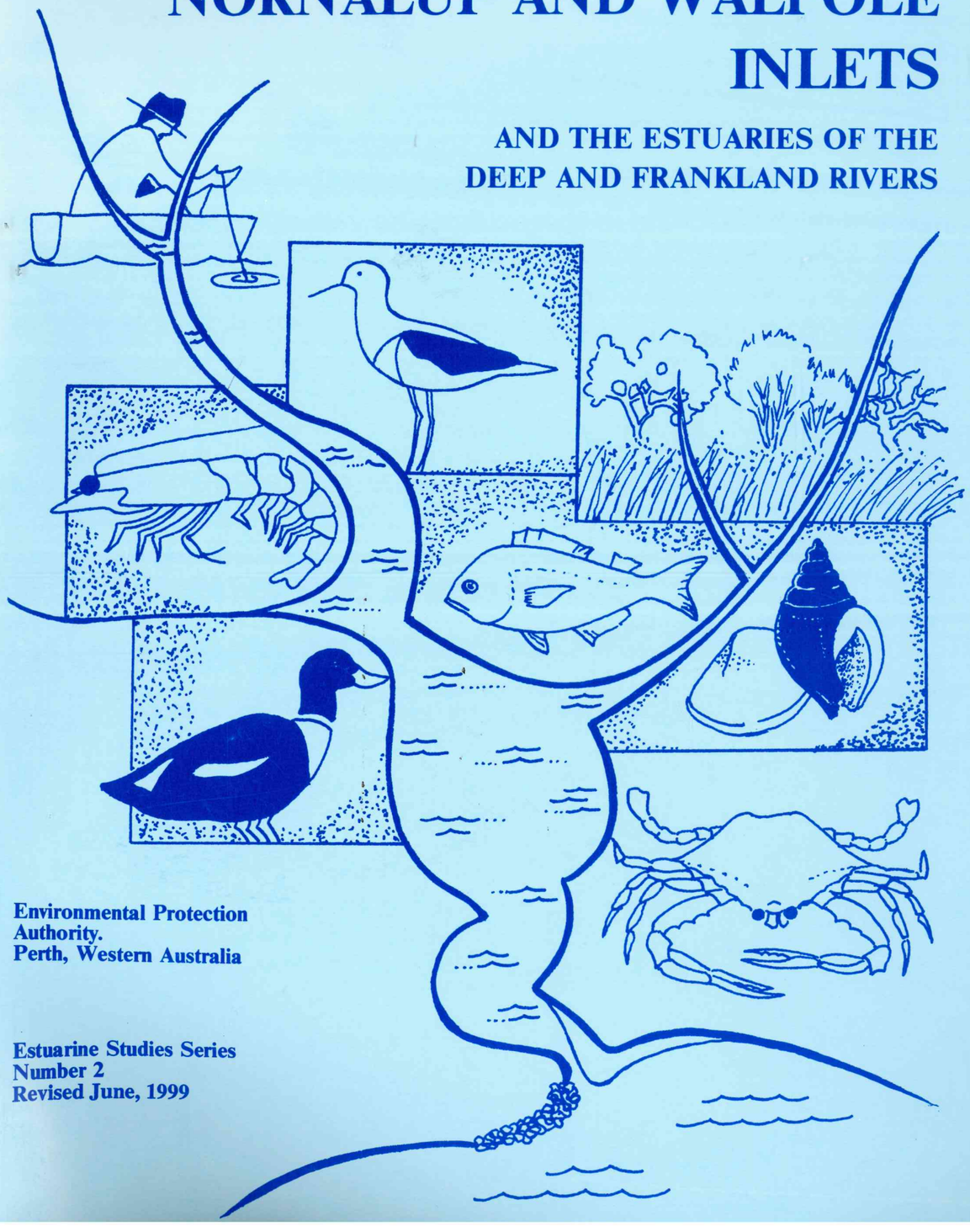
COASTAL LAGOONS
WESTERN AUSTRALIA

NORNALUP AND WALPOLE INLETS

AND THE ESTUARIES OF THE DEEP AND FRANKLAND RIVERS



Environmental Protection Authority.
Perth, Western Australia

Estuarine Studies Series
Number 2
Revised June, 1999

An Inventory of Information on the
Estuaries and Coastal Lagoons of South Western Australia

NORNALUP AND WALPOLE INLETS

and the estuaries of the Deep & Frankland Rivers

By: Ernest P Hodgkin and Ruth Clark

Nornalup-Walpole Estuary March 1988

Photo Land Administration, WA

Environmental Protection Authority
Perth, Western Australia

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COMMON ESTUARINE PLANTS AND ANIMALS

Approximate sizes in mm.

Plants
- A Rush - *Juncus kraussii*
- B Samphire - *Sarcocornia* spp.
- C Paperbark tree - *Melaleuca cuticularis*
- D Seagrass - *Ruppia megacarpa*
- E Diatoms 0.01

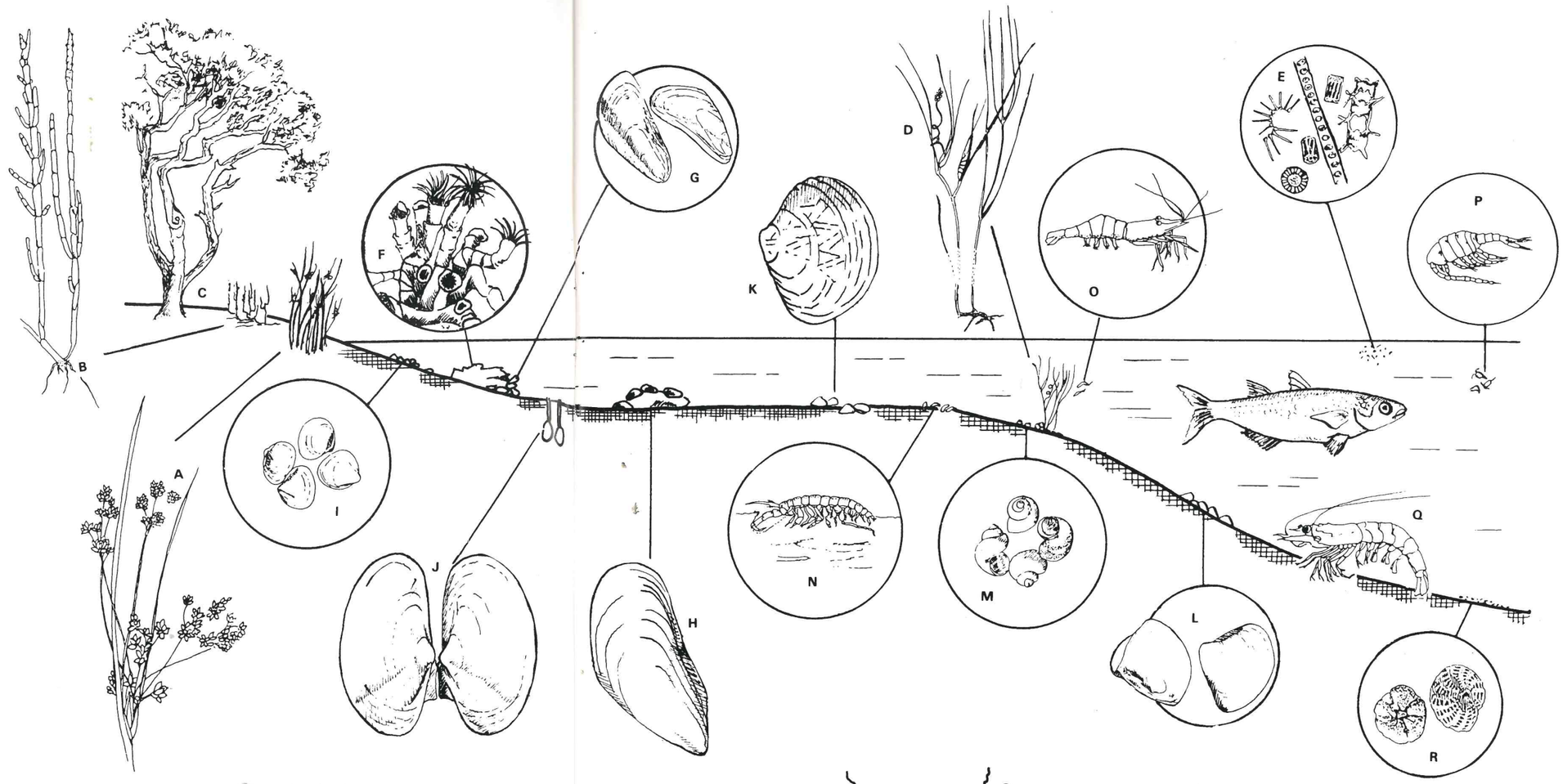
F Tubeworms - *Ficopomatos enigmaticus* 20

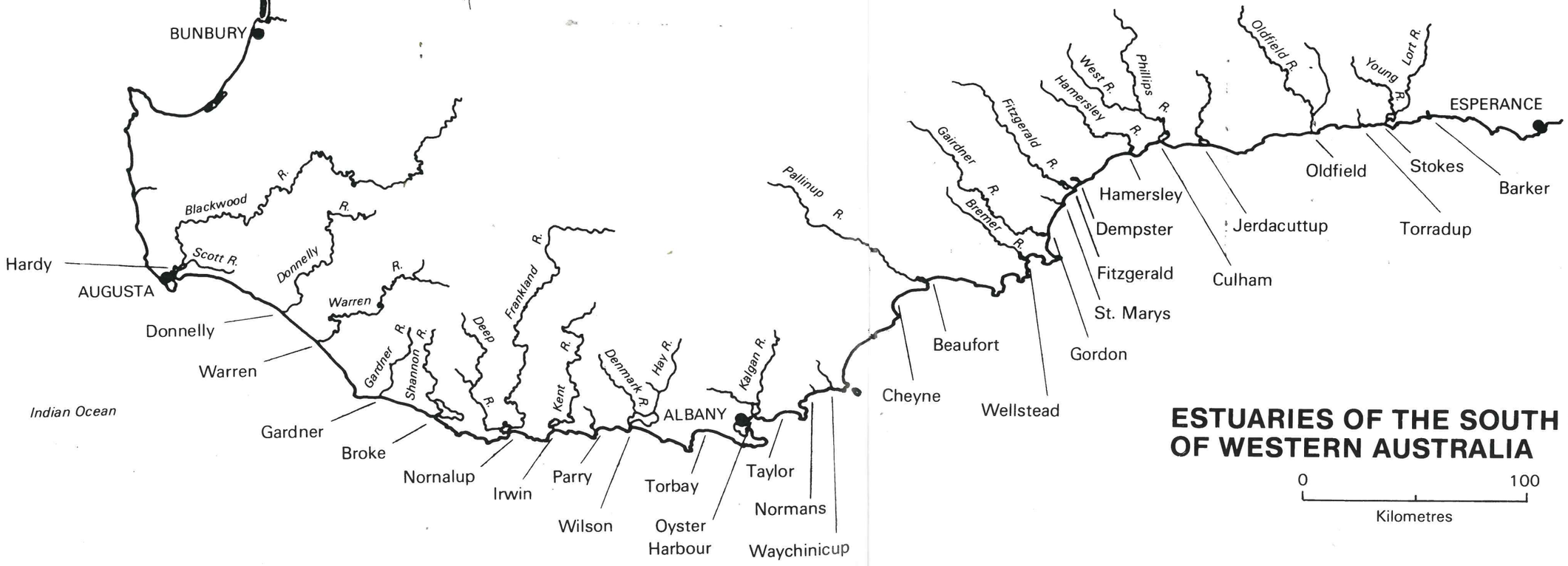
Bivalve molluscs
- G Estuarine mussel - *Xenostrobus securis* 30
- H Edible mussel - *Mytilus edulis* 100
- I *Arthritica semen* 3
- J *Sanguinolaria biradiata* 50
- K Cockle - *Katelysia* 3 spp. 40
- L *Spisula trigonella* 20

Gastropod molluscs
- M Snail - *Hydrococcus brazieri* 4

Crustacea
- N Amphipod - *Corophium minor* 15
- O Shrimp - *Palaemonetes australis* 40
- P Copepod - *Gladioferens imparipes* 2
- Q King Prawn - *Penaeus latisulcatus* 100

R Foraminifera 0.02





ESTUARIES OF THE SOUTH COAST OF WESTERN AUSTRALIA

0 — 100

Kilometres

FOREWORD

In 1987, the Government initiated, as part of the State Conservation Strategy, a series of studies of the estuaries of the south west of Western Australia. These studies summarised and interpreted data on the estuaries and provided background information for people and organisations interested in managing, conserving, studying and using the estuaries.

The original report on the estuary of Nornalup-Walpole Inlets and the Deep and Frankland Rivers was first published in 1988 and has now been revised to incorporate new information collected over the past decade.

Nornalup and Walpole Inlets and the estuarine reaches of the Deep and Frankland Rivers are fortunate in that they are mainly within the Walpole-Nornalup National Park and much of the catchment is in State forest. It is one of the few estuaries in the south-west that is permanently open to the sea, allowing good flushing and permanent access for marine fauna. This makes the Inlets as close to pristine as any waterways in the south west of the State.

This inventory of the Nornalup - Walpole estuary is highly recommended as a valuable information source to organisations such as local authorities, planners and conservation groups concerned with management, as well as for individuals interested in further study of our estuaries and coastal lagoons.

The principal author and coordinator of this series of studies - the late Dr Ernest Hodgkin - was a highly respected scientist who dedicated much of his work and life to estuarine and marine areas subject to environmental stress. His work on Hardy Inlet at Augusta and the Peel-Harvey estuary, has led to a better understanding of these sensitive environments and how they function, as well as providing management solutions to environmental problems. He developed these information inventories of the south coast estuaries with the assistance of his co-author Ruth Clark.

This report, combined with the others in the series compile an anthology of our estuarine wealth which will serve our society well into the future.

Hon Cheryl Edwardes, M.L.A.
Minister for the Environment

Hon Kim Hames, M.L.A.
Minister for Water Resources

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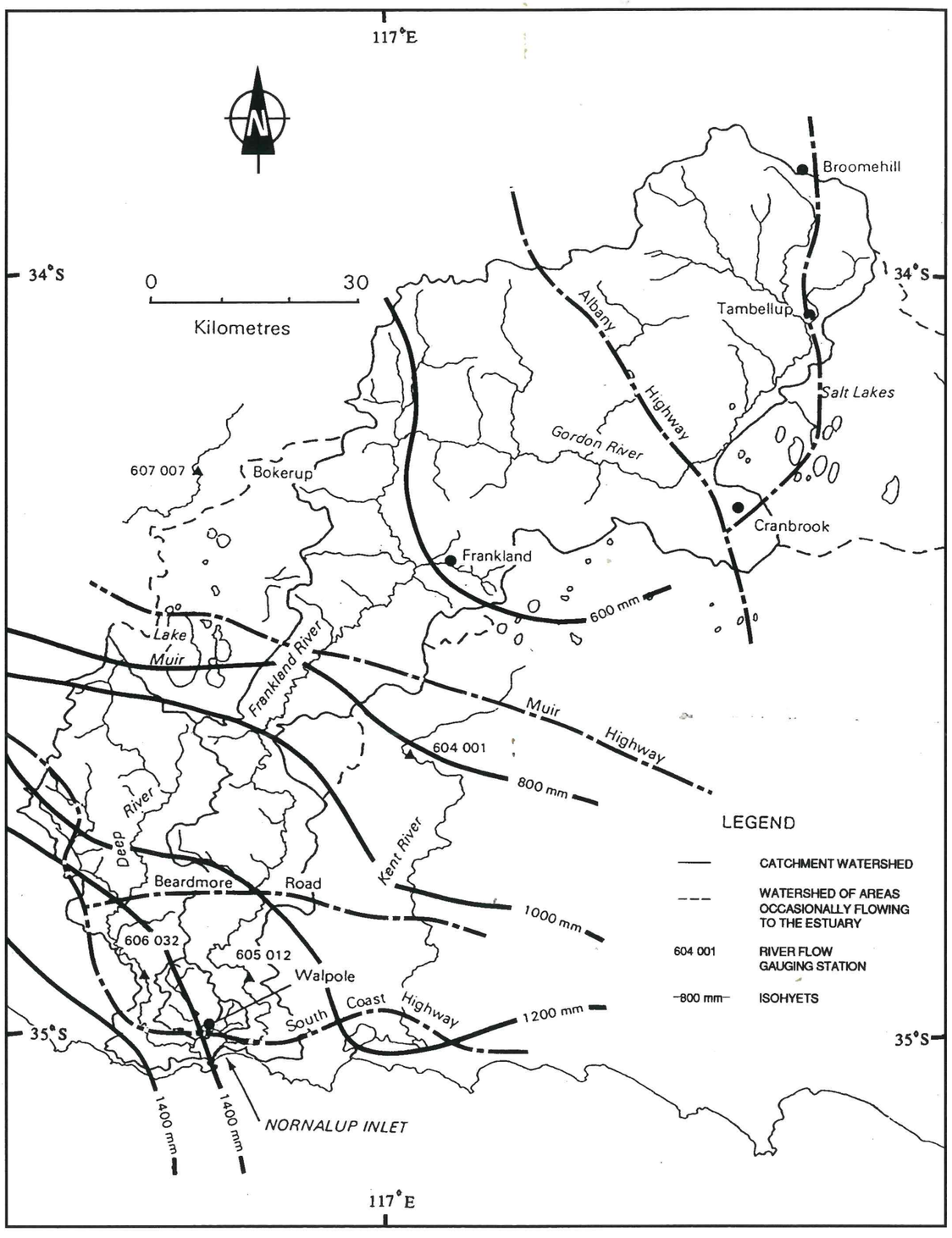


Figure 1 The catchment of the Nornalup-Walpole estuary.

1 INTRODUCTION

The Nornalup - Walpole estuarine system consists of the two coastal lagoons Nornalup Inlet and Walpole Inlet together with the tidal reaches of the Deep and Frankland rivers and the small Walpole River. It lies between the steep, granite hills on the southern edge of the Western Shield plateau and high Limestone dunes of the south coast. The Deep River is estuarine for 6 km and the Frankland River for 12 km. The small, shallow Walpole Inlet is linked to the larger, deeper Nornalup Inlet by a kilometre-long channel between steep rocky headlands. The channel from Nornalup Inlet to the sea opens against the granite cliffs of Rocky Head to the west and the dunes of the 10 km long Bellanger Beach on the east. The ocean bar never closes and the estuary is always tidal, unlike most estuaries on the south coast.

The estuary is in the highest rainfall region of the south west and the Deep and Frankland rivers discharge a large volume of fresh water into it in winter. With little river flow in summer, marine water (35 ppt salinity) fills the Inlets and extends far up the rivers, though often overlain by a layer of fresh water. In winter, the surface water of Nornalup Inlet is nearly fresh (10 ppt) but the deep water is seldom less than 30 ppt. In consequence there is a more diverse fauna than in other south coast estuaries (except Oyster Harbour).

Although the bar does not close, the entrance channel is shallow, variable and dangerous for navigation by small craft because of the heavy swell which constantly rolls into the bay, even during light winds and fine weather.

The first settlers, the Bellanger family, arrived by sea in 1910, they landed on the beach near the entrance and ferried their belongings across Nornalup Inlet to a site on the Frankland River at Nornalup. Later the Thompson family settled 5 km up the Deep River, at Tinglewood (Bellanger, 1980).

The Nornalup-Walpole estuary has a scenic beauty unlike anywhere else in Western Australia. The open waters of Nornalup and Walpole Inlets lie among the steep forest-clad hills and coastal dunes of the Walpole - Nornalup National Park, with its fine stands of tall Karri and Red Tingle trees that also border the peaceful waters of the Frankland River where it twists and turns in the deep valley it has carved through high hills. The sheltered lower reaches of both Frankland and Deep Rivers with their swamps and deltas backed by forest also have their special charm. The Nuyts Wilderness area stretches from the Deep River to the coast with dense coastal scrub, where an attempt to introduce the rare Noisy Scrub bird from Two Peoples Bay was not successful, probably because of a lack of suitable food.

The town of Walpole and the small settlement of Nornalup are the only centres of population in the southern, largely forested part of the catchment of the estuary. There are a number of towns in the low rainfall, agricultural area of the upper Frankland-Gordon River catchment (Figure 1).

1.1 LOCATION AND ACCESS

The estuary is located between 116° 40' and 116° 45' East and 34° 58' and 35° 03' South, on Natmaps 2227 Rame Head and 2228 Deep River: the mouth of Nornalup Inlet is at grid reference 760235.

The estuary is in the Shire of Manjimup. The Frankland River and the southern shore of Nornalup Inlet form the boundary between Manjimup Shire and Denmark Shire to the east. The catchment of the Frankland River extends into the Plantagenet, Cranbrook, Kojonup, Tambellup and Broomehill Shires.

The town of Walpole is 110 km west of Albany on South Coast Highway and 120 km by road from Manjimup to the north west. It is on the north shore of Walpole Inlet and boats can be launched to the Inlet at the town jetty. From 2 km east of Walpole a road leads to the Coalmine Beach Caravan Park and the Walpole Yacht Club where boats can be launched to Nornalup Inlet. Boats are launched to the Frankland River at Nornalup.

Walpole (population 290) has a hotel, cottage and other self catering accommodation and the large Coalmine Beach Caravan Park (leased from the National Park). There is a caravan park and cottages at Rest Point and there is cottage accommodation at Nornalup. House boats are also available for hire.

1.2 GEOLOGICAL HISTORY OF THE ESTUARY

The Deep and Frankland are ancient rivers that have cut deep valleys through the hard Precambrian rock over millions of years. However the estuary is of recent origin. Early in the Pleistocene (the last 2 million years) it would have been an open marine bay and Rocky Head would have been an island. It can only have been enclosed from the sea after development of the coastal dunes along Bellanger Beach and Circus Beach. During the last glaciation, 18 000 years ago, sea level was more than 100 m lower than it is now and Nornalup Inlet would then have been an open valley with river channels through it, many metres below its present bottom (the Frankland River channel was about 16 m below its present level at Nornalup). The Nornalup and Walpole Inlets only became an estuary when the Holocene rise in sea level flooded the valley about 6000 years ago.

Initially the estuary was deep and there was a deep channel to the sea, but the rivers have brought a considerable depth of sediment to it and formed the relatively flat bottom at 3 to 4 m deep. Wave action eroded the shores of the estuary, especially the northern and south eastern shores, and redistributed the sand to form the wide marginal shoals. The river valleys silted up and the river deltas and adjacent beach ridge flats grew out into the Inlet. Sand from the ocean beach washed into Nornalup Inlet and built the shallow flood tide delta, and sand from the Bellanger Beach dunes built the spit obstructs the entrance. The delta and narrow channel restrict tidal exchange with the ocean and so too the marine influence on the estuary. All these processes of erosion and sedimentation continue at the present time but there are no data on the quantities involved or the current rate of change.

2 CATCHMENT CHARACTERISTICS

The boundaries of the catchments are ill-defined, especially in the north, and the following areas are only estimates. There is rarely any river flow to the estuary from the Lake Muir basin or from the salt lake country east of the Gordon River catchment (Figure 1) where drainage is normally internal.

	Catchment gauged	areas	km² internal
Frankland River	4520	+100	1430
Deep River	882	+100	690
Walpole River	70		
Collier Creek	20		
Total	5690		2120

A total of 54 % of the catchment had been cleared for agriculture by 1968, most of this in the area north of Muir Highway where much of it had been cleared before 1930. South of Muir Highway most of the catchment is in State Forest and only small areas have been cleared. Most of the Lake Muir and salt lakes areas of internal drainage have been cleared.

2.1 LANDFORMS, GEOLOGY AND SOILS

The catchment lies on the southern edge from the Western Shield plateau where the hard Precambrian granitic rocks determine the main physical features. The area north of Muir Highway is open, gently undulating country at about 300 m above sea level with granite outcrops and laterite residuals. South of the Highway where the land slopes to the coast it is hilly with deeply incised valleys.

On the coast there are steep granite cliffs to the west of Nornalup Inlet, and at Rocky Head, but to the east the Pleistocene limestone dunes along Bellanger Beach sweep round to the next rocky headland. This dune barrier encloses the Inlet and the lower Frankland River. Hard limestone (Travertine) often forms a cap over softer rock beneath. Holocene (the last 10 000 years) dune sand often caps both the granite and the limestone, it is only stabilized by vegetation and there are a number of blowouts from the beach.

Most of the lower rainfall area north of Muir Highway is in the catchment of the Frankland River and its major tributary the Gordon River. It is largely cleared land with moderate slopes and sandy or loamy yellow duplex soils so that the erosion risk is high in summer. The Gordon River catchment extends east into salt lake country from which there is normally no drainage to the estuary. South of the Highway rainfall is greater than about 700 mm, and the southern third of the Frankland River catchment and the Deep River catchment are mainly forested country, hilly with a thinner laterite cover and leached sandy and gravelly soils. Erosion is normally low under the forest cover, though there is a risk of sediment movement with clear felling operations.

Much of the small Walpole River catchment is a low-lying valley with hilly country in the north and sandy swampy soils near the estuary. The catchment includes a small area of dairy farming.

2.2 COASTAL FEATURES Figure 2.2

The entrance to the estuary is at the extreme western end of the 10 km long, south-facing Bellanger Beach where it is protected from south westerly winds and swell by Rocky Head. In this sheltered location tidal exchange keeps the bar open in summer when there is no river flow, and although it shallows in summer it never closes. Transport of sand along Bellanger Beach is predominantly from west to east in winter, away from the entrance, and in summer from east to west depositing sand near the entrance channel and shallowing the bar while there is no river flow to help keep it scoured.

West of the mouth, Rocky Head is linked by the low-lying sandy peninsula of Circus Beach and The Peppermints to the precipitous coastline that stretches 8 km westwards to Point Nuyts and beyond. Eastwards along Bellanger Beach, the dunes rise from the bar to 20 to 40 m high for 5 km and then to dune limestone cliffs up to 80 m high bordering the beach. The pattern of dune blowouts reflects the direction of the prevailing winds: near the mouth in the shelter of Rocky Head the easterly and south-easterly winds of summer; along the exposed eastern end of Bellanger Beach and at Circus Beach the strong winter south-westerlies. Holocene dune sand has invaded the estuary at The Peppermints and in the vicinity of the mouth.

2.3 RAINFALL

Rainfall decreases progressively inland, with 1300 mm a year at the coast to less than 500 mm in the northern part of the catchment (Figure 1) (Table 2.3). This is mainly winter rainfall (Figure 2.3), but there are occasional summer storms: 163 mm at Walpole in February 1955 and more than 200 mm at Tambellup in January 1982. There has been a gradual decrease in mean annual rainfall in the lower catchment since the early 1950s, 250 mm at Walpole:

1956 to 1965 1465 mm
1966 to 1975 1319 mm
1976 to 1985 1265 mm
1986 to 1995 1215 mm

Table 2.3 Highest and lowest rainfalls for the Walpole and Tambellup Post Offices rainfall stations since 1951 and 1948 respectively (Commonwealth Bureau of Meteorology).

	Walpole PO	Tambellup
Average annual	1331 mm	459 mm
Lowest annual	913 mm (1987)	273 mm (1987)
Highest annual	1997 mm (1955)	695 mm (1955)
Highest monthly	422 mm	>200 mm
Highest two monthly	718 mm	236mm

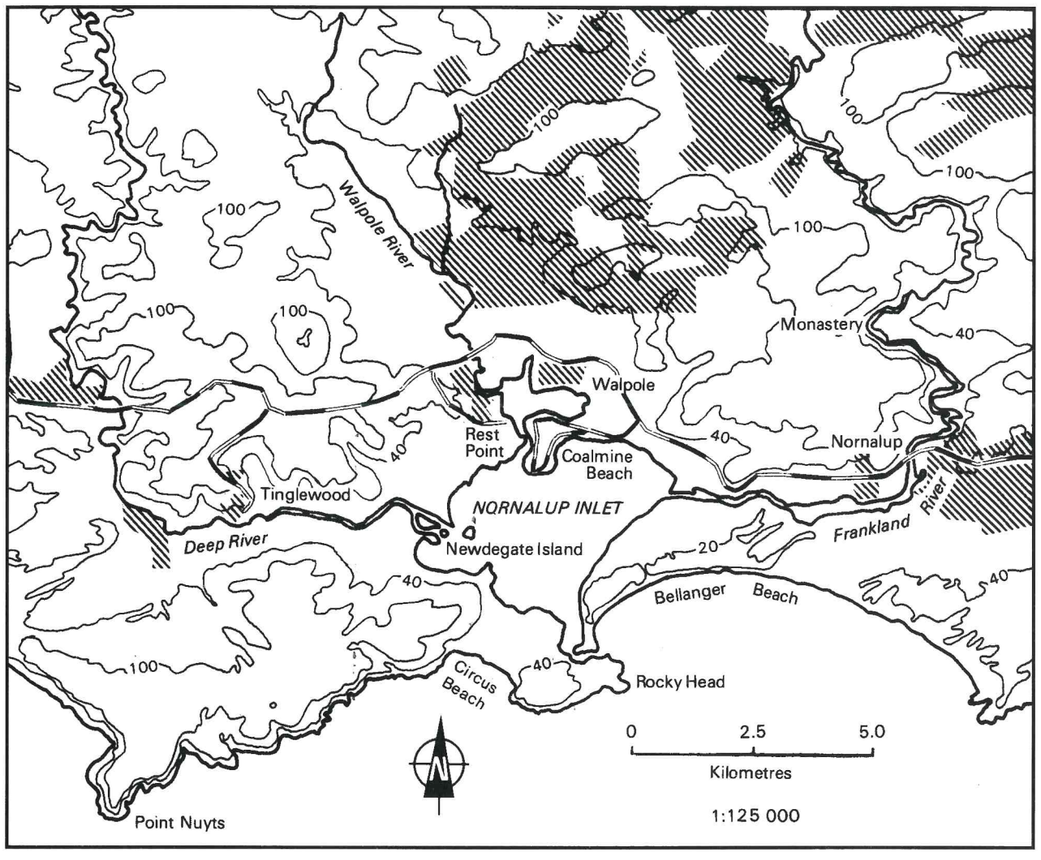


Figure 2.2 The Nornalup-Walpole estuary. Contour map. Shaded areas cleared land, 1987.

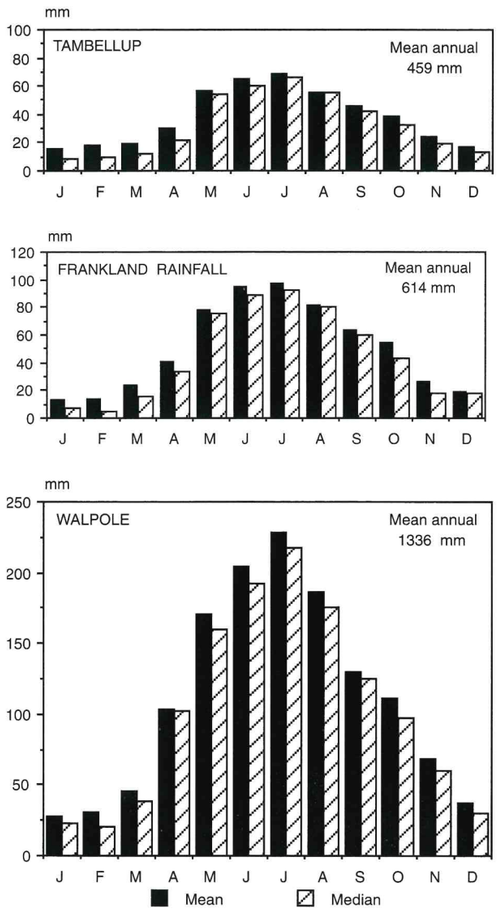


Figure 2.3 Monthly rainfall at Tambellup (1904-1997), Frankland (1923-1995) and Walpole (1951-1993). means ■ medians ▨. (Commonwealth Bureau of Meteorology)

2.4 RIVERS

The Frankland-Gordon River is about 400 km long and the Deep River 120 km. The Walpole River (15 km) and several small creeks flow to Walpole Inlet from the north and east. The estimated mean annual flow to the estuary is 390 x 10^6 m^3. Eighty percent of river flow comes during the five months June to October with negligible flow during the summer, except from infrequent floods in the upper Frankland River catchment (Figure 2.41). Both rainfall and runoff decrease rapidly away from the coast and 80% of river flow is from the high rainfall (800-1400 mm) forested area south of Muir Highway where mean annual runoff is about 190 mm. Figure 2.42 illustrates a similar situation in the nearby Warren River catchment.

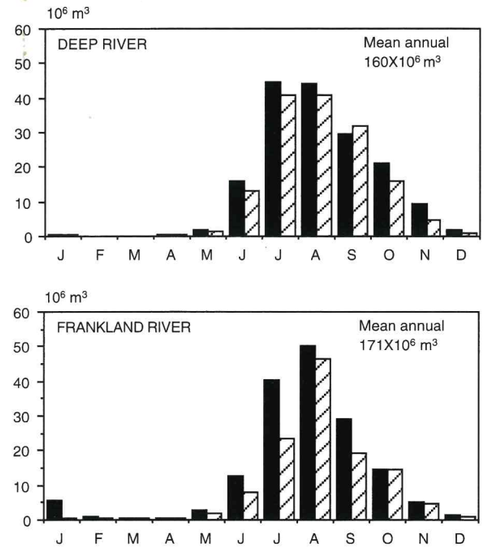


Figure 2.41 Monthly flows at the Deep River 606032 (1964-1972) and Frankland River 605012 (1953-1995) gauging stations. means ■ medians ▨. (WA Water and Rivers Commission)

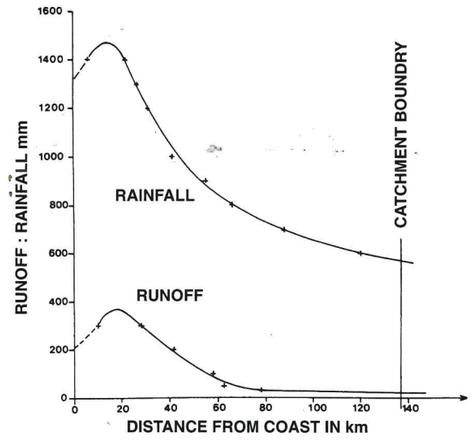


Figure 2.42 Profile of rainfall and runoff distribution in the Warren River catchment. (Collins and Fowlie, 1981)

There is great variation in flow from year to year, with up to 5 times the mean in a wet year (1945) and less than one third in dry years. Moreover a large proportion of the annual flow occurs over brief periods. For example: following 387 mm of rain in July 1964 at Walpole, the August river flow at the Frankland River gauging station (605012) was 146 x 10^6 m^3: this was almost half the total for the year and about twice the volume of the estuary. The downpour of January 1982 produced an exceptional summer flow of 118 x 10^6 m^3, most of it from the upper catchment.

SEDIMENT TRANSPORT During winter, river water has a high content of silt- and clay-sized particles, mostly clay minerals, organic matter and fine siliceous sand which are carried into the estuary (Hassell, 1962). Fine sediment flocculates in contact with salt water and settles out in the Inlets, but during strong river flow much also goes out to sea.

It is unlikely that there has as yet been any great increase in the volume of sediment entering the estuary as the result of clearing in the catchment; most of the coarse sediment probably collects in river pools. However, there are no data on the volume of sediment transport and it would be valuable to have records of both fine suspended and coarse bed load sediment during river flow, especially during floods when sediment transport is greatest.

The lower estuarine reaches of both large rivers are dredged periodically to maintain navigable channels, especially near the deltas, but the need for this is probably mainly because of redistribution of sediment already present in those parts of the rivers and scoured from the banks, rather than as the result of an increase in sediment brought to the estuary.

WATER SALINITY The waters of both Deep and Walpole rivers are fresh. The Frankland River is saline; the average for the 10 years 1973-82 was 1980 mg/l TSS (2 ppt), but salinity has increased progressively over the last 40 years by over 40 mg/l a year from only 590 mg/l in the 1940-49 decade (figures from gauging station 605012). As in the Blackwood and other major rivers of the south west, salinity increases progressively upstream and the saline water (about 10 ppt) of the Gordon River in the upper catchment is diluted by fresh water from the high rainfall lower catchment.

2.5 LAND OWNERSHIP AND USE

North of Muir Highway the catchment is mainly alienated agricultural land for cereal production and sheep farming. Most of the Deep River catchment and that of the Frankland between Muir Highway and Beardmore Road is Forest Reserve (Figure 1). The Nornalup Land Settlement began in the 1920s and the southern part of the Frankland catchment is partly cleared for grazing. Most of the land south of the estuarine reaches of the Deep and Frankland rivers and an area immediately north and west of the estuarine part of the Frankland is in the Walpole-Nornalup National Park. A bushfire burnt through parkland south of Nornalup Inlet in December 1986 and a large bush fire in January 1987 burnt areas north of the Frankland river. Only a small portion of the National Park is now untouched by fire in recent times.

2.6 VEGETATION

Much of the coastal sand dune country is covered by Peppermint *(Agonis flexuosa)* scrub or woodland with some open heath. Inland from the dunes, stands of Karri *(Eucalyptus diversicolor)* with Red Tingle *(E. jacksonii* and *E. guilfoylei)*, Marri *(E. calophylla)* or Jarrah *(E. marginata)* dominate higher ground, depending on the soils. Lower sandy ridges carry Banksia woodland, while low ground is occupied by Paperbark *(Melaleuca)* woodland and sedge swamps.

Karri forest covers hilly country with loamy soils in the southern part of the forest, giving way to Jarrah and Marri forest northwards, with Jarrah reaching its best development in the hilly, dissected laterites with a mean annual rainfall above 900 mm and becoming more open and depauperate as rainfall decreases. Blackbutt *(Eucalyptus todtiana)* and Bullich *(E. megacarpa)* occur in the damper valley floors and along streamlines. Throughout the forest, broad swampy drainage lines and open sandy flats subject to seasonal inundation carry a low open woodland of Melaleuca and Banksia with an understorey of heaths and sedges. Logging activity has been widespread through the forests, but current integrated logging for sawlogs and chip logs is mainly concentrated in the Karri-Marri forest.

3 ESTUARY Figure 3.11

Nornalup and Walpole Inlets together cover an area of 14.8 km^2. Nornalup Inlet is 5 km east-west, parallel to the coast and 3 km north-south and Walpole Inlet is also elongate 2 km east-west. The Deep River is estuarine for 6 km and the Frankland for 12 km. Because the bar is open, water level in the Inlets varies tidally, but the daily range is only 40% of the ocean range (at Albany) being damped by the small, shallow entrance (Marine and Harbours). There can be dramatic rises of water level in the riverine stretches during floods, with a much smaller rise in the Inlets. In January 1982 the water rose 4.5 m in the Frankland River at Nornalup, over the hand rail of the bridge.

3.1 LANDFORMS

RIVERS Upstream of Nornalup the Frankland River winds for 6 km in a well defined channel through steep-sided, forest-clad hills and is navigable for most of that distance. It is scoured to 5 m deep in places. For 6 km downstream it flows in a wide, shallow (less than 1 m) stretch, through parts of which a navigation channel has been dredged, and is flanked by riverine flats, swamps, and rock on the north shore near the Inlet. The Deep River also has a well defined channel between steep hills on its north bank and sandy flats and swamps on the

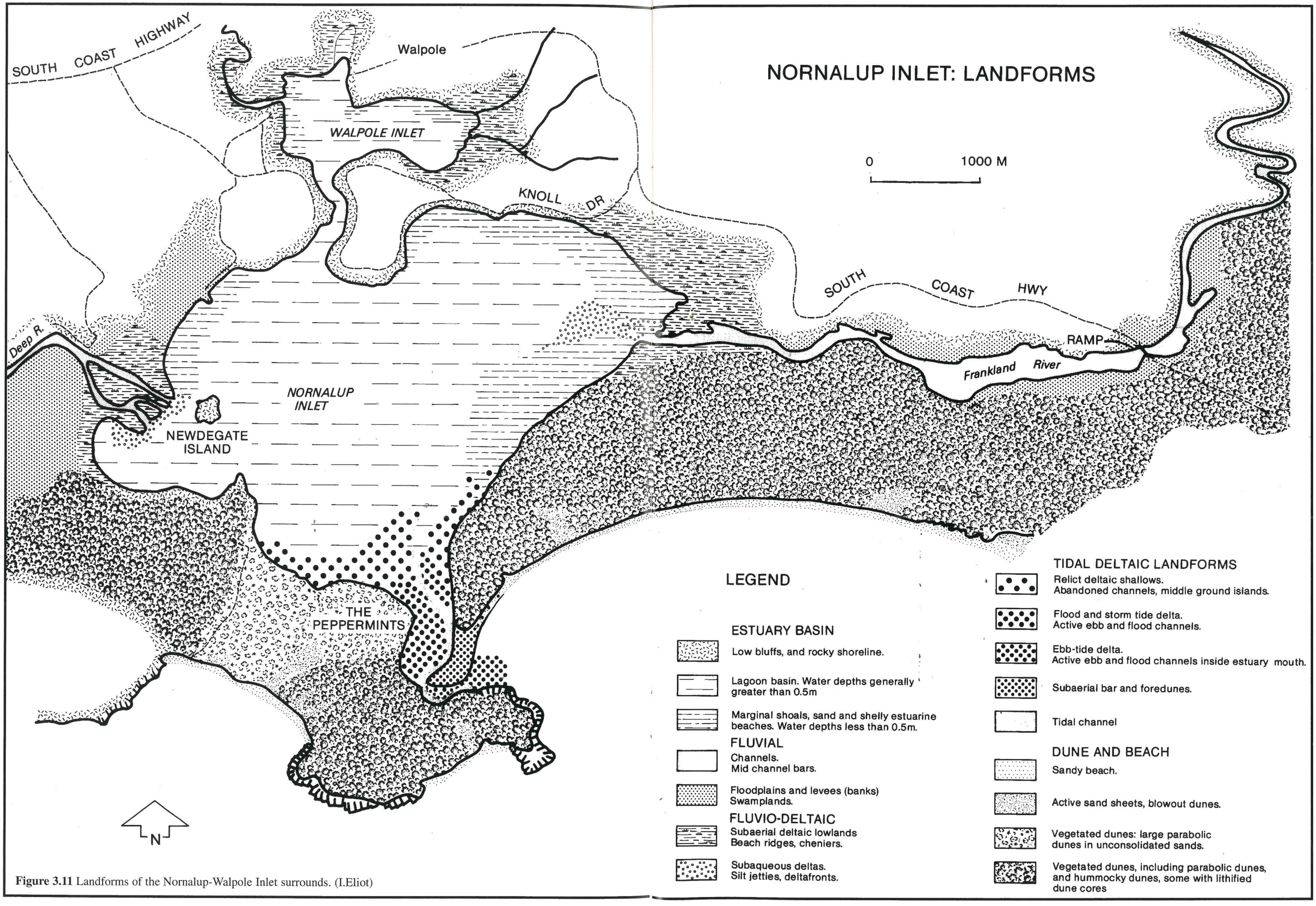


Figure 3.11 Landforms of the Nornalup-Walpole Inlet surrounds. (I.Eliot)

south bank; it is 1-2 m deep in the lower reaches and to 5 m in the upper reaches. There are three river channels through the Deep River delta only, one of which is navigable. The uppermost estuarine reaches of both rivers are blocked by fallen logs.

Both rivers discharge through extensive riverine deposits and deltas and over the wide sandy shallows into Nornalup Inlet with navigation channels are dredged through them. The Deep River was originally dredged in 1954. L. H. Thompson (local resident) reported that nearly 2000 mm of rain had fallen over the whole of 1955 and a lot of silt had come down the River, but the dredged channels were not filled in. The banks fell in and left a course about 35 feet wide which was a fraction wider and approximately a foot deeper than the original bed. On the south side of the river, the sediment fell in to a small part of the channel. Progressive siltation occurred but no dredging was required until 1956. In the summer of 1961/62 explosives were used to increase the depth slightly.

The Frankland River was also dredged in 1954. No siltation was observed when the channels were examined in 1956 and 1958, but in 1963, 30 m^3 had to be dredged. During the January 1982 flood the Frankland River banks were seen to be falling in near the Monastery and one of the dredged channels had silted up to almost half its depth since the last dredging (Marine and Harbours).

The delta sands have been reworked by wave action to form a series of beach ridges that are now fixed by vegetation. These are particularly well developed in the Deep River delta.

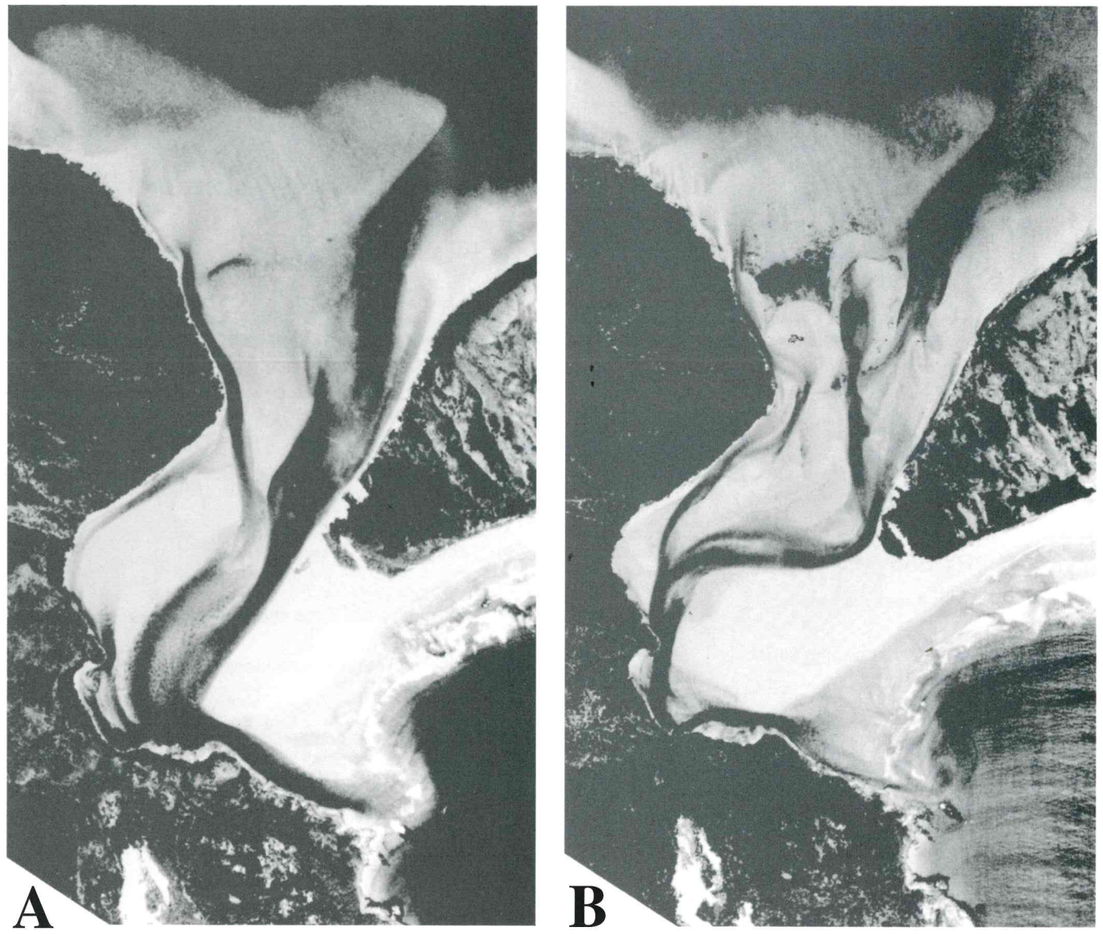


Figure 3.12 Nornalup Inlet. The inlet channel, tidal delta and bar. A January 1966, B January 1987. (Photos, Department of Land Administration, WA).

WALPOLE INLET There are rocky shores on the southern and north eastern shores; the eastern and western shores are low-lying and sandy or swampy where the Walpole River and Collier Creek discharge to it. The 1 km long channel from Walpole Inlet to Nornalup Inlet is bordered by steep granite hills with rocky shores.

NORNALUP INLET The shoreline is granite on either side of the Walpole Inlet channel entrance; eastwards the northern shore is in the softer Tertiary Siltstone of Coalmine Beach which is eroded into a cliff with a narrow beach at its foot. Along the south-eastern shore the dunes are truncated against the shoreline and sand eroded from the shore has formed wide shallow marginal shoals that continue north of the Frankland River mouth

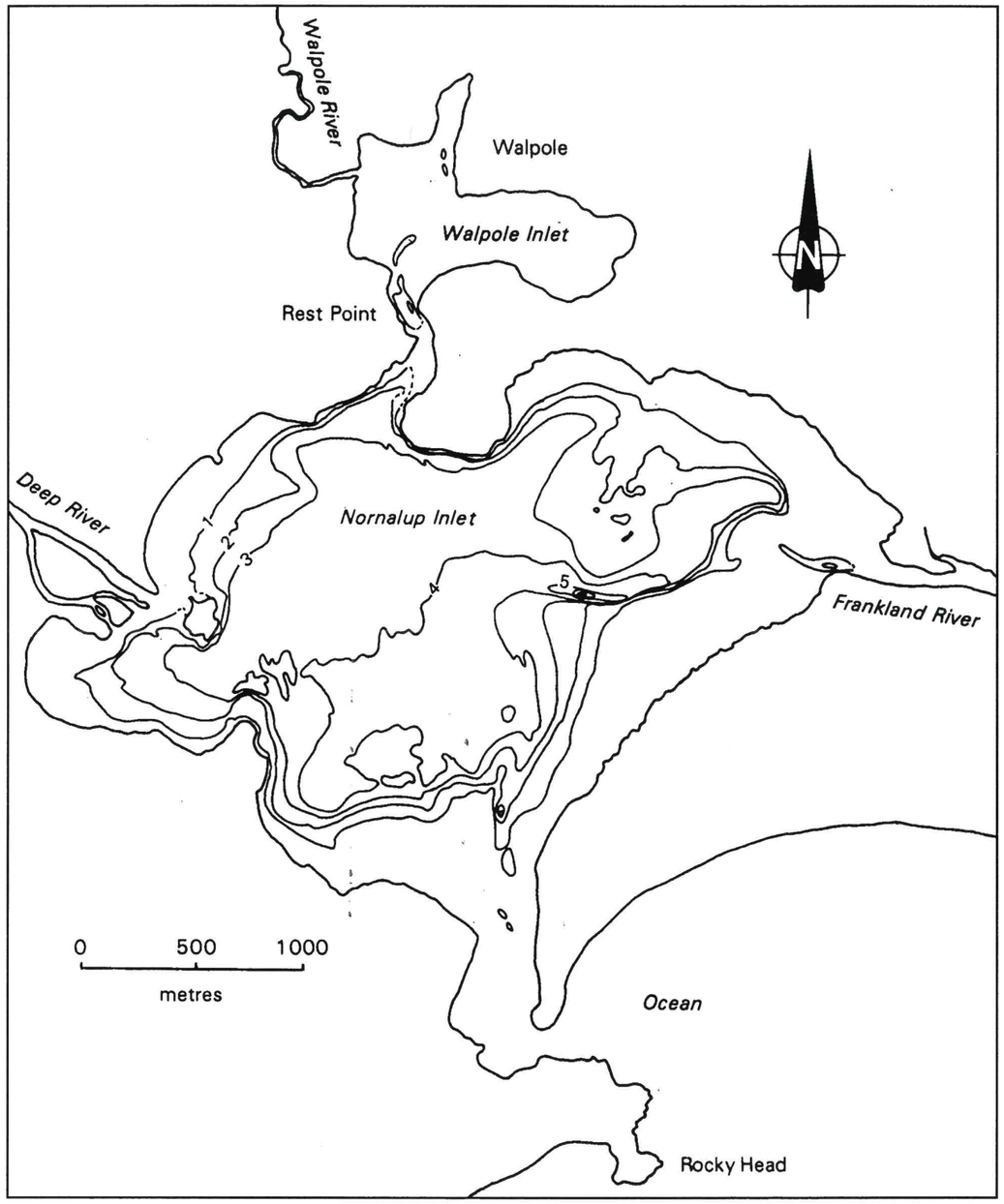


Figure 3.2 Water depths of Nornalup and Walpole Inlets. Depths in metres below chart datum, approximately 0.2m above mean sea level (AHD) (Marine and Harbours 142-1-1, May-June 1985).

to Coalmine Beach. The western shore is formed by the swamps and beach ridges on either side of the Deep River delta. South of this a sand spit is progressively enclosing a small bay. A shoal links the delta to the granite Newdegate Island (Snake Island), which rises to 19 m. The sandy south-western shore is interrupted for a short distance by rock and poorly consolidated sandy lignite outcrops on the floor of the Inlet.

ENTRANCE CHANNEL and BAR The channel from Nornalup Inlet to the sea takes different routes through the mobile sands of the flood tide delta where it is less than 1 m deep (Figure 3.12). At the bar it first swings south west and then sharply eastward against a limestone cliff and the granite of Rocky Head (Figure 3.11). The channel here narrows to about 20 m, being constricted by the sand spit from the coastal dunes to the north east. It may be several metres deep here but shallows to less than 1 m where it crosses the beach to the sea, but it never closes completely. The sand spit from the eastern shore is about 2 m above mean sea level, with only sparse vegetation for 500 m to the stable dunes. The beach is made of well sorted, fine sand with 65% quartz and 25% shell material.

3.2 WATER DEPTHS Figure 3.2

A hydrographic survey of Nornalup Inlet was made by PWD in 1912 (Chart 16302) and Walpole and Nornalup Inlets were resurveyed in 1985 (Figure 3.2). There are only minor differences between the two charts. Walpole Inlet is very shallow (less than 1 m) except for the dredged boat channels. The channel connecting Walpole Inlet to Nornalup Inlet has a maximum depth of 2 m. The marginal shoals of Nornalup Inlet slope steeply to the 3 to 5 m deep central area. A well defined channel persists off the mouth of the Frankland River to the central deep part. The flood tide delta is very shallow except where the narrow channels cut through it.

3.3 SEDIMENTS

The marginal shoals and deltas have clean, well sorted sands and, with a small water content, they are generally firm. There are muddy sands with shells on the margins of the shoals (1 - 2 m deep). In the deeper parts of Nornalup Inlet the sediment consists of sandy and clayey silts with a high water content, up to 80%. Hassell (1962) examined the sediments and reported on their mineralogical content. In Walpole Inlet the sediment is mainly a fine organic mud.

Probes taken in the dredged channels of the Frankland River produced soft mud for 2-4 m and then clay (Marine and Harbours map: 33962-5-1B). A test bore at the Frankland River Bridge penetrated 16 m of sediment over weathered granite (PWD, quoted by Hassell).

4 WATER CHARACTERISTICS

4.1 SALINITY

The CSIRO Division of Fisheries took water samples at eight stations in the estuary at roughly quarterly intervals from 1944 to 1951, with data for temperature, salinity (chlorinity), oxygen, phosphate and nitrate (Rochford, 1953a , 1953b, Rochford & Spencer, 1953a, 1953b and Spencer, 1952). This, and more recent salinity data, are summarised in Figure 4.11. Marine salinity water (36 ppt) fills the Inlets for about six months in summer and extends far up the rivers, but in winter the surface water of Nornalup Inlet may be nearly fresh (10 ppt) over the deep water which is seldom less than 30 ppt. Salinity can be lower in winter in Walpole Inlet, but even there deep water may be half sea water salinity.

In the Frankland River the deep water is greater than 30 ppt almost to the head of the estuary in summer with lower salinity water flowing over the surface. All marine water can be flushed out in winter or may persist below fresh surface water (Figure 4.12). Marine salinity water also penetrates to the head of the Deep River estuary in summer, however in its sheltered reaches there is frequently an abrupt change (halocline) between a surface layer of fresh water and high salinity deep water. The surface layer becomes shallower and more saline as it moves down river (Figure 4.13).

4.2 TEMPERATURE

In summer, water temperature in Nornalup Inlet is 20°C to 22°C and in winter it ranges from 12°C to 17°C at the surface and the deep water is often several degrees warmer. River waters show a greater range of temperature, from 11°C to 26°C at the surface and up to 28°C in deep water near the end of summer (Figures 4.12 & 4.13).

4.3 LIGHT

The rivers carry dark tannin-stained water and fine suspended sediment in winter so reducing light penetration. In summer the intrusion of sea water makes the water much clearer.

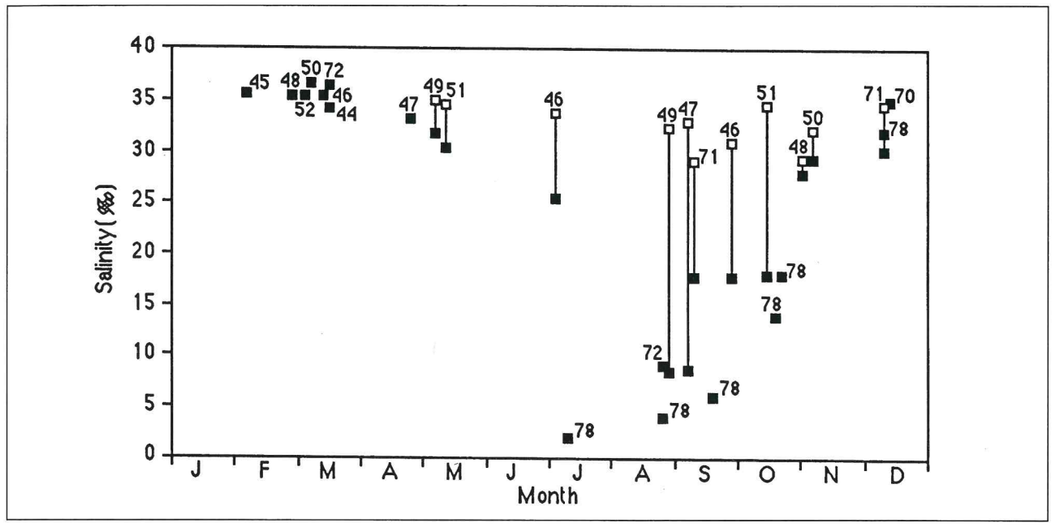


Figure 4.11 Salinities in the centre of Nornalup Inlet between 1944 and 1978, ■ surface, □ benthic. (Spencer, 1952, Lenanton and Hodgkin)

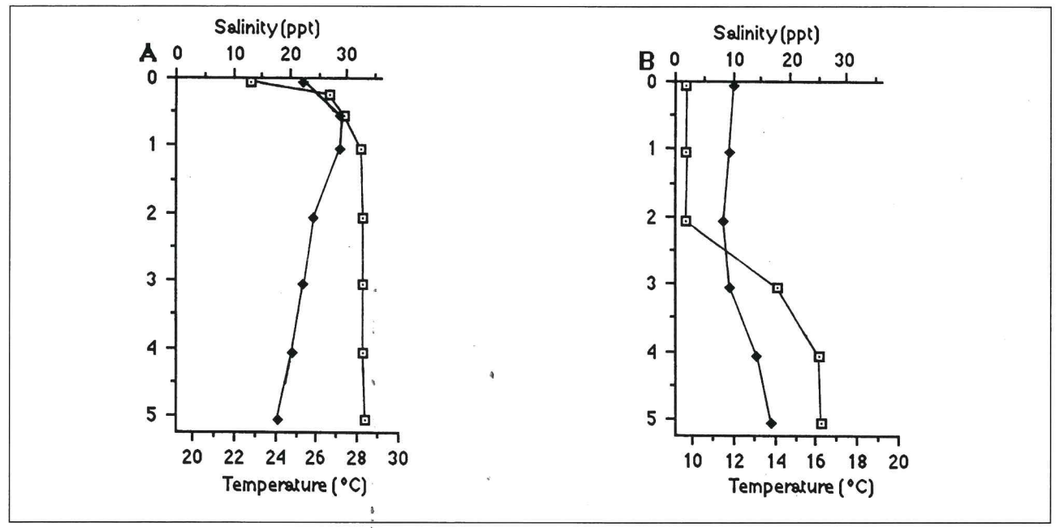


Figure 4.12 Salinity and temperature profiles in the Frankland River **A** Summer (16.2.1971, 11km upstream) **B** Winter (21.8.1971, 6km upstream). ⊡ salinity ◆ temperature. (Hodgkin)

4.4 OXYGEN

The open water of the Inlets is well oxygenated most of the time, but when stratified in winter there can be some degree of deoxygenation of deep water. CSIRO figures for river water are generally somewhat lower than for the Inlets, with less oxygen (50% saturation) in bottom water when stratified. There could be severe oxygen lack in the deep water if the extreme stratification shown in Figures 4.12 and 4.13 is prolonged.

4.5 NUTRIENTS

The limited nutrient data (Spencer, 1952; WA Fisheries Dept data 1975; EPA data 1987) indicate that nutrient levels are low in river and estuary water. Fisheries Department data are shown in Tables 4.51 and 4.52.

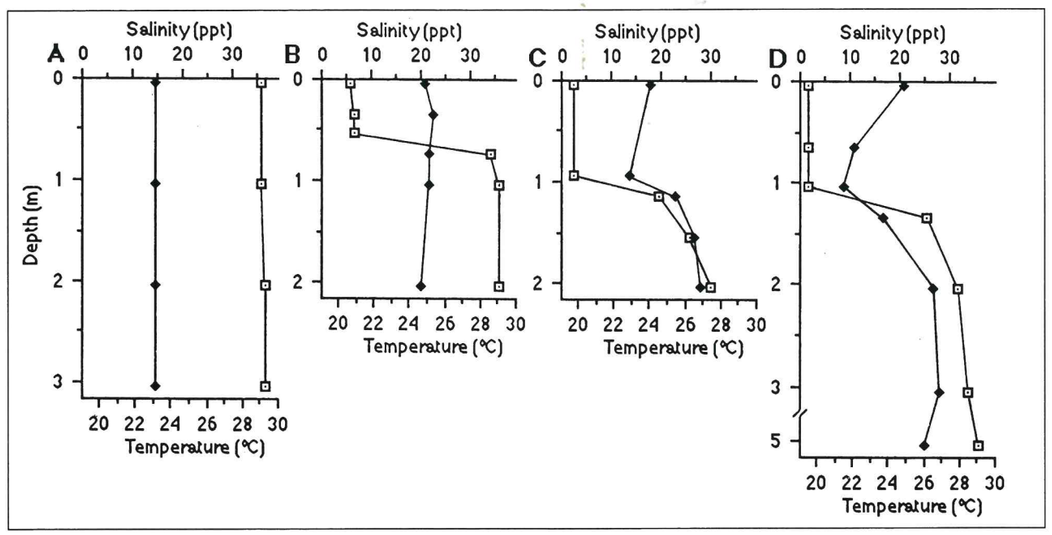


Figure 4.13 Salinity and temperature profiles along the Deep River on March 1972 at, **A** the mouth, **B** 2.4km, **C** 4.5km, D 5.9km upstream. ⊡ salinity ◆ temperature. (Hodgkin)

Table 4.51 Nitrogen, ug/l, August 1974 (winter) and February 1975 (summer), S=surface, B=bottom. Lenanton and Edmonds, 1975, unpubl.

Sample site	S/B	Winter		Summer	
		NO3	TOT	NO3	TOT
Deep River	S	20	700	30	620
	B	20	960	20	600
Walpole	S	30	1100	20	400
River	B	20	1300	20	510
Frankland	S	20	1600	20	500
River	B	20	1600	20	410
Nornalup	S	20	1400	30	230
Inlet	B	20	480	20	300
Walpole	S	30	640	20	390
Channel	B	20	450	20	980

Table 4.52 Phosphorus, ug/l, August 1974 (winter) and February 1975 (summer), S=surface, B=bottom. Lenanton and Edmonds, 1975, unpubl.

Sample site	S/B	Winter		Summer	
		PO4	TOT	PO4	TOT
Deep River	S	10	10	10	10
	B	10	10	10	10
Walpole	S	40	60	10	30
River	B	30	60	10	40
Frankland	S	30	30	10	10
River	B	10	40	10	30
Nornalup	S	10	30	10	10
Inlet	B	10	30	10	20
Walpole	S	10	40	20	40
Channel	B	10	40	10	40

Samples of river water taken in 1995-96 show similarly low nutrient levels, though with slightly higher phosphorus levels in Frankland River water (Deeley). The somewhat higher total P figures for Walpole River and Inlet suggest some degree of nutrient enrichment. Walpole town relies on septic tanks sewage disposal.

5 VEGETATION

5.1 AQUATIC PLANTS

The aquatic vegetation was surveyed in October 1976 (M. Cambridge) and again in January 1987 (J. Chambers) and on both occasions was found to be sparse.

The seagrass *Ruppia megacarpa* grows in shallow water on sand flats near the Deep River delta and stunted plants on the south eastern shore, where the more marine species *Heterozostera tasmanica* was also found towards the mouth in 1976. A brown alga *Cystoseira trinodes* covered the sublittoral rocks near the mouth of the Walpole-Nornalup channel in 1987; both this and the *Ruppia* were heavily overgrown by the epiphytic filamentous green alga *Chaetomorpha billardieri* and the fine filamentous red alga *Monosporus australis*. The *Ruppia* was healthier in slightly deeper water in 1976 and was then flowering.

The green algae *Chaetomorpha linum* and *C. aurea* were abundant in Walpole Inlet in 1973-74 (Lenanton pers. comm.) and *Cladophora* was reported to be growing on muddy sand in 1976. Occasional mats of floating green algae *Enteromorpha intestinalis* and *Chaetomorpha billardierii* were noted in the shallows on the eastern side in 1987. The small green alga *Acetabularia calyculus* was commonly attached to rocks and shells in the shallows. In 1976, living algae covered a layer of dying and dead algae 10-20 cm thick over black deoxygenated ooze in water 1-2 m deep in Walpole Inlet.

5.2 MARSH PLANTS Figure 5

The rocky shores are steep and allow little colonisation by fringing marsh. Elsewhere the rush *Juncus kraussii* fringes the estuary in front of all the terrestrial plant communities except coastal heath. In general the rush band is only one plant wide due to the steep slopes. In slightly flatter areas the sedges and grasses *Baumea juncea, Ammophila arenaria*, Lepidosperma gladiatum, Paspalum vaginatum** and *Isolepis nodosa* grow behind the Juncus community.

Scented Boronia *(Boronia megastigma)* and the insectivorous pitcher plant *(Cephalotus follicularis)* grow in the peaty swamps of the National Park.

5.3 TERRESTRIAL VEGETATION

The sand spit at the mouth is sparsely colonised by *Ammophila arenaria*, Arctotheca populifolia** and Isolepis nodosa and marram grass has been planted on it. The nearby dune vegetation includes these plants, but is dominated by the shrubs *Leucopogon parviflorus, Olearia axillaris, Acacia littorea* and the sedge *Lepidosperma gladiatum.*

On the lee side of the dune, on the banks of the Inlet, this coastal heath gives way to a community dominated by Peppermint trees *(Agonis flexuosa)* together with the shrubs *Spyridium globulosum, Olearia axillaris, Rhagodia baccata, Billardiera variifolia* and the sedge *Lepidosperma gladiatum.*

In low-lying areas near the mouths of the rivers and near Walpole a low scrub community is dominated by the yellow-flowered shrub *Oxylobium heterophyllum* (Table 5.3). Near Walpole this community contains numerous weed species, bracken and grasses, and is covered with native dodder (*Cassytha* sp.).

Table 5.3 Species identified in the *Oxylobium heterophyllum* community (J. Chambers).

Jacksonia horrida
Beaufortia sp.
Acacia pulchella
Astartea fascularis
Anigozanthos sp.
Macrozamia riedlei
Xanthorrhea preissii
Lepidosperma gladiatum
Euphorbia sp.

The steep, forested hillsides fringing the Walpole-Nornalup channel, the southwestern shore of Nornalup Inlet, and along the Deep and Frankland rivers, have fine stands of Karri *(Eucalyptus diversicolor)*, with Red Tingle *(E. jacksonii)* and Yellow Tingle *(E. guilfoylei)*. On the headlands a narrow community dominated by Peppermints separates the forest from the *Juncus* fringe. On the southern shore peppermints are replaced by *Oxylobium heterophyllum.*

*Introduced species

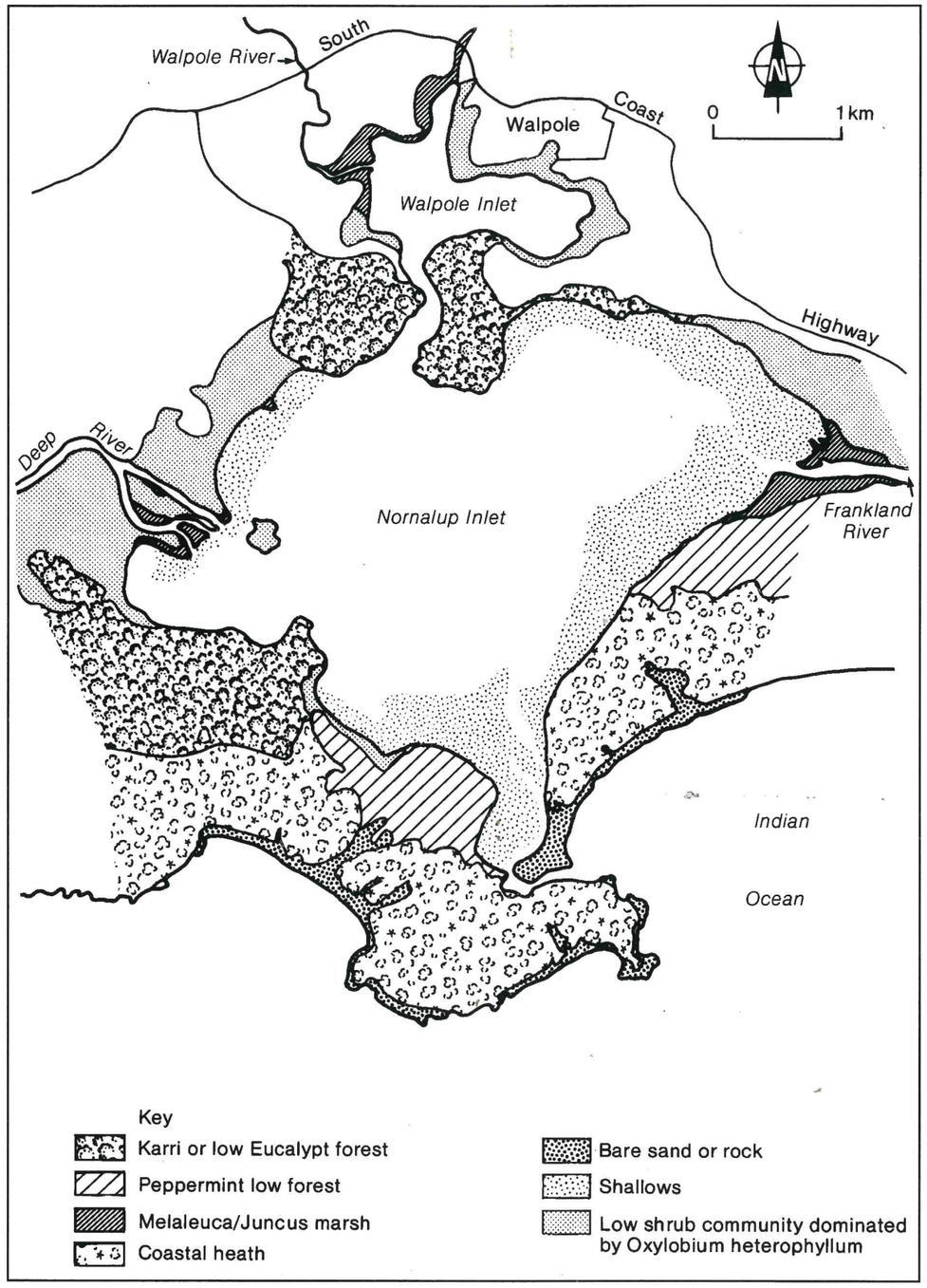


Figure 5 The Nornalup-Walpole estuary. Marsh and terrestrial vegetation. (J. Chambers)

6 FAUNA

6.1 ANIMAL PLANKTON

The common estuarine copepod *Gladioferens imparipes* dominates the true zooplankton of the Deep and Frankland rivers, over the full range of salinities experienced. The euryhaline marine species *Acartia tonsa* is dominant at higher salinities in the Inlets, but *G. imparipes* is also common there at lower salinities (Table 6.1). The larvae of benthic animals are also abundant at times, particularly the veliger larvae of gastropod molluscs.

Table 6.1 Copepods taken in zooplankton samples 1970-72 (Hodgkin).

	River		Inlets	
	Deep	Frankland	Nornalup	Walpole
Gladioferens imparipes	++++	+++	++	+++
Acartia sp.	+	+	+++	++++
Oithona sp.	++	+	++	+
Kelleria sp.	++	+		
Sulcanus conflictus	+		+	
Halicyclops sp.	+	+		

6.2 BOTTOM FAUNA

The benthic fauna of the estuary was surveyed by J. Wallace in October 1976 (Table 6.21) and J. Shaw in April 1987 (Table 6.22).

Table 6.21 Benthic fauna (Hodgkin, Kendrick & Wallace; Wells, 1984).

POLYCHAETA:
Arenicola sp.

CRUSTACEA:
Metapenaeus dalli
Palaemonetes serenus
Leander sp.
Cyclograpsus audociuni
Portunus pelagicus

MOLLUSCA: Gastropoda
Haminoea sp.
Nerita atramentosa
Tatea preissii
Assiminea sp.
Hydrococcus brazieri

MOLLUSCA: Gastropoda
Salinator fragilis

MOLLUSCA: Bivalvia
Mytilis edulis
Xenstrobus pulex
Ostrea sp.
Fulvia tenuicostata
Paphies elongata
Sanguinolaria biradiata
Fluviolanatus subtorta
Pholas australasiae

INSECTA:
Pontomyia cottoni
Chironomid

The permanently open bar and marine salinity water of Nornalup Inlet permit the establishment and survival of more invertebrate species than are found in other estuaries of the south coast, except in Oyster Harbour.

Two amphipod species dominated the mud of Walpole Inlet in 1987; occurring only sporadically at other sites. The small 'opportunistic' polychaete *Capitella capitata* was abundant throughout the estuary.

In Nornalup Inlet the fine mud of the deep sites (2 and 3) had a relatively impoverished fauna compared with the three sandy sites in the shallows. This was particularly evident with the total lack of Crustacea and few molluscs collected in the basin.

A range of mollusc species was collected from all the sandy sites. The Frankland River site was dominated by the typical estuarine bivalves *Xenostrobus, Arthritica* and *Spisula.*

There are no data on the seasonal abundance of the invertebrate fauna in Nornalup Inlet, however Lenanton (pers. comm.) found a decrease in diversity of species and of their abundance in winter while studying the fauna of Walpole Inlet in 1973/74.

The large number of species of Foraminifera found by Hassell (1962) reflects the relatively marine condition of the estuary (Table 6.23).

Table 6.23 Forminifera of Nornalup and Walpole Inlets (Hassell, 1962).

Massilina secans
Labrospira wiesneri
Miliammina arenacea
Quinqueloculina seminula
Spiroloculina cushmani
Vertebralina striata
Lagena globosa
Bolivina bassensis
Bolivina subreticulata
Anomalina bassensis
Elphidium poeyanum
Sigmoilina schlumbergeri
Ammobaculites agglutinans
Quinqueloculina bosciana
Halplophragmoides canariensis
Triloculina oblonga
Fissurina sp.1
Guttulina pacifica
Bolivina punctata
Cassidulina crassa
Elphidium macellum
Robertina sp.

6.3 FISH

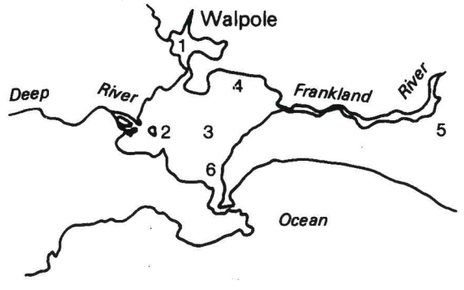
Table 6.3 lists 37 fish species identified from the estuary. Apart from Black bream, the recreationally important species are primarily inshore marine species which spawn in the sea and use estuaries opportunistically: Whiting, Trevally, Herring and juvenile WA salmon. The few estuarine species make up 98% of fish netted in shallow water, as in Wilson Inlet. But a number of marine species are caught in Nornalup Inlet that are rarely or never caught in Wilson Inlet: these include five species of sharks and rays. This is probably because the Nornalup bar does not close and marine salinity water persists in the deeper parts of the estuary throughout the year (Potter and Hyndes, 1994).

Figure 6.2 Benthic Invertebrate fauna. Nornalup-Walpole estuary, April 1987. (J. Shaw)

	Sample site	Walpole Inlet[1]	Newdegate Island[2]	Nornalup basin[3]	Coalmine Beach[4]	Frankland River[5]	Tidal delta[6]
POLYCHAETA:							
Phyllodocidae	- Phyllodoce sp.	+	+	—	+	+	—
Hesionidae	- Gyptis sp.	—	+	+	++	—	—
Nereididae	- Ceratonereis aequisetes	—	+	—	+	+++	—
	- Laeonereis sp.	—	—	—	++	—	++
	- Neanthes sp.	—	—	—	—	—	++
Nephtyidae	- Nephtys inornata	++	++	++	—	—	—
Orbiniidae	- Scoloplos simplex	++	—	+	++	++	++
Paraonidae	- Polydora sp.	—	—	—	—	+	—
	- Prionospio sp.	+	+	+	—	—	—
	- Boccardia sp.	+	—	—	+	—	—
Opheliidae	- Armandia sp.	—	—	—	—	—	+
Capitellidae	- Capitella capitata	+++	+++	+++	+++	++	+++
Serpulidae	- Mercierella enigmatica	—	++	—	—	—	—
CRUSTACEA:							
Cirripedia	- Balanus variegatus	+	—	—	++	+	—
	- Eliminus modestus	—	—	—	+	—	—
Mysidacea	- Mysid sp.	+	—	—	+	—	+
Amphipoda	- Corophium minor	+++	+	—	—	+	+
	- Paracorophium sp.	—	—	—	++	—	—
	- Neomicrodeutopus sp.	+++	—	—	—	—	—
	- Melita sp.	+	—	—	—	—	—
Decapoda	- Halicarcinus ovatus	+	—	—	+	+	++
	- Pilumnus fissifrons (cf)	—	++	—	+	—	—
	- Ovalipes australiensis	—	—	—	—	—	+
	- Portunus pelagicus	—	—	—	—	—	+
	- Palaemonetes australis	+	—	—	+	+	+
	- Macrobrachium intermedium	—	—	—	—	—	+
MOLLUSCA:							
Gastropoda	- Diala sp.	—	—	—	—	+	—
	- Nassarius burchardi	+	—	—	++	—	++
	- Nassarius pauperatus	—	—	—	—	—	+
	- Liloa brevis	+	—	—	—	—	—
	- Philine sp.	+	++	—	++	+	+
Bivalvia	- Xenostrobus securis	—	—	—	—	++	—
	- Musculus paulucciae	—	—	—	+	+	+
	- Anomia trigonopsis	—	—	+	—	—	—
	- Wallucina assimilis	—	+	—	+	—	++
	- Arthritica semen	—	—	—	—	+++	—
	- Spisula trigonella	++	—	—	++	++	+
	- Soletellina donacioides	—	—	+	+	—	+++
	- Katelysia peroni	—	—	—	+	—	—
	- Katelysia scalarina	—	—	—	+	—	+
	- Irus crenata	—	—	—	—	+	—
	- Theora lubrica	++	+	++	—	+	—
	- Macomona deltoidalis	—	—	—	—	+	—
	Depth (m)	2.5	1-2.5	3	2	1-1.5	0.5-2
	Bottom type	Mud			Sand		

— not found
\+ present
++ abundant
+++ very abundant

Sites are referred to above.



The only hindrance to recruitment may be when the water is extremely turbulent in the shallow entrance as a result of sea swell, or during periods of strong outflow from the estuary in winter.

Table 6.3 Fish of Nornalup and Walpole Inlets (Lenanton pers. comm.).

Common name	Scientific name
Anadromous	
Wide Mouthed Lamprey	*Geotria australis*
Estuarine	
Black Bream	*Acanthopagrus butcheri*
Blue spot goby	*Pseudogobius olorum*
Hardthead	*Atherinosoma wallacei*
Hardyhead	*Atherinosoma elongata*
Predominantly estuarine	
Sea mullet	*Mugil cephalus*
Tarwhine	*Rhabdosargus sarba*
Marine and inshore marine	
Hardyhead	*Atherinosoma*
presbyteriodes	
Yelloweye mullet	*Aldrichetta forsteri*
King George whiting	*Sillaginodes punctata*
Southern blue spotted flathead	*Platycephalus speculator*
Striped trumpeter	*Pelates sexineatus*
Sand Trevally	*Pseudocaranx wrighti*
W.A. salmon	*Arripis truttaceus*
Pink Snapper	*Chrysophrys auratus*
Long snouted flounder	*Ammotretis rostratus*
Cobbler	*Cnidoglanis*
macrocephalus	
Herring	*Arripis georgianus*
Tailor	*Pomatomus saltator*
Southern anchovy	*Engraulis australis*
fraseri	
Predominantly marine	
Beardie	*Lotella rhacinus*
Southern School whiting	*Sillago bassensis*
Long-finned goby	*Favonigobius lateralis*
Lemon tongue sole	*Paraplagusia unicolor*
Spiny-tailed leatherjacket	*Bigener brownii*
Toothbrush leatherjacket	*Penicipetta vittiger*
Tevally	*Pseudocaranx dentex*
Banded toadfish	*Torquigener pleurgramma*
Rosy weedfish	*Heteroclinus roseus*
Wirrah	*Acanthistius serratus*
Porcupine fish	*Dicotylichthys jaculiferus*
Serpent eel	*Ophisurus serpens*
Gummy shark	*Mustelus antarcticus*
Southern shovelnose ray	*Aptychotrema vincentiana*
Yellow-finned whiting	*Sillago schomburgkii*
Beaked salmon	*Gonorynchus greyi*
Red gurnard	*Cheilidonichthys kuma*

6.4 WATERBIRDS

Table 6.4 lists 21 species of waterbird recorded by various observers.

Table 6.4 Waterbirds recorded at Nornalup-Walpole Inlet (Ashby & LeSouef (1928); R. Clark; J. Lane; Munro; Peden; RAOU; P. Yewers). Indicate highest recorded.

Common name	Scientific name	
Australian Pelican	*Pelecanus conspicillatus*	43
Great Cormorant	*Phalacrocorax carbo*	
Little Black Cormorant	*Phalacrocorax sulcirostris*	
Pied Cormorant	*Phalacrocorax varius*	
Little Pied Cormorant	*Phalacrocorax melanoleucos*	
White-faced Heron	*Ardea novaehollandiae*	
Black Swan	*Cygnus atratus*	468
Pacific Black Duck	*Anas superciliosa*	140
Silver Gull	*Larus novaehollandiae*	
Crested Tern	*Sterna bergii*	
Caspian Tern	*Hydroprogne caspia*	
Musk Duck	*Biziura lobata*	3
Grey Teal	*Anas gibberifrons*	50
Australian Shelduck	*Tardorna tadornoides*	2
Eurasian Coot	*Fulica atra*	
Wood Duck	*Chenonetta jubata*	
Pacific Gull	*Larus pacificus*	3
Sacred Ibis	*Threskiornis aethiopicus*	2
Osprey	*Pandion haliaetus*	1
White Breasted SeaEagle	*Haliaeetus leucogaster*	2
Red Capped Plover	*Charadrius reficapillus*	1

7 MANAGEMENT

Nornalup-Walpole is the only estuarine system in southwestern Australia that is surrounded by predominantly forested National Park and is permanently open to the sea. It is scenically and aesthetically one of the state's most spectacular estuarine environments and is of special scientific interest. Every effort should be made to preserve it and protect it from developments that would compromise this outstanding resource.

For many years the estuary has been the recreational focus both for visitors to the Walpole-Nornalup National Park and for the local community who enjoy activities such as fishing and boating (many through the facilities of the sailing club at Coalmine Beach). Net fishing and spear fishing are prohibited throughout the estuary at all times. There is no restriction on line fishing other than legal minimum sizes for nominated species. The long standing net fishing ban has helped conserve estuarine fish stocks and so contributed to the excellent recreational fishing opportunities in the estuary today.

Nornalup Inlet is not eutrophic and it is unlikely to become so while the major river flow continues to come from forested land, the mouth remains open, and land adjacent to the estuary remains largely undeveloped. However, Walpole Inlet is potentially eutrophic, the restricted exchange with Nornalup Inlet, the shallow water, and the proximity of unsewered residential areas make it vulnerable.

Boat channels were dredged in Walpole Inlet in 1974 and though there have been complaints about weed accumulating in them they have not needed to be dredged since. The channels through the lower reaches and deltas of the Deep and Frankland Rivers have to be dredged from time to time, especially following major floods. They were last surveyed in 1970 (PWD WA 33962-5-1 and 16302-10-1). Logs brought down by the river obstruct the uppermost reaches of the Frankland river, preventing boat access, and some logs remain as snags lower down. They protect the banks from erosion, particularly by the wash from speeding boats, and provide sheltered habitats for fish and other fauna. There is an 8 knot speed limit in the rivers and through the channel between Walpole and Nornalup Inlets. The channel to the sea is shallow and ill defined through the flood tide delta, and the sea bar is often very shallow and made dangerous by waves breaking on it.

For half the year the Nornalup entrance channel is only kept open by tidal exchange, unlike the nearby Broke and Wilson Inlets where the bars close seasonally, and closure of the bar must be considered a possibility. Extrapolating from the history of those and other south coast estuaries, it is probably the combined effect of the sheltered location of the entrance channel against Rocky Head and the great volume of river flow relative to the size of the Inlet that keep the bar open. The bar could close in summer, but even in the driest year the volume of river flow is several times the volume of the estuary so that it is most unlikely that the bar would ever fail to break in winter — unless the rivers were dammed. Closure of the bar in summer would greatly alter the hydrology of the estuary, making it more like Broke or Wilson Inlets, and change the ecology of the system with the disappearance of the present more marine fauna.

8 REFERENCES

Ashby, E and LeSouef, A S (1928) *Birds observed during the RAOU Campout at Nornalup, South West Australia.* The Emu. 27, 266-267.

Bellanger, B J A (1980) *Champagne and Tingle Trees.* Apollo Press, Nedlands, WA.

Collins, P D K and Fowlie, W G (1981) *Denmark and Kent river basins water resources study.* Engineering Division, Public Works Dept., W.A. (Water Resources Branch).

Hassell, G W (1962) *Estuarine sedimentation on the south coast of Western Australia with particular reference to Nornalup Inlet.* PhD Thesis, Geology Department, University of Western Australia, (Ms).

Lenanton, R C J (1974) *Fish and Crustacea of the Western Australian south coast rivers and estuaries.* Fish. Bull. West. Aust. 13, 1-17.

Potter, I C and Hyndes, G A (1994) *Composition of the fish fauna of a permanently open estuary on the southern coast of Australia, and comparisons with a nearby seasonally closed estuary.* Marine Biology 121:199-209

Public Works Department (1984) *Streamflow records of Western Australia to 1982. Vol 1 Basins 601-612.* Water Resources Branch.

Royal Automobile Club (1986) *RAC Accommodation Guide Book.* 27th Edition, RAC, Perth, WA.

Rochford, D J (1953a) *Estuarine hydrological investigations in eastern and south-western Australia, 1951.* C.S.I.R.O. Aust. Div. Fish. Oceangr. Sta. List Vol. 12.

Rochford, D J (1953b) *Analysis of bottom deposits in eastern and south-western Australia, 1951, and records of twenty-four hourly hydrological observations at selected stations in eastern Australian estuarine systems, 1951.* C.S.I.R.O. Aust. Div. Fish. Oceangr. Sta. List Vol. 13.

Rochford, D J and Spencer, R S (1953a) *Estuarine hydrological investigations in eastern and south-western Australia, 1952.* C.S.I.R.O. Aust. Div. Fish. Oceangr. Sta. List Vol. 15.

Rochford, D J and Spencer, R S (1953b). *Analysis of bottom deposits in eastern and south-western Australia, 1952, and records of twenty-four hourly hydrological observations at selected stations in eastern Australian estuarine systems, 1952.* C.S.I.R.O. Aust. Div. Fish. Oceangr. Sta. List Vol. 16.

Spencer, R S (1952) *Hydrological investigations in south-western Australia, 1944-50.* CSIRO Aust. Div. Fish. Oceanogr. Sta. List Vol. 8.

Wells, F E (1984) *A guide to the Common Molluscs of South-western Australian estuaries.* Western Australian Museum.

9 ACKNOWLEDGEMENTS

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Limestone rocks and a patch of the rush, *Juncus kraussii*, near the mouth of Nornalup Inlet, Photo E P Hodgkin.

Siltstone cliffs at Coalmine Beach. Photo E P Hodgkin.

The channel from Walpole Inlet to Nornalup Inlet. Rest Point Caravan Park on the right. Photo Ruth Clark.