brunner 1972). The introduced rodents, the House Mouse (*Mus domesticus*) and the Black

Rat (*Rattus rattus*) are also found on the island, the former being abundant while the latter is mainly associated with settlements. Although the Rabbit (*Oryctolagus cuniculus*) was released on the island some time ago, luckily it failed to become established (Waite & Wood Jones 1927). On the mainland they cause immense environmental and agricultural damage and it is essential that the island is maintained as 'rabbit free'.

Kangaroo Island is South Australia's largest island encompassing over 440000 hectares and, with vegetation covering nearly half of the island, it provides a wide diversity of habitats for wildlife. Clearly the existence of large reserves of natural vegetation, such as Flinders Chase National Park. are necessary for the long term survival of many species but there is also a number of threatening processes operating that need to be managed if the island's biodiversity is to be conserved. Probably the most important factors threatening the survival of native mammals on the island at the present time are habitat fragmentation and degradation caused through clearance and grazing of vegetation. feral animals such as goats and pigs. invasion of weed species and the spread of the plant disease Phytophthora. Predation by feral cats is also likely to have an impact on the smaller mammals while the use of fire for managing habitat for a variety of species needs to be examined and appropriate fire regimes put in place.

9: Marine Mammals

by John Ling

INTRODUCTION

Knowledge of the marine mammals of Kangaroo Island has increased greatly since the first edition of this volume was published: so much so that a separate chapter on this group of mammals now seems appropriate. Detailed studies have been carried out in recent years on the fur seals and sea lions inhabiting the island and there is also new information on whales in adjacent waters and stranding on the island's shores.

Some of the island's earliest white settlers were sealers and whalers engaged in a thriving trade in seal skins and oil and "whalebone" (baleen) and whale oil more than 30 years before South Australia was colonised in 1836. Indeed, one of the chief objects at the time of settlement was to hunt whales off the coast. A small colony was established on Kangaroo Island for this purpose, even before South Australia was founded at Holdfast Bay on the mainland (Parsons 1986).

Marine mammals thus were an important part of South Australia's early history and today they continue to make a substantial, but indirect, contribution to the State's economy in a more passive and recreational sense. This can be gauged from the tens of thousands of visitors who flock to Seal Bay and Cape du Couedic each year to view the sea lions and fur seals at play in and out of the sea. Southern Right Whales are also being sighted more frequently with their calves off the coast of Kangaroo Island during the winter months and these attract many visitors to vantage points around the island, again with financial spin-offs to nearby tourist centres.

SEALS

In spite of its name, Kangaroo Island is now as justly famous for its seals as it was for its kangaroos in Matthew Flinders' time when he named the island. The sight of hundreds of sea lions on the beach at Seal Bay or fur seals on rocks below the cliffs at Cape du Couedic and Cape Gantheaume, so close and enticing to a major centre of population such as Adelaide, is certainly a rare treat for the nature lover and scientist alike. Stirling (1972) estimated that seals were worth $100000 annually to Kangaroo Island's economy. Today's figure would have to be 20 to 50 times that amount.

However, the economic value of the seals of Kangaroo Island, even before the colonisation of South Australia, was considerable. Escaped convicts from Hobart fled to Kangaroo Island, where they eked out an existence by exchanging seal and wallaby skins for food from passing ships. Sealing gangs from Sydney and Hobart also visited the island - some staying for a year or more before being picked up again - where they procured fur seal pelts for the lucrative Canton and British trades, sea lion hides and oil, and salt to cure the skins (Cumpston 1974).

The resident species of seals on Kangaroo Island belong to the family of eared seals (Otariidae): the New Zealand Fur Seal, *Arctocephalus forsteri*, and the Australian Sea Lion, *Neophoca cinerea*. Small numbers of the

Fig. 1. New Zealand Fur Seals, *Arctacephalus forsteri*, at Cape du Couedic. Photo: Advertiser Newspapers Ltd.,

Australian Fur Seal *Arctocephalus pusillus. doriferus*, also have been sighted at Cape Gantheaume and on both Casuarina Islets (Shaughnessy *et al*. 1994). Vagrant earless ("true") seals (Phocidae) occasionally visit but do not breed on Kangaroo Island. These include the Southern Elephant Seal, *Mirounga leonina*, Leopard Seal, *Hydrurga leptonyx*, and Weddell Seal, *Leptonychotes weddellii*. New Zealand Fur Seal, Arctocephalus forsteri (Fig 1).

This species occurs around New Zealand and the adjacent Subantarctic islands, and between longitudes 117°E and 145°E in southern Australia, with the main concentrations occurring between Kangaroo Island and islands of the Recherche

Table 1. FUR SEAL SKIN CARGOES BY DECADE FROM KANGAROO ISLAND: 1803-1912 (data from Ling 1999a)

Decade/Year	Number of skins	Average per year	Cumulative total	Cumulative percentage
1803-1810	25143	3143	25143	25
1811-1820	43005	4301	68148	68
1821-1830	26477	2648	94625	95
1831-1834	5016	1254	99641	100
1912	20		99661	100

Archipelago in southern Western Australia. In fact, the species' Australian distribution overlaps that of the sea lion (see Figs 1 and 2 in Ling 1999a), apart from a small population on Maatsuyker Island off southern Tasmania.

At the end of the eighteenth century and the beginning of the nineteenth, coastal explorers and navigators noted the teeming colonies of fur seals and sea lions ('hair seals') on many of the islands in Bass Strait and beyond to Kangaroo Island. These were quickly and ruthlessly exploited; seal skins and seal oil were among Australia's earliest exports. Records of these cargoes are now held in archives in the form of cargo manifests, ships' logs, letters and contemporary newspaper reports. There are numerous historical publications derived from this information - and in the present context, notably Cumpston's (1974) maritime history of Kangaroo Island - from which it is possible to gain some idea of those early seal harvests.

In a wide-ranging review of fur seal and sea lion exploitation in the Australasian region, Ling (1999a) estimated that almost 100 000 fur seal skins were harvested at Kangaroo Island between 1803 and 1834 (Table 1) - and that would have been a minimum figure. Kangaroo Island supplied over a quarter of the fur seal skins obtained in southern Australia and, with pelts fetching upwards of a pound sterling on the English market (Steven 1978), sealing was very profitable in early colonial times. It was, however, a short-lived industry, because the fur seal stocks had become severely depleted by the mid-1830s. Some fur seals were still being taken from caverns around the island's coast in 1844 (Nunn 1989), and Wood Jones (1925) reported that 20 were taken on North Casuarina Islet in 1912. They were not protected in South Australia until 1919 (Warneke 1982).

More recently, fur seals had been known to occur in the vicinity of Cape du Couedic for many years; and by 1975 up to 500 were present during the summer months, including a few blackcoated pups (Inns *et al*. 1979). The first recent sighting of fur seals at Cape Gantheaume was in 1972 (Shaughnessy *et al.* 1994). Today there are large breeding colonies at Cape Gantheaume, on the Casuarina Islets and at several localities around Cape du Couedic (Shaughnessy *et al.* 1995). These authors estimate that the Kangaroo Island population now stands at about 10000, with more than 2000 pups being born each year; and is at the 'recolonisation phase of growth with high rates of increase at individual colonies resulting from local immigration' (p. 201). This figure represents almost a third of the total New Zealand Fur Seal population in South Australia, estimated recently to be 34700 (Shaughnessy *et a*l 1994).

Fur seals prefer inaccessible rock platforms at the bases of cliffs which give them protection and easy access to the sea. They are very agile and move quickly on all fours over the rocks made slippery from breaking waves and flying spray, which also wash away the seals' natural products and keep the sites clean. Adult males range in length from 1.5 to 2.5 m and weigh between 120 and 180 kg, while females are from 1 to 1.5 m in length and 30 to 50 kg in weight. Pups weigh about 4 to 6 kg at birth (Goldsworthy & Crawley 1995). These dimensions are considerably smaller than those of the Australian Fur Seal, *A. pusillus doriferus*, which occurs in south-eastern Australia.

Breeding males begin to defend territories as early as mid-October, well before the first pregnant females arrive. Each harem comprises about nine females per territorial male. At Cape Gantheaume the annual breeding season lasts from late November to mid-January, with most births occurring in the 10 days centred on 21 December. The females are mated again about a week after giving birth and go back to sea a few days later. (Goldsworthy & Shaughnessy 1994); thus having fasted for about 10 days. Suckling lasts for several months, with the female returning to sea every few days to forage before resuming lactation.

The pups are born with a black coat, without guard hairs, which begins to be replaced at the first moult when the pups are about three to four months old, the whole process taking two months. The sleek new coat, consisting of guard hairs and fine underfur, is a tawny brown colour on the uppers and creamy yellow below, with silvery streaks around the head. Although the dark natal fur wets easily and a thick layer of blubber may not be developed, the pups do venture into the water. At first they play in tidal and wave pools on the rock platforms themselves. They also escape into the sea when being chased by researchers trying to tag them at the end of January, which may put them in some danger of being drowned. Later, as they grow stronger and more confident and, following the moult, there is an underfur layer as well as subcutaneous fat, they can and do spend longer periods in the ocean.

The sight from the cliff tops of hundreds of fur seals bobbing about and 'porpoising' in the huge waves that roll in onto Kangaroo Island's south coast during stormy weather is vivid testimony to their remarkable adaptations to life in the water. Fur seals must breed on land and feed in the ocean: they truly lead two ways of life.

Fig. 2. Breeding male and female Australian Sea Lions, *Neophoca cinerea*, at Seal Bay, April 1978.

Australian Sea Lion, *Neophoca cinerea* (Fig. 2).

This species was first described - albeit very briefly - by Francois Peron (1816) when he visited Kangaroo Island in 1802. He noted the smoky-grey colour of the coat which led him to ascribe the scientific name *Otaria* (later changed to *Neophoca*) *cinerea*. Matthew Flinders (1814) also encountered sea lions at Kangaroo Island in 1802, when one of his seamen was bitten on the leg by a large seal which he "attacked incautiously" (p. 184). Today Kangaroo Island's sea lions are arguably its most popular and important tourist attraction. They are also unique among seals in having a reproductive cycle that spans one and a half years instead of the usual annual cycle (Ling & Walker 1978; Higgins 1993; Gales et al. 1994; Gales & Costa 1997); and thus are the subject of much scientific research.

The present range of the Australian Sea Lion extends from the Pages in Backstairs Passage just east of Kangaroo Island to Houtman Abrolhos near Geraldton in Western Australia (see Fig. 2 in Ling 1999a). Stragglers are seen occasionally on the ocean beach along the Coorong in the South East of South Australia and there have been reports of sightings on the central coast of New South Wales (Iredale & Troughton 1934; Fulton 1990). Matthew Flinders (1814) saw fur seals and sea lions, which he called 'hair seals', on the islands in eastern Bass Strait; and there is also evidence from Aboriginal middens of their existence in north western Tasmania (Wood Jones 1925). The largest mainland colony occurs at Point Labatt near Streaky Bay in South Australia, and smaller colonies exist under the cliffs at the Head of the Great Australian Bight (Dennis & Shaughnessy 1996). Thus Neophoca cinerea covered and, if the stragglers are included, still covers much the same range as that of the two species of fur seals combined (see Figs 1 and 2 in Ling (1999a)).

In the course of harvesting fur seals the early sealers also took sea lions for their skins and oil; cargoes of several hundred "hair seal" skins sometimes appear among the more numerous and much larger cargoes of fur seal pelts shipped from Kangaroo Island. However, it would appear that the sea lion skin harvest amounted to no more than a few thousand. Only about 2000 can be accounted for in the historical records (Cumpston 1974); but many more may have been killed for their oil alone. Because the sources and specific identity of 'seal oil' are almost impossible to distinguish, the sea lion component cannot be determined. Nevertheless, their uncontrolled slaughter led to the extinction of sea lions from the north coast of Kangaroo Island and from all but the most inaccessible locations along the rugged southern coast (Robinson & Dennis 1988).

The current total size of the Australian Sea Lion population is estimated to be between 9300 and 11700, based on the most complete census carried out to date. Using the estimated number of pups (750) at Seal Bay on Kangaroo Island and on the North and South Pages, the total sea lion population here can be calculated by invoking a multiplier factor between 3.81 and 4.81, which gives figures of 3300 and 3600, respectively: about one third of the whole Australian population. The population at Seal Bay on Kangaroo Island alone ranges between 685 and 865 (Gales *et al*. 1994).

The Pages, where the majority of the island's sea lions reside, are low, rocky islands, whereas Seal Bay on the south coast consists of a series of sandy beaches backed by sandhills and low limestone cliffs in the eastern sector and rocky caves under sheer cliffs up to 100 m high to the west. Initially, the latter were Prohibited Areas under the National Parks and Wildlife Act, 1972, within the whole area which is known as the Seal Bay Conservation Park, seaward of which is also an Aquatic Reserve under the Fisheries Act, 1971. In recent years, the numbers of tourists visiting Seal Bay have increased so dramatically that members of the public are now not allowed onto any of the beaches used by sea lions as haul-out areas, unless accompanied by an official guide (Robinson & Dennis 1988).

Most births take place in the rugged western coves and the majority of pups, accompanied by their mothers, move in an easterly direction as they get older and are able to fend for themselves in the sea - since they would have to swim a kilometre or more in order to travel from the otherwise inaccessible breeding coves to other parts of Seal Bay. A series of length and weight measurements has revealed a general increase in the size of pups going east from a western breeding cove (Ling & Walker 1976).

Fig. 3 Australian Sea Lion pup a few weeks old (carrying a plastic tag no 149), April 1978.

The pups (Fig. 3) are born with a chocolate-brown to dark grey fur which is replaced at the post-natal moult, beginning at about two to three months of age and taking two months to complete, by the typical adult-type pelage of silvery or smoky grey above and creamy white below. Adult males tend to be a darker brown in colour with a characteristic creamy-white mane on the head and nape of the neck; which led to the name 'counsellor seal' being applied in earlier times (Wood Jones 1925). The fur of the Australian Sea Lion contains only coarse, flattened guard hairs; there is no fine underfur (Ling unpublished data).

Newborn pups range from 6.4 to 7.9 kg in weight and from 62 to 68 cm in length (nose - tail). Male pups are slightly heavier than females at birth. Pups double their birth weight in two to four months. Adult females range from 61 to 104 kg for a pregnant animal (average: 77 kg); and lengths range from 132 to 181 cm. Adult males may weigh from 250 to 300 kg and measure in excess of 2 m (Walker & Ling 1981).

Neophoca cinerea has a non-annual, non-seasonal breeding cycle of approximately 17.6 months duration, that shifts forward in time to 13.6 days earlier every 18 months. The pupping period lasts about five months (Higgins 1993). Females show great fidelity to birth sites, often returning to exactly the same spot in successive breeding seasons (Ling & Walker 1978). Moulting also takes place at 17- to 18-month intervals: females begin their moult about four months after giving birth, juveniles moult throughout the breeding period, and adult males start moulting about nine months after breeding ceases (Higgins 1993).

The lengthy pupping season, during which mating occurs, causes a high turnover of territories and disruption of any harem system. Instead, the Australian Sea Lion practises what is known as sequential polygyny which allows males access to several females in a season, but one at a time. Despite this, males of all ages indulge in aggressive behaviour which often results in injury or death to young pups unfortunate enough to be in the way, particularly of large, rampaging bulls.

Mating occurs about a week after the pups are born and the next birth occurs some 17 months later. Tedman (1991) demonstrated, for the first time, that embryonic diapause or delayed implantation takes place in this species - in common with all other seals so far studied. If foetal growth were to last the same length of time (7 - 9 months) as in other seals, there should be a free blastocyst stage of similar duration. However, Gales & Costa (1997) believe that diapause lasts only about 3.5 months (which is similar to other species of seals), and foetal development takes approximately 14 months (similar only to the northern hemisphere walrus).

Females suckle their young for 15 to 16 months, i.e. during almost the entire succeeding pregnancy, and weaning takes place only three to four weeks before the birth of the next pup (Higgins 1993). Thus there is a greatly extended period of maternal care in this species, during which time the females are most solicitous of their offspring. They have even been observed at Seal Bay apparently giving swimming lessons to their pups out beyond the breakers.

No fully-satisfactory explanation has yet been proposed for the 17- to 18-month breeding cycle that is unique to this species. Does it cause, or is it caused by, the prolonged lactation period? What is the significance of the 14-month foetal growth phase which follows a 'normal' 3.5-month free blastocyst stage? What other ecological/survival factors may be involved? Why, also, can the New Zealand Fur Seal, which is sympatric with the Australian Sea Lion, sustain a larger and expanding population in the same habitat?

Clearly the unusual reproductive cycle must have had survival value for the species during its evolution long before sealing began. The availability of resources is always likely to dictate the timing of reproductive events in animals, and in the case of Neophoca, whose resources appear to be limited, an endogenous reproductive cycle will be well-adapted to ecological conditions (Gales *et al*. 1994). The lengthy breeding cycle confers several advantages on the species' survival as follows:

- it results in an extended maternal association;
- a reduction in the rate of energy transfer from mother to young when food for the former is limited;

and

- achieves a normal growth rate, despite the low energy content of the milk (Kretzmann *et al*. 1991);
- small colonies with asynchronous breeding seasons mean the demands made by breeding sea lions on nutrient-poor waters are reduced and staggered;
- energy requirements of females are reduced and competition between females for scarce resources is also decreased; and
- the prolonged pupping season also means that large numbers of new animals are not suddenly

released onto a limited food resource.

Gales & Costa (1997, p.78) perhaps best summa rise the Australian Sea Lion's unique life history by stating 'the prime determinant for its reproductive cycle and behaviour is a nutrient-poor, stable marine environment in which seasonality offers no advantage to the temporal targeting of energetically expensive lactation'.

The cause and effect relationships of this unique breeding cycle will continue to intrigue scientists for some time yet. More research must be carried out, particularly on food availability, feeding strategies and competition with the New Zealand Fur Seal, before the life history of the Australian Sea Lion can be fully understood and explained.

Despite the fact that sea lion pelts were much less valuable than fur seal skins, *Neophoca* was hunted almost to extinction along with *Arctocephalus* (both species) in the nineteenth century. Yet sea lion skin harvests were much fewer and smaller than those of fur seals; although "seal oil" probably was procured from sea lions (as well as fur seals), resulting in more being killed than might be indicated by skin cargoes alone. This suggests that even in those days the sea lion populations around our coast were quite small, although the exact figure is beyond estimation. If they were abundant, it is difficult to imagine that the early sealers would not have taken them, at least for their oil which was itself a valuable commodity. Thus there may have been ecological factors already operating to keep the pre-sealing sea lion population at a low level.

Recent studies of the population genetics of the Australian Sea Lion have shown that the species throughout its distribution consists of many genetically discrete stocks, due largely to the very high level of female birth site fidelity (Campbell *et al*. 2001). This has important implications for past and present sea lion populations, because, once a colony has been wiped out either by sealers, tourist disturbance or, say, an oil spill, it will not be able to recover through recruitment from another colony. These colonies behave and must be managed as separate entities.

Adult male Australian Sea Lions, much-scarred and with very worn teeth, sometimes haul out along Adelaide beaches. These old animals are probably nearing the end of their 10- to 12-year life span and, having ceased breeding, moved out of the colony. They may have come from any of the five main breeding colonies in South Australia, with the Pages being the closest. *Neophoca cinerea* is a fairly sedentary species, although the extent of intra- and inter-island movements is not known precisely. One young sea lion tagged at Seal Bay was found dead (apparently from propeller injuries) at Port Vincent in Gulf St Vincent, some 160 km distant from its place of origin. Similarly marked sea lions have been seen at the "Seal Slide" in D'Estrees Bay to the north of Cape Gantheaume and at Cape Bouguer, east and west of Seal Bay, respectively, and at Snug Cove on the north coast (Ling & Walker 1976,1977,1979).

Fig. 4. Southern Elephant Seal, Mirounga leonina, near Cape Kersaint, January 1988 (possibly a mature female or an immature male). Photo: Terry Dennis.

Southern Elephant Seal, *Mirounga leonina* (Fig. 4)

There have been occasional visits by this species to Kangaroo Island. All have been solitary animals seen at Seal Bay (1977), Ravine des Casoars (1985) and near Cape Kersaint (1988). They are a Subantarctic species which may have visited Kangaroo Island more frequently when they inhabited King Island in western Bass Strait, where they were exterminated by sealers in the early nineteenth century (Ling 1999b).

Fig 5. Blue Whale, *Balaenoptera musculus*, in Nepean Bay, April 1987. Photo: Rob Davis.

Leopard Seal, *Hydrurga leptonyx*

These are true Antarctic forms which. occasionally haul out on Kangaroo Island beaches. They are fairly common visitors to the southern coasts of Australia, but are solitary and do not move around in packs.

Weddell Seal, *Leptonychotes weddellii*

This is a very rare visitor to Kangaroo Island from the Antarctic continent.

WHALES

Several species of whales (Order Cetacea) are either sighted around the coast of Kangaroo Island or strand along its shoreline. In particular, Southern Right Whales, *Eubalaena australis*, are frequently seen close inshore on the southern and northern coasts during the winter months, and females with calves have frequently been observed in some of the more sheltered bays. There have been several sightings of Blue Whales, *Balaenoptera musculus*, and Humpback Whales, *Megaptera novaeangliae*, off Kangaroo Island. A Blue Whale was photographed in Nepean Bay near Kingscote in 1987 (Fig. 5), and others were seen at Weirs Cove (1990) and West Bay (1993). (It is interesting to note the recent discovery of a Blue Whale feeding ground near Cape Otway in western Victoria and government moves to create a sanctuary in this region). Humpback Whales were seen at Stanley Beach (1988) and Flinders Chase (1993). Another interesting sighting was of a Beaked Whale, Beradius sp., at D'Estrees Bay in 1994, where it breached several times. Killer Whales, *Orcinus orca*, the largest members of the family Delphinidae, were often sighted around Kangaroo Island between 1982 and 1990 (Ling 1991). Bottlenose Dolphins, *Tursiops truncatus* sometimes wrongly called porpoises - are frequently seen swimming within a few hundred metres of the island. Common Dolphins, *Delphinus*

Fig. 6. Young female Minke Whale, *Balaenoptera acutorostrata*, stranded at Brownlow Beach in 1975. Photo: Peter Aitken.

Fig. 7. Adult Sperm Whale, *Physeter macrocephalus*, stranded at Snellings Cove in August 1974. Photo: Peter Aitken.

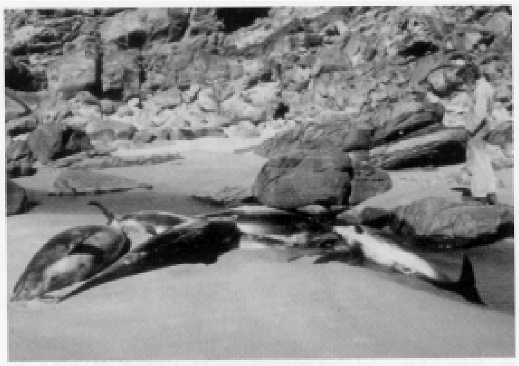


Fig. 8. Bottlenose Dolphins, *Tursiops truncatus*, stranded at Snug Cove, April 1985.

delphis, are also encountered in large numbers further out to sea off western Kangaroo Island.

However, most of our information about whales in the vicinity of Kangaroo Island comes from strandings. The South Australian whale strandings record from 1881 to 1989 (Kemper & Ling 1991) shows that 25 stranding events were recorded on the north coast and 16 on the south coast of Kangaroo Island. Twelve out of the 25 species of whales recorded as having stranded in South Australia have been found on coasts around Kangaroo Island. The recorded species, including new records since 1989, are as follows:

Family Neobalaenidae (Pygmy Right Whales)

Caperea marginata, Pygmy Right Whale: six specimens from the northern side of the island. The Pygmy Right Whale is restricted to temperate waters in the southern hemisphere but is rarely seen at sea.

Family Balaenoptera (Rorquals, i.e. with throat grooves)

Balaenoptera acutorostrata, Minke Whale (Fig. 6): two specimens from Nepean Bay (incorrectly identified in the earlier edition of this volume as B. edeni, Bryde's Whale). Minke Whales are widely distributed in tropical, temperate and polar waters of both hemispheres.

Megaptera novaeangliae, Humpback Whale: a sub-adult stranded near Seal Bay. This species breeds off the coasts of Western Australia and Queensland, but is seen occasionally in southern Australia.

Family Physeteridae (Sperm Whale)

Physeter macrocephalus, Sperm Whale (Fig. 7): the largest toothed whale, there have been six strandings of this species on the north and south coasts. A deep-diving species, it is distributed widely throughout the world except in polar regions.

Family Delphinidae (Dolphins and others)

Tursiops truncatus, Bottlenose Dolphin: there have been 13 strandings of this common species, one of

Fig. 9. Three Southern Right Whales, *Eubalaena australis*, at the mouth of Stuns'l Boom River on the south coast, 3 August 1985.

which involved 14 to 17 animals at Snug Cove on the north coast (Fig. 8). These dolphins occur close inshore and are probably the most frequently seen whale anywhere in the world.

Delphinus delphis, Common Dolphin: an offshore species of which there have been 11 strandings around Kangaroo Island, including one consisting of five animals at American River.

Grampus griseus, Risso's Dolphin: one specimen stranded near Willson River on Dudley Peninsula; but it tends to inhabit warmer temperate and tropical waters.

Globicephala melas, Long-finned Pilot Whale: two strandings on the south coast of this abundant species in cold temperate waters of both hemispheres.

Globicephala macrorhynchus, Short-finned Pilot Whale: two stranded on the south coast (another unidentified Pilot Whale also was found on the south coast). This is a warm temperate to tropical species.

Family Ziphiidae (Beaked Whales)

Mesoplodon grayi, Gray's Beaked Whale: two specimens stranded, one at Strawbridge Point, the other near Kingscote. This is a southern hemisphere, circumpolar species, possibly most abundant around New Zealand.

Mesoplodon bowdoini, Andrew's Beaked Whale: one stranding on the south coast. Confined to temperate waters of the South Pacific and Indian Oceans.

Mesoplodon layardii, Strap-toothed Whale: two strandings on northern parts of the island and two on the south coast. These whales are also restricted to the southern hemisphere with a circumpolar distribution.

Mass strandings involving more than three whales or dolphins are rare in South Australia, but there were two, as mentioned above, on Kangaroo Island, concerning both species of dolphins (Kemper & Ling 1991). Strandings may be classed as passive when whales are washed up moribund or dead; or 'active' .when live whales strand. Because so few strandings are actually observed, total figures for both active and passive events are consequently minimal. Overall, however, stranding and sighting records indicate that more than a dozen species of whales frequent the waters around Kangaroo Island. Because Kangaroo Island is close to the edge of the continental shelf, whales which generally frequent deep water, such as Sperm, Beaked and Pilot Whales, would be expected to occur around the island. Southern Right Whales, Eubalaena australis, are of growing interest as they are again appearing in apparently increasing numbers at many vantage points around the coast (Fig. 9), following reduction of the whole population almost to extinction by the mid-nineteenth century. Whaling was one of South Australia's earliest industries and whale oil among its first exports. The main prey were the Southern Right (or 'Black') Whale and Sperm Whale. There were at least three whaling stations on Kangaroo Island: at Hog Bay, Doyle's Bay near Point Ellen, and Flour Cask Bay at the northern end of D'Estrees Bay (Nunn 1989). These were bay whaling stations, in that the whales were pursued by crews operating small boats from shore-based factories where the whales were processed. Simpson Newland's (1893) novel 'Paving the Way' provides a first rate account of life at a nineteenth century whaling station near Victor Harbor. Whaling at Kangaroo Island lasted only from 1831 to 1844 and the total number of whales taken - the majority most probably being Southern Right Whales - is not known; but was unlikely to have been large. On the other side of Backstairs Passage at Encounter Bay, according to Hosking (1973), about 375 to 450 Southern Right Whales were taken between 1837 and 1872. The South Australian Museum has had a long interest in whales and possesses the largest collection of cetacean material, including much from Kangaroo Island, in the nation. Further information on whales in South Australia may be obtained from a recent Museum publication (Judd *et al*. 1993).

10: Birds

by DAVID C. PATON, JODY A. GATES AND LYNN P. PEDLER

INTRODUCTION

The dynamics of bird assemblages on islands played a pivotal role in the development of the Theory of Island Biogeography (MacArthur & Wilson 1963, 1967) which says that rates of extinction and colonisation of islands by bird species are related to: (1) the size of the island, and hence diversity of habitats, and (2) the island's isolation or distance from other islands and the mainland and hence sources for colonisation. The theory predicts smaller islands, and islands that are more isolated, will have higher rates of extinction and lower rates of colonisation. Thus smaller islands should support fewer species than larger and less isolated islands. Kangaroo Island, however, is a very large island and relatively close to the mainland, so local extinctions are unlikely and the need for subsequent re-colonisation limited. This does not mean, however, that there is no exchange of individuals between mainland and island but the exchange is probably limited to those species with moderate to good powers of dispersal (e.g. Abbott 1974).

Despite its size and its proximity to the mainland, there are fundamental differences in the avifauna of Kangaroo Island and the mainland. These differences have been brought about by a period of separation and isolation, and by differences in the pre- and post-European environments of the two regions, as well as differences in the extent and timing of vegetation clearance. Several species also have been introduced successfully to the island by humans.

Kangaroo Island was last connected to mainland South Australia about 8 900 years ago when sea levels were lower than they are today (Wells *et al.* 2001). With rising sea levels, ocean barriers effectively isolated many of the less mobile birds on the Island from their mainland counterparts. As a result of isolation, mainland and Island populations of even common birds like New Holland and Brown-headed Honeyeaters have evolved slight differences in morphology. As such, the birds of Kangaroo Island are unique and form an integral part of Australia's biodiversity. In fact many of the terrestrial birds on Kangaroo Island are now regarded as distinct subspecies (Schodde & Mason 1999).

With one exception, the birds found on Kangaroo Island are more widely distributed than just the Island. The exception was the dwarf Kangaroo Island Emu *(Dromaius baudinianus)* that was reported by Matthew Flinders as quite common around Nepean Bay in 1802. This species of emu became extinct between 1802 and formal European settlement of the Island in 1836, possibly the result of disease, bushfires, or hunting by a small number of American sealers and whalers who colonised the island around 1803 (Baxter & Berris 1995). Nicolas Baudin named this Ravine des Casoars on the western end of Kangaroo Island after these 'cassowaries', suggesting the Kangaroo Island Emus were originally widespread.

Most of the ornithological knowledge for the Island is collated in bird lists (e.g. Abbott 1974; Ford 1979; Baxter & Berris 1995). The list compiled by Chris Baxter and Mel Berris is the most comprehensive. These lists are often compared with similar lists compiled for adjacent mainland areas with the differences highlighted. Some of the obvious differences are that there are no treecreepers, sitellas, babblers, shriketits or mistletoebirds on Kangaroo Island, and some of the common honeyeaters, thorn bills and flycatchers of the adjacent mainland are also largely absent (Yellow-faced, White-plumed and Singing Honeyeaters, Yellow-rumped and Buff-rumped Thornbills, Hooded Robin and Rufous Whistler; Baxter & Berris 1995). Inability to disperse and/or absence of suitable habitats are proffered as explanations for these absences (Abbott 1974, 1976; Ford & Paton 1975; Ford 1979). There is a dearth of mistletoes on the island, and only recently have a few individuals of the mistletoe *Amyema melaleucae* been found on some *Melaleuca halmaturorum* in tea-tree swamps towards the centre of the island. For mistletoebirds that feed almost exclusively on the fruits of mistletoes, these would never be sufficient to support even one individual even if the bird was able to find them.

Many of the species that are absent from the Island are species of more open habitats (Ford & Paton 1975; Ford 1979). When Flinders and Baudin sailed into the coastal regions of South Australia 200 years ago, smoke from fires lit by Aborigines often wafted over the mainland but there was no smoke over Kangaroo Island, reflecting an absence of Aboriginal people, an absence that had been sustained for at least 2 000 years (Lampert 1979; Wells *et al.* 2001). Lack of frequent burning reduces the availability of more open habitats and this may account for the absences of those species.

Although lacking some of the characteristic species present on the adjacent mainland, Kangaroo Island still supports substantial populations of Bush Stone-curlews and Glossy Black-Cockatoos. Both of these charismatic species are extinct on the adjacent Fleurieu Peninsula - Mt Lofty Ranges system. This reflects, first, the differences in the extent of vegetation clearance between mainland and Island with the Island less extensively cleared than the mainland, and, second, the absence of rabbits and foxes on the Island, the latter considered a major predator of the ground-dwelling Stone-curlew. Several other species that are still widespread and common on Kangaroo Island have small, fragmented and/or declining populations on the mainland (e.g. Southern Emu-wren, Beautiful Firetail, Scarlet Robin, Bassian Thrush).

The avifauna of Kangaroo Island is changing in concert with the avifauna of the mainland, with some species increasing in distribution and abundance and others declining. Most of these changes are linked to European occupation of the Australian landscape and specifically with vegetation clearance and agricultural development both on and off the Island. Galahs and Little Corellas have expanded naturally into southern Australia from inland areas in the last 100 years having benefited from the clearance of vegetation and the provision of both water and additional food (e.g. Rowley 1990; St John 1994). These cockatoos have also subsequently colonised the Island, Little Corellas as recently as 1969 (Baxter & Berris 1995). Other species that have colonised the Island and are expanding in distribution or abundance include the Magpie-lark and Willie Wagtail, while Restless Flycatchers are declining for both mainland and Island.

In all 257 species of birds from 60 families have been recorded for the Island but many of these have been reported infrequently with 78 species recorded on less than ten occasions (Baxter & Berris 1995, Appendix 1). Many of the oceanic birds, for example, have only been recorded as beach-washed specimens and others are rarely sighted close to shore (Baxter & Berris 1995; Appendix 1). The list of birds for the Island includes six species that have been successfully introduced. Five were deliberately introduced to the Island: the mainland Emu, Australian Brush-turkey, Cape Barren Goose, Gang-Gang Cockatoo and Laughing Kookaburra; the sixth, the Indian Peafowl, escaping from captivity. Of these the Cape Barren Goose is perhaps the only species that would have likely colonised the Island naturally. However, attempts to establish populations of Magpie Geese, Peaceful Doves, Diamond Doves, Bar-shouldered Doves, Plumed Pigeons, Crested Pigeons, Wonga Pigeons, Zebra Finches and Malleefowl on the Island failed (Bartlett 1948; Condon 1948; Ford 1979). Interestingly the last free-living mainland Emu died in the 1990s, despite reports of the species breeding shortly after its initial introduction to the Island. Other species introduced to the mainland have reached and established populations on Kangaroo Island by their own means. These include Rock Dove, Spotted Turtle-Dove, House Sparrow, European Goldfinch, Common Starling, Common Blackbird and Skylark.

Although there is a considerable amount of information on the distribution of many of the bird species that inhabit the Island, including some historical and ecological information (Baxter & Berris 1995 and references within), detailed ecological studies are limited to the Glossy Black Cockatoo (Joseph 1982; Pepper 1997; Garnett *et al.* 1999; Pepper *et al.* 2000; Crowley & Garnett 2001), Bush Stone-curlew (Gates 2002), Hooded Plover (Dennis 2001), Musk Duck (McCracken 1999; McCracken *et al.* 2000a, 2000b) and some raptors (e.g. Dennis & Lashmar 1996).

The following text provides a brief account of the birds found in different parts of Kangaroo Island, beginning with seabirds and coastal species before discussing the birds associated with the swamps and lagoons, the agriculturally-altered landscapes, and the mallee-heaths and woodlands.

SEABIRDS AND COASTAL SPECIES

A wide variety of albatrosses, petrels, prions and shearwaters is reported for Kangaroo Island, but few of these largely oceanic species are seen alive close to shore. Of the larger species, Black-browed Albatrosses are the most frequently encountered close to shore particularly during winter, followed by Giant Petrels, and then Yellow-nosed Albatrosses (Swanson 1973; Lashmar 1984). Baxter and Berris (1995) suggest they feed on large numbers of dead and dying cuttlefish that float to the ocean surface after periods of rough weather during winter. Fluttering, Short-tailed and Flesh-footed Shearwaters are seen more often closer to shore than albatrosses, with thousands of Short-tailed Shearwaters or Muttonbirds migrating past Kangaroo Island to their breeding islands north west of Kangaroo Island (Copley 1996) in October and November. These birds have come from non-breeding areas in the northern Pacific and after breeding migrate back to the northern hemisphere in May. At times large numbers of muttonbirds can be washed ashore if storms coincide with their migrations, particularly in autumn when there are many inexperienced immature birds migrating for the first time. Of the smaller petrels, few if any species are seen close to shore - the Cape Petrel is the most likely along with the diminutive White-faced Storm-Petrels, the latter breeding on Nobby Island off Seal Bay and possibly on Kangaroo Island proper, southeast of Bales Bay (Baxter & Berris 1995; Copley 1996).

The only prominent oceanic species is the Australasian Gannet. This species is more prominent during the winter half of the year when both adults and immatures are frequently seen from the ferry in Backstairs Passage and immediately off shore along the exposed southern coasts of Kangaroo Island. Baxter & Berris (1995) report several instances of large concentrations of several hundred gannets diving for surface fish with Crested Terns close to shore along the southern and western coastline. Small numbers of Great Skuas are seen off the Kangaroo Island coasts during most winters but Arctic and Pomarine Jaegers are reported infrequently and more often during summer (Baxter & Berris 1995).

Terns, gulls and cormorants are common coastal species that are widely distributed around the Island as is the Little Penguin. Little Penguins spend most of the day at sea fishing but come ashore at dusk. They spend the night in burrows dug in sand under coastal vegetation, or in crevices between or under rocks or in caves, and have adapted well to human-made burrows provided at rookeries near Penneshaw. As well as roosting, these burrows are used for nesting which can begin as early as July. Noisy, harsh braying frequently accompanies the penguins as they make their way to their burrows. Braying and various growls are used in a variety of social contexts: advertising, greeting and agonistic encounters (Marchant & Higgins 1990). Adult penguins usually moult during summer after breeding. While moulting they must remain on land and cannot feed, since the growing feathers are neither adequately water-proofed nor provide sufficient insulation for swimming in cold water. While on land, whether breeding, moulting or simply resting, penguins are prone to predation from feral and domestic cats and dogs, and control programs have been implemented at rookeries close to major townships.

Three species of terns were once considered common around the island: Crested, Caspian and Fairy Tern. Of these species, Crested Terns largely fish out to sea taking surface-swimming marine fish and are easily the most abundant Tern around the Island. The other two species tend to fish in shallower, more protected waters often in coastal bays and inlets, with Caspian Terns also fishing in estuaries. Although all three species have been reported breeding around Kangaroo Island, only the occasional pairs of Caspian Terns have been reported nesting and there are no recent reports of Fairy Terns nesting around the Island, despite regular searches of traditional nesting sites. Both species appear to be declining generally in South Australia, and the reasons for the declines are not known. In the 1970s, 1980s and early 1990s colonies of 40 to 60 pairs of Fairy Terns were reported nesting on Paisley and Casuarina Islets, Flinders Chase National Park, with other birds nesting on sheltered sandy beaches on the eastern side of Kangaroo Island (Baxter & Berris 1995; Copley 1996).

Both Pacific and Silver Gulls are widespread around the entire coast of Kangaroo Island, with Silver Gulls being particularly abundant. Both species breed on many of the sandy and rocky offshore islets. Silver Gulls also nest inland from the coast on some occasions (e.g. on levy banks of flooded tea-tree lagoons or on banks of human made inland salt lakes; Baxter & Berris 1995). Both species mainly scavenge food around the shoreline but Silver Gulls will also feed in flooded pastures or in freshly ploughed fields.

Black-faced and Pied Cormorants are the most abundant cormorants on Kangaroo Island preferring the more sheltered eastern and northeastern coastline, with both species breeding on Busby Islet off Kingscote. Up to 800 Black-faced Cormorants and 400 Pied Cormorants nest here during autumn (Baxter & Berris 1995). Smaller numbers of Little Pied, Little Black and Great Cormorants also frequent the more protected eastern and northeastern coastline of Kangaroo Island, although Great Cormorants and Black-faced Cormorants will both venture onto the high energy southern coast. Small numbers of Little Pied Cormorants and the occasional Great, Pied and Little Black Cormorants also move in from the coast visiting farm dams to catch yabbies and marron. As a consequence commercial producers often shoot the birds or net their dams to prevent losses of these crustaceans to the birds. Little Pied Cormorants nest around some of the inland tea tree swamps and gum-lined lagoons, nesting during spring in contrast to predominantly autumn breeding for the other species.

The other major groups of birds associated with the coasts of Kangaroo Island include some of the palaearctic waders, as well as resident species like the Hooded Plover, Pied and Sooty Oyster catchers, and three species of raptor; the Peregrine Falcon, Osprey and White-bellied Sea-Eagle. The majority of the migratory waders that visit Kangaroo Island during summer come in small numbers, and are recorded infrequently (Appendix 1; Baxter & Berris 1995). Sharp-tailed Sandpipers, Red-necked Stints and Curlew Sandpipers, are the most prominent migratory waders frequenting the more sheltered tidal mudflats on the eastern end of the Island as well as visiting some of the brackish inland wetlands like Murray Lagoon. Common Greenshanks and Ruddy Turnstones are also widespread and abundant at times, the latter sometimes in flocks along the northern coastline searching for food on tidal mudflats and amongst mounds of seaweed dumped along beaches, or in smaller numbers on rocky shorelines on the western end of the Island.

Hooded Plovers are beach specialists and are widespread on the island with pairs present on most beaches. The birds feed mainly in the wave wash zone and nest on the upper beach above the high tide mark. A small scrape in the sand suffices for the two or three cryptically coloured eggs that take up to four weeks to hatch. On the mainland, Hooded Plovers have declined in distribution and abundance as a consequence of increased human activity on beaches. Nests of Hooded Plovers are particularly vulnerable and can be destroyed by off-road vehicles driving along beaches or trampled by people walking along the beach (e.g. Buick & Paton 1989). Introduced predators like faxes can add to the toll. Kangaroo Island has many isolated beaches, limited vehicle access and no faxes and so is considered a safe haven for Hooded Plovers but beach-goers should be aware that they too can disrupt breeding efforts and should keep their activities on beaches to a minimum during the spring breeding season. Dennis (2001) reports that Hooded Plover populations are decreasing throughout their range in southeastern Australia, including Kangaroo Island where a 15% overall decline in the numbers breeding has taken place since 1985. Dennis (2001) suggests that the declines reflect increased human activity on beaches disturbing the birds, with the greatest declines for those beaches with the greatest vehicle and human use. Red-capped Plovers may also use some of the more protected beaches, occasionally nesting above the high tide mark. They also use some of the brackish tea-tree swamps and will forage on some the sandy mudflats when exposed at low tide, rarely getting their feet wet.

Pied and Sooty Oystercatchers also nest around the Kangaroo Island coastline. Pied Oyster-catchers are prominent on the sheltered sandy beaches and tidal flats on the eastern end of the island, while Sooty Oystercatchers also use the rocky shorelines of the southern and western coasts. Other birds along these coasts include the occasional Eastern Reef Egret and White-faced Heron, the two species sometimes difficult to distinguish from a distance. Australian Pelicans are also prominent in some of the sheltered bays along the north coast of the Island, a small number have been fed near the Kingscote jetty for a number of years.

Ospreys, White-bellied Sea-Eagles and Peregrine Falcons are widespread around the Island, nesting on the rugged coastal cliff faces. The Island is an important breeding area for these birds, particularly for Sea-Eagles with a third of the South Australian breeding population nesting on the island (Dennis & Lashmar 1996). Ospreys and Sea-Eagles are more abundant than Peregrine Falcons and primarily hunt fish close in shore in protected bays and estuaries, while the Peregrines specialize on hunting birds. Sea-Eagles will also take penguins, fledgling gulls and terns and, like Peregrines, will move away from the coastline to hunt, taking various waterbirds off inland wetlands. Sea-Eagles will also feed at carrion including road-killed wallabies and dead lambs in paddocks. One Osprey banded as a nestling by Terry Dennis at Hanson Bay in January 1989 was recovered on the Loxton to Pinnaroo Road thirteen months later. The bird had presumably followed the coast and then the River Murray inland. All three of these birds of prey are potentially vulnerable species as they are at the top of food chains and deserve special attention. In some areas of Kangaroo Island coastal walks along the cliff-tops may disturb the birds, resulting in nest sites being abandoned (Dennis & Lashmar 1996). These walks may need to be closed during the breeding season or redirected inland to prevent disturbing the birds at critical times.

BIRDS OF WETLANDS, TEA-TREE SWAMPS AND LAGOONS

Eleven species of ducks are reported regularly from the Island with all but two found breeding. Key habitats for them are the brackish tea-tree *(Melaleuca halmaturorum)* lined swamps with extensive areas of open water such as Murray, Birchmore and Lashmar Lagoons on the eastern half of the Island. Freshwater Red gum *(Eucalyptus camaldulensis)* swamps along the Cygnet River are important for some ducks and various species have also been reported from Grassdale Lagoon and other freshwater swamps to the southwest (Baxter 1995). Although Grey Teal, Chestnut Teal and Pacific Black Ducks are the most widespread and abundant, significant numbers (often in the hundreds) of Australasian Shovellers, Blue-billed Ducks and Musk Ducks are regularly seen, the latter preferring the deeper permanent water bodies. Blue-billed and Musk Ducks are both stiff tailed ducks that sit low in the water and regularly dive to catch aquatic invertebrates and other foods. Musk Ducks have an unusual lek-breeding system where the larger males (often twice the size of females) with conspicuous lobes hanging under their bills aggregate in selected areas of wetlands and display. The displays are bizarre and consist of a series of backward kicks, each kick sending a spray of water backwards perhaps as far as 10m and in the process making 'ker-plonk' noises. The displays are often accompanied with high-pitched whistling. Females select one of these males with whom they mate, their choice presumably based on the male's performance. But other than mating with females, males are emancipated and take no further part in rearing the young. The female builds the nest often in a clump of *Gahnia,* lays and incubates the eggs and then cares for the ducklings alone. Two ducklings are the most common brood size on Kangaroo Island (McCracken *et al.* 2000a). The female Musk Duck actually feeds the recently hatched ducklings until they fledge, something that no other duck does. Populations of both Blue-billed and Musk Ducks have declined on the mainland due to the loss and degradation of wetlands, some reclaimed, others filling infrequently because of upstream extraction of water, and most lacking suitable fringing habitat to allow either species to breed. Elsewhere in Lakes Alexandrina and Albert and in the adjacent Coorong, changes in the wetlands brought about by adjustments of water levels, increased turbidity, reduced food availability due to introduced European Carp coupled with losses of Musk Ducks drowned in fishing nets all contribute to the declines. Given this, Kangaroo Island is now important for the conservation of both species. There are, however, growing concerns that some of the island's key terminal wetlands such as Murray Lagoon, are gradually becoming saltier and now experience changes in flows, a legacy of extensive vegetation clearance in many of the catchments and extensive damming of some of the streams that feed into some of the wetlands.

Other resident species of duck include the Australian Shelduck and Australian Wood Duck, both species often grazing on lush pastures and crops, the latter having benefited from widescale agricultural development during the last 50 years, a pattern mirrored on the mainland.

Freckled Ducks, Pink-eared Ducks and Hardheads are irregular visitors to the island, but in drought years substantial numbers may congregate on Kangaroo Island's permanent wetlands, illustrating the importance of these wetlands as drought refuges for these ducks.

Two other 'waterfowl' in the duck family are prominent on Kangaroo Island: Black Swans and Cape Barren Geese. The geese are rarely directly associated with wetlands and are discussed in the next section. Black Swans, however, frequent a wide variety of wetland habitats, ranging from the brackish tea-tree swamps, to the freshwater swamps along the Cygnet River, to the coastal salt marshes and estuaries. Large numbers even forage on tidal flats in sheltered bays such as those associated with American River (Pelican Lagoon), Bay of Shoals and Nepean Bay (Baxter & Berris 1995). Large numbers of Black Swans nest on Murray Lagoon and along the Cygnet River and on other seasonally flooded wetlands. Flooded pastures are also favoured haunts for foraging in winter.

Black Swans are not the only waterfowl that exploit marine habitats. Musk Ducks, Chestnut Teal and Pacific Black Ducks regularly move to some of the tidally influenced sheltered bays at certain times in the year to feed, the Musk Ducks sometimes forming large rafts involving as many as a hundred birds (Baxter & Berris 1995).

A range of other waterbirds is associated with the island's wetlands, including grebes, water hens, rails, crakes, spoonbills, ibis, and herons.

The two small grebes, Hoary-headed and Australasian, largely use different wetlands. Hoary-headed Grebes prefer the brackish and more saline systems with several hundred

Fig. 1 An elusive Australian Spotted Crake foraging in shallow water around the edge of Murrays Lagoon (photo Lynn Pedler).

congregating at times on Murray Lagoon and similar wetlands. Australasian Grebes are more likely to be encountered singly or in pairs on farm dams and other freshwater systems. Both species are incompetent on land and never venture on shore. Despite their aquatic existence, Hoary-headed Grebes, Chestnut Teal and even Freckled Ducks were all taken as prey by a feral cat at Murray Lagoon, the grebes at least taken off the water. This cat was caught and fitted with a radio transmitter and was frequently found with very wet fur, indicating the cat was comfortable swimming. Unfortunately the radio-transmitter often malfunctioned when submerged in water and so the cat could rarely be detected when in the lagoon.

Most of the crakes and rails are secretive and difficult to see. The Australian Spotted Crake (Fig. 1) is the most frequently and widely sighted usually around the edges of a variety of wetlands such as Murray Lagoon and rarely far from dense vegetation into which they will quickly scurry if disturbed. Lewin's Rail, Baillon's Crake, Spotless Crakes and Buff-banded Rails are all probably more widespread than the few records indicate (Baxter & Berris 1995), with Buff-banded Rails just as likely to appear in grassland areas away from water.

Purple Swamphens, Dusky Moorhens and

Eurasian Coots use a variety of wetlands. Of these the Coots are by far the most abundant with some fiocks on the larger brackish tea-tree wetlands (e.g. Murray lagoon) consisting of several thousand birds (Baxter & Berris 1995). Dusky Moorhens are on many of the same brackish wetlands as well as on some of the sedgeland wetlands like Grassdale Lagoon, where Purple Swamphens often outnumber them. All three species breed on the island. The only other hen recorded on the island is the irruptive Black-tailed Native-hen, its black upright and squared off tail giving it the silhouette of a bantam. Small numbers are present in most years and some breeding occurs but every now and again large numbers appear around some of the main lagoons. This species breeds in large numbers in the interior of South Australia following good rains that flood extensive areas but when these wetlands dry up vast numbers move south giving the appearance of an irruption. The birds appear in thousands on the banks of virtually every wetland in southern South Australia as well as being prominent around some golf courses and in some pastures and crops. In these years, 2001 being the last one, Kangaroo Island also receives its share of Black-tailed Native-hen.

White-faced Herons, Australian White Ibis and Yellow-billed Spoonbills all breed in small numbers on Kangaroo Island. Both the heron and spoonbill regularly nest in large Red gums around wetlands associated with the Cygnet River. White-faced Herons also nest in tea-trees around some of the brackish swamps. Straw-necked and Australian White Ibis are mainly seen in the eastern half of the island, often in paddocks feeding on invertebrates, although White Ibis are also comfortable feeding on tidal mudflats. Yellow-billed Spoonbills and White-faced Herons are more widespread than the ibis with both being seen at least as far west as Rocky River in Flinders Chase National Park. Small numbers of Great Egrets wade in the shallows of both fresh and brackish wetlands, flooded pastures and coastal mudflats but have not been found breeding on the Island.

A few waders are also associated with the freshwater, brackish and saline wetlands. Black fronted Dotterels are widely spread, and usually found in pairs or singly around the freshwater wetlands of the Cygnet River, on the edges of farm dams and also around some of the brackish tea tree swamps. Black-winged Stilts (Fig. 2) also frequent these wetlands, while Banded Stilts and Red-necked Avocets, when seen, are usually on the saline and brackish wetlands on the eastern half of the Island. Red-necked Stints, Curlew Sandpipers, Sharp-tailed Sandpipers and Recapped Plovers will also forage around the shores of some of the brackish swamps, and Masked Lapwings are often nearby.

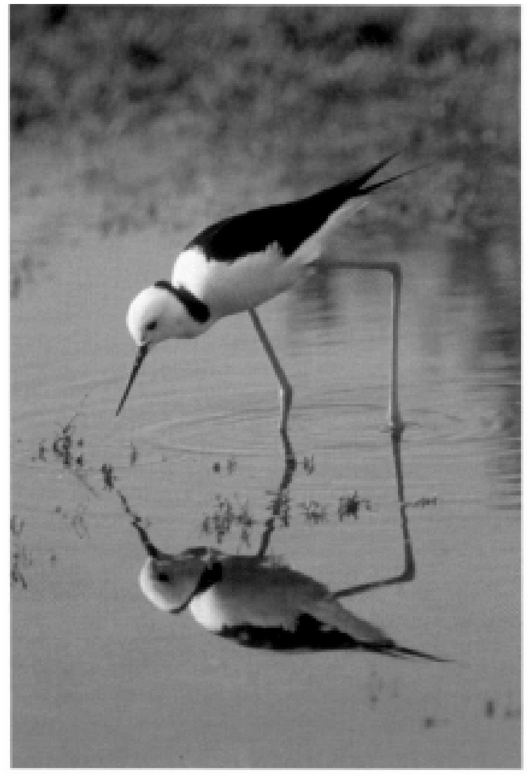


Fig 2. Black-winged Stilt (photo Lynn Pedler)

One raptor, the Swamp Harrier is closely associated with wetlands and swamps, taking waterbirds but also foraging over nearby grassland areas. Peregrine Falcons and White-bellied Sea Eagles also hunt in these areas.

BIRDS OF GRASSLANDS AND AGRICULTURAllY-MODIFIED HABITATS

The extent of grasslands on Kangaroo Island has changed dramatically since European colonisation with approximately 53% of the island's native vegetation removed and converted to various agricultural grasslands and crops. The clearance of native vegetation and conversion to primary production has been most intense over the eastern two-thirds of the Island, most of which has taken place since the 1950s. Clearing of the deep-rooted perennial native vegetation and replacing it with shallow-rooted pastures and annual crops has had, and will continue to have, a profound effect on the natural history of the Island. First and foremost the removal of native vegetation reduces the habitat available for native flora and fauna, reducing their population sizes and lowering their prospects of surviving through time. Second the shallow-rooted plants that replace the deep-rooted plants intercept less of the rain that falls and percolates through the soil, so the underlying saline water-tables have risen in many areas bringing salt to the surface, affecting both agricultural production and remnant native vegetation in the more heavily cleared catchments. Increased runoff and surface flooding is another legacy. Third, the new pastures provide a surfeit of food for a range of native herbivores, including Kangaroo Island Grey Kangaroos *(Macropus fuliginosus fuliginosus),* Tammar Wallabies (M. *eugenii)* and Brush-tailed Possums *(Trichosurus vulpecula)* all of which have undoubtedly increased substantially in abundance since European settlement. Although Brush-tailed Possums are normally an arboreal species, the absence of ground predators (there are no dingoes or foxes on Kangaroo Island) means that they are comfortable spending extended periods of time on the ground foraging. Changes in the abundance of these herbivores particularly Brush-tailed Possums in turn can affect the quality of other habitats for other fauna. For example, Brush-tailed Possums are now significant nest predators for some hollow nesting species, like the Glossy Black-Cockatoo. Also the high density of Tammar Wallabies in some moderately cleared areas contributes to degradation of the remaining patches of native bush through grazing and trampling, although this is probably a minor impact compared to the ongoing grazing of these patches by sheep and cattle. In some of the larger patches of native vegetation, feral pigs, goats and more recently deer add to this degradation. Fourth, the clearance of native vegetation breaks up the natural mallee and woodland systems and disrupts natural processes such as dispersal. Furthermore the fragmentation increases edge effects. Edge effects can be defined as the intrusion of components of one system into another, perhaps best illustrated by the intrusion of introduced grasses and weeds into native bush, but even pines and olives find their way into the bush. These edge effects further reduce the quality of the remaining habitat for wildlife. Finally the agricultural habitats that replace the native vegetation are both structurally and floristically less diverse. In many cases they are simply monocultures that will in due course be harvested. These new habitats, including recent Tasmanian Blue Gum *(Eucalyptus globulus)* and *Pinus radiata* plantations, support far fewer species and usually a different suite of species to those that once occupied that part of the landscape.

Recent and ongoing changes to the avifauna of Kangaroo Island are all linked to the changes that humans have made to the vegetation of the Island. Of the species that largely exploit the agricultural grassland habitats most are widespread species over the adjacent South Australian mainland having benefited from similar changes in the landscape there. Amongst those that have likely increased in abundance and distribution on Kangaroo Island are the Australian Magpie, Australian and Little Ravens, Stubble Quail, Bush Stone-curlew and Cape Barren Goose, and probably other grazing waterfowl such as the Australian Shelduck and Australian Wood Duck. A range of other species have been able to

Fig. 3. Cape Barren Geese have flourished on Kangaroo Island (photo: Lynn Pedler)

colonise and then expand their distribution and abundance on the Island including the Galah, Little Corella, Magpie-lark, Skylark, Common Starling and possibly Straw-necked and Australian White Ibis. Other species to benefit include the Masked and Banded Lapwing, Barn Owl, Nankeen Kestrel, Black-shouldered Kite, Wedge-tailed Eagle and Rock Dove. All of these species are often seen foraging or heard in grassland and pasture, or perched nearby. Most are of no conservation concern, in fact some are regarded as pests both of agriculture and natural systems. Two species that have benefited from the changes in the landscape, however, are of conservation significance: the Bush Stone-curlew and Cape Barren Goose.

Cape Barren Geese (Fig. 3) are largely distributed around the south-eastern coasts of Australia, nesting on many of the offshore islands, including those in Bass Strait and on some of the islands in the Sir Joseph Banks Group northwest of Kangaroo Island (e.g. Delroy *et al.* 1989). During the early part of the 20th century their populations were decimated by hunting and the species was threatened with extinction. At this time though, small numbers of Cape Barren Geese were introduced to a grassland area near Rocky River in Flinders Chase National Park (Bartlett 1948). This grassland area, no more than 50 hectares, was originally cleared and converted to pasture for stock by the original settlers. It is now the site of the visitor facilities and NPWS headquarters in Flinders Chase. Some of the geese from Flinders Chase were subsequently translocated to other parts of the Island to establish satellite colonies. The initial introductions of birds to parts of Kangaroo Island were likely to have involved pinioned birds. Pinioning involves removing the final segment of the wing in young birds so that they cannot fly. This was done so the geese would remain at Rocky River, breed and so add new birds to the nearby diminished populations, the young at least being free to go. The program has been highly successful and as many as 100 pairs continue to nest at

Fig. 4. Bush Stone-curlews are widespread on Kangaroo Island in the absence of European faxes (photo: Lynn Pedler).

Rocky River each winter. Although males and females have the same appearance, they differ in the pitch of their calls, males have a higher-pitched bisyllabic honk and females a deeper pig-like grunt and both can be very aggressive and noisy when protecting nests or goslings.

With protection of the birds from hunting, the populations have grown substantially throughout southern Australia, particularly in the last 20 or so years, with the Island's goose population estimated to be at least 1000 birds now (Baxter & Berris 1995), and the species is no longer of conservation concern. In fact the populations have grown to the point where Cape Barren Geese have now become pests by grazing some of the irrigated pastures and crops on the mainland. In some years the production of young birds is reduced on Kangaroo Island by pricking some of the eggs.

The Bush Stone-curlew (Fig. 4) is another success story for Kangaroo Island. Bush Stone curlews were widespread over southern Australia at the time of settlement, but except for a few tiny isolated populations of these birds, the species became functionally extinct over most of southern Australia (Johnson & Baker-Gabb 1994; Gates 2002). Two factors are cited as contributing to this decline - extensive vegetation clearance and predation by foxes. Bush Stone-curlews spend most of their time on the ground and also nest there and so are particularly vulnerable to predation by foxes. Kangaroo Island, however, has no foxes, and despite extensive vegetation clearance Stone curlews are abundant and widespread on the Island (Gates 2002). Bush Stone-curlews are active at night but extremely shy and so are rarely seen, but the wailing, eerie calls are often heard. Ironically they are absent from extensive areas of dense native vegetation and reach their highest densities in the agriculturally modified areas of the Island where remnant patches of native vegetation are mixed with open cleared areas. The birds forage on a range of ground invertebrates gleaned from paddocks at night and roost cryptically on the ground in nearby patches of native vegetation (Gates 2002). Their nests, too, are often placed on the ground in paddocks, although they are usually near the edge of native vegetation where the partner of an incubating bird may roost during the day.

BIRDS OF WOODLANDS, HEATHLANDS, AND MALLEE

The woodlands, heaths and mallee have been extensively cleared in southern Australia because these were areas of fertile land and hence favourable for agriculture. In many parts of southern Australia, as much as 90% of these habitats have been cleared and fragmented, and the remnants degraded (e.g. Paton *et al.* 2000). As a consequence of vegetation clearance and the introduction of rabbits, foxes, cats and a wide range of other plants and grazing animals, the native flora and fauna has suffered irreparably. Although few bird species have gone extinct, the birds of woodlands and heaths are declining in abundance and distribution at an alarming rate and at least half of the bird species that use these habitats are threatened with regional extinction in many parts of southern Australia. Some species have already disappeared from large areas of the mainland.

The level of vegetation clearance on Kangaroo Island has not been as extensive but still some 53% of the island has lost its native vegetation cover and is slowly but surely being degraded by grazing, weed invasion, changing water regimes, and possibly changes in burning regimes. For Kangaroo Island the vegetation clearance has been more extensive over the eastern and northern parts of the Island. However, large areas of native vegetation remain along the southern coast and over the western end of the Island. Much of this vegetation is close to pristine and not fragmented and is set aside for conservation. Setting land aside for conservation, however, will not guarantee the conservation of native flora and fauna and ultimately even these large remnants of pre European Australia will need to be managed carefully if the flora and fauna of these habitats are to survive.

Fig. 5. The Red Wattlebird, the largest of the honeyeaters on Kangaroo Island (photo: Lynn Pedler)

The birds of the woodlands, forests, mallee and heaths of southern Australian are dominated by one group of birds the Meliphagidae or honeyeaters, and Kangaroo Island's bush birds are no exception. Some sixteen species of honeyeater have been recorded for Kangaroo Island but of these only ten species breed and maintain year round populations on the Island. The six itinerant species: Spiny-cheeked, White-plumed, Regent, White-fronted, Yellow-faced and Singing Honeyeaters have been recorded infrequently, and at least some of the records for these species are considered dubious (Baxter & Berris 1995; Appendix 1).

The resident honeyeaters show a great diversity in body size, bill length and feeding habit (Ford 1976; Ford & Paton 1982). Red Wattlebirds (Fig. 5) are the largest of the honeyeaters on Kangaroo Island, weighing around 110 g, and along with the slightly smaller Little Wattlebird (70 g) forage for nectar at the flowers of a wide range of native plants, particularly various *Eucalyptus, Banksia* and to a lesser extent some of the larger tubular flowers such as *Correa reflexa* and *Templetonia retusa.* Both species of wattlebird reach their highest abundances in woodland areas with *Eucalyptus leucoxylon, E. cosmophylla* and/or *Banksia marginata.* When required both species will defend individual feeding territories excluding conspecifics and smaller honeyeaters from their food sources (e.g. Ford 1981; Ford & Paton 1982). When wattlebirds are present, some of the smaller species of honeyeater may be forced to use areas with lower densities of flowers (Ford & Paton 1982). The smaller New Holland (20 g), Crescent (15 g), and Tawny-crowned Honeyeaters (17 g) have relatively long decurved bills and also forage for nectar on a wide range of plants including many species of eucalypt, various heaths, *Banksia, Adenanthos* and *Correa.* As a general rule, Tawny crowned Honeyeaters are found mainly in the low coastal heaths and heaths with scattered clumps of emergent mallee, while Crescent Honeyeaters appear more numerous in the stringy-bark and gum woodlands with a shrubby understorey. Crescent Honeyeaters usually build their nests in the foliage of *Xanthorrhoea* clumps, so the presence of this plant may be critical for this species. New Holland Honeyeaters tend to be more widely distributed and use all habitats. These smaller nectarivorous honeyeaters will also defend feeding territories from similar-sized honeyeaters and the smaller Eastern Spinebill (11 g), the most morphologically specialised with the longest, most attenuated and decurved bill of the honeyeaters on Kangaroo Island. The numbers of these nectarivorous honeyeaters in an area often varies dramatically during the year depending on the species of plant in flower and its abundance, with the honeyeaters moving from one flowering plant species to another or from one area to another to exploit different resources. Breeding for these nectarivorous honeyeaters can also take place in autumn and winter as well as spring if sufficient floral resources are available.

The short-beaked White-naped, Brown-headed, Purple-gaped and White-eared Honeyeaters will also feed at flowers, harvesting nectar from a range of plant species when these are easily accessible. However, these species generally spend more time gleaning the foliage of eucalypts and probing under bark, harvesting honeydew, manna or lerp as well as a few invertebrates (Paton 1980; Ford & Paton 1982). White-naped Honeyeaters and to a lesser extent White-eared Honeyeaters appear to be closely associated with woodlands that include Manna gum *(E. viminalis)* while Purple-gaped and Brown-headed Honeyeaters are found over a range of habitats from mallee heaths to woodlands. Except for the Purple-gaped Honeyeater, these shorter-beaked honeyeaters seem to be relatively sedentary.

Of the ten resident honeyeaters on Kangaroo Island, six are considered to be distinct at an ultrataxon level (e.g. subspecific level) and two others form distinct ultrataxa with abutting mainland populations in the Mt Lofty Ranges that are isolated from populations found elsewhere in Australia (Schodde & Mason 1999). The Brown-

Table 1. IMPORTANCE OF BIRDS AS POLLINATORS OF SELECTED PLANT SPECIES IN FLINDERS CHASE NATIONAL PARK, KANGAROO ISLAND.
The table shows the percentage of flowers that set fruit when all floral visitors were excluded with fine mesh voile (0.1 mm mesh size), when birds but not insects were excluded from the flowers with plastic bird mesh (1 cm mesh size), and when birds and insects had access to the flowers. Source: Paton 1993 and unpublished.

Plant species	**No floral visitors**	**Insects only**	**Insects plus birds**
Astroloma conostephioides	18.5	25.0	57.1
Brachyloma ericoides	0.4	15.9	27.0
Callistemon rugulosus	16.8	41.8	69.6
Correa reflexa	3.5	10.7	26.1

headed Honeyeater is the most different on Kangaroo Island, being duller and darker than mainland birds and larger in body mass with a disproportionately long bill (Ford 1976; Schodde & Mason 1999). Keast (1968) attributed this difference to Brown-headed Honeyeaters spending more time foraging under bark due to the absence of treecreepers and sitellas on Kangaroo Island. Treecreepers and sitellas harvest food resources living on or under the bark of eucalypts and Keast suggested that in the absence of these birds, Brown-headed Honeyeaters may have simply expanded into their vacant niche. However, other explanations are possible, such as clinal variation or the birds evolving morphologically to other components of their environment (e.g. differences in vegetation structure). At present there are only limited data to suggest that Brown-headed Honeyeaters spend more time foraging under bark on Kangaroo Island compared to the mainland (see Keast 1968).

Purple-gaped and White-eared Honeyeaters are primarily honeyeaters that exploit mallee habitats on the South Australian mainland. Both species are darker in plumage on Kangaroo Island with Purple gaped Honeyeaters also being larger than birds on the immediate South Australian mainland. This pattern of increased melanism is a common feature for many of the Island's terrestrial avifauna. Both the Red and Little Wattlebird are consistently more melanistic on Kangaroo Island than the mainland, with Little Wattle birds also slightly larger than on the mainland, as is the New Holland Honeyeater which also has a longer bill (Ford 1976; Schodde & Mason 1999).

Ford (1976) suggested that most of the small nectarivorous honeyeaters *(Phylidonyris, Acanthorhynchus)* on Kangaroo Island had slightly longer bills on Kangaroo Island and suggested that this was an adaptation to feeding on flowers that were on average slightly longer. However, subsequent measurements by Schodde & Mason (1999) were unable to confirm these patterns for the Crescent Honeyeater *(Phylidonyris pyrrhoptera)* and Eastern Spinebill *(Acanthorhynchus tenuirostris).* Although Schodde & Mason (1999) report slight plumage differences for island birds (slightly darker and duller) they concluded that these were probably ecophenotypic and that the lack of differentiation between the Kangaroo Island and Mt Lofty Ranges populations suggested some trans-Backstairs Passage movement for these species. In support of this, an Eastern Spine bill banded near Rocky River in Flinders Chase National Park was recaptured alive at Bundy State Forest north of Forreston in the Mt Lofty Ranges 32 days later. That this spinebill, the smallest of the island's honeyeaters, could cross Backstairs Passage suggests that the other species of honeyeater are also capable of crossing to the mainland.

The prominence and importance of honeyeaters in the terrestrial ecosystems of Kangaroo Island is easily illustrated. At least three and often as many as eight species are seen in every habitat and in some areas and at times when key plants are flowering honeyeaters can account for more than 80% of the individual birds present in an area. That their numbers fluctuate with changes in flowering suggests that these birds depend on flowering plants for food. But the relationship is more complex than this, since many of the flowering plants in turn depend on the honeyeaters for successful pollination. This is easily illustrated. When honeyeaters are excluded from the flowers of a range of plants, the plants set far fewer fruit (Table 1). Although insects, predominantly introduced honeybees effect some pollination, fruit production is significantly higher when birds have access to the flowers.

This close interdependence between the birds and the plants is easily perturbed, since if either partner is disturbed then the other also suffers. The major perturbation that threatens these mutualistic relationships, and those between other plants and their pollinators, are the activities of introduced honeybees. European honeybees *(Apis mellifera)* were introduced to Kangaroo Island in 1884 by three settlers, Fiebig, Bonney and Turner. These bees originated from Liguria, a northwestern province of Italy, and were noted for their particularly docile behaviour. Surprisingly in 1885 the South Australian Government passed the Ligurian Bee Act that restricted the import of other races of honeybees to the Island and essentially declared the Island a sanctuary for this introduced bee. More by chance than design the bees have remained more or less pure and now Kangaroo Island is the only place in the world where supposedly pure Ligurian honeybees still exist. Their gentle nature also prompted the State Government to establish a queen breeding facility in Flinders Chase National Park in 1944 where feral colonies were cut from logs, trees and rock holes to establish the apiary. The apiary was eventually disbanded following several severe bush fires in 1958 and 1960. The gentle nature of the bees has made them popular with amateur beekeepers from all over the world and the Island's beekeepers still export queens around the world.

Sadly these introduced honeybees are now major visitors to the flowers of a wide range of native plants and they potentially threaten some of the intricate plant-pollinator relationships of the Island. Not only do the bees visit a wide range of plants, but they also consume a substantial proportion of the nectar and pollen being produced by some plants, sometimes in excess of 90% (Paton 1990, 1993, 1996). This includes many of the bird-pollinated plants. In consuming this nectar and pollen the honeybees take away floral resources from native fauna and so potentially compete with native fauna. They have one advantage over most of the endemic insects including native bees because they are social. By being social, honeybees can more readily maintain their body temperature. In fact the temperature within a hive of honeybees is maintained at around 35°C. This gives honeybees an enormous advantage in that they can start foraging at least an hour earlier in the day than most other insects, including native bees which are essentially solitary. On some of the plants pollinated by native bees, honeybees will have made 10 or more visits to the flowers before the first native bee starts foraging and can remove 99% of the resources (Paton 1993, 1996). Although honeybees might provide the same pollinator services as the native bees, the loss of most of the floral resources to honeybees is likely to impact on the numbers and types of native bees that live in an area, as well as other populations of native flower-visiting invertebrates. Similar arguments can also be developed for those plants pollinated by birds, but here the birds get first access to the flowers in the morning, and this usually means that only 20-40% of the floral resources are lost to honeybees, sometimes more

Fig. 6. A feral colony of Ligurian honeybees occupying a cavity in the trunk of a Sugar gum in Flinders Chase National Park (photo: David Paton)

(Paton 1990, Table 2). Even so this loss of floral nectar can cause dominant honeyeaters to increase the size of their territories by excluding subordinate individuals (often females and juveniles) from flowers, and this effectively reduces the numbers or density of honeyeaters able to live in an area (e.g. Paton 1993). Furthermore honeybees are often not as effective as the birds in pollinating the plants so the plants suffer reduced seed production. This is because honeybees often forage over smaller areas and may not transfer pollen between flowers and plants as effectively as the birds, or may reduce or disrupt the services provided by the birds (Paton 1993, 1996).

Honeybees may also affect a range of other species by usurping hollows in trees (Fig. 6) that would otherwise be used by native animals, such as birds and mammals for nesting and roosting. Certainly feral honeybees will use hollows that are suitable for or have been used by Glossy Black Cockatoos for nesting and removal of these feral colonies is part of the recovery program for that species. However the loss of some of the nesting hollows to feral honeybees is only likely to be a contributing, and not a key limiting, factor for the cockatoos (see below).

Lorikeets and Silvereyes are two other important groups of birds that visit the flowers of Australian plants and aid in pollination. Only two species of lorikeets are common on the Island - the Rainbow Lorikeet and Purple-crowned Lorikeet. Both are

Table 2. QUANTITIES OF NECTAR REMOVED BY HONEYBEES AND NATIVE FAUNA VISITING PLANTS NEAR ROCKY RIVER IN FLINDERS CHASE NATIONAL PARK.
Sets of data for the same plant species illustrate temporal variation in resource use, largely due to inclement weather which reduces the activity of honeybees. Note that native bees also removed 0.1 to 0.2% of the nectar from the eucalypts listed in the body of the table. For more details see Paton (1990, 1993, 1996).

Plant species	Months	% **of nectar production removed by**	
		honeybees	**honeyeaters**
Eucalyptus cosmophylla	mid Aug 1987	14.1	85.8
Eucalyptus cosmophylla	late Aug 1987	29.9	70.0
Eucalyptus remota	Jan 1989	16.1	83.7
Callistemon rugulosus	Nov 1988	40.9	59.1
Callistemon rugulosus	Dec 1988	92.1	7.9
Adenanthos terminalis	Aug 1987	0	100
Adenanthos terminalis	Jan 1989	97.2	2.8

usually seen in flowering eucalypts or flying overhead and are regarded as blossom nomads on the island, as large numbers, particularly of Rainbow Lorikeets can congregate in areas when certain eucalypts are flowering. Sugar gums *(E. cladocalyx*), Swamp gums (*E. ovata*), Brown Stringybarks *(E. baxteri)*, Cup gums *(E. cosmophylla)* and South Australian Blue gums *(E. leucoxylon)* are the most popular, but both lorikeets will also visit the flowers of some of the mallees *(E. albopurpurea, E. diversifolia, E. remota)* as well as understorey plants such as *Banksia* and *Xanthorrhoea.* Surprisingly Musk Lorikeets have only been reported on the Island once despite their presence on both Fleurieu Peninsula and Eyre Peninsula (Appendix 1).

Silvereyes, too, are frequent floral visitors to eucalypt blossoms, as well as banksias and some of the heaths like *Epacris, Astroloma* and *Brachyloma.* Silvereyes are also important seed dispersers for a number of coastal shrubs including *Rhagodia candolleana, Myoporum insulare* and *Leucopogon parviflorus.* These plants produce fleshy fruits that are consumed whole by the birds which extract nourishment from the flesh but void the seeds intact and unharmed. Silvereyes and perhaps some of the honeyeaters (e.g. Purple gaped) and Grey Currawongs are all perching birds and so defaecate from perches depositing seeds under the canopies of other plants. This may seem a poor dispersal strategy, but many of these coastal shrubs germinate and establish best under the canopies of another plant. The seeds of *Acacia sophorae* are also dispersed by birds - the inducement in this case being a fleshy aril attached to the side of the seed. Other birds like Superb Fairy-wrens are also partial to a few fleshy fruits, including acacia arils and may playa small role in seed dispersal as well (Forde 1986). Introduced Common Blackbirds and Common Starlings may also consume some of these fleshy-fruit.

Several introduced pest plant species, notably Bridal Creeper *(Asparagus asparagoides)*, Bridal Veil *(A. declinatum)* and to a lesser extent South African Boxthorn *(Lycium ferocissimum)* have benefited because of these frugivorous birds. These plants all produce fleshy-fruits and are also readily dispersed by birds. The two species of *Asparagus,* in particular have benefited since both of these are understorey plants and grow best under the canopies of other plants. In fact, Bridal Creeper is now a serious threat to understorey vegetation and biodiversity, particularly in roadside vegetation over the eastern half of the Island (Ball Chapter 6).

The now extinct Kangaroo Island Emu may have also been an important seed disperser, but on the mainland Emus tend to deposit large numbers of seeds in single 'pads' in the open. Germination rates for seeds in these pads is very low in part because many of the seeds are parasitised and because emus tend to repeatedly walk along the same tracks and so either tread on the young seedlings or consume any that do germinate. If Kangaroo Island Emus behaved in the same way then they too would have been relatively ineffective as seed-dispersers. Instead, from the plants' perspective, Emus would be regarded as seed predators.

One of the most specialised relationships between birds and plants is that between the Glossy Black-Cockatoo and its primary food source the Drooping Sheoak *(Allocasuarina verticillata).* In this case though the sheoaks gain nothing from the birds, since the cockatoos feed almost entirely on the seeds of Drooping Sheoak on the island, spending as much as 60% of their daytime extracting the seeds from the woody cones. Glossy Black-Cockatoos are 'laevopedrous' or left-footed, and always hold the sheoak cones that they have ripped from the plant in the left foot while extracting the seeds. They also usually start at the stem end of the cone and work to the base - the large beak not only able to tear apart the woody structure of the cone, but also, with use of the tongue, delicate enough to sort and husk the seeds without spillage or hesitancy. The birds take a little over three minutes to remove the seeds from a cone and remove the seeds from around 100 cones per day, more when breeding (Pepper *et al.* 2000). Males are actually more proficient or quicker at processing cones than females, and there may be an explanation for this.

Glossy Black-Cockatoos have a precarious breeding system in that only a single egg is laid in late summer or autumn with the nestling present during late autumn and winter. Females do all the incubation and brooding and depend on their mate for food. Males, therefore, need a good food supply, preferably not too far away, where they can harvest sufficient food for themselves and their mate. Recently, some males have been found feeding 14 km from their nests but still breeding successfully. In winter, with shorter day lengths the male may need to spend more than 80% of the daylight hours foraging. Typically, once a day the male returns to the nest, calls to his mate, and she leaves the nest briefly to be fed by the male who regurgitates seeds from his crop. The female may also take the opportunity to go to a nearby waterhole for a drink before returning to the nest. If the food supply is inadequate then the male cannot gather enough food, and the female may not be attentive to the nest, as she too may need to gather food. Under such conditions nests may fail. Even after nestlings have fledged, adults will continue to supplement their fledgling's food intake while the young cockatoo gains proficiency in harvesting sheoak seeds for itself. This varies from several months to over a year.

An important management consideration is limiting the amount of disturbance that feeding birds encounter during critical periods. Typically when Glossy Black-Cockatoos are disturbed they stop foraging and watch for danger. Natural dangers might be Wedge-tailed Eagles that are known to take Glossy Black-Cockatoos, perhaps on their flights between nesting and feeding areas. But humans can also disturb feeding birds when they approach them. In due course some management or restriction of human activity in key areas may be required.

In South Australia Glossy Black-Cockatoos used to occur on the adjacent southern Mt Lofty Ranges and Fleurieu Peninsula but the species has gone extinct in these areas primarily because of the loss of *Allocasuarina* stands (Joseph 1989). *Allocasuarina* was harvested extensively to fuel paddle-steamers working up and down the Murray. Adding to this, any seedling sheoak was quickly removed by rabbits (e.g. Cooke 1988), and if the rabbits failed then sheep and cattle undoubtedly would have taken any that survived. The loss of extensive woodland areas with large hollow bearing trees added further pressure on the birds and it is little wonder that they disappeared from the adjacent mainland. On Kangaroo Island, however, extensive stands of sheoak remain and there are no rabbits to remove the seedlings, although stock, wallabies and possums may be a problem for recruitment of Drooping Sheoaks in some areas. Despite abundant food resources the Glossy Black-Cockatoo population size on Kangaroo Island was estimated at about 170 birds in the mid 1990s with a preponderance of males, a precariously low population size.

Since 1995, a recovery program for the South Australian Glossy Black-Cockatoo (a distinct subspecies; Schodde *et al.* 1993) has commenced on Kangaroo Island. Initially the recovery program looked at increasing the numbers of nest hollows by adding human-made ones to woodland areas near major stands of *Allocasuarina,* and the Glossy Black-Cockatoos began using them. Despite this the population did not increase until observations revealed that Brush-tailed Possums were a major nest predator, not only occupying nest sites but also killing and or eating nestlings and eggs (Garnett *et al.* 1999). Now nests are protected from possums by nailing sheets of corrugated iron around the base of trees and trimming overhanging branches from adjacent trees so possums cannot jump from these onto the trees with nests. Since implementing this the cockatoo population has grown to over 250 birds, but ongoing monitoring of the population and maintenance of nest hollows are still required (Garnett & Crowley 2000). Since the birds change hollows from time to time, any new hollows need to be located and protected. In recent years there has been increased concern that other factors may impede recovery of the population including possible competition for nest hollows with Little Corellas, Galahs, Yellow-tailed Black-Cockatoos and feral honeybees. Since colonising the Island Little Corellas and Galahs have expanded in distribution and abundance, as possibly have

Fig. 7. Beautiful Firetail, one of two native finches on Kangaroo Island (photo: Lynn Pedler)

Yellow-tailed Black-Cockatoos. Yellow-tailed Black-Cockatoos have benefited from the plantings of introduced Monterey Pines *(Pinus radiata)* that now provide them with an abundant and alternative source of seeds to their natural seed sources such as *Hakea* and *Banksia.* Galahs and Little Corellas have benefited from agricultural development on the Island.

The other parrots that inhabit Kangaroo Island include the diminutive Elegant and Rock Parrots which are seen infrequently, Elegant Parrots mainly associated with stringybark and coastal mal lee habitats, and Rock Parrots on the coast. Neither species has been recorded breeding on the Island although young birds have been seen (Baxter & Berris 1995). Crimson Rosellas are seen in many woodland areas but usually in small numbers, often pairs. These rosellas, as with other isolated forms on Kangaroo Island are darker than their mainland conspecifics in southeastern Australia, but also distinctly different from the rich orange 'Adelaide' Rosellas of adjacent Fleurieu Peninsula. In woodland areas they feed mainly on the seeds of eucalypts and other myrtaceous plants like melaleucas ripping open the woody fruits with their bills and littering the ground underneath feed trees. Away from extensive woodland areas they will also feed on the ground harvesting the seeds of various introduced plants and spilt grain. Young Crimson Rosellas are mostly green and lack the brilliant crimson of adult birds.

Two other groups of predominantly woodland birds also feed on seeds of native plants: bronzewing pigeons and firetail finches. Both the Brush and Common Bronzewings are widespread on Kangaroo Island and often harvest the fallen seeds of various species of *Acacia.* Brush Bronzewings appear to be more prominent in shrubby coastal scrubs while Common Bronzewings will venture more into agricultural areas. Both species are often seen foraging on the sides of roads, and some are hit and killed by vehicles. Beautiful Firetails (Fig. 7) and Red browed Finches are partial to the seeds of sheoaks

Fig. 8. Koalas often rest on the trunks of eucalypts during the day, but can over browse the canopies of these trees at night, if their populations are too high (photo: David Paton).

and bulloaks (*Allocasuarina* spp.) which they extract from partly open cones. Beautiful Firetails are mainly found in areas of denser native vegetation where they also obtain seeds from various sedges, while Red-browed Finches will use more open areas such as grassy woodlands and are more likely to be seen in areas modified for agriculture. Both species forage mainly on or near the ground, and often the first view is of their red rumps as they fly to cover. Beautiful Firetails on Kangaroo Island along with those on the adjacent Fleurieu Peninsula are slightly darker than those found in southeastern Australia, a pattern reiterated by many of the bush birds.

While a range of species consume the seeds, fruit and nectar produced by plants, another equally diverse suite of birds gleans the foliage and probes under the bark of trees and shrubs for food. Depending on the plant species, manna, honeydew and/or lerps, as well as invertebrates are taken off the foliage and from under the bark (Paton 1980; Ford & Paton 1982). Manna, honeydew and lerp are sugary substances secreted by plants or insects. Manna is secreted directly from the plants at wounds left on foliage by phytophagous insects, while sap-sucking invertebrates living on the plants secrete or manufacture honeydew and lerp themselves. These sugary resources are particularly prominent on certain eucalypts. Manna gums *(E. viminalis)* as the name suggests weep profuse amounts of manna during summer and autumn and are particularly popular foraging trees for a variety of birds. Amongst the birds that harvest manna are the tiny pardalotes and thorn bills, as well as many of the honeyeaters, but the White-naped Honeyeater, in particular, appears to be closely associated with Manna gums.

Manna gums, however, are favoured browse trees for the introduced Koala, and many stands of this eucalypt are threatened with local extinction due to overbrowsing by Koalas. In fact at least one population of Manna gums within Flinders Chase National Park has gone extinct and another near Scotch Thistle Flat is not far behind due to this browsing pressure. One needs to remember that Koalas (Fig. 8) were introduced to the island and are not part of the natural system. From a mere 22 individuals introduced in the 1920s, the population has grown to over 25 000 and is still growing. This population growth has been possible because of the absence of any natural controlling agents such as predators. Now the Koalas are affecting not just the health of Manna gums but a range of other species including Red gum, SA blue gum, Cup gum and Stringybarks. This ongoing loss of condition for many of the tree species is clearly not sustainable and eventually the Koala population will crash, but not before they have eliminated or destroyed many of their food trees to the detriment of the island's endemic wildlife.

The impact of Koalas is more complex than simply the elimination of some of the food trees. Their foraging behaviour is such that they not only reduce the amount of foliage that a plant can produce, but also the position where that foliage is produced. This loss of foliage also reduces the numbers of flowers that are subsequently borne on browsed branches and the quantities of nectar and pollen that they produce, not to mention reducing the amount of manna produced. Other changes also take place such as changes to the fine structure in the branching and leafing patterns of the outer canopy. For example, in healthy Manna gums the leaves are borne alternately on long drooping branch lets but on heavily-defoliated branches, the leaves are borne in parallel pairs. Furthermore the leaves are often smaller in size and borne on a number of shorter branchlets each radiating out like a rosette from the point where the original branchlet had been snapped by a hungry Koala. With continued browsing the thickness of the foliage in the tree's canopy thins out substantially and eventually if the tree is not protected from Koalas it dies. All of these changes have a profound impact on the native fauna that depends on the trees. For example, more than 40 species of native bee have been collected from the

Table 3. CHANGES IN THE COMPOSITION AND BEHAVIOUR OF BIRDS USING MANNA GUMS THAT HAVE BEEN VARIOUSLY AFFECTED BY OVER-BROWSING BY KOALAS NEAR PIONEER BEND, KANGAROO ISLAND. The table shows the amount of time spent by different groups of birds in Manna gums *(Eucalyptus viminalis)* that were in 'good' condition (no more than 25% canopy lost), 'poor' condition (at least 50% of canopy lost to over-browsing by Koalas), and 'dead' trees. Data were collected between January and June 1998 by watching pairs or triplets of trees that differed in condition for 1-5 hours in ten different locations within 1 km of the Pioneer Bend homestead, north of Parndana. The amount of time the birds spent foraging versus perching in each of these trees was also recorded during these observations. The table shows that the numbers of species, total time and foraging time, particularly for the small insectivorous species, declined when the trees were conspicuously affected by over-browsing by koalas. Data are based on 32.75 hours of observing dead trees, 54.75 hours of observing trees in poor condition, and 62.25 hours of observing trees in good condition. SmaH insectivores included Striated and Brown Thornbills, Spotted and Striated Pardalotes, Silvereye, Grey Fantail, Scarlet Robin and Superb Fairy-wren. Small honeyeaters included Brown-headed, White-naped and Crescent Honeyeaters and the Eastern Spinebill, while the medium honeyeaters were White-eared and New Holland Honeyeaters and the large honeyeater was the Red Wattlebird. Rainbow Lorikeets, Crimson Rosellas and Galahs were in the parrot group, Australian Magpies, Australian Ravens and Magpie-larks were in the large ground insectivores, while the Golden Whistler, Grey Shrike-thrush, Black-faced Cuckoo-shrike, Dusky Woodswallow, Grey Currawong, Restless Flycatcher and Willie Wagtail were seen infrequently and listed in 'other birds'.			
Bird group	Bird minutes/tree-hour*)*% time foraging)		
	GOOD	**POOR**	**DEAD**
Small insectivores	19.65 (99.0)	6.58 (83.4)	0.46 (23.1).
Small honeyeaters	7.67 (96.7)	4.92 (82.9)	20 (11.0)
Medium honeyeaters	4.47 (92.8)	4.36 (81.7)	2.51 (15.6)
Large honeyeaters	1.97 (71.5)	4.47 (55.7)	1.75 *(*0.0)
Parrots, lorikeets	0.40 *(*0.0)	1.77 *(*0.0)	2.24 *(*0.0)
Other birds	0.33 *(*0.0)	0.45 *(*0.0)	0.63 (0.0)
Large ground insectivores	< 0.01 *(*0.0)	0.46 *(*0.0)	1.16 (0.0)
Total (all birds)	34.51 (94.4)	23.01 (67.8)	9.95 (23.1)
Total species (# foraging)	20 (17)	23 (14)	18 (7)

flowers of Manna gums and if the plants produce fewer flowers and less resources then these species will be negatively affected. Other invertebrates such as those living under the canopies of the trees are likely to be affected by changes in the amount of insolation or sunlight reaching the ground and or by changes in the type and amount of litter (both bark and leaves) that falls from the trees.

The over-browsing pressure caused by too many Koalas also affects the bird communities. As the canopy thins smaller species like the Spotted Pardalotes, Striated Pardalotes, Striated Thornbills, White-naped and Brown-headed Honeyeaters are disadvantaged, as larger more aggressive species of honeyeater exclude them. Presumably these relatively small birds are hard to detect and or chase from a tree when the foliage is thick and luxurious. As the canopy is opened up, these small birds become easier for the larger species to detect as they enter the tree and easier for them to chase away and so exclude. Thus, as the tree loses condition (and the Koala population grows) the bird community that uses Manna gums in particular becomes less diverse and dominated by just a few species (Table 3). Eventually as the trees lose further condition even the medium honeyeaters depart presumably because the tree no longer produces enough resources for them. Eventually only a few large species (e.g. Galah, Rainbow Lorikeet, Australian Magpie) are all that use the heavily defoliated and dead trees and then only for perching.

The obvious legacy, then, of failing to quickly reduce the size of the introduced Koala population on Kangaroo Island is the loss of significant local biodiversity, biodiversity that is genetically unique.

Other birds that glean the foliage of trees and shrubs or hawk and snatch insects that they flush from foliage include the Grey Fantail, Golden Whistler and Grey Shrike-Thrush. Shrike-thrushes will also forage on the ground, on the trunks and branches of trees and will also take eggs and nestlings of other birds, if the nests are not well concealed or guarded. A range of other insectivorous birds, notably the Superb Fairy-wren, White-browed Scrub-wren, Southern Emu-wren, Shy Hylacola and Brown Thornbill fossick for invertebrates in low shrubs or in the litter that accumulates under dense vegetation. All five species are distinctly darker on the island than the adjacent mainland and have been given subspecific status (Schodde & Mason 1999). Of the five species the Fairy-wren, Scrub-wren and Brown Thornbill are the most widespread and conspicuous occurring in woodlands and heaths and often venturing into openings and showing themselves. The Hylacola and Emu-wren, however, are much shyer, the former in areas of dense but moderately tall mallee and the latter in dense heaths. Other birds that occupy these areas include the Western Whipbird (Fig. 9), and like the previous species is often heard but rarely seen. Western Whipbirds on Kangaroo Island are also distinctly darker with a slightly longer and narrower bill than individuals found on Yorke Peninsula and in the Murray Mallee of South Australia. In some of the moister gullies and woodlands Bassian Thrush are also found scratching the litter layer for invertebrates. Bassian Thrushes are not as shy

Fig. 9. Western Whipbirds occupy dense mallee heath vegetation on Kangaroo Island but occasionally sing from an elevated perch (photo: Lynn Pedler)

Fig. 10. Restless Flycatcher, one of a suite of woodland birds declining in southern Australia (photo: Lynn Pedler).

and will often venture into well-watered and lush gardens around farm-houses. The introduced Common Blackbird uses similar habitats to Bassian Thrushes. Common Blackbirds found their own way to the Island being first reported in 1938 (Baxter & Berris 1995) and although they are now widely distributed over the Island they are not abundant in any natural areas.

Two other insectivores that glean food mainly from the ground are also prominent on the Island: the Scarlet Robin and Restless Flycatcher (Fig. 10). Both are found in woodlands and tall shrublands, the robins mainly in eucalypt woodlands while the flycatchers are often common in tall tea-tree woodlands that line many of the lagoons on the Island. These robins and flycatchers like relatively open understoreys on which to search for food, the robin perching low to the ground on horizontal branches, on the side of a tree trunk or fence post and pouncing on anything that moves on the ground. The flycatcher, on the other hand, will often hover a metre or less off the ground, emitting an unusual grinding noise, before it too pounces on some fossorial prey such as a spider. The calls of Restless Flycatchers are reminiscent of the noise made by the olden day scissors grinders from which it obtains its nickname. Scarlet Robins and Restless Flycatchers have declined in abundance on the adjacent mainland and also appear to be declining on Kangaroo Island. The reasons for the declines are not known but the invasion of weeds that reduce the amount the open ground in some of the open woodland areas may reduce the amount of suitable foraging habitat for these species and so may contribute to the decline.

Two mound-nesting birds, the Australian Brushturkey and Mallee Fowl have been introduced to Kangaroo Island. A pair of Brush-turkeys was introduced to Flinders Chase National Park in 1936. Since then they have become well established in the south-western parts of Island, particularly in the mallee covered sandhills from Ravine de Casoars to Seal Bay where their large and rather untidy mound nests are frequently found (Baxter & Berris 1995). Mallee Fowl were introduced in 1911 near Cape Borda and although they were reported to be breeding in the early 1920s failed to establish (Sutton 1926; Ford 1979). Both Mallee Fowl and Brush-turkeys rake fallen leaves and twigs and loose soil into mounds in which the eggs are placed. The rotting plant material then decays (like a compost heap) generating heat which helps to incubate the eggs. Mallee Fowl also open up their mounds during the morning to allow the sun to provide additional heat to the egg chamber before covering the mound as dusk approaches. Brush-turkeys, however, are not as industrious. The only other bird that digs and scratches in the litter layer is the Painted Button quail. Like most quails this species is difficult to detect and is usually flushed from mal lee and woodland habitats with a heathy understorey before it is clearly seen. However, Painted Buttonquails make distinctive scrapes or slight depressions when they scratch in the litter for food and keen observers will notice these.

Welcome Swallows, Tree Martins, Fairy Martins, Dusky Woodswallows and two species of swift, the White-throated Needletail and Fork-tailed Swift are the main aerial insectivores. The two swifts are seasonal visitors being seen mainly between January and March and more often on hot, humid and unsettled days, when flocks of up to 300 birds of one or other species may be seen swishing low over heathlands or cliffs hawking insects. The numbers of swallows, martins and woodswallows also fluctuate seasonally with Welcome Swallows and Dusky Woodswallows more abundant in spring and summer, and Tree Martins relatively scarce in winter. As many as several hundred swallows, woodswallows or martins may gather at key feeding areas in late summer. Baxter & Berris (1995) suggest that many individuals of these species then migrate to the mainland for winter but at least a few of each remain throughout the year.

Dusky Woodswallows are more prominent in the more open scrubs and woodlands, including areas modified for agriculture. They often build their stick nests in stringy-barks. Welcome Swallows and Tree Martins also breed on the island. Welcome Swallows like to build their mud nests in and around buildings particularly under eaves or verandahs protected from winds, while Tree Martins will nest in holes or cracks in coastal cliffs or in hollows in branches of large eucalypts. Fairy Martins are also reported to breed on the island but records for this species relative to the other hirundines are infrequent.

Other bush birds that show marked seasonal changes in abundance on Kangaroo Island are several species of cuckoos. Cuckoos are more conspicuous during spring when they are easily detected by their almost incessant calls. The three common species on the island are easily separated aurally. Fan-tailed Cuckoos have a mournful trilling call that goes down the scale, Horsfield Bronze Cuckoos a descending whistle 'fee-ew' and the Shining Bronze-Cuckoo a repeated 'fee fee fee' call. A fourth species, the larger Pallid Cuckoo is reported occasionally (Baxter & Berris 1995). The three, relatively common and widespread, cuckoos largely disappear from the Island during autumn and winter, presumably flying to the mainland. Like many other cuckoos, these cuckoos lay their eggs in the nests of other birds, particularly species that build dome-shaped nests such as various wrens and thorn bills. These cuckoos lay a single egg in the nests of their hosts. On hatching the young cuckoo pushes the host's nestlings and or eggs out of the nest to become sole occupant. This may be important to secure adequate food for the young cuckoo since the host species are all much smaller than the cuckoo and consequently may struggle to provide sufficient food for the growing cuckoo if that food was to be shared with the host's chicks. Even after it has fledged from the nest the young cuckoo continues to beg and, despite the burden, the hosts, and sometimes other birds in the vicinity, continue to provision the cuckoo with food.

About the only threat to the begging cuckoo are Brown Goshawks and Collared Sparrowhawks, two birds of prey that largely hunt small birds in woodland and heath land areas. Southern Boobooks are also prominent in these areas and will take birds as prey but hunt at night. Their characteristic 'mopoke' calls echoing from wooded areas over most of the island particularly in spring and summer, breaking any nocturnal silence. Other nocturnal species that use woodland and mallee areas on the island include the Australian Owlet nightjar, Tawny Frogmouth and Spotted Nightjar. However the later two species have only been reported on one or a few occasions respectively (Baxter & Berris 1995).

Another potential predator during the day is the Grey Currawong, but Currawongs have a diverse diet that may include fruit, as well as a range of invertebrates and small vertebrates (lizards and chicks). Like many of the Island's bush-birds, Grey Currawongs are slightly darker and have more slender bills than mainland equivalents and like so many of Kangaroo Island's unique birds also given ultrataxon status (Schodde & Mason 1999).

APPENDIX 1

List of birds recorded on Kangaroo Island.

This list and comments is based largely on the annotated listed compiled by Baxter & Berris (1995) where further details can be obtained. The taxonomy used follows Christidis & Boles (1994) for species names. Subspecific names are given for those species with distinct populations on the island and these largely follow Schodde & Mason (1999). Those species that have been introduced to Australia post European settlement are indicated with an asterisk.

CASUARIIDAE - Emus

Emu D*romaius novaehollandiae.* Introduced 1920s & 1950s. Breeding until 1972 but now extinct in the wild on Kangaroo Island.

Kangaroo Island Emu D*romaius baudinianus.* Discovered Matthew Flinders 1802. Extinct by 1836.

MEGAPODIIAE - Mound builders

Australian Brush-turkey *Alectura lathami*. Introduced 1936. Well established and breeding.

Malleefowl *Leipoa ocellata*. Introduced but failed to establish.

PHASIANIDAE - Quails, pheasants and allies

Stubble Quail *Coturnix pectoralis*. Breeding, abundant in agricultural pastures and crops.

Brown Quail *Coturnix ypsilophora*. Probably breeding, infrequently recorded from sedge thickets.

*Indian Peafowl *Pavo cristatus*. Introduced, breeding, mainly seen in farmland areas with remnant bushland.

ANATIDAE - Swans, ducks and geese

Blue-billed Duck *Oxyura australis*. Breeding. Mainly on deeper permanent swamps

Musk Duck *Biziura lobata*. Breeding. Mainly on deeper permanent swamps also protected marine waters.

Freckled Duck *Stictonetta naevosa*. Irregular visitor usually at times when mainland affected by drought.

Black Swan *Cygnus atratus*. Breeding. Widespread. Uses fresh to brackish wetlands and tidal flats.

Cape Barren Goose *Cereopsis novaehollandiae*. Introduced plus natural colonisation. Breeding. Increasing.

Australian Shelduck *Tadorna tadornoides*.Breeding. Numbers increasing.
Australian Wood Duck *Chenonetta jubata*. First recorded 1959. Breeding. Numbers increasing
Pacific Black Duck *Anas superciliosa*. Breeding. Freshwater swamps.
Australasian Shoveller *Anas rhynchotis*. Breeding. Brackish swamps.
Grey Teal *Anas gracilis*. Breeding. Most abundant duck on island.
Chestnut Teal *Anas castanea*. Breeding. Strong affinity with more saline wetlands.
Garganey *Anas querquedula*. One record. Murray Lagoon August 1992.
Pink-eared Duck *Malacorhynchus membranaceus.* Irregular reports. Breeding. Brackish swamps.
Hardhead *Aythya australis*. First recorded 1979. Infrequent sightings since. Possibly breeding.

PODICIPEDIDAE - Grebes
Australasian Grebe *Tachybaptus novaehollandiae.* Breeding. Widespread. Often on farm dams.
Hoary-headed Grebe *Poliocephalus poliocephalus*. Breeding. Mainly brackish swamps, salt marshes.
Great Crested Grebe *Podiceps cristatus*. Infrequently recorded.

SPHENISCIDAE - Penguins
Fiordland Penguin *Eudyptes pachyrynchus*. Beach-washed specimens only.
Little Penguin *Eudyptula minor*. Breeding, widespread around coast.

PROCELLARIIDAE - Fulmars, Petrels and allies
Common Diving-Petrel *Pelecanoides urinatrix*. Beach washed specimens only.
Southern Giant-Petrel *Macronectes giganteus*. Scattered sightings off shore in most winters.
Northern Giant-Petrel *Macronectes halli*. Recorded less frequently than Southern Giant Petrel.
Southern Fulmar *Fulmarus glacialoides*. Uncommon winter visitor and beach-washed specimens.
Cape Petrel *Daption capense*. Occasional visitor to inshore waters. Mostly beach-washed specimens.
Kerguelen Petrel *Lugensa brevirostris*. A few beach-washed specimens.
Great-winged Petrel *Pterodroma macroptera*. A few sightings inshore but mainly beach-washed.
White-headed Petrel *Pterodroma lessonii*. Several beach-washed specimens.
Blue Petrel *Halobaena caerulea*. Occasional sightings inshore and beach-washed specimens.
Broad-billed Prion *Pachyptila vittata*. Single beach-washed specimen from Kangaroo Island.
Salvin's Prion *Pachyptila salvini*. Two beach washed specimens.
Antarctic Prion *Pachyptila desolata*. A few beach-washed specimens in winter.
Slender-billed Prion *Pachyptila belcheri*. Occasional sightings inshore and beach washed.
Fairy Prion *Pachyptila turfur*. Occasional sightings offshore. Rarely beach-washed.
White-chinned Petrel *Procellaria aequinoctialis*. Two beach derelicts.
Grey Petrel *Procellaria cinerea*. Single beach washed specimen.
Flesh-footed Shearwater *Puffinus carneipes*. Summer visitor. Frequently beach-washed.
Short-tailed Shearwater *Puffinus tenuirostris*. Very common Oct-Nov and around May.
Fluttering Shearwater *Puffinus gavia*. Infrequent records. Mainly seen Apr-Oct.
Hutton's Shearwater *Puffinus huttoni*. Single beach-washed specimen.

DIOMEDEIDAE - Albatrosses
Wandering Albatross *Diomedea exulans*. A few birds seen inshore in most years.
Royal Albatross *Diomedea epomorphora*. Only one sighting off Cape Borda.
Black-browed Albatross *Diomedea melanophris*. Large numbers inshore Apr-Oct.
Shy Albatross *Diomedea cauta*. Rarely seen inshore more common offshore.
Grey-headed Albatross *Diomedea chrysostoma*. Infrequent visitor to inshore waters.
Yellow-nosed Albatross *Diomedea chlororhynchos*. Numerous inshore Apr-Oct.
Sooty Albatross *Phoebetria fusca*. Very infrequent records, about five in last 100 years.
Light-mantled Sooty Albatross *Phoebetria palpebrata.* Only one beach-washed skeleton.

HYDROBATIDAE - Storm-Petrels
Wilson's Storm-Petrel *Oceanites oceanicus*. Rarely seen inshore.
White-faced Storm-Petrel *Pelagodroma marina*. Breeding (limited). Occasional sightings.

PHAETHONTIDAE - Tropicbirds
Red-tailed Tropicbird *Phaethon rubricauda*. Two records in the 1960s.

SULIDAE - Gannets
Australasian Gannet *Morus serrator*. Frequently seen close inshore.

ANHINGIDAE - Darters
Darter *Anhinga melanogaster*. Less than ten records all of single birds.

PHALACROCORACIDAE - Cormorants
Little Pied Cormorant *Phalacrocorax melanoleucos*. Breeding. Sheltered coasts and farm dams.
Black-faced Cormorant *Phalacrocorax fuscescens*. Breeding. Common sheltered coasts.

Pied Cormorant *Phalacrocorax varius*. Breeding. Mainly sheltered coasts.
Little Black Cormorant *Phalacrocorax sulcirostris*. Breeding. Mainly sheltered coasts.
Great Cormorant *Phalacrocorax carbo*. Scattered reports around coast.

PELECANIDAE - Pelicans
Australian Pelican *Pelecanus conspicillatus*. Breeding. Sheltered coastal areas.

ARDEIDAE - Herons, Egrets and allies
White-faced Heron *Egretta novaehollandiae*. Breeding. Widespread.
Little Egret *Egretta garzetta*. First recorded June 1976. Occasional records since.
Eastern Reef Egret *Egretta sacra*. Breeding. Small numbers widespread around coast.
White-necked Heron *Ardea pacifica*. Three records all of individual birds.
Great Egret *Ardea alba*. Infrequent records of single birds.
Cattle Egret *Ardea ibis*. A few birds visiting Island in most winters.
Nankeen Night Heron *Nycticorax caledonicus*. Resident small population.
Australasian Bittern *Botaurus poiciloptilus*. Three records only, the last in 1986.

THRESKIORNITHIDAE - Ibises and Spoonbills
Glossy Ibis *Plegadis falcinellus.* First recorded in 1965, infrequent records since.
Australian White Ibis *Threskiornis molucca.* Breeding. Mainly seen tidal flats and lagoons.
Straw-necked Ibis *Threskiornis spinicollis.* Occasional visitor to Island.
Royal Spoonbill *Platalea regia.* First recorded 1964. Scattered records since.
Yellow-billed Spoonbill *Platalea flavipes.* Breeding. First reported in 1960s. Favours red gum swamps.

ACCIPITRIDAE - Kites, hawks and eagles
Osprey *Pandion haliaetus.* Breeding. Small numbers around the coast.
Black-shouldered Kite *Elanus axillaris.* Breeding. First reported 1934. Regularly seen in farmland.
Letter-winged Kite *Elanus scriptus.* Rare visitor. Three records all in September 1976.
Square-tailed Kite *Lophoictinia isura.* Two records only.
Black Kite *Milvus migrans.* One record only in 1957.
Whistling Kite *Haliastur sphenurus.* Infrequent records scattered over Island.
White-bellied Sea-Eagle *Haliaeetus leucogaster.* Breeding. Small numbers around the coast.
Spotted Harrier *Circus assimilis.* Four records all of single birds.
Swamp Harrier *Circus approximans.* Breeding. Prominent around lagoons.
Brown Goshawk *Accipiter fasciatus.* Breeding. Widespread over Island.
Collared Sparrowhawk *Accipiter cirrhocephalus.* Breeding. Wid spread over Island.
Wedge-tailed Eagle *Aquila audax*. Breeding. Often soaring over farmland.
Little Eagle *Hieraaetus morphnoides.* First recorded March 1988, a few reports since.

FALCONIDAE - Falcons
Brown Falcon *Falco berigora.* Breeding. Mainly in farmland areas.
Australian Hobby *Falco longipennis.* Scattered records in wooded and urban areas.
Black Falcon *Falco subniger.* Seven sightings all between 1990 and 1993.
Peregrine Falcon *Falco peregrinus.* Breeding. Regularly recorded since 1970s.
Nankeen Kestrel *Falco cenchroides.* Breeding. Often hovering over grassland.

GRUIDAE - Cranes
Brolga *Grus rubicunda.* Single report in 1920.

RALLIDAE - Rails and allies
Buff-banded Rail *Gallirallus philippensis.* Breeding. A few scattered records from disparate areas.
Lewin's Rail *Rallus pectoralis.* A few scattered records mainly associated with freshwater swamps.
Baillon's Crake *Porzana pusilla.* Breeding. A few scattered records.
Australian Spotted Crake *Porzana fluminea.* Breeding. Recorded occasionally from a variety of wetlands.
Spotless Crake *Porzana tabuensis.* Breeding. A few scattered records from dense riparian vegetation.
Purple Swamphen *Porphyria porphyrio.* Breeding. Sometimes common in sedge and reedy swamps.
Dusky Moorhen *Gallinula tenebrosa.* Breeding. Small numbers on larger wetlands.
Black-tailed Native-hen *Gallinula ventralis.* Breeding. Irruptive species seen in large numbers in some years.
Eurasian Coot *Fulica atra.* Breeding. Widespread and abundant on large wetlands.

TURNICIDAE - Button Quails
Painted Button-quail *Turnix varia.* Breeding. Widespread but in small numbers in dense vegetation.

SCOLOPACIDAE - Sandpipers and allies
Latham's Snipe *Gallinago hardwickii.* Scattered records during summer around densely vegetated wetlands.
Black-tailed Godwit *Limosa limosa.* One record from 1969.
Bar-tailed Godwit *Limosa lapponica.* Infrequently recorded on tidal mudflats.
Whimbrel *Numenius phaeopus.* Infrequently recorded on tidal mudflats.

Eastem Curlew *Numenius madagascariensis.* Small numbers up to 16 recorded from tidal mudflats.
Marsh Sandpiper *Tringa stagnatilis.* First recorded in 1967 and irregularly since. Lagoons and tidal flats.
Common Greenshank *Tringa nebularia.* Regular summer visitor. Widespread tidal areas.
Wood Sandpiper *Tringa glareola.* One record December 1980.
Terek Sandpiper *Xenus cinereus.* One record September 1994.
Common Sandpiper *Actitis hypoleucos.* Infrequent sightings since 1974. Usually single birds. Coastal.
Grey-tailed Tattler *Heteroscelus brevipes.* Regular summer visitor in small numbers.
Ruddy Turnstone *Arenaria interpres.* Summer visitor mainly coastal areas.
Red Knot *Calidris canutus.* First recorded 1979. Scattered records since, during austral summer.
Sanderling *Calidris alba.* One record only in 1969
Red-necked Stint *Calidris ruficollis.* Common summer visitor.
Long-toed Stint *Calidris subminuta.* Rarely reported. A few records in the 1980s.
Pectoral Sandpiper *Calidris melanotos.* Three records in the 1980s.
Sharp-tailed Sandpiper *Calidris acuminata.*
Abundant summer visitor to mudflats and lagoon shores.
Curlew Sandpiper *Calidris ferruginea.* Regular summer visitor, tidal areas and brackish lagoons.

ROSTRATULIDAE - Painted Snipe
Painted Snipe *Rostratula benghalensis.* One record only from 1963.

BURHINIDAE - Stone Curlews
Bush Stone-curlew *Burhinus grallarius.* Breeding. Widespread over agricultural areas.

HAEMATOPODIDAE - Oystercatchers
Pied Oystercatcher *Haematopus longirostris.* Breeding. Coastal species particularly sandy beaches.
Sooty Oystercatcher *Haematopus fuliginosus.* Breeding. Coastal species including rocky shores.

RECURVIROSTRIDAE - Avocets and Stilts
Black-winged Stilt *Himantopus himantopus.* Breeding. Widespread. Brackish swamps and marshes.
Banded Stilt *Cladorhynchus leucocephalus.* Infrequent sightings, usually flocks on saline wetlands.
Red-necked Avocet *Recurvirostra novaehollandiae.* Breeding. Small numbers on brackish swamps at times.

Grey Plover *Pluvialis squatarola.* Regular summer visitor to tidal mudflats. Up to 200 birds.
Red-capped Plover *Charadrius ruficapillus.* Breeding. Widely distributed around coast line.
Double-banded Plover *Charadrius bicinctus.* A few visit margins of brackish lagoons in autumn-winter.
Lesser Sand Plover *Charadrius mongolus.* Occasional records over summer.
Greater Sand Plover *Charadrius leschenaultii.* Three records. Beaches and tidal mudflats.
Black-fronted Dotterel *Eiseyornis melanops.* Breeding. Widespread. Margins of inland lagoons, dams etc.
Hooded Plover *Thinornis rubricollis.* Breeding. Pairs or family groups on most sandy beaches.
Red-kneed Dotterel *Erythrogonys cinctus.* First recorded 1975, occasionally since. Brackish lagoons.
Banded Lapwing *Vanellus tricolor.* Breeding. Agricultural paddocks with short pasture.
Masked Lapwing *Vanellus miles.* Breeding. Widespread. Coasts, agricultural areas, often on roadsides.

LARIDAE - Skuas, Jaegers, Gulls and Terns
Great Skua *Catharacta skua.* Small numbers reported inshore most winters and out to sea.
Pomarine Jaeger *Stercorarius pomarinus.* A few sightings near coast, mostly in summer.
Arctic Jaeger *Stercorarius parasiticus.* Regular sightings of small numbers off the coasts.
Pacific Gull *Larus pacificus.* Breeding. Widespread around coastline.
Kelp Gull *Larus dominicanus.* One record in December 1975.
Silver Gull *Larus novaehollandiae.* Breeding, abundant and widespread. Mainly around coasts and wetlands.
Gull-billed Tern *Sterna nilotica.* One record December 1989.
Caspian Tern *Sterna caspia.* Breeding. Small numbers reported mainly around eastern coastline.
Crested Tern *Sterna bergii.* Breeding. Abundant and widespread around coastline.
White-fronted Tern *Sterna striata.* First recorded in 1974. Occasional records since.
Common Tern *Sterna hirundo.* Two records only in 1959 and 1994.
Fairy Tern *Sterna nereis.* Formally breeding but now rarely seen in coastal areas.
Sooty Tern *Sterna fuscata.* One record of breeding in 1884. No confirmed records since.
Whiskered Tern *Chlidonias hybridus.* Mainly seen flying over brackish lagoons eastern end of island.

COLUMBIDAE - Pigeons and Doves
*Rock Dove *Columba livia.* Breeding. First noticed 1930s. Abundant around towns and coastal areas.

*Spotted Turtle-Dove *Streptopelia chinensis.* Breeding. First recorded 1949. Mainly urban areas.
Common Bronzewing *Phaps chalcoptera.* Breeding. Widespread. Often seen edges of roads.
Brush Bronzewing *Phaps elegans.* Breeding. Mainly coastal scrubs and mallee areas.
Crested Pigeon *Ocyphaps lophotes.* Introduced in 1937. Did not establish. Last record 1966.

CACATUIDAE - Cockatoos
Glossy Black-Cockatoo *Calyptorhynchus lathami halmaturinus.* Breeding. Northern woodlands and sheoak areas.
Yellow-tailed Black-Cockatoo *Calyptorhynchus funereus.* Breeding. Widespread.
Gang-gang Cockatoo *Callocephalon fimbriatum.* Introduced to Flinders Chase. Breeding. A few remain.
Galah *Cacatua roseicapilla.* First reported 1913. Breeding. Increasing. Widespread in agricultural areas.
Little Corella *Cacatua sanguinea.* First reported 1969. Breeding. Increasing. Mainly agricultural areas.
Sulphur-crested Cockatoo *Cacatua galerita.* First reported 1905. Breeding. Mainly northern agricultural areas.

PSITTACIDAE - Parrots and allies
Rainbow Lorikeet *Trichoglossus haematodus.* Breeding, widespread, abundant when gums flower.
Musk Lorikeet *Glossopsitta concinna.* 25+ birds at American River May 1996 (Pedler *et al. 1996).*
Purple-crowned Lorikeet *Glossopsitta porphyrocephala.* Breeding, widespread, abundant at times.
Crimson Rosella *Platycercus elegans.* Breeding, widespread. Usually seen in pairs or small parties.
Budgerigar *Melopsittacus undulatus.* Rare summer visitor to the island.
Elegant Parrot *Neophema elegans.* Irregular sightings, mainly summer-autumn, stringybark areas.
Rock Parrot *Neophema petrophila.* Irregular summer-autumn visitor to more remote coastal areas.

CUCULIDAE - Cuckoos
Pallid Cuckoo *Cuculus pallidus.* Very occasional visitor to island.
Fan-tailed Cuckoo *Cacomantis f1abelliformis.* Breeding, widespread. More prominent spring-summer.
Horsfield's Bronze-Cuckoo *Chrysococcyx basalis.* Breeding, widespread spring and summer.
Shining Bronze-Cuckoo *Chrysococcyx lucidus.* Breeding. May favour taller woodlands, tea trees.

STRIGIDAE - Owls
Southern Boobook *Ninox novaeseelandiae.* Breeding. Widespread. Woodlands mainly.

TYTONIDAE - Barn Owls
Barn Owl *Tyto alba.* Breeding. Irregular reports from woodlands and agricultural areas.

PODARGIDAE - Frogmouths
Tawny Frogmouth *Podargus strigoides.* One record in 1978.

CAPRIMULGIDAE - Night jars
Spotted Night jar *Eurostopodus argus.* First recorded 1951. A few records since, east end of Island.

AEGOTHELIDAE - Owlet-night jars
Australian Owlet-night jar *Aegotheles cristatus.* Breeding. A few records. Mainly stringybark areas.

APODIDAE - Swifts
White-throated Needletail *Hirundapus caudacutus.* Summer-autumn. Most records on hot unsettled days.
Fork-tailed Swift *Apus pacificus.* Summer-autumn visitor, most records on hot unsettled days

HALCYONIDAE - Kingfishers
Laughing Kookaburra *Dacelo novaeguineae.* Introduced. Breeding Red gum woodlands along Cygnet River.
Sacred Kingfisher *Todiramphus sanctus.* A few reported from riparian woodlands mostly seen in summer.

MEROPIDAE - Bee-eaters
Rainbow Bee-eater *Merops omatus.* Breeding 1980s. Summer-autumn visitor. Not recorded every year.

CORACIIDAE - Rollers
Dollarbird *Eurystomus orientalis.* One record. April-May 1978.

MALURIDAE - Australo-Papuan Wrens
Superb Fairy-wren *Malurus cyaneus ashbyi.* Breeding and widespread in native vegetation.
Southern Emu-wren *Stipiturus mala churus halmaturinus.* Breeding, widespread low dense native vegetation.

PARDALOTIDAE - Pardalotes, Scrubwrens and Thornbills
Spotted Pardalote *Pardalotus punctatus.* Breeding. Widespread, particularly mallee areas.
Striated Pardalote *Pardalotus striatus.* Breeding. Widespread, forest and woodland areas.
White-browed Scrub-wren *Sericomis frontalis ashbyi.* Breeding. Widespread in dense undergrowth.

Shy Heathwren *Hylacola cauta halmaturina.* Breeding. Widespread mallee heaths with dense understorey.
Brown Thornbill *Acanthiza pusilla zietzi.* Breeding. Mallee and woodland areas with shrubby understorey.
Yellow Thornbill *Acanthiza nana.* Several reports. Only one confirmed because several birds caught.
Striated Thornbill *Acanthiza lineata whitei.* Breeding. Widespread in woodland, mallee and in forest.

MELIPHAGIDAE - Honeyeaters and Chats

Red Watllebird *Anthochaera carunculata clelandi.* Breeding. Widespread.
Little Wattlebird *Anthochaera chrysoptera halmaturina.* Breeding. Often associated with *Banksia.*
Spiny-cheeked Honeyeater *Acanthagenys rufogularis.* Occasional sightings from Kingscote-Emu Bay area.
Regent Honeyeater *Xanthomyza phrygia.* Two records both pre-1960.
Yellow-faced Honeyeater *Lichenostomus chrysops.* One, January 2000, Reeve's Pt (Lloyd & Lloyd 2000a).
Singing Honeyeater *Lichenostomus virescens.* Three records accepted by Baxter (1995).
White-eared Honeyeater *Lichenostomus leucotis thomasi.* Breeding. Often associated with Manna gum.
Purple-gaped Honeyeater *Lichenostomus cratitius cratitius.* Breeding widespread, mainly coastal mallee.
White-plumed Honeyeater *Lichenostomus penicillatus.* Only two records.
Brown-headed Honeyeater *Melithreptus brevirostris magnirostris.* Breeding widespread.
White-naped Honeyeater *Melithreptus lunatus.* Breeding, often in Manna gums, particularly Cygnet River.
Crescent Honeyeater *Phylidonyris pyrrhoptera halmaturina.* Breeding. Widespread.
New Holland Honeyeater *Phylidonyris novaehollandiae campbelli* Breeding. Widespread.
White-fronted Honeyeater *Phylidonyris albifrons.* First recorded 1948. Occasional records since.
Tawny-crowned Honeyeater *Phylidonyris melanops.* Breeding, prefers low mallee heath areas.
Eastern Spinebill *Acanthorhynchus tenuirostris.* Breeding. Widespread
Crimson Chat *Epthianura tricolor.* Very irregular visitor. Several reports in 1967-69, and again 1988-90.
White-fronted Chat *Epthianura albifrons.* Breeding. Common around lagoons, saltmarshes and swamps.

PETROICIDAE - Robins

Scarlet Robin *Petroica multicolor.* Breeding. Wide-spread. Prefers woodlands with an open understorey.
Red-capped Robin *Petroica goodenovi.* One male, Jan 2000. Cape Border (Lloyd & Lloyd 2000b).
Flame Robin *Petroica phoenicea.* Increasingly rare winter visitor to Kangaroo Island.

CINCLOSOMATIDAE - Chowchillas and allies

Western Whipbird *Psophodes nigrogularis lashmari.* Breeding. Widespread in dense coastal mallee.

PACHYCEPHALIDAE – Whistlers

Golden Whistler *Pachycephala pectoralis.* Breeding. Widespread.
Rufous Whistler *Pachycephala rufiventris.* Two birds, April 2000, Rocky Point (Reid & Cox, 2000).
Grey Shrike-thrush *Colluricincla harmonica halmaturina.* Breeding. Widespread. Often seen road edges.

DICRURIDAE - Flycatchers, Fantails and Drongos

Satin Flycatcher *Myiagra cyanoleuca.* One record of two males April 1991.
Restless Flycatcher *Myiagra inquieta.* Breeding. Declining. Prefers more open woodlands with grassy understorey.
Magpie-lark *Grallina cyanoleuca.* Breeding. Increasing. Usually close to water - lagoons, dams.
Grey Fantail *Rhipidura fuliginosa.* Breeding. Widespread.
Willie Wagtail *Rhipidura leucophrys.* Breeding. Increasing particularly since the 1950s.
Spangled Drongo *Dicrurus bracteatus.* One record. June-August 1988.

CAMPEPHAGIDAE - Cuckoo-shrikes

Black-faced Cuckoo-shrike *Coracina novaehollandiae.* Breeding. Widespread.

ARTAMIDAE - Woodswallows, Australian magpies, currawongs

Masked Woodswallow *Artamus personatus.* Rare spring-summer visitor to island. Two records.
White-browed Woodswallow *Artamus superciliosus.* Rare spring-summer visitor. One record.
Black-faced Woodswallow *Artamus cinereus.* One record July 1982.
Dusky Woodswallow *Artamus cyanopterus.* Breeding. Widespread. Some birds depart for winter.
Australian Magpie *Gymnorhina tibicen.* Breeding, widespread, increasing with vegetation clearance.
Grey Currawong *Strepera versicolor halmaturina.* Breeding. Widespread.

CORVIDAE - Ravens and Crows

Australian Raven *Corvus coronoides.* Breeding. Widespread throughout farmland.

Little Raven *Corvus mellori.* Breeding. Widespread. Often in large mobile flocks.

ALAUDIDAE - Larks

Singing Bushlark *Mirafra javanica.* Two records only, one in 1959 the other 1994.

*Skylark *Alauda arvensis.* Breeding. First recorded in 1959. Increasing in open farmland areas.

MOTACILLIDAE - Pipits

Richard's Pipit *Anthus novaeseelandiae bilbata.* Breeding. Now widespread over agricultural areas.

PASSERIDAE - Old World Sparrows, Australian grass finches

*House Sparrow *Passer domesticus.* Breeding. Arrived before 1910. Now widespread around farms.

Red-browed Finch *Neochmia temporalis.* Breeding. Open woodlands and agricultural areas.

Beautiful Firetail *Stagonopleura bella samueli.* Breeding. Prominent in mallee-bulloak scrubs.

FRINGILLIDAE - True Finches

*European Goldfinch *Carduelis carduelis.* Breeding. Farmland areas.

HIRUNDINIDAE - Swallows and Martins

Welcome Swallow *Hirundo neoxena.* Breeding. Widespread. Often nesting in and around buildings.

Tree Martin *Hirundo nigricans.* Breeding. Widespread. Woodland areas.

Fairy Martin *Hirundo ariel.* Breeding. A few records only.

SILVIIDAE - Old World Warblers

Clamorous Reed-Warbler *Acrocephalus stentoreus.* Breeding. Spring-summer visitor. Riparian areas.

Little Grassbird *Megalurus gramineus.* Breeding. Spring-summer visitor. Riparian areas.

Brown Song lark *Cincloramphus cruralis.* Sporadic reports. One breeding record. Last seen 1977.

ZOSTEROPIDAE - White-eyes

Silvereye *Zosterops lateralis.* Breeding. Widespread. Abundant coastal scrubs and mallee-heaths.

MUSCICAPIDAE - Thrushes

Bassian Thrush *Zoothera lunulata halmaturina.* Breeding. Widespread but small numbers. Moister areas.

*Common Blackbird *Turdus merula.* First reported 1938. Small numbers around eastern townships.

STURNIDAE - Starlings and allies

*Common Starling *Sturnus vulgaris.* Breeding. Increasing. Widespread. Mainly agricultural areas.

11: Reptiles and Amphibians

by M. N. HUTCHINSON and M. J. TYLER

INTRODUCTION

Intensive biological survey work over the last decade and a half has led to the reptile and amphibian fauna of Kangaroo Island being better known than is the case for any comparable-sized region in South Australia. Twenty-four species are known to be endemic to Kangaroo Island. Two mainland species, the skinks *Tiliqua rugosa* and *T scincoides* were introduced to Flinders Chase in the 1920's but appear not to have survived. One other species, the bearded dragon *Pogona barbata,* is believed to have become established over the last 20-30 years (Jenner 1996). A further species, the little whip snake, *Suta flagellum,* is of uncertain status. The total fauna is thus no more than 26 species (Appendix 1).

Islands typically have lower species diversity than do comparable mainland areas, but the species often occur in higher numbers. In this respect, the reptiles and amphibians of Kangaroo Island constitute a typical island fauna. The total of 24 or 25 native species is rather low, given the island's area, but most of these species are more common on Kangaroo Island than on the nearby mainland of South Australia. None of the Kangaroo Island species is endemic, which no doubt reflects the fact that Kangaroo Island was continuous with the adjacent mainland during the last ice ages until about 10 000 years before present, and was regularly connected in preceding ice ages. Species expanding onto the Island during periods of lowered sea level have evidently not been isolated long enough to have differentiated. The climate during ice ages was cooler and drier than it is now, which may also partly explain why several mainland species are not found on the island.

In the first edition of this Natural History volume several errors were present in the herpetofaunal checklist of Houston & Tyler (1979 p. 21) which we are now in a position to correct. Species erroneously reported as present or possibly present were *Tympanocryptus lineata, Delma* sp. *Sphenomorphus (=Eulamprus) quoyii, Leiolopisma (=Lampropholis) delicata, Notechis scutatus* and *Pseudechis porphyriacus.* Species referred to in the earlier work as *Leiolopisma trilineatum* and *Lerista frosti* are now known as *Bassiana duperreyi* and *Lerista dorsalis.* The presence of two other species *(Menetia grayii* and *Pseudemoia entrecasteauxii,* the former completely unknown and the latter only from a literature record) has also been confirmed.

Even though the species tally is low, some Kangaroo Island species are common and obvious components of the island's habitats. Large goannas are often seen by the roadside throughout the island, and large snakes are commonly encountered. Several small lizard and frog species are abundant.

The composition of the fauna is most similar to

Table 1. COMPARISON OF THE NUMBER OF SPECIES OF REPTILES AND AMPHIBIANS OF KANGAROO ISLAND WITH ADJACENT MAINLAND AREAS. NUMBERS IN PARENTHESES INDICATE SPECIES SHARED WITH KANGAROO ISLAND

Family	Number of Species			
	Kangaroo Island	Fleurieu Peninsula[1]	S. Yorke Peninsula[2]	S. Eyre Peninsula[3]
ANURA				
Hylidae	1	1(1)	0	0
Myobatrachidae	5	6(5)	2(1)	2(2)
TESTUDINES				
Chelidae	0	1	0	0
LACERTILIA				
Agamidae	1[4]	4(1)	5(0)	4(0)
Gekkonidae	3	6(3)	8(3)	8(3)
Scincidae	11	16(10)	13(7)	13(6)
Varanidae	1	1(1)	2(1)	2(1)
SERPENTES				
Typhlopidae	0	1	2	2
Elapidae	2[4]	6(1)	6(1)	7(1)
Total	24	42(22)	38(13)	38(13)

[1] South of the line connecting Pt Noarlunga and Langhorne Ck; [2] south of Minlaton; [3] south of the line connecting Tumby Bay and Coulta; excludes *Pogona barbata*, regarded as a recent introduction, and *Suta flagellum*, status uncertain

Fig. 1. *Nolechis ater,* juvenile, Bronte Park, Tasmania (photograph P. Robertson).

the adjacent Fleurieu Peninsula, but the diversity is lower (the southern Fleurieu Peninsula supports 42 species) and Kangaroo Island includes two species, *Egernia multiscutata* and *Notechis ater* (Fig. 1) which do not occur on the southern Fleurieu. Both species occur on the southern Yorke and Eyre peninsulas, which each support 38 species (Table 1). The greater similarity to the Fleurieu is probably a reflection of its more temperate climate compared with Yorke and Eyre peninsulas. This is particulary noticeable in the frogs, but obscured somewhat by the intrusion of species entering the Fleurieu Peninsula via the River Murray: *Litoria peroni, L. raniformis* and *Limnodynastes fletcheri.* If these 'additions' are excluded from consideration, the Kangaroo Island frog fauna can be seen for what it is: an extension of that of the Fleurieu Peninsula during periods of lower sea level.

SNAKES

Only two species of snakes are certainly known from Kangaroo Island. Both are members of the family Elapidae, characterized by the presence of short, hollow venom-conducting fangs at the front of the mouth. There are no pythons (Boidae) or blind snakes (Typhlopidae) on Kangaroo Island.

The larger species, the black tiger snake, *Notechis ater,* grows to about 1.4 m in length and occurs throughout the Island. It is very variable in colour and pattern, and this variation is responsible for earlier reports of red-bellied black snakes, *Pseudechis porphyriacus,* from the Island. In fact, some Kangaroo Island tiger snakes are blackish above and have a red wash on the belly scales, superficially resembling the colour of P. *porphyriacus* (Schwaner 1984). Whereas the typical tiger snake pattern includes pale crossbands or rings along the body, many Kangaroo Island specimens are uniformly coloured, blackish or brown.

Tiger snakes are dangerously venomous, with extremely potent neurotoxic (nerve-poisoning) venom. The species is often active on cool days and may be reluctant, or too cold, to move when

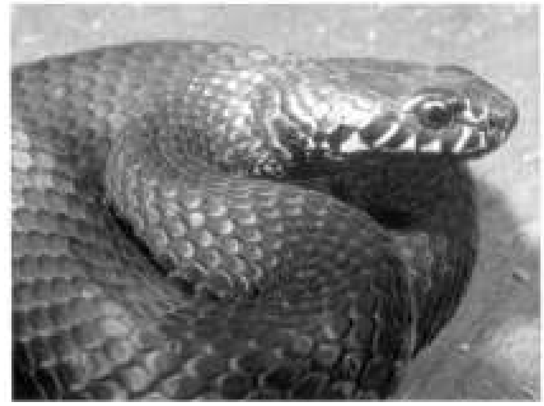


Fig. 2. *Austrelaps labialis,* Adelaide Hills (photograph M. N. Hutchinson).

approached. Under these circumstances it may bite in self-defence, although not before providing a warning via a threat display, in which it greatly flattens its body and emits short, loud, sneeze-like hisses. Tiger snakes take a wide range of prey, including lizards, small mammals and birds, but appear to prey heavily on frogs when these are available.

The second Kangaroo Island snake is the pigmy copperhead, *Austrelaps labialis* (Fig. 2), a smaller species which seldom exceeds 75 cm in length. This size is reached only by males; like many Australian elapid snakes, males grow larger than females. This species is confined to Kangaroo Island, where it is common, and the Adelaide Hills-Fleurieu Peninsula where it is restricted to the coolest habitats (Rawlinson 1991). Pygmy copperheads are primarily lizard eaters, although they also feed on frogs and, occasionally in larger specimens, small mammals. Like tiger snakes, to which they are closely related, copperheads are active in cool weather. They have similar neurotoxic venom, but the venom of the pigmy species is not yet well studied. The species is not regarded as deadly, but a bite from a large specimen might lead to serious symptoms.

The little whip snake, *Suta flagellum,* has been recorded from Kangaroo Island only once and its presence there is doubtful. In 1913 a single specimen from 'Willson's River, Hog Bay' (the Penneshaw area) was registered into the South Australian Museum's herpetology collection. The donor, L. Willson, was presumably a resident of the area and so it is not certain that the location represents the actual collection site of the specimen or merely the address of the donor. No further records of this species have been made, in spite of considerable field work over the rest of the century. The little whip snake is a small species, usually less than 30 cm in total length and is nocturnal, hiding during the day under ground cover or in cracks or holes. It is moderately common on the Fleurieu Peninsula.

Fig 3 Tracks of *Varanus rosenbergi* at Seal Bay, Kangaroo Island (photograph M. N. Hutchinson

LIZARDS

Australia has five main groups of lizards and all are represented on Kangaroo Island.

Varanidae

Largest and most obvious during warm weather are the Island's goannas. The heath goanna, *Varanus rosenbergi* can be seen allover the island (Fig. 3), often along roads where they forage for road kills. Aside from carrion, the usual diet consists of large invertebrates, such as centipedes and scorpions, and small vertebrates such as lizards. Goannas have sharp, blade-like teeth with finely serrated edges, like steak knives. They are the largest native terrestrial predators on Kangaroo Island.

The goanna family, Varanidae, is characterized partly by body form, goannas all being relatively elongate lizards with long necks (the neck is longer than the head) and slender, finely-chiseled heads. The tongue is snake-like, long and forked and the tail is large and strong and can be used as a weapon. Unlike the tails of some other lizards, a goanna's tail cannot be voluntarily shed if it is grabbed or hit. If it is accidently broken, it does not regenerate. The skin is very tough, covered in small, bead-like scales. The legs are relatively short but powerful and the claws are strong and sharp.

Heath goannas have been the subject of extensive study (Green & King 1978), which makes them among the better understood members of the family in Australia. King & Green (1979) found that these lizards have a varied diet, with commonly eaten prey including mammals (bush rats), birds, lizards, large insects, centipedes and spiders. They occupy home ranges that averaged about 20 ha, but some home ranges were two or three times larger. Although activity was at a maximum during spring and summer, these goannas remained active throughout the year, basking near their burrow entrances on warm winter days. As is the case with some other goannas, female heath goannas were recorded using termite mounds as incubation sites for their eggs, clutches of up to 14 being laid during summer. Males are larger and much more often seen than females.

Kangaroo Island is a stronghold for this species in South Australia. Although it occurs in heathy mallee and woodland on the southern mainland, its numbers there appear to have fallen considerably over the last few decades. The causes are unclear, but habitat loss and possible predation by foxes and cats may be contributing factors. Further habitat degradation, cat predation and increasing

Fig. 4. *Morethia obscura* male, Mt Stockdale, Kangaroo Island. (photograph M. N. Hutchinson).

Fig. 5. *Hemiergis peronii,* 8 km WSW Emu Bay, Kangaroo Island (photograph M. N. Hutchinson).

traffic are three factors in the Kangaroo Island environment most likely to cause problems for the heath goanna in the future.

Scincidae

While goannas are the largest lizards on Kangaroo Island, skinks are the most numerous and diverse. Eleven species representing eight genera, occur there. Skinks as a family have characteristic scales which tend to be relatively large, smooth and overlapping. The skin is tough and often has a glossy or iridescent surface. Skinks include some normally-proportioned lizards, with well-developed legs and toes, and also some much slenderer animals, in which snake-like undulation is an important mode of locomotion and the limbs are greatly reduced in size.

The most commonly seen lizards are probably the small, fast-moving skinks belonging to three genera, *Lampropholis, Morethia* (Fig. 4) and *Bassania.* All are similar in being active, basking species growing to a total length of only 10 to 15 cm. They have well-developed limbs and long tails which are easily shed - these skinks are collectively known as 'drop-tail' lizards. All are egg layers, and they frequently nest communally (Mitchell 1959; Rounsevell 1978; Greer 1980) with as many as 50 females depositing their eggs at the same site under an embedded rock or other ground cover. In spite of the admonitory proverb, putting all their eggs in one basket can be a good thing for these lizards. It ensures that the predators of eggs and juvenile lizards in a local area will be too few to take more than a minor proportion of the reproductive output.

One other small skink, the southern grass skink, *Pseudemoia entrecasteauxii,* is rare on Kangaroo Island, but has a quite different reproductive strategy - it is placental. This species, along with three other Kangaroo Island skink genera *(Hemiergis, Egernia* and *Tiliqua)* and the two venomous snakes, bears live young. The other live-bearers are essentially egg retainers, the embryo being nourished entirely from yolk, laid down as it would be for a typical egg-layer. A rudimentary placental connection with the mother in these species serves only to maintain water balance and to ensure oxygenation. In *Pseudemoia* however, although some yolk is supplied, it is insufficient to 'build' a complete neonate, and may well act mainly as insurance. It is thought that the main nutrient supply for the embryos comes direct from the maternal blood stream via the well-developed, complex placenta formed by these skinks (Stewart & Thompson 1993).

Several Kangaroo Island skinks mainly forage out of sight in leaf litter and loose sand. The tiny dwarf skink, *Menetia greyii* which is mature at a weight of half a gram, is one such species. It is slenderer than the more surface-dwelling species, enabling it to more easily slither through cluttered litter. Other species are much more short-legged and elongate, sometimes almost snake-like in proportions. By far the most common in many parts of the island are the earless skinks, *Hemiergis,* especially the four-toed species, *H. peronii* (Fig. 5). These lizards have very small limbs with tiny toes and no ear openings. Where the earhole should be, there is only a scaly depression. Evidently these lizards spend so little time on the surface they have lost the need to hear airborne sounds. The two species of *Lerista,* the slider skinks, are sand· swimmers, propelling themselves through sand and loose soil by eel-like undulations, and using the flat head as a shovel or plough. Bougainville's skink, *L. bougainvillii,* is distinctive among the world's lizards in being one of only a few that are geographically variable in mode of reproduction. Almost all *Lerista* species (60 or more, all confined to Australia) are egg layers, and it is true for most populations of *L. bougainvillii.* However, Kangaroo Island populations, and also those on Bass Strait islands and in Tasmania, have live young (Qualls el *al.* 1995). This may be an adaptive response to the cool island climates, where a thermoregulating female can maintain the embryos at higher temperatures, ensuring faster maturation, than

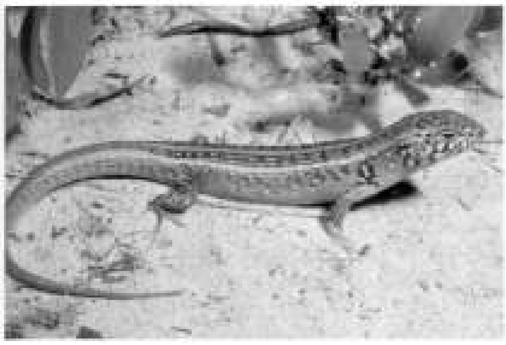


Fig. 6. *Egernia multiscutata,* Cape Hart, Kangaroo Island (photograph M. N. Hutchinson).

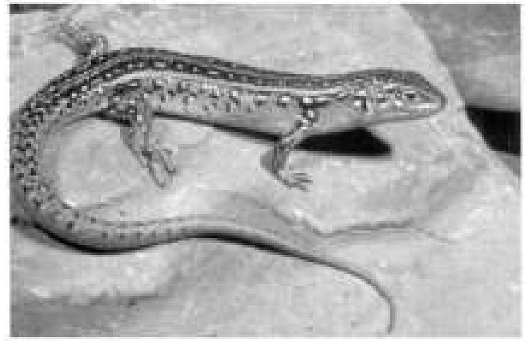


Fig. 7. *Egernia whitii,* Sandy Point Victoria (photograph M. N. Hutchinson).

would be possible if the eggs were laid.

The two species of *Egernia* are larger lizards, growing to 20 cm or more in total length and up to 15 g in weight. White's skink, *E. whitii,* is found all over the island, while the bull skink, *E. multiscutata* (Fig. 6), is restricted to coastal sand dune sites. Both inhabit burrows, those of White's skink usually dug beneath a rock or log, while bull skinks often build small warrens with several interconnected tunnels and several openings (Hickman 1961; Coventry & Robertson 1980). The two species are similar in size and colouring, but usually occupy different habitats elsewhere in Australia; Kangaroo Island, and nearby Wedge and Neptune islands, are the only places where the two species occur together. Both are unusual among skinks in showing colour pattern polymorphism. In both species, the basic colour pattern consists of a pair of dark dorsal stripes enclosing pale dots and a lateral pattern of pale speckling (ocellate markings in *E. whitii,* Fig. 7). Some individuals, termed the 'plain-back' form, have a uniform reddish-brown back, while others, the 'plain' form, are completely unmarked on the back and sides. Kangaroo Island is notable for the relatively high numbers of plain and plain-back individuals of both species.

Gekkonidae

This family, consisting of the geckos and closely related pygopods (legless lizards) has three representatives on Kangaroo Island, each representing one of three major lineages of this family that occur in Australia. The three species also represent quite different sets of adaptations.

The marbled gecko, *Christinus marmoratus* (formerly *Phyllodactylus marmoratus)* is a member of the subfamily Gekkoninae, the 'typical' gecko subfamily that occurs world-wide. Like many geckos, marbled geckos are climbers, and have specialized adhesive pads on the toe tips that assist climbing. The toe pads, which are paired in this genus, have tiny bristle-like projections on their surface, which give the toe pad a 'Velcro'-like ability to catch and hold microscopic irregularities on apparently smooth surfaces. Marbled geckos are strictly nocturnal and have large eyes with a pupil which closes to a vertical slit in bright light. As with almost all members of this family, normal moveable eyelids are absent, and the unblinking eye is covered by a single large transparent scale.

Gekkonine geckos reproduce by eggs, nearly all species laying just two per clutch. In this subfamily eggs are unusual in having highly calcified brittle shells, making them like tiny birds' eggs rather than the parchment-like, water-absorbing shells found on most other lizard and snake eggs. Females store calcium in large glandular lumps on each side of the neck.

The barking gecko, *Nephrurus milli* (Fig. 8) is a member of the subfamily Diplodactylinae, a gecko group restricted to Australia, New Caledonia and New Zealand. Diplodactylines are very diverse in structure and habits, with some, like the genus *Nephrurus* being specialised ground dwellers, lacking adhesive toe pads. *Nephrurus* geckoes have specialized tails, broadened at the base with a thin terminal 'rat tail'. Most have a knob on the tail tip, but *N. milii* is one of two primitive members of the group that lack this peculiar structure. Barking geckos sometimes use a threat display rather than trying to flee when confronted by an enemy. They arch the back and raise and twist the tail to and fro, and will lunge forwards trying to bite and uttering a

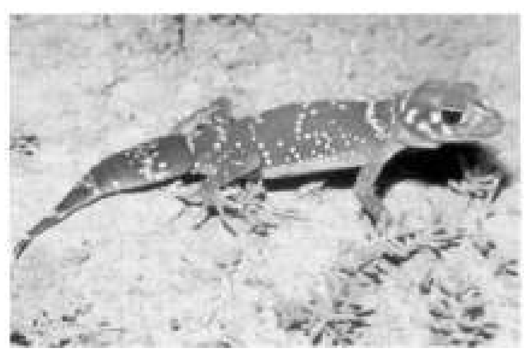


Fig. 8. *Nephrurus milii,* Morgan, S. A. (photograph M. N. Hutchinson).

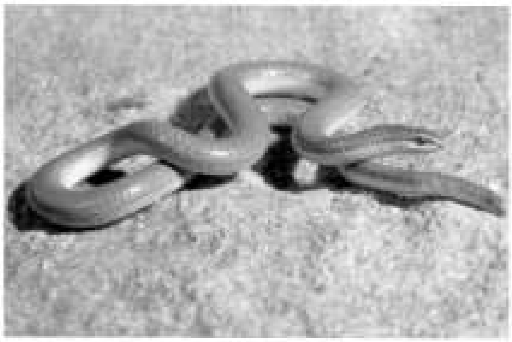


Fig. 9. *Aprasia striolata* Mt Stockdale, Kangaroo Island (photograph M. N. Hutchinson).

rasping squeak. A voice, often used in moments of stress, is a general feature of all gekkonids. Barking gecko eggs have soft flexible shells, unlike those of marbled geckos.

Legless lizards are very close relatives of the diplodacyline geckos, showing several unique similarities in internal anatomy, but quite unlike them in external appearance and habits. The lined worm lizard, *Aprasia striolata* (Fig. 9) is a diurnal species which spends much of its time below the surface of sandy soil. Its burrowing habits are connected with its specialized diet of ants, particularly the larvae and pupae. Its small size and thin body allow it to move through the galleries of ant nests. It is not known how this lizard is able to avoid attack by the ants as it invades their nests and eats their young.

Worm lizards are widespread on Kangaroo Island, often being dug up or discovered as rocks or logs are turned over. Two colour patterns occur, one with the typical alternating lines of dark brown and creamy brown along the body and tail, the other almost completely unmarked pale brown. It is thought that, like other legless lizards, they lay a single clutch of two parchment-shelled eggs in late spring.

Agamidae

The agamids, generally known in Australia as dragon lizards, have two representatives on Kangaroo Island, one native, the tawny dragon, *Gtenophorus decresii* (Fig. 10) and one introduced, the eastern bearded dragon, *Pogona barbata.* The presence of the eastern bearded dragon on Kangaroo Island appears to represent a case of human introduction, but whether accidental or deliberate is unknown. This large and easily observed species was only recorded for the first time on Kanagaroo Island in 1977. Since then the species has been sighted several times, all records coming from the general vicinity of Kingscote (Jenner 1996). The species is relatively common on the Fleurieu Peninsula.

The tawny dragon is a typical member of its family in most respects. It is sun-loving and a sit-and-wait predator, choosing an exposed perch from which it can scan the area for signs of

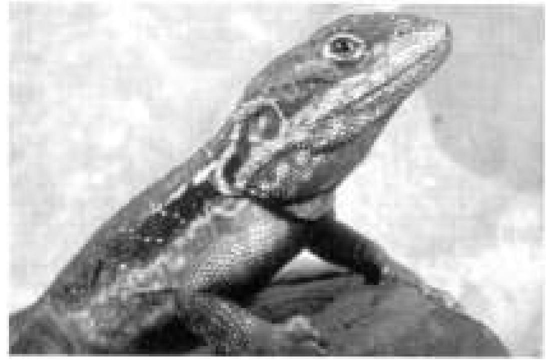


Fig. 10. *Ctenophorus decresii,* male, Spring Creek, Flinders Ranges, S. A. (photograph M. N. Hutchinson).

movement. Vision is the key sense used by dragons, not only for detecting food and enemies, but also for recognizing members of their species. Males and females have markedly different colouring and often a blueish or greenish tinge to the body colouring. Females and juveniles are camouflaged in sandy brown to grey-brown, patterned with darker markings. Males are probably territorial, defending an exclusive area from encroachment by other males. The tawny dragon is one of a group of five species in South Australia that are specialized inhabitants of rocky areas. On Kangaroo Island, tawny dragons are generally confined to coastal areas in the west and north, as these provide the most extensive rock exposures in the form of coastal cliffs and creek lines.

FROGS

Throughout the island there is little evidence of any of the resident frog species being confined to or particularly dominant within any area. Somewhat in support is the vast geographic range that each occupies within south or southeastern Australia, diminishing any likelihood of sharply defined habitat requirements.

The single tree frog is *Litoria ewingii* (Fig. 11), a relatively small, pale brown species with pale yellow

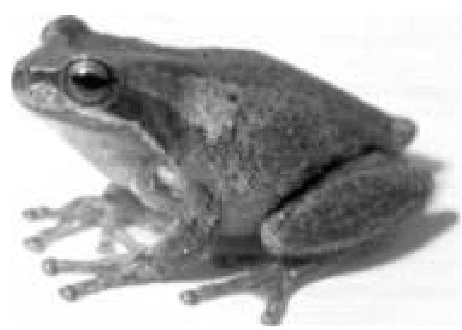


Fig 11 *Litoria ewingii*, Adelaide Hills (Photograph M Davies)

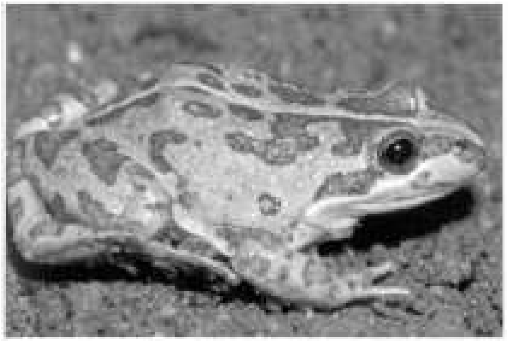


Fig. 12. *Limnodynastes tasmaniensis,* Adelaide (photograph M. Davies).

thighs sparsely marked with black, and readily recognized by the expanded tips to its fingers and toes. *L. ewingii* breeds in temporary pools whenever there are moderate falls of rain. The pairs mate and lay clumps of 7-8 eggs in virtually any body of static water. The spawn clumps do not float, but are attached to surface or subsurface vegetation (Waite 1927). Provided that the water persists for two or three days, the eggs will hatch, but they require two to three months to complete development. Only too often the breeding sites dry up and the tadpoles perish. The low survival rate is compensated for by the repeated deposition of eggs with every rainfall, so that the chances of the survival of one or more spawn clumps is greatly enhanced.

L. ewingii does not occur on Eyre Peninsula, so that the Kangaroo Island population is the westernmost extremity within an extensive south-eastern Australian range.

Among the ground dwelling frogs, the spotted grass frog *Limnodynastes tasmaniensis* (Fig. 12) is by far the most abundant species. Unlike other genera on the Island *Limnodynastes* species lay their eggs in a foamy white mass of froth rising above the surface of the water. Although a few eggs are trapped in the foam, the majority lie at the base.

Whereas *L. tasmaniensis* breeds throughout the year whenever climatic conditions are suitable, the larger *L. dumerilii* (Fig. 13) is a spring breeder favouring slightly higher water temperatures. When mating in the water, *L. dumerili* is often plagued by leeches. Waite (1925) wrote: 'Leeches abound in the water, and every frog I saw had several of these annelids attached to it. Pairing frogs being unable to rid themselves of the temporary parasites had, literally, scores of leeches attached to their bodies like so many streamers.'

In appearance the two *Limnodynastes* species are readily distinguishable: *L. dumerilii* is a robust, brown animal bearing large protruding glands on the upper surface of its calves (Fig. 13). In contrast *L. tasmaniensis* is a smaller and flatter-bodied species tending to a greyish or greenish

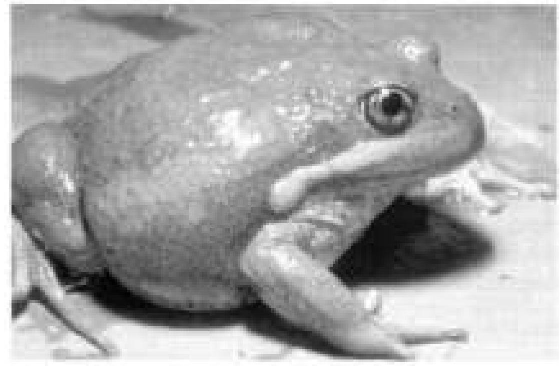


Fig. 13. *Limnodynastes dumerilii,* Adelaide (photograph M. Davies).

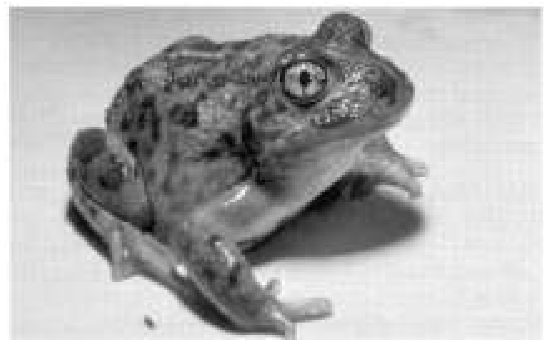


Fig. 14. *Neobatrachus pictus,* Roseworthy, S. A. (photograph M. Davies).

ground colour, bearing large patches of darker pigment, and lacking calf glands. An illustrated key to these and the other Kangaroo Island species is provided in Tyler (1977).

During the summer months the *Limnodynastes* species seek subterranean refuges. *L. tasmaniensis* lacks structural modifications to the foot to permit active burrowing, and so tends to penetrate fissures in the soil, or else shelters beneath surface structures such as flat rocks or fallen timber. In contrast *L. dumerili* is equipped with tubercles protruding from the under-surface of the foot, and uses its feet to cut a vertical shaft into the soil.

Neobatrachus pictus (Fig. 14) is similarly equipped for burrowing, but also exhibits more refined physiological adaptations, such as the secretion around its entire body of a loose, multi-layered coating of shed skin. This 'cocoon' inhibits the rate of water loss from the buried frog to the surrounding soil, and so lengthens the ability to survive underground during periods of sustained drought.

The *Limnodynastes* species and *N. pictus* are most likely to be seen on damp nights crossing sealed roads or unsealed tracks. The remaining species are only up to approximately 30 mm in total length, and are more likely to be heard than seen. *Pseudophryne bibroni* (Fig. 15) is unusual in its breeding habits; it calls following the first substantial late summer or autumn rains at any period between late February and early May. Males call from small depressions or burrows covered with leaf litter, on slopes above the sites of temporary pools. The call is a short harsh squelch. The eggs are laid on land in groups, with each egg contained within a capsule quite separate from the others, and the male frog remains with the fertilized eggs. The tadpoles develop within capsules and are released and washed down to the pools by subsequent rains.

Crinia signifera is an agile species that uses its long legs to leap away at the first sign of danger. The similarly-sized P *bibroni* has short digits and stumpy legs and walks. It feigns death when disturbed. C. *signifera* calls throughout the year: a high rapid clicking.

Fig. 15. *Pseudophryne bibroni,* Kingston, S. A. (photograph M. Davies).

APPENDIX 1
REPTILES AND AMPHIBIANS OF KANGAROO ISLAND

AMPHIBIA
ANURA (frogs)
Hylidae (Treefrogs)
- Brown Treefrog *Litoria ewingii* (Dumeril & Bibron, 1841)

Myobatrachidae (Australian Ground Frogs)
- Common Froglet *Crinia signifera* (Girard, 1853)
- Banjo Frog *Limnodynastes dumerilli* (Peters, 1863)
- Spotted Grass Frog *L. tasmaniensis* Gunther, 1858
- Painted Frog *Neobatrachus pictus* Peters, 1863
- Brown Toadlet *Pseudophryne bibroni* Gunther, 1858

REPTILIA
LACERTILIA (lizards)
Agamidae (Dragons)
- Tawny Dragon *Ctenophorus decresii* (Dumeril & Bibron, 1837)
- Eastern Bearded Dragon (introduced) *Pogona barbata* (Cuvier, 1829)

Gekkonidae
- Gekkoninae (typical geckos)
- Marbled gecko *Christinus marmoratus* (Gray, 1845)

Diplodactylinae (Australasian geckos)
- Barking Gecko *Nephrurus milii* (Bory de Saint-Vincent, 1825)

Pygopodinae (Australian Legless Lizards)
- Lined Worm-lizard *Aprasia striolata* (Lutken, 1863)

Scincidae (skinks)
- Eastern Three-lined skink Bassiana *duperreyi* (Gray, 1838)
- Bull Skink *Egemia multiscutata* Mitchell & Behrndt, 1949
- White's skink *E. whitii* (Lacepede, 1804)
- Three-toed Earless Skink *Hemiergis decresiensis* (Cuvier, 1829)
- Four-toed Earless Skink *H. peronii* (Gray, 1831)
- Garden Skink *Lampropholis guichenoti* (Dumeril & Bibron, 1839)
- Bougainville's Skink *Lerista bougainvilli* (Gray, 1839)
- Southern Four-toed Slider *L. dorsalis* Storr, 1985
- Dwarf Skink *Menetia greyii* Gray, 1845
- Mallee Snake-eye *Morethia obscura* Storr, 1972
- Southern Grass Skink *Pseudemoia entrecasteauxii* (Dumeril & Bibron, 1839)

Varanidae (goannas)
- Heath Goanna *Varanus rosenbergi* Mertens, 1957

Elapidae (Venomous snakes)
- Pygmy Copperhead *Austrelaps labialis* (Jan, 1859)
- Black Tiger Snake *Notechis ater* (Krefft, 1866)
- Little Whip Snake (presence doubtful) *Suta flagellum* (McCoy, 1878)

12: Fossil Vertebrates

by NEVILLE PLEDGE

CAVE DEPOSITS

When the Kelly Hill Caves were opened in 1926, several decades after their initial discovery by the horse 'Ned Kelly' which fell through the roof into one cave in 1880 (Cordes 1969; Osterstock 1973), quantities of bone were found in several of the chambers (Bell 1926), and samples were collected by H. M. Hale and N. B. Tindale (Morgan & Sutton 1928). The richest deposit so far discovered was found in several small grottos leading from the natural entrance chamber. This chamber is a pitfall trap formed when the roof of the cave collapsed. A considerable amount of silt was washed in through this entry, and helped preserve the remains of animals that accumulated there. These remains were the result of either accidental death in the pitfall trap itself, or disintegration of pellets regurgitated by owls that occupied the site. Howchin (1930) made a brief mention of fossils, including a Wombat and a Tiger Cat, both of which were previously unknown on the island. Finlayson (1938) described a Rat Kangaroo, *Potorous morgani,* from sub-fossil deposits in the Kelly Hill Caves, though Ride (1970) considered this species to be the same as P *platyops,* the Broad-faced Rat Kangaroo still living in Western Australia (see also Butler & Merrilees 1971).

A tooth of the Tasmanian Devil *(Sarcophilus harrisii)* of uncertain age was collected in the Kelly Hill Cave (Calaby & White 1967), whilst D. J. Taylor reported, in upublished records of the Cave Exploration Group of SA (1956), collecting a quantity of bones from the natural entrance cavern. This material included: Kangaroo Island Kangaroo *(Macropus fuliginosus),* Tammar Wallaby (M. *eugenii),* Common Brushtail Possum *(Trichosurus vulpecula),* Koala *(Phascolarctos cinereus),* Ringtail Possum *(Pseudocheirus peregrinus),* Tiger Cat *(Dasyurus maculatus),* Brushtail Phascogale *(Phascogale tapoatafa),* and Kangaroo Island Emu *(Dromaius baudinianus).* A complete skeleton of the Kangaroo Island Emu was collected in the Kelly Hill Caves by E. Burgess in 1926 and footprints of the bird preserved in hardened sand in dunefield of the 'Little Sahara', near Seal Bay, were also found in 1991. Except for a tooth of *Sthenurus* reported by CEGSA records by Daily (1959 unpublished), no real fossil or Pleistocene species has yet been found in the Kelly Hill Caves. The same may be said about a number of other small caves within Flinders Chase. (Those bones seen have been of modern species and quite unaltered).

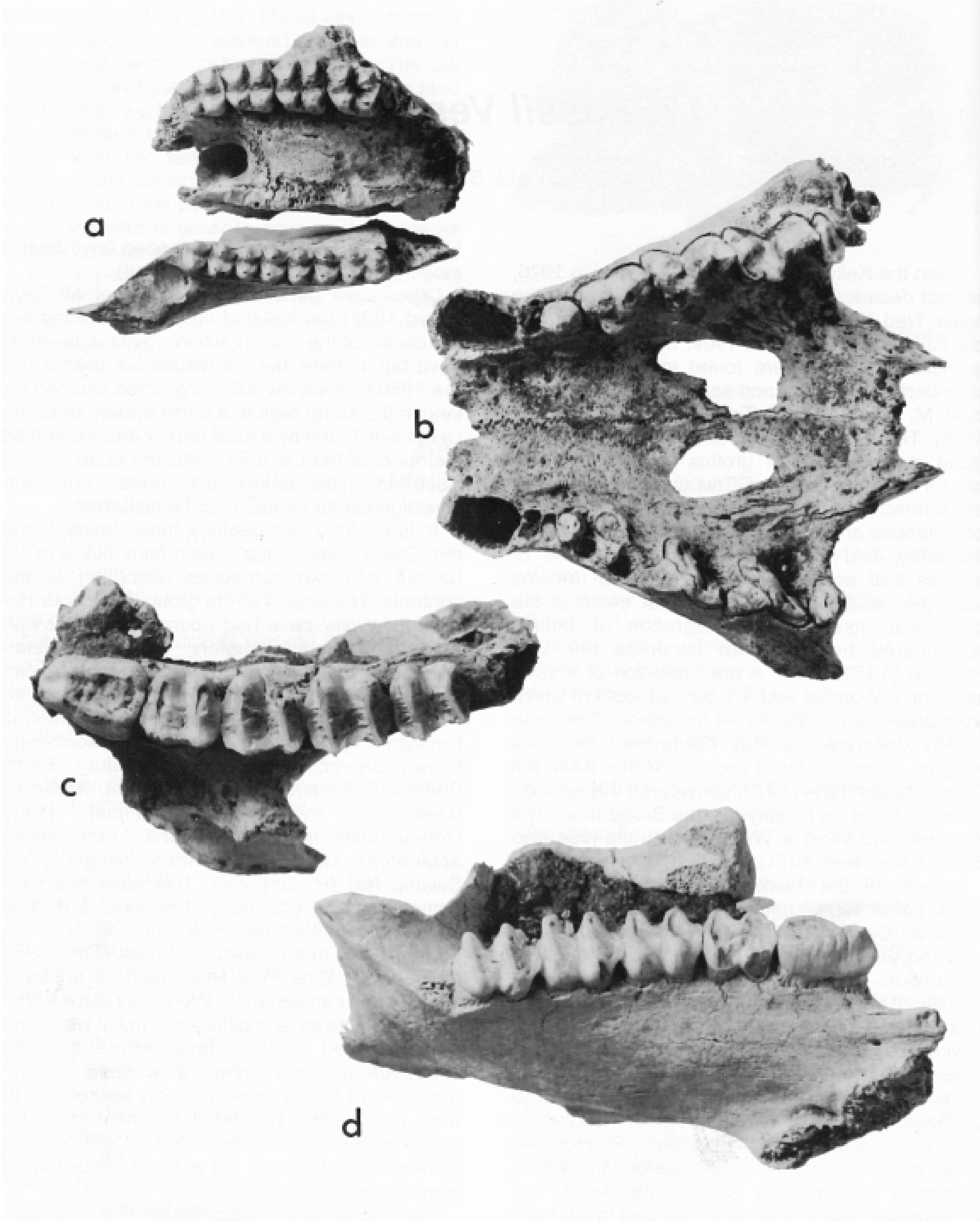
Other cave deposits are known at Mt Taylor (Ward 1926) (an isolated consolidated dune near the center of the island), where minor excavations have been made, but the results are unknown. In the 1960's, however, following scrub clearance of land in the same region, a small system of several caves was found by a local farmer and explored by members of the Cave Exploration Group of South Australia. The caves are under continuing investigation and should not be disturbed.

To judge from their geology, these caves, termed the 'Emu Caves Group', seem fairly old, and may be put into two categories according to their contents. The largest of the group, Emu Four Hole or 'Four Wells' cave had abundant subfossil and modern material; mainly Kangaroo Island Kangaroo, tammar Wallaby and Kangaroo Island Emu, as well as the Broad-faced Rat Kangaroo *(Potorous platyops)*, Brushtail Possum, Ring-tail Possum, Pigmy Possum *(Cercartetus concinnus),* Brown Bandicoot *(Isoodon obesulus),* Barred Bandicoot *(Perameles* sp.), Tiger Cat, Native Cat *(Dasyurus viverrinus),* Marsupial Mouse *(Sminthopsis murina),* Echidna *(Tachyglossus aculeatus),* Bush Rat *(Rattus fuscipes),* and Swamp Rat (R. *lutreolus)*. This cave has by its name, four roof entrances; it is about 6 m deep, and is thus an effective pitfall trap.

Only a few metres away is Fossil (Three Hole) Cave. While Emu Four Hole needs a ladder for access, one can scramble into Fossil Cave without such aids. The cave is different in that it was at one time choked with fossiliferous silt and subsequently has been evacuated, leaving remnants of hard bone-breccia in pockets on the walls and ceiling. This breccia is hard enough to make extraction of the fossils difficult and somewhat hazardous, but a small collection has been made.

The Fossil Cave assemblage (Fig. 1) has a typical Pleistocene aspect, with at least one extinct species: Kangaroo Island Kangaroo, Tammar Wallaby, a Short-faced Kangaroo *Sthenurus* sp., ct. S. *brownei),* Koala, unidentified wombat, Tasmanian Devil *(Sarcophilus* ct. *harrisii)* and an unidentified rodent.

Small holes in or under the calcrete, barely warranting the term 'cave', have long been known



g. 1. Pleistocene vertebrate fossils from Emu Cave system (all natural sizes). a) *Phascolarctos cf. cinereus,* Koala, right half palate and lower jaw. b) *Sarcophilus cf. harrisii* 'Tasmanian' Devil, palate. *c) Sthenurus* sp., *cf. brownei*, extinct Short-faced Kangaroo, right maxilla. *d) Sthenurus* sp., *cf. brownei*, left lower jaw still in matrix with other bone.

in numerous places on the Island. However, on one of the islets in Pelican Lagoon, American River, a proper karst solution tube between 4-5 metres deep in the calcrete opens into a broader chamber having an undetermined thickness of sediment. It is a natural animal trap. In 1985, a small scale test excavation was conducted here to a depth of about 60 cm, to ascertain whether any faunal changes were recorded. A few bones of sheep and kangaroos lay on the surface, and the top layer, up to 9 cm thick, is a dark loam with numerous bones of sheep, wallabies (M. *eugenii),* kangaroos (M. *fuliginosus),* rats *(Rattus rattus)*, snakes, the occasional goanna and house mouse *(Mus musculus),* and the jaw of a rabbit *(Oryctolagus cuniculus).* Rabbits have long been banned from Kangaroo Island, and were never released except for a single rabbit, the pet of a young child; rather than put the animal down, the child's father let it go on the islet, thinking, correctly, that it would not escape. The base of the top layer is marked by a concentration of charcoal, the result of a deliberately-lit fire to clear the island of scrub and undergrowth to allow sheep grazing. Because of the lack of fresh water, this activity proved nonviable, and the islet has been allowed to revegetate.

The second layer, reaching to the bottom of the pit (about 60 em), is a lighter, sandy loam, containing bones of (in decreasing order of abundance), wallabies, *Rattus fuscipes,* snakes, *Varanus* and other lizards, *Hydromys,* kangaroos, small birds and *Pseudomys.* There were no emu bones. The bottom of the pit was marked by a barren, red clay. If the top layer were deposited in about 100 years, by more rapid sedimentation due to the clearance fire, the second layer could represent as much as 1000 years, before which the cave was apparently sealed.

OPEN SITES

The Fossil Cave assemblage contrasts strongly with that of the only known open site at Rocky River Homestead. First discovered by C. J. May in 1907 during excavations for building sand, the site remained almost untouched until 1934 when Tindale *et al.* (1935) undertook some small excavations on the southern margin of the small swamp plain of Black Creek, near its confluence with Rocky River. They excavated a quantity of bone from three recognizable layers. The upper, much disturbed by ploughing and/or pigs, yielded only goat and wallaby bones, but the others produced several extinct species. *Diprotodon optatum* (a rhinoceros-sized herbivore), *Zygomaturus trilobus* (a cow-sized herbivore), kangaroos *(Macropus* ct *fuliginosus)* similar to the modern Grey Kangaroo, Tammar Wallabies *(Macropus* ct. *eugenii),* two or more species of Short-faced Kangaroos *(Sthenurus),* and a species of giant wallaby *(Protemnodon)* and some unidentified rodents.

Major & Vitols (1973) reported a recently discovered lower tooth of D*iprotodon* (Figs 2-3) at Rocky River, and in 1974, another major investigation of the site was made by a team led by J. H. Hope of the Australian National University.

A number of trial holes were put down in an effort to locate the original discovery site, before bones were found. An area of 1 m^2 was then carefully excavated to 'bed-rock', the underlying dune limestone. In contrast to the 1934 digs which produced an abundance of *Diprotodon* remains and a few smaller mammals, the new hole yielded mainly macropodids with a large number of *Sthenurus* but no *Oiprotodon.* Grey kangaroos, Tasmanian devil and Kangaroo Island emu were present.

A later visit in 1975 undertook a coring programme of the swamp, and further test-pitting to delineate the deposit. The fossils appear to be very restricted in area. In fact the distribution seems to follow the shore of the swamp. Radiocarbon dating of peaty material from the fossil excavation and from the cores have given preliminary ages of the vertebrate fossils of about 29 000 years, and pollen analysis has indicated some interesting climatic changes (J. H. Hope pers. comm.).

The most significant discovery, however, is an

Fig. 2. Skull of *Diprotodon,* a rhinoceros-sized herbivore whose remains have been found at Rocky River. Skull length approx. 0.8 m.

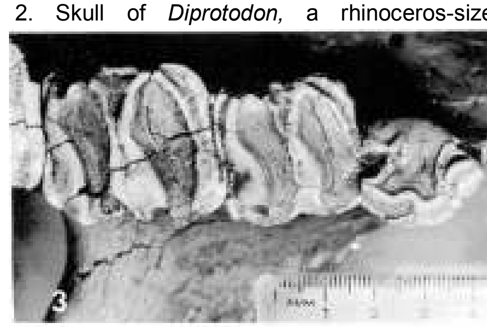


Fig. 3. Upper premolar and two molars of *Zygomaturus,* a cow sized herbivore also present at Rocky River. The teeth are similar to those of *Diprotodon* (Scale in mm).

extension of the fossil deposit in Black Creek Swamp at Rocky River. In 1996, student Darren Gröcke searched for Tindale's 1934 excavation site to collect material for chemical analysis. Instead he found a new site nearby and excavated a number of marsupial bones *(The Advertiser* 23.ii.1996), including the skull and jaw of a new diminutive species of *Zygomaturus.* Further excavations were done by R.T. Wells and members of the Flinders University Palaeontological Society in 1996 and 1997 (unpublished reports) and these indicate a large, potentially fossiliferous area (Wells *et al.* 1999), but work has been suspended because of the possibility of aboriginal involvement in the accumulation of the bones, artifacts having been found on nearby sand dunes and a few quartz chips in the swamp deposits. There has been some contamination of the site by goats and pigs.

The new excavations have yielded the following species (Dalgairns 1998, 1999; Thammakhantry *1998): Dromaius, Thylacinus, Diprotodon, Zygomaturus trilobus, Zygomaturus* dwarf? species, *Thylacoleo, Sthenurus, Macropus, Wallabia, Protemnodon, Lagorchestes, Bettongia, Potorous, Rattus, Pseudomys, Mastacomys* and *Capra* (goat), the last an obvious contaminant. The age of this deposit and fauna is, therefore, important, but in view of problems with sample purity and specimen association, published dates of around 19 000 years BP must be regarded as minimum ages only (pers. comm. G.S. Hope to R.T. Wells 2000).

Fig. 4. Test excavation in progress at Rocky River, 1974. J. Hope is second from left, R. Lampert is in the pit.

ARCHAEOLOGICAL SITES

So far, there is only one published archaeological excavation on Kangaroo Island of significance to this chapter. This, the Seton Site, is a rock shelter in the side of the doline collapse northeast of Kelly Hill Caves, and was excavated by Lampert (1974) The faunal remains of this site, both those associated with the human occupation levels (see also Chapter 7), and those from elsewhere in the sequence, have been analysed (Hope *et al. 1977).* The site was occupied by Aborigines for a short time at 16 000 years and again for longer, at 11 000 years B.P. During the sparse earlier part of this occupation, *Sthenurus* may have formed part of the diet, although the evidence rests solely on a few fragmentary teeth. The rest of the assemblage consists of modern species, but in an unusual combination including: the Tasmanian Devil, Brown Bandicoot *(Isoodon obesulus),* smaller Barred Bandicoot *(Perameles bougainville),* the Hairy nosed Wombat *(Lasiorhinus latifrons)*, Rat Kangaroos *(Bettongia lesueur,* B. *penicillata* and *Potorous platyops),* the Hare Wallaby *(Lagorchestes leporides),* the extinct Toolache Wallaby *(Macropus greyi)* and possibly the Red Kangaroo *(Megaleia rufa)* which no longer live on the island.

REMARKS

Except for some unusual occurrences which relate to different climatic/vegetational regimes, the Pleistocene fauna of Kangaroo Island differs little from that of the mainland. The one obvious difference is the presence of the diminutive Kangaroo Island Emu, *Dromaius baudinianus,* similar to the also extinct King Island emu, *D. minor.*

The presence of dwarf species or races on offshore islands is not unknown, examples being the Channel Islands of Southern California and many of the Mediterranean islands - Cyprus, Malta, the Balearics, but it is unusual that there is only one possible mammalian example on Kangaroo Island. Therefore it must be assumed that the periods of isolation were too brief for speciation to occur, and the island was too large and benign to enforce miniaturization. Extinctions seem to have occurred at the same time as on the mainland, perhaps aided by extensive bushfires. Aboriginal human's role in this is unknown.

13: Terrestrial and Freshwater Invertebrates

by A. D. AUSTIN, R. H. FISHER, M. S. HARVEY, D. B. HIRST, N. A. LOCKET, C. P. MADDEN, F. REAY and W. ZEIDLER

INTRODUCTION

The invertebrates are animals that lack a backbone, a somewhat uninspiring description that underlies their critical importance in the environment. They constitute a great range of animal types and represent tens of thousands of species in any given habitat. Rather than being an uninspiring title, the name 'invertebrates' is synonymous with the concept of biodiversity, because the vast majority of species are invertebrates (Wheeler 1990). Compared with both plants and vertebrates (amphibians, reptiles, birds, mammals), the proportion of invertebrate species is huge, more than 1000:1. However, most species are small in size (< 2 mm) and they are not very obvious in the environment. The exceptions are a small number of eye-catching species, such as butterflies, metallic beetles, hunting wasps, or a few species that cause problems for humans (mosquitoes, bush flies, agricultural pests, etc). Ecologically, invertebrates are central to the maintenance of all habitats: they break-down litter and wood by assimilating this material into the soil; they are the major herbivores of flowering plants and grasses; they are at least partly responsible for the health of freshwater streams; and they limit the population size of other invertebrates because of the habits of predatory and parasitic species.

Of all life-forms, invertebrate animals are also the least known because of their sheer diversity, and that there are so many undescribed species. For the most species-rich groups (i.e. insects, arachnids, crustaceans and nematodes) possibly as many as 60-80% of species are still to be described, and the biology of an even greater proportion than this is unknown. This paucity of knowledge applies to every region of Australia, including Kangaroo Island. The discussion below, therefore, provides an overview of the groups of invertebrates that are found on the island and what is known about their biology and ecological role. For most groups, reference to individual species serves only as specific examples. However, for some groups, such as butterflies, scorpions and spiders, the fauna of the island is better known and more specific statements can be made about them.

Although most invertebrates are small, the observant visitor will see a very large number of species during even a short visit to the Island. The account below will hopefully assist in understanding more of what can be seen. For those who wish to pursue aspects of invertebrate identification and biology in more detail, the literature referred to below is designed to be synoptic rather than comprehensive. References that are particularly useful as an information source and/or guide for identification are CSIRO (1991), Harvey & Yen (1991), Koch (1977), Lee (1985) and Main (1976).

INSECTS

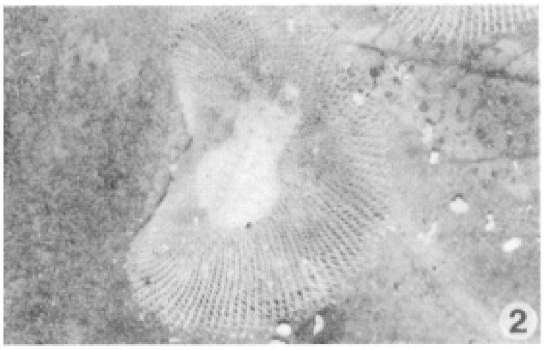
Insects comprise some 28 common orders and, along with spiders, are the most obvious component of the island's invertebrate fauna. There are probably several thousand insect species associated with various island habitats, but there has been no large-scale surveys to specifically document the fauna. However, numerous specialist collectors, both professional and amateur, have visited the Island over many years and there is a wealth of material and knowledge available on various insects groups, though most is unpublished. The advent recently of specialised collecting devices, such as Malaise traps and yellow pan traps (Upton 1991), has provided new insights into the diversity and seasonality of insects. The catch from just one Malaise trap left *in situ* for seven days can yield hundreds of species which can then be mounted for identification and incorporation into collections. Of the very speciose groups of flying insects that blunder into such traps (mostly flies, wasps and beetles), the majority are small and many will be undescribed. Significantly, the problem is not one of finding new species, but undertaking the research to demonstrate that they are indeed new and to formally describe them.

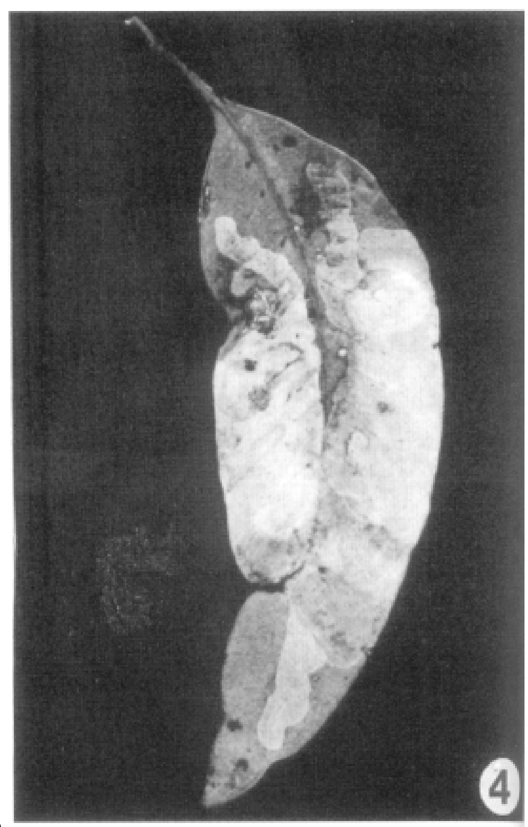
Most insect groups on Kangaroo Island, where sufficient information is available, show a very close association with the fauna of the adjacent mainland and, in many cases, the species involved are identical. In some respects, the more extensive tracts of undisturbed vegetation on the Island provide an indication of what the Fleurieu Peninsula must have looked like before the excessive clearing that has occurred with agricultural development since World War II. Those species that are currently thought to be restricted to the island may in fact reflect a paucity of knowledge of insects in nearby mainland habitats, and future collecting may reveal that these species are more widely distributed.

Insects on foliage

The leaves of trees and shrubs are the feeding site of a large number of phytophagous insects (Majer *et al.* 1994). Indeed, it can be difficult sometimes to find a leaf on, say, a eucalypt tree that has not been damaged by insect feeding. Insects can affect leaves in one of several ways; by simply chewing away the leaf so that the leaf-edge has a scalloped appearance (leaf-feeders); by feeding on the mesophyll layer between the upper and lower epidermis (leaf-miners); by sucking sap from the leaf and causing brown blotches (sap suckers); and by causing a proliferation of leaf tissue on which they feed (gall-makers).

Leaf-feeding insects include the larvae and adult stages of beetles (Coleoptera), the caterpillar (larval) stage of moths (Lepidoptera), the larvae of sawflies (Hymenoptera), and grasshoppers (Orthoptera). Of these, the first two groups are highly speciose and comprise a large number of families. Leaf-beetles (Chrysomelidae) such as *Paropsis* spp., weevils (Curculionidae), and *Anoplognathus* spp., the Christmas beetles (Scarabaeidae), are commonly seen feeding on the





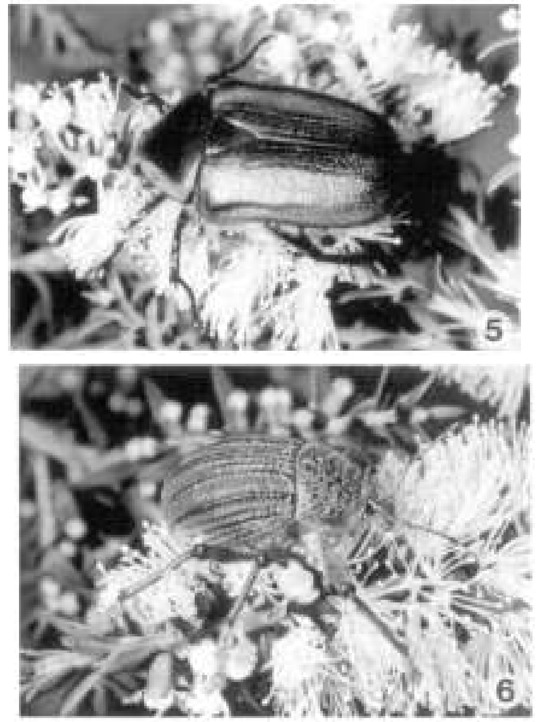
Figs 1-4. Insects associated with eucalypts on Kangaroo Island. 1. A saturniid moth larva, O*podiphthera* spp; 2. the psyllid *Cardiospina* sp. feeding under its lerp; 3, gregarious larvae of the eucalupty sawfly, *Perga dorsalis* (Hymenoptera); 4, the leah-mining sawfly *Phylacteophaga froggatti* Reik, which causes blotched effect on leaves.

leaves of bushes and trees during spring and summer. Lepidopteran larvae are also very common and comprise numerous families, such as Oecophoridae, Limacodidae, Geometridae, Notodontidae and Noctuidae, which can be seen grazing the leaves of eucalypts and acacias (Common 1990). Many are small, well camouflaged and difficult to see, while some are brightly coloured, such as the larva of the saturniid *Opodiphthera* spp. (= *Antheraea)* (Fig. 1), and probably distasteful to vertebrate predators. Occasionally, the silken retreats of 'bag-shelter' moths (Thaumetopoeidae), possibly *Ochrogaster* sp., can be seen in low vegetation. Also sometimes referred to as processionary caterpillars, the larvae are nocturnal, leaving their day-time shelter as a group, to feed on the surrounding vegetation. The larvae of the eucalypt sawfly, *Perga dorsalis* Leach (Hymenoptera), can sometimes been seen on young trees as a gregarious group (Fig. 3) which, when disturbed, regurgitate their strong eucalypt-smelling gut contents as a defensive reaction. These larvae, like many caterpillars, disperse over the foliage at night and are capable of causing substantial damage to trees.

Leaf-mining insects are more cryptic than exposed feeders, because of their much smaller size and the fact that they feed inside leaves. The Lepidoptera is the largest group of leaf-mining species, but this behaviour is also apparent among some dipteran larvae, and the small sawfly *Phylacteophaga froggatti* Riek, which causes a blotched effect on leaves of young eucalypt trees (Fig. 4).

Numerous insects feed at flowers and are often more obvious than those associated with foliage. The majority of native flowering plants are pollinated by insects (and birds), or they have open pollinating systems where they are either insect or wind-pollinated. When in flower, native trees and bushes are often swarming with many different species of insects, including scarab (Fig. 5), lycid and cantharid beetles, weevils (Fig. 6), many flies (Diptera) and wasps (Hymenoptera), thrips (Thysanoptera), halicitid and colletid native bees, and the introduced honey bee (see below). These species are foraging for nectar and/or pollen as a source of food, and their presence also attracts many predatory insects and spiders.

Sap-sucking insects mostly belong to the order Hemiptera, with the mouth parts modified into a sucking tube, used by many species to tap into plants and extract the liquid contents, or sap. They often tend to feed at a single location for long periods of time and are therefore rather sedentary. They include groups such as the cicadas and pentatomid, merid, lygeid, cicidellid and eurymelid bugs, which are winged and move around to different feeding sites, and psyllid and scale insects, the females of which are wingless and feed at a single location. Some members of the Psyllidae that feed on eucalypts construct intricate



Figs 5 & 6. Beetles feeding on *Melaleuca* flowers. 5, the scarab *Diaphonia dispar,* 6, the weevil *Psaphanus ruficornis.*

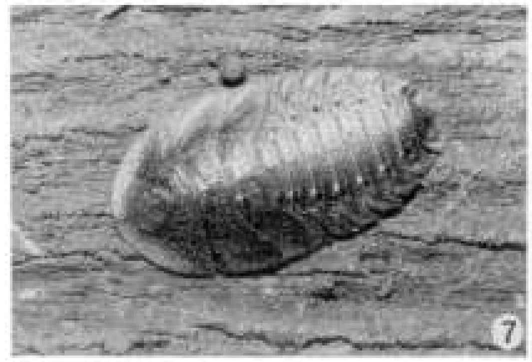
covers, from their excreta (honeydew), called lerps, under which the female feeds. Genera such as *Cardiospina* (Fig. 2) and *Glycaspis* often go through huge population explosions that cause browning of the leaves and almost total defoliation. However, it seems that these events rarely kill trees although they can appear to do so (Morgan 1984). Also common on myrtaceous plants are scale insects (Coccoidea), which are the most highly modified of the Hemiptera and the most speciose superfamily in Australia. The females are usually oval and flattened, without an obvious head or legs, and they are sometimes covered with a waxy scale or powdery layer (CSIRO 1991). One common genus is *Eriococcus,* which sometimes covers the upper branches of young eucalypts, causing localised dieback of leaves and sooty mould which grows on the excessive honeydew. The scales are white or brown in colour, have a characteristic red staining body fluid if squeezed and, like many other coccoids and psyllids, are sometimes tended by ants. This association is a mutualistic one, with the ants protecting the scales and, in return, feeding on their honeydew. However, when they are not protected, scales and lerps are sought after by insect predators, particularly coccinellid beetles (ladybirds) and the larvae of green and brown lacewings (Neuroptera).

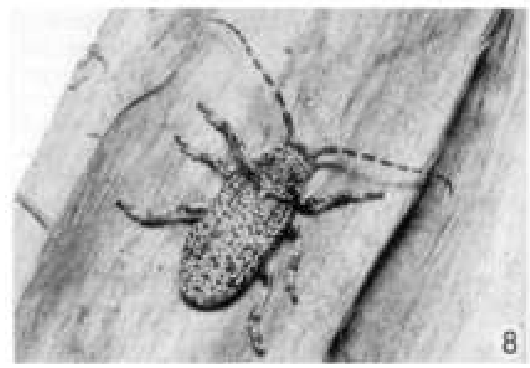
The major groups of gall-forming insects are flies and wasps, which mostly form small ovoid swellings, sometimes in large numbers on an individual leaf. One common wasp associated with Acacias is *Trichilogaster,* which forms nodule-like galls, about thumb-nail size, that are sometimes mistaken to be the tree's fruit. Several groups of Hemiptera also elicit galls, including some psyllids and scale insects. Of these, the most interesting are members of the genus *Apiomorpha* (Eriococcidae), which induce large (2-5 cm in length), sexually dimorphic galls on their host. The galls of females are species-specific in morphology and of diverse form (Gullan 1984). All species feed and induce galls only on *Eucalyptus* spp., on which they may be relatively host-specific or oligophagous (on several subgenera of eucalypts). However, karyotypic and allozyme electrophoretic data suggest that *Apiomorpha* is more speciose and host specific than indicated by the current morphological-based taxonomy (Cook pers. comm.). Seven species of *Apiomorpha* are known from Kangaroo Island, all of which also occur on the mainland. The most numerous galls are those of A. *subconica* (Tepper), known from near Murray Lagoon, which can be seen on low foliage within about one metre above the ground, a position which is atypical for *Apiomorpha* galls on mallee eucalypts.

Insects associated with wood and bark

Several groups of insects can be found living inside live and dead timber, but the two commonest groups are the wood-boring beetles, which comprise numerous families, and the termites (see below). The largest family of wood-boring beetles are the longicorns (Cerambycidae), whose larvae form long tunnels as they feed. These tunnels may eventually weaken the branch causing it to break off in strong wind. The only external evidence of the presence of longicorn larvae is when they cut a hole to the outside, to expel the build-up of faecal material in tunnels. This has the appearance of fine, discoloured saw-dust and can sometimes be seen behind bark or at the base of a tree.

The space between plates of corticating bark and the trunk, particularly of mature eucalypts, provides an idea habitat for many insects and spiders. The insects found under bark include many species which use the space as a temporary refuge to overwinter or to escape the hottest and driest part of summer. The old nests of spiders are sometimes used by these insects as a retreat, possibly because they provide further protection from the elements and/or predators (Austin 1993). At least nine orders of insects can be found, including Collembola, Coleoptera, Psocoptera (booklice) Diptera and Hymenoptera. Other species, such as some cockroaches (e.g. *Laxta* spp. - Fig. 7), are specifically adapted to living under bark. They have very flattened bodies and are scavengers, feeding on dead insects, fungi, plant material, etc. Also specifically associated with this habitat are numerous predatory and parasitic insects which prey on other bark-living species. The reduviid bug *Empicoris rubromaculatus*





Figs 7 & 8. 7, The cockroach, *Laxta* sp., whose fialtened body is an adaptation to living under bark; 8, adult longicorn beetle, *Penthea intricata.*

(Blackburn) feeds on other insects, while the larvae of acrocerid flies, mantispid lacewings (Neuroptera) and scelionid wasps exclusively prey on spiders or their eggs.

Insects associated with grassland, litter and soil

Much of the grassland areas of Kangaroo Island are coastal, near water courses, or have been developed with agricultural practices. The insects associated with these areas share some similarities at family or order level, but many of the species are different. The most prominent group in these habitats is undoubtedly the Orthoptera (crickets and grasshoppers). In the warmer months of the year, numerous small species can been seen when disturbed and they jump away. Two common native gregarious species are sporadic pests of agricultural pastures; these are the wingless grasshopper, *Phaulacridium vittatum* (Sjöstedt), and the black field cricket, *Teleogryllus commodus* (Walker). Both species are also common in native grasslands and, along with other species of crickets, the latter can be heard singing at night. Other orthopterans, such as the Tettigoniidae (longhorn grasshoppers) are more solitary and cryptic in grass and heathland. Most are predatory and several species are known from Kangaroo

Island, of which several, including *Metaballus mesopterus* Rentz and the subfamily Microtettigoniinae (Rentz 1979), are endemic to the island.

In the grassland areas adjacent to the coast, there is a rich fauna of insects, the most obvious of which are the larger predatory flies, such as asilids (robber flies), which forage for insect prey on the wing, and hunting wasps which search the ground and low vegetation for prey with which to stock their nests. Several species of impressive pompilid wasps *(Cryptocheilus, Priocnemis* and *Ctenostegus)* are often seen in summer hunting for spiders in these areas, while numerous genera of sphecid wasps hunt for caterpillars, grasshoppers, as well as spiders. Pompilids and sphecids paralyse their prey with a sting, and then provision it in a nest as food for their larvae. Nests are constructed as a tunnel in the ground, as a chamber in wood, or are built of mud. Parasitic wasps are also common in grassland, particularly coastal areas, where large ichneumon ids can be seen searching for caterpillar hosts, and several large hatchet wasps *(Evania* spp.) hunt for their specific hosts, native cockroaches (Blattodea). Often some distance from bodies of water, aeshnid and gomphid dragonflies *(Austroaeschna, Aeschna* and *Austrogomphus* spp.) can be observed on warm days foraging for insect prey in grasslands and over low vegetation (Watson *et al.* 1991). Closer to streams smaller dragonfly species (libellulids) are evident, together with numerous damselflies and, if the conditions are favourable, large numbers of nematoceran flies and mayflies (Ephemeroptera) move out over grassed areas. These groups exclusively have aquatic nymphs or larvae (see Aquatic Invertebrates, below)

The insect fauna of litter and soil is highly diverse and biologically specialised, but the great majority of species are tiny in size (< 2 mm). They feed on decaying vegetable matter, rotting wood or microorganisms, or are predatory and feed on other invertebrates. The most prominent groups are the cockroaches, beetles, termites, springtails (Collembola) and ants. Several native genera of cockroaches are present on the island, which are common in litter, as well as under bark and rocks. Some such as *Cosmozosteria* and *Methana* spp. can be easily recognised by their distinctive dark colour and white or yellow marginal line. The major superfamilies of beetles found in litter are the Staphylinoidea, Cucujoidea and Tenebrionoidea, representing some 20-30 families. Most genera are phytophagous but some are known to be scavengers or predatory. They are one of the few large orders of insects which can be identified to genus level (Matthews 1980-1997).

The Collembola are small, primitive insect-like organisms which are highly abundant in litter and soil. They have a forked tail which is flexed rapidly to launch them into the air as a defensive mechanism (hence the name 'springtails'). Collembolans can occur in very large numbers, several thousand per square metre, particularly in damp, deep litter. They feed on micro-organisms associated with decaying plant material, and are therefore an important component of the soil biota (CSIRO 1991).

Also extremely important in soil nutrient turn-over are the termites. These social insects form large colonies, mostly below ground level, but a few such as *Coptotermes* spp. construct complex mound shaped nests partly above ground which provide a stable environment for the colony. All termites are pale in colour, soft-bodied and highly susceptible to desiccation. They confine themselves to cool, moist micro-habitats, or they construct protective mounds and tunnels, thereby creating a suitable environment in habitats that would be otherwise unfavourable. The sterile workers build tunnels radiating from the nest in litter and soil, through which they move along to forage on grass, fungi, rotting wood or live timber. They are responsible for assimilating huge quantities of plant matter which they digest with the aid of symbiotic gut protozoa. As a group, they represent the most important herbivores in many habitats, as well as contributing to soil turn-over and fertility. Common genera that are widespread in southern Australia and occur on Kangaroo Island are *Nasutermes, Coptotermes, Kalotermes* and *Amitermes.*

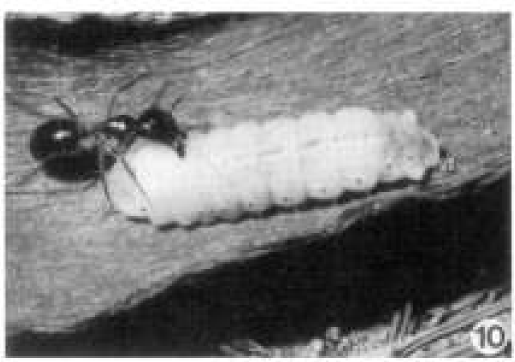
Also social and living in colonies are the ants (Formicidae), a group of insects which, together with termites, are the most ubiquitous of all invertebrates. Together, the termites and ants represent a significant proportion of the animal biomass in many habitats, and they have a profound effect on their environment. However, ants are more obvious because many forage on the surface in daylight hours, and the majority of species are predators or scavengers. As a group, they are the single most important predators of invertebrates and they consume vast numbers every day during the warmer part of the year. They nest in soil, logs and under rocks, and more than 50 species can occur in an area of a few hectares (Andersen 1991). The most common genera are *Myrmecia* ('bulldog' and 'jumper' ants), *Iridomyrmex* ('meat' ants), some species of which form large, pebbly mounds in open spaces, and *Camponotus* ('sugar' ants). However, numerous genera of smaller, less obvious species are found in litter, and under rocks and logs.

Nocturnal insects that come to light

Many species of insects are nocturnal and are often seen when they are attracted to lights in camping grounds and around buildings. This behaviour is also used as a survey and collecting technique, where a powerful mercury-vapour light is employed to attract nocturnal flying insects (Upton 1991). In a relatively short period of time a 'light trap' can bring in more than 200 species of insects. This 'community' is usually dominated by moths and comprises numerous large members of Arctiidae, Noctuidae and Sphingidae (hawk moths), as well as a large number of smaller species belonging to families like the Cosmopterigidae, Gelechidae, Geometridae, Gracillaridae, Oecophoridae, Pyrlaidae and Tortricidae (Common 1990). The tiniest of these species, the so-called 'microlepidoptera', are only a few millimeters in length and are very difficult to identify, even by professional entomologists.

Other groups of insects that can be often seen at light include beetles, lacewings, wasps and ants, bugs and the adults of some aquatic insects (dragonflies, damsel flies, caddisflies, etc). Three common families of beetles that are collected at light are the cockchafers (Scarabaeidae), which feed on dung *(Onthophagus* spp. and other genera), or in the soil where some are pests in agricultural pastures *(Aphodius tasmaniae* Hope), longicorns (Cerambycidae) (Fig. 8), which have wood-boring larvae, and click beetles (Elateridae). The commonest lacewings at light are the adults of ant lions (Myrmeleontidae), green lacewings (Chrysopidae), the larvae of which are predatory on soft-bodied insects on foliage, and the Mantispidae that have highly specialised larvae which feed on spider eggs.

Numerous families of parasitic wasps are attracted to light and they often have a characteristic morphology, i.e. yellow or light brown colour with large ocelli on the top of the head. The most common genus is *Enicospilus* (Ichneumonidae), which have an elongate, compressed abdomen, large transparent wings, and are parasitic on nocturnal-feeding lepidopteran larvae. Observations over consecutive nights show that environmental conditions (temperature, wind, humidity, moon-light) influence the number of insects that come to light. Further, seasonal activity of particular groups affects the species composition of the insects attracted. For instance, a recent emergence of scarab beetles may mean that the majority of insects attracted to light for several nights over a given area belong to this group. Later, moths or adults of aquatic groups may dominate. Although nocturnal insects can be effectively surveyed in this way, little insight into their biology can be gleamed from their arrival at a light.



Figs 9 & 10. Small brawn azure butterfly, *Ogyris atanes* (Lycaenidae). 9, adult female; 10, Larva with attendant ant, *Campanatus testaceipes.*

Butterflies

Some twenty-five species of butterflies have been recorded from Kangaroo Island. Considering the small size of the Island and restricted number of habitats, this figure compares favourably with the 68 species known to occur in the whole of South Australia. Most of those recorded are known to have breeding colonies associated with their respective host plants, but four species, the small grass yellow, *Eurema smilax* (Donovan), the wanderer, *Danaus p. plexippus* (L.), the lesser wanderer, *Danaus chrysippus petilia* (Stoll) and the caper white, *Belenois Java teutonia* Hubner probably reach the Island from the mainland occasionally, with the aid of favourable winds, or as a result of migratory flights (Fisher 1985). In fact, the first known reference to a butterfly from the island is that of the French explorers Peron and Freycinet (1816) who state "une espece de papillon de la division des Brassicaires de M. Latreille" in their list of insects collected. This specimen could well have been a caper white.

Of the resident species, the Hesperiidae (skipper butterflies) is represented by five species (and one additional subspecies) of the genera *Hesperilla, Motasingha* and *Antipodia* whose host plants are various *Gahnia* or *Lepidosperma* spp. These plants are comparatively widespread on the Island although not common. Skipper butterflies are rather small and dull, and not easily recognised or identified by the casual observer. The taxa recorded are the chrysotricha skipper, *Hesperilla chrysotricha* (Meyrick & Lower); the donnysa skippers, *Hesperilla donnysa delos* Waterhouse and *H. d. diluta* Waterhouse; the flame skipper, *Hesperilla idothea* (Miskin); the dirphia skipper, *Motasingha trimaculata* (Tepper), and the black and white skipper, *Antipodia atralba* (Tepper).

The only species of Pieridae (whites and yellows) which appears to be well established is the introduced cabbage white, *Pieris rapae* (L.), whose larvae feed on a number of domestic plants as well as some native species. Two other species, the small grass yellow and the caper white, are seen occasionally but do not appear to have established breeding colonies on the Island. Likewise, there are no records of the Papilionidae (swallowtails) from the Island.

Three species of Nymphalidae (nymphalids, browns) occur commonly throughout much of Kangaroo Island. These are the common brown, *Heteronympha merope* (F), Klug's xenica, *Geitoneura klugii* (Guerin-Meneville), and the painted lady, *Vanessa kershawi* (McCoy). The meadow argus, *Junonia villida* (F) has been recorded rarely. Two species of *Danaus,* as mentioned previously, probably reach the island with favourable winds from the mainland, and there are occasional records of the Australian admiral, *Vanessa itea* (F).

At least nine species of Lycaenidae (blues, azures, etc.) have been recorded but only two, the chequered blue, *Theclinesthes serpentata* (Herrich-Schaffer) and the common grass-blue, *Zizina labradus* (Godart) appear to be widespread. The genus *Theclinesthes* is represented also by *T. albocincta* (Waterhouse) and *T. miskini* (T. P. Lucas). Two other species, the double-spotted Iineblue, *Nacaduba biocellata* (C. & R. Felder) and the fringed blue, *Neolucia agricola* (Westwood) are known from a number of scattered records. Two species of the genus *Candalides* have been collected, the blotched blue, C. *acastus* (Cox), and the common dusky blue, C. *hyacinthina simplexa* (Tepper). All of these Iycaenids are rather small butterflies.

Two larger species of this family occur on the island and are of particular interest, both taxonomically and biologically. A subspecies of the large brown azure, *Ogyris idmo halmaturia* Tepper, was first described in 1890, using material collected on Kangaroo Island. This species is quite rare across its range, and little is known of its life history and taxonomy. The larvae may be carnivorous and feed on ants or their immature stages. The small brown azure, *Ogyris otanes* C. & R. Felder (Fig. 9), has been recorded widely on the island but it is not common. Its host plant, *Choretrum glomeratum,* occurs frequently along roadsides and in areas of natural vegetation. The larvae and pupa, which were first described by Burns and Angel (1952), are associated with the sugar ant, *Camponotus testaceipes* (Smith) (Fig. 10), a mutualistic relationship that provides protection from predators for the butterfly larvae and pupae, and provides food for the ants in the form of larval secretions.

Introduced insects

As for the adjacent mainland, the Island is home to numerous insect species which have been introduced into Australia since European settlement. These include several pests species of ornamental and garden plants, such as green peach aphid, *Myzus persicae* (Sulzer), rose aphid, *Macrosiphum rosae* (L.), the garden earwig, *Forficula auricularia* L., and several species of scale insects (Hemiptera: Coccoidea). Given that agriculture on the island is mostly restricted to broad-acre cereal and sheep farming, the associated pest species are also mostly restricted to these activities. The pests of sheep include the sheep blowfly, *Lucilia cuprina* (Wiedemann), and sheep louse, *Bovicola ovis* (Schrank), both of which are sporadic in their effect and occurrence, depending on season and management practices used.

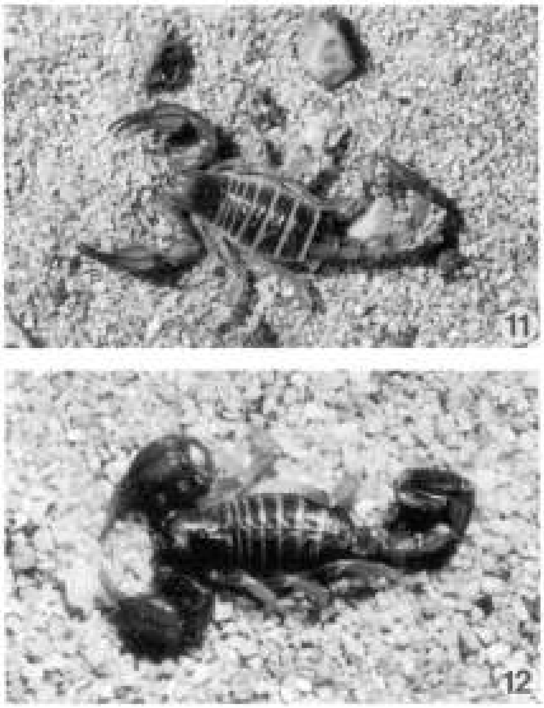
One species that is probably more prominent and important on the Island than anywhere in Australia is the introduced honeybee, *Apis melifera* L. Although there is some concern about the environmental impact of feral honeybees in natural areas because of their competition for nesting sites and food sources with native species (Paton 1993), the 'ligurian' strain of honeybees on Kangaroo Island is unique in many respects and is important to Australian apiary industry. This variety of honeybee was originally imported from Europe many years ago and, because of its geographic isolation, is now the only genetic pure population that remains in the world. It is renowned for the quality and quantity of honey that it produces, and the docile behaviour of the worker bees. Because of these traits, apiarists have banned the introduction of other strains of honeybee onto the Island. They also export queen bees around the world so that these advantageous traits can be genetically introduced into other populations.

ARACHNIDS

Scorpions

Four species of scorpion are known from Kangaroo Island, none of them dangerous. They live in different habitats, and are fairly easily distinguished. Males of all have proportionately longer tails than females, and more developed spines on tail segments. Females may be found with young on their backs in January-March. Being nocturnal, scorpions are probably more common than casual observation suggests, but the use of a hand lantern with an ultra-violet (black light) tube may reveal significant numbers at night, since all scorpions fluoresce. Also, pitfall trapping for litter inhabiting invertebrates during summer indicates that the population size of some species may be quite high. For instance, 6-12 *Lychas marmoreus* (C. L. Koch) have been collected per trap, per night near Rocky River (Austin unpublished).

Extensive collecting for taxonomic research has not been carried out on the island, but Shanahan (1989a, 1989b) sampled widely for her studies on the genetics of two taxa, *L. marmoreus* and *Urodacus manicatus* (Thorell). Koch (1977) recorded only three species, those above and *Cercophonius squama* (Gervais), but *U. armatus* Pocock (Fig. 11), a burrowing species which is



Figs 11 & 12. Two scorpions from Kangaroo Is. 11, *Urodacus armatus;* 12, *Urodacus manicatus.*

widely distributed on the mainland, also occurs and is probably widespread where there is suitable sand for burrowing. The burrows, oval in section, and usually with a scrape of sand outside, slope at a shallow angle for ca. 17 cm, then spiral to an expanded end chamber, in which the scorpion spends most of its time. Here the young are born, remaining with the mother until their first moult. Both sexes make burrows, but the males wander on the surface in search of females, so are more likely to be seen by UV light. *Urodacus armatus,* grows to about 50 mm, is reddish-brown and notably shiny; the prominent keels on the squat pedipalps (pincers) and the leg joints are redder due to strong sclerotisation. In common with other burrowing *Urodacus* spp., there are rows of stout hairs, known as sand combs, along the front two pairs of legs.

Sand combs are absent in the related *U. manicatus* (Fig. 12), which lives beneath stones, excavating at most a shallow burrow. Darker and less shiny than *U. armatus,* this species is also squatter and less active when disturbed. The pedipalps are broader, and without the prominent keels of *U. armatus.* Widespread in south-eastern Australia, including the Adelaide hills, this scorpion has also been recorded from Western Australia, though it is apparently not common there. On Kangaroo Island *U. manicatus* is common where suitable habitat remains, and extends almost to the tidal zone in places, for instance at Cape du Couedic. Frequently this scorpion and the thick-tailed gecko, *Nephrurus milli* (Bory de Saint-Vincent), sometimes with its eggs, are found under the same stone. The relationship between the two animals, if any, is unknown.

A larger relative, *Urodacus novaehollandiae* Peters, also a burrower, has not been recorded from Kangaroo Island, though it may well occur there. Widespread in coastal dunes on mainland South Australia, including the tip of Yorke Peninsula, *U. novaehollandiae* is distinguished from *U. armatus* by its matt, drab colouration and narrower pedipalps and larger body size.

Cercophonius squama, a bothriurid, is a small, mottled scorpion which lives in leaf litter and soil. Though seldom seen by UV light, it may be caught in pitfall traps or by Berlese funnel. Present over much of southern Australia, and the only scorpion found in Tasmania, this endemic Australian genus is a Gondwanan form, with close relatives in South America. Koch (1977) listed C. *squama* as the sale Australian representative of the genus, but more recently Acosta (1990) has recognised six species. However, both authors agree that the Kangaroo Island population is C. *squama.*

The only buthid recorded from the Island is *L. marmoreus.* This species is small, slender, mottled and usually dark. Not a burrower, but found under stones and beneath loose tree bark, this scorpion may be found in aggregations of up to 20 individuals. Most scorpions are solitary, but such aggregations also occur in small New World buthids, including the highly venomous *Centruroides* of Mexico and south-western United States. The pedipalps of *L. marmoreus* are small and narrow, but the tail is prominent with respect to the rest of the body. Adjacent to the sting, the vesicle bears a spur, a character absent in all other Kangaroo Island species.

Spiders

In recent years several biological surveys on Kangaroo Island have dramatically increased the number of spiders (Araneae) known to occur with over 230 species in 40 families now being recorded. However, the majority of those species are yet to be named. Most species found on the island also occur on the mainland and reflect the fauna of the Fleurieu Peninsula, the south-east and in some cases, the southern Murray mallee region of South Australia. While a few species have so far been collected only from Kangaroo Island, their endemism is in question until the fauna of the adjacent mainland is more fully known (for information on biology and identification of spiders, see Main 1976 and Davies 1986).

The 12 species of Mygalomorphae now known from Kangaroo Island include a mouse spider, *Missulena* sp. (Actinopodidae), of which only a handful of males have been collected from various localities. They are conspicuous because of their bright red cephalothorax and habit of wandering during the daylight hours in autumn or winter, while the female is represented only by one specimen dug from a Kingscote garden. The Barychelidae (brush-footed spiders) are represented by a species of *Idiommata* of which only two wandering males have been collected. The burrows are securely closed with a door and difficult to find.

Moggridgea australis Main (Migidae), a relictual Gondwanan spider has been collected from short burrows closed with a small circular door. It is known only from American River and Western River Conservation Park. However the genus is also found in south-western Western Australia and southern Africa.

The Idiopidae contain both door-building spiders and those which never close the burrow with a door. A four-spot trapdoor, possibly *Aganippe smeatoni* Hogg, is uncommon and, while a *Blakistonia* sp. has also been recorded, no recent collections of this trapdoor species are known. The open burrows of what appear to be two species of *Misgolas* are commonly found in many undisturbed areas, with one species, possibly *Misgolas andrewsi* (Hogg), being found at one end of the Island and the second species occurring at the other end.

The Nemesiidae are represented by several genera with *Chenistonia tepperi* Hogg (regarded as *Aname tepperi* by some authorities), *Stanwellia nebulosa* (Rainbow & Pulleine) and *Teyloides bakeri* Main being common. A black species of *Aname* is also common and has a short burrow with a side branch, much like its larger relative, the black-wishbone spider, *A. diversicolor* (Hogg). Most nemesiids have an open burrow which is often covered with a thin film of silk during the day. *Kwonkan,* a genus which occurs mainly in semi-arid regions, is known from one species at Dudley Conservation Park, and is also found at Ferries McDonald on the adjacent mainland.

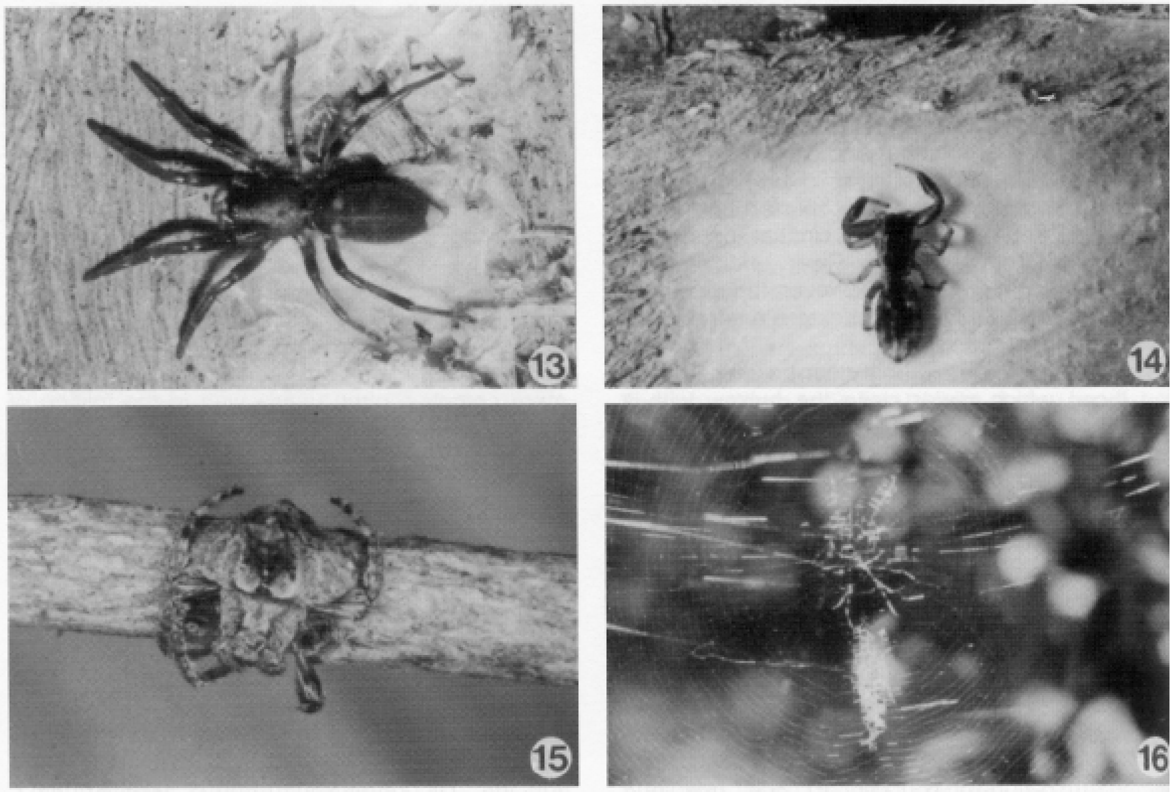
The Araneomorphae (advanced spiders) contain many species whose biology is poorly known, as they have mostly been collected by pitfall trapping. The six-eyed spiders are represented by three families. The Oonopidae, with at least two genera, *Gamasomorpha* (three species) and *Orchestina* (one species), and the Orsolobidae (one species), are all very small spiders about three millimetres or less which live in leaf litter and similar moist, sheltered habitats. The larger Segestriidae live in borer holes or under the bark of trees, in crevices, in rock outcrops or occasionally in burrows in the soil. Members of this family construct silk triplines which radiate out from the burrow entrance. The two species known are easily separated as one has black bands on the abdomen.

Most of the remaining araneomorphs are eight eyed spiders. Of the Pholcidae (daddy long-legs) only the introduced *Pholcus phalangioides* (Fuesslin) is known to occur. *Amaurobioides isolatus* Hirst (Anyphaenidae), another Gondwanan spider, constructs its retreat in rock crevices in the littoral zone. The Desidae is a larger family containing the familiar black-house spider, *Badumna insignis* (L. Koch), as well as B. *longinquus* (L. Koch) and a third undescribed species. *Baiami loftyensis* Gray is a long-legged spider found in large webs under rock overhangs, in hollow tree bases or other moist, sheltered situations. It is also found in the Mount Lofty Ranges. At least one species of *Forsterina* is present under rocks or logs on the ground where it spins a sparse web. In hollowed twigs of shrubs *Paramatachia* (possibly P *tubicola* (Hickman)) hides waiting for insects to become ensnared in the small ladder-like web it constructs above the entrance. *Phryganoporus candidus* (L. Koch) has a more complex, often untidy web in the foliage of shrubs, and constructs a retreat of silk and debris in which it hides. There are several undetermined species of Desidae, but these are small and seldom collected.

The Dictynidae are all small spiders less than 4 mm long, which make small webs in leaf-litter, under rocks or in crevices. They are poorly known and few species have been described, although three have been collected from the island, along with two species of Hahniidae, *Scotospilus bicolor* Simon and a species of *Alistra,* also of which little is known. The red and black spiders (Nicodamidae) are not well represented with only one large species, *Nicodamus peregrinus* (Walckenaer), being recorded.

Large webs of the platform spider, *Corasoides* spp. (Stiphidiidae), are more easily seen on dewy mornings and can be found in forest or low, windswept shrubs on coastal cliff tops. The web narrows at one end where it curves funnel-shaped into a short burrow in the ground. The eggsacs of these spiders resemble rabbit droppings and are suspended in the burrow. A smaller relative is the hammock-web spider, *Stiphidium facetum* Simon, which has an often dusty web suspended under rock overhangs or on tree trunks. The spider is usually found hiding at the base of the web in a crevice.

A record of a *?Toxops* sp. (Toxopidae) is uncertain as the only specimen collected is not mature and accurate identifications are based on male or female genitalia, which are not evident until after the final moult. Minute spiders (Micropholcommatidae) are usually found only by sieving leaf litter, and several have been recorded from the Island, i.e. *Micropholcomma longissima* (Butler), *Micropholcomma* sp. and *Textricella luteola* Hickman. Lined spiders (Miturgidae) are common with most species making a tubular nest of silk under logs or in low dense shrubs such as *Isopogon ceratophyllus* R. Br., the prickly nature of which provides extra protection. When threatened the spider escapes from one end of the retreat to disappear into grass or other ground cover. Two species of *Miturga* have also been collected; one is possibly M. *maculata* Hogg, while the other with distinct linear markings is unidentified.



Figs 13-16. Some spiders from Kangaroo Is. 13, The white-tailed spider, *Lampona cylindrata*; 14 the jumping spider, *Holoplatys fusca*; which lives under bark 15, *Dolophones* sp. camouflaged on a dead branch; 16, the golden orb-weaving spider, *Nephila edulis*.

'Ground spider' is the general name given to several families, members of which rarely burrow to any depth, nor are found very far above ground. One example is the Zoridae which live and hunt in leaf-litter or ground-cover plants and usually roam in search of prey at night. There are many species, some of which have long legs and can move rapidly. Species of *Argoctenus, ?Ctenomma, Hestimodema* and two undetermined genera are common on the Island. Another speciose family, the Zodariidae, are also mostly ground spiders, but many live in short burrows or construct retreats in leaf-litter. Some species are found under bark at the base of trees. Many are active during the day, but prefer to hunt amongst the shelter of leaf-litter. One species of *Asteron* appears to prefer open sandy ground over which it runs during the day in search of prey. Five species of *Habronestes,* of which *H. bradleyi* (0. P.-Cambridge) mimic's the colour of meat-ants *(Iridomyrmex)*, and 12 other species of uncertain genera have also been recorded.

The Gnaphosidae, also referred to as ground spiders, though many live under bark of trees or in foliage of shrubs, was previously a very large family, but has recently been more narrowly defined (Platnick 1990). Only *Hemicloea* spp. and *Megamyrmaekion* spp. have been identified to generic level, but as many as six other genera with numerous species have been collected from the island, particularly in pitfall traps. Members of the Prodidomidae (previously classified as the subfamily Molycriinae within the Gnaphosidae) are easily recognised by the long anterior spinnerets which originate in some cases from the mid-ventral area on the abdomen. Often pale coloured and fast moving, these spiders may be found under objects on the ground or wandering at night. Three species belonging to either *Molycria, Myandra* or *Honunius* are known to occur on the Island. The Lamponidae, also recently removed from the Gnaphosidae and elevated to family rank, contains the white-tailed spider, *Lampona cylindrata* (L. Koch) (Fig. 13), which is widespread and common on the island just as it is on the mainland. Although *L. cylindrata* is reputed to cause serious skin necrosis, none of a dozen or so confirmed bites from this spider in South Australia have resulted in such injuries. The genus *Lamponina* and other unknown genera also occur, members of which are smaller than *L. cylindrata.* A large flat-bodied spider, *Rebilus* (also previously included in the Gnaphosidae), is the only known representative of the Trochanteriidae to occur on Kangaroo Island. It is usually found under large slabs of rock and is also common in the Mount Lofty Ranges.

Two common genera of sac spiders (Clubionidae), *Cheiracanthium* (one species) and *Clubiona* (eight species), are recorded from the Island. Two species of the latter genus, C.

cycladata Simon and C. *robusta* L. Koch, are widely distributed on the mainland and are mostly found in small silk shelters under bark of trees, while *Cheiracanthium* is found in silk nests in foliage. One species of *Meedo,* a genus previously recorded only from Western Australia, has recently been found on the Island and from several other localities in South Australia. The family Corinnidae is known from *Corinnomma* (one species) and *Supunna* (at least two species) which are extremely fast and can be seen during the day as they forage over the ground, rocks or tree trunks.

Although around 50 species of the Hersiliidae or two-tailed spiders have now been described from Australia, only one, *Tamopsis reevesbyana* Baehr & Baehr, has been found on Kangaroo Island. *Tamopsis* is usually seen at night on smooth tree trunks. Lynx spiders (Oxyopidae), found on low herbaceous vegetation, are represented by two species, one of which may be *Oxyopes rubicundus* L Koch.

Watercourses on Kangaroo Island provide an ideal habitat for water spiders (Pisauridae) and one species of *Dolomedes,* which is widespread throughout South Australia, is known. Wolf spiders (Lycosidae) are more diverse with numerous small species recorded from the island. Among the larger species are *Lycosa gilberta* Hogg, *L. godeffroyi* L. Koch, *L. leonhardii* (Strand), *L. senilis* L. Koch and *Venator fuscus* Hogg. Other species include *Lycosa speciosa* L. Koch, a medium-sized wolf spider which is also common in Adelaide suburbs, at least four other *Lycosa* spp., *Trochosa expolita impedita* (Simon) which is widespread and common, the rarer *Trochosa tristicula phegeia* Simon, and at least seven other small species similar to *Trochosa* and *Artoria,* some of which prefer damp situations.

Jumping spiders (Salticidae) are also very diverse with 28 species being recorded, nine of which cannot be placed to generic level. Of those which are completely identified, *Breda jovialis* (L. Koch), *Helpis minitabunda* (L. Koch), *H. occidentalis* Simon and *Servea vestita* (L. Koch) are common, widespread and often invade houses. *Opisthoncus* sp. (possibly O. *alborufescens* L. Koch) and *Jotus* spp. are commonly seen in gardens as they frequent foliage of shrubs, while *Holoplatys fusca* (Karsch) prefers the bark of trees (Fig. 14). Other genera represented are *Damoetus, Lycidas* (seven species), *Maratus* (two species), *Myrmarachne* and *Rhombonotus.*

The flower or crab spiders (Thomisidae) are rather cryptic and not often noticed by the casual observer. *Bomis larvata* L. Koch and *Cymbacha* sp. (possibly C. *festiva* L. Koch) hide in a retreat often of a folded and silk-bound living gum-leaf. *Diaea inornata* (L. Koch) is brightly coloured and well camouflaged on the flowers they frequent. *Sidymella trapezia* (L. Koch) is a larger species which may be found on flowers or leaf-litter. *Hedana valida* L. Koch prefers the foliage of trees on which its bright green colour renders it inconspicuous. At least one species of *Tmarus* is commonly seen at night hanging from shrubs on a silk line waiting for prey. *Stephanopis cambridgei* Thorell and two species of *Stephanopis* are more likely to be found on tree-trunks where their brown-grey warty-like body merges with the bark. *Tharpyna* spp. are also found under bark but are not well camouflaged and rely on faster movements to escape predation. A single specimen of *Synalus* has been collected from the Kelly Hill area and only one other specimen, from the Mount Lofty Ranges, has been collected in South Australia. Excepting the latter records, all other thomisids known from the island are species common on the adjacent mainland.

Huntsman spiders (Heteropodidae) from Kangaroo Island are well known and include the social huntsman, *Delena cancerides* (Walckenaer), two large brown species, *Isopeda leishmanni* Hogg and *Isopedella leai* (Hogg), found on tree trunks, and the badge huntsmen, *Neosparassus calligaster* (Thorell), *N. diana* (L. Koch) and *N. punctatus* (L. Koch) which prefer the foliage of shrubs. One smaller unnamed species of *Neosparassus* frequenting low herbaceous vegetation appears to be uncommon.

Only one member of the Deinopidae (retiarus spiders), *Avella* sp. (possibly *A. angulatus* L. Koch), has been collected and is much smaller than its larger relatives, *Deinopis* spp. The Uloboridae are the only spiders which lack venom glands and *Philoponella congregabilis* (Rainbow), which is also common around Adelaide, relies on its web to ensnare prey then binds the captive insect with silk. The webs often occur in aggregates in dark sheltered places, but the spiders do not share webs or prey. Members of *Miagrammopes* have only four eyes (the front set being lost) and a single species recorded from the island uses only a single snare line.

Orb weavers (Araneidae) may be found throughout the year, but are more noticeable during the warmer summer months when most species reach full-size. *Arachnura higginsi* (L. Koch), the scorpion-tailed spider, and *Araneus eburnis* (Keyserling) are common, but seldom noticed as webs are usually amongst vegetation, while the large common garden orb-weaver, *Eriophora biapicata* (L. Koch), has webs strung over open spaces such as walkways. Webs of *Eriophora pustulosa* (Walckenaer) are not as large and usually anchored out of the way on tree-trunks or branches. Several small *Araneus* spp. from the island are very similar to those occurring in eastern Australia, but future taxonomic research may eventually recognise them as new closely-related species. *Carepalxis* spp. all have unusual-shaped abdomens that resemble nodes on a branch when the spider is at rest during the day. *Dolophones turrigera* (L. Koch) and a second unidentified species have a similar method of camouflage but the abdomen is flatter and partly wraps around the branch (Fig. 15). *Celaenia kinbergii* Thorell, the bird dropping spider, *Cyclosa bifida* (Doleschall) and *Cyclosa trilobata* (Urquhart) appear to be uncommon while the spiny spider, *Gasteracantha minax* Thorell is most evident in late summer when it builds massed webs amongst bushes. *Paraplectanoides crassipes* Keyserling has only been collected twice in South Australia with one record being from Kangaroo Island. This species makes a nest under logs or in other sheltered places but little else is known of its biology.

Two species of *Tetragnatha,* the long-jawed orb-weavers (Tetragnathidae), are usually found near water where they make an orb-web between sedges or similar plants. They often remain in the web during the day but sometimes shelter on thin plant stems and, with their elongate body and long thin legs stretched out along the stem, they are not easily seen. The golden orb-weaver, *Nephila edulis* (Labillardiere), is most obvious in its large web strung across open areas (Fig. 16). *Phonognatha dimidiata* (L. Koch) makes a web in the dead branches of trees where it lives in borer holes while the leaf-curling spider, *Phonognatha graeffei* (Keyserling), is common in low vegetation.

The Linyphiidae are represented by four species: *Laperousea blattifera* (Urquhart), *L. quindecimpunctata* (Urquhart) and two species of *Laetesia,* all making small webs in foliage of shrubs or on tree-trunks. Tangle web weavers (Theridiidae) are numerous with many species being recorded. *Achaearanea properum* (Keyserling) and A. *veruculata* (Urqhuart) are common throughout the island, while a third species (possibly A. *tepidariorum (C.* L. Koch), the grey house spider), is mostly found in disturbed areas around human habitation. *Theridion* (six species) are uncommon, while *Argyrodes antipodianus* O. P.-Cambridge, the dew-drop spider, and three other *Argyrodes* spp. frequent the webs of large orb-weavers and feed on small insects which are unnoticed by the web owner. One species of *Argyrodes* has a stick-like body with long thin legs and was previously referred to the genus *Ariamnes* (Levi & Levi 1962). Many therids are small with a body length of only a few millimetres. Several tiny *Oipoena* spp., one *Moneta, Phoroncidia trituberculata* (Hickman) and two *Euryopis* spp., of which one resembles *E. elegans* Keyserling, are more usually seen suspended on a silk line at night. *Euryopis* appears to feed exclusively on ants, often much larger than itself, while another small spider, *Hadrotarsus* sp., is more usually found on the ground or tree-trunks. The redback spider, *Latrodectus hasseltii* Thorell, is probably more common around buildings and in disturbed areas. Other theridiids associated with human habitation are the introduced cupboard spider, *Steatoda grossa (C.* L. Koch), which is found indoors or in similar sheltered places, and S. *capensis* Hann, which prefers garden situations. One native species of *Steatoda* collected from Flinders Chase is not known to occur on the mainland.

The family Mimetidae includes the pirate spiders, recorded by *Australomimetus* sp., and the triangular spiders, *Arkys simsoni* (Simon) and *Arkys* sp., both of which also occur in the Mount Lofty Ranges. *Arkys* sit on foliage and grasp its prey with strong spiny front legs while *Australomimetus* invades the web of other spiders and feeds on the resident spider.

Other arachnids

The harvestmen (Opiliones) include the endemic *Nunciella kangarooensis* Hunt, previously the only known species occurring on Kangaroo Island. The smaller *Yatala hirsti* Roewer has since been found to be common and also occurs on the adjacent mainland. Both belong to the family Triaenonychidae.

The pseudoscorpion (Pseudoscorpiones) fauna has been little investigated but at least three species have been recorded. *Geogarypus taylori* Harvey (Geogarypidae) is common in mallee litter, and *Synsphyronus mimetus* Chamberlin (Garypidae) occurs in near-coastal habitats in litter and under rocks; both are also common on the mainland. An unidentified chernetid (Chernetidae) has also been found in mallee litter on the Island.

Despite their abundance and incredible diversity, the mite (Acarina) fauna of rnuch of Australia is still largely unknown. On Kangaroo Island, one species of Caeculidae *(Neocaeculus)* is commonly collected by pitfall trapping as is the large red velvet mite, *Erythrites reginae* Hirst (Erythraeidae); both species being abundant on the mainland. *Sphaerotarsus leptopilus* Womersley & Southcott (Smaridiiae) has been collected, while *Parasitiphis littoralis* Womersley, originally described from American River (Womersley 1956) and known from Myponga Cove on the adjacent mainland, has not been collected since. The introduced red-legged earth mite, *Halotydeus destructor* (Tucker) (Penthaaleidae), is an occasional pest of agricultural pastures. Of the ticks, *Ornithodoros capensis* Neumann (Argasidae), *Ixodes eudyptidis* Maskell and *I. kohlsi* Arthur (Ixodidae) have been recorded from penguins, *I. victoriensis* Nuttall from a robin red breast, *I. fecialis* Warburton from the short-nosed bandicoot, *I. tasmani* Neumann from a brushtail possum, and *Aponomma fimbriatum (C.* L. Koch) from a goanna. *Ixodes trichosuri* Roberts has been collected from litter, but is known from the mainland as a parasitise of possums, rats or bandicoots.

MYRIAPODS

The myriapods comprise the centipedes (Chilopoda), which are predatory on other invertebrates, and the millipedes (Diplopoda) which are phytophagous. Several species of centipedes occur on Kangaroo Island, including members of the widespread genera *Scolopendra, Cormocephalus* and *Ethmostigmus.* Only C. *aurantiipes*

(Newport) has been officially recorded from Kangaroo Island (Koch 1983), but the occurrence of numerous other centipede species in several genera from the nearby mainland suggests that the fauna is more diverse. They are often brightly coloured (yellow, red, orange and black), and are commonly found under bark, rocks, logs, and, if you are unlucky, in sleeping bags. Other than a very painful bite because of the large size of their fang-like mandibles, no species is particularly dangerous.

Millipedes occur in leaf-litter and soil as well as under bark, rocks and logs, sometimes in large numbers. Numerous native species belonging to several orders occur on the island but apparently none have been identified to species level. In addition to these, the introduced Portuguese millipede, *Omatoiulus moreletti* (Lucas), is also known. It was recorded from Kingscote in 1988 and has since been found at several other locations. This species is best known as a domestic and garden pest as it can occur in large numbers around houses and other buildings (Bailey 1992). However, its local distribution also extends into the native vegetation and it probably has a significant detrimental effect on the biodiverity of litter and soil invertebrates.

TERRESTRIAL CRUSTACEANS

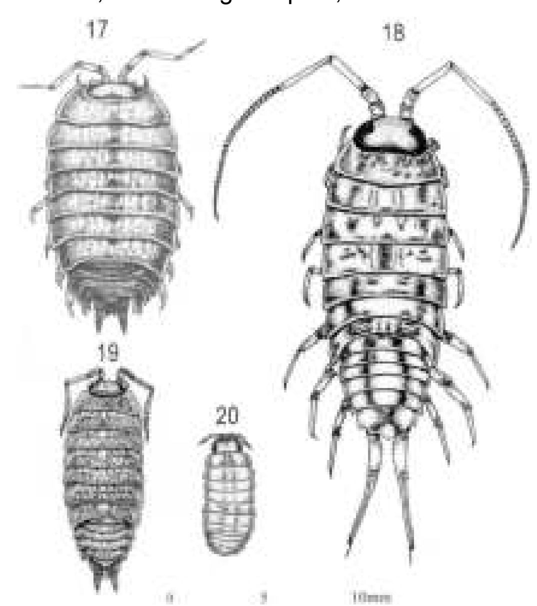
Terrestrial Crustacea such as slaters are often mistaken for insects but they belong to a very large order, the Isopoda, with many marine and also some freshwater relatives. Slaters occur in moist conditions, usually under debris, and are widespread throughout Australia but the fauna is very poorly known. Several species occur on Kangaroo Island but very little is known about them as no systematic collections have been made. The European woodlouse *Porcellio laevis* (L.) (Fig. 17) which was introduced to Australia during early settlement, is common on Kangaroo Island, occurring under debris in domestic gardens and elsewhere. It is slate-grey in colour with white markings on each side and, unlike some species, does not roll into a ball when disturbed but runs for cover.

Native species of slater may be found in leaf litter or in rock crevices near creek beds, but are more common along the sea-shore. *Ligia australiensis* (Dana) (Fig. 18), the swift beach louse and *Deto marina* (Chilton) (Fig. 19), the rock louse, are common under rocks at high tide level. *Ligia australiensis* is easily distinguished from *D. marina* by its larger size and long antennae and uropods. It also moves quickly for cover when disturbed whereas *D. marina* is rather slow and sluggish. *Actaecia pallida* (Nicholls & Barnes) (Fig. 20), the beach pill bug, may be found on clean, sandy beaches but is difficult to see because of its white with brown markings which match the background. When disturbed it rolls up into a ball and may be blown across the sand by wind, thus making it a difficult animal to see and capture. All of the above species are also common on the shores of mainland southern Australia.

The only other terrestrial crustaceans that occur on Kangaroo Island are land or beach-hoppers (Amphipoda) which are similar to isopods and occur in similar habitats, but are distinguished by having laterally compressed bodies. The most common beach-hopper is *Allorchestes compressa* Dana, which can be very abundant under fresh sea-weed, and sometimes occurs with other amphipod species that have been washed up with sea-weed. There may also be other species of beach-hopper present but very little is known about this group in Australia and no systematic collections have been made on Kangaroo Island or elsewhere. Similarly, very little is known about land-hoppers but it is likely that *Austrotroides crenatus* Friend, which is very common in the gardens of the Adelaide hills region, also occurs on Kangaroo Island. Both slaters and amphipods are an important part of the complex community of invertebrates that break down leaf litter and other debris prior to its decomposition by micro-organisms and subsequent incorporation into the soil.

TERRESTRIAL MOLLUSCS

The terrestrial and aquatic molluscan fauna of Kangaroo Island is very similar to that of the mainland, as one might expect, but it is less well-



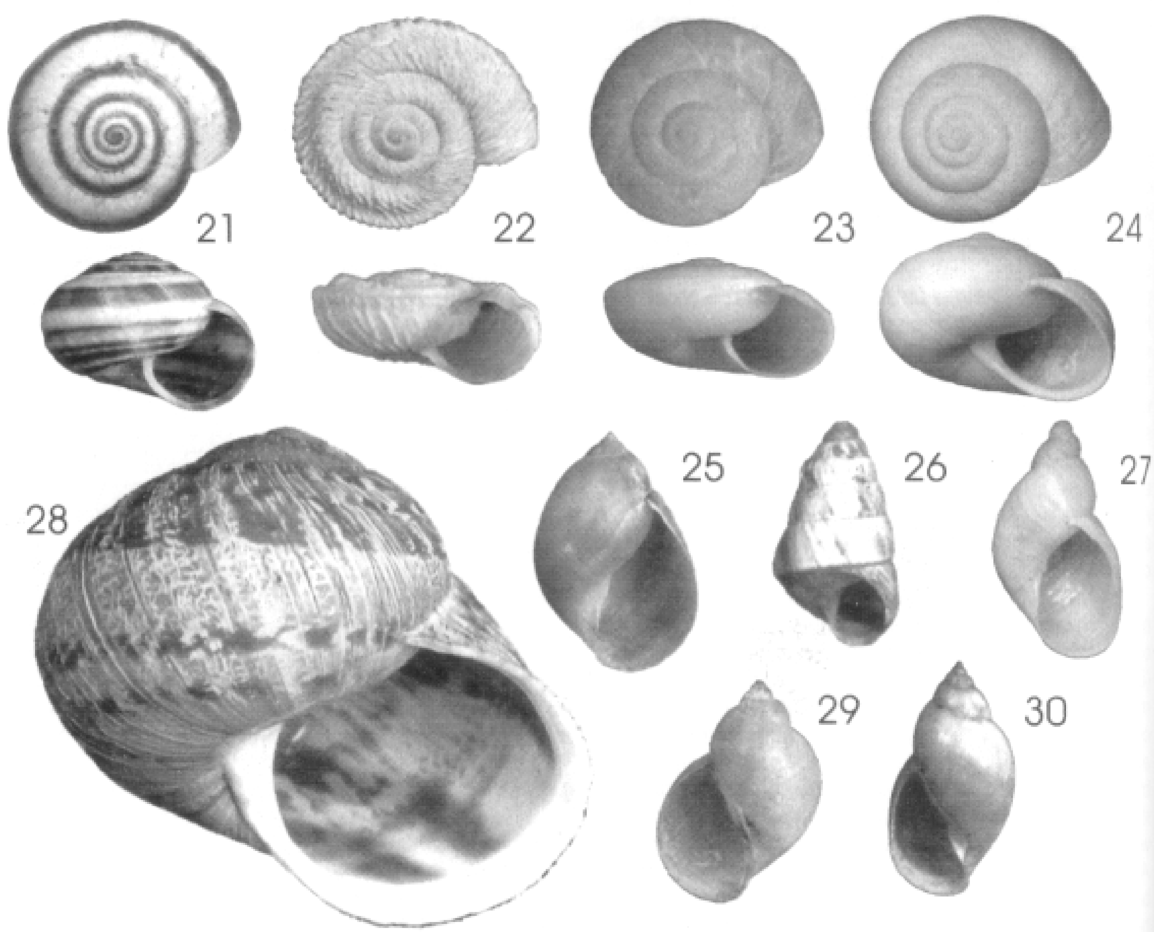
Figs 17-20. Slaters (isopods) known from Kangaroo Island. 17, the introduced European woodlouse *Porcellio laevis;* 18, the swift beach louse, *Ligia australiensis;* 19, the rock louse, *Deto marina;* 20, the beach pill bug, *Actaecia pallida.*

known and undoubtedly several undescribed species await discovery. The fauna consists of three main groups: endemics with closely related species occurring on the mainland; widespread native species that are also common in southern Australia, and widespread introduced species such as those belonging to the Helicidae, i.e. *Cochlicella barbara* (L.) (Fig. 26), *Cernuella (Cernuella) virgata* (Da Costa) (Fig. 21) and *Helix (Cornu) aspersa* Muller (Fig. 28).

The three known endemic species are all land snails of the family Camaenidae. Of these *Cupedora sutilosa* (Ferussac) (Fig. 24) is the largest and is relatively common over the eastern three-quarters of the island. It is very similar to C. *bednalli* (Brazier) of the Mt Lofty Ranges but differs in colour pattern and genital structure (Solem *1992). Cupedora tomsetti* (Tate) (Fig. 23) is similar in appearance to C. *sutilosa* and occupies a similar habitat but the adult shell is thinner and darker in colour and has a slightly depressed spire. According to Solem (1992) there are insufficient data to characterise this species, and this is a reflection on our lack of knowledge regarding land snails in general. *Glyptorhagada bordaensis* (Angas) (Fig. 22) is an attractive species with strong wavy axial sculpture. It is restricted to the western edge of the island where it may be found in rock crevices of cliffs or rock outcrops that have afternoon shade.

Of the remaining land snails, *Bothriembryon (Bothriembryon) mastersi* (Cox) (Bulimulidae) is restricted to the coast of South Australia along the Eyre and Yorke Peninsulas, including some offshore islands, while the remainder are widespread southern Australian species. *Bothriembryon (B.) mastersi* usually occurs in litter underneath shrubs that grow on sandhi lis near the coast and is sometimes found buried in sand near the base of vegetation. Kershaw (1986) provides some anatomical information on this interesting species and compares it to other mainland species.

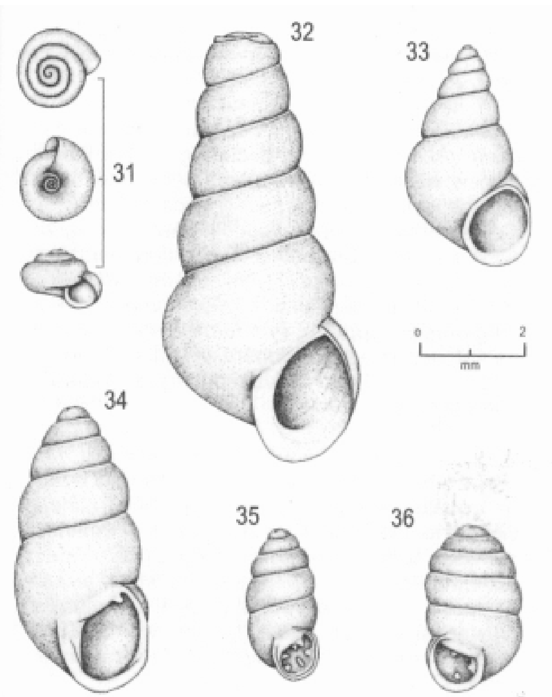
The widespread southern Australian species that occur on Kangaroo Island are all relatively small and typical of coastal habitats, often relying on moisture from sea spray or morning dew. At least



Figs 21-30. Terrestrial and freshwater gastropod molluscs from Kangaroo Island. 21, *Cernuella (Cernuella) virgata*; 22, *Glyptorhagada bordaensis*; 23, *Cupedora tomsetti*; 24, *Cupedora sutilosa*; 25, *Austropeplea lessoni*; 26, *Cochlicella barbara*; 27, *Succinea* sp.; 28, *Helix (Cornu) aspersa*; 29, *Isidorella newcombi*; 30, *Glyptophysa (Glyptophysa) gibbosa*.

three species of Pupillidae have been recorded from the island (Solem 1986). Members of this family all aestivate by sealing to an object and are common in debris, gravel and leaf litter, and are therefore easily dispersed by floods. *Gastrocopta margaretae* (Cox) (Fig. 35) and *Pupoides adelaidae* (Angas) (Fig. 34) are common along the entire southern Australian coastline and also occur in the Gawler and Southern Flinders Ranges. *Pupilla (Gibbulinopsis) australis* (Angas) (Fig. 36) occurs in similar habitats, but on the mainland it is rarely found east of Ceduna and has not been found in the Gawler or Flinders Ranges. The Kangaroo Island population is thus an interesting remnant of a once more widespread species. One species of *Succinea* (Succineidae) (Fig. 27) is also common on the island, but it occupies a semi aquatic habitat and is usually found under debris in dry creek beds or near the edge of swamps and salt marshes. Other minute snails may also be found in similar habitats to the Pupillidae. Most of these are sub-globose in shape, often measuring less than 5.0 mm across and belong to the Punctidae (e.g. *Paralaoma* sp. - Fig. 31). The systematics of this family is the least well understood of all Australian land snails, probably because their small size makes them difficult to collect and study. The Punctidae comprise a wide variety of forms and sculpture, and they are an interesting group for future study with many new species still awaiting discovery.

In summary the Kangaroo Island molluscan fauna, including aquatic species (see below), consists



Figs 31-36. Terrestrial and freshwater gastropod molluscs from Kangaroo Island. 31, *Paralaoma* sp.; 32, *Coxiella (Coxiella) striata*; 33, *Potamopyrgus antipodarum*; 34, *Pupoides adelaidae*; 35, *Gastrocopta margaretae*; 36, *Pupilla (Gibbulinopsis) australis*.

mainly of widespread southern Australian species with a few endemics that have closely related species on the mainland. These populations, having been isolated from the mainland for about 10,000 years, provide an exciting opportunity for genetic and evolutionary studies

OLIGOCHAETE ANNELIDS

The annelids comprise the segmented worms, the most important terrestrial component of which is the earthworms (Oligochaeta). Freshwater species are treated below under 'Aquatic Invertebrates'. Although they are extremely important in maintaining and developing soil structure and fertility, very little is known about their biology, particularly of the native species. Surveys in southern Australia show that native species are mostly restricted to areas of natural vegetation, while agricultural areas are dominated by introduced European species, mostly from the family Lumbricidae (Baker *et al.* 1992, 1993). Two species that are common on the adjacent mainland and undoubtedly occur on the Island are *Aporrectodea trapezoides* (Duges) and *A. rosea* (Savigny). Activity of these and other introduced species is restricted to the cooler, wetter times of year (late autumn to late spring), and this probably corresponds to a longer period on Kangaroo Island compared with the mainland because of its more maritime climate. Species vary in their feeding and burrowing biology (Lee 1985). For instance, *A. trapezoides* forms casts on the surface and therefore has open burrows, while *A. rosea* is less surface active and this results in soils of different structure.

Virtually nothing is known of the native species found on Kangaroo Island, although it is suspected that the faunal composition is likely to be similar to the southern Fleurieu Peninsula. One species, *Perionychella inconstans* Jamieson, collected from the banks of Rocky River among grass roots is reported to be endemic to the Island. This species is atypical of the genus and its generic status is in need of review (Jamieson 1974).

NEMATODES

Nematodes are worm-like invertebrates that are found free-living in soil, in both fresh water and maritime habitats, or parasitic in roots and foliage of plants, in other invertebrates such as insects, as well as in most vertebrates. Nematodes which are not parasitic feed on other living organisms rather than on dead organic matter. Discussion here is limited to terrestrial nematodes which live in soil.

Soil nematodes are all worm-like in shape but are unsegmented and more closely related to the yellowish flat worms sometimes found in gardens than to earthworms (Annelida). They are usually microscopic, with most less than 3 mm long, but a few are up to 10 mm. There are many species, most of which are undescribed, and almost all soils contain some nematodes. They move in a snake like manner, in the thin film of water which surrounds soil particles and, therefore, are usually more active during periods when soil is moist or wet. When soil dries out, the film of moisture around soil particles becomes very thin, and restricts nematode movement so that they become inactive and often become coiled, remaining in a dormant state until soil moisture levels rise again. They may also survive dry periods as eggs. When there is sufficient moisture, nematode eggs hatch into small juveniles which undergo four moults before becoming adults. This may take from a few weeks to several years, depending on species and season.

For many soil nematodes, there is insufficient knowledge, particularly for Australian species, and the feeding habits of some groups is not known. There are several types of soil nematodes of which plant parasitic species are the best known. These nematodes feed on plant roots and sometimes within plant foliage. The head contains a stylet or spear which the nematode uses to feed on plant cells. The stylet is a hollow structure, like a hypodermic needle, which is inserted into plant cells. The nematode then sucks out the contents of the cell through the tubular stylet. Other soil nematodes feed on bacteria, algae, fungal hyphae and other nematodes, as well as other small invertebrates such as protozoa, rotifers and enchytraeids (Yeates *et al. 1993).*

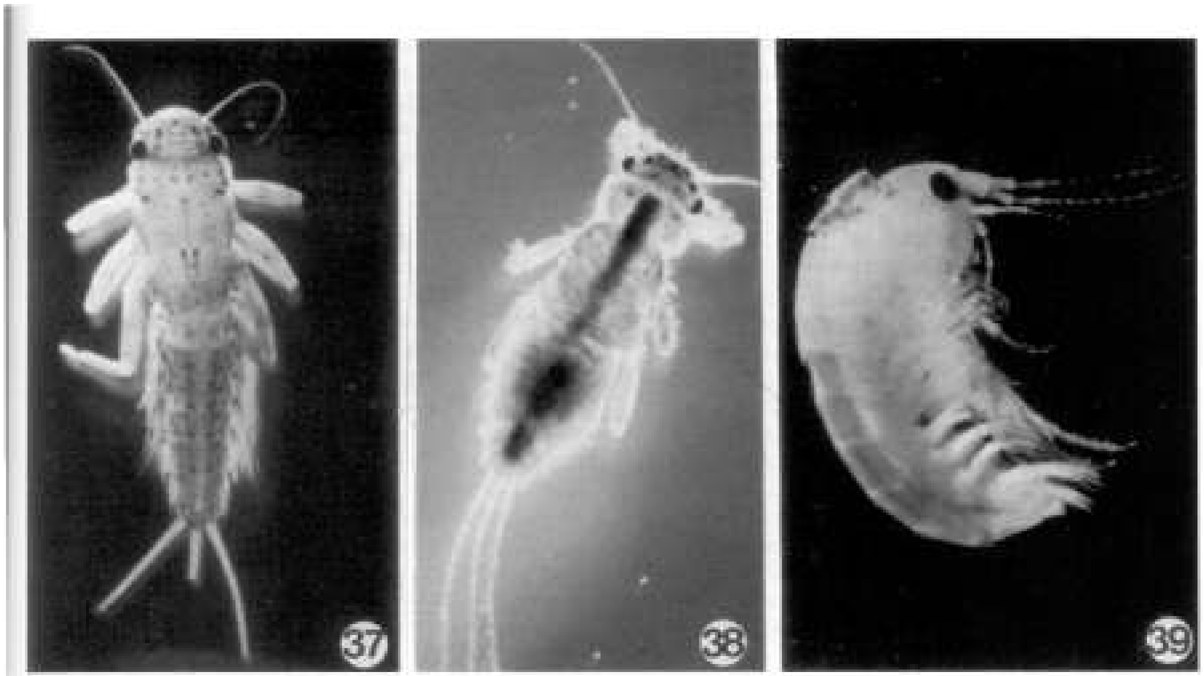
Mononchid nematodes are predators, and have teeth within a large mouth with which they seize their prey. They often feed on other nematodes, particularly the juveniles of other species which have a thin cuticle (Bilgram 1992; Bilgram & Jairajpuri 1989). Some species of plant nematodes have a very thick cuticle (e.g. *Arboritynchus),* or a second cuticle (e.g. *Hemicycliophora)*, or scales on the body (e.g. *Ogma),* which protect them from predation. Some mononchids grasp their prey and consume it whole; others suck out the body contents and then reject the remaining cuticle. Dorylaimids form a large group of soil and fresh water nematodes. Some species of dorylaimids feed on plants, some on bacteria and algae and possibly fungal hyphae, while others are predacious. Most dorylaimids are stylet bearing and the predacious species use the stylet in a similar manner to plant parasitic species, feeding on other nematodes and small invertebrates by puncturing the surface and sucking out the body contents. The size of the stylet in dorylaimids is highly variable, presumably as an adaptation to their feeding source. In plant feeding species the stylet is very long and slender, enabling penetration of thick roots, whereas other species have a short but wide stylet with a wide aperture for feeding on bacteria, algae and protozoans. Rhabditid nematodes usually feed on bacteria but some are predatory: none has a stylet. They ingest bacteria through a tube-like mouth that may contain teeth at the base. Many such species live in soil for part of their life cycle and then inside larger invertebrates such as insects and snails. Some rhabditids are being used for the biological control of pest insects and molluscs.

Many species and a few genera found associated with native plants are endemic to Australia. The diversity of soil species is usually greater in areas of higher moisture, such as gulleys and in areas of higher rainfall. Several species of plant nematodes are known only from South Australia, but due to lack of study those occurring on Kangaroo Island are mostly unidentified. Only two species are known from Kangaroo Island. The economically important cereal cyst nematode, *Heterodera avenae* Wollenweber, has been recorded from two farming properties in the Kingscote area on wheat and oats (Field Crops Pathology, SARDI, pers. comm.). In 1964 *Telotylenchus whitei* Fisher was described from specimens around the roots of *Acacia armata* (R. Br. ex Aiton) on the bank of Timber Creek. This species has since been transferred to the genus *Morulaimus,* which is widespread in Australia and also recorded from New Zealand. All species in this genus have a very long stylet, usually over 80 IJm long. Individuals are about 0.7- 2.0 mm in length, and preliminary studies show that at least one species feeds on *Eucalyptus* roots.

In view of a similar climate and vegetation it is probable that the nematode fauna of Kangaroo Island is similar to that occurring on the Fleurieu Peninsula. Such native plant nematodes would include spiral nematodes *(Helicotylenchus* and *Scutellonema* spp.), pin nematodes *(Paratylenchus* and *Gracilacus* spp.), ring nematodes *(Ogma, Criconema* and *Hemicriconemoides* spp.), plant parasitic dorylaimids *(Xiphinema* and *Paralongidorus* spp.), *Tylodorus* spp., sheath nematodes *(Hemicycliophora, Filenchus* spp. and others), as well as various mononchids, rhabditids and dorylaimids.

AQUATIC INVERTEBRATES

The streams on Kangaroo Island harbour a fauna of aquatic macro-invertebrates which, although similar to that found on the Fleurieu Peninsula, shows some distinctive features. Macroinvertebrates is an arbitrary group which includes all species visible to the naked eye, viz. molluscs, crustaceans, mites, insects, and worms. Some crustaceans, such as copepods, cladocerans and ostracods are therefore excluded because of their tiny size (usually < 0.2 mm). There is little published information available on the freshwater invertebrates of Kangaroo Island, apart from *ad hoc* taxonomic records (e.g. Suter, 1986; Suter & Bishop 1990; Wells 1985). Since 1994 a



Figs 37-39. Some aquatic macro-invertebrates from Kangaroo Is. 37, nymph of *Atalophlebia australasica,* a mayfly found in streams of Flinders Chase National Park; 38, *Tasmanocoenis tillyardi,* a caenid mayfly which occurs in southern and central streams; 39, the amphipod *Austrochiltonia australis* which is common, in freshwater and saline streams.

nationwide program of monitoring Australian rivers and streams has been undertaken as part of the National River Health Program. This systematic sampling program, called the Monitoring River Health Initiative, has provided much of the following information on the fauna of Kangaroo Island streams.

The results from samples show a difference in the fauna between the western and eastern ends of the island, with species richness declining from west to east. In addition, the streams in the Flinders Chase National Park (Rocky and Breakneck rivers) contain a higher species diversity than streams outside the park. Water chemistry also reflects this gradient, with Rocky and Breakneck rivers being *very* fresh, Willson and Chapman rivers on Dudley Peninsula being very saline (> 10 g/l), and streams in the centre of the island (e.g. Eleanor, Cygnet and Middle rivers) being intermediate in salinity (1-2 g/l) The streams of Kangaroo Island generally are highly coloured by tannins from surrounding vegetation. However, *even* in agricultural areas nutrient concentrations in the water are low and large amounts of filamentous algae, commonly found in mainland streams, are rare on the island. The streams in the cleared areas of the island are much more eroded and provide less habitat for aquatic insects, a factor that has probably contributed to a reduction in species diversity. The many freshwater lagoons on the island have not been sampled, but they probably share a significant proportion of the macrofauna found in still sections of streams.

Insects

Most insects found in freshwater are immature, nymphs or larval stages of species that have airborne adults (e.g. dragonfly and mayfly nymphs, caddis-fly and midge fly larvae). Some adult stages also inhabit the water, most notably bugs (Hemiptera) and beetles (Coleoptera) that can fly between water bodies if water conditions become unfavourable. Insects are the most diverse of aquatic macro-invertebrates on Kangaroo Island, as elsewhere in Australia.

Six species of Ephemeroptera (mayflies) representing the families Leptophlebiidae, Baetidae and Caenidae are found on the island, mostly in the less saline streams in the western part of the Island. This diversity is significant *given* that only 14 species are recorded for all of South Australia (Suter 1986; Alba-Tercedor & Suter 1990). The Letophlebiidae are represented by three species; *Atalophlebia australasica* (Pictet) (Fig. 37) is found in streams in Flinders Chase National Park, mainly on logs in slow flowing pools; *Koorrnonga inconspicua* (Eaton) is common in many western and central streams, while *Nousia fuscula* (Tillyard) is restricted to streams in and near Flinders Chase. The Baetidae are represented by two species. *Centroptilum elongatum* Suter which, on the mainland is restricted to a few streams on the Fleurieu Peninsula, is the most common member of the family on Kangaroo Island and is dominant *over* the more widespread *Cloeon fluviatile* Ulmer at most sites in the western part of the Island. It is also noteworthy that the baetid mayfly recorded as *Baetis soror* Ulmer by Suter (1986) which occurs in flowing waters throughout the ranges on the mainland, does not occur on the island where streams are more intermittent and slow flowing, particularly in summer. *Tasmanocoenis tillyardi* (Lestage) (Fig. 38), the only caenid mayfly on Kangaroo Island occurs in southern and central streams and in the Cygnet River at localities where salinity is generally below 3 g/l. These small mayflies are rarely observed as the nymphs are cryptic and the adult fly at night.

Nymphal stages of the Odonata (dragonflies and damselflies) are not abundant in any streams but five families are represented on the Island. Those collected include the damselflies *Ischnura heterosticta* (Burmeister) (Coenagrionidae) and *Austrolestes* spp. (Lestidae), and dragonflies of the genera *Austrogomphus* (Gomphidae), *Aeschna* and *Austroaeschna* (Aeschnidae) and the widespread *Hemicordulia tau* (Selys) (Corduliidae) (Watson *et al.* 1991). The above species occur in virtually all streams including the more saline Willson River at the eastern end of the Island.

Five of the seven species of stoneflies (Plecoptera) recorded from South Australia occur on Kangaroo Island. Of these nymphs of three species, *Newmanoperla thoreyi* (Banks), *Illiesoperla mayi* Perkins and *Oinotoperla evansi* Kimmins are common and widespread, while *Riekoperla naso* Kimmins has only been collected from South West River. *Austrocerca tasmanica* (Tillyard), the only notonemurid stonefly recorded from South Australia, has been recorded from Middle River near Glencorrie, South West River at St Andrews, Eleanor River at Daws Diggings, and in the Tin Hut/Bullock Creek. Unlike many aquatic insects, stoneflies are generally seasonal with nymphs being most common in winter and spring, and adults occurring only in spring.

In pools along streams and rivers and freshwater wetlands many species of true bugs (Hemiptera) can be found. Water boatmen (Corixidae) are numerous with *Micronecta annae* Kirkcaldy and M. *gracilis* Hale being the most widespread, and *Diaprecoris barycephala* Kirkcaldy and *Sigara* spp. commonly occurring at particular sites. Backswimmers (Notonectidae) are represented by the genus *Anisops.*

Beetles (Coleoptera) are well represented both in slower flowing pools and also in the faster flowing sections of streams. Dytiscidae and Hydrophilidae are most common in pools, with the former family being more diverse and represented by *Platynectes* spp., *Rhantus suturalis* (MacLeay), *Sternopriscus* spp. and *Necterosoma* spp. Only one genus of hydrophilid is known from pools, the small inconspicuous *Paracymus.* Species of *Ochthebius* (Hydraenidae) are tolerant of high salinity and can be common in the eastern streams, while some temporary lagoons can harbour larger beetles like *Hyderodes shuckhardi* Hope (Dytiscidae) and *Limnoxenus mastersi* MacLeay (Hydrophilidae). Larvae of the Scirtidae are very abundant in the fine organic material in creeks with *Pseudomicrocara* being one of the genera represented. In fast-flowing sections of streams riffle beetles (Elmidae) can be found with taxa such as *Kingolus* being widespread at the western end of the Island.

Many families of flies (Diptera) have aquatic larval stages, such as the Tipulidae, Dixidae, Culicidae, Psychodidae, Empididae, Muscidae, Stratiomyidae and Ceratopogonidae. Black-fly larvae (Simuliidae) again show a difference in species between the eastern and western parts of the Island. The saline streams in the east are populated by *Simulium ornatipes* Skuse, while western streams have *Austrosimulium furiosum* (Skuse) as the main species. Midge-fly larvae (Chironomidae) are very common in streams, with some species having their stronghold on Kangaroo Island and being rare on the adjacent mainland. Apart from occurring in Kangaroo Island rivers, representatives of the genera *Stictocladius, Aphroteniella* and *Stempellina* are found only in upland streams of the Mount Lofty Ranges. The larvae of *Stempellina* are notable because they build a case out of sand grains that they carry around with them, whereas most other chironomids are sessile in tubes built in or on the substrate. *Parochlus* and *Nilothauma* spp. have been found on Kangaroo Island and these are the only records for South Australia.

Another group for which the only South Australian records come from Kangaroo Island are the scorpion flies (Mecoptera) of the genus *Nannochorista.* Larvae have been collected from the headwaters of the Cygnet and Eleanor Rivers. Both the Nannochoristidae and midge larvae of the subfamily Aphroteniinae mentioned above are examples of ancient groups with a Gondwanan distribution (i.e. Australia, New Zealand and South America).

Caddis-fly (Trichoptera) larvae are completely aquatic. They generally require clean, cool water and their distribution pattern is similar to many other macro-invertebrates, in that the greatest diversity occurs in streams at the western end of the Island. Caddisflies are represented by seven families: the Atriplectididae, Calamoceratidae, Conoesucidae, Ecnomidae, Hydrobiosidae, Hydroptilidae and Leptoceridae. The predatory hydrobiosids are represented by *Taschorema evansi* Mosely and *Ethochorema hesperium* Neboiss, amongst others. Species of the Australia wide genus *Ecnomus* are also predatory in streams on the Island. The Leptoceridae are very common with *Oecetis, Triplectides* and *Notalina* spp. all occurring, as well as *Lectrides varians* Mosely. The presence of *Atriplectides dubius* Mosely (Atriplectidae), *Anisocentropus latifascia* (Walker) (Calamoceratidae) and *Lingora aurata* Mosely (Conoesucidae) again shows the similarity with the fauna of the Fleurieu Peninsula, as these species are restricted to headwater streams of the

Mount Lofty Ranges and southwards to the Island. The micro-caddises (Hydroptilidae) are very abundant and diverse with undescribed species known of *Hellyethira* and *Hydroptila.* The distinctive flask-shaped cases of *Oxyethira columba* (Neboiss) and wheat-seed shaped cases of *Orthotrichia bishopi* Wells make these species readily distinguishable despite their small size (Wells 1985).

Hydracarina

The sandy nature of sediments in Kangaroo Island streams favours the presence of many species of water mite, a group collectively referred to as the Hydracarina. To date at least nine families of water mite have been recorded, although none has been identified beyond generic level. The family Unionicollidae is represented by the genera *Recifella* and *Koenikea.* The Hygrobatidae are common with *Rynchaustrobates, Dropursa* and *Corticacarus* spp. all being recorded. The Aturidae are represented by the laterally compressed *Frontipodopsis,* similar in appearance to the Oxidae. Other families recorded are the Hydryphantidae, Momoniidae, Arrenuridae, Johnstonannidae as well as several species of orabatid mite. It is unlikely that any species are restricted to Kangaroo Island. Water mite larvae are parasites upon the external surface of adult aquatic insects, including chironomids, dragonflies, water beetles and water bugs.

Crustaceans

The amphipod *Austrochiltonia australis* (Sayee) (Fig. 39) is very common, especially in more saline streams, where members of the Eusiridae (also amphipods) and the isopod *Haloniscus* are also found. Two large decapod crustaceans are now very common throughout the Island. The yabby, *Cherax destructor* Clark, which may have been introduced to the island, can be found in virtually all streams. The marron, *Cherax tenuimanus* (Smith), a Western Australian native and an escapee from farm dams, now also appears to be present throughout the island, including Flinders Chase National Park (P. Goonan, pers. comm.). Gross *et al.* (1979) recorded the presence of an undescribed species of *Geocharax* (reported by Riek 1969), but this has not been substantiated. One of the most common crustaceans in waters of the Fleurieu Peninsula is the shrimp *Paratya australiensis* (Kemp), but this species was not recorded from streams on the Island during the recent extensive surveys of the Monitoring River Health study.

Molluscs

The aquatic snails found on Kangaroo Island are all species that are widespread in southern Australia. In the salt lakes on the eastern half of the island the pink salt lake snail *Coxiella (Coxiella) striata* (Reeve) (Fig. 32) is very abundant, often giving the lake a pink appearance. The adult shells of *Coxiella* usually have the apical whorls broken off. Just why this should occur is not known but it may be in response to the extreme salty conditions. In the still waters of creeks, billabongs, swamps and even farm dams at least four species of thin-shelled snails occur, three belonging to the family Planorbidae, *Isidorella newcombi* (Adams & Angus) (Fig. 29), *I. hainesii* (Tryon) and *Glyptophysa (Glyptophysa) gibbosa* (Gould) (Fig. 30), and one to the Lymnaeidae, *Austropeplea lessoni* (Deshayes) (Fig. 25). The systematics of both families is not well understood and species can be difficult to determine, as the shell shape and form can vary with environmental conditions. In the running waters of most creeks, particularly on the eastern half of the Island, the black river snail, *Potamopyrgus antipodarum* (Gray) (Hydrobiidae) (Fig. 33), can be very abundant. Ponder (1988) demonstrated that this species was introduced to Australia from New Zealand in the early 1800's. It is very common in south-eastern parts of the mainland and Tasmania and, being both parthenogenic and ovoviviparous, it is thus a very successful coloniser. The bivalve *Sphaerium tasmanicum* (Tenison-Woods) is also found in slow flowing pools.

Annelids

Several families of earthworms (Oligochaeta) can be found in freshwater sediments, with four families having been recorded from streams on the Island. The Naididae are represented by the genera *Nais, Siavina, Pristina* and *Paranais,* while members of the Enchytraidae and Tubificidae have also been collected. The Phreodrilidae primarily have a southern distribution and the most widespread species, *Antarctodrilus proboscidea* (Brinkhurst & Fulton) has been recorded from the Breakneck River (Pinder 1994). The other main group of aquatic annelids, the leeches (Hirudinea), were not collected during recent sampling but are known to occur.

14: Fishes

by C. J. M GLOVER

INTRODUCTION

The 226 species of fish known regularly to inhabit the inshore coastal waters (to depths of approximately 20 metres) and inland waters of Kangaroo Island represent more than half of the families, and half of the species recorded off the entire South Australian coast. Probably very few, if any, species are restricted to the island

This diverse temperate fish fauna, over a fairly small geographic range, is partly attributable to the wide variety of aquatic habitats to be found along the Island's extensive coastline, and the Island's close proximity to, and central location off, the South Australian mainland.

Most of the major marine habitats to be found on the southern Australian coast exist around the Island - protected bays, sand, weedy and rocky shallows, open-ocean surf zones, rocky intertidal pools, headlands and reefs, as well as a number of ephemeral and permanent freshwater and brackish streams, and estuaries. Furthermore, 53% of the known Kangaroo Island fish fauna extends discontinuously around the southern Australian coast from the east to the west coasts of the continent. A further 22% extends from the island to the east coast and 10% to the west coast, whilst another 7% is possibly restricted to the South Australian region. Insufficient is known of the remaining 8% of species to be certain of their full range. In any event, at least 85% of the Island's fishes range beyond the South Australian region.

Clearly, by virtue of its central location and extensive and diverse coastline, Kangaroo Island's relatively prolific fish fauna is typical of southern Australian waters: a zoogeographical area termed the Flindersian Province. This is the most significant feature of the Island's fish fauna.

HISTORICAL

The earliest records of Kangaroo Island fishes are in the journals of the French explorers who visited the Island in 1803 in vessels under the command of Captain Nicolas Baudin. Baudin (1800-1803) noted 'mackerel' and 'parrot fish', whilst Francois Peron (1816) described the fishes in greater detail (Chapter 17).

In 1826 the 'Hobart Town Gazette' noted *(vide* Gill 1909) that fish around Kangaroo Island were 'very superior and well flavoured; among them, a kind of whiting (is) described as being excellent eating' (King George (Spotted) Whiting, *Sillaginodes punctata).*

A. H. Zietz collected fish from around Kangaroo Island during 1887-88, and in 1908 described a new species of cat-shark taken there, the Gulf Catshark *(Asymbolus vincenti).* E. R. Waite collected during 1917-18 and 1923-26, from which material he described, in collaboration with others, several new species: the Blind-fish *(Oermatopsis multiradiatus),* the Dusky Snake Blenny *(Ophiclinus antarcticus),* the Variegated Snake Blenny *(Ophiclinops varius)* and the Smooth Pipefish *(Lissocampus caudalis).*

H. M. Cooper collected during 1942--43 and 1960-61, including two species from Pelican Lagoon -Verco's Pipefish *(Vanacampus vercoi)* and the Barred Three-fin *(Brachynectes fasciatus).*

In 1966 a South Australian Museum expedition made collections of inshore fishes, mainly from intertidal rock pools, and in March 1975 a joint Australian Museum-South Australian Museum expedition collected extensively around the Island, taking a number of species previously not recorded from South Australia as well as some undescribed forms.

DIVERSITY OF THE FISH FAUNA

At the present time, 226 species representing 85 families, are recorded from along the Island's inshore-coastal and inland waters. These represent mainly indigenous fish fauna. Species not represented among the Island's resident fauna include those that normally inhabit deeper offshore waters or are typically oceanic, e.g. Oar Fishes (Family Regalecidae) or Sunfishes (Family Molidae). A few such isolated records upon the Island's shores have not been included in the checklist here.

Although considerable taxonomic work remains to be done before the Island's fishes are fully described, a species checklist is given in Appendix 1. Particularly well-represented groups include the families Syngnathidae (Pipefishes, Pipe horses, Seahorses, Seadragons), Gobiidae (Gobies), Clinidae (Snake Blennies, Weedfishes), Labridae (Parrotfishes), Neoodacidae (Weed Whitings, Rock Whitings, Herring Cale), Gobiesocidae (Clingfishes, Shore Eels) and Monacanthidae

(Leatherjackets): these are predominantly inshore coastal fishes.

Although only two exclusively freshwater fishes inhabit the inland waters of Kangaroo Island, several species that spend only part of their lives in freshwater, and a number of brackish water and estuarine species, have been recorded there.

For identification, the reader is referred to the handbook edited by Gomon, Glover, & Kuiter (1994).

SPECIES-HABITAT RELATIONSHIPS

Habitat preferences of fish are determined largely by a multitude of interacting environmental factors including water salinity, temperature, turbidity, depth and movement, type of substrate, food availability and presence or absence of predators and cover, and in part are hereditary. To varying degrees such factors influence, regulate and limit the geographical distribution (spatially laterally and vertically - and temporally) of fish populations on both a large and small scale. In effect, fish preferentially occupy those habitats which best satisfy their species-specific requirements, abilities and tolerances. For example, schooling marine fish and those adept at swimming (e.g. tuna) tend to be found in open pelagic waters, whilst less mobile swimmers (e.g., boxfishes) are more often found inshore in sheltered, shallower waters. Nevertheless, relatively few species are totally restricted to only one type of habitat. Furthermore, there are frequently daily or seasonal movements on the part of many species between major habitats or geographical regions; such movements often being associated with either feeding and/or breeding. Other species (e.g. parrot fishes) are territorial throughout most of their lives.

Rocks, crevices and pools around reefs, headlands and wave-cut platforms offer protective cover from both water movement and larger predators, and tend to be occupied by small or slower-moving fish such as shore eels. Small bottom-living fish are found amongst and under rocks (e.g., eel blennies) or, if capable of burrowing (e.g., flounders) over soft sand or silt into which they can seek refuge. Some small fish found over rocky substrates in intertidal zones (e.g. gobies and c1ingfishes) possess ventral suckers for anchoring themselves to the rock surfaces, thereby preventing them from being swept away. Fish living amongst seaweeds, sometimes in association with rocky outcrops or sandy patches, are frequently found to be appropriately camouflaged from predators by virtue of colour and/or shape (e.g., pipefishes, seadragons and weedfishes). The various seaweeds or small crustaceans which may live upon them, also provide specific food items for certain fishes (e.g., Luderick and seahorses). The variety and complexity of adaptations to specific habitats and niches is almost limitless.

Many of the island's fish populations, particularly the distinctive inshore varieties, are probably permanent residents of the local waters, although other populations of the same species are, in almost every case, found elsewhere beyond the Island. Some other species (e.g., Western Australian salmon and mullet) are undoubtedly migratory, usually present at all times but appearing in large concentrated schools around the Island only at certain times of the year. A very few records are of lone oceanic strays, and are not considered part of the indigenous fauna. These include the Oar Fish *(Regalecus glesne),* the Point-tailed Sunfish *(Masturus lanceolatus)* and the Suckerfish *(Remora* remora).

Of the permanent local populations, some species (e.g. the Blue-throated Parrot Fish) are cosmopolitan, occupying nearly every type of major habitat, whereas others (e.g., c1ingfishes) tend to favour and consistently occupy one particular habitat type. This provides a useful criterion by which to categorise the major groups of fish to be found around the Island.

FISH AND INLAND WATERS (Fig. 1)

There is relatively little permanent fresh water on Kangaroo Island, though most of the Island's streams flow during the winter months, and retain at least some water over the summer-if only of brackish quality in estuarine regions.

Four species of native fish which need to spend part of their life cycles in fresh water have been recorded from the Island: three species of *Galaxias,* also termed native trouts, and the Short-headed Lamprey *(Mordacia mordax).*

The adult Common Galaxias *(Galaxias maculatus)* normally migrates downstream to spawn in estuaries; upon hatching the larvae drift out to sea before returning to fresh water and growing to adult size at about one year. The Pieman Galaxias (G. *brevipinnis)* evidently has a similar life cycle, except that it is thought to spawn upstream from estuaries.

The Short-headed Lamprey, an eel-like fish, spends part of its adult life at sea. With the

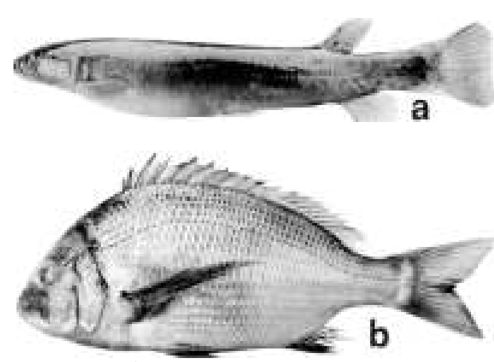


Fig. 1. Fish of Inland waters (With maximum lengths of species):
a. Pieman Galaxias, *Galaxias brevipinnis* - 15 cm;
b. Black Bream, *Acanthopagrus butcheri* - 60 cm.

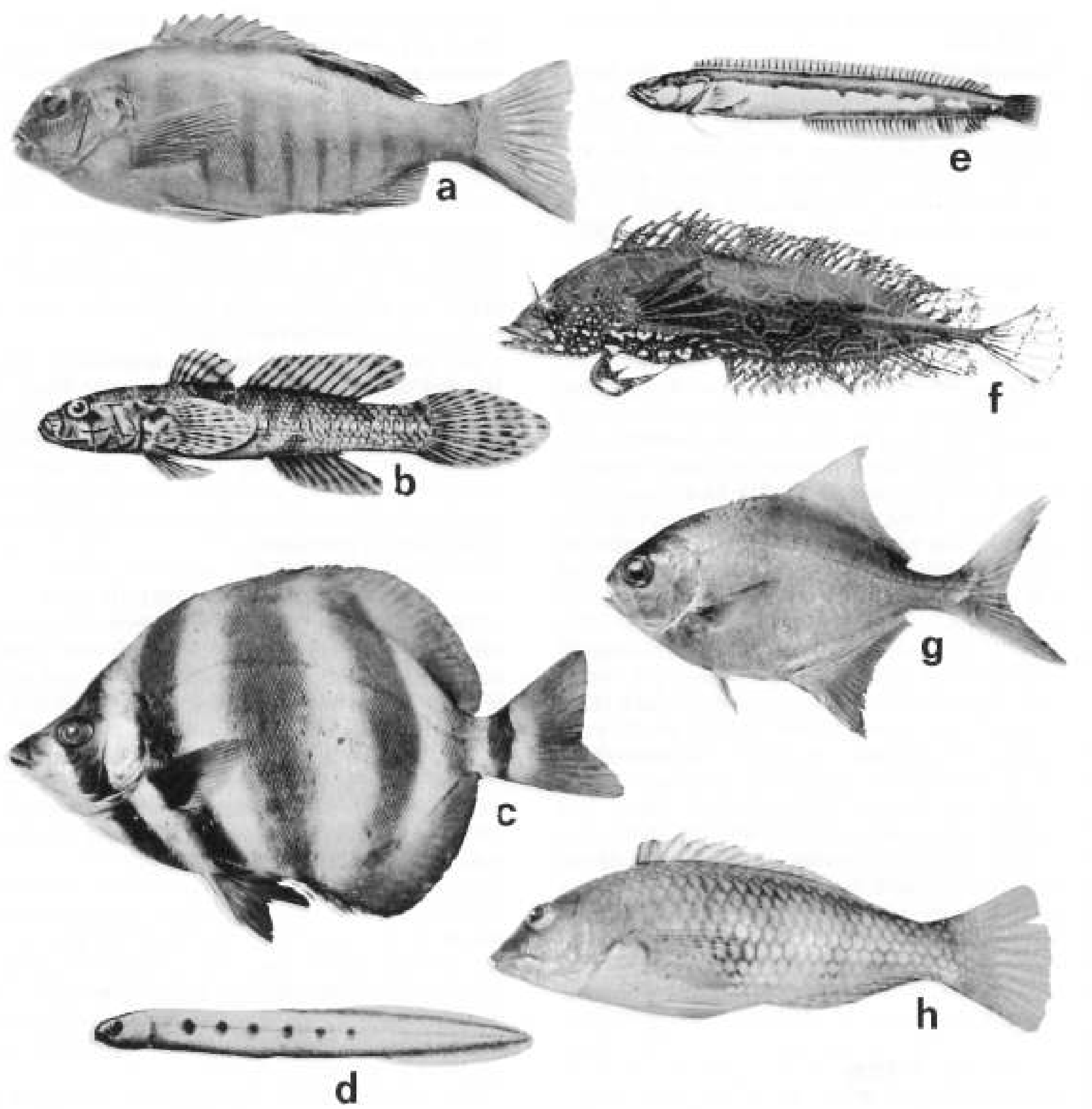


Fig. 2. Fish of the Rocky Intertidal Zone (with maximum lengths of species) a. Zebra fish, *Girella zebra* – 33 cm; b. Sculptured Goby, *Callogobius mucosus* – 9 cm; c. Moonlighter, *Tilodon sexfasciatum* – 25 cm; d. Shore Eel, *Alabes dorsalis* – 10 cm; e. Blackback Snakeblenny, *Ophiclinus gracilis* – 6.4 cm; f. Longnose Weedfish, *Heteroclinus tristis* – approx. 23 cm; g. Banded Sweep *Scorpis georgiana* – 33 cm; h. Blue-throated Wrasse *Notolabrus tetricus* (juvenile) – 46 cm.

approach of spawning, adults ascend rivers where they prepare stone nests. Upon hatching the larvae remain in fresh water until metamorphosing into adults, and later enter the sea. The lamprey's occurrence on Kangaroo Island is based on only a few specimens collected many years ago, and it is possible that these fish enter the Island's streams from the sea only very infrequently.

Rainbow Trout *(Salmo gairdneri)* and possibly Brown Trout *(S. trutta)* are also present in inland waters, having reportedly been first introduced to the Island during the 1950's. Farm dams are regularly stocked with Rainbow Trout from the mainland, some of which have evidently escaped into natural waterways (including Western River and Middle River) and there established breeding populations. Brown Trout have only occasionally been released on the Island and may have established breeding populations: evidently they have not proved as successful on the Island as Rainbow Trout.

Other species, all essentially marine forms, are known to enter and regularly frequent the estuaries and lower reaches of the Island's streams. These include, most notably, the Black Bream *(Acanthopagrus butcheri)* and the Yellow-eye Mullet *(Aldrichetta forsteri);* in addition a number of smaller species-at least four varieties of goby *(Favonigobius tamarensis, Pseudogobius olarum, Tasmanagobius gloved* and *Arenigobius bifrenatus),*

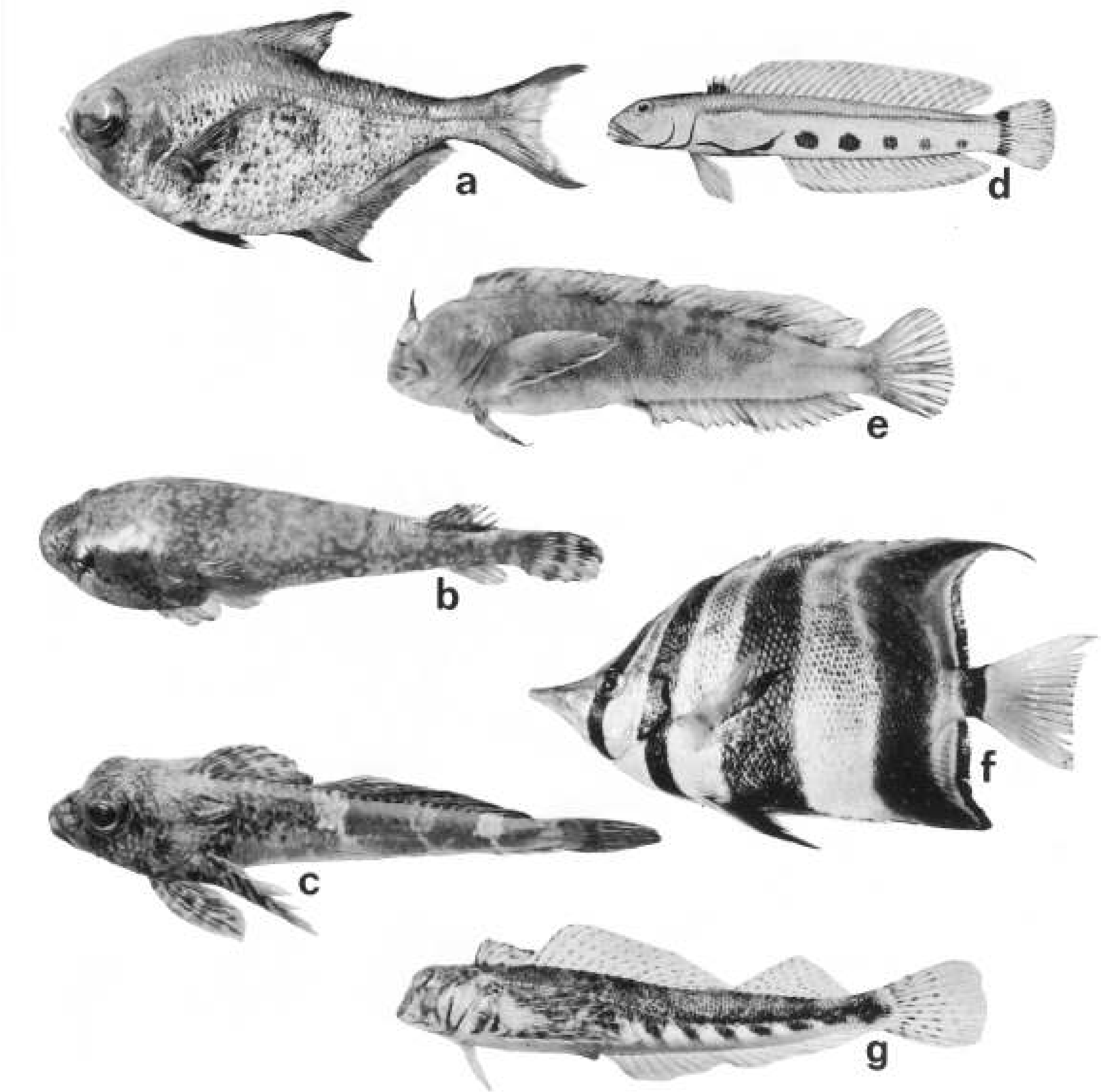


Fig. 3. Fish of the Rocky Intertidal Zone (with maximum lengths of species): a. Common Bullseye *Pempheris multiradiata* – 20 cm; b. Broad Clingfish *Creocele cardinalis* – 6 cm; c. Dragonet *Bovichtus angustifrons* – 28 cm; d. Spotted Grubfish, *Parapercis ramsayi* – 20 cm; e. Tasmanian Blenny *Parablennius tasmanianus* – 13 cm; f. Coral Fish *Chelmanops curiosus* – 20 cm; g. Jumping Blenny *Lepidoblennius marmoratus* – 13 cm.

and several species of hardyhead (Family Atherinidae). The Estuary Catfish *(Cnidoglanis macrocephalus)* and the Jumping Mullet *(Liza argentea)* have been also recorded in estuarine waters.

A number of other marine fish, including Snapper *(Chrysophrys auratus),* Tommy Ruff *(Arripis georgiana)* and the Banded Sea Perch *(Hypoplectrodes nigroruber)* also have been recorded in estuarine water. Evidently such sporadic or casual intrusions into estuaries are not necessary for these otherwise essentially marine forms, but occur on an infrequent basis-possibly in seeking food or simply through 'straying'. Certainly such species are able to tolerate lower salinity waters for at least short periods.

FISH OF ROCKY INSHORE WATERS

Intertidal Zone (Figs 2 & 3)

Fishes typical of shallow intertidal rocky waters and rock pools comprise a variety of forms, frequently smaller species and juveniles of species whose adults may usually be found in mainly deeper waters. Species typically of the rocky intertidal zone include:

Shore eels, *Alabes* spp

Clingfishes, (Family Gobiesocidae) (several genera and species)

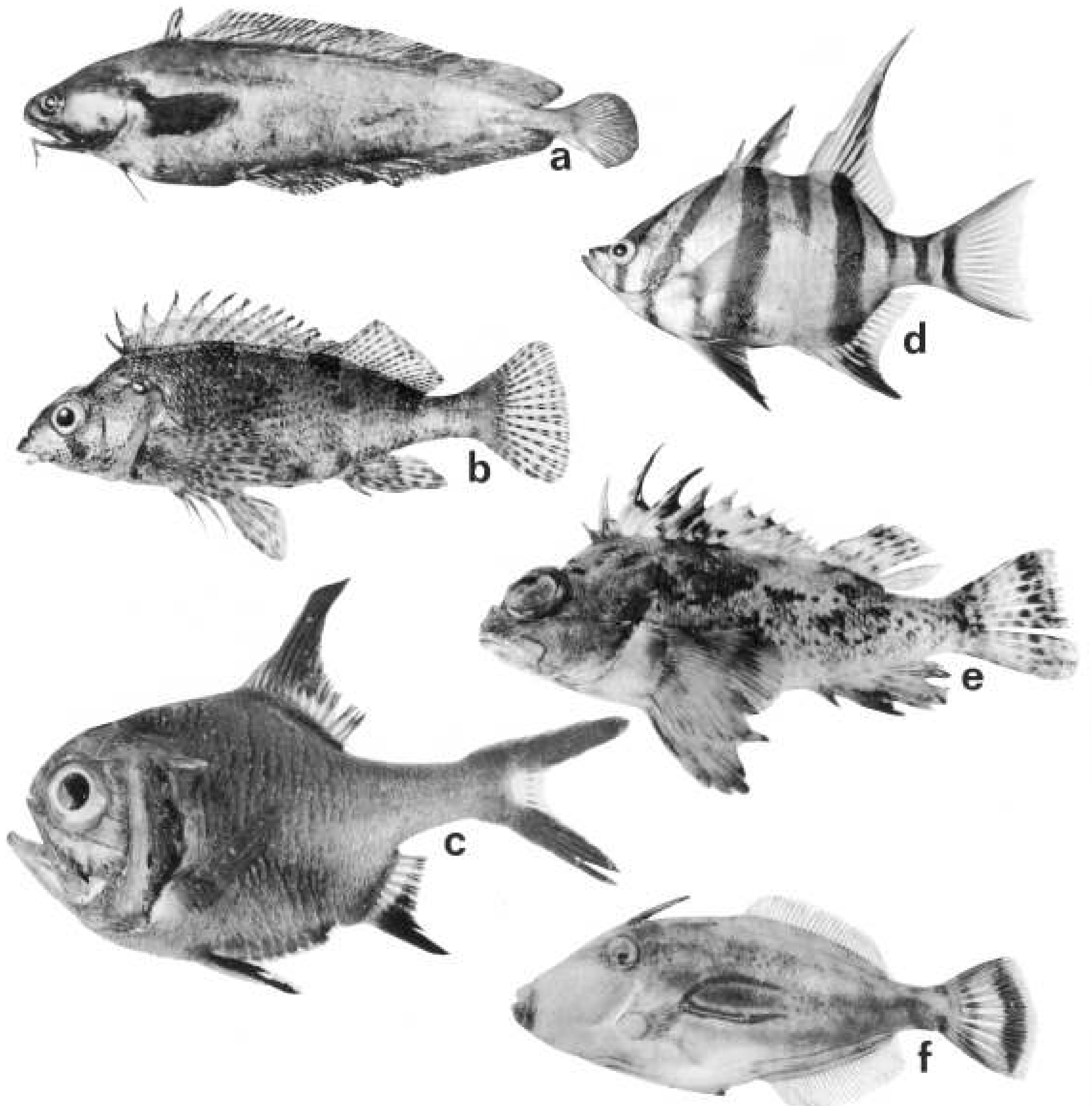


Fig. 4. Fish of the Rocky Subtidal Zone (with maximum length of species): a. Beardie *Eeyorius hutchinsoni* – 51 cm; b. Silver Spot *Threpterius maculosus* – 33 cm; c. Roughy *Trachichthys australis* – 15 cm; d. Old Wife *Enoplosus armatus* – 23 cm; e. Gurnard Perch *Neosebastes pandus* – 33cm; f. Horseshoe Leatherjacket *Meuschenia hippocrepis* – 51 cm.

Longfinned Worm Eel, *Muraenichthys breviceps*
Blindfish, *Dermatopsis multiradiatus*
Zebra Fish, *Girella zebra*
Common Bullseye, *Pempheris multiradiata,*
Moonlighter, *Tilodon sexfasciatum*
Coral Fish, *Chelmonops curiosus*
Banded Sweep, *Scorpis georgiana*
Spotted Grubfish, *Parapercis ramsayi*
Dragonet, *Bovichtus angustifrons*
Sculptured Goby, *Callogobius mucosus*
Tasmanian Blenny, *Parablennius tasmanianus*
Snakeblennies, *Ophiclinus* spp.
Longnose Weedfish, *Heteroclinus tristis*
Southern Crested Weedfish, *Cristiceps australis*
Jumping Blenny, *Lepidoblennius marmoratus*
Blue-throated Wrasse, *Notolabrus tetricus* (mainly juveniles)

*Subtidal Zone (*Figs 4 & 5)

Fishes typical of deeper subtidal rocky waters, in the vicinity of headlands, offshore reefs and other rocky outcrops, are often larger forms and include, as well as some of the above, the following species:

Sergeant Baker, *Aulopos purpurissatus*
Beardie, *Eeyorius hutchinsi*
Bearded Rock Cod, *Pseudophycis barbata*
Roughy. *Trachichthys australis*

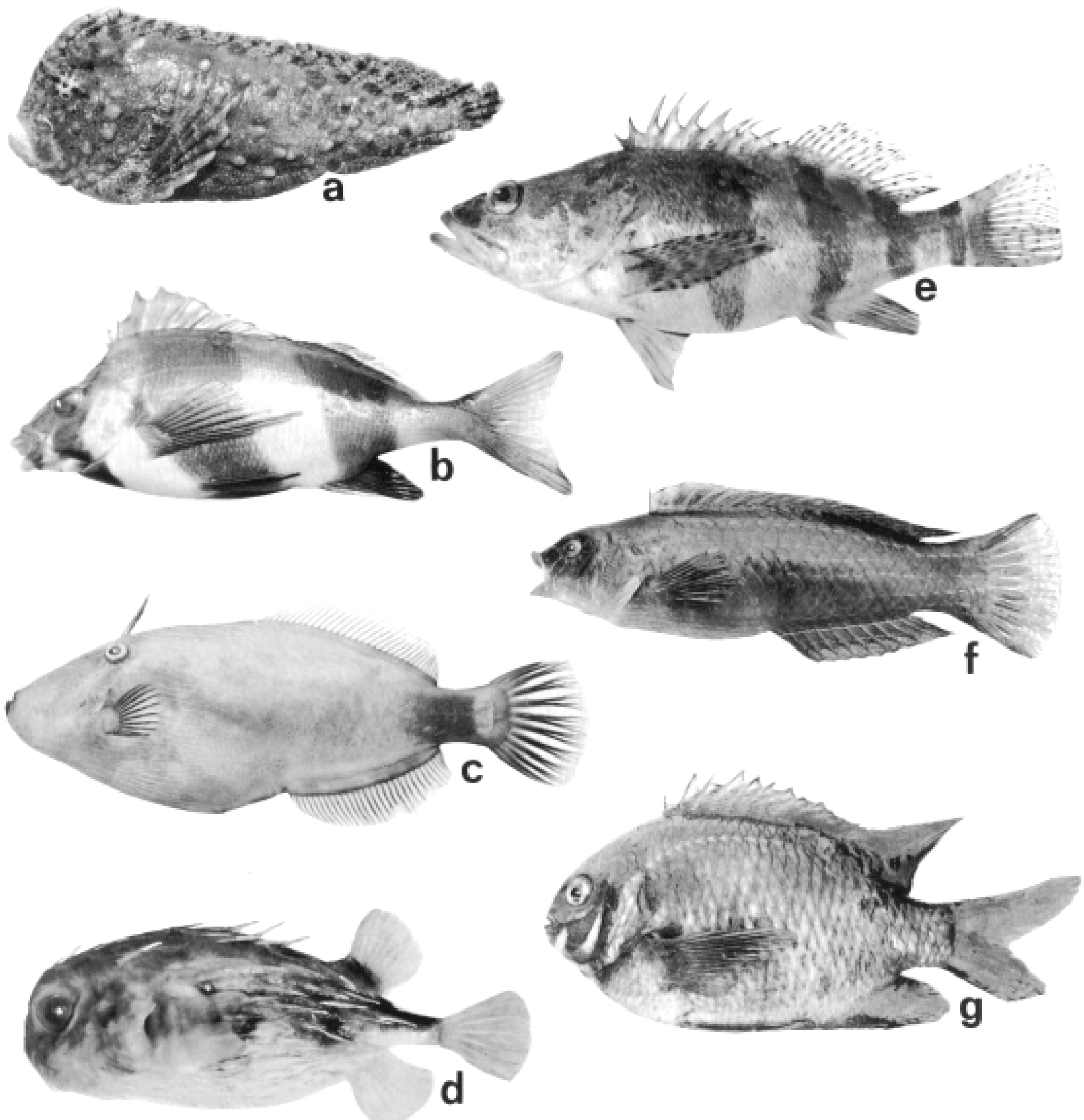


Fig. 5. Fish of the Rocky Sub-Tidal Zone (with maximum lengths of species): a. Warty Prow Fish *Aetapcus maculatus* – 22 cm; b. Magpie Perch *Cheilodactylus nigripes* – 41 cm; c. Spiny-tailed Leatherjacket *Acanthaluteres brownii* – 46 cm; d. Globe Fish *Diodon nichthemerus* – 28 cm; e. Banded Sea Perch *Hypoplectrodes nigroruber* – 25 cm; f. Senator Wrasse *Pictilabrus laticlavius* – 20 cm; g. Scaly Fin *Parma victoriae* – 20 cm.

Gurnard Perch, *Neosebastes pandus*
Rock Flathead, *Thysanophrys cirronasus*
Warty Prow Fish, *Aetapcus maculatus*
Red Mullet, *Upeneichthys vlamingii*
Old Wife, *Enoplosus armatus*
Drummer, *Kyphosus sydneyanus*
Blue Devil, *Paraplesiops meleagris*
Silver Spot, *Threpterius maculosus*
Dusky Morwong, *Dactylophora nigricans*
Magpie Perch, *Cheilodactylus nigripes*
Banded Sea Perch, *Hypoplectrodes nigroruber*
Western Blue Groper, *Achoerodus gouldii*
Senator Wrasse, *Pictilabrus laticlavius*
Scaly Fin, *Parma victoriae*
Globe Fish, *Diodon nichthemerus*
Horseshoe Leatherjacket, *Meuschenia hippocrepis*
Spiny-tailed Leatherjacket, *Acanthaluteres brownii*

FISH FROM ROCK-FREE INSHORE WATERS
Species encountered usually in shallow inshore waters away from major rocky outcrops, over either intervening sandy patches or large beds of sand, seagrass or algae, are often forms that feed upon small invertebrate life living in or on sand or on vegetation. Alternatively they feed upon one or more of the various seagrasses *(Zostera, Posidonia)* or algae. Frequently they are juveniles of species whose adults normally inhabit deeper offshore waters but breed inshore.

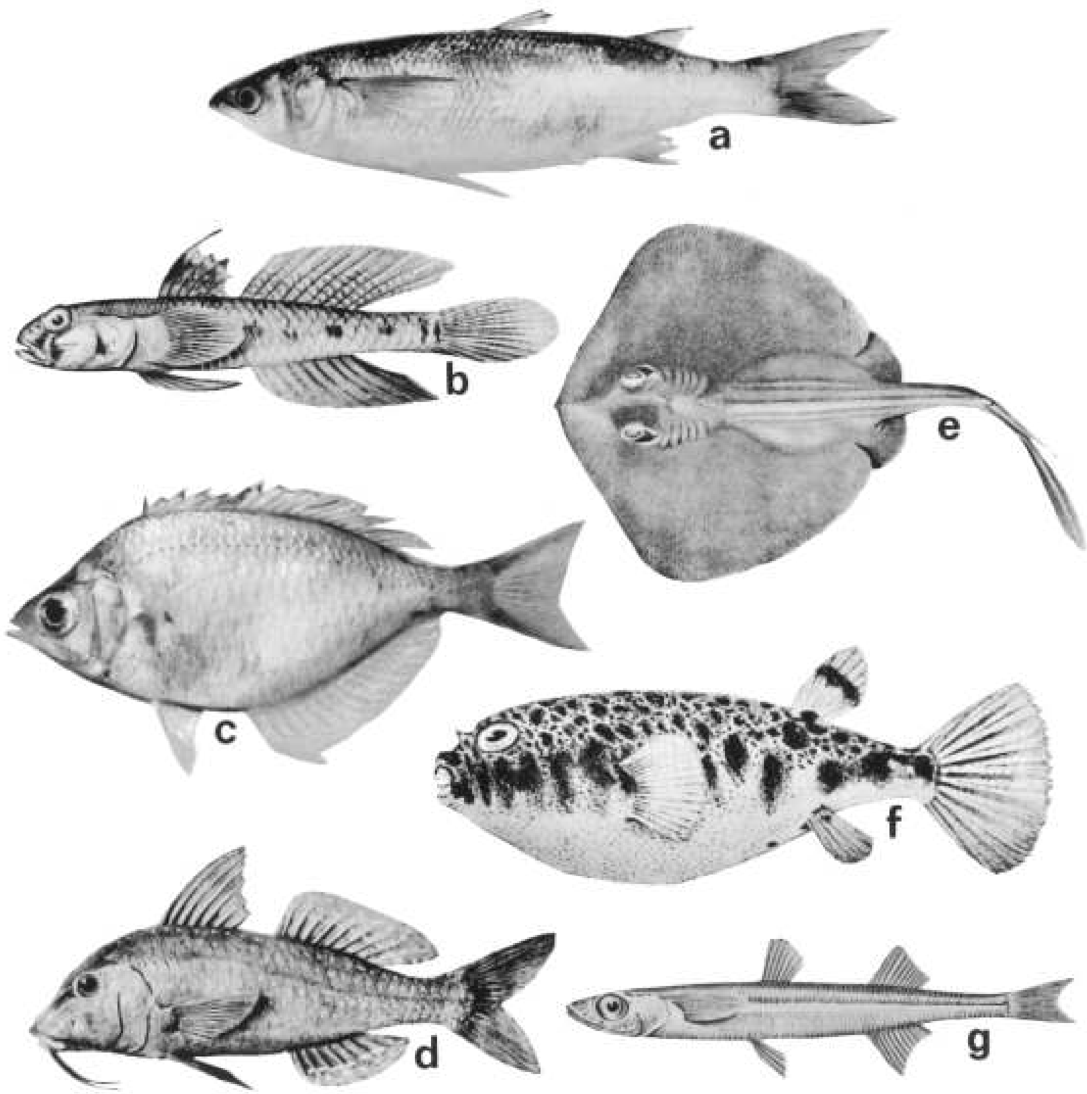


Fig. 6. Fish over Sandbeds (with maximum lengths of species): a. Yellow-eye Mullet *Aldrichetta forsteri* – 40 cm; Longfin Goby *Favonigobius lateralis* – 9 cm; c. Silverbelly *Parequula melbournensis* – 18 cm; d. Red Mullet *Upeneichthys vlamingii* – 33 cm; e. Western Stingaree *Trigonopterus mucosa* – 76 cm; f. Smooth Toadfish *Tetractenos glaber* – 9 cm; g. Richardson's

Over Sand Beds/Patches (Fig. 6)

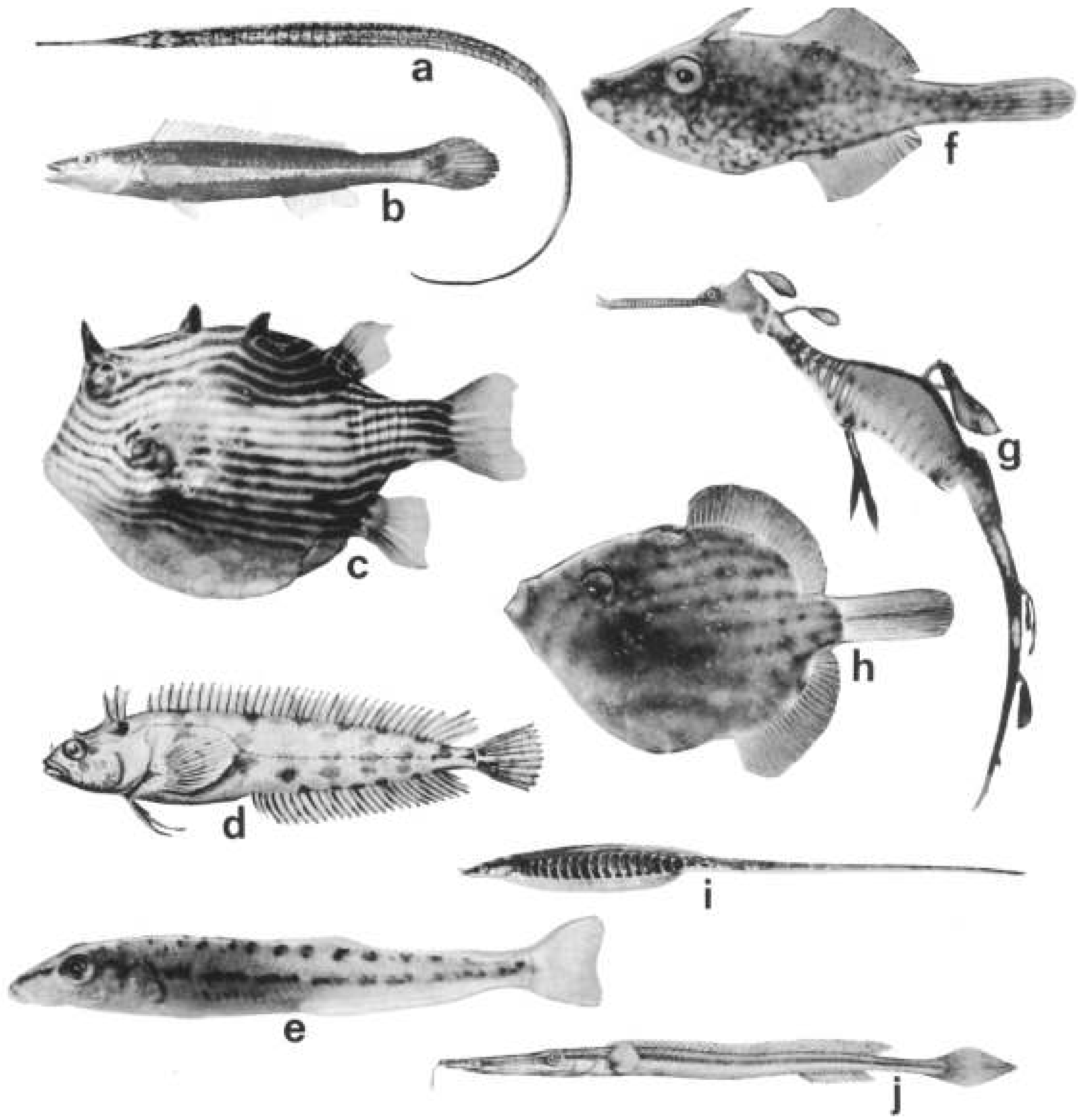
Fishes encountered over relatively bare sandbeds include:

Western Stingaree, *Trigonopterus mucosa*
Southern Fiddler Ray, *Trygonorhina fasciata guanerius*
Yellow-eye Mullet, *Aldrichetta forsteri*
Richardson's Hardyhead, *Atherinason hepsetoides*
Red Mullet, *Upeneichthys vlamingii*
King George (Spotted) Whiting, *Sillaginodes punctata*
Silverbelly, *Parequula melbournensis*
Western Australian Salmon, *Arripis truttacea*
Tommy ruff, *Arripis georgiana*
Flathead Sandfish, *Lesueurina platycephala*
Longfin Goby, *Favonigobius lateralis*
Sailfin Goby, *Nesogobius pulchellus*
Smooth Toadfish, *Tetractinos glaber*

Amongst Vegetation (Fig. 7)

Fishes found amongst vegetation include, as well as some of the above:

South Australian Garfish, *Hyporhamphus melanochir*
Spotted Pipefish, *Stigmatopora argus*
Deepbody Pipefish, *Kaupus costatus*
Verco's Pipefish, *Vanacampus vercoi*
Knifesnouted Pipefish, *Hypselognathus rostratus* Common Seadragon, *Phyllopteryx taeniolatus*
Eelblenny, *Peronedys anguillaris*



ig. 7. Fish of Rock-free Vegetated Waters (with maximum lengths of species) a. Spotted Pipefish *Stigmatopora argus* – 25 cm; b. Long Rock Whiting *Siphonognathus radiatus* – 20 cm; c. Ornate Cowfish *Aracana ornata* – 15 cm; d. Spotshoulder Weed *Heteroclinus perspicillatus* – 9.5 cm; e. King George (Spotted) Whiting *Selaginella punctata* (juvenile) – 69 cm; f. Toothbr Leatherjacket *Acanthaluteres vittiger* (juvenile) – 30.5 cm; g. Common Seadragon *Phyllopteryx taeniolatus* – 46 h. Southern Pigmy Leatherjacket *Brachaluteres jacksonianus* – 9 cm; i. Deepbody Pipefish *Kaupus costatus* – 13 j. Tubemouth *Siphonognathus argyrophanes* – 43 cm.

Spotshoulder Weedfish, *Heteroclinus perspicillatus*
Longray Rock Whiting, *Siphonognathus radiatus*
Blue Rock Whiting, *Haletta semifasciata*
Herring Cale, *Odax cyanomelas*
Tubemouth, *Siphonognathus argyrophanes*
Ornate Cowfish, *Aracana ornata*
Southern Pigmy Leatherjacket, *Brachaluteres jacksonianus*
Toothbrush Leatherjacket, *Acanthaluteres vittiger*

COMMERCIAL FISHES

The island's coastal waters support a small but viable portion of South Australia's fishing industry. During the financial year 1977-78 this constituted approximately 3.8% by weight and 5.2% by cash value of the State's total catch of scale fish.

More than a dozen species of fish are caught commercially around the island. The largest and most valuable quantities have been of King George (Spotted) Whiting *(Sillaginodes punctata),* School Shark *(Galeorhinus gale us)* and Gummy Shark *(Mustelus antarcticus):* whiting are caught mainly by handline throughout the year, whilst outside the rock lobster season sharks are caught by net from rock lobster boats. Smaller catches are taken of

Snapper *(Chrysophrys auratus),* Garfish *(Hyporhamphus melanochir),* Tommy Ruff *(Arripis georgiana),* Snook (Shortfin Pike) *(Sphyraena novaehollandiae),* Yellow-eye Mullet *(Aldrichetta forsteri)* and Western Australian Salmon *(Arripis truttacea).* Snapper and Snook are taken by hand lining and the other species by hauling nets. Southern Bluefin Tuna *(Thunnus thyrinus maccoyii)* are plentiful at certain times of the year offshore from the west coast of the island, but due to lack of tuna processing facilities any catches from these waters are landed either at Port Adelaide or Port Lincoln.

Whiting, Garfish and Tommy Ruff are fished for by net and handline in sheltered waters, whilst Snapper and Shark are taken by handline and net respectively further offshore. The main landing ports for scale fish on Kangaroo Island are Kingscote, American River and Vivonne Bay: minor landings occur at Emu Bay, Penneshaw and Western River. One commercial plant at Kingscote receives and processes the catches of the Island's professional fishermen before despatching them to the mainland market.

Pelican Lagoon, a shallow embayment opening into American River, is known to provide a nursery and feeding area for the juvenile stages of a number of commercially important species (King George (Spotted) Whiting, Yellow-eye Mullet, Salmon Trout (young Australian Salmon), Garfish and Tommy Ruff); because of this, these waters have been accorded the protective status of an aquatic reserve where fishing of any form is prohibited.

SPORT FISHES

A variety of marine species occupying a range of habitats provide Kangaroo Island with excellent seasonal and all-year-round game. King George (Spotted) Whiting, Snapper, Western Australian Salmon, Yellow-eye Mullet, Trevally *(Pseudocaranx . dentex)* and Black Bream all provide good sport for line fishing. Bronze Whaler Shark *(Carcharhinus brachyurus)* and White Pointer Shark *(Squalus carcharius)* are available for big-game fishing, whilst spear fishermen mainly take Dusky Morwong *(Dactylophora nigricans)* and Silver Drummer *(Kyphosus sydneyanus).* Furthermore, introduced Rainbow Trout *(Salmo gairdneri)* provides good game in certain farm dams and natural waterways.

CONCLUSIONS

The fishes of Kangaroo Island constitute a representative community of typically southern Australian species which are readily accessible to the naturalist for observation and study. However, because of the island's developing tourism there is a growing threat to this fauna-due to increasing recreational fishing and spoilage of the aquatic environment arising from other human activities such as power boating. Although no immediate danger is evident, measures to minimise the potential threat to this vulnerable fauna should be considered.

APPENDIX:
CHECKLIST OF THE INSHORE AND INLAND FISHES OF KANGAROO ISLAND

Class PETROMYZONES
Family PETROMYZONTIDAE (Lampreys)
Mordacia mordax (Richardson, 1846)
Class CHONDRICHTHYES
Subclass ELASMOBRANCHII
Family HETERODONTIDAE (Port Jackson Sharks)
Heterodontus portusjacksoni (Meyer, 1793)
Family SCYLIORHINIDAE (Catsharks, Sawtail Shark)
Asymbolus vincenti (Zietz, 1908)
Family LAMNIDAE (White Pointer & Blue Pointer Sharks)
Squalus carcharias (Linnaeus, 1758)
Family TRIAKIDAE (Gummy Shark, Whiskery Shark)
Mustelus antarcticus Günther, 1870
Furgaleus macki (Whitley, 1943)
Galeorhinus gale us (Linnaeus, 1758)
Family CARCHARHINIDAE (School Shark, Whaler Sharks)
Carcharhinus sp.
Family PRISTIOPHORIDAE (Saw Sharks)
Pristiophorus cirratus (Latham, 1794)
Family UROLOPHIDAE (Stingarees)
Trigonoptera mucosa Whitley, 1939.
Family MYLIOBATIDAE (Eagle Rays)
Myliobatis australis Macleay, 1881
Family DASYATIDAE (Stingrays)
Dasyatis brevicaudata (Hutton, 1875)
Family TORPEDINIDAE (Electric Rays or Numbfishes)
Hypnos monopterygium (Shaw & Nodder, 1795)
Family RHINOBATIDAE (Shovel nose Rays)
Trygonorrhina melaleuca Scott, 1954
Trygonorrhina guanerius Whitley, 1932
Subclass HOLOCEPHALI
Family CALLORHYNCHIDAE(Ghost Sharks)
Callorhynchus milii Bory de St Vincent, 1823
Class OSTEICHTHYES
Family CLUPEIDAE (Pilchards, Sprats)
Spratelloides robustus Ogilby, 1897
Family GALAXIIDAE (Galaxias)
Galaxias maculatus (Jenyns, 1842)
Galaxias brevipinnis Gunther, 1866
Family AULOPIDAE (Sergeant Baker)
Aulopus purpurissatus Richardson, 1843

Family PLOTOSIDAE (Eel-Tail Catfishes)
*Cnidoglanis macrocephalus (*Valenciennes in Cuvier & Valenciennes, 1840)
Family CONGRIDAE (Conger and Ladder eels)
Conger verrauxi Kaup*, 1856*
Family OPHICHTHYIDAE (Worm Eels)
Muraenichthys breviceps Gunther*, 1876*
Family HEMIRAMPHIDAE (Garfishes)
*Hyporhampus melanochir (*Valenciennes in Cuvier & Valenciennes, 1846)
Family MORIDAE (Codfishes)
*Latella rhacina (*Bloch & Schneider, 1801*)*
Family PLEURONECTIDAE (Right-hand Flounders)
Rhombosolea tapirina Gunther*,* 1862
Ammotretis rostratus Gunther*,* 1862
Family ZEIDAE (Dories)
*Zenopsis nebulosus (*Temminck & Schlegel*,* 1845)
*Cyttus australis (*Richardson, 1843*)*
Family BERYCIDAE (Swallowtail, Nannygai)
*Centroberyx lineatus (*Cuvier in Cuvier & Valenciennes, 1829*)*
*Centroberyx gerrardi (*Gunther, 1887*)*
Family TRACHICHTHYIDAE (Roughy's)
Trachichthys australis Shaw & Nodder, 1799
Family SYNGNATHIDAE (Pipefishes, Pipehorses, Seahorses. Seadragons)
*Stigmatopora argus (*Richardson, 1840*)*
Stigmatopora nigra Kaup, 1856
*Hypselognathus rostratus (*Waite & Hale, 1921
Lissocampus caudalis Waite & Hale, 1921
*Lissocampus runa (*Whitley, 1931*)*
Maroubra perserrata Whitley, 1948
*Notiocampus ruber (*Ramsay & Ogilby, 1886*)*
Heraldia nocturna Paxton, 1975
*Kaupus costatus (*Waite & Hale, 1921*)*
*Histiocampus cristatus (*Macleay, 1882*)*
Leptoichythys fistularius Kaup, 1853
*Pugnaso curtirostris (*Castelnau, 1873*)*
*Vanacampus vercoi (*Waite & Hale, 1921*)*
*Vanacampus poecilolaemus (*Peters, 1869*)*
*Vanacampus phillipi (*Lucas, 1891*)*
Leptonotus costatus Waite & Hale. 1921
*Phyllopteryx taeniolatus (*Lacepede, 1804*)*
*Phycodurus eques (*Gunther, 1865*)*
Family SPHYRAENIDAE (Snook, Pike)
*Sphyraena novaehollandiae (*Gunther, 1860*)*
Family MUGILIDAE (Mullets)
Mugil cephalus Linnaeus, 1758
*Liza argentea (*Quay & Gaimard, 1825*)*
*Aldrichetta forsteri (*Valenciennes in Cuvier & Valenciennes, 1836)
Family ATHERINIDAE (Hardyheads, Silversides)
*Leptatherina presbyteroides (*Richardson, 1843*)*
*Atherinasoma elongata (*Klunzinger, 1879*)*
*Atherinason hepsetoides (*Richardson, 1843*)*
*Kestratherina esox (*Klunzinger, 1872*)*
Family GEMPYLIDAE (Barracoutas)
Thyrsites atun (Euphrasen, 1791)
Family CENTROLOPHIDAE (Trevallas, Sea Bream)
*Seriolella brama (*Gunther, 1860*)*
Family PLATYCEPHALIDAE (Flatheads)
Platycephalus fuscus Cuvier & Valenciennes, 1829
Platycephalus bassensis Cuvier in Cuvier & Valenciennes, *1829*
*Thysanophrys cirronasus (*Richardson, 1848*)*
Family TRIGLIDAE (Gurnards)
*Pterygotrigla polyommata (*Richardson, 1839*)*
Family SCORPAENIDAE (Rock Cads, Gurnard Perches)
Cenitropogon latifrons Mees, 1962
*Gymnapistes marmoratus (*Cuvier in Cuvier & Valenciennes, 1829*)*
*Neosebastes pandus (*Richardson, 1842*)*
*Neosebastes bougainvilli (*Cuvier in Cuvier & Valenciennes, 1929*)*
Maxillocosta scabriceps Whitley, 1935
Family PATAECIDAE (Prow Fishes)
Pataecus fronto Richardson, 1844
*Aetapcus maculatus (*Gunther, 1861*)*
*Neopataecus waterhousii (*Castelnau, 1872*)*
Family APLOACTINIDAE (Velvet Fishes)
*Aploactisoma milesii (*Richardson, 1850*)*
Family GNATHANACANTHIDAE (Red Velvet Fish)
Gnathanacanthus goetzeei Bleeker, 1855
Family CONGIOPODIDAE (Pig fishes)
*Perryena leucometopon (*Waite, 1922*)*
Family SYNANCEJIDAE (Goblin Fish, Stone Fish)
*Glyptauchen panduratus (*Richardson, 1850*)*
Family CALLIONYMIDAE (Stinkfishes)
*Foetorepus calauropomus (*Richardson, 1844*)*
Eocallionymus papilio Gunther, 1864
*Repomucens calcaratus (*Macleay, 1881*)*
Family OPHIDIIDAE (Lings, Blindfish)
*Genypterus blacodes (*Bloch & Schneider, 1801*)*
Family BYTHITIDAE (Brotulas)
Dermatopsis multiradiatus McCulloch & White, 1918
Ogilbia sp.
Family CARANGIDAE (Trevally, Yellowtail, Scad, Horse Mackerel, Pilot Fish)
*Pseudocaranx dentex (*Bloch & Schneider, 1801*)*
Seriola lalandi Valenciennes in Cuvier & Valenciennes, 1833
Seriola hippos Gunther, 1876
Trachurus novaezelandiae Richardson, 1843
Family POMATOMIDAE (Tailor)
Pomatamus saltatrix (Linnaeus, 1766)
Family MULLIDAE (Red Mullet)
*Upeneichthys vlamingii (*Cuvier in Cuvier & Valenciennes, 1829*)*
Family DINOLESTIDAE (Long-Finned Pike) *Dinolestes lewini (*Griffith, 1834*)*
Family ENOPLOSIDAE (Old Wife)
*Enoplosus armatus (*White, 1790*)*
Family SILLAGINIDAE (Whitings)
*Silaginodes punctata (*Cuvier in Cuvier & Valenciennes, 1829*)*

Family APOGONIDAE (Cardinal Fishes, Gobbleguts)
Vincentiana punctata (Klunzinger, 1829)
Siphemia cephalotes (Castelnau, 1875)
Vincentia badia Allen, 1987
Family PERCICHTHYIDAE
Apogonops anomalus Ogilby, 1896
Family SCIAENIDAE (Mulloway)
Argyrosomus hololepidotus (LacepMe. 1802)
Family KYPHOSIDAE (Drummer)
Kyphosus sydneyanus (Gunther, 1886)
Family GIRELLIDAE (Zebra Fish)
Girella zebra (Richardson, 1846)
Family PEMPHERIDAE (Bullseyes)
Pempheris multiradiata (Klunzinger, 1879)
Pempheris klunzingeri McCulloch, 1911
Parapriacanthus elongatus (McCulloch, 1911)
Pempheris sp.
Family SPARIDAE (Snapper, Black Bream)
Chrysophrys auratus (Bloch & Schneider, 1801)
Acanthopagrus butcheri (Munro, 1949)
Family CHAETODONTIDAE (Coral Fish)
Chelmonops curiosus Kuiter, 1986
Family GERREIDAE (Silverbellies)
Parequula melbournensis (Castelnau, 1872)
Family PLESIOPIDAE (Blue Devils, Trachinops)
Paraplesiops meleagris (Peters, 1870)
Paraplesiops sp.
Trachinops noarlungae Glover, 1974
Family ACANTHOCLINIDAE (Longfins)
Beliops xanthocrossos Hardy, 1984.
Family APLODACTYLIDAE (Sea Carp)
Aplodactylus arctidens Richardson, 1839
Family LATRIDIDAE (Trumpeters)
Latris lineata (Bloch & Schneider, 1801)
Family CHIRONEMIDAE (Kelpfishes, Siiverspot)
Chironemus georgianus (Cuvier *in* Cuvier & Valenciennes, 1829)
Threpterius maculosus Richardson, 1850
Family CHEILODACTYLIDAE (Morwongs, Strongfish, Magpie Perch)
Dactylophora nigricans (Richardson, 1850)
Cheilodactylus nigripes Richardson, 1850
Nemadactylus sp.
Family ARRIPIDAE (Australian Salmon, Tommy Ruff)
Arripus truttacea (Cuvier *in* Cuvier & Valenciennes, 1829)
Arripis georgiana (Valenciennes *in* Cuvier & Valenciennes, 1831)
Family PENTACEROTIDAE (Boarfishes)
Pentaceropsis recurvirostris (Richardson, 1845)
Family SCORPIDIDAE (Sweeps, Moonlighter)
Scorpis georgiana Cuvier & Valenciennes, 1832
Tilodon sexfasciatum (Richardson, 1842)
Family SERRANIDAE (Sea Perches)
Hyploplectrodes nigroruber (Cuvier *in* Cuvier & Valenciennes, 1828)
Caesioperca rasor (Richardson, 1839)
Family PINGUIPEDIDAE (Grubfishes)
Parapercis ramsayi Steindachner, 1884
Parapercis haackei (Steindachner, 1884)
Family LEPTOSCOPIDAE (Sandfish)
Lesueurina platycephala Fowler, 1907
Family URANOSCOPIDAE (Stargazers)
Kathetostorna laeve (Bloch & Schneider, 1801)
Family BOVICHTHYIDAE (Dragonet, Congolli)
Bovichtus angustifrons Regan, 1913
Family GOBIIDAE (Gobies)
Callagobius mucosus (Gunther, 1871)
Favonigobius lateralis (Macleay, 1881)
Favonigobius tamarensis (Johnston, 1883)
Arenigobius bifrenatus (Kner, 1865)
Pseudogobius alarum (Sauvage, 1880)
Nesogobius pulchellus (Castelnau, 1872)
Nesogobius n. spp. (4)
Tasmanagobius sp.
Tasmanagobius gloveri Hoese, 1991
Family BLENNIIDAE (Blennies)
Parablennius tasmanianus (Richardson, 1839)
Family CLiNIDAE (Snake Blennies, Weedfish)
Sticharium dorsale Gunther, 1867
Peronedys anguillaris Steindachner, 1884
Ophiclinus antarcticus Castelnau, 1872
Ophiclinus brevipinnis George & Springer, 1980
Ophiclinus gracilis Waite, 1906
Ophiclinus grabrieli Waite, 1906
Ophiclinops pardalis (McCulloch & Waite, 1918)
Ophjclinops varius (McCulloch & Waite, 1918)
Cristiceps australis Valenciennes *in* Cuvier & Valenciennes, 1836
Heteroclinus perspicillatus (Cuvier & Valenciennes, 1836)
Heteroclinus roseus (Gunther, 1861)
Heteroclinus nasutus (Gu nther, 1861)
Heteroclinus adelaide Castelnau, 1872
Heteroclinus eckloniae (McKay, 1970)
Heteroclinus heptaeolus (Ogilby, 1885)
Heteroclinus johnstoni (Saville-Kent, 1886)
Heteroclinus tritus (Klunzinger, 1872)
Heteroclinus wilsoni (Lucas, 1890)
Heteroclinus macrophthalmus Hoese, 1976
Heteroclinus spp. (4)
Family TRIPTERYGIIDAE (Blennies, Threefins)
Lepidoblennius marmoratus (Macleay, 1878)
Helcogramma decurrens McCulloch & Waite, 1918
Trianectus bucephalus McCulloch & Waite, 1918
Brachynectes fasciatus Scott, 1957
Norfolkia clarkei (Morton, 1888)
Norfolkia cristata Kuiter, 1986.
Family ANTENARIIDAE (Angler Fishes)
Histiophryne bougainvilli (Valenciennes *in* Cuvier & Valenciennes, 1837)
Phyllophryne scortea (McCulloch & Waite, 1918)
Echinophryne crassispina McCulloch & Waite, 1918
Rhycherus filamentosus (Castelnau, 1872)
Family LABRIDAE (Parrot Fishes)
Ophthalmolepis lineolata (Valenciennes *in* Cuvier & Valenciennes, 1838)
Pictilabrus laticlavius (Richardson, 1839)

Notolabrus fucicola (Richardson, 1840)
Notolabrus tetricus (Richardson, 1840)
Notolabrus parilus (Richardson, 1850)
Pseudolabrus psittaculus (Richardson, 1840)
Dotalabrus aurantiacus (Castelnau, 1872)
Achoerdus gouldii (Richardson, 1843)
Eupetrichthys angustipes Ramsay & Olgilby, 1888

Family ODACIDAE (Weedy Whitings, Rock Whitings, Herring Cale)
Siphonognathus radiatus (Quay & Gaimard, 1835)
Siphonognathus argyrophanes Richardson, 1858
Siphonognathus beddomei (Johnston, 1885)
Siphonognathus attenuatus (OgilbY,.1897)
Siphonognathus caninus Scott, 1976
Neoodax balteatus (Valenciennes *in* Cuvier & Valenciennes, 1839)
Haletta semifasciata Valenciennes *in* Cuvier & Valenciennes,1840
Odax acroptilus (Richardson, 1846)
Odax cyanomelas (Richardson, 1850)

Family POMACENTRIDAE (Scaly Fin, Demoiselles)
Parma victoriae (Gunther, 1863)

Family GOBIESOCIDAE (Clingfishes, Shore Eels)
Alabes dorsalis (Richardson, 1845)
Alabes hoesi Springer & Fraser, 1976
Alabes parvulus (McCulloch, 1909)
Aspasmogaster tasmaniensis (Gunther, 1861)
Cochleoceps spatula (Gunther, 1861)
Creocele cardinalis (Ramsay, 1882)
Parvicrepis parvipinnis (Waite, 1906)
Parvicrepis sp.
Gobiosocidae spp. (4)

Family SALMONIDAE (Trout)
(?) *Salmo trutta* Linnaeus, 1758
Salmo gairdneri Richardson, 1836

Family TETRAODONTIDAE (Toadfishes. Puffers)
Tetractenos glaber (Freminville, 1813)
Torquigener pleurogramma (Regan, 1903)
Contusus richei (Freminville, 1873).
Polyspina piosae (Whitley, 1955)

Family DIODONTIDAE (Porcupine Fishes, Globe Fishes)
Diodon nichthemerus Cuvier *in* Cuvier & Valenciennes, 1818

Family OSTRACIONTIDAE (Boxfishes, Cowfishes)
Aracana aurita (Shaw, 1798)
Aracana ornata (Gray, 1838)
Capropygia unistriata (Kaup, 1855)

Family MONACANITHIDAE (Leatherjackets)
Acanthaluteres spilomelanurus (Quoy & Gaimard, 1824)
Acanthaluteres brownii (Richardson, 1846)
Acanthaluteres vittiger (Castelnau, 1873)
Brachaluteres jacksonianus (Quoy & Gaimard, 1824)
Eubalichthys cyanoura (Gunther, 1870)
Eubalichthys mosaicus (Ramsay & Ogilby, 1886)
Meuschenia scaber (Forster, 1801)
Meuschenia hippocrepis (Quoy & Gaimard, 1824)
Meuschenia galii (Waite, 1905)
Meuschenia flavolineata Hutchins, 1977
Scobinichthys granulatus (Shaw, 1790)

15: Intertidal Invertebrates

by I. M. THOMAS and S. J. EDMONDS

INTRODUCTION

Intertidal animals live along the sea shores between the levels of the highest and lowest tides and are mostly invertebrates or animals without backbones. As far as is known there are no intertidal species of animals endemic to Kangaroo Island. However, the island provides a wide range of coastal environments in a comparatively small area, the only coastal habitat found on the mainland but not on the island being mangrove forest.

Only the commonest species of intertidal animals are noted in this chapter and several important groups which are not obvious to the casual observer, such as the hydroids, sponges, bryozoans and ascidians are omitted. The literature on the fauna is sparse and scattered and only a few of the more important references are given here.

The fauna of the intertidal region is determined largely by three factors, the nature of the substrate (whether it is rocky, muddy or sandy), the rise and fall of the tides and the action of the waves or the degree of wave energy of the sea. In the case of the last, three categories are usually recognised, namely high, moderate and low energy coasts. Because open coast and the Southern Ocean lie to the south and west of the island and the strongest and prevailing winds come from those directions, the southern and western coasts are generally high energy coastlines. It is true, however, that a conspicuous headland or a deep bay might produce a small region of moderate or even low energy coastline with its typical fauna within a large expanse of high energy coastline with typical high energy fauna. The northern and eastern coasts of the island, on the other hand, are generally moderate or low energy coastlines. The strong northerly winds which sometimes blow across the island and produce waves of fairly high energy on the north coast are of relatively short duration and insufficient to influence the general nature of the fauna.

The distribution of animals within the intertidal zone is determined largely by the rise and fall of the tides. Their disposition between high and low water marks also depends on their ability to withstand exposure to air and changes in temperature, their resistance to desiccation and to changes in salinity produced by fresh water and rain. Their range across the shoreline (as distinct from along the shore) can be extended considerably by the wash of waves on a high energy coast.

The intertidal zone is usually divided into three regions (described in Chapter 16), ranging from the uppermost supra-littoral fringe, which is wetted by the sea only by spray in normal weather, although it may receive the full force of waves in rough weather, down to the lowest level which is exposed only at the lowest tides. Each region has a more or less characteristic flora and fauna.

ANEMONES

Anemones belong to the Phylum Cnidaria. Their structure is relatively simple, consisting of a cylindrical column which has a pedal disc at the fixed end and an oral disc at the other. When an anemone is fully extended the oral disc is surrounded by tentacles while at its centre is an oval or slit-like mouth. If a living animal or food particle brushes against the tentacles, they will shoot out hollow, barbed, stinging threads which carry a toxin. If the object is a living animal, it will be partially immobilised and the tentacles will then direct it to the mouth.

Of the dozen or more species known to occur in South Australia (all of which probably occur on the island), only the commonest will be dealt with here. *Actinia tenebrosa* can be recognised when the tide is out as a dark red, hemispherical blob of jelly about 10 to 20 mm across. When covered with water it can be seen that the column is dark red and the tentacles and oral disc somewhat paler. At the junction of the column and the ring of tentacles there is a row of spots, usually iridescent blue, but sometimes white or pink. The species is found usually at about mid-tide level and sometimes higher up in permanent rock pools or where there is deep shade. It is found in large numbers on the terraced reef at the west of Pennington Bay, in crevices under Admiral's Arch at Cape du Couedic and in fissures between rocks at Stokes Bay. *Oulactis muscosa* is a larger anemone and grows to 60 to 70 mm across. The column is white or pale buff speckled with light brown. These marks are adhesive organs and often have sand or shell fragments fixed to them. The tentacles are fine and white, the disc brown or greenish and the mouth rimmed with red or orange. The species occurs on

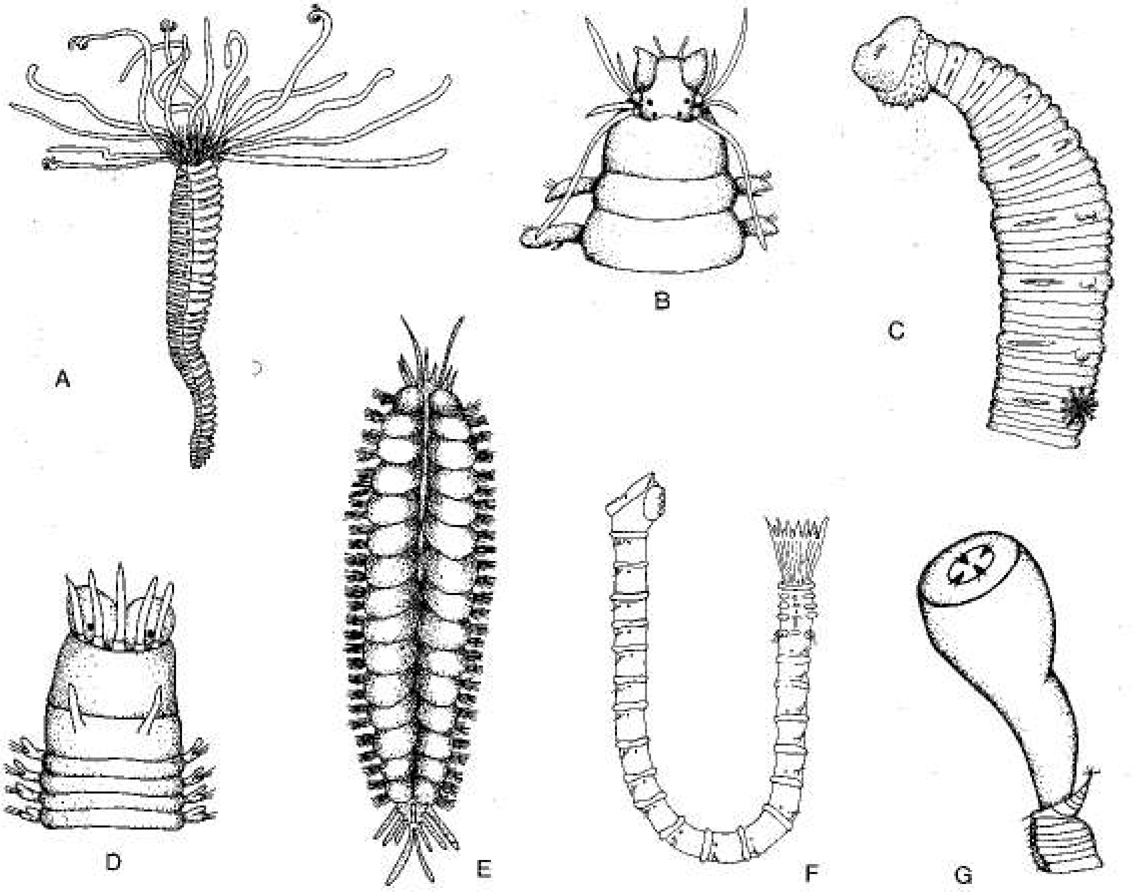


Fig. 1. Polychaetes: A, *Thelepus* (terebellid); B, *Nereis* (Nereid), anterior; C, *Arenicola*, anterior; D, *Eunice* (eunicid), anterior; E, *Lepidonotus* (polynoid); F, *Clymenella* (maldanid); G, *Glycera* (glycerid), proboscis everted. (Drawings by Lesley Howard).

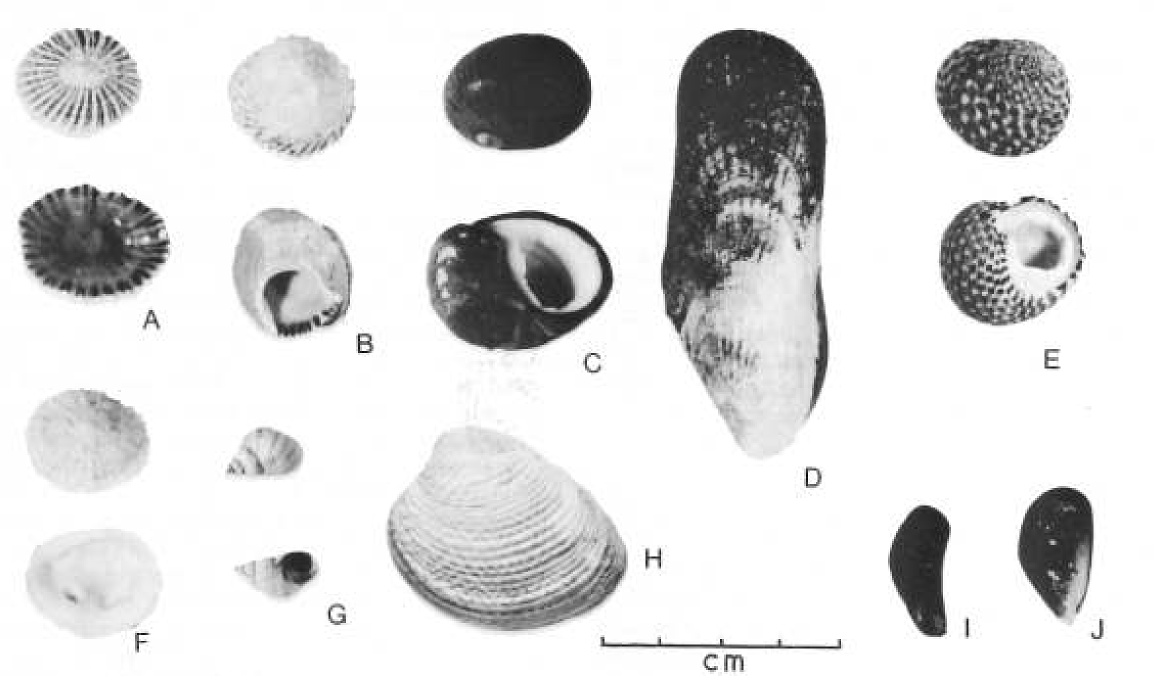


Fig. 2. Gastropods: A, *Siphonaria diemenensis* (two views); B, *Bembicium nanum* (two views); C, *Nerita atramentosa* (two views); E, *Monodonta constricta* (two views); F, *Siphonaria zelandica* (two views); G, *Littorina unifasciata* (two views); Bivalves: D, *Brachidontes erosus*; H, *Katelysia scalarina*; I, *Xenostrobus pulex*; J, *Brachidontes rostratus*.

the landward margins of reef platforms at Pennington Bay in rock pools, and is sometimes buried in the sand so that only the oral disc and tentacles are visible. *Isanemonia australis* is another large anemone which has a brown to green-brown column, a dark brown disc and greenish-yellow to grey, rather long tentacles. It is found in protected places such as under stones and boulders. It seems to be omnivorous and often contains plant material in its body. It has been found at Emu Bay and American River. *Anthathae albocincta* is smaller and rarely more than 15 mm across. It is found on the walls of rock pools or under rocks. Its column is white and has longitudinal, green or orange stripes; its tentacles are white. *Cnidapus verater* is always green and usually dark green. Its long tentacles may be a little paler than the column. It is found in crevices in rock pools on moderate to high energy coasts; it has been collected on the landward margin of the reef at the east of Port Ellen Light at Vivonne Bay.

The true corals belong to the same subclass of the animal kingdom as the sea-anemones. Although no reef building corals are present in South Australia, species allied to them are found. One is the star coral, *Plesiastrea versipara* (Fig. 3G), which forms encrusting masses on the undersurfaces of rocks and occurs in some of the rock pools on the western side of Port Ellen, Vivonne Bay.

BRISTLE WORMS

Polychaetes or bristle worms are a group of segmented worms possessing usually one pair of lateral trunk appendages or para podia per segment and a number of head appendages such as antennae, tentacles and cirri. Bundles of setae or bristles form an important part of the parapodia. Polychaetes are a class of the Phylum Annelida and are mostly marine. They are soft-bodied creatures not readily noticed because most live in protected places such as under rocks, in sand, in mud, in calcareous, horny or membranous tubes or in beds of mussels.

The most commonly observed polychaete on the island is probably the serpulid *Galealaria caespitasa* (Fig. 7A) which lives in a hard calcareous tube attached to rocks or jetty piles at about mid-tide level on high, moderate and low energy coasts. On jetty piles large numbers of the tubes usually form an encrusting mass but on rough coasts the tubes are more scattered. With the aid of a set of feather-like tentacular appendages it filters and traps microscopic organisms from the sea.

A number of other polychaetes usually can be collected by breaking up an encrusted mass of *Galealaria* from a jetty pile (Emu Bay, Kingscote, American River or Muston) or a mass of mussels like those of *Brachidantes rostratus* (Fig. 2J) and *Xenastrobus pulex* (Fig. 21) on high energy coasts, or of *Brachidontes erosus* (Fig. 2D) on low energy coasts (American River), where the worms are able to gain protection and food. The commonest of these are the nereids, *Neanthes* spp., *Perinereis* sp. and *Nereis* sp. (Fig. 1 B), the longer and quick moving eunicid, *Eunice* sp. (Fig. 1 D) and the rather flat polynoid or scale worm, *Lepidanatus* sp. (Fig. 1 E). Nereids and eunicids possess jaws and are usually carnivorous and predacious.

Terebellids or tentacle worms are found under· stones or in dead shells that have settled on muddy or sandy surfaces like those at Bay of Shoals, Emu Bay and American River. They construct membranous tubes which are coated with shell fragments and particles of sand or mud. They possess a number of long, extensible tentacles which they spread over the surface of the substrate and use to scrape up and entrap food particles. The commoner ones at Kangaroo Island are *Thelepus* spp. (Fig. 1A) and *Eupalymnia* sp. Sometimes they are pink or red.

The long maldanid or bamboo worm, *Clymenella* (Fig. 1 F), is often found under stones and among shell debris at Bay of Shoals and American River. It also lives in a soft tube to which particles of shell may adhere and feeds on fine organic material that settles on sand or mud. Specimens as long as 250 mm have been collected at Bay of Shoals.

Glycerid or blood worms have long slender bodies and are sharply conical anteriorly. They are active burrowers, reddish in colour and live in sand and mud. They possess a long, cylindrical, readily eversible pharynx at the end of which are four black teeth. They appear to be carnivorous although some species are said to be detritus feeders. *Glycera americana* (Fig. 1 G) is often collected in the sand and mud flats at American River and Muston.

At low tide on the sandy stretch of beach lying between Sapphire Point and Rocky Point at Eastern Cove, sand casts of the large, burrowing polychaete, *Arenicala* sp. or the lug-worm (Fig. 1C) are very common. *Arenicola* forms a U - or L shaped burrow and feeds by ingesting a column of sand through which sea water has been filtered.

SEA SHELLS OR MOLLUSCS

The Phylum Mollusca comprises a very large and varied group of animals. Of the six classes into which the phylum is divided three are common in the intertidal region: the chitons (Amphineura or Crepipoda), the snails and their allies (Gastropoda), and the cockles and mussels (Bivalvia). Members of a fourth class (Cephalopoda), which includes squids and octopuses, are occasionally collected.

Chitons possess a shell of eight parts which are hinged to one another. As a result, a chiton can bend its body and so protect its vulnerable underside when it creeps over uneven surfaces, something which a single-shelled limpet is unable to do. Living chitons are found attached to rocks; they have no mechanism for creeping on sand.

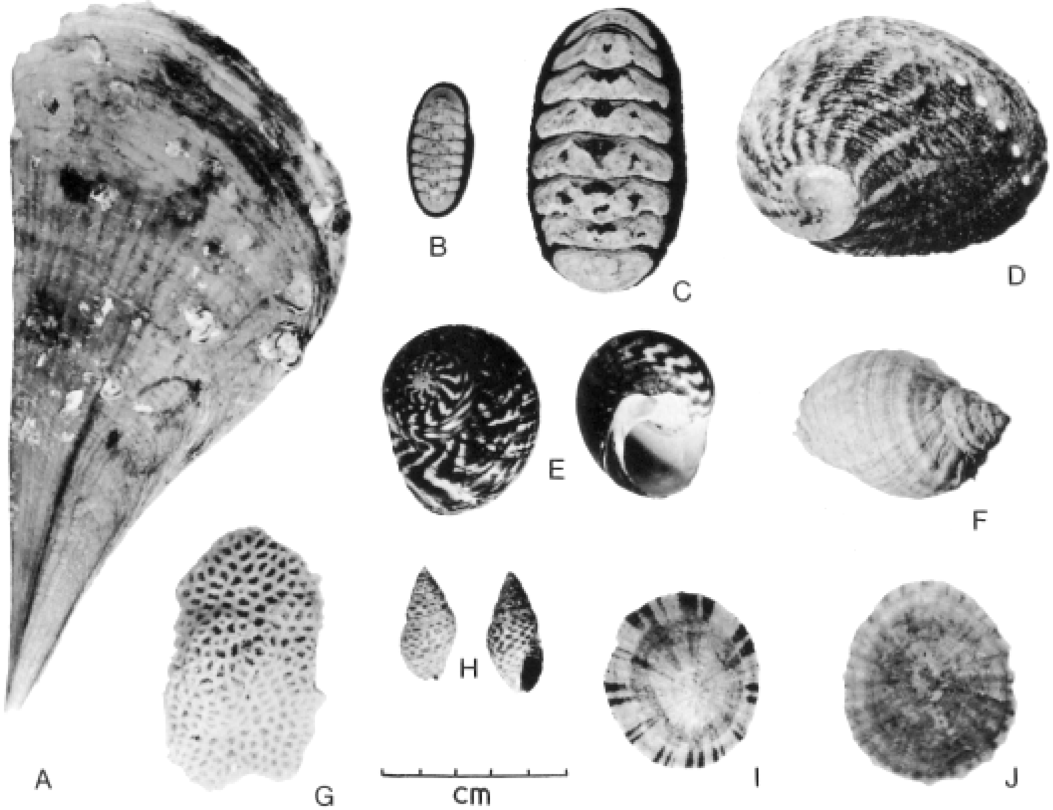


Fig. 3. Bivalves: A, *Pinna bicolor* (with remains of young oysters adhering); B, *Ischnochiton lineolatus*; C, *Plaxiphora albida*; Gastropoda: D, *Haliotis roei*; E, *Turbo undulates* (two views; F, *Thais orbita*; H, *Cominella lineolata* (two views); I, *Cellana tramoserica*: J, *Cellana solida*; Cnidaria: G, *Plesiastrea versipora*.

They feed, mostly at night, by rasping plant material from rock surfaces. *Ischnachitan linealatus* (Fig. 3B) occurs under rocks at low water on ocean coasts and on moderate or low energy shores such as those at Emu Bay and American River. Its valves are delicately sculptured in wavy or zig-zag lines and it grows to about a length of 50 mm. *Plaxiphora albida* (Fig. 3C) is the commonest chiton on high and moderate energy coasts. It is about twice as big as *I. linealatus,* has coarser sculpturing on its valves and is usually covered with fine algae. It is found in depressions or crevices on rock platforms or on the sides of rocks in the lower littoral zone. Gastropods are either herbivorous or carnivorous, the latter sometimes feeding on the former. The carnivores usually have a notch at the mouth of their shell (Fig. 3H) which in some may extend to form a canal. Through the canal a siphon can be projected which leads back to the mantle within the shell. The mantle contains organs of taste and smell. *Littarina unifasciata* (Fig. 2G) and *L. praetermissa* are two small, greyish-blue herbivorous gastropods commonly found in the supralittoral zone of high and moderate energy coasts. They feed on surface algae, when rocks are wetted by spray or at night, using a flexible file-like structure (a radula) which they carry in their mouths to scrape off plant material. *L. unifasciata* is found usually in more exposed places. *L. praetermissa* is found in more sheltered places and has a chequered pattern on its shell. Specimens of either species are usually less than 10 mm long.

The limpets (Chinaman's hats), *Cellana tramaserica* (Fig. 3I) and C. *salida* (Fig. 3J) are common on rocks in the mid-littoral on high to low energy coasts. The shell of the former has about 36 ridges, every third or fourth of which has a darker marking, seen more clearly on the underside of the shell. C. *salida* is slightly larger, has a reddish or orange tinge to its shell and is found only on high energy coasts. Both feed on the microscopic algae that grow on the rocks. In the upper part of the mid-eulittoral there are two species of limpet-like molluscs, *Siphonaria diemenensis* (Fig. 2A) and S. *zelandica* (Fig. 2F). Both are small, rarely more than 20 mm across, and have on the right front quarter of the shell a raised ridge which corresponds to a groove on the under side. The groove carries an extension of the mantle which lines the shell and conveys air to a 'lung' inside the body. The animals breathe air and may drown if immersed for long periods. S. *diemenensis* has a shell with radiating white ridges between which are dark grooves while S. *zelandica* has similar ridges and a uniformly pale colour. They feed like limpets and occur on rocks or jetty piles in any but the roughest positions.

On rocks in the upper eulittoral zone there are several snail-like gastropods. *Nerita atramentosa* (Fig. 2C) has a dark blue-black shell and *Monodonta eonstrieta* (Fig. 2E) has a shell with spiral grooves, dark coloured but with a spiral speckling of yellow. *Bembieium nanum* (Fig. 2B) has a conical, chalky-yellow shell with darker, oblique stripes and brown markings on the inner lip. All of these graze off the rock surface and are commonest on moderate energy shores. The warrener, *Turbo undulatus* (Fig. 3E), occurs in the lower eulittoral zone or in permanent rock pools. It is greenish in colour and has paler zig-zag streaks. Two species of ear shells or abalone can be found, usually subtidally; they are *Haliotis sealaris* and *H. roei* (Fig. 3D). The latter has well-marked concentric ridges while in the former they are less well marked and radial markings tend to appear.

Thais orbita (Fig. 3F), a common carnivorous gastropod, occurs on both high and moderate energy coasts. Its shell is large (up to 50 mm long), light brown or creamy white. It feeds on a variety of other molluscs or on barnacles, using its radula as a rasp or drill to gain entry to the soft parts within the shell. The shell of *Cominella lineolata* (Fig. 3H) is smaller and ornamented with spiral rows of purplish, oblong spots on a yellow to cream base. It feeds on herbivorous gastropods, penetrating them through the edge of their operculum. C. *lineolata* is common on wave-washed rock platforms like those at Pennington Bay and South West River and on moderate energy coasts such as at Stokes Bay.

The bivalve molluscs (Class Bivalvia) possess a shell in two parts hinged together. All intertidal bivalves are filter feeders and most are sedentary. In life, when the shell opens, two tubes, the siphons, emerge at the hinder end. Water is drawn through one and ejected through the other. Within the animal it is filtered through the gills and, by a complex system of ciliary flow, food particles are sorted out and carried to the mouth. On rocky shores of moderate to high energy two bivalves, *Braehidontes rostratus* (Fig. 2J) and *Xenostrobus pulex* (Fig. 21) grow, often in very large numbers, forming a shiny blue-black cover on the rocky surface. The shells of *Braehidontes* are larger and ribbed while those of *Xenostrobus* are smaller and smooth. Each individual is attached to the rock surface or its neighbour by a tuft of dark-brown threads, the byssus. *Braehidontes erosus* (Fig. 20) grows in a similar fashion on moderate and low energy shores; it has a large, purplish shell with longitudinal grooves and fairly well-marked growth lines. Buried in sandy mud on low energy coasts as at American River, near or below the level of low tide, occurs the razor-fish, *Pinna bieolor* (Fig. 3A). Razor fish are large bivalves with triangular shells up to 250 mm long. The narrow pointed end of the shell lies buried deep in the mud or sand so that only a narrow rim of the shell shows above the substratum. The protruding part, although fragile, is sharp enough to cut an unprotected foot.

Some other bivalves which live in the sand have no byssus but have a highly muscular, almost spade-shaped foot. With the aid of the foot the animal can bury itself, often deeply, in the sand. *Katelysia* spp. (Fig. 2H) are the common sand cockles and are found on the sandy stretch of beach near Rocky Point, Eastern Cove. Another cockle is the stouter *Anapella eyeladea* found in the quieter waters of Pelican Lagoon. Its shell is more globular, light reddish brown with some darker concentric markings.

CRUSTACEANS

Crustaceans are a very large group of animals possessing a hard external covering, a segmented body and jointed appendages. Crustaceans are mostly aquatic and include such animals as crabs, crayfish, prawns, shrimps, sandhoppers and barnacles.

Barnacles are probably best known for their powers of sticking tightly to the place where they grow. They begin their lives as minute creatures, swimming and drifting in the sea as nauplius and cypris larvae and feeding on microscopic marine organisms. They grow, moult (like other crustaceans) and eventually settle on something suitable, which may be rock, wood, a floating object or even another animal such as a whale, where they will spend the rest of their lives. The animal owes its adhesive powers to a strong cement which it produces. Once a larva has settled it begins to change its form almost completely and to secrete a protective, calcareous or membranous 'shell' or 'tent' about itself. The tent-like house is usually made up of plates and has a hole at the top which is open when the animal feeds and closed by means of a two-part lid or operculum when it is not covered by the sea or when danger threatens. Adult barnacles are filter feeders and obtain their food by protruding their sieve-like cirri through the opening at the top of the tent and straining small particles of organic matter from the water. Barnacles of the same species usually form clusters when they settle. At least ten species are found on the shores of Kangaroo Island and most are present in great numbers.

The largest of them (and the most dangerous to collect) is *Balanus nigreseens* (Fig. 4A) which lives on well-washed rocks of the lower eulittoral zone and the sublittoral fringe at the most exposed positions, such as those at Cape du Couedic and Vivonne Bay. It is able to withstand the strongest buffeting of the sea. Its 'tent' is made up of six plates and is 35 to 50 mm tall and 20 to 25 mm wide at its base. Small molluscs, growths of crustose coralline algae and blue-green algae are often present on its grey to greyish-blue shell.

The surf barnacle *Catophragmus polymerus* (Fig. 4B) also lives on rocks in exposed places but usually at higher levels than *Balanus nigreseens.* It is flatter than *Balanus,* about 25 mm wide at its

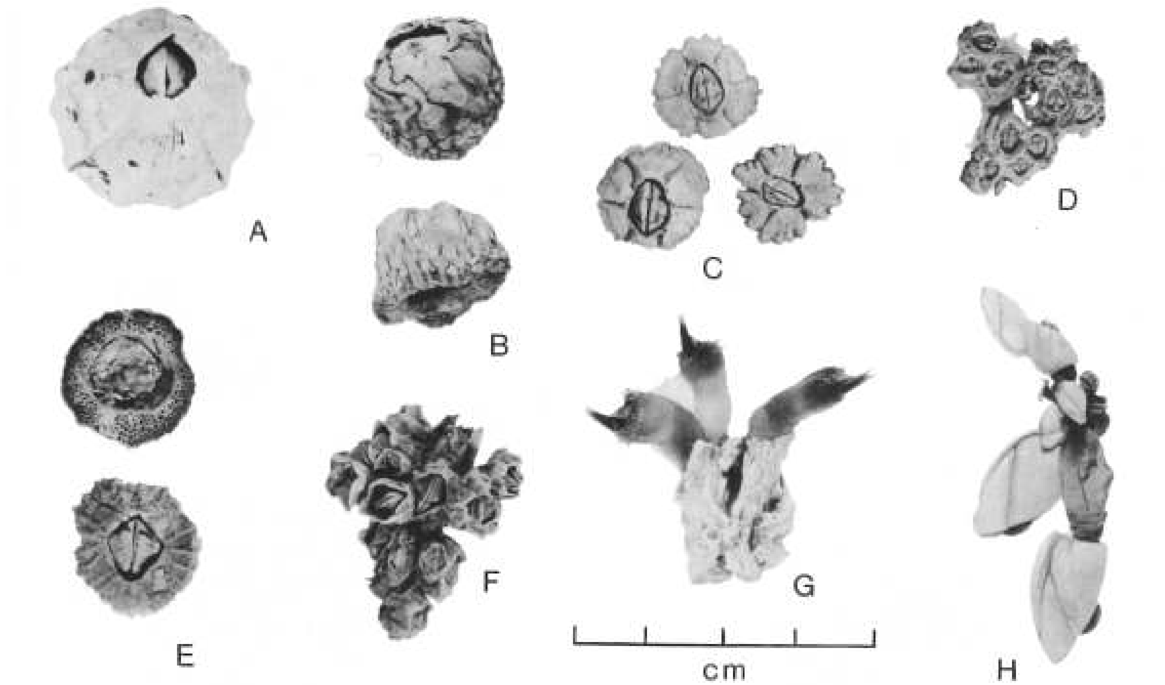


Fig. 4. Barnacles: A, *Balanus nigrescens*; B, *Catophragmus polymerus* (two views); C, *Cthamalus antennatus*; D, *Chamaesipho columna* (group); E, *Tetraclyta purpurascens* (two views); F, *Elminius modestus* (group); G, *Ibla quadrivalvis* (group) on *Galeolaria* tubes; H, *Lepas anatiferai* (group).

base and its eight plates are surrounded by a large number of small plates which become smaller and more numerous towards the base of the animal. It is found mostly on the southern and western coasts at such places as Cape du Couedic, Vivonne Bay and on a terraced reef at the western end of Pennington Bay. The honey-comb barnacle, *Chamaesipho columna* (Fig. 40), is so called because the animals grow so closely together that their shells seem to fuse. It is the smallest of the barnacles that live on the open coast and its shell consists of four plates. It is usually found above the level of *Catophragmus* and below that of *Chthamalus.* It is found on both the north and south coasts of the Island and sometimes on jetty piles in the mid- to upper eulittoral. *Chthamalus antennatus* (Fig. 4C) has six plates and is larger than *Chamaesipho.* It lives in the upper eulittoral zone, usually on rocky surfaces but sometimes on jetty piles at places like Vivonne Bay and Emu Bay. Although it tends to be gregarious, isolated animals are not uncommon.

Tetraelita purpurascens (Fig. 4E) is less common and prefers to live in shaded spots, in crevices or on the undersurfaces of rocks that slope. The shell is about 20 mm wide basally, flat, grey-white in colour and not uncommonly tinged green or purple. On Kangaroo Island it is found in the upperlittoral and supralittoral fringe. Its shell consists of four plates. The species occurs at Pennington Bay (on shaded rocks near the base of the cliffs) and near Admiral's Arch at Cape du Couedic. *Tetraclita* *rosea* is about the same size basally as *T purpurascens* but taller and more tent-like. Its shell consists of four plates and often is pinkish in colour. It lives in the mid- to upper eulittoral zone on exposed, rocky coasts. We have not found it to be common at Kangaroo Island.

Along low energy coastlines *Chthamalus antennatus* and *Chamaesipho columna* may occur but not *Balanus nigrescens* nor *Catophragmus.* In places like the inlet at American River, at Muston and Pelican Lagoon the small, gregarious barnacle *Elminius modestus* (Fig. 4F) is found. Its shell has four plates and is grey to bluish-green. It forms a well-defined zone in the upper eulittoral along the shore where it is rocky and on jetty piles and mooring stakes. The shell of *Elminius simplex* is conical, about 10 mm tall and 10 mm wide basally and corrugated externally. It consists of four plates with well-marked sutures between them; off-white in colour. This barnacle is one of the less common on Kangaroo Island. It is found along the open coast on the underside of large rocks and in depressions under overhanging ledges of rock platforms.

Two stalked barnacles, *Lepas anatifera* (Fig. 4H) and *L. anserifera,* are sometimes found on wooden planks, logs and bottles that are washed up on the shore. The stalk of the former is long and that of the latter short. *L. anatifera* seems to be more common. These barnacles settle on objects at sea and not on rocks or wood along the shore.

The brown, hairy stalked barnacle, *Ibla*

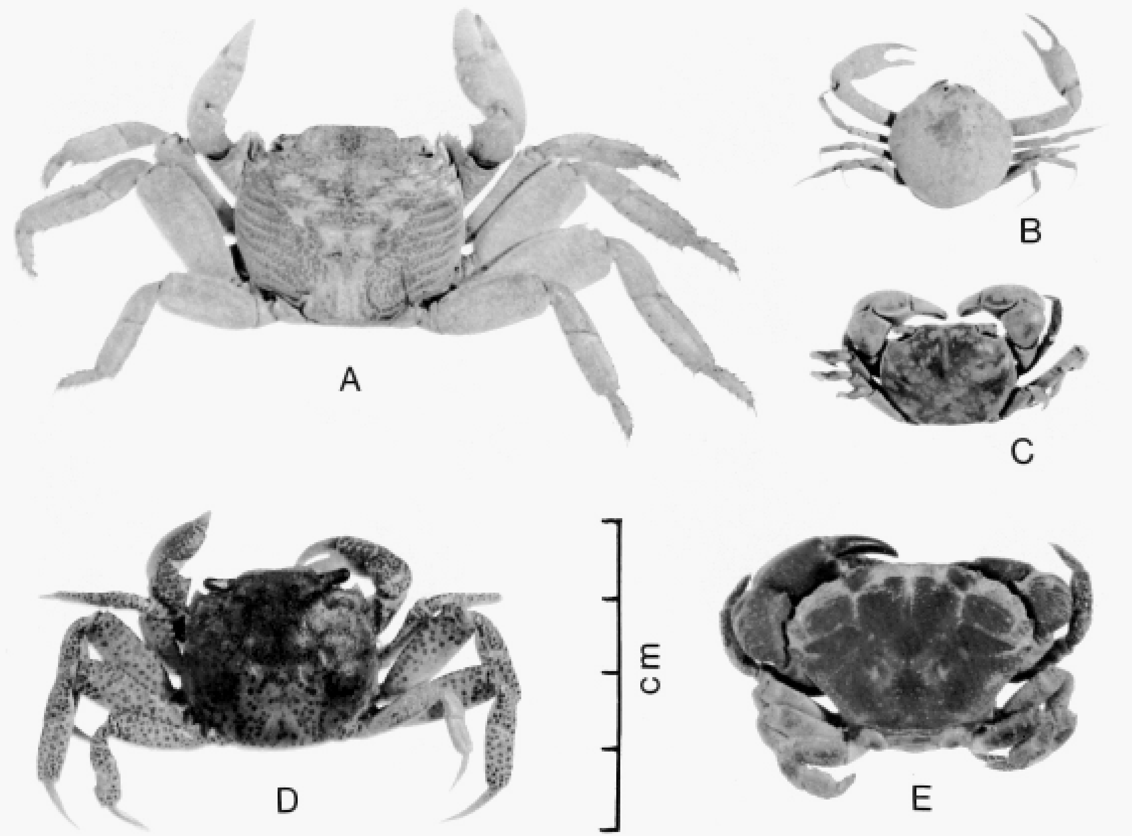
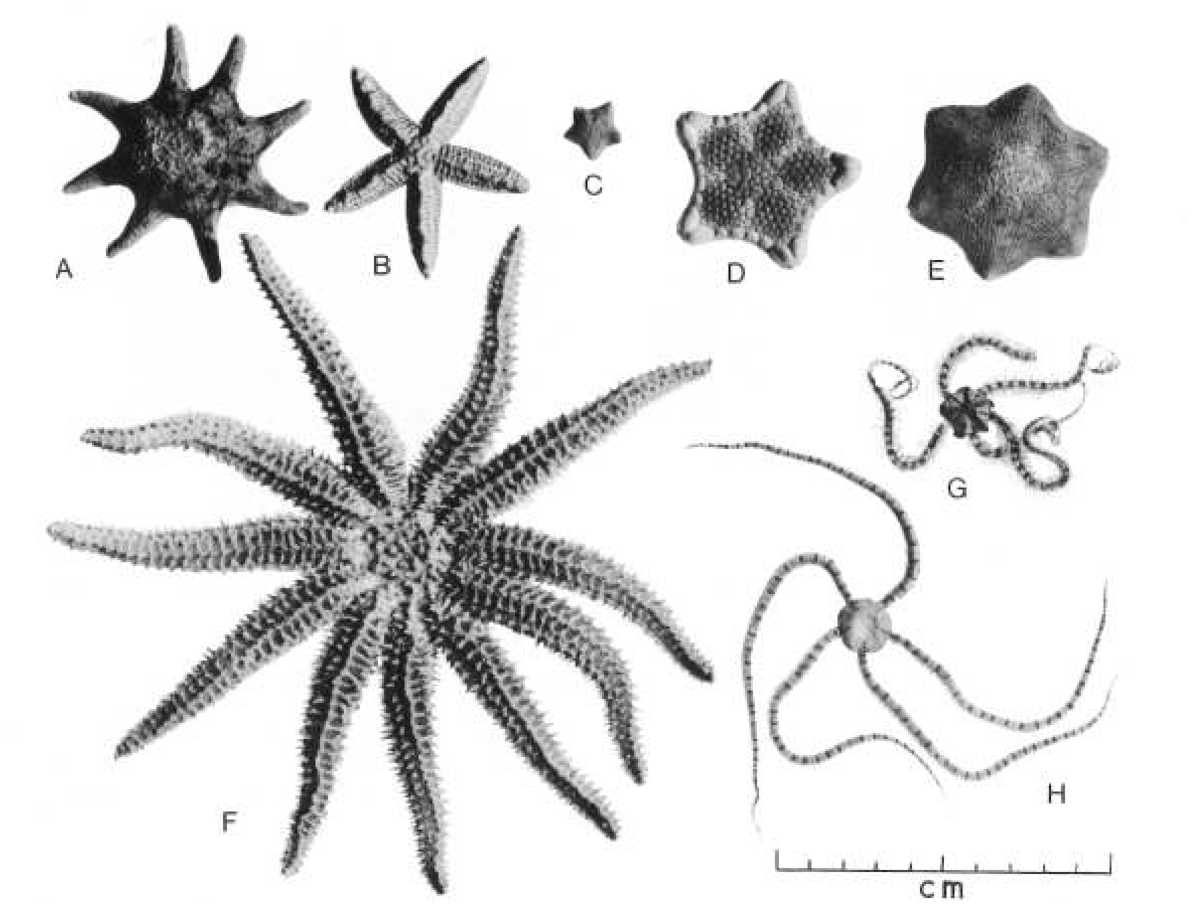


Fig. 5. Crabs: A, *Leptograpsis variegates*; B, *Philyra laevis;* C, *Helograpsus haswellianus*; D, *Paragrapsus gaimardii*; E, *Oziu truncatus.*

quadrivalvis (Fig. 4G) is found where there are well-developed growths of the serpulid worm, *Galealaria caespitasa,* especially on jetty piles, under stones and boulders and among mussels in the inlet at American River. Its horny plates and the stalk together are usually 15-25 mm tall.

A quick-moving isopod, *Ligia australiensis,* is common in sheltered places among pebbles, rocks and boulders on most coasts. It needs to remain in a humid environment and prefers places where the light intensity is low. It has a dorsoventrally flattened body and can squeeze very easily into narrow spaces. Sand hoppers or sea fleas such as *Talarchestia quadrimana* are usually exposed when the seaweed and flotsam cast up on most beaches is disturbed or turned over. They are amphipods and their body is compressed from side to side. Their last three pairs of legs are larger than the others and act as powerful jumping organs. Because, like *Ligia,* they are scavengers they play an important part in keeping beaches clean.

The common intertidal crabs are usually scavengers or raptorial predators. They are found in most parts of the intertidal zone, different species being, to some extent, separated by their ability to tolerate exposure to air. The common shore crab, *Leptograpsus variegatus* (Fig. 5A), is often found high in the intertidal zone and at night will forage in the supralittoral zone and even farther inland. It can be recognised by its rather long legs and the oblique and transverse striations on its shell. Its colour is said to be variable, though on the island most are yellow or light orange. When disturbed it will either 'freeze' or scuttle away rapidly for cover. The species may grow to 50 mm or more across the shell. The reef crab, *Ozius truncatus* (Fig. 5E), has conspicuous brown to black flippers and is found under rocks or weed or in holes in the mid-eulittoral and in deeper water. It rarely comes out when not covered by water. On low energy sandy and muddy shores three smaller crabs are common. The pebble crab, *Philyra laevis* (Fig. 58) inhabits shallow pools in Bay of Shoals and American River and is most noticeable as the incoming tide moves up the shore. It is readily attracted by a crushed mollusc. In regions of low wave energy, as for example, at Muston, the mottled shore crab, *Paragrapsus gaimardii* (Fig 50) is common. This grows to about 40 mm across the shell and can be readily recognised by its mottled red colour. A small crab, *Helagrapsus haswellianus* (Fig. 5C) occurs in the upper eulittoral on muddy shores. at places like Muston. It avoids desiccation at low tides by digging holes 100 mm or more deep. It is a scavenger, feeding on whatever plant or animal remains it can find.



ig. 6. Starfish: A, *Patriella calcar*; B, *Uniophora nuda*; C, *P. exigua*; D, *Tosia australis*; E, *P. gunnii*; F, *Coscinasterias muricata*; Brittle stars: G, *Ophiothrix spongicola*; H, *Ophionereis schayeri*.

ECHINODERMS

Five classes of the Phylum Echinodermata, the sea stars, brittle stars, sea urchins, sea cucumbers and feather stars, are found in the intertidal zone. Echinoderms are radially symmetrical and under each of the usual *five* rays of the sea stars, there are rows of tube feet or podia. These are highly mobile organs which sometimes end in suckers. They are used for locomotion, adhesion and opening bivalve shells, the contents of which are often used for food. Sea stars *have* remarkable powers of regeneration. If an animal loses one or more of its arms, they will be gradually replaced by new growth. Consequently it is common to find sea stars with arms of different lengths.

A typical sea star (Class Asteroidea) with *five* arms is *Uniophora nuda* (Fig. 6B) which is common on the northern and eastern shores of the Island. At low tide it may be found under growths of *Hormosira* at American River and at Muston. It is reddish brown, its arms are almost circular in cross section and it grows to be about 120 mm across. Its upper surface is not conspicuously spiny and such spines as there are, are almost *covered* by a thick skin. *Stolasterias calamaria* (Fig. 6F) is often found under stones and in weeds near low tide mark at American River and Emu Bay. It may *have* from *seven* to fourteen arms, although *eleven* is frequent. The arms are narrow and heavily beset with short spines and a specimen may be 300 mm across. The biscuit star, *Tosia australis* (Fig. 6D), is about 50 to 60 mm across and looks like a five-sided biscuit. The upper surface is *covered* with neatly fitting, flattened plates and around its edges is a row of larger plates. Its colour varies within the range of brown, green, yellow and grey, two or more or shades of these sometimes appearing in the same animal.

Three species of the genus *Patiriella* are commonly found on the Island. P *exigua* (Fig. 6C), the smallest of them, is about 20 mm across and five-sided like *Tosia.* It is blue-green on its upper surface but paler below and is found on moderate energy coasts such as at Emu Bay and low energy coasts such as at American River and Pelican Lagoon. P *gunnii* (Fig. 6E) is hexagonal and is found on the flats at American River and under stones at Emu Bay. It may be red, pink, blue, purple or light brown. P *calcar* (Fig. 6A) has eight short arms and a wide disc. It grows up to 100 mm across or more and is mottled in shades of red, orange, green, blue, brown or grey. It is common amongst the algae on exposed rock platforms such

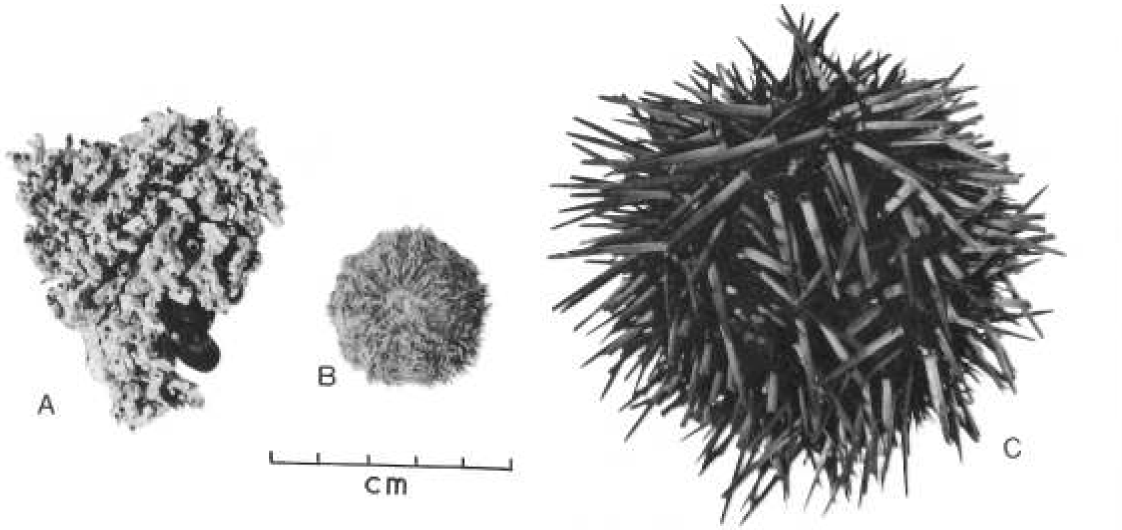


Fig. 7. Polychaete: A, *Galeolaria caespitosa*; Echinoids: B, *Amblypneustes ovum*; C, *Heliocidaris erythrogramma*. (Photography by Jan Forrest).

as those at Pennington Bay and South West River, in shallow pools on the reef flat. All three species are herbivorous in contrast with most other sea stars which are carnivorous.

The brittle stars (Class Ophiuroidea) are distinguished from the sea stars by their thinner arms which are sharply divided from the disc. *Ophionereis schayeri* (Fig. 6H) grows to about 150 mm or more across and is recognised by its arms which have alternating bands of chocolate and biscuit colours. The edges of the disc of *Ophiothrix spongicola* (Fig. 6G) are divided into five lobes, the arms coming off between the lobes. Thorny spines are present on the sides of the arms and along the longitudinal axes of the latter there are alternating light and dark bands, the dark ones being consistently a little narrower than the light. Podia which lack suckers are present on the undersides of the arms of ophiuroids. They are sensory and help to transfer food to the mouth which lies on the underside of the disc. The animals propel themselves by the muscular action of their very flexible arms. Usually two arms pull the disc forwards and the other three push from behind.

The common southern Australian sea urchins or sea eggs (Class Echinoidea) while retaining the basic five rayed symmetry have bodies which are hemispherical or almost globular. Their outer shell or test bears spines of varying sizes jointed at their bases. *Amblypneustes ovum* (Fig. 7B) is found on shores of moderate wave energy under stones near low tide level. The test is 20 to 30 mm across, almost spherical, and slightly flattened below. If a living specimen is examined under water, five double rows of podia can be seen, equally spaced around the surface, each row running from near the top to the underside where the mouth lies. Tests, often with spines still adherent, are frequently washed up onto beaches. Another common intertidal species is *Heliocidaris erythrogramma* (Fig. 7C) which can be recognised by its more hemispherical shape, its larger size (up to 80 mm across and 50 mm high), its longer spines (up to 25 mm) which are tinged green and its deep red to purple test. This species also has longer podia which can reach well beyond the spines. As in all sea urchins the spines move on a ball and socket joint, enabling them to be directed towards a potential danger. These echinoids are grazers, feeding on the algae and other organisms that grow on rocky surfaces. Their spines can enter human skin easily but, as far as is known, no South Australian species has poisonous spines. However, because they fragment easily, they may be difficult to remove.

Sea cucumbers (Class Holothuroidea) include the beche-de-mer of tropical waters. They are usually sausage-shaped and can throw out at one end a cluster of branched tentacles, which are used when feeding. *Mensamaria intercedens* may be as long as 70 to 80 mm and is pale grey to black, the older specimens being paler. Five rows of podia run along the length of the body. Three of them are close together and are the ones on which the animal crawls. As in sea stars the podia are used for locomotion and adhesion. This holothurian is found in weed and under rocks at low tide mark on shores of moderate wave energy. *Leptosynapta dolabrifera* is found in muddy sand on low energy coasts. Although this species has lost its podia, five lines in the more or less translucent skin show the basic five-rayed symmetry. A ready means of identification of *Leptosynapta* is that its skin feels slightly sticky on the fingers. This is because the skin contains small anchor-shaped structures whose 'flukes' stick through and tend to hold on to the finger.

Members of the fifth class of existing

echinoderms, the Crinoidea, are not common. However, feather stars are sometimes found sheltering under rocks at the lowest tide levels on moderate energy shores. They possess twenty or more delicate, feathery arms. When out of water the arms collapse and become entangled, but when fully immersed they spread out, allowing the animal to swim gracefully. They can attach themselves to rocks or weeds by ten or more short cirri on the underside of the body. The commonest species on the Island is *Cenolia trichoptera.*

There is a number of references that are of value in identifying the marine invertebrates of Kangaroo Island. These include Bennett (1966,1969), Carlgren (1950), Dakin (1952), Edmonds (1948), Hale (1927-29), Shepherd & Thomas (1982, 1989), Shepherd & Davies (1997), Totton (1952), Underwood (1977) and Womersley & Edmonds (1958).

16: Intertidal Ecology of *Marine Organisms*

by H. B. S. WOMERSLEY AND S. J. EDMONDS

Kangaroo Island has long been recognised by marine biologists as one of the richest and most fascinating areas of the southern Australian coasts. Marine plants, both algae and seagrasses, are prolific in the many suitable areas, though mangroves do not extend as far south as the Island. Many animal groups - molluscs, echinoderms, fishes, etc. - are well represented, and a thorough analysis may well show that the diversity of marine life is as great or even greater than on the Great Barrier Reef.

This richness is partly due to the great variety of coastal habitats provided by the Island, from surf bound rocky coasts with steeply-sloping granite rocks to horizontal limestone platforms, to coasts of moderate wave action and the almost completely sheltered sandy-mud tidal flats of American River inlet. Such coastal areas include virtually all types of coast found anywhere along southern Australia.

For the casual explorer or the experienced marine biologist, great care must be taken on the rocky south and west coasts, where strong surf action and occasional erratic 'king waves' can make the intertidal region a hazardous place.

This account summarises existing knowledge of the marine biology and ecology of the coasts of Kangaroo Island. For further information, reference should be made to the papers of Womersley (1947, 1948: Pennington Bay, and 1956: American River inlet), Edmonds (1948: Pennington Bay), and also to the general account of the intertidal ecology of South Australian coasts by Womersley & Edmonds (1958) and in Womersley 1984.

These papers and indeed our ecological knowledge in general is limited to the intertidal and just subtidal zones on Kangaroo Island. The biology of the deeper subtidal zone has been little explored, and great opportunities exist for the knowledgeable and enthusiastic SCUBA diver to make contributions.

Unfortunately in an account such as this it is not possible to illustrate all of the organisms referred to, though many are shown in the illustrations. The preceding chapter, however, discusses many of the invertebrate animals in more detail, and gives references to other accounts of animal groups. The marine algae and seagrasses are described in Womersley 1984,1987,1994 and 1996.

ENVIRONMENTAL FEATURES

The coastal geology is described in Chapter 1. While the type of rock has little direct effect on the plants or animals, the topography and aspect is determined by the geological nature of the coast and this in turn determines the habitat relative to tidal fluctuations, amount of wave action, and presence of sediment.

On the south coast three distinctive coastal types occur. The 'backbone' of the coast comprises points or capes of Precambrian granites, schists and gneisses (Fig. 1A), steeply sloping through the intertidal zone into deep water. Between these areas, the coast is usually indented, with horizontal, calcareous sand-rock platforms (Fig. 2A, B) formed by wave action from consolidated dune systems of Recent to Pleistocene age alternating with loose sandy beaches. The west coast has few calcareous platforms and these do not occur on the north coast which consists of Precambrian rock and boulders dropping irregularly and more gently into deeper water (Fig. 3E). American River inlet (Fig. 4A) consists of extensive sandy or sandy-mud tidal flats, backed by samphire flats (Fig. 4B) or low calcareous cliffs, and sloping gently to the central channel 3 - 5 m deep with some deeper areas (6 -10 m) in Pelican Lagoon.

The degree of wave action, which is of great importance to the intertidal organisms, is largely correlated with the coastal topography. The south and west coasts have constant surf (so-called 'high energy' coasts), while wave action decreases along the north coast from Cape Borda, reaching a minimum in American River inlet where it is very slight; in the latter area, however, strong tidal currents occur in the central channel.

Tidal ranges are from about 1 m spring range on the south coast to 1.5 m at Kingscote on the north coast and 1.25 m in American River inlet. The tides are generally of mixed, semidiurnal nature, with 'dodge' tides occurring on the north coast and at American River inlet and commonly resulting in a diurnal tide with amplitude as great as the spring tides. The monthly mean sea level is some 10 - 15 cm lower in summer than in winter, and the lower of the two daily low tides is usually during day hours in summer but night hours in winter; these facts, coupled with the more frequent presence of northerly (offshore on the south coast) wind in

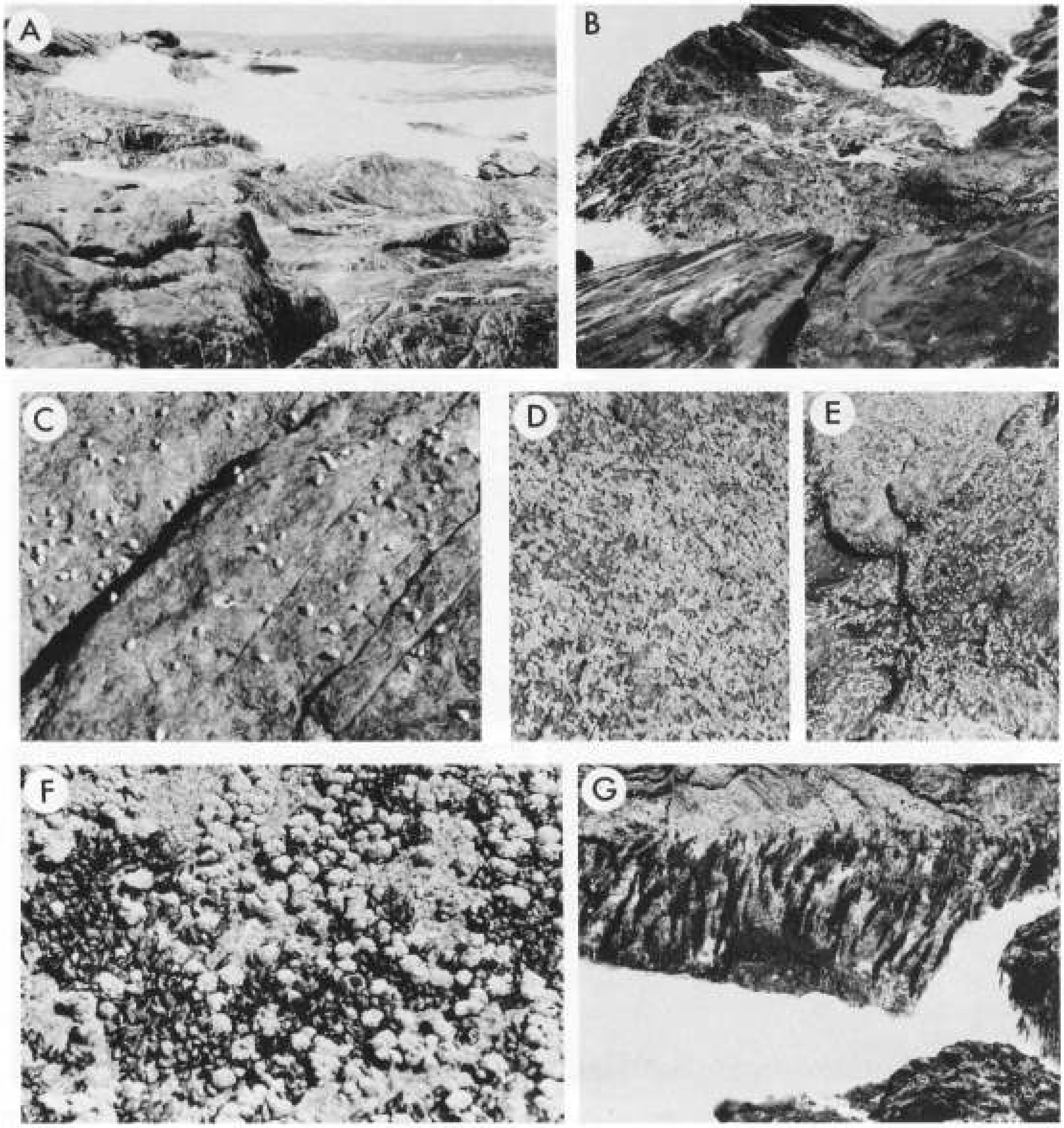


Fig. 1. A. The coast at Vivonne Bay, with steeply sloping gneissic rock and strong surf action. B. The intertidal region at Vivonne Bay; *Littorina unifasciata* occupies crevices in the foreground (supralittoral), and the just emergent rock on the left bears *Cystophora intermedia*; *Balanus nigrescens* is just visible in the upper center (near the white water) and *Catophragmus polymerus* in the centre right. C. *Littorina unifasciata* in the supralittoral. D. *Chamaesipho columna* (honeycomb barnacle). *Chthamalus antennatus*, upper eulittoral. F. *Catophragmus polymerus* and *Brachidontes rostratus*, mid-eulittoral. G. *Cystophora intermedia* forming the sublittoral fringe.

summer, make intertidal investigations distinctly easier during summer.

Sea temperatures range from about 14°C winter to 18-19°C summer on the south and west coasts; from 13°C in winter to 20°C in summer on the north coast, and from as low as 10°C to as high as 30°C (on occasional hot days) on the shallow tidal flats in American River inlet. Air temperatures and humidity are important to intertidal organisms especially on hot dry days (with northerly winds) in summer; if these conditions occur during low tides, considerable damage may be done to intertidal algae and animals.

Salinity of the sea around Kangaroo Island is relatively uniform (35.5 to 36%0), and in American River inlet it increases slightly in the lagoons in summer. Run off from rivers and creeks around the island has little effect on salinity, though the rare heavy rains, if falling during low tide, may reduce salinity significantly on the intertidal flats in American River inlet (to as low as 17%0).

Nutrients such as phosphate and nitrate are generally very low from the few recordings available, with some higher phosphate figures from American River inlet (probably due to the larger bird population). Dissolved oxygen varies

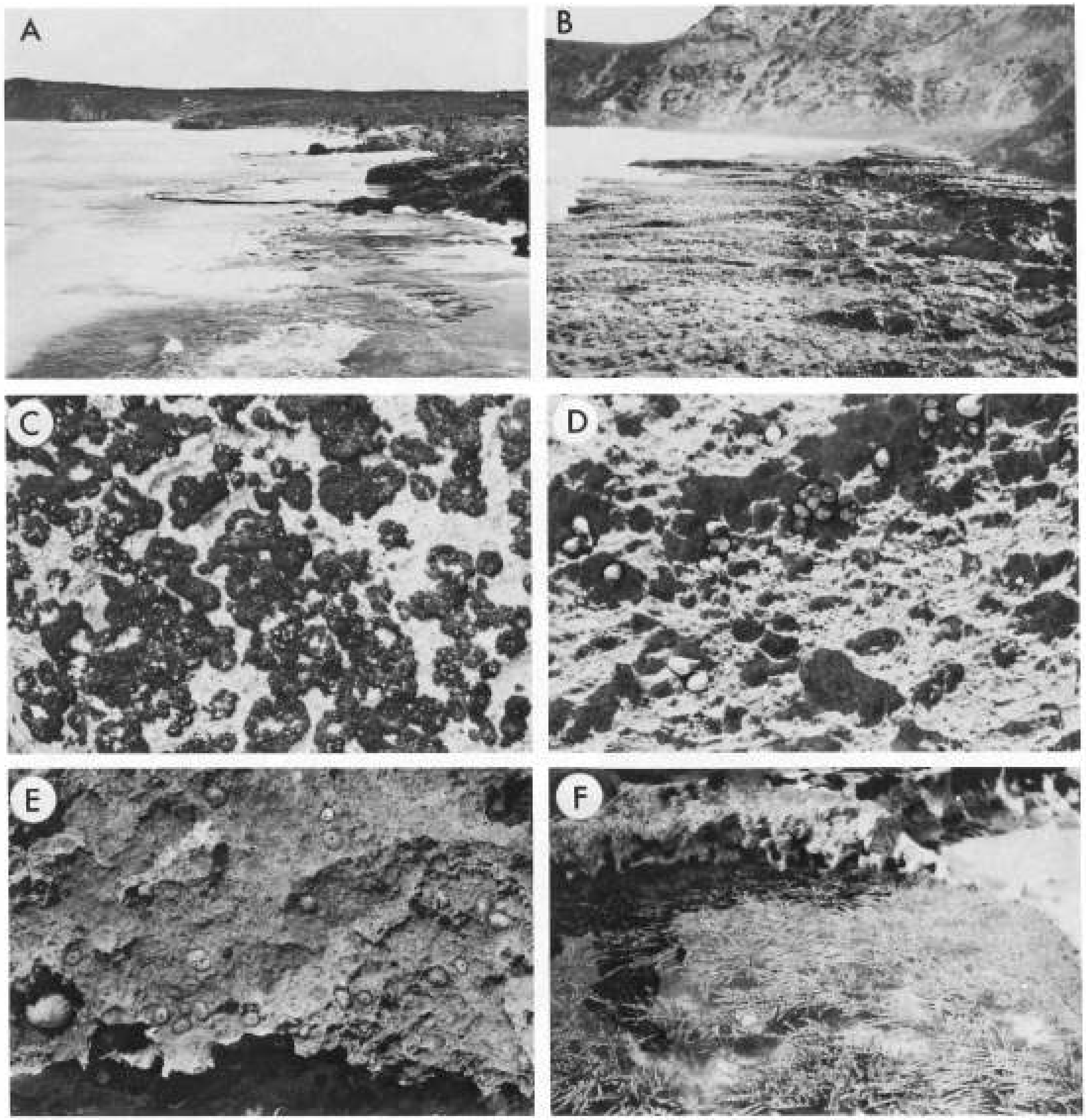


Fig. 2. A. Pennington Bay with rock platforms just emergent at low tide and a calm sea. B. The terraced platform at the western end of Pennington Bay. The mussels *Xenostrobus pulex* and *Brachiodontes rostratus* from black patches on the seaward face of the upper terrace. C. The lichen *Lichina confinis* in the supralittoral. D. *Littorina unifasciata* in hollows in the rock, supralittoral. E. Mid eulittoral rocks with *Cellana tramoserica* (lower left) and numerous *Siphonaria diemenensis*. F. A *Hormosira* pool on the terraced platform; the anemone *Actinia tenebrosa* occurs in the rock pockets at the rear of the pool.

considerably in calm waters with time of day, light intensity, etc., from the water being only half saturated at night to greatly supersaturated during the afternoon, but on surf-bound coasts the water is always just supersaturated.

Light penetration is usually fairly high on the south coast, moderate on the north coast, and low in American River inlet due to silt kept in suspension by the strong tidal current flow in the channel.

TERMINOLOGY

Terminology for the intertidal zones is the same as given by Womersley & Thomas (1976) in describing the zonation of coasts near Adelaide, and is briefly as follows.

Supralittoral or eulittoral fringe zone: the region above high tide level, including the organisms which have marine affinities but which do not tolerate submersion for more than occasional short periods.

Eulittoral zone: the main intertidal zone, where organisms at any level are immersed or emergent for regular periods dependent on the tidal fluctuations. The organisms in this zone commonly distinguish three sub-zones, the upper, mid- and lower eulittoral zones (see Table 1).

Sublittoral zone: from about mean low tide level down to the limit of plant dominance; at the upper limit, the organisms cannot tolerate emergence for more than very short periods. On some coasts,

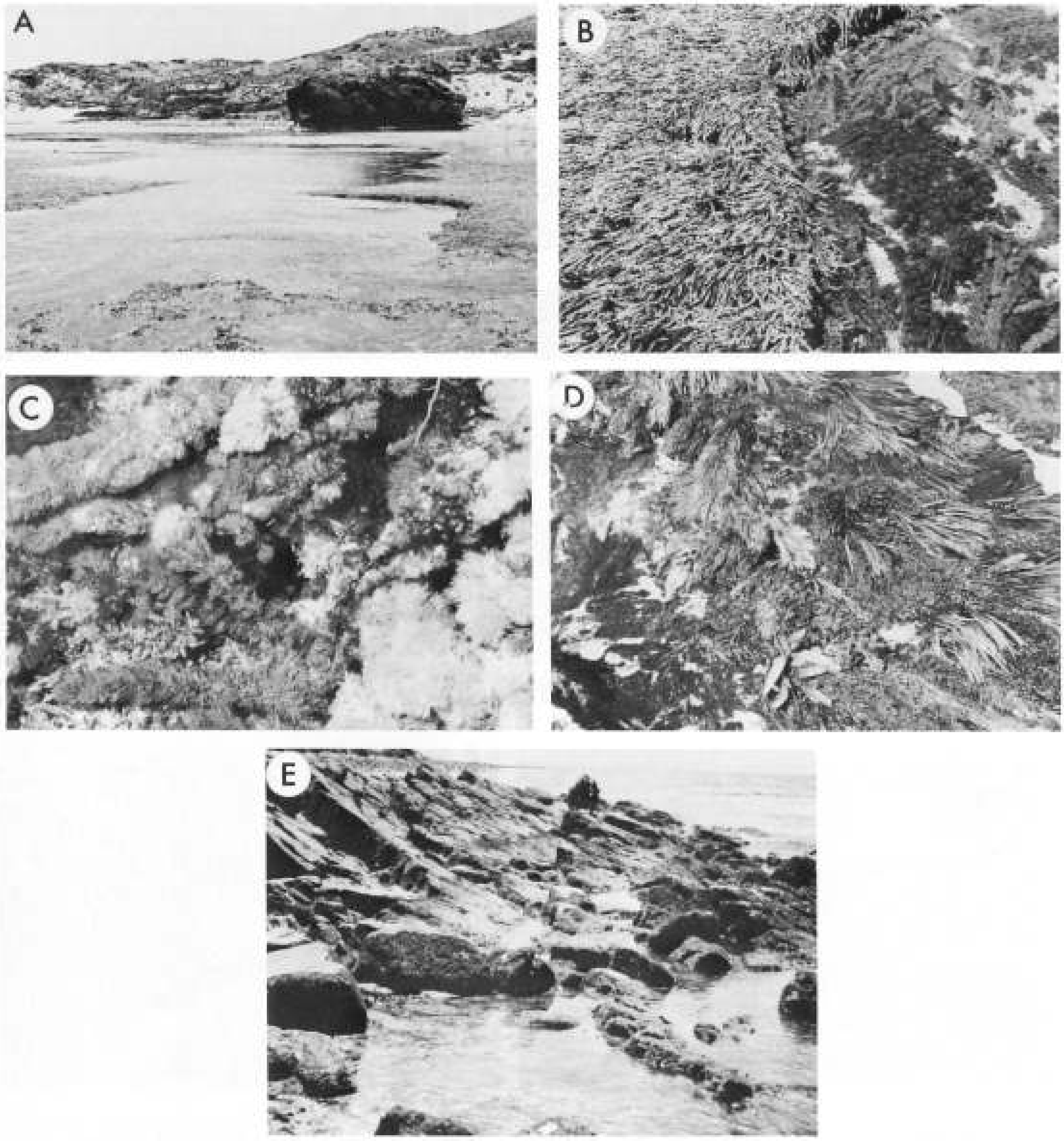


Fig. 3. A. A platform at Pennington Bay, with a shallow channel (with brown algae such as *Cystophora* spp.) and raised (lower eulittoral) areas of *Hormosira* on both sides. B. *Hormosira banksii* on the left (lower eulittoral) and *Cystophora* spp. and *Caulocystis* on the right (uppermost sublittoral). C. The algal community near the platform edge, at low tide level, but wave-washed with *Cystophora* spp. and light-coloured coralline algae. D. An uppermost sublittoral mat of brown algae; *Sargassum* (leaf like), *Scytothalia* (strap like) and *Cystophora* spp. are shown. E. Coasts of moderate wave action at Emu Bay, at low tide; the top of the algal mat (*Capreolia*, coralline algae) in the lower eulittoral is shown left of the figure.

especially those with strong surf action, the uppermost metre or so, which is, emergent during the suck-back of waves at low tide, may bear a distinctive zone of the alga *Cystophora intermedia.* Such a zone, limited to the uppermost part of the sublittoral, is referred to as the sublittoral fringe.

INTERTIDAL ZONATION

The zonation and organisms present on the coast of Kangaroo Island depend largely on the degree of water movement in the intertidal area and the topography and nature of the coast. Thus

1. Coasts subject to strong wave action (south and west coasts, extending along the north coast to about Western River).

A. Steeply sloping coasts of ancient rock.
B. Horizontal, calcareous platforms of recent age.
C. Sandy beaches.

2. Coasts subject to moderate wave action (most of the north coast).

A. Sloping rocky or pebbly coast.

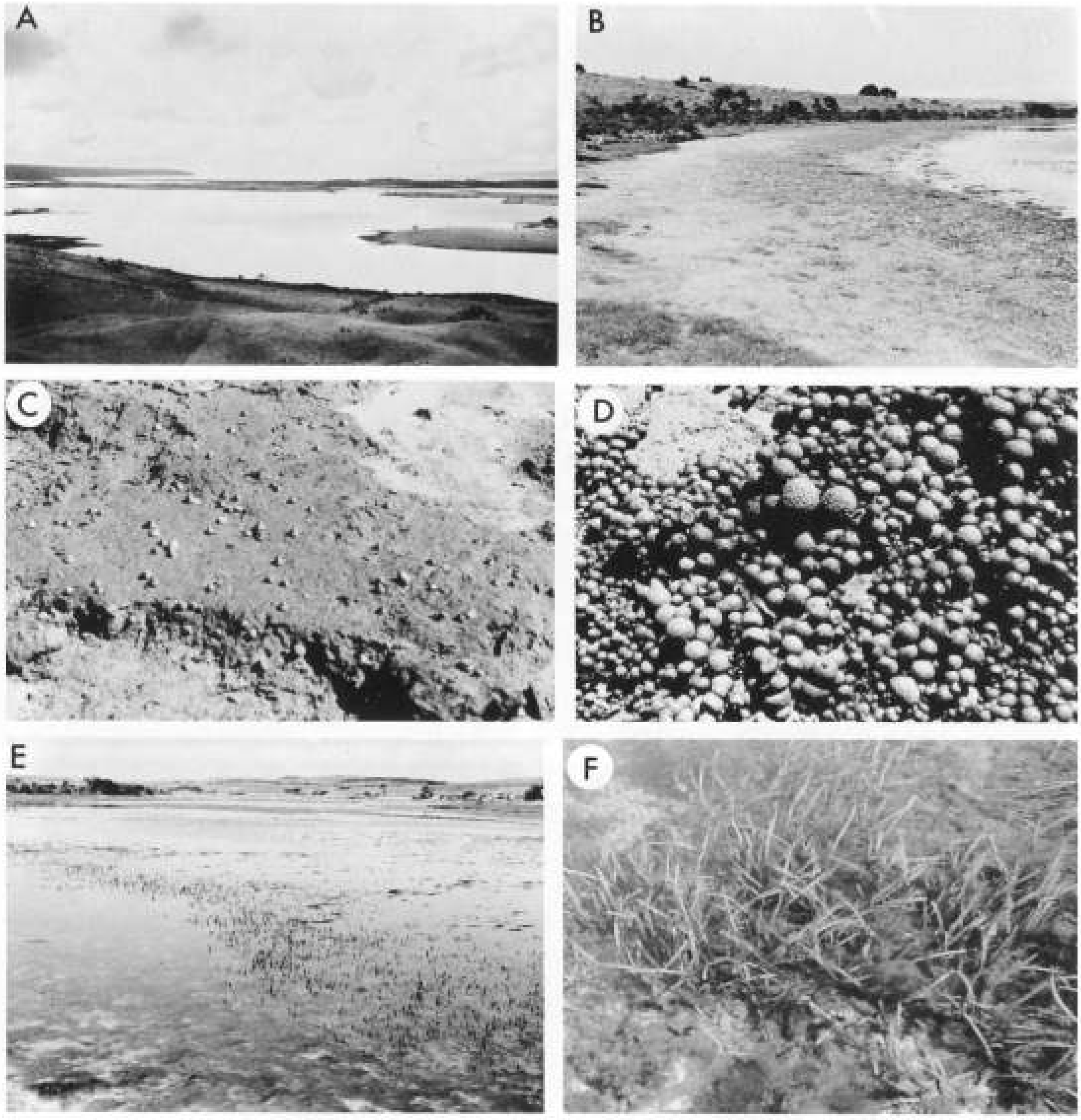


Fig. 4.A. American River inlet from the south. B. Typical sand-mud intertidal flat with samphires in the supralittoral and upper eulittoral, and the lower eulittoral with *Hormosira* just above water level; *Posidonia* leaves are just emergenton the far right. C. *Bembicium nanum* on firm mud in the mid eulittoral. D. *Hormosira banksii* in the lower eulittoral. E. A *Posidonia* bed at low tide, with the leaves a few cm above the water surface. F. The edge of a *Posidonia* bed, with numerous epiphytes on the leaves.

B. Sandy beaches.

3. Protected coasts with no or little wave action and sandy-mud tidal flats (American River inlet).

These areas were described in some detail by Womersley (1947, 1948, 1956) and by Edmonds (1948) and only the main features and organisms will be outlined here. The occurrence of the dominant intertidal organisms is given in Table 1.

1 A. *Steeply Sloping Coasts* of *Ancient Rock, subject to Strong Surf Action*

Capes or points of granitic or gneissic rock form the backbone of the south and west coasts of Kangaroo Island, and are subject to constant heavy surf. Their smooth, steeply sloping surfaces usually show well-defined zonation of organisms.

The supralittoral is dominated by the small blue-grey littorinid snail *Littorina* (Fig. 1 B, C) which in hot dry weather may migrate to a lower level. In some areas extensive black patches in the supralittoral are due to the blue-green alga *Calothrix,* but otherwise there is much rock bare of organisms.

The eulittoral zone shows three main sub-zones.

The upper eulittoral is dominated by the smaller barnacles *Chamaesipho* (Fig. 1 0), and *Chthamalus* (Fig. 1 E) often with much bare rock between them. Below this, in the mid-eulittoral, occurs a more diverse zone, dominated by the surf barnacle *Catophragmus* (Fig. 1 F) sometimes intermixed with the mussel *Brachidontes rostratus* where the surf breaks, and in slightly less turbulent areas by limpets such as *Cellana,* the calcareous tubes of

Table 1. SUMMARY OF INTERTIDAL ZONATION ON COASTS OF KANGAROO ISLAND

Zone	Strong wave action			Moderate wave action		No or slight wave action
	Steeply sloping rock (south & west coasts)	Horizontal rock platforms(south coast)	Sandy beaches (south andwest coasts)	Sloping rocky areas (north coast)	sandy beaches (north coast)	(American River inlet)
Supralittoral	*Callothrix* *Littorina*	*Littorina* *Lichina*	*Talorchestia*	*Caloplaca* *Buellia* *Littorina* *Lichina* *Ligia*	*Talorchestia*	samphires
Upper eulittoral	*Chamaesipho* *Chthamalus*	*Chamaesipho* *Chthamalus*	*Actaecia*	*Chthalamus* *Chamaesipho*	*Talorchestia*	Samphires *Chaetomorpha* *Bostrychia* *Bembicium* *Capreolia* *{Elminius]*
Mid eulittoral	*Catophragmus* *Brachidontes rostratus* *Cellana* etc. Galeolaria Rivularia	*Catophragmus* *Rivularia* *Symploca* *Cellana* *Siphonaria* *Austrocochlea* *Brachidontes* *Xenorostrobus* *Galeolaria*	*Actaecia*	*Nerita* *Bembicium* *Monodonta* *Rivularia* *Isactis* *Galeolaria*		*Bembicium* *Modiolus inconstans* *Philyra* *Paragrapsus* *Helograpsus* *Enteromorpha*
Lower eulittoral	*Balanus* *Corallina* *Jania*	*Capreolia* *Hormosira* *Actinia* chitons	bivalves	*Capreolia* *Corallina* *Jania* *Hormosira*	*Katelysia* *Arenicola*	*Hormosira* *Chaetomorpha* *Brachidontes erosus* *Patiriella exigua* *Uniophora* *Heterozostera*
Sublittoral Fringe	*Cystophera intermedia*	*Cystophora intermedia*		*Ecklonia*		Hypnea
Upper sublittoral	*Cystophora* spp. *Sargassum* spp. (larger brown algae) Red algae	*Cystophora* spp. *Sargassum* spp. *Caulocysti* *Caulerpa* spp. *Patiriella*	bivalves	*Cystophora* spp. *Sargassum* spp. *Heterozostera* *Posidonia*	*Heterozostera* *Amphibolis* *Posidonia*	*Spyridia* *Ulva* *Pinna* *Heterozostera* *Posidonia* *Halophila*

the serpulid worm *Galeolaria* and by the hemispherical, dark blue-green colonies of *Rivularia firma,* a blue-green alga. The lower eulittoral shows almost complete cover of the rock, largely by a turf of coralline algae *(Corallina* and *Jania)* and other small algae, and with the large *Balanus* barnacle usually present amongst or just above the turf. Slightly below it and extending many metres deep, or in areas of slight shelter, is a profusion of other large brown algae such as species of *Cystophora* and *Sargassum, Myriodesma, Scytothalia* and others.

1 B. *Horizontal Calcareous Platforms* of *Recent Age*

These platforms, mostly on the south coast, are subject to similar surf conditions as steeply sloping rocks, modified by the topography of the platforms. The upper sublittoral has a distinctive sublittoral fringe zone emergent in the suck-back of waves at low tide. This zone is dominated and characterised by the dark brown, pinnate fronds of the brown alga *Cystophora intermedia* (Fig. 1 G), with the turf of coralline algae extending below it. The level of the platform (Fig. 2A) corresponds closely to low tide level, and waves passing across the platform are attenuated slightly (especially at low tide) until they hit the steeply sloping rock at the rear of the platform. Occasional terraced platforms occur, such as one in the western part of Pennington Bay (Fig.2B).

These platforms are cut, probably largely by wave action, from consolidated sand dunes of Recent to Pleistocene age. The surface presents a hard and irregular substrate for algal attachment, and with the many and varied depressions or rock holes and rough-water conditions, the richness of algal and animal life is greater here than in most other coastal regions.

The supralittoral zone is also dominated by *Littorina* (Fig. 2D), and blue-green algae are rarely prominent. In some areas the small, branched black lichen *Lichina* (Fig. 2C) occurs.

The eulittoral zone occurs largely at the rear of the platforms or on slightly higher areas of the surface. The upper eulittoral zone carries the same two barnacles *(Chthamalus* and *Chamaesipho)* as on steeply-sloping rock, but in the mid-eulittoral the surf barnacle *(Catophragmus)* is less common except where surf hits the platform rear most strongly. The mid-zone is characterised by a variety of molluscs *{Cellana, Siphonaria* (Fig. 2E) and *Monodonta},* scattered tubes of *Galeolaria* and blue-green algae such as *Rivularia* and *Symploca.* In some areas, densely packed beds of the blue-black mussels *Brachidontes* and/or *Xenostrobus* occur. As on steeply sloping rock, the lower eulittoral carries a dense cover of algae; flat areas of the platforms which are emergent at low tide (Fig. 3A) are dominated by a dense community (Fig. 3B) of the brown alga *Hormosira banksii* ('sea grapes'), usually bearing the epiphyte *Notheia. Hormosira* is common in shallow pools (Fig. 2F) at this level, and on rock just above such pools the red anemone *Actinia tenebrosa* often occurs. On sloping rock at the rear of platforms thin turfs of the alga *Capreolia implexa* occur, as well as *Hormosira,* and animals such as chitons are often present.

The sublittoral includes the platform edge and below, and also pools or lower areas of the platform surfaces which are never emergent. The platform edge is distinguished by a sublittoral fringe zone of *Cystophora intermedia* where surf is most violent, giving way to other brown algae in slightly calmer regions. The edge, especially where it is dissected and pools are present, carries a rich and profuse growth of algae (Fig. *3C,* D); as many as 60 species may be present in a square metre, completely covering the rock surface. Pools on the platform surface are colonised by various species of *Cystophora, Sargassum* and *Caulocystis* (Fig. 3B), together with the starfish *Patiriella calcar;* sweeping by the brown algal fronds probably restricts the growth of other species in such areas. Parts of the platform at about low tide level are covered by a variety of smaller, mostly red, algae, such as *Laurencia, Wrangelia plumosa,* and *Jania,* and the green *Caulerpa.*

The deeper sublittoral is rich in algae and most areas are dominated by them: the kelp *Ecklonia,* numerous species of brown fucalean algae such as *Cystophora, Sargassum, Myriodesma* and *Scytothalia,* and a great variety of red algae occur. Most of these are as yet known only from drift collections, since few SCUBA collections have been made on this coast.

1C. *Sandy Beaches on Surf Bound Coasts*

Such beaches alternate with the rocky coasts described above. The sand is generally coarse and often mobile, and the beach is usually fairly steeply sloping. At first sight the beach is barren of organisms, and certainly the number of species present is very few compared with those on the rocky coast described above.

Clear sandy beaches bear little algal life except for microscopic diatoms adhering to the sand grains, and these have not been investigated in southern Australia as yet. Animal life may be more prominent, as is seen by washing sand in calm water with a few drops of formalin or alcohol. The amphipod sand-hopper *Talorchestia* is found under drift seaweed, and in sand at upper and mid-eulittoral levels a number of isopods (e.g. *Actaecia)* may be found. Nearer to low tide level various bivalves may occur.

2. *Coasts Subject to Moderate Wave Action*

Most of the north coast of Kangaroo Island is subject to moderate wave action, which becomes stronger passing west to Cape Borda and near to Cape Willoughby in the east. The change from strong wave action occurs somewhat west of Western River, where *Cystophora intermedia* becomes infrequent in the sublittoral fringe. The sheltered and protected bays on the north coast, especially American River inlet, are described below under 3.

The intertidal region (Fig. 3E) consists of sloping rock, boulders or pebbly beaches, or sandy beach, and usually drops off into a few metres of water where seagrass beds become dominant.

2A. *Sloping Rocky or Boulder Coast*

In the supralittoral zone, *Littorina* is dominant in many areas but is very variable in numbers. The black lichen *Lichina* may be conspicuous, and above any wave wash the orange and grey lichens *Caloplaca* and *Buellia* occur. In crevices, and occurring lower at low tide, is the active isopod *Ligia.*

The eulittoral zone is sparse of organisms compared to this zone on rougher-water coasts. In the upper eulittoral the small barnacles *Chthamalus* and *Chamaesipho* occur, but these are the only barnacles (apart from *Tetraclita* in shaded crevices) on such sheltered coasts. The mid-eulittoral often has a band of *Galeolaria* relatively low in this zone, and above it molluscs such as *Nerita, Bembicium* and *Monodonta* occur, with occasional blue-green algae such as *Rivularia, Isactis* and *Brachytrichia.* The lower eulittoral (Fig. 3E) again carries an algal mat, comprising the 'red' algae *Capreolia* (yellow-brown in colour), *Haliptilon* and *Jania,* and often the larger brown alga *Hormosira* ('sea grapes'). This algal turf provides a home and food for a variety of animals, such as crustaceans and polychaete worms.

The upper sublittoral is marked by a sudden and conspicuous change to the larger brown algae *Ecklonia, Cystophora* and *Sargassum.* These extend into deeper water provided a rock substrate occurs, and under them smaller algae and animals such as chitons and starfish occur. Often sandy or muddy areas occur just below low tide level, and here the sea grasses *Heterozostera* (in shallow water) and *Posidonia* (from 1 m downwards) become dominant.

2B. *Sandy Beaches*

Sandy beaches on coasts of moderate wave action usually are composed of finer sand particles and some mud; consequently they are more compact and stable than beaches on the south coast of the Island, and the organisms present are different.

Plants are represented in the intertidal only by microscopic algae; diatoms, some blue-green algae, and probably dinoflagellates may be found on the sand surface at low tide. At upper levels, *Talorchestia* occurs, and *Katelysia* (sand cockle) is found buried in the sand at lower eulittoral levels. The sand or lug worm *Arenicola* may also be found at this level on some beaches.

The seagrasses occur from a low intertidal level down. *Heterozostera* ('eel grass') is often common from just above low tide level to a metre or two below, while *Posidonia* ('tape weed') occurs from one to about 10 metres deep. Beds of *Amphibolis* may also occur on rock or in sandy substrate, and the latter two seagrasses usually bear numerous epiphytes.

An indication of the distribution of sea-grass meadows etc. north of Kangaroo Island is given by Shepherd & Sprigg (1976).

3. *Protected Coast with Sandy-Mud Tidal Flats*

This type of coast is exemplified by American River inlet (Fig. 4A), and is approached by the calm water areas of the Bay of Shoals. American River inlet is a system of lagoons with extensive tidal flats, either emergent or just covered at low tide, flanking a channel 3 - 5 m deep; some areas in Pelican Lagoon are 8 - 10m deep. A strong current flows in the channel between American River settlement and Strawbridge Point, and there is no significant freshwater flow into the inlet.

American River inlet is an aquatic reserve, and is a rich area for both marine plants and animals.

The supralittoral zone consists of either sandy mud flats (Fig. 4B) bearing a low shrub community of samphires *(Salicornia* and *Arthrocnemum)* or of the relatively bare rock of low, calcareous cliffs. Only in a few areas subject to wave wash does *Littorina* occur.

The eulittoral zone has the above samphires extending down into the upper part, with several small filamentous algae *(Chaetomorpha, Bostrychia* and *Capreolia)* growing in shade, either under the samphires or in shaded parts of the cliffs. The small barnacle *Elminius* is usually present on wooden structures (such as jetty piles) or rocks at this level. The mid-eulittoral invariably consists of a gently sloping sandy-mud substrate, mostly bare of algae except for patches of the green *Enteromorpha,* thin mats of blue-green algae, and diatoms. The dominant organism here is the mollusc *Bembicium* (Fig. *4C),* which extends well up into the upper eulittoral, together with beds of the mussel *Modiolus areolatus;* the crabs *Philyra, Paragrapsus* and *Helograpsus* also occur here. In the lower eulittoral, *Hormosira* ('sea grapes') is by far the most conspicuous organism (Fig. 40). However, it will usually be found to be growing on the large mussel *Brachidontes erosus,* which often forms beds at this level. Mats of *Chaetomorpha* and other small algae may occur here also, as well as the starfish *Patiriella exigua* and *Uniophora.*

The upper sublittoral is marked by the change to beds of seagrasses and also by the absence of the large brown algae which are so typical of rocky, wave-washed coasts. Various green (e.g. *Ulva,* the 'sea lettuce') and red algae (e.g. *Hypnea, Spyridia)* are common in the uppermost-sublittoral. *Heterozostera* occurs from just above low tide level to 2 m deep, and *Posidonia* (Fig. 4E, F) covers extensive areas of the flats, from 0.5 m to 3 or 4 m below low tide level. Another seagrass, *Halophila,* occurs along the edge of the channel or in deeper areas.

In the channel, especially on any rocks, large plants of the brown algae *Sargassum paradoxum* and *Scaberia* may occur, as well as numerous other algae, many of them epiphytic on *Posidonia.* But the striking organisms in the channel are the animals, where large colourful sponges, starfishes, anemones, holothurians, polychaetes and the razor fish *Pinna* are common, as well as sting-rays, eagle rays, small sharks and various fish.

American River inlet is a rich biological region, and is now a marine reserve.

THE MARINE FLORA IN GENERAL

The marine flora of Kangaroo Island is rich and diverse (see Womersley 1984 - 1996), and includes about half of the species found in the whole of southern Australia. Five genera of seagrasses, plus two normally brackish-water angiosperms *(Ruppia* and *Lepilaena)* occur on the coasts, and probably 500 - 600 species of marine algae.

A previous survey (Womersley 1959) of the distribution of marine algae along the coasts of southern Australia showed that of 1010 species analysed, 8% were cosmopolitan (widely distributed throughout the world), 32% generally found along southern Australia, 42% found in the eastern region (Victoria, Tasmania, and often extending to Kangaroo Island or Eyre Peninsula), and 16% were found in the western region, many of which reach Kangaroo Island. Only a few species appear to be endemic to Kangaroo Island or nearby coasts.

It is apparent that the geographical situation and varied coastal types and topography have led to Kangaroo Island having a particularly rich and diverse algal flora. Associated with this rich flora is the remarkably low grazing pressure of animals on the flora, and on both these grounds the flora is worth more investigation.

17: Historical Perspective:Kangaroo Island - 1803

by FRANCOIS PERON*

Important as our first work on 'Terre Napoleon' (South Australia) had been, it still did not cover all the details of this immense land; the excessive lateness of the season, the size of our ship, the frequent storms and contrary winds had not allowed us to complete the charting of 'Decrès Island' and the two gulfs opposite. This was the interesting point of New Holland for which we headed after joining up with the 'Casuarina' on the morning of the 27th of December, as I mentioned elsewhere.

The atmosphere was thick with fog and, as the winds were unfavourable, we experienced great difficulty rounding King Island to the south. On the morning of the 28th, the 'Casuarina' was almost lost on two rocks which rose very high but were so enveloped in haze that they could only be seen the very moment they could no longer possibly be avoided: a channel largely 400 yards wide separated these fearsome rocks: we had to rush into it: luckily it was deep and our consort was able to escape the danger threatening her. At that time, the barometer was steady at 28P,' to 28P! (and the thermometer barely rose above 12°, although we were then in a season corresponding to late June in our own climate.

From the 29th to the 31st of December, the humidity continued, and this last day was marked by one of those optical illusions of which the history of travel offers several examples. An immense band of mist fixed on the horizon gave such a perfect impression of land that everyone on board the two ships was taken in by it. All around we thought we could make out the capes, peaks and different indentations which form a great coastal system; but after having raced for several hours towards these imaginary shores, we recognised our error and hastened to get back on the course we had so inadvisably changed.

On the 2nd of January 1803, we sighted the lands forming the eastern-most tip of Decres Island. Of all the islands linked to the New Holland system, this is the largest one known: it is almost 100 miles long, from East to West, by about 30 miles wide, from North to South, and it is not less than 300 miles in circumference; it stretches from 35°32' to 36°5' in latitude South and from 134°14' to 135°50' East of the Paris meridian in longitude. Its entire southern side is exposed, unsheltered to the violent waves of the great Southern Ocean; Josephine Gulf (Gulf St Vincent) opens onto it to the North, and Colbert Strait (Backstairs Passage), to the East, separates it from Fleurieu Peninsula; to the West it is faced by the great Cambaceres Peninsula (Yorke Peninsula) and Lacepede Strait (Investigator Strait), at this point displays its magnificent channel.

As the entire northern coast of this island had already been charted on our previous campaign in 'Terre Napoleon', we came first of all to tackle Cape Sane (Cape Hart), the eastern-most cape on the island** and began immediately afterwards our operations on the South Coast. About twenty miles to the west of Cape Sane lies a bay which is very wide but shallow and unsafe and which we named D'Estrees Bay: Cape Linois forms its southern tip.

On the 3rd, at noon, we were already alongside the South Cape of Decres Island; it was called Cape Gantheaume: two small islands, completely encircled by reefs, are not far from it and are to the S.S.E. Vivonne Bay which we next discovered, has a mouth four or five leagues wide; but, like the previous one, it is not deep and could afford no shelter from the violent winds prevailing in these regions. Five or six miles out from this bay, towards its western tip, we sighted a large chain of reefs which we skirted around very closely.

From Cape Kersaint, which bounds Vivonne Bay to the West, as far as Cape du Couedic, Decres Island stretches for more than thirty miles in an almost East-West direction and presents no noteworthy details. The sea breaks violently along this coastline and here and there can be seen reefs which appear to be very close to shore: however, one of these reefs lying abreast of a little cape that we called Cape Bouger extends more than three

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*Chapter XXIV, from 'Voyage de Decouvertes aux Terres Australes', Vol. II, by Francois Peron (1816). Paris. [Translated by Jean Fomasiere].

**The French charts were wrong in showing Cape Sane to be the easternmost point of Kangaroo Island which is, of course, Cape Willoughby. This was correctly charted and named previously by Matthew Flinders reds].

miles out to sea constituting a hazard which is even more fearsome the closer it is to surface level. Cape du Couedic itself is guarded by a double chain of reefs and the small islands off Cape Casuarina are surrounded by similar reefs. Maupertuis Bay, between Cape du Couedic and Cape Bedout, has the same contour as the previous ones and is no more worthy of interest than they are.

Beyond Cape Bedout, which forms the western most tip of the island, can be found a deep ravine which appears to serve as a riverbed: we named it Ravine des Casoars after the large number of animals of this kind living on Decres Island.

On the morning of the 4th, we rounded the North West Cape which we charted under the name Cape Borda: from this point, we could see the coastline veering to the East and featuring several capes which were not very prominent and which were named Cape Forbin, Cape Prony (Cape Dutton), Cape Cassini, Cape d'Estaing and Cape Vend6me (Point Marsden), this last cape forming both the Northern point of the island and the Western tip of a large bay which we named Bougainville Bay (Nepean Bay) in honour of the worthy senior among French navigators: we cast anchor there on the morning of the 6th of January.

This bay, which is near the North Eastern tip of Decres Island, is the largest of all the indentations which occur on the island and also the most important in every respect; it is sheltered, by its position, from the South Westerly winds and its dimensions make it suitable for harbouring large fleets; its mouth is more than twenty miles across by eight to ten miles in length; its depth varies from nine to twelve fathoms and the bottom is all slimy sand and grass and very firm. In the western part of this bay are two coves of note: the longer one which is very narrow, was named Shoal Cove (Bay of Shoals) because of the shoals which obstruct it; the other, which is wider and less obstructed, was a special refuge for many herds of amphibian animals: we named it Seal Cove (Western Cove). A kind of cape, large and jutting out, Kangaroo Cape (Point Morrison), lies in the middle of the bay and separates the last mentioned cove from a small harbour which is extremely irregular and almost completely obstructed by sandbanks, but whose calm waters provide food for countless legions of pelicans; we named it Port Dache (Eastern Cove, American River). Cape Delambre (Kangaroo Head) bounds Bougainville Bay to the East. About two miles beyond this last mentioned cape is the small cove, Spring Cove (Hog Bay), which rates a special mention, because this is the only point on the island where we could obtain fresh water. Further along is du Guai-Trouin Bay (Antechamber Bay) which is three or four miles wide and almost as long and within which we had already lain at anchor the previous year. At this particular point the coast, sloping towards the SSE, heads off to meet Cape Sane of which we first spoke. Because of the complex outline of the eastern part of Decres Island, it so happens that the whole area lying between Port Dache and the last mentioned Cape, forms a peninsula twenty-five miles long by a league wide at its narrowest part and which we named la Galissonniere Peninsula (MacDonnell (Dudley) Peninsula), in memory of Admiral Bing's vanquisher.

I have just rapidly sketched the geographical portrait of Decres Island; now we will turn our attention to the physical and meteorological history of this large island.

This monotonous, barren quality which is so common to the different parts of New Holland and the number of islands around it, is indeed a singular phenomenon; such a phenomenon becomes even more inconceivable because of the contrast between this vast continent and the neighbouring lands. As when, to the North West, we saw the fertile islands of the Timor Archipelago meet our astonished gaze with their high mountains, their rivers, their many streams and their dense forests, when barely forty-eight hours had elapsed since we had left the drenched, arid and bare coasts of Witts Land (Northwest Western Australia), as when, to the South, we had admired the hardy vegetation of Van Diemen's Land (Tasmania) and the lofty mountains rising up over the entire surface of this land: even more recently, we praised the coolness and fertility of King Island .... The scene changes; we are reaching the shores of New Holland; and, for each point in our observations we will henceforth have to reproduce those dull images which have already wearied the reader so many times, just as they astonish the philosopher and afflict the navigator.

In fact, in spite of its great size, Decres Island is without mountains of any kind, in the true sense; the land is entirely made up of hills differing in height but whose peaks are almost all regular and uniform. All along the southern coast these hills spread out along a single plane and range in vertical height from two to three hundred feet. Their slopes are so smooth that on their upper sections they appear to be slippery; but, on the sea front, these same hills form a sheer drop and rise up like ramparts almost everywhere. Their colours are dreary and wild; they vary from grey to brown, or even a blackish colour; the patches which are not so dark are yellow ochre and more or less dingy.

From Cape Bedout to Ravine des Casoars, there can only be seen on these lands a single line of hills exactly like those on the southern part, but higher; and although they are devoid of every kind of tree, here and there one can still discern some traces of green vegetation. Ravine des Casoars affords us a glimpse through this chain of other hills inland which are wooded in parts. The north coast is arid and bare like the south coast and similar physical features can be seen all along it.

The shores of Bougainville Bay are themselves formed of low hills; but the green vegetation covering them and the forests, whose tips can be seen at different points, make this tart of the island more pleasant in appearance.

This is how the largest island in New Holland appears in the eyes of the navigator who circumscribed it on his route: however, the picture I have just traced, strictly accurate though it is for all the coasts on this island, would probably have become more interesting and varied had it been possible for us to go into the interior of this land to observe its physical features and different products.

As it is devoid of mountains and as that active vegetation which increases the earth's humidity and maintains it, is unknown here, Decres Island seemed to us almost entirely lacking in fresh water; it is true that we were at that time in the hottest season of the year: we managed, however, by digging a few holes in the small cove, Spring Cove (Hog Bay), to get ourselves a sufficient quantity of water for our daily consumption.

It is not only along the shore that Decres Island at the period mentioned, was without fresh water; it is a distinctive feature of the history of its animal populations which would seem to indicate that this shortage was then, if not total, at least fairly well general inland. In fact, as soon as the heat of the day began to abate, we could see large herds of Kangaroos and Cassowaries hurrying down to claim from the ocean a drink which the land probably denied them.

As this scarceness of water, the lack of high ground, the general poorness of the vegetation, combine, on these shores, to make the heat of the atmosphere more intense, it is not surprising that the average figure for our thermometric readings was *18.r* at midday. The 20th, 25th, 27th, 29th and 30th of January were especially hot days; at two p.m. and in the shade, the mercury rose on the island to 27.5°; the land breezes, that is, the ones from the North-East, NNE, and ENE, were then prevailing and we were able to determine that they were of the same nature as the scorching winds which devastate the inland region of New Holland.

The atmosphere on the arid and flat of Decres Island almost always to be perfectly calm: we barely had moments of light rain within the of twenty-eight days; and on the coasts proved a few course 15th of January, a slight storm which came upon us from the West was dispelled, so to speak, as soon as it reached the island's shores. The hygrometer functioned in accordance with the state of the atmosphere and the variations measured on this instrument, all within 68 and 94°, gave us 82.5° as the average reading: but of all the results of this kind which we obtained, the most precious was probably the rapid movement of the needle towards dry the instant the North East winds blew in strong gusts during the afternoon of the 29th: from 94 it fell right down to 68°.

From these remarkable facts and from similar observations we will have to report in chapter XXV, we can thus draw the following conclusion: 'The winds crossing New Holland from the North-East to the South-West, from the NNE to the SSW, and from the ENE to the WSW, are, for Terre Napoleon, hot, dry winds.

If we now try to compare these results from our meteorological research on Decres Island with the ones of the same kind we obtained on King Island, we find that the thermometer rose 11.5° higher on the first than on the second of these islands; and that the average temperature which had only been 14° in Elephant Bay, is *18.r* on Decres Island; and that the average humidity is at this last-mentioned spot 18.28° less than on King Island. Such differences would probably not depend on the location of two places so close together; but its true cause can be found in the different physical structure of the two islands I am comparing. And so everything is linked in the observation of natural phenomena: knowledge of the physical state of the land here throws light on the meteorological history of the island and the two together will be a useful aid to the naturalist.

Decres Island's mineral products, although less varied than those on King Island, are of more interest than they are; they are essentially composed of different kinds of primitive shale; between their layers can be found a few veins of opaque quartz, usually whitish in colour and sometimes reddish. The whole western side of Bougainville Bay is chiefly made up of ferruginous and very hard red sandstone: it is to this unusual stone that Kangaroo Cape, Cape Geographe (Bear Point), Cape Rouge and Cape Vendame owe their dark reddish colour which makes them stand out from a distance.

Two other kinds of sandstone are still to be found on Decres Island: one which is primitive, quartzy and very close-grained, forms rather long stretches of the coastline; the other, secondary, calcareous and not as hard, plays a role in the geological history of the earth which is, if not more important, at least more unusual than the first kind. In the midst of this stone trees are buried; one could even say entire portions of petrified forests .... In several places where the dunes drop away sharply, the trunks of these trees can be made out perfectly clearly; we can observe them right down to the slightest detail; we can see their branches, petrified as well, running into and merging with the common matrix: everything, right down to the parasitic climbing plants winding around the trees in question can be found in the same petrified state. At several points the sandstone dunes have caved in; their debris has been successively carried away by the waters and dispersed by the wind: the ground has been levelled and its surfaces are more or less even and at times very extensive. There can be seen, in an even more remarkable way, the unusual petrifications which I am describing. Cut down naturally to ground-level, the tree trunks seem to form vast mosaics: by carefully examining these trunks we can still recognize the different layers of ligneous tissue .... The astonished mind lingers over such a great phenomenon and seeks to discover in Nature the principle and agents to such a metamorphosis .... We will say in chapter XXVII what these agents appear to be; let us be content here with having stated the facts.

At several points on Bougainville Bay one encounters two kinds of calcareous stones: the first, of a closer grain and of more homogeneous tissue, is close in nature to the sandstones; the other is more like the cretaceous substances. These calcareous stones are usually superimposed on schistose rock, as in the primitive sandstones: they can be seen at more than 50 or 60 feet above sea-level, and at this height they contain a great quantity of detritus and remains of petrified shells.

The sand on the shore is very fine, of a quartzy nature, and mixed with about a fifth part of soil much reduced in calcareous content. This sand, pushed back from the seashore by the winds and the waters, rises up along a large part of the shore in dunes 60 to 80 feet high. I will come back to this sand and these dunes in one of the following chapters and we shall see how their history is linked in an interesting manner to that of the petrifications.

At the far end of the great bay under discussion are to be seen some forests which appear to extend quite a long way inland and which are made up (as are all forests in these distant regions) of different species of *Eucalyptus, Banksia, Phebalium, Mimosa, Casuarina, Metrosideros, Leptospermum, Styphelia, Conchium, Diosma, Hakea, Ebothrium,* etc. There are a great number of these trees, and especially the bigger ones, which are so completely rotten inside that they could not be put to any kind of use; this deterioration seemed to me to depend, in general, on the poorness of the soil, which does not provide these plants with a sufficient quantity of nutrient liquids when, after attaining great size, they require more moisture to keep them in good condition. What shall I say about the uselessness of the island's forests where food for man and animals is concerned? They have this unfortunate characteristic in common with all the forests of New Holland and the islands around it; a characteristic which is even more inconceivable seeing that these distant regions foster a great number of magnificent plants.

No trace of man's stay here can be discerned on the shores which we are discussing, and we only saw three species of mammals there: one belongs to the pretty genus of the Dasyures; the two others are new species and seem to be the largest of the unusual Kangaroo family. Several of those on Decres Island are as tall as man, and more so when they are sitting on their hind legs and tail and holding their body upright. As the absence of all enemies has favoured their propagation, these great quadrapeds have multiplied extensively on this island, where they form many herds. In a few spots which they frequent more commonly, the ground is so trampled that you can no longer see a blade of grass. Wide tracks blazed through the midst of the woods all lead, from all points inland, to the. sea-shore; these tracks, which crisscross in all directions, are all very beaten; you could think, at first sight, that an active and large tribe lived in the vicinity.

As this abundant number of kangaroos makes it as easy as it is profitable to hunt them, we were able to get twenty-seven of them taken alive on board our ship, quite apart from those killed and eaten by our crew. This precious acquisition cost us nothing by way of either ammunition or strain; one single dog, called Spott, was our provider: trained by English fishermen in this type of hunting, he chased the Kangaroos; and, when he had caught up with them, he killed them on the spot by tearing open their jugular arteries. Nothing less than the presence and shouts of the hunter was required to rescue the victim from certain death. With such a dog and such hunting methods, it is unquestionable that several men staying on Decres Island could have obtained plenty of food; one can even foresee that the weak and harmless race of Kangaroos would undoubtedly be wiped out in a few years by several dogs of the same species as the one mentioned.

Among the many seals to be found on the island's shores, a new species of the genus *ataria* * can be especially singled out; it reaches 30 to 32 decimetres in length (9 to 10 feet). The animal's fur is very short, hard and coarse; but its hide is thick and strong, and the oil prepared from its fat is as good as it is plentiful. In both respects, fishing for this amphibian would offer precious advantages; it is the same with some smaller species of seals which are also to be found in very great numbers on these shores and which bear furs of good quality. In the case of a business venture of this kind, Spring Cove would provide fishermen with enough water for their consumption; while the Kangaroos and Cassowaries would give them an inexhaustible and wholesome food supply.

Like all the other uninhabited islands of New Holland, this particular one is a gathering place for great flocks of land and sea birds: the first group is made up of many fine species of Parrots, Cockatoos, Tomtits, Muscicapidae, Bullfinches, Thrushes, etc.: among them we found the beautiful golden-winged Pigeon, the pretty ultramarine-ringed Tomtit, the red-rumped Bullfinch, the white New Holland Goshawk, a new species of Owl, etc. The oceanic and shore tribes provided for our special scrutiny yellow-necked Pelicans with half-white, half-black wings; Sea-gulls, a large species of which could be picked out by the beautiful lilac colour on the top of its body; Terns, Sea Pies, different species of Procellarians, a great Sea

Eagle, several Teals, distinguished by the brightness and diversity of their colours, etc., etc. But of all the birds that nature conferred on Decres Island the most useful to man are the Cassowaries: these large animals seem to inhabit the island in great flocks; but as they are very fleet runners and we went to little tr-ouble hunting them, we could only get three live specimens.

On land which is without fresh water, it is not surprising that we found no trace of Toads, Frogs and tree-frogs; on the other hand, the Lizard family, whose structure adapts so easily to arid and sandy places, was represented there by a great many new species: such as the Black Skink *(Scincius atterrimus,* N.), the Gecko *pachyurus,* the Gecko *sphincturus,* the Ocellate Skink *(Scincoides ocellatus,* N.), the Decres Island Iguana *(Iguana decresiensis,* N.) etc., etc. However important these different animals may be, they are nonetheless much less interesting as far as Science is concerned than are two other Saurians I described as a Tridactyl and a Tetradactyl: the first, like the Seps and Chalcideans, has only three toes on each paw, whereas the second has four, either on the front or the hind feet; a combination of toes hitherto unknown among reptiles but whose existence had been declared possible and even probable by my eminent master M. de Lacepede.

Of the different parts of New Holland we were able to visit, Decres Island seemed to us one of the places which were the least well *off* for fish. All our usual fishing methods and all our research could only just provide us with twelve species of fish, new ones, it is true, but five or six of which are not usually eaten. Among these species figured a *Labrus,* which, due to its dingy, grey, dull colours seemed to me to deserve the specific name of *squalidus;* a scomber, rather like the European mackerel but differing from it in its much smaller proportions and some details of its fins; a Scad, with a beautiful azure back; a Saury, 60 centimetres (22 inches) in length and glittering with all the colours of the prism; a small reddish dolphin; two barracuda; a fistularia; three *Batistes,* one of which is noticeable for its four brown lateral bands, another for its beautiful purple colour and pectoral fins; the third, which is a Balistacanthure can be distinguished particularly by the black colour of its body and by the four big spikes arming its tail on each side. But of all the Decres Island fish, the most amazing is a species of Shark attaining a length of 50 to 60 decimetres (15 to 20 feet) and which is very common in Bougainville Bay: night and day we could see several of these monstrous animals prowling around the ship in search for food and numbing with terror all those watching. One of these deadly Sharks became caught up in the swivel and we had to strike the tackle to hoist it on board: it was 50 decimetres long (15 feet 6 inches) and weighed no less than 500 to 600 kilogrammes (1000 to 1200 lbs); the span of its hideous jaws, lined with seven rows of teeth, was 74 decimetres (sic) (23 inches) .... And yet we could see specimens in the sea which were much larger than this one .... What animals then can satisfy the voracious appetite of such monsters! It must be the seals and their young; for otherwise one could not conceive of the existence of so many gigantic Sharks in a bay which, moreover, is so lacking in fish.

To declare that Decres Island was able to provide my collections with one hundred and thirty-six species of Molluscs, Crustaceans, Araneides, Insects, Worms and Zoophytes, is to state strongly enough that it would be impossible for me to enter into any lengthy details about this multitude of animals; so I will confine myself to presenting some of the principal results of my observations on this subject.

1. At the entrance to the small harbour, Port Dache, can be found a large species of Oyster which forms very extensive banks at this point; this animal's flesh is tender and delicate.

2. Among the shells peculiar to these shores, I will especially point out a fine species of Haliotis (Haliotis conicopora, N.), all of whose pores jut out and form so many open, truncated little cones. A second species of the same genus which I described under the name of Cyclobate (Haliotis cyclobates, N.), because of its almost orbicular and very deep mouth, is one of the finest and largest ormers known. Its nacre sparkles with all the colours of the prism.

3. To the far end of the bay are kinds of meadows covered with Algae and Ulva, amidst which live millions of sea Pen nates or Fan mussels in the slime and sand: these shellfish yield a silk comparable in every way to the silk obtained from similar animals along the coasts of Calabria and Sicily; the European Fan Mussels only live at a depth of 100 to 130 decimetres (30 to 40 feet) and it is very difficult to fish for them; whereas the ones on Decres Island are barely covered by 60 to 70 centimetres (25 to 30 inches) of water and one could easily gather up thousands of them in a few hours.

4. Our entomological collections were enlarged by fifty-four new species belonging to thirty-three different genera. Among this number of species was a species of Termes whose nests were 6 to 9 decimetres (2 or 3 feet) high; several species of Ants, which were to be found everywhere in countless hordes. We also saw two Scorpions, six Spiders, a magnificent *Cossus,* nine species of Cockroaches, Grasshoppers and Crickets, two Oniscidae, one *Lulus,* two Centipedes, one of which could be distinguished by the beautiful red colour of its belly; two Pentastomids, one black Earwig, one species of Butterfly from the division of Brassicaires of M. Latreille, in addition to different species of

Chrysomelids, Buprestids, Oedemeres, Lebies, Opis, Helops, Cerambycids, Thynnes, etc., etc.

From this enumeration of the principal insects on Decres Island, it follows that those from amongst these animals which thrive in arid, sandy places are in fact the most numerous and diverse on this island. On the contrary, on King Island, where the entire beach was covered with carcasses of Sea Elephants, carnivorous Insects make up the main body of insects I was able to collect there; there could be found Sylphes which exhale, so to speak, the foul odour of the rotten flesh they feed on; *Staphylinus,* designed, to use the expression of a famous naturalist, to reduce carcasses to their finaL state of decomposition; Trox which devour the ligaments and membranes of the oldest carrion; Histers greedy for brood, voracious Ixodes, etc .... And so, the most obscure details of a country's natural history are related in an interesting way to the whole of its physical structure.

5. At different points on Bougainville Bay, we observed with admiration some very massive blocks of a kind of calcareous rock entirely formed from a prodigeous number of Serpulas entwined together. Those among these animals which were on the surface of each group were the only ones alive; all the others, probably smothered because of the successive growth of their own offspring had died during a more or less remote age; but their tubes still retained their original strength. Of all the testaceous worms I was able to see, none seemed to me so close to the tubulous lithophytes; and it was on this account that I thought I should describe the animal in question by the name of lithogenous *Serpula (Serpula lithogena,* N.).

6. Decres Island is unquestionably one of the places richest in sponges; I collected twenty-six of the largest and finest specimens there. This remarkable fecundity enabled me to make a more detailed study of these zoophytes, which, by their structure, find themselves pushed back to the outer limits of the animal kingdom, and to establish within the genus to which they belong the following three sections:

Sponges without ocellated pores and distinct tubes, *Spongiae caecae,* N.;

Sponges with ocellated pores, without distinct tubes, *Spongiae occellatae,* N.;

Sponges with distinct tubes, *Spongiae tubiporae,* N.

In the zoological part of our work, I shall return to the advantages and details of these particular divisions.

7. Our collections of Acidians, already very numerous, were enlarged still more by several species peculiar to Decres Island. One of them which I described by the name of Anthropocephale *(Ascidae anthropocephala,* N.), is a beautiful red colour and its form bears a singular resemblance to a man's head seen in profile. Since then I have found this unusual zoophyte on the Josephine Islands (Nuyts Archipelago, Murat Bay) and in King George Port (King George Sound) in Nuyts Land (Southern Western Australia).

I shall say nothing of the beautiful starfish, the varied Sandstars, the glittering Sea-anemone, which the island was able to offer us; the history of so many animals, however important it may be, would not be in keeping with the nature of this work; suffice it for me to have pointed out how the shores in question abound in these creatures and how vast is the scope they offer the naturalist's research.

By skimming over in such a way the different branches of the general history of Decres Island, I naturally had to enter into details which would render superfluous most of those dealing with our stay in Bougainville Bay: the reader will probably remember that we cast anchor there on the morning of the 6th of January; the 'Casuarina' which had remained slightly behind, came to join us there the next day. After it had received some essential repairs this ship set sail on the night of the 10th-11th in order to go and complete the charting of the gulfs of 'Terre Napoleon'. M. Freycinet was only to spend twenty-six days on this difficult task; our engineer-geographer M. Boullanger was assigned to him in order to carry it out.

In the meantime, we mapped out the bay, the coves and harbour adjoining it; we lay a new sloop on the stocks and prepared the wood necessary for its construction: several men staying on shore were engaged in collecting our daily supply of water in Spring Cove: our astronomer regulated the chronometers and repeated different experiments on the dipping needle, the tides, etc., etc. Finally, M. Leschenault, Bailly, Lesueur and I collected, from all over, the island's mineral products, different plants and many animals peculiar to it.

When all this work had been completed, and, as the 'Casuarina' had not reappeared on the last day agreed on for its return, we set sail on the morning of the 1 st of February and thus left our consort behind, although her pressing needs were known to us and her help essential to us for the pursuit of our operations .... But we had hardly been gone for a few hours when the 'Casuarina' appeared on the horizon in full sail so as to catch up with us. We shall say, in the next chapter, why, in spite of all his efforts, M. Freycinet was unable to join up with us, to what danger he was exposed, what work he did during his separation from us; but, so as not to invert the natural order of events and of the narration, it is best to deal first with everything concerning the 'Casuarina's' mission in the two gulfs of 'Terre Napoleon'

18: References

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