South Coast Terrestrial and Marine Reserve Integration Study

A review of estuaries and their catchments between Broke Inlet and Israelite Bay

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Report to the
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Nature Conservation Division,
Department of Conservation and Land Management

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Report N° 97/9

September 1997

EXECUTIVE SUMMARY

The Wilson Report (MPRWG 1994), recommended that a number of areas along the south coast of Western Australia were worthy of consideration for marine reserve status, to protect marine and estuarine areas having high conservation value but which were not currently part of the conservation estate. The Western Australian Department of Conservation and Land Management (CALM) undertook the South Coast Terrestrial and Marine Reserve Integration Study to identify issues, opportunities and constraints toward integrated management of existing terrestrial National Parks and Reserves with the proposed marine reserves. This report reviews published information for estuaries along the south coast between Broke Inlet and Israelite Bay and identifies their current status and potential future impacts.

The estuaries and catchments of the south coast region are highly heterogeneous systems having high seasonal variability in rainfall and runoff, particularly in the region east of Albany. Some estuaries in the region, such as Wilson Inlet and the Albany Harbours have had extensive research into the symptoms and causes of eutrophication and seagrass loss while most of the estuaries of the region have had little or no scientific attention. Accordingly, much of the information in this report has been gleaned from a sparse literature, and the risk assessment has been based on extrapolations from better studied estuarine systems on the south and west coast.

Many of the estuaries and catchments of the south coast region are showing some evidence of ecosystem distress syndrome, suffering from eutrophication, soil and wind erosion, saline groundwater intrusion, weed infestation, loss of remnant vegetation and loss of diversity. Some estuaries show no evidence of degradation, and several with catchments wholly or mostly in National Parks are considered unimpacted or pristine. Because of the risks of further degradation of south coast estuaries through inappropriate agricultural practices in their catchments, conservation of less impacted systems is of great importance both environmentally and economically.

From Broke Inlet to Torbay Inlet, many estuaries show symptoms of degradation. Broke Inlet, however, is considered pristine with a largely uncleared catchment, however potential threats to long term conservation of biological diversity in this high value conservation area, posed by commercial fisheries and estuary bar intervention, needs to be reviewed. Any proposed development along its foreshore needs to be preceded by rigorous environmental impact assessment if detrimental impacts are to be avoided. The Walpole-Nornalup Inlets and Wilson Inlet also have high conservation value and visual amenity but show some evidence of human impacts.

Extensive agricultural clearing in the upper Frankland, Hay and Sleeman catchments pose significant eutrophication risks for the longer term. Current nutrient loads from these catchments need to be better assessed and managed if the long term integrity of these estuaries is to be protected. Riparian buffer zones need to be established along all developed catchments in this region, to help lessen the nutrient and sediment pollution loads currently entering the estuaries. Foreshore development in Walpole and Denmark should be based on water sensitive urban design principles to minimize passage of pollutants to waterways.

Industrial, rural and urban pollution loads have been identified as causing extensive loss of seagrass beds and heavy metal contamination of sediments in the Albany Harbours. Successful pollution control licensing has significantly reduced pollutant loads to Princess Royal Harbour which shows early signs of recovery. A move toward sustainable agricultural systems in the Kalgan and other catchments should see improvements in runoff quality in the longer term, but the extent and nature of problems in these catchments will preclude rapid improvements in current diffuse pollutant loads. Fencing and re-establishment of riparian corridors show early improvements in environmental quality, but much more work needs to be completed.

Exotic marine species and potentially harmful dinoflagellates introduced through discharge of ballast waters from ocean going vessels pose a real threat to the ecology of the harbours, and to the viability of aquaculture industries currently operating in the region.

There has been almost no research or monitoring of estuaries in the internationally significant Fitzgerald River Biosphere. A biosphere by definition is an unimpacted area against which changes in the baseline environmental quality of a region are to be compared. Extensive agricultural clearing in the upper catchments of the Hamersley and Fitzgerald Inlets are of primary concern as they are within the core of the Biosphere and soil erosion and sediment movement have been observed. The impact of clearing on sediment and nutrient movement is largely unknown and the lack of scientific investigation in this region is cause for considerable concern. The extreme variablity of rainfall and runoff in the region (eg. Stokes Inlet), means that monitoring programs would need to span many years before a clear picture of the impact of normal and extreme runoff events could be determined.

The threats to Wellstead, Gordon and Culham Inlets are largely unknown although agricultural clearing in their catchments is cause for concern. The potential for translocation of fouling organisms on gear used during commercial fishing in the estuaries of the biosphere, and subsequent disturbance to estuarine ecology may need to be assessed. As with estuaries of the biosphere, the estuaries of the Esperance environs have had almost no research. There is some evidence of increased weed accumulations in Stokes Inlet, but a lack of scientific information precludes proper assessment of the nature of threats posed by agricultural clearing in the region.

Clearly there are potential benefits of greater integration of terrestrial and marine conservation reserves. The impact of catchment landuse practices on the ecology of receiving waters is well established, and improved understanding of the longer term threats to downstream systems will follow improved integration of the monitoring and management effort. For some estuaries, catchments are currently wholly or partially within conservation reserves. For many estuaries however, the long term viability of their conservation value is largely outside the jurisdiction of conservation agencies or their legislation. There needs to be greater emphasis on improved policy and land management practices in cleared catchments of high conservation value estuaries. Because of the nature of land tenure in these systems, a greater level of coordination of the limited available resources is required, supported by a whole of community and government approach.

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1. INTRODUCTION

1.1. Objective

The South Coast Terrestrial and Marine Reserve Integration Study which is being undertaken by the Marine Conservation Branch, Department of Conservation and Land Management (CALM), covers the coastline from Broke Inlet in the west (34°55.91' S 116°24.01' E), to Israelite Bay in the east (33°36.22' S 123°53.04' N) (Figure 1.1).

The aim of the CALM project is:

"*...to facilitate a regional classification of the marine environment ....according to ecological, economical and cultural criteria, and to provide an information base for proposed marine reserve areas identified in the Wilson Report*" and "*to provide recommendations that will facilitate the integrated management of adjacent terrestrial and marine reserves and will ensure that the potential impacts of terrestrial and estuarine ecosystems upon their marine counterparts are known prior to the creation of any marine reserves*" (p.4, Colman 1996).

The aim of this position paper is to review estuary catchment characteristics (Section 2), review characteristics and classify estuaries and coastal lagoons (Section 3), and finally to discuss estuary management issues that may possibly affect the long term viability of marine reserves proposed in the south coast region (Sections 4 & 5).

1.2. Overview

One hundred million years ago when Antarctica broke away from Australia and the southern part of the Australian continent subsided, marks the beginning of the formation of the south coast. Over time after the receding of the Holocene marine transgression (4000-8000 years ago), the region developed a series of catchments with unique geomorphology; soils, landforms, lakes and estuaries (SCRAP & SCRIPT 1996c, Hodgkin & Hesp in prep).

It is possible that the first Australians wandered the south coast over 50,000 years ago. They travelled seasonally between the coastal regions to the inland forests. The first archaeological evidence of the Nyungar Aborigines in the south coast region are in stone tools, and their stone fish traps are still found at Broke Inlet, Wilson Inlet and Oyster Harbour (Way '79 1979, SCRAP & SCRIPT 1997a, SCRAP & SCRIPT 1997c).

The first European exploration of the south coast came in 1622. The "*Leeuwin*" a dutch trader examined the coast from Cape Leeuwin to King George Sound. Captain Nuyts sailing in the "*Gulden Zeepaard*" explored the coastline eastwards from Cape Leeuwin in 1627. It was not until after the French D'Urville expedition (the "*Astrolabe*"), landed in King George Sound, that the then Governor, Darling sent Lockyer to establish a convict settlement at Albany in 1826 (Way '79 1979).

Presently, Albany is a bustling township with a population of 28,600 and Esperance, the only other major coastal town in the south coast region has a population of 11,500. The major industries in the region are primary production and tourism. The south coast region is renown for its floral diversity and spectacular landscapes, including coastal mountain ranges, tall forests, offshore islands, estuaries and wetlands, and its rocky headlands and sandy beaches (CALM 1992a, SCRAP & SCRIPT 1996c).

The local government areas of the southern coastline are managed by the Shires of Manjimup, Denmark, Albany, Jerramungup, Ravensthorpe and Esperance. The south coast catchments includes the Shires of Kent, Plantagenet, Cranbrook, Kojonup, Tambellup, Broomehill, Gnowangerup, Jerramungup and Dundas (Figure 1.1).

In association with the shires of the south coast region, there are many Land

Conservation and Catchment groups (LCDCs) and six larger catchment management groups which in some instances are composed of a few LCDCs (SCRAP & SCRIPT 1996c):

1. The Franklin-Gordon Management group which manages and coordinates work in the large catchments of the Gordon and Frankland Rivers (467,106 ha collectively);

2. The Kent Catchment Steering and Technical Group oversees salinity research and development. The Kent River catchment is one of five focal catchments of the National Dryland Salinity Programme;

3. The Wilson Inlet Catchment Committee oversees one of three national focal catchments of the National Eutrophication Management Programme which is managed by the Land & Water Resources Research & Development Corporation and the Murray-Darling Basin Commission. The Wilson Inlet catchment includes the Denmark, Sleeman and Hay Rivers;

4. The Oyster Harbour Management Group supervises the work in its catchments (King and Kalgan Rivers). The group also oversees work under the National Riparian Zone Management Programme;

5. The chain of wetlands at Lake Warden are listed under the Ramsar Convention for the protection of wetlands of international significance for migratory waterfowl. Recently, the Neridup, Bandy Creek and Coramup LCDCs have united to attract funding; and

6. The Water and Rivers Commission declared the catchments of the Kent and Denmark Rivers as Clearing Control Catchments with a view to protect the regions water resources from rising salinity.

In addition to the LCDCs, there are a number of statutory local area management authorities that have been established along the south coast. They include the Albany Waterways Management Authority and the Wilson Inlet Management Authority, covering the management of the Albany Harbours and Wilson Inlet respectively (WWC 1992, AWMA 1995, Seal 1995). An advisory committee, the Walpole and Nornalup Inlet Systems Advisory Committee, based around the Walpole-Nornalup Inlet provides advice on a range of issues of the Manjimup Shire.

There are a number of national parks in the south coast region. These are the Shannon, D'Entrecasteaux, Walpole-Nornalup, Mt Franklin, William Bay, West Cape Howe, Torndirrup, Gull Rock, Porongurup, Stirling Range, Frank Hann, Peak Charles, Waychinicup, Fitzgerald River National Parks, Stokes, Cape Le Grange and Cape Arid. There are also a number of Nature Reserves including Lake Shaster, Lake Magenta, Jerdacuttup, Mt Manypeaks, Two Peoples Bay, Peeniup, and Corackerup Nature Reserves (CALM 1988, SCRAP & SCRIPT 1996c).

The south coast is a wave dominated coast because it has small tides and moderate surge activity, which are both are exceeded by the modal annual wave heights. The southern coastline has many embayments, usually separated by granite or siltstone headland. Behind the coastal dune systems lie many estuaries and coastal lakes (EPAWA 1992).

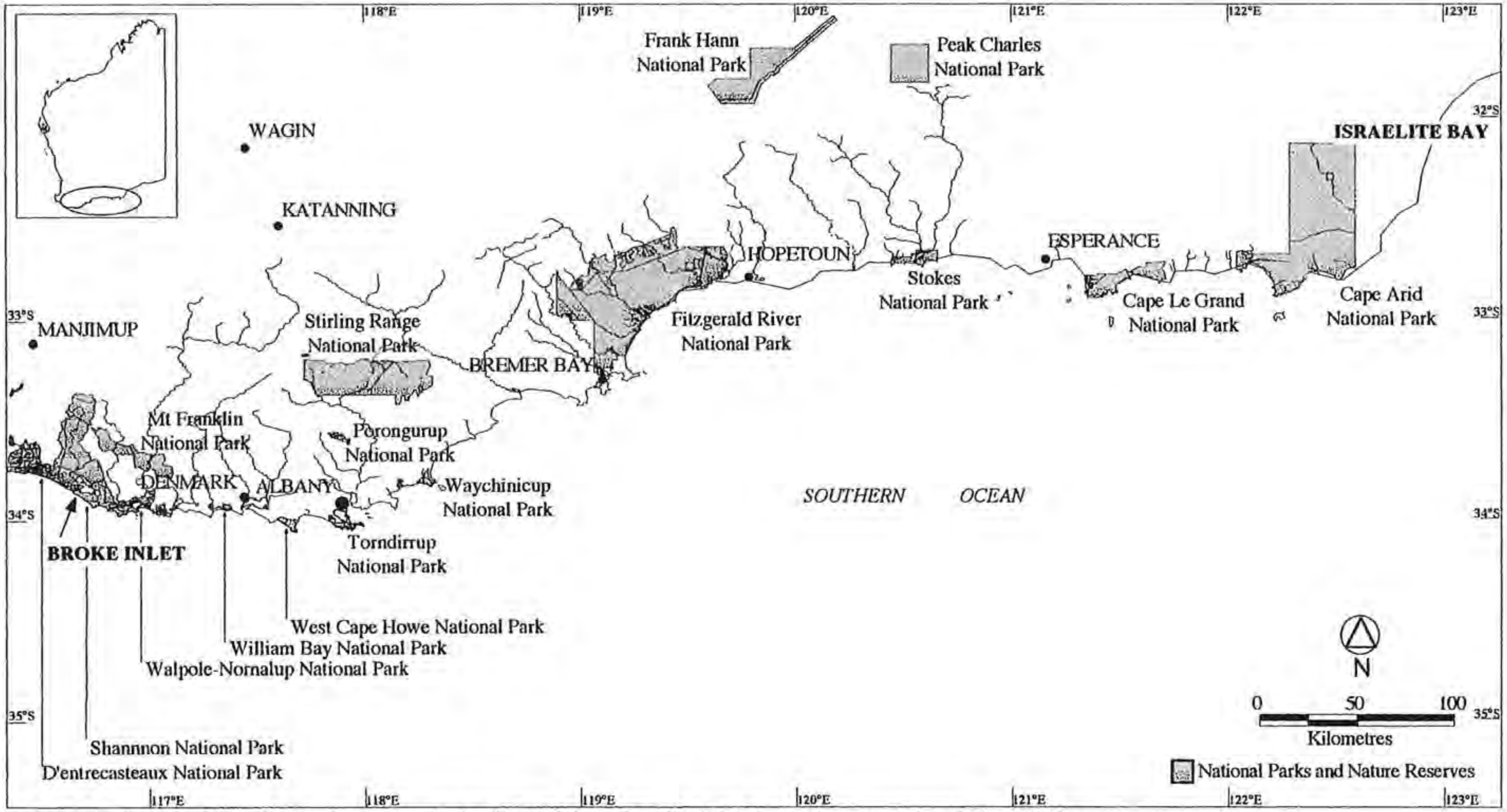

Figure 1.1. Locality Map: The south coast study site (Broke Inlet to Israelite Bay), in relation to existing National Parks.

2. Catchment Characteristics

This section covers the characteristics of the watershed or catchments of the south coast estuaries. It will describe the ancient geology, the relatively new soils, climate and rainfall, remnant vegetation, the catchments and the land use.

This review identifies four regions (Figure 2.1):

1. Broke Inlet to Torbay Inlet;
2. The Albany Environs;
3. Fitzgerald Biosphere;
4. Esperance Environs.

2.1. Geology and Soils

The basement geology (Figure 2.2.) of the south coast region is ancient. Some rocks were formed around 2,600 to 3,200 million years before present (mybp) are deeply weathered or overlain by weathered profiles and relevantly recent soils. Geology, characteristic landforms, weathering intensity and climate influenced the development of soil types in the South Coast region (CALM 1992a).

2.1.1. Broke Inlet to Torbay Inlet

The upper catchment is mainly cleared agricultural lands and lies on the Yilgarn Plateau. The Yilgarn Plateau rocks (or the Western Australian Archaean Shield), are amongst the oldest in Australia, being formed around 3,000 mybp. The predominant rock form of this plateau of hard Archaean rock is granite and gneiss, and the second major rock types are greenstones which are metamorphosed, interbedded sedimentary and igneous rocks, important for their nickel and gold deposits (CALM 1992a, SCRAP & SCRIPT 1996b). The soils of the upper catchment are yellow sands and red/yellow duplex soils which are highly erosive and saline (Hodgkin & Clark 1988b, 1988c, 1989a).

The middle catchment lies on the Albany-Frazer Orogen. The rocks of the Albany-Fraser Orogen were formed around 1200-1600 mybp. These Proterozoic rocks are mainly made up of the Nornalup complex: deformed and recrystallised porphyritic granites, granitic orthogneiss and heterogeneous granites. It is mainly forested with deep valleys and steep slopes. In the valleys the basement rock is covered by Tertiary and Quaternary sands. Most of the soils have ferruginous gravels/laterites in the surface which reduce erosion. The subsoils can be either leached sandy and gravelly soils or red karri loams with a high clay content. This region's soils are characterized by lateritic plateaux with many variations in soil types. Lateritic plateaux and quartzite ranges give way to gravelly and loamy soils, yellow clayey subsoils to the poorer sandy soils near the coast.

The coastal strip in the west of the lower catchment is characterized by sand dunes between steep granitic headlands. The older, usually higher sand dunes have Pleistocene calcareous sands with a lithified dune limestone core. The younger Holocene dunes have a high percentage of quartz sands and are only stable when vegetated. Behind the coastal dune system, there are some swampy lakes in poorly developed soils. In the east of the lower catchment, closer to Wilson Inlet, there are more occurrences of Tertiary sandstones and spongolite (Pallinup siltstone). The soils on the low sand plain are mainly poor Quaternary sands and swamps (Hodgkin & Clark 1988b, 1988c, 1989a).

2.1.2. The Albany Environs

The upper catchments of the longer river systems (Kalgan and King Rivers), are mainly cleared agricultural lands. They are on the southern boundary of the Yilgarn plateau and have Archaean granitic rocks underlying the plateau sand plain. There are saltlakes and swamps in this area which mainly consist of sandy loams and yellow duplex soils or fine grey brown sands and laterites.

The Albany-Fraser Orogen is the basement geology of the middle catchment of the Albany region. These deformed rocks form the peaks and ridges of the Stirling Ranges and the mountains north of Doubtful Bay.

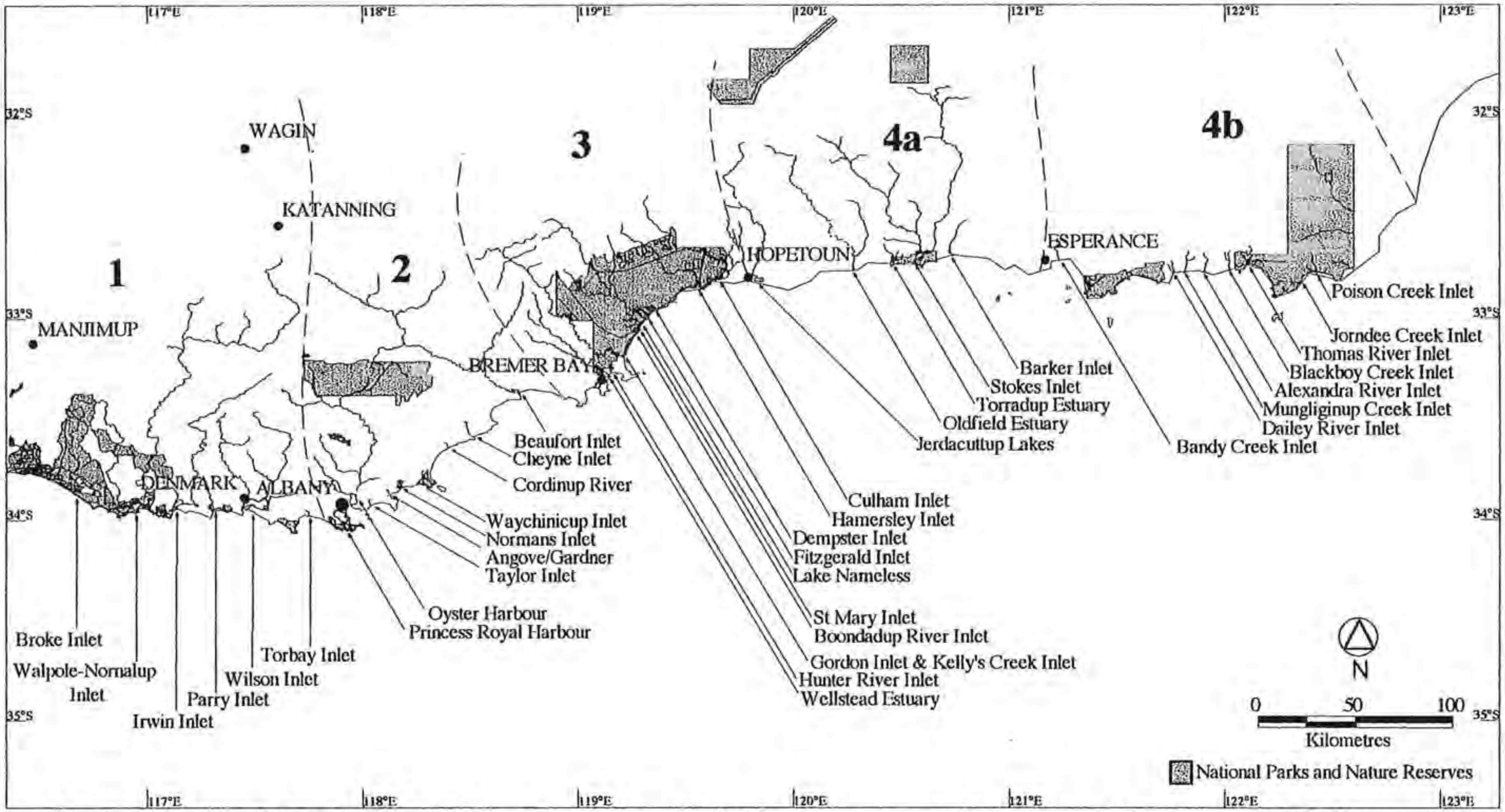

Figure 2.1. The four regions of the south coast: (1) Broke Inlet to Torbay Inlet; (2) The Albany Environs; (3) The Fitzgerald Biosphere; and (4) The Esperance Environs.

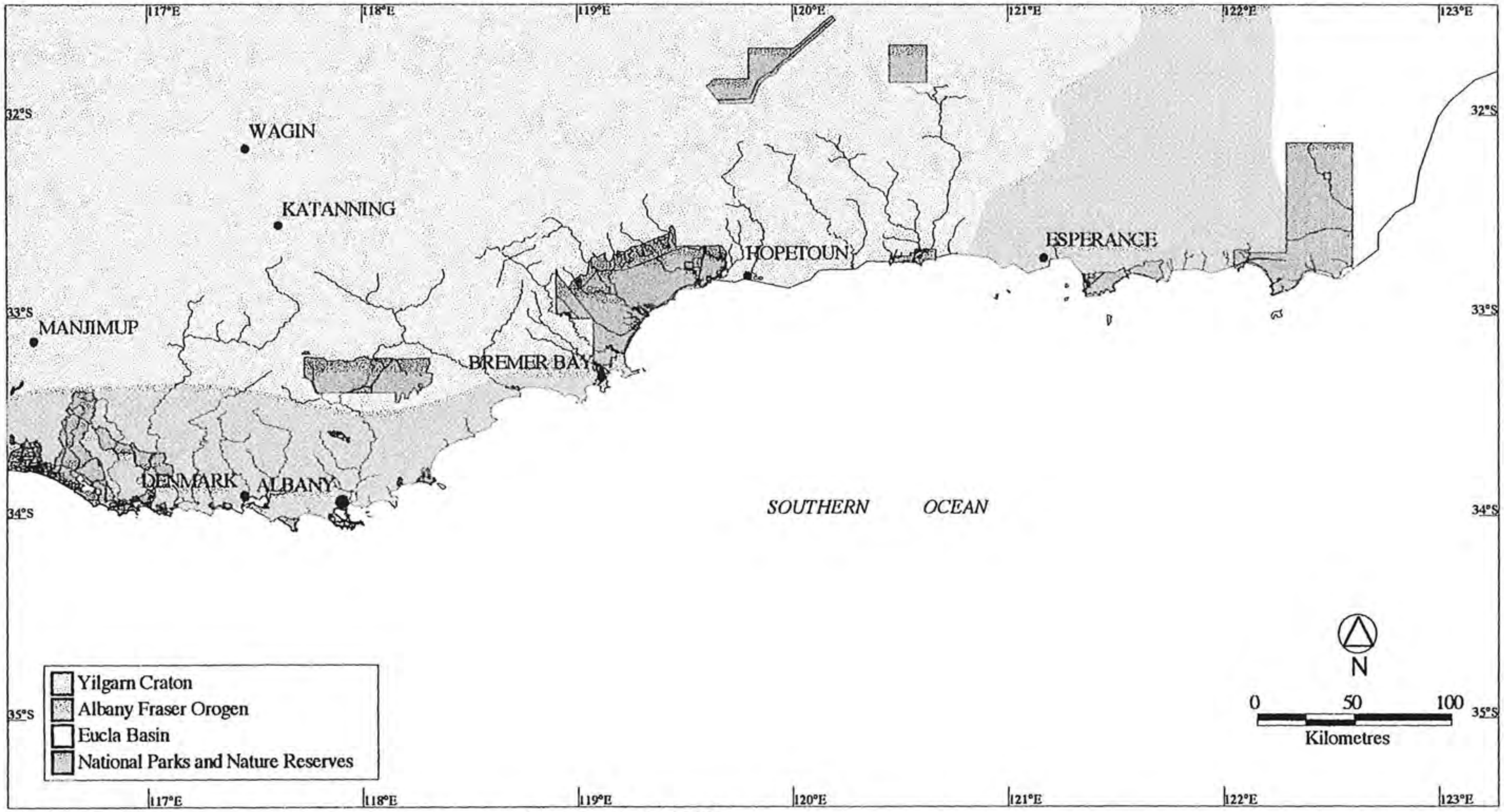

Figure 2.2. The basement geology for the south coast region (*after* CALM 1992a)

The soils are a combination of sandy loam and yellow duplex soils on the higher slopes with river sediments in the broad valleys. The headwaters of the smaller East Albany catchments are in sand plains on gentle undulating spongolite over Pre-Cambrian bed rock (CALM 1992a, SCRAP & SCRIPT 1996a).

The lower catchments have large Pre-Cambrian rock headlands which are rugged and cliffed. These are usually composed of various plutonic igneous rocks (e.g. granite) and metamorphic rocks such as gneiss and schists. The eastern bays are of spongolite with duplex soils of sand and gravel overlaying clay subsoil. The region has many isolated granite outcrops. The coastal sands are Pleistocene calcareous in nature with overlying Holocene quartz sands. East of Princess Royal Harbour and Two Peoples Bay have poor sands with swamplands behind the coastal dune systems (Hodgkin & Clark 1990a, CALM 1992a).

2.1.3. Fitzgerald Biosphere

The upper reaches of the Fitzgerald Biosphere is on the Yilgarn Plateau. It is mainly sand plains over the Archaean granitic rock formed over 1200 mybp. It is mainly cleared agriculture lands which are suffering from wind erosion and rising salinity. The soils are mainly sandy but there are areas of lateritic gravels overlying dense clays.

The Albany-Fraser Orogen dominates the middle catchment region. There is a combination of the sediments of a recent (Tertiary) marine inundation in the form of spongolite which overlies deeper granitic rocks. Spongolite is composed of clays, sponge spicules, sand and fossil shells. The rivers have formed deep gorges through the soft spongolite. Soils are mainly loamy with clay subsoils.

The coastal ranges (the Mt Barrens), are of Proterozoic schists and quartzites which were formed from metamorphosed sedimentary rocks. The coastal strip has high Pleistocene dunes with lithified calcareous dune rocks (limestone, sandstone) and highly mobile Holocene sand dunes. The embayments are between Pre-Cambrian headlands of granite, gneiss, schists and quartzite, which are covered in either dune sands or calcareous sandstones (CALM 1992a, SCRAP & SCRIPT 1997b).

The coastal dunes are mainly silica and calcareous sands, the latter being mainly made up of calcareous materials from red seaweeds and marine fauna. Behind the coastal dunes the soils are mainly poorly formed and sandy (Hodgkin & Clark 1987, Hodgkin & Clark 1988a, Hodgkin & Clark 1990b).

2.1.4. Esperance Environs

The coastal region is dominated by Quaternary, Pleistocene and Holocene sands. Sandy beaches are interspersed with headlands of Pleistocene granite. These basins were formed during an oceanic inundation of the land approximately 135 mybp. The sedimentation of eroded crystalline rock and marine silt, resulted in soft spongolite (Pallinup siltstone), and lignite, a high organic clay bed, similar to a low quality coal (CALM 1992a, SCRAP & SCRIPT 1997a).

The greater part of the larger catchments to the west of Esperance are on the Albany-Frazer Orogen. The basement rocks are Pleistocene granitic rocks and the soils are sandy and gravelly over a clay subsoil.

The upper edges of these catchments are on the lower slopes of the Yilgarn plateau (Archaean rock). The soils are shallow loams over yellow clayey subsoils. These soils are saline.

To the east of Esperance there is a wide belt of Quaternary dune sands which are up to 40 km from the coast. There are stabilized and mobile sand dunes interrupted by granite headlands. The soils behind these dunes are poorly developed and sandy. Many catchments of the smaller streams are wholly within this geological region. The middle catchment is sand plain with sandy duplex soils over a clay subsoil. The upper regions of the larger streams are on a spongolite plateau overlying the deep granites of the Yilgarn (Hodgkin & Clark 1990b).

2.2. Climate and Rainfall

The south coast region experiences a Mediterranean climate which is described as having hot dry summers and moderately cold wet winters. The region is characterized by east-west and a north-south rainfall gradients. Rainfall decreases eastwards from an annual average of 1200 mm at Walpole, to 900 mm at Albany and 650 mm at Esperance. The northern gradient decreases northwards from these coastal rainfalls to less than 400 mm experienced north of Esperance (Craig & Oma 1984, Muirden in prep.-a, Muirden in prep.-b).

The rainfalls quoted here are annual averages. For regional comparisons, it is necessary to consider the variation between the 90th percentile and 10th percentile rainfalls. The variation between average annual rainfalls for the Broke Inlet to Torbay Inlet region is nominal, in other words between any two years the difference is small. Albany Harbours and East Albany region are also similar. However for the Fitzgerald Biosphere and the Esperance Environs regions, the range between the 90th percentile and 10th percentile rainfalls is great, reflecting the marked difference between high and low rainfall years (Deeley et al. in prep).

Generally the rainfall in the Broke Inlet to Torbay Inlet region can be classified as high. The average annual rainfall varies from 1200 mm near the coast to 450 mm in the upper catchments of the Frankland, Kent and Hay Rivers. About two thirds of the annual rainfall falls between the months of May and October (SCRAP & SCRIPT 1996b). This region occasionally experiences unseasonal summer storms. Average monthly rainfalls were exceeded in January 1939, March 1943 and February 1954 at Denmark, February 1955 and January 1982 at Walpole, and at Broke Inlet in February 1946 (Hodgkin & Clark 1988b, 1988c). The average daily temperature ranges from 12-30°C in summer to 4-14°C in winter at Walpole.

The Albany Environs has a high to medium rainfall. Albany experiences an average of 800 to 1000 mm per year near the coast west of Princess Royal Harbour to 500 mm at head waters of the King and Kalgan Rivers. Eastwards of Albany, the rainfall decreases to around 520 mm per annum at Cheynes Inlet. Most of the rainfall occurs in winter (May to October) which represents 60% of the annual rainfall. Periodically the region experiences cyclonic summer storms which have been known to produce over 200 mm of rain in two days. Monthly averages were exceeded in January 1939, February 1955 and January 1982 (Hodgkin & Clark 1990a, SCRAP & SCRIPT 1996a). For Albany, the average daily temperatures range from 14-25°C in summer to 6-14°C in winter while Katanning (upper Pallinup catchment), experiences temperatures in summer of 17-32°C and 4-14°C in winter (SCRAP & SCRIPT 1996a).

The Fitzgerald Biosphere experiences low rainfalls of around 550 mm per year on the coastal strip to 400 mm in the upper catchment of the Fitzgerald River. This region has also in the past experienced unusually high summer rainfalls. In February 1955 and January 1982 higher than average monthly rainfalls were recorded. The rainfall in the Fitzgerald Biosphere, in relation to the western regions of the south coast, is more evenly distributed throughout the year (Hodgkin & Clark 1990b, SCRAP & SCRIPT 1997b).

In the Esperance Environs, the average daily temperature ranges from 16-26°C in summer to 6-16°C in winter. East of Esperance the rainfall is low with Stokes Inlet receiving 540 mm per annum and the upper Oldfield River receiving less than 350 mm. The western district of the Esperance region experiences a slightly higher rainfall (around 600 mm). Most of the rain falls in the winter months between May and August. The Esperance region's rainfall is highly variable and periodically experiences drought (Hodgkin & Clark 1989b, SCRAP & SCRIPT 1997a).

In summer, the south coast region predominantly experiences winds from the south east which become quite fresh in the afternoon. However in winter, the prevailing winds are from the west and the north west (CALM 1992a).

2.3. Remnant Vegetation

The river catchments of the south coast mainly cover three different botanical districts of the South West Botanical Province: The Menzies and Warren sub-regions of the Darling Botanical District, and the Eyre Botanical District (Figure 2.3). Only the very uppermost reaches of the Pallinup River lie in the Roe Botanical District and is not discussed in this paper. The vegetation of the south coast region is closely linked to geology and soil type (see Section 2.1).

2.3.1. Broke Inlet to Torbay Inlet

The Broke Inlet to Torbay region includes both sub-regions of the Darling Botanical District and a small portion of the upper catchment lies in the Avon Botanical District (CALM 1992a).

The upper catchment receives less than 700 mm of yearly rainfall and has been extensively cleared for agriculture. The remaining vegetation consists mainly of woodlands of Wandoo *(Eucalyptus wandoo)* and Salmon Gums (*E salmonphloea*) on loams. Jarrah (*E. marginata*) and Marri (*E. calophylla*) dominate on gravelly/sandy soils. Also present amongst the Jarrah/Marri woodlands, are Yate (*E, cornuta*) and Swamp Yate (*E. occidentalis*). Salt tolerant species occur on the more saline soils. There are patches of paperbarks (*Melaleuca* spp.), Flooded Gums (*E. rudis)* and sedgelands usually along streamlines and gullies.

The majority of the catchment of this region consists of uncleared high rainfall (>700 mm) forests. Basically there are Karri (*E. diversicolor*) and Marri forest systems on duplex loam soils on the hills ridges and alluvial soils along the streams. Jarrah and Marri are present on leached sands and laterites. Some patches of Casuarina, Blackbutt (*E. todliana*) and Bullich (*E. megacarpa*) on the damper valley floors. In the lowlands there are Paperbarks (*Melaleuca* spp.) and sedgelands (Hodgkin & Clark 1988b, 1988c).

There are tall Tingle forests dominate the higher ground of the coastal ridge around Walpole. There are three Tingle species which are endemic to the region; the Rates Tingle (*E. brevistylis*), the Yellow Tingle (*E. guilfoylei*) and the Red Tingle (*E. jacksonii*) (CALM 1992b).

The coastal plain has mostly been cleared for agricultural enterprises. It is a high rainfall, high runoff region which supports low Jarrah bushlands on the hills and diverse swamp vegetation (*Melaleuca* spp.) in the lowlands. Around Irwin Inlet there are small stands of the distinctive Red Flowering Gum (*E. ficifolia*). The dunes are covered by coastal heath on the seaward slope and in the sheltered hollows behind, peppermint thickets (*Agonis flexuosa*) and Banksia scrubland occur (CALM 1992b, SCRAP & SCRIPT 1996b). There are patches of peaty swamps around the inlets (SCRAP & SCRIPT 1996a).

2.3.2. The Albany Environs

The Albany region mainly lies in the Menzies Sub-Region of the Darling Botanical District. While east of Albany is located in the Eyre botanical District of the South West Botanical Province.

The upper catchment consists predominantly of Jarrah, Marri, Wandoo, Yate and Flooded Gum woodlands. The upper reaches of the Kalgan River has Paperbark shrublands with Swamp Yate and many halophytes (salt tolerant plants) in the valleys. The upper King has Swamp Yates and Blackbutt in the valley basins with patches of Albany Blackbutt (*E. staeri)* on the higher ground (Hodgkin & Clark 1990a).

Around Mt Garner and Mt Manypeaks is dominated by Mallee bushlands consisting of *E. decipens* if sandy and *E. cornuta* if on loamy soils. The Stirling Ranges are covered by mallee heath of *E. tetragona* (Tallerack), typically on sand over clay. The swampy depressions have stands of *E. decipens.*

The coastal strip has largely been cleared for agriculture. The remnant vegetation is mainly coastal mallee heath (*E. tetragona*),

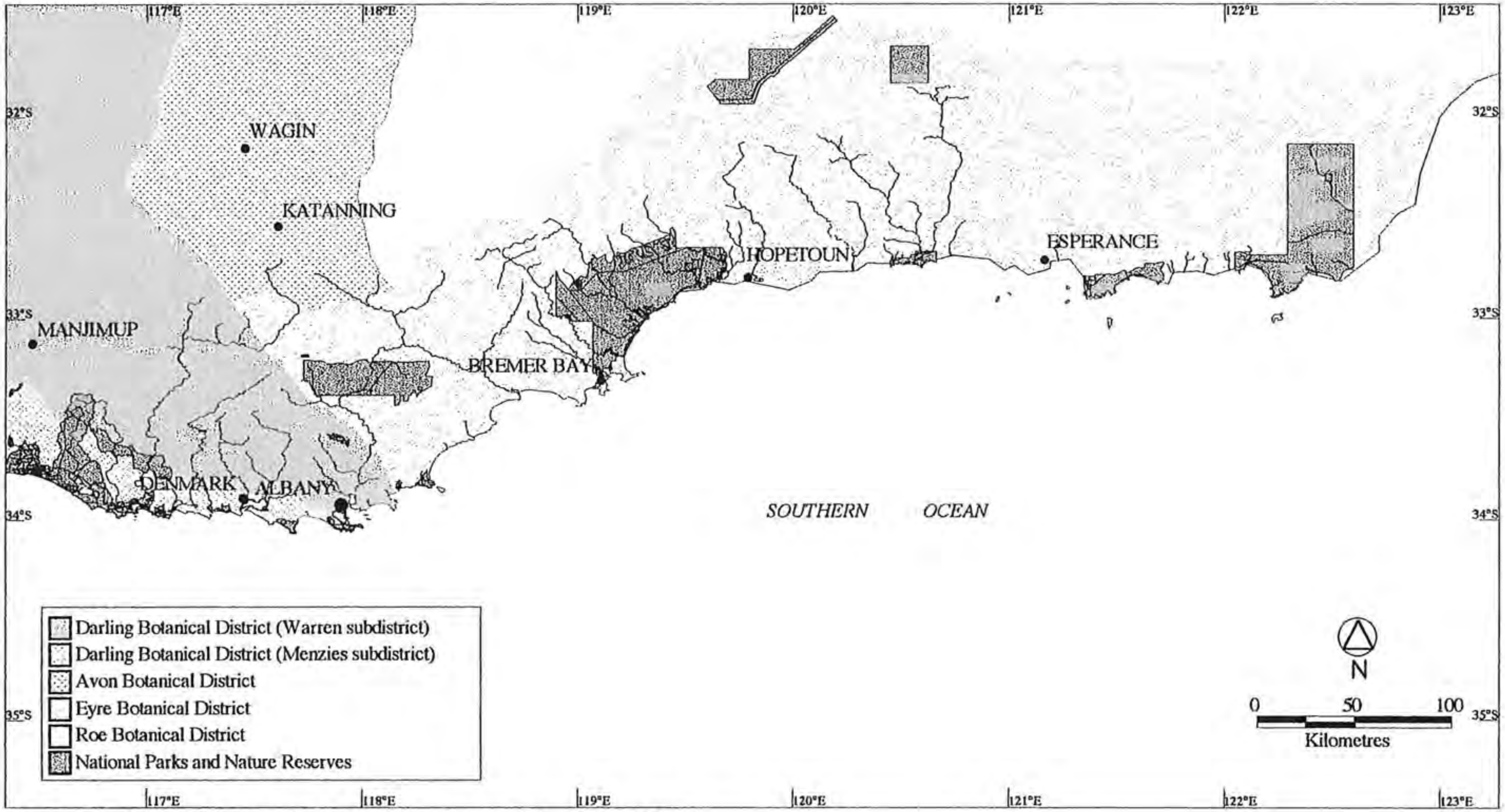

Figure 2.3. Botanical districts for the south coast region (*after* CALM 1992a).

with patches of Jarrah and *Banksia attenuata.* The dune system has coastal heath with *Acacia cochlearis* on the foreslopes and *Agonis flexuosa, Melaleuca thymoides* and *Leucopogon revolutes* in the protected hollows. Low Jarrah, *E. staeri* and Casuarina bushlands surrounds Waychinicup Inlet. The Two Peoples Bay region similarly has low jarrah and *E. staeri* bushlands, however patches of Banksia bushlands (*B. littoris*) with Hakea are present. *Dryandra sessalis* (Parrot Bush) occurs on limestone (Hodgkin & Clark 1990a, CALM 1995, SCRAP & SCRIPT 1996a).

2.3.3. FITZGERALD BIOSPHERE

The Fitzgerald River National Park is the most dominant feature of this region. The park is 3280 km^2 and lies within the Eyre Botanical District of the South West Botanical Province.

The Eyre Botanical District is a narrow strip that follows the south coastline from Albany to Esperance. It is a medium to low rainfall district with an annual rainfall range of 350-800 mm. The Fitzgerald River National Park forms the only remaining representative bushlands of the Eyre Botanical District, as much of the district has been recently cleared for agriculture.

There are nearly 1800 plant species recorded with 75 species being endemic to the region. The park contains over 20% of known western Australian plant species (both named and unnamed). The flora of the Fitzgerald River National Park include five families of ferns, and 87 families of flowering plants. Two hundred and fifty plant species have been identified as being rare and of high conservation value (CALM 1991).

The uppermost reaches of the Fitzgerald River have not been cleared, however the region below these reaches and above the Fitzgerald River National Park have in recent time been extensively denuded for agriculture. Of the little remaining vegetation, there are shrublands of mallee eucalypts. *E. redunca, E. gardeneri, E. nutens, E. tetragona,* E. *eremorphylla* and *E. oleosa* form associated patches. There are also patches of Proteaceae, Myrtaceae and Leguminosaceae (Hodgkin & Clark 1987). The upland plains are patched with bottlebrushes (*Callistemon pheoniceus, Melaleuca elliptica, M. fulgens* and *Calothamnus quadifidus*) and the Pincushion Hakea, *Hakea laurina.*

The ranges in the Fitzgerald River National Park consist of schist and quartzite and are dominated by shrublands of *Banksia oreophila, Dryandra quercifolia, Hakea victoria, Petrophile fastigiata* and *Adenantha venosus.* On the shallow schistose soils there are mallee of many Eucalypt species and the distinctive *E. sepulcralis* (Weeping Gum). In association with these mallee and in deeper soils are *Allocasuarina trichodon, Banksia media* and *E. incrassata.* On the Ravensthorpe Ranges are a mixture of mallee such as *E. annulata, E. nutens* (Red-Flowering Moort), *E. trans-continentalis, E. leptophylla* and *E. leptocalyx* (Hodgkin & Clark 1990b).

The river gorges that cut through soft spongolite siltstone have low woodlands on the slopes interspersed with *E gardneri* and Swamp Yate (*E. occidentalis*) in the valleys. Where the soils are loamy, open mallee of *E. conglobata* and *E. incrassata* dominate with patches of Moorts (*E. platypus* var. *platypus*) being common. The marine sand plain is dominated by shrub mallee *E. incrassata, E. leptocalyx* and *E. unicata* with *E. tetragona* and *Banksia baxteri* in the deeper sediments. Also occurring on the marine plain is the unusual Royal Hakea (*Hakea victoria*) with its blazing red-gold leaf variegations.

Coastal heaths with Hairy Spinifex (*Spinifex hirsutus*) and Cushion Bush (*Calocephalus brownii*) occur on the seaward slope of the low coastal dunes of the Fitzgerald River National Park. These coastal dunes lie between rocky headlands of granite, gneiss and schists. Low Banksia scrubland of *Banksia media, B. speciosa, B. pulchella, B. coccinea* and *Calothamnus perifolius,* is found behind the dunes. In the protected hollows are thickets of *Melaleuca lanceolata, M. nesophyla* and *Agonis flexuosa.* Coastal Moort (*E. platypus* var. *heterophylla*) and open shrub mallee (*E. angulosa*) are found in the more stable areas (Hodgkin & Clark 1990b, CALM 1991, SCRAP & SCRIPT 1997b).

2.3.4. ESPERANCE ENVIRONS

The Esperance region lies in the Eyre Botanical Region of the South West Botanical Province. West of Esperance has in recent time been cleared for agricultural purposes and the remnant vegetation is dominated by low coastal Banksia shrublands. The shrublands are composed of *B. media*, *B. speciosa*, *B. repens*, *B. blechnifolia* and Hakeas such as the Cauliflower Hakea (*Hakea corymbosa*) and the Ashy-leaved Hakea (*H. cinera*). The vegetation overlying the lateritic soils are predominantly mallee heath. The two most evident mallee are the widespread Tallerack (*E. tetragona*) and the localized Four-Winged Mallee (*E. tetraptera*). Closer to the coast, on the shallow limestone ridges are the Bell-fruited Mallee (*E. preissiana*). The Scarlet Pear Gum (*E. stoatei*) is present but has restricted distribution. The brackish swamps and the estuaries are surrounded by paperbarks (*Melaleuca preissiana*) and Yate (*E. occidentalis*). The upper reaches of the catchments of the Young and Lort Rivers are mainly mallee woodlands of *E. redunca*, *E. unicata* and *E. eremorpha* (Craig et al. 1984, Hodgkin & Clark 1990b).

The vegetation east of Esperance is predominantly low coastal banksia scrubland consisting of *B. media* and *B. speciosa*, Peppermints (*Agonis flexuosa*), Christmas Trees (*Nutzia florabunda*) and Grasstrees (*Xanthorrhoea preissei*). Interspersed in patches are mallee heathlands of *E. tetragona*, *E. redunca* and *E. unicata*. A complex coastal heath including *Scaevola crassifolia* and *Spinifex hirsutus*, occurs on the foreslopes of the coastal dunes. In the wetter depressions are Melaleuca thickets of *M. cuticularis* and *M. preissiana*. The granite outcrops are covered with Agonis, Acacia, Hakea and Zamia Palms (*Macrozamia reidlei*) (DCEWA 1983, Craig & Oma 1984, SCRAP & SCRIPT 1997a).

2.4. The Catchments

There are numerous rivers and creeks that flow to the south coast. Many of these flow into inlets which are either semi-permanently or permanently closed to the ocean by a sand bar at their mouths (Hodgkin & Kendrick 1984, Hodgkin & Hesp in prep). Detailed descriptions of the major rivers can be found in Olsen and Skitmore (1991), and in SCRAP and SCRIPT (1996a, 1996b, 1997a, 1997d, 1997b, 1997c). This section briefly describes the catchments in the four regions of the south coast (*see* Figure 2.1.).

2.4.1. BROKE INLET TO TORBAY INLET

This region there are six major estuaries: Broke, Walpole-Nornalup, Irwin, Parry, Wilson and Torbay Inlets. These estuaries are fed by 18 rivers and creeks (Table 2.1.). The Shannon, Forth, Inlet, Weld and the Deep Rivers can be considered pristine as little of their catchment has been cleared. Their catchments are mainly forested (>90%) and receive an annual rainfall greater than 700 mm. The waters of these catchments are fresh.

The catchments of Karri Creek and the Denmark and Bow Rivers are around 20% cleared while the other catchments have mostly been cleared for agriculture. Of the cleared catchments, the Franklin, Hay and Kent River headwaters drain sandy soils in areas that receive <700 mm rainfall per annum. The Franklin is saline, the Kent River is marginal and the Hay is brackish (EPAWA 1992).

The Cuppup, Sleeman, Kordabup and Little river catchments cover mainly cleared leached sandy soils of the coastal sand plain. These catchments also receive >700 mm annual rainfall and have a high runoff. The water quality of these rivers is fresh to marginal.

2.4.2. THE ALBANY ENVIRONS

Omitting Princess Royal Harbour, which has minimal runoff impacts and is the only coastal embayment mentioned in this review, the Kalgan, King and the Pallinup Rivers are the major catchments in this

Table 2.1. Rivers and streams of the Broke Inlet to Torbay Inlet region (after Muirden in prep.-b, in prep.-a). b = Deeley et al. (in prep), c = Hodgkin & Clark (1988c, 1988b, 1989a, 1990a), d = PWD (1979), f = SCRAP & SCRIPT (1996a), g = Schofield et al. (1988) i = GovWA (1996) and k = EPAWA (1992).

ESTUARY	BASIN	CATCH-MENT AREA (km^2)	AREA CLEARED (%)	MEAN ANNUAL RAINFALL (mm)	MEAN ANNUAL FLOW (Ml)	MEAN ANNUAL RUNOFF (mm)	WATER QUALITY	CoV	MEAN ANNUAL SALINITY (mg/l TSS)	MEAN ANNUAL TURBIDITY (NTU)	MEAN ANNUAL COLOUR (Hazen)
BROKE	Shannon	612	g 3	1320	141400	231	fresh	0.36	150	2	325
	Forth	24	5	1420	6920	288	fresh	0.34	150	3	370
	Inlet	56	5	1410	15700	282	fresh	0.34	170	3	170
WALPOLE-NORNALUP	Weld	250	0	1275	52300	209	fresh	0.39	175	3	255
	Deep	1003	d 2	1120	167000	166	fresh	0.45	d 200	4	290
	Walpole	c 76	13	1415	19100	316	fresh	0.33	260	5	140
	Frankland	b 5762	56	630	201500	43	saline	0.55	5500	8	100
IRWIN	Bow	211	c 22	1200	43360	205.5	g fresh	0.46	g 163		
	Karri	21	20	1230	5210	248.1	k fresh	0.45			
	Kent	1830	40	800	89420	48.9	marg	0.56	g 1750	2.25	154
PARRY	Kordabup	55	70	1100	11090	326	f fresh	0.33			
WILSON	Little	16	70	1200	4500	281.6	k fresh	0.23			
	Denmark	772	21	850	54900	81.1	marg	0.49	g 910	4.91	135
	Hay	1277	40	770	f 9400	80.9	f brack	0.46	i 1800		
	Sleeman	87	60	890	15320	176	k marg	0.46			
	Cuppup	58	80	1005	16040	274	k fresh	0.27			
	Marbellup	121	65				f fresh				
TORBAY	Torbay	c 278	c 71		c 37000	c 135	f fresh				

region. The catchments are far reaching, about 100 km inland and drain the saline sand plains of the wheat belt. These catchments consist of extensively cleared agricultural lands, which receive an annual rainfall of <700 mm. The King River is fresh and the Kalgan is brackish (EPAWA 1992).

The region east of Albany has eleven rivers, most of which have small catchments of less than 120 km^2 (Table 2.2.). All of the catchments, excepting Angove/Gardner creeks, Bluff and Little Bluff Rivers, have significant percentages of cleared agricultural lands. The smaller catchments of the Hassel Beach rivers (Bluff, Little Bluff and Wongerup Rivers), are mainly in the coastal strip reserve.

2.4.3. FITZGERALD BIOSPHERE

The Fitzgerald National Park is the most dominant feature of this region. There are twelve rivers that discharge into eleven estuaries (Table 2.3.). The waters of these rivers are brackish to saline (EPAWA 1992). There are five long river systems in the Fitzgerald Biosphere: The Bremer, Gardiner, Fitzgerald, Hamersley, and Phillips Rivers. Their catchments extend inland between 50 to 100 km.

These systems arise on the Yilgarn Plateau and cut deep into the soft Pallinup Siltstone plateau before discharging into their inlets. All of the major rivers in the Fitzgerald Biosphere region are saline as they rise from the saline soils of the Wheatbelt. The rivers also carry large sediment loads which are still increasing due to the catchment clearing of recent times (EPAWA 1992). Sediments are slowly filling these coastal lagoons (Hodgkin & Clark 1987, Hodgkin & Clark 1988a, Hodgkin & Clark 1990b).

There are a number of smaller rivers whose entire catchments are contained within the Fitzgerald River National Park. The Hunter, Kelly's, Boondadup, St Mary, Lake Nameless, and the Dempster tributaries could be classed as pristine. They could be used as comparative baseline ecosystems when monitoring for ecosystem change in adjacent degraded estuaries such as the Beaufort, Fitzgerald and Hamersley Inlets.

2.4.4. ESPERANCE ENVIRONS

East of Esperance has a low average annual rainfall with a range of 450-600 mm along the coastal strip. The rainfall declines rapidly northwards. The streams of this area are small and ephemeral, with most of their catchment in the coastal plain which is

Table 2.2. Rivers, streams and drains of the Albany Environs region. (after Muirden in prep.-a, in prep.-b). a = AWMA (1995), c = Hodgkin & Clark (1988a, 1990a), e = SCRAP & SCRIPT (1997b), f = SCRAP & SCRIPT (1996a), g = Schofield et al. (1988).

ESTUARY	BASIN	CATCH-MENT AREA (km^2)	AREA CLEARED (%)	MEAN ANNUAL RAINFALL (mm)	MEAN ANNUAL FLOW (Ml)	MEAN ANNUAL RUNOFF (mm)	WATER QUALITY	CoV	MEAN ANNUAL SALINITY (mg/l TSS)	MEAN ANNUAL TURBIDITY (NTU)	MEAN ANNUAL COLOUR (Hazen)
PRINCESS ROYAL HARBOUR	Robinson	8.9	95	940	1826	205	[f] fresh	0.17			
	Albany	[a] 5	[a] 49	[f] 1000			[f] fresh				
OYSTER HARBOUR	King	[c] 402	[c] 83	[f] 860	[f] 34126	[c] 140	[f] fresh	0.29	[c] 1500		
	Kalgan	[c] 2562	[c] 66	[f] 600	[f] 53400	[c] 21	[f] brack	0.64	[c] 3100		
	Yakamia	16	95	890	2870	177.2	[f] fresh	0.2			
	Johnstone	16	[a] 51	800	1330	81.2	[f] fresh	0.37			
TAYLOR	Taylor	[c] 10	[c] 70		[c] 1400	[c] 140	[k] fresh				
TWO PEOPLES BAY	Angove	42	5	850	3040	72.5	[g] fresh	0.37	[g] 422		
KING	King	25	[g] 70	830	2320	92.9	[f] marg	0.35	[c] 600		
NORMANS	Normans	[c] 18	[c] 46		[c] 1800	[c] 100	[f] marg				
WAYCHINICUP	Waychinicup	231	[g] 45	760	8555	37.1	[f] marg	0.61	[c] 720		
BLUFF	Bluff	[f] 18	[f] 10	[f] 805	532	29.6	[f] marg	0.63			
LITTLE BLUFF	Little Bluff	[f] 22	[f] 10	[f] 710	610	27.7	[f] marg	0.64			
WONGERUP	Wongerup	66	20	650	1150	22.9	[f] marg	0.67			
CORDINUP	Cordinup	113	[c] 38	610	1670	14.8	[f] marg	0.68			
WILYUNUP	Wilyunup	[f] 113	[f] 30	[f] 610	2110	18.7	[f] marg	0.57			
CHEYNE	Eyre	67	40	610	1760	26.2	[f] marg	0.57			
SWAN GULLY	Swan Gully										
BEAUFORT	Pallinup	[e] 4800	[g] 90	390	28043	7.8	[g] saline	1.11	[g] 19478		

Table 2.3. Rivers and streams of the Fitzgerald Biosphere region. (after Muirden in prep.-a, in prep.-b). a = AWMA (1995), c = Hodgkin & Clark (1987, 1988a, 1990b), e = SCRAP & SCRIPT (1997b), k = Chapman (1985), k = EPAWA (1992).

ESTUARY	BASIN	CATCH-MENT AREA (km^2)	AREA CLEARED (%)	MEAN ANNUAL RAINFALL (mm)	MEAN ANNUAL FLOW (Ml)	MEAN ANNUAL RUNOFF (mm)	WATER QUALITY	CoV	MEAN ANNUAL SALINITY (mg/l TSS)	MEAN ANNUAL TURBIDITY (NTU)	MEAN ANNUAL COLOUR (Hazen)
WELLSTEAD	Bremer	716	[c] 80	510	[e] 9800	4	[e] saline	0.34			
HUNTER	Hunter	19	0	610	191	9.3	[e] marg	1.72			
KELLY'S	Kelly's	15	0	595	129	8.4	[e] marg	1.82			
GORDON	Gardiner	1770	60	405	13560	7.7	[e] saline	0.71			
BOONDADUP	Boondadup	38	0	500	146	3.8	[k] fresh	2.38			
ST MARY	St Mary	169	0	490	550	3.3	[k] marg	2.43			
LAKE NAMELESS	unnamed	49	0	485	145	3	[k] marg	2.46			
FITZGERALD	Fitzgerald	1611	40	410	[c] 8000	5.6	[h] saline	0.99	[h] 14885		
DEMPSTER	Dempster	320	0	470	680	2.1	[e] marg	2.55			
	Coppermine	157	0	460	245	1.6	[e] marg	2.61			
HAMERSLEY	Hamersley	835	[a] 19	440	[e] 3000	1.4	[h] saline	2.28	[h] 19244		
CULHAM	Phillips	2370	[c] 44	405	[e] 7300	0.6	[h] saline	3.71	[h] 10414	20	80

in some areas up to 40 km wide. In most cases, the catchments have recently been substantially cleared for agriculture (Table 2.4.), subsequently putting stream pools and inlets at risk from salinity, sedimentation and eutrophication (Hodgkin & Clark 1989b).

The Jerdacuttup River drains coastal sand plains and discharges into the Jerdacuttup Lakes. These lakes are now separated from the oceans by high dunes. The runoff from these catchments are brackish to saline, except for Jorndee, Poison and Fern Creeks, which all drain a small catchment. The catchments of the Thomas, Jorndee, Poison and Fern creeks lie mostly in the Cape Arid National Park (Hodgkin & Clark 1989b, SCRAP & SCRIPT 1997a).

The area west of Esperance is a lower rainfall region around 350-500 mm per annum. All of the river catchments have

Table 2.4. Rivers and streams of the Esperance Environs region. (after Muirden in prep.-a, in prep.-b). b = Deeley et al. (in prep), c = Hodgkin & Clark (1989b), e = SCRAP & SCRIPT (1997b), m = SCRAP & SCRIPT (1997a).

ESTUARY	BASIN	CATCH-MENT AREA (km^2)	AREA CLEARED (%)	MEAN ANNUAL RAINFALL (mm)	MEAN ANNUAL FLOW (Ml)	MEAN ANNUAL RUNOFF (mm)	WATER QUALITY	CoV	MEAN ANNUAL SALINITY (mg/l TSS)	MEAN ANNUAL TURBIDITY (NTU)	MEAN ANNUAL COLOUR (Hazen)
JERDACUTTUP	Jerdacuttup	1818	[c] 50	415	[e] 4400	0.9	saline	2.68	10000	50	80
OLDFIELD	Oldfield	2479	[c] 35	440	8100	3.1	saline	2.16	5000	10	100
	Munglinup	302	50	470	1810	6	saline	1.45	6000	10	60
TORRADUP	Torradup	89	[m] 71	550	1160	13	brack	1.03	3000	15	80
STOKES	Young	[b] 1808	[m] 75	410	[b] 8400	[b] 1.5	saline	2.06	[g] 11988	20	100
	Lort	[b] 2800	60	375	[b] 9900	[b] 0.5	saline	2.15	16000	5	30
BARKER	Coolmalbidgup	133	95	500	1410	10.6	saline	0.84	10000	50	50
BANDY	Bandy	[m] 259	[m] 80	450	8175	16	saline	1.1	12000	10	80
DAILEY	Dailey	79	90	610	2670	34	brack	0.59	4000	11	50
MUNGLIGINUP	Mungliginup	139	60	590	3170	22.8	saline	0.78	20000	25	100
ALEXANDER	Alexander	70		595	980	14	saline	1.16	18000	10	60
BLACKBOY	Blackboy	89	[c] 25	595	1140	12.8	saline	1.24	10000	10	50
THOMAS	Thomas	129	30	560	1470	11.4	saline	1.32	15000	10	40
JORNDEE	Jorndee		[m] 0								
POISON & FERN	Fern	[m] 78	[m] 0	580	101	84.1	fresh	0.33	300	5	20

recently (1950s) been significantly cleared (around 50%) for agriculture. The larger catchments of the Esperance region, the Jerdacuttup, Oldfield, Young and Lort Rivers, some of which extend inland for about 100 km, drain marginal wheatbelt broadacre farms. The Barker and Torradup Rivers have smaller catchments which lie within the coastal plain (SCRAP & SCRIPT 1997a).

2.5. Land Use

2.5.1. DRYLAND AGRICULTURE

In the south coast region, agricultural development has replaced native vegetation with shallow rooted annual crops and pastures. Broadacre cropping requires extensive cultivation, fertilization and chemical spraying for disease, pest and weed control. There are various farm sizes, depending on rainfall, soil type and farming history. Cattle and sheep farms in high rainfall regions are as small as 200-300 hectares, whereas the wheat and sheep farms in established regions are from 1000-4000 hectares (EPAWA 1992).

Most farms in the dryland areas (wheatbelt), of the south coast region are mixed grain and sheep farms. The crops of these broadacre farms are a mixture of wheat, oats, barley, lupins, field peas and canola. The south coast region produces around 10% of the state's wheat production. Sheep meats such as prime lamb, mutton, shipping wethers and Awassi, have always been secondary to the production of wool. The wool industry of this region produces around 30,000 to 60,000 tonnes per year (SCRAP & SCRIPT 1996c).

In the 1950s and 1960s, large areas of crown land initially not suitable for cropping or grazing because of nutrient deficiencies were released along the coastal margins of the wheat belt. The deficiencies were overcome through the additions of trace elements in fertilizers (EPAWA 1992).

2.5.2. TIMBER PRODUCTS

The western extent of the south coast region (Broke Inlet to Torbay Inlet), has large areas of forests which are logged for sawn timber, veneer production, poles, bridge timbers, particle board manufacture and wood chips for paper. The timber industry has been established in the region since early European settlement, when forested areas were cleared for town sites and agriculture (CALM 1992a). The major Western Australian native trees harvested are *Eucalyptus marginata* (Jarrah), *E. diversicolor* (Karri) and *E. calophylla* (Marri).

Jarrah is harvested by selective methods which is mainly a thinning out process, removing mature trees. This method is used because Jarrah regenerates from adventitious root budding (suckers) rather than from seed. These areas are then allowed to regenerate naturally. Mature Karri forests are harvested by the clearfelling method which is the complete harvest of all viable timber for sawlogs and wood chips. Clearfelled areas are regenerated using either seedfall from retained "seed trees", by sowing collected seeds or by hand planting nursery raised seedlings (EPAWA 1992, SCRAP & SCRIPT 1996c). Tree harvesting is not permitted in National Parks, nature reserves or conservation parks but is permitted in state forests and timber reserves.

Agroforestry, the commercial tree production, is a rapid growth industry. Species such as *Eucalyptus globulus* (Tasmanian Blue Gum), *Pinus radiata* (Radiata Pine) and *P. pinaster* (Maritime Pine) are the most extensively planted. The Tasmanian Blue Gum is produced mainly for pulp wood and the pines for sawlogs. In recent years there has been extensive tree farms developed around Esperance, the Albany hinterland (in particular the Mt Manypeaks district), and in the high rainfall areas around Walpole, Denmark and Elleker. Albany's treated wastewater is used to irrigate large Blue Gum plantations which were established 10 km north of the city.

Minor forest products such as firewood, fencing posts, mining timber and craftwood which are usually aquired from crown lands, are still in strong demand. Sandalwood is still collected from the Esperance region (CALM 1992a).

2.5.3. HORTICULTURE

Intensive horticulture occurs mainly along the coastal strip from Walpole to the Albany hinterland. It is a rapidly expanding industry on the south coast. Intensive horticulture includes vegetables, fruit, nuts, viticulture (table grapes and wineries), and floriculture (wildflowers).

Floriculture is expected to expand rather rapidly in the near future as a result of the world market demands for the south coast off season harvests and the cultivation of species that have traditionally been harvested from public lands. Floriculture allows traditional farmers/graziers to diversify their income. There are Protea floriculture projects in the Mt Barker, Esperance, Mt Manypeaks, and Albany to Denmark areas.

The viticulture (grape growing) and winemaking industry has had considerable growth over the last decade. Mt Barker and Denmark are recognized internationally as regions of fine table wine production. The industry is predicted to expand east of Albany with viticultural trials being conducted and assessed at Mt Manypeaks, Wellstead and Bremer regions.

The south coast fruit and vegetable growers meet the domestic market demands, however the Asian market opportunities may see an increase in this type of land use. In recent years the south coast growers group have increased their share of the State market in cauliflowers, potatoes, broccoli, strawberries and cherries. Peas and potatoes are processed locally in Albany (EPAWA 1992, SCRAP & SCRIPT 1996c).

2.5.4. TOURISM

Tourism is also a growth industry in the south coast region. The mild climate, scenic coastline, mountain peaks, the unique flora and fauna, whale watching, wine tasting, farmstay and recreational fishing are a few of the region's attributes and activities that attract tourists to the area. The natural features of the south coast such as the Stirling and Porongurup Ranges, high Karri and Tingle forests, the many sandy beaches, spectacular cliffs, inlets, rivers and gorges have been shown to be the major tourist attraction (CALM 1992a).

The National Parks of the region; Shannon, D'Entrecasteaux, Walpole-Nornalup, Mt Franklin, William Bay, West Cape Howe, Torndirrup, Gull Rock, Porongurup, Stirling Range, Frank Hann, Peak Charles, Waychinicup, Stokes, Cape Le Grange, Cape Arid and especially Fitzgerald River National Parks, are known for the high degree of endemism in their flora and fauna. The Fitzgerald River National Park, which is one of two internationally recognized Man and Biosphere Reserves in Western Australia, has 1800 plant species and around 100 are considered rare or endemic to the region (CALM 1988, SCRAP & SCRIPT 1996c).

2.5.5. Mining

There is little mining activity in the south coast region besides the quarrying of industrial materials such as spongolite (Pallinup Siltstone), limestone (eolianite), kaolin clay, silica sands, gravel and limestone roadbase. Pink and Black granites are quarried north of Albany and peat from Lake Muir (Way '79 1979). Gold, silver and copper are mined in the Ravensthorpe region and barite is mined in the Cranbrook region (CALM 1992a).

Some of the mineral resources of the south coast are prospective and yet to be mined (CALM 1992a):

- Iron ore deposits in the form of magnetite have been found 80 km north east of Albany.
- High grade manganese ore has been discovered in the Eyre range.
- Mineral sands deposits have been located at Cheyne Bay and Hassel Beach.
- Graphite has been periodically mined at Kendenup since 1875, and new high grade deposits have been found.
- Beryl has been found in pegmatite veins near Ravensthorpe.

2.6. Runoff Quality

Waters in the streams and rivers are derived from surface drainage and ground water seepage. The quality of runoff is dependant on the amount of sediment, nutrient or organic matter coming off the catchment. Materials either suspended or dissolved in river waters are transported downstream and deposited in river channels, the estuaries or the ocean.

It is the volume of river flow and pattern of runoff (reliable or episodic), that influences the character of the estuary.

The rivers of the south coast have displayed two distinct trends (EPAWA 1992, GovWA 1996):

(a) Rivers in areas of high rainfall, have catchments that are forested or have large tracts of remnant vegetation. The rivers tend to be fresh and have dropped in salinity due to decreasing rainfall (e.g. Shannon, Deep, Walpole).

(b) In areas of low rainfall, the river catchments have been mainly cleared for broadscale agriculture. These rivers show signs of stress with the increase in nutrient loads, siltation and salinity (e.g. Frankland, Kent, Kalgan, Pallinup, Fitzgerald).

Olsen and Skitmore (1991), have classified the rivers of the south coast using descriptive categories:

1. Medium length rivers rising in moderate to low rainfall woodlands on the Yilgarn Plateau. They flow through Jarrah/Marri forests and in western areas through, high rainfall Karri forests on their way to the ocean (e.g. Frankland, Kent).

2. Short rivers contained mostly within the high rainfall areas of the Karri forests (eg. Shannon, Deep).

3. Medium length rivers whose catchments are mostly contained within the moderate rainfall Jarrah/Marri forests e.g. Denmark, Hay).

4. Rivers east of Albany which are mostly ephemeral and rise in Mallee. On their way to the coast, these rivers flow through Mallee heathlands which are now largely cleared. These river catchments experience infrequent, intense rainfall (e.g. Pallinup, Young, Lort).

3. Estuaries and Coastal Lagoons

An estuary by definition is a partially enclosed water body where marine and riverine waters mix. It is a body of water where tidal effects can be evident.

The estuaries of the south coast of Western Australia were formed around 7000 y before present (ybp), however they remained tidally-dominated systems until 4000 ybp. Many of the estuaries are closed by a sand bar at their mouths until catchment runoff during high rainfall periods, fills the estuaries and bursts the bar.

This section outlines a classification for estuaries on the south coast (Section 3.1). Secondly it includes a brief description of the estuaries and their possible impacts on proposed marine reserves (Section 3.2), and finally, Section 3.3 outlines the commercial estuarine fishery activities of the region.

3.1. Classification of Estuaries

The estuaries on the south coast vary in size from Broke and Wilson Inlets with areas of 48 km^2 to those east of Esperance with areas less than 1 km^2. Most of the estuaries are seasonal, they are fresh in winter and brackish to hypersaline in summer/autumn. This is the result of the extreme seasonal variation in rainfall and river flow, the small tidal regime, fluvial and entrance sand bars (Hesp 1984, Hodgkin & Hesp in prep).

3.1.1. Marine Exchange

The hydrology, ecology and trophic state of a particular estuary is dependant on the degree of marine exchange. There are four categories of marine flushing (Hesp 1984):

1. Permanently open;
2. Seasonally open/closed;
3. Normally closed (semi-permanent); and
4. Permanently closed.

3.1.1.1. Permanently Open Estuaries

The bar of these estuaries are permanently open although their entrance channel restrict the marine flushing. There are only a few estuaries on the south coast that are permanently open (Table 3.1.).

3.1.1.2. Seasonally Open/Closed Estuaries

The bars of these estuaries open seasonally. When river flow ceases, the bars close therefore isolating the estuary from the marine waters. Typically for the south coast region, river flow occurs in winter and ceases in summer. The waters of estuaries in this category vary greatly, from fresh in the wet season to marine or hypersaline during the dry months.

3.1.1.3. Normally Closed Estuaries

The bars of estuaries in this category seldom open to the sea and may stay closed for several years at a time. Most of these estuaries are found east of Albany in the Fitzgerald River National Park region and to the east of Esperance. These areas have low annual rainfall of 400-600mm. Normally closed estuaries tend to be brackish during river flow and become saline to hypersaline during low or no river flow. Most tend to be either riverine or valley lagoonal estuaries.

3.1.1.4. Permanently Closed Estuaries

Permanently closed estuaries are in the low rainfall region of the south coast where river discharge is episodic and saline. Culham Inlet has in recent historical time, opened naturally once and has since been opened artificially. Lake Nameless and the Jerdacuttup Lakes have not been open to the ocean in recent history and fossil records suggest not even during the Holocene.

3.1.2. Estuary Morphology

Hesp (1984) outlined four types of morphological classifications for estuaries: (1) Drowned river; (2) Riverine; (3) Valley lagoon and; (4) Basin lagoon. However, only the latter three categories are discussed in this section, as no drowned river estuaries are present in the south coast region.

Table 3.1. Classification of south coast estuaries (Hesp 1984, Hodgkin & Hesp in prep). South coast regions are defined: 1 = Broke Inlet to Torbay Inlet; 2 = Albany Environs; 3 = Fitzgerald Biosphere; 4 = Esperance Environs.

	RIVERINE	VALLEY LAGOON	BASIN LAGOON
PERMANENTLY OPEN	[4]Jorndee	[2]Waychininup	[1]Walpole-Nornalup [2]Oyster Harbour
SEASONALLY OPEN/CLOSED	[3]Kelly's [4]Torradup [4]Thomas [4]Poison & Fern	[2]Taylor [2]Angove/Gardner [2]King Ck [2]Normans [2]Cheynes [2]Swan Gully [2]Cordinup	[1]Broke [1]Irwin [1]Parry [1]Wilson [1]Torbay
NORMALLY CLOSED	[4]Bandy [4]Dailey [4]Mungliginup [4]Alexander [4]Blackboy [4]Torradup [3]Boondadup	[2]Beaufort [3]Wellstead [3]Hunter [3]Gordon [3]St Mary's [3]Fitzgerald [3]Dempster [3]Hamersley [4]Oldfield [4]Stokes	[4]Barker
PERMANENTLY CLOSED		[3]Lake Nameless	[3]Culham [4]Jerdacuttup

3.1.2.1. Riverine

Riverine estuaries are confined to narrow riverine channels throughout their length and are roughly perpendicular to the coast (Hodgkin & Hesp in prep). Examples of this morphological group are Torradup, Mungliginup, Blackboy and Thomas Inlets.

3.1.2.2. Valley Lagoon

Valley lagoonal estuaries have lagoons in drowned valleys roughly perpendicular to the coast. Most lagoons receive flow from a single river (e.g. Beaufort Inlet), however some have secondary tributaries, for example Stokes Inlet (Hodgkin & Hesp in prep). Other examples of valley lagoonal estuaries are Normans, Cheynes, Fitzgerald, Dempster and Hamersley.

3.1.2.3. Basin Lagoon

Basin lagoonal estuaries have lagoons in depressions on the coastal plain or in Pleistocene bays (e.g. Walpole-Nornalup, Broke). Two small lagoons are enclosed by Holocene sand dunes (e.g. Torbay, Gardner Lake). Irwin, Parry, Culham and Barker Inlets are also examples of this morphological group (Hodgkin & Hesp in prep).

3.1.3. SOUTH COAST ESTUARIES

Estuaries in the Broke Inlet to Torbay region all have basin lagoon morphology. All except Walpole-Nornalup Inlet which is permanently open, possess seasonally open/closed sandbars (Table 3.1.). This reflects the high rainfall experienced in this area.

The Albany Environs estuaries mostly fall into the category of seasonally open, valley lagoonal estuaries. The exceptions are Waychinicup Inlet being permanently open and Beaufort Inlet being normally closed.

The Fitzgerald Biosphere estuaries are mainly normally closed valley lagoonal types which reflects the low rainfall of the region. Kelly's Creek Inlet (seasonally open/closed and riverine), Boondadup Inlet (normally closed and riverine) and Culham Inlet which is a basin lagoonal estuary that is considered permanently closed, are the exceptions.

The estuaries of Esperance Environs are nearly all classified as riverine and either seasonally open/closed or normally closed. Jorndee Inlet is the only estuary east of Esperance that is permanently open while Oldfield and Stokes Inlets are valley lagoonal estuaries that are normally closed. Barker and Jerdacuttup Inlets are basin lagoons that are normally closed and permanently closed, respectively.

3.2. Descriptions of the Estuaries

This section includes a brief description of each estuary, status of proposed marine reserves, and possible impacts on proposed marine reserves. The classification of the estuaries are in parentheses:

Marine exchange

- PO = permanently opened;
- SO = seasonally opened/closed;
- NC = normally closed;
- PC = permanently closed.

Estuary morphology

- R = riverine;
- VL = valley lagoon;
- BL = basin lagoon.

3.2.1. BROKE INLET TO TORBAY INLET

3.2.1.1. Broke Inlet

(34°56' S 116°22' E)

Broke Inlet (SO/BL) is one of the largest estuaries on the south coast. It is a shallow lagoon which covers an area of 48 km^2 (15 km long by 2-3 km wide). The average depth is 1.5 m however the southern basin deepens to 4 m and the ocean channel is up to 6 m deep. The inlet is comprised of three main basins which are separated by sandbars that can be exposed in summer. There are two large islands (Clarke and Shannon Islands), and several small low granite islands (Hodgkin & Clark 1989a).

The bar opens seasonally and at times is artificially broken. In wet winters the bar has been known to stay open to the ocean for six months (Olsen & Skitmore 1991). The estuary is open to commercial fishermen and is extensively fished (Bucher & Sanger 1989, SCEFWG 1995).

Broke Inlet is unique on the western part of the south coast because the estuary and its catchment are entirely within the Shannon and the D'Entrecasteaux National Parks, therefore having no anthropogenic pollution inputs (Olsen & Skitmore 1991). The Shannon, Inlet and the Forth Rivers discharge into Broke Inlet. Broke Inlet is listed on the register of significant wetlands of national importance (ANCA 1996).

It has been proposed that Broke Inlet and the estuarine parts of the Shannon, Forth and Inlet rivers be reserved for recreation and conservation. It was also proposed that the management of such reserve be integrated with that of the D'Entrecasteaux National Park (MPRSWG 1994).

The major management problem in the area is off road vehicles, which cause the spread of dieback, and wind blowouts of the foreshore dunes. Human intervention in the opening of ocean bars is controversial, however in the case of Broke Inlet, it is opened to allow recruitment of marine fish species into the inlet, thus maintaining a commercial crop (Hodgkin & Clark 1989a).

3.2.1.2. Walpole-Nornalup Inlet

(35°02' S 116°44' E)

The Walpole-Nornalup Inlet (PO/BL) has an area 13.5 km^2. Walpole Inlet is shallow (to 1 m) whereas Nornalup Inlet can be up to 5 metres deep. This estuary in unlike any in the south coast with its richly vegetated shore where steep forested hills meet the estuary. The Inlet has one island, Newdegate (Snake) Is. Nornalup Inlet is not eutrophic (Hodgkin & Clark 1988b), whereas Walpole Inlet is showing signs in areas.

The ocean bar does not close. Walpole-Nornalup Inlet is a well flushed estuary, permanently open to the sea (Olsen & Skitmore 1991). The estuary receives waters from the Deep, Walpole and the Frankland Rivers.

Walpole-Nornalup Inlet is closed to commercial fishing but has a high recreational usage (Bucher & Sanger 1989, SCEFWG 1995). It has been proposed the Walpole-Nornalup Inlet and the estuarine reaches of the Franklin, Walpole and Deep rivers be declared as a marine reserve and be implemented as a matter of high priority. It was also proposed that the management of such reserve be integrated with that of the Walpole-Nornalup National Park (MPRSWG 1994).

A major issue in this region is the rate of development along the shores of the Walpole Inlet. Associated with these developments are the loss of perched wetlands unique to the area and the potential eutrophication of groundwater and Walpole Inlet by unsewered housing (Hodgkin & Clark 1988b, CALM 1992b). The rising salinity, increased nutrient pollution and sediment loads of the Franklin River are also a management concern.

3.2.1.3. Irwin Inlet

(35°01' S 116°58' E)

Irwin Inlet (SO/BL) is a small shallow estuary which has been considerably filled with sediment and is considered to be approaching the end of its life (Olsen & Skitmore 1991). The estuary has an area of 10.2 km^2 and is located wholly within the Walpole-Nornalup National Park. The basin is elongate with a length 5.5 km and a width of 2.5 km. Central basin is 2.5 m deep with shallow marginal sandbanks up to 0.5 km wide. There is a small granite island in the south-western corner of the inlet. Irwin Inlet has high levels of tannins (Hodgkin & Clark 1988c) and depending on the season, has a salinity that ranges from fresh to hypersaline (SCRAP & SCRIPT 1996b).

Karri Creek, Bow River and Kent River flow into Irwin Inlet. Owingup Swamp is at the lower reaches of the Kent River. The swamp may have a role in reducing the sediment and nutrient loads into Irwin Inlet and is listed on the register of significant wetlands of national importance (ANCA 1996). Irwin Inlet is open to commercial fishing and has high recreational value (SCEFWG, 1995).

The bar usually opens but in recent times fishermen and land owners open it every year. This intervention allows for fish recruitment and prevents inundation of low lying farm lands and the estuary becoming hypersaline. The Walpole-Nornalup National Park management plan outlines that CALM is to ensure that the artificial opening of the bar at the mouth of Irwin Inlet does not result in excessive erosion or long term disruption of inlet processes and, where possible, to allow the bar to open naturally (CALM 1992b).

Management problems include eutrophication (Bucher & Sanger 1989), the management of the ocean bar and most importantly the increase in salinity and sediment loads of the Kent River (Hodgkin & Clark 1988c, Schofield et al. 1989, Olsen & Skitmore 1991).

3.2.1.4. Parry Inlet

(35°02' S 117°10' E)

Parry Inlet (SO/BL) is a small, shallow, basin estuary which in the dry months becomes hypersaline and in some years dries out. The inlet has an area of 1.4 km^2 and has a maximum depth of 1 m. The estuary is open to commercial fishing, but is only occasionally fished (Bucher & Sanger 1989, SCEFWG 1995). Parry Inlet is very picturesque with fringing upland forest, coastal heath and swamplands. The waters of Parry Inlet are tannin stained (Hodgkin & Clark 1988c).

Increases in nutrient and sediment in estuarine discharge to the ocean, may have impacts on the proposed William Bay marine reserve (MPRSWG 1994).

Management problems include eutrophication, excessive macroalgae growth, the management of the ocean bar and most importantly, the increase sediment loads to the estuary (Hodgkin & Clark 1988c, EPAWA 1992).

3.2.1.5. Wilson Inlet

(35°02' S 117°20' E)

Wilson Inlet (SO/BL) is coloured by tannins and is one of the largest south coast estuaries. The estuary has two major basins covering an area of 48 km^2 (14 km long and 4 km wide). The inlet is 2 m deep on average, with the basins being up to 5 m. *Ruppia macrocarpa*, a "seagrass", is the major macrophyte. The inlet is a major marine fish nursery habitat and supports extensive commercial fishing activities (SCEFWG 1995). The inlet also supports a fledgling mussel aquaculture project.

Historically the bar has opened seasonally and in recent years it has been artificially opened every year by the Wilson Inlet Management Authority (WIMA). The bar is broken when the inlet water level is 1.0 m higher than mean sea level to stop local inundation (Hodgkin & Clark 1988c, SCRAP & SCRIPT 1996a).

Presently a debate regarding the bar is taking place. This discusses which bar opening strategy is most suitable as to whether a east or west opening or permanent opening with channel or no human intervention is ongoing. An assessment of the importance of artificially opening the bar on the estuarine fisheries was not studied however the timing of the bar opening and period of opening would greatly influence the recruitment of juvenile fish species into the inlet. This supports the suggestion of opening the bar in low rainfall years (Lukatelich 1984). Other considerations in the bar opening debate are the flooding of low lying developed agriculture and urban areas, and weed accumulations (Hodgkin & Clark 1988c)

Management issues of the inlet include increased salinity of its rivers, increased nutrient and pesticide input and modified flushing of the inlet. Changes that could trigger rapid eutrophication include reduction of marine flushing, increases in agricultural activities on nearby sandy soils, increases in engineered drainage of these soils, or an increase in unsewered urban development (Olsen & Skitmore 1991, OCM 1992).

In 1995, studies supported by WIMA, concluded that the estuary is shifting towards increased eutrophication. They also highlighted that large nutrient loads were experienced with little flushing to the sea, therefore an increase in internal storing, that seagrass beds are pivotal to ecological functioning of the whole estuary and must be protected and the opening of the estuary on either east or west perform with a similar result, therefore in the context of overall estuarine health, the location of the bar opening is not an environmental issue (WWC 1995).

The National Eutrophication Management Program (NEMP), which is overseen by the Land & Water Resources Research & Development Corporation (LWRRDC) and the Murray-Darling Basin Commission (MDBC), was established to undertake research and communication activities necessary to reduced the frequency and intensity of harmful or undesirable algal blooms in Australian fresh and estuarine waters, with informed public and peer group consultation and participation. NEMP has selected Wilson Inlet as the focus estuary in WA (LWRRDC & MDBC 1996).

In August 1996, NEMP held a public workshop, the Wilson Inlet Catchment Workshop. Participants were invited from Government Authorities, Research Groups, Local community groups and local individuals. They were asked to determine the major issues in relation to research into the eutrophication of the waterways. The results of these discussions were (WIMA 1996) :

(a) The management of water in the catchment to control nutrients, salt, water-logging and rising water tables;

(b) Determining whether nitrogen or phosphorus, or both, are driving the eutrophication process;

(c) Identifying sediment sources, including river pools, and studying the transport of nutrients down rivers;

(d) Establishing the role of episodic events such as flooding, in the management of eutrophication;

(e) Determining the water flow characteristics of drains, including sediment transport;

(f) Examination of land-use changes (eg. natural veg to rural land to residential or agro forestry), in particular the impacts and benefits with respect to nutrient transport;

(g) Developing techniques for identifying nutrient hot spots in the catchment;

(h) Determining whether research studies on processes contributing to eutrophication are transferable to other catchments;

(i) Establishing the sources of phosphorus (P), e.g. fertilizer as a source versus natural soil P versus other organic P;

(j) Evaluating the effectiveness of community education - Is it working What do we know What we don't know What are we doing about it;

(k) Studying how nutrients are transported to waterways (e.g. through leaching, surface erosion, subsurface flow);

(l) Assessing the potential capability of computer modelling; and

(m) Reviewing existing findings of research in the focus catchments.

3.2.1.6. Torbay *(35°02' S 117°40' E)*

Torbay Inlet (SO/BL) and nearby Lake Powell and Lake Manerup, were once estuarine, but are now part of a managed drainage system which is seriously eutrophic. Torbay Inlet now has a highly altered watercourse with a barrage on the tidal creek to the southern ocean. Torbay Inlet covers 1km^2 and its water has tannin discolouration. Marbellup Creek and several other small creeks, discharge into the inlet.

The bar may open naturally but in recent times the Water Authority intervenes to protect low lying potato agriculture. The sandbar is artificially opened several times each winter (Hodgkin & Clark 1990a).

Torbay Inlet has healthy fringing vegetation. There are wide fringes of paperbarks and sedgelands. The area is important habitat for the Australasian Bittern and many other migratory waterbirds which is reflected in the high waterbird species richness and individual abundances observed. Torbay Inlet is also an important frog breeding habitat (SCRAP & SCRIPT 1996a). Torbay Inlet is closed to commercial fishermen (SCEFWG 1995). Increased nutrients and sediments in estuarine discharge to the ocean, may have impacts on the proposed West Cape Howe marine reserve (MPRSWG 1994).

Eutrophication, blue-green algal blooms and bar management are major management issues in this estuary (Hodgkin & Clark 1990a, LCSC 1990, EPAWA 1992).

3.2.2. THE ALBANY ENVIRONS

3.2.2.1. Princess Royal Harbour
(35°02' S 117°40' E)

Princess Royal Harbour is best described as a marine embayment which covers an area of 29 km^2. The embayment is mostly less than 2 m deep and has extensive intertidal flats, which are important to migratory waterbirds, and marine fauna and flora. Princess Royal Harbour has little fringing vegetation, mainly on the southern foreshore where there is groundwater seepage. Although vegetation is presently very healthy, there are increasing signs of anthropogenic disturbances (Pen 1995). Princess Royal Harbour supports an extensive commercial fishery (SCEFWG 1995). Princess Royal Harbour has a catchment of 80 km^2, which includes part of the town and a substantial proportion of its industrial area (OCM 1992). Robinson Drain is the major rural/industrial drain and there are numerous urban storm water discharge points.

Industrial pollution has long been a problem and eutrophication is a major concern with its highly visible effect of excessive macroalgal growth. The algae *Cladophora prolifera* and *Chaetomorpha* sp. have smothered many of the seagrass beds (SCRAP & SCRIPT 1996a). Only 10% of the originally extensive *Posidonia australis* and *P. sinuosa* beds remain, however a 1996 seagrass survey showed an increase in distribution (Bastyan et al. 1996, SCRAP & SCRIPT 1996a). The survey also showed that in areas of intermediate depth there was a succession of seagrass species from *P. sinuosa* to *P. australis*. The extent of macroalgal distribution has declined since 1988 (WWC 1995, Bastyan et al. 1996).

In 1990 target loads were set for the embayment relative to their assimilative capacity. Seagrass restoration was targeted as being of high importance and subsequently algal harvesting commenced in 1991 (EPAWA 1990). During 1992-93 over 18,800 m^3 of algae was harvested. This represents approximately 27 tonnes N and 17 tonnes P (WWC 1993). During 1995-96 nearly 17,300 m^3 of algae was harvested (WRC 1996). About 30% of western Princess Royal Harbour has been included into the proposed King George Sound-Princess Royal Harbour Marine Reserve (MPRSWG 1994).

The Albany Waterways Management Authority (AWMA) was established on the 17th May 1991. AWMA's management area comprises of all of the waters of Princess Royal Harbour, Oyster Harbour & King George Sound and, the land and waters within the Albany Harbours catchments.

AWMA's management goals include (AWMA 1995):

(1) Reduction of nutrient inputs from rural, urban and industrial sources;

(2) Conservation of the environment being water quality, seagrass and macroalgae, foreshore management, catchment vegetation, fisheries (commercial and recreational), and landscape, lowland management, protection of aboriginal cultural sites;

(3) Planning the future through integration of local and regional planning and making contingency for the effects of climate change;

(4) Providing for the community, recreational, tourism and public access;

(5) Increasing concern for the waterways through community involvement, information and education;

(6) Increasing knowledge of the harbours through research and monitoring; and

(7) Ongoing management performance evaluation.

3.2.2.2. Oyster Harbour
(35°00' S 117°57' E)

Oyster Harbour (PO/BC) has a large basin with an area of 15.6 km^2 and is elongate (5.5 km long and 3 km wide). The hydology of Oyster Harbour is not truly estuarine however it behaves more as an estuary than an ocean embayment. The estuary is mainly shallow around 2-5 m while the deep basin is up to 12 m deep. Oyster Harbour is one of the few estuaries along the south coast that are permanently open to the sea. Its waters are not tannic (Hodgkin & Clark 1990a) and has a deep channel to the sea which is maintained by the Department of Transport.

Oyster Harbour is on the register of wetlands of national significance (ANCA 1996) and is used by thousands of waterbirds including pelicans and migratory waders. Green Island which is at the south end of the harbour, is a major pelican breeding habitat (SCRAP & SCRIPT 1996a). The King and Kalgan Rivers, and Yakamia and Johnstone Creeks discharge their waters into Oyster Harbour.

Oyster Harbour is the major harbour for Albany's commercial fishing fleet. Oyster and mussel farming are carried out in this estuary, which is also open to commercial fisheries (SCEFWG 1995).

Nutrient inputs into Oyster Harbour have fluctuated in recent years and trends are indistinguishable. In 1990 target loads for nutrients were set for the estuary relative to their assimilative capacity (EPAWA 1990). Oyster Harbour has seen a loss in seagrass meadow of up to 80 % since 1961, however in a recent seagrass survey, an increase in biomass and distribution has been observed (Hodgkin & Clark 1990a, Bastyan et al. 1996). There also has been a gradual contraction of macroalgal distribution and a reduction in biomass since 1992 (Bastyan et al. 1996). Potentially toxic species of phytoplankton have been identified as being present in the estuary (Hosja et al. 1994, WWC 1995)

Major management issues in Oyster Harbour include the increase in sediment and nutrient loads from the Kalgan River and sedimentation of the King River delta which shows signs of unnatural acceleration in deposits (Hodgkin & Clark 1990a).

3.2.2.3. Taylor Inlet

(35°00' S 118°03' E)

Taylor Inlet (SO/VL), also known as Nanarup Inlet is 1 km^2 in area. The lagoon is kidney shaped with an average depth of 2-3 m which goes to 5 m in the deeper holes. Taylor Inlet is the estuarine coastal lagoon of the Taylor River and is surrounded mainly by farmland with the exception of a narrow recreational reserve of paperbarks on its shoreline (SCRAP & SCRIPT 1996a). The inlet show some evidence of eutrophication. The ocean bar usually opens naturally however, at times the Shire of Albany or fishermen intervene (Hodgkin & Clark 1990a). Taylor Inlet does not have a commercial fishing season (SCEFWG 1995).

Increases in nutrients and sediments in the estuarine discharge to the ocean, may have impacts on the proposed marine reserve between Herald Point and Breaksea Island (MPRSWG 1994).

The major management issues of the estuary are bar management, 4WD vehicle access and, increases in sediment and nutrient loads from its catchment (Hodgkin & Clark 1990a).

3.2.2.4. Angove /Gardner Lakes

(34°57.03 S 118°10.55' E)

The Angove and Gardner Lakes are included in the Two Peoples Bay wildlife sanctuary which was implemented in 1993 (EPAWA 1993). The coastal lakes are fed by Angove and Goodga Rivers, which both discharge into Two Peoples Bay via the Gardner Lake Creek (Storey et al. 1993). Lake Gardner has sea inflow during spring tides and storm surges. The bar at the mouth of the Gardner Creek (SO/VL) is open to the ocean in the wet season. Seagrass debris washes back into the creek and at times can obstruct flow through the channel (Hodgkin & Clark 1990a).

The Moates Lake system which includes Angove and Gardner lakes are listed on the register of significant wetlands of national importance (ANCA 1996). The associated extensive wetlands have moderate bird numbers and some breeding by rare migratory waterfowl has been observed (CALM 1995, SCRAP & SCRIPT 1996a).

Angove and Gardner Lakes are open for commercial fishing (SCEFWG 1995). Increased nutrients and sediments in estuarine discharge to the ocean, may have impacts on the proposed Cape Vancouver to Bald Island marine reserve (MPRSWG 1994).

Major management issues for the estuary are increases in nutrients. The proposed Albany liquid waste disposal wastewater treatment site (Alan Tingay & Assoc. & Evangelisti & Assoc. 1997) which will be located near the Goodga River if endorsed, may have an impact on the level of nutrients that enter the system.

3.2.2.5. King Creek

(34°56' S 118°12.50' E)

King Creek Inlet (SO/VL) is adjacent to Norman's Inlet. The inlet is a long narrow valley which is nestled behind the sand dunes and generally flows across the sand all year (SCRAP & SCRIPT 1996a). The inlet has a fringe of coastal vegetation and its water has dark tannin discolourations (Hodgkin & Clark 1990a). Seventy percent of its catchment has been cleared for agricultural purposes.

Little is known about this inlet however, its waters discharge into the proposed Cape Vancouver to Bald Island marine reserve (MPRSWG 1994).

3.2.2.6. Normans Inlet

(34°55' S 118°13' E)

Normans Inlet (SO/VL) is the small riverine estuary of the Norman River. The inlet has an area of 0.5 km^2. Normans Inlet is very shallow and makes its way to the ocean through a gap in the coastal granite hills. At the mouth, the bar opens annually but usually for only a brief period, sometimes as little as a few days (SCRAP & SCRIPT 1996a).

Normans Inlet is surrounded by bushland in reserves and supports substantial paperbark thickets and ephemeral sedgelands. The surrounding steep slopes are well vegetated and dark tannins stain the estuarine waters. The inlet is totally surrounded by vegetation except for a small portion of farmland. There is little sign of eutrophication (Hodgkin & Clark 1990a).

The waters of this inlet discharge into the proposed Cape Vancouver to Bald Island marine reserve (MPRSWG 1994). Normans Inlet has no commercial fishing season (SCEFWG 1995).

3.2.2.7. Waychinicup

(34°53.78' S 118°19.45' E)

Waychinicup Inlet (PO/VL) is not a true inlet, it is more properly defined as a fiord gorge. The inlet is a riverine estuary of 1 km in length which cuts through a granite faultline. Waychinicup Inlet is highly scenic and unique along the south coast (SCRAP & SCRIPT 1996a). The water has tannin discolouration and is only significantly diluted in winter flows of the Waychinicup River.

Waychinicup Inlet supports periodic commercial fishing (SCEFWG 1995) and is included in the proposed Cape Vancouver to Bald Island marine reserve (MPRSWG 1994). Visitor management of this estuary needs to be addressed (Hodgkin & Clark 1990a).

3.2.2.8. Hassel Beach Creeks

(34°48' S 118°25' E)

Hassel Beach which is 20 km long has about a dozen short intermittent streams. A few of these such as Bluff River, Little Bluff Creek, Coal Creek and Wongerup River, form tiny coastal estuaries. Others form small lakes and swamps such as Mirrabeen, KcKenna's and Swan Lakes which are nested behind the coastal dune system (SCRAP & SCRIPT 1996a).

Little is known about these inlets except that they occasionally breach their bar usually after exceptional winter rains and storm surge. Some of the lakes flow through the dense dune vegetation across blowouts to the sea. The waters of these small inlets discharge into the proposed Cape Vancouver to Bald Island marine reserve (MPRSWG 1994).

Sedimentation of the behind dune swamps and coastal dune accretion are major concerns for the management of these small inlets (Hodgkin & Clark 1990a).

3.2.2.9. Cordinup Inlet

(34°42' S 118°34' E)

The Cordinup River estuary (SO/VL) is surrounded by cleared hillsides. The lagoon is around 2 m deep and has a ocean channel which winds through the coastal dunes. There are Samphire and Paperbark swamps on the river delta (Hodgkin & Clark 1990a, SCRAP & SCRIPT 1996a). The water has dark tannin discolouration. The bar at the mouth breaks every 2-3 y and winter storms wash over it.

The estuary shows little evidence of eutrophication and the encroachment of mobile coastal dunes is threatening this little inlet (Hodgkin & Clark 1990a)

3.2.2.10. Swan Gully

(34°53' S 118°24' E)

Swan Gully (SO/VL) a small estuary in the middle of Cheynes Beach and is approximately 1 km long. The inlet cuts through the coastal sandstone rock and is encircled by stable vegetated fringing sand dunes. Very little is known about this inlet besides that marine waters inundate the estuary during storm surge, large swells and spring tides. During winter the inlet flows over its bar (SCRAP & SCRIPT 1996a).

3.2.2.11. Cheyne Inlet

(34°36.50' S 118°45' E)

Cheyne Inlet (SO/VL) is the estuarine section of the Eyre River. This linear estuary is 4.5 km in length and its lagoon is approximately 1 km long, 2-300 m wide and has a depth of less than 1 m. The estuarine waters are highly discoloured by tannins (Hodgkin & Clark 1990a). The southern shore of the inlet is cleared farmland and the other parts of shoreline have saltmarsh and paperbark thickets (SCRAP & SCRIPT 1996a). The bar at the inlet's mouth breaks naturally most winters. Cheyne Inlet is closed to commercial fisheries (SCEFWG 1995).

Cheyne Inlet periodically experiences high nutrient levels, though it is not considered seriously eutrophic. The estuary seems to be progressively getting shallower, sediment erosion is accelerating the process (Hodgkin & Clark 1990a).

Increases in nutrient and sediment loads entering the estuary are major management issues.

3.2.2.12. Beaufort Inlet

(34°28' S 119°25' E)

The lagoon of Beaufort Inlet (NC/VL) is 3 km long and 1.5 km wide. The estuary has an area of 4.5 km^2 and has an average depth of <1.5 m deep. Beaufort Inlet is fed by the Pallinup River and Corackerup Creek. The Pallinup River and estuary are permanently saline (18-65 ppt), and both are regularly visited by commercial fishermen (Newbey 1987, Hodgkin & Clark 1988a, SCEFWG 1995). The inlet is seriously eutrophic and receives an increasing sediment load (SCRAP & SCRIPT 1997b). The wetland associated with the estuary, are mainly cleared and two rare birds, the Western Whipbird and the Red-eared Firetail, have been documented here (Newbey 1987).

The bar at Beaufort breaks naturally and seldom stays open for more than a few weeks. The opening of the bar is infrequent, up to 8 y without breaching and recently has been artificially opened by fishermen (van Steveninck & Craig 1984).

It is proposed to establish a conservation park around the Pallinup River estuary (Beaufort Inlet). Also a corridor nature reserve between the Corackerup and Peeniup Nature Reserves and the proposed Pallinup Conservation Reserve is to be vested in the National Parks & Nature Conservation Authority (NPNCA) (CALM 1992a). Recreation and camping on crown lands at the mouth of the Beaufort Inlet and its southern shoreline are managed by the Jerramungup Shire Council (van Steveninck & Craig 1984).

Sedimentation and nutrient pollution are major management issues in this estuary (Bucher & Sanger 1989). Beach sand migration is also an issue as it changes the estuary geomorphology (Olsen & Skitmore 1991, SCRAP & SCRIPT 1997b).

3.2.3. FITZGERALD BIOSPHERE

3.2.3.1. Wellstead Estuary

(34°25' S 119°25' E)

The Wellstead estuary (NC/VL) is a basin of only 600 m wide with a fetch of no more than 3 km. The basin is quite shallow <1.0 m with a small deep channel to 4-5 m deep (Hodgkin & Clark 1987). Wellstead Estuary is 2.5 km^2 in area and shows little sign of nutrient pollution (Hodgkin & Clark 1987, SCRAP & SCRIPT 1997b). The Bremer River flows into the Wellstead Estuary. Commercial fishermen are banned all year round (SCEFWG 1995). The bar opens after heavy rain (every 2-3 y), and is opened longer than other estuaries east of Albany (6-12 mths) (van Steveninck & Craig 1984).

Management of the Crown Lands, adjacent Wellstead Estuary is vested in the Shire of Jerramungup (van Steveninck & Craig 1984). Wellstead Estuary also lies within nature reserve and National Park (SCRAP & SCRIPT 1997b). Increases in nutrients and sediment in the estuarine discharge may impact the proposed Fitzgerald Biosphere marine reserve (MPRSWG 1994).

Catchment clearing has caused sedimentation of the shallow basin. The heavy use of vehicles such as motorcycles, wheeler bikes and 4WDs, on the bar may have management implications (Hodgkin & Clark 1987). Nutrient pollution is a problem, however the *Ruppia* seagrass and other macrophytes ensure low phosphate and high oxygen conditions (Olsen & Skitmore 1991).

3.2.3.2. Hunter River

(34°24.50' S 119°25.50' E)

The Hunter River Estuary (NC/VL) is a "V" shaped lake with 2 km long arms (SCRAP & SCRIPT 1997b). It is approximately 0.75 km inland from the high water mark. The Crown lands which surround the Hunter River have been used as water catchment and are not vested in any authority. The waters of this inlet discharge into Bremer Bay (MPRSWG 1994).

Little is known about this estuary excepting that it seldomly flows into the sea. In recorded history, it has opened to the ocean only twice, 1919 and 1979 (SCRAP & SCRIPT 1997b).

3.2.3.3. Kelly's Creek Inlet

(34°17.50' S 119°27' E)

Kelly's Creek Inlet (SO/R) is a narrow estuary of no more than 5 m wide and 1 km in length. It is darkly stained by tannins and was saline (42 ppt) when sampled in May 1987 (Hodgkin & Clark 1990b). It is occasionally connected to the sea through a 1 km long channel. It has substantial fringing vegetation and wetlands (SCRAP & SCRIPT 1997b). The waters of this little inlet discharge into Doubtful Island Bay which is in the proposed Fitzgerald Biosphere marine reserve (MPRSWG 1994). Little is known about this inlet.

3.2.3.4. Gordon Inlet

(34°17' S 119°27' E)

Gordon Inlet (NC/VL), the estuarine lagoon of the Gardiner River, is considered a "transient " estuary as it is seldom opened to the ocean. The inlet is very shallow, <0.5 m and is permanently saline. The water salinity changes with the seasons, however measurements of up to 160 ppt have been recorded. The bar at the mouth opens naturally every 2-3 years and often stays open for months (Olsen & Skitmore 1991, SCRAP & SCRIPT 1997b).

Commercial fishing is permitted in the waters of Gordon Inlet (SCEFWG 1995). It has been proposed that Gordon Inlet be included in the proposed Fitzgerald Biosphere marine reserve and its management be integrated with that of the Fitzgerald River National Park (MPRSWG 1994).

Increases in the sediment loads from the catchment, are progressively shallowing the estuary. Beach sand migration is also changing the estuary geomorphology and increases in nutrient pollution has resulted in algal blooms (Hodgkin & Clark 1988a). Gardiner River is saline and eutrophication is a problem in both river and estuary (Olsen & Skitmore 1991).

3.2.3.5. Boondadup Inlet

(34°10.91' S 119°33' E)

Boondadup Inlet (NC/R) is a small narrow intermittent estuary 700 m long by 250 m wide and 1 m deep. Discolouration of the waters in the inlet are due to the high levels of tannins. The estuary had low salinity of 5 ppt when visited in February 1989. The oceanic bar opens infrequently, however when it breaks weed and drift wood are carried a fair distance up the Boondadup River (Hodgkin & Clark 1990b). Little is known about Boondadup Inlet, however it could be utilized as a baseline reference for investigating estuary degradation in the district as its catchment (approximately 48 km^2), is entirely within the Fitzgerald River National Park (SCRAP & SCRIPT 1997b).

The waters of this little inlet discharge into the proposed Fitzgerald Biosphere marine reserve (MPRSWG 1994).

3.2.3.6. St Mary Inlet

(34°10.91' S 119°33' E)

St Mary Inlet (NC/VL) is the small shallow estuary of the St Mary River. It is 1 km in length and only 250 m wide. All of its catchment is vegetated and lies entirely within the Fitzgerald River National Park. It has an oceanic bar that breaks infrequently (Hodgkin & Clark 1990b). St Mary Inlet (as well as Dempster and Boondadup Inlets) would prove to be a useful reference site for comparative studies with degraded estuaries & their catchments (CALM 1991). The estuary is closed all year to commercial fisheries (SCEFWG 1995). It has been proposed that St Mary Inlet be included in the proposed Fitzgerald Biosphere marine reserve and its management be integrated with that of the Fitzgerald River National Park (MPRSWG 1994).

Little is known about St Mary Inlet, however bar management and the impact of the many visitors to the Fitzgerald River National Park are considered to be major management issues (Hodgkin & Clark 1990b).

3.2.3.7. *Lake Nameless*

(34°07.64' S 119°34.29' E)

A number of unnamed tributaries form Lake Nameless (PC/VL) which has an area of around 2 km^2. It is 3 km long and 700 m wide (SCRAP & SCRIPT 1997b). Lake Nameless is a former estuary but now considered a salt lake with no connection to the sea. In February 1989, it was a shallow hypersaline lake of 190 ppt. The connecting channel to the sea is now closed by a 1 km wide sand dune (Hodgkin & Clark 1990b). The catchment of Lake Nameless is entirely within the Fitzgerald River National Park (CALM 1991).

3.2.3.8. *Fitzgerald Inlet*

(35°04' S 119°26' E)

Fitzgerald Inlet (NC/VL) is a shallow lagoon that covers an area of 7 km^2 which has a length of 4 km and a width of 1-2 km. The estuary is saline and has a maximum depth of 1.5-2 m (Hodgkin & Clark 1990b). The bar breaks infrequently about every 3-4 y. Fitzgerald Inlet is open to commercial fishermen (SCEFWG 1995). The inlet is wholly within Fitzgerald River National Park but most of its upper catchment is in land that has been cleared for broadscale agriculture.

Fitzgerald Inlet has been included on the register of wetlands of national importance (ANCA 1996). It has been proposed that Fitzgerald Inlet be included in the proposed Fitzgerald Biosphere marine reserve and its management be integrated with that of the Fitzgerald River National Park (MPRSWG 1994).

Water salinity has increased due to the clearing of natural bushland in the upper catchment of the Fitzgerald River and nutrient pollution in runoff is minimal, however sedimentation from erosion off cleared farmlands has increased (Olsen & Skitmore 1991). Management of its oceanic bar is an issue, due to the increase in visitors to the Fitzgerald River National Park (Hodgkin & Clark 1990b).

3.2.3.9. *Dempster Inlet*

(34°05' S 119°38' E)

The Dempster Inlet (NC/VL) has a length of 7 km and width of 400-700 m. The lagoon has an area of 2.3 km^2 but holds water for only a few months. It is a saline estuary with a range of 15-55 ppt. The Dempster River and Coppermine Creek discharge into the inlet. The bar breaks infrequently for short periods (Hodgkin & Clark 1990b). Dempster Inlet is closed to all commercial fishing activities (SCEFWG 1995).

All of the catchment of the Dempster Inlet is completely uncleared and lies entirely in the Fitzgerald River National Park. Dempster Inlet, which is classed as pristine, would prove to be a useful reference when compared to degraded estuaries & catchments (CALM 1991). It has been proposed that Dempster Inlet be included in the proposed Fitzgerald Biosphere marine reserve and its management be integrated with that of the Fitzgerald River National Park (MPRSWG 1994).

3.2.3.10. *Hamersley Inlet*

(33°57' S 119°55' E)

Hamersley Inlet (NC/VL) is the coastal lagoon of the Hamersley River. The estuary has a length of about 4 km long and only 500 m wide. It has an area of 2.3 km^2 and is shallow to 2 m in depth. Dempster Inlet is saline with waters ranging from 15-50 ppt (Hodgkin & Clark 1990b). The oceanic bar across the mouth of Hamersley Inlet, historically was closed for decades at a time, however in the last two decades the estuary has been open to the sea six times (Olsen & Skitmore 1991).

Hamersley Inlet is open to commercial fishing activities (SCEFWG 1995). CALM allow commercial fishermen access to Hamersley Inlet and give permission for them to carry their catch from the inlet across the National Park (CALM 1991). It has been proposed that Hamersley Inlet be included in the proposed Fitzgerald Biosphere marine reserve and its management be integrated with that of the Fitzgerald River National Park (MPRSWG 1994).

Sedimentation from erosion off cleared farmlands, increases in river salinity and higher nutrient loads, are a concern to the shallow estuary. Bar management is important in respect to the impact of the increasing visitor numbers to the Fitzgerald River National Park (Hodgkin & Clark 1990b).

3.2.3.11. Culham Inlet

(33°04' S 119°03' E)

Culham Inlet (PC/BL) is a saline estuary with an area of 11.3 km^2 and its basin can have a depth of up to 4.5 m (Hodgkin & Clark 1990b). The runoff from the Phillips and Steere River catchments discharge into the inlet. Consequently the Inlet has high levels of nutrient pollution and there has been increases in both river and estuary sedimentation (Olsen & Skitmore 1991) . The eastern edge of Culham Inlet is "A" class reserve and the reserve is vested in the Shire of Ravensthorpe (EPAWA 1993). Culham Inlet is listed on the register of significant wetlands of national importance (ANCA 1996) and is also open to commercial fisheries (SCEFWG 1995).

The last recorded opening of the oceanic bar at Culham Inlet was in Winter 1993. The bar burst after a period of significant rainfall, and while construction of a new causeway and culverts were underway. There was a discharge of large quantities of sediments and organic material into the near shore waters. The following months saw significant increases in sedimentation in marine habitats adjacent to the opening (*pers comm.* True 1997).

Sedimentation from erosion off cleared farmlands are a concern to the shallow estuary. Bar management is important as is the impact of the many visitors to the Fitzgerald River National Park (Hodgkin & Clark 1990b). If the oceanic bar is artificially opened (or by natural causes), the waters that discharged into the sea, may have increased nutrient and sediment loads which may impact the proposed Fitzgerald Biosphere marine reserve (MPRSWG 1994).

The draft coastal management plan for the Ravensthorpe district did not include any management strategies pertaining to the Culham Inlet (Craig et al. 1984).

3.2.4. ESPERANCE ENVIRONS

3.2.4.1. West Esperance

<u>JERDACUTTUP LAKES</u> *(34°04' S 120°18' E)*

The Jerdacuttup Lakes (PC/BL) are a group of paperbark tree swamps which covers approx 15 km of shallow depression behind the coastal dune. The major basin is approx 5 km long and 2 km wide, however the wetland group stretches a further 5 km. The lakes are saline with a range from 5-70 ppt (Hodgkin & Clark 1990b). The lakes receive intermittent flow from the Jerdacuttup River (SCRAP & SCRIPT 1997b) and they are now separated permanently from the sea (Olsen & Skitmore 1991). The Jerdacuttup Lakes are open to commercial fishermen (SCEFWG 1995).

The Jerdacuttup Lakes is a Class "A" nature reserve for the conservation of flora and fauna and is vested in the National Parks and Nature Conservation Authority (EPAWA 1993).

Sedimentation from erosion off cleared farmlands, increases in nutrient loads and river salinity, are a concern to the shallow estuary. Semi-rural development near the lakes and in their catchment, may be an issue in the management of the Jerdacuttup Lakes.

The draft coastal management plan for the Ravensthorpe district did not include any management strategies pertaining to the Jerdacuttup Lakes (Craig et al. 1984).

<u>OLDFIELD ESTUARY</u> *(33°52' S 120°47' E)*

The Oldfield Estuary (NC/VL) has 3 km long basin with a 5 km riverine stretch. The lagoon basin has a maximum width of 600 m and covers an area of 1 km^2. For most of the year the estuary is shallow (1 m deep), however in winter depths may be up to 4-5 m during flood flows. The channel to the ocean can be up to 2.5 m deep. It is a saline estuary, 5-60 ppt and the bar at the ocean breaks infrequently, only every 3-4 y. The lower catchment is mainly cleared, and there have been increases in both sediment and nutrient loads. The estuary is in a recreation reserve with blocks of the Lake Shaster Nature Reserve to the east and the west (Hodgkin & Clark 1989b). Oldfield Estuary is fished commercially (SCEFWG 1995).

Catchment soil conservation is important to stem increased sediment loads to the estuary. Management of campers, visitors and beach access are also a concern (Hodgkin & Clark 1989b).

TORRADUP ESTUARY *(33°52' S 121°01' E)*
Torradup Estuary (NC/VL) is 3.5 km long and very narrow (only 200 m wide). The estuary covers an area of less than 1 km^2 and its depth is no more than 2 m. Its waters are deeply tannin stained and has a salinity range from 11 ppt to 40 ppt. The Torradup River feeds into the estuary which is located within Stokes National Park. The bar opens regularly for short periods and waves wash over in storm surges (Hodgkin & Clark 1989b). Torradup Estuary is open to commercial fishing activities (SCEFWG 1995).

It has been proposed that Torradup Estuary be included in the proposed Stokes Inlet marine reserve and its management be integrated with that of the Stokes National Park (MPRSWG 1994). Catchment soil conservation is important to stem increased sediment and nutrient loads which are currently entering the estuary. Management of campers and visitors, beach access are also issues of concern (Hodgkin & Clark 1989b).

STOKES INLET *(33°52' S 121°08' E)*
Stokes Inlet (NC/VL) covers an area 14 km^2 and its major basin is approx 10 km long and 2 km at its widest point. It is quite shallow, being no more than 2 m deep while the channel to the ocean (approximately 2 km long and 500 m wide), can be to 8 m deep. It is a saline to hypersaline estuary 28-96 ppt. The estuary which is mostly surrounded in the Stokes National Park, has extensive paperbark and samphire habitats. The estuary is charged by the waters of the Young and Lort Rivers which are now saline. In recent time, increases in the rates of sedimentation and nutrient loads due to agriculture in their catchments, has been observed (Deeley et al. in prep). These increases in runoff water quality will ultimately affect the estuary (Olsen & Skitmore 1991). The estuary has slight tannin discolouration. The bar breaks infrequently and is open for short periods up to 6 wks (Hodgkin & Clark 1989b).

Currently, there are 17 commercial fisheries licences at Stokes Inlet. A half yearly closed season (30/11-1/5) was introduced at Stokes Inlet in 1982 by the Fisheries Department (CALM 1992a, SCEFWG 1995).

It has been proposed that the adjacent Lake Shaster Nature Reserve block is to be added to the Stokes National Park (CALM 1992a), and the Stokes Inlet be included in the proposed Stokes Inlet marine reserve and its management be integrated with that of the Stokes National Park (MPRSWG 1994).

Catchment soil conservation is important to stem increased sediment and nutrient loads to the estuary. River salinity and coastal dune migration filling the oceanic channel are a concern. Management of campers and visitors, and 4WD beach usage are also important issues (Hodgkin & Clark 1989b).

BARKER INLET *(33°48' S 121°20' E)*
Barker Inlet (NC/BL) is a small lagoonal estuary with an area of 1.8 km^2. Its is 2 km long, 1 km in width, very shallow (no more than 1 m in depth) and often dry. Barker Inlet is a saline estuary with salinities greater than 23 ppt. Waves wash over the sand bar which probably opens regularly (Hodgkin & Clark 1989b). Barker Inlet is closed to all commercial fishing (SCEFWG 1995), and lies within Conservation of Flora Nature Reserves.

Catchment soil conservation is important to stem increased sediment and nutrient loads to the estuary. Management of campers, visitors and motor vehicle usage are also a concern (Hodgkin & Clark 1989b).

3.2.4.2. East Esperance

East of Esperance there are numerous creeks. They are only small and only a few are estuarine. The waters of all these inlets discharge into the proposed Recherche Archipelago marine reserve (MPRSWG 1994). Information on these estuaries is scarce as there has been little or no investigation into the surface waters of this region, therefore only a few of the estuaries are briefly described here. In most of these little estuaries the major management issues are the increase in river salinity and the increases in sediment loads.

BANDY CREEK INLET *(33°39' S 122°02' E)*
Bandy Creek (NC/R) is no longer considered a true estuary as it has been grossly modified. In 1983, construction for the Bandy Creek Boat Harbour was commenced. The mouth of the inlet had two stonewall groins constructed and the bar was removed (DCEWA 1983, Hodgkin & Clark 1989b). The creek water is saline (Olsen & Skitmore 1991) and recently, The introduced marine tube worm *Sabella spallanzanii* has recently been observed at Bandy Creek Inlet (*pers comm.* G. Clapin 1997). There is little information on this estuary.

DAILEY RIVER INLET *(33°51' S 122°34' E)*
The Dailey River (NC/R) has a small estuary, only 2 km long, 7-10 m wide and to 2 m deep. The salinity of the inlet was 8-10 ppt on 4/5/77. Most of the catchment is cleared and at times, the inlet becomes hypersaline (Hodgkin & Clark 1989b). There is little information on this inlet.

MUNGLIGINUP INLET *(33°51' S 122°46' E)*
Mungliginup Inlet (NC/R) is a narrow riverine estuary 2 km long, 10-20 m wide and has a maximum depth of 2.5 m. The estuary cuts through coastal spongolite rock and always holds water. The waters of the estuary are hypersaline and on 6/5/77 recorded 46 ppt. *Ruppia* seagrass beds and *Polyphysa* algae have been observed (Hodgkin & Clark 1989b). There is a small camping area with a small borehole toilet on the fringe of the inlet. Mungliginup Inlet enters the ocean at Membinup Beach and the bar breaks infrequently (DCEWA 1983).

ALEXANDER RIVER INLET
(33°51' S 122°47' E)
Only about 1 km of the Alexander River (NC/R) is estuarine. The estuary is very narrow with a width of 10 m. On 6/5/77 salinity was 26 ppt. The Inlet is a popular camping and recreational area, and it has a small camping area with a small borehole toilet (Hodgkin & Clark 1989b). The estuary opens into Alexander Bay over a 200 m wide white silica sand beach. The maintenance of human impacts are management issues (DCEWA 1983).

BLACKBOY CREEK INLET
(33°53.45' S 122°53.33' E)
Blackboy Creek Inlet (NC/R) is a small estuary of about 1 km long and 10 m wide. It cuts through spongolite rock and reaches the ocean over a 250 m wide sandy beach. Most of its catchment is naturally vegetated (Hodgkin & Clark 1989b). Not much is known about Blackboy Creek Inlet.

THOMAS RIVER INLET *(33°49' S 123°02' E)*
The Thomas River Inlet (SO/R) is narrow estuary of 10-20 m wide and approx 1 km long. The majority of the Thomas River catchment lies within the Cape Arid National Park, however a small part is cleared farmlands. Salinities recorded were 22.5 in October 1971 and 26 ppt in May 1977. A pool has been observed to be always present on the beach (Hodgkin & Clark 1989b).

JORNDEE CREEK INLET *(33°57' S 123°18' E)*
Jorndee Creek Inlet (PO/R) is the only permanently opened inlet, east of Albany besides Waychinicup Inlet. This shallow estuary is 500 m long, 5-7 m wide and is tidally influenced. On occasions the inlet empties at low tide. The creek cuts through the granite rocks of the eastern face of Cape Arid. On two sampling occasions in 1971 and 1971, salinity recorded was seawater, 35 ppt. Jorndee Creek Inlet is the Cape Arid National Park. On the northern shore of the inlet, there is a camping ground and a borehole toilet (Hodgkin & Clark 1989b).

POISON AND FERN CREEKS
(33°54.32' S 123°21.10' E)
The estuary of Poison and Fern Creeks (SO/R) is nestled behind coastal dunes. It has a length of 700 m, width of 15 m and is quite shallow near the ocean cut. It has dense natural vegetative fringe of paperbarks and coastal heath. Salinities recorded are from 20-51 ppt (Hodgkin & Clark 1989b). Poison Creek Inlet is wholly within the Cape Arid National Park.

The fringing paperbark thickets have been badly degraded by campers. The maintenance of this and other human impacts are management issues.

4. MANAGEMENT ISSUES

This section firstly gives an overview of the major management issues that affect the majority of estuaries in the south coast region: loss of native bushland (Section 4.1); salinity (Section 4.2); erosion (Section 4.3); eutrophication (Section 4.4); commercial fisheries (Section 4.5); dieback (Section 4.6); exotic weeds (Section 4.7); and pesticides (Section 4.8). Specific regional management issues are discussed (Section 5).

4.1. Loss of Native Bushland

The most damaging change to riverine and estuarine ecosystems that has occurred since European settlement of the south coast region, has been the wholesale clearing of native bushland in most river catchments. The clearing of vegetation within catchments has indirectly caused rising water tables which has contributed to or has been associated with many environmental problems (WAWRC 1992):

1. Water logging and the subsequent loss of riparian vegetation;
2. Increases in the rate and volume of runoff which transports nutrients from artificial fertilizers applied to broad-acre farmlands and increases erosion;
3. Soil erosion leading to river and estuary siltation, and nutrient transportation in the form of sediment bound phosphorus, nitrogen and trace metals;
4. Leaching of salts from soils leading to increases in river salinity;
5. Increased flooding requiring engineered drainage systems, especially in low lying areas; and
6. Loss of buffer zones allowing transport of nutrient and sediment to rivers and estuaries.

The 1950's and 1960's saw the introduction of mechanical methods of bushland clearing which resulted in vast areas of land being stripped of deep rooted vegetation. The south coast region covers an area of around 5,400,000 ha, however approximately 50% (2,985,000 ha) has been cleared of natural bushland (SCRAP & SCRIPT 1996c). This represents about 86% of all alienated land (3,840,000 ha). The clearing of virtually all (if not all), of the fringing vegetation along the watercourses, radically changed the character of the streams. The water course changes from an environment that supported a multitude of organisms, to that of an open drainage channel (WAWRC 1992). The loss of riparian vegetation in some areas represents a loss of endemic plant and animal species and a loss of sediment trapping and denitrification processes.

The health of remnant riparian vegetation determines the structural and ecological stability of a river which ultimately determines the structural and ecological stability of its receiving estuary. Riparian vegetation has important ecological functions which include the stabilisation of river banks and the reduction of surface water velocities. It is the source of leaf litter which is important in maintaining healthy aquatic food chains (Davies 1994) and the source of river snags of roots and dead wood which results in retention of habitat diversity, river bed stabilisation, retention of organic matter and traps sediments.

Riparian vegetation provides shade to the water surface which decreases water temperature and light intensity, both of which limits algal growth and fosters healthy aquatic invertebrate communities. Riparian vegetation functions as a buffer to protect rivers and estuaries from nutrient and sediment pollution, as well as providing food and habitat for terrestrial fauna and wetland bird life (Olsen & Skitmore 1991, EPAWA 1992, WAWRC 1992, Pen 1995).

4.2. Salinity

In the south coast region, the fundamental cause of the increase in salinization has been the widespread removal of perennial deep-rooted native vegetation and its replacement with shallow-rooted annual crops and pastures, in areas with rainfall of less than 700 mm per annum. This is regarded as the most serious environmental problem in Western Australia (EPAWA 1992, WAWRC 1992, AgWA 1996, GovWA 1996).

Extensive clearing throughout low rainfall regions has resulted in surface water streams having increased salinity. In the south coast region, these areas are mainly the inland agricultural properties that have large quantities of salt stored in the soils. The permanent removal of native bushland has given rise to the accelerated leaching of salts to the river systems (Sanders 1991).

Salt leaching has had devastating effects on the environment which impact both the catchment and the rivers. Rising water table levels as a result of clearing, often causes death of remnant vegetation through water logging and salinity. There has been extensive losses of productive agricultural farmlands due to the salt seepage and waterlogging, which subsequently renders the land useless. The area of affected farmland is extensive and is expected to increase five times over the next two decades (WAWRC 1992).

The loss of water supplies that were considered fresh to marginal (diverted for potable domestic, industrial and irrigation usage), is another consequence of increased salinity. Approximately 48% of divertible water in the state has potable potential, with the remainder being too saline.

Another environmental problem caused by increased salinity is the effect on native flora and fauna. For example, some water birds are tolerant of high salt levels as long as there is vegetation available for nesting, whereas other birds can only tolerate freshwater and move on until they locate it. Once a wetland is abandoned by wetland birds, they may not return. Aquatic communities change with different salinity gradients (WAWRC 1992, GovWA 1996).

All waterways with extensive agricultural clearing in their catchments, are exhibiting the effects of salinity. The Frankland, Kent, Hay, Denmark, Kalgan, Cordinup, Bremer, Fitzgerald, Hamersley, Phillips, Young and Lort rivers have saline affected areas within their catchments. Increased salinity in catchment runoff, in most cases can be detrimental to the estuarine ecosystem.

4.3. Erosion

Removal of natural vegetation from rivers and stream courses and their natural flood plains, has exposed the fragile, shallow topsoil over large areas of land. Increased runoff from these areas facilitate the transport of sediments to streams, rivers, estuaries and ultimately to the sea. Erosion rates in the south coast region have increased greatly in recent time, resulting in many of the estuaries silting up at alarming rates (Hodgkin & Clark 1987, 1988a, 1988c, 1988b, 1989b, 1989a, 1990b, 1990a). All estuaries with catchment clearing and a lack of riparian buffer strips, have significant signs of silting. The Gordon, Parry, Fitzgerald, Wellstead and Beaufort inlets are the worst affected.

While broad-scale clearing is the major cause (WAWRC 1992), other activities result in river, wetland and estuary siltation:

1. De-snagging and engineering of rivers to minimize flooding risks;

2. Stock disturbance of river banks and beds, which includes the trampling of river banks and stock grazing on riparian vegetation; and

3. Human recreation activities also affect the rate of riverbank degradation. Examples are the overuse of river banks by campers and day visitors, destruction of riparian vegetation for fires and barbeques, and motor vehicles, in particular four wheel drives and

motor cycles causing blowouts on coastal dunes (DCEWA 1981, DCEWA 1983, Craig & Oma 1984, Craig et al. 1984, van Steveninck & Craig 1984, Newbey 1987). Water-based activities such as boating, water skiing, jet skiing and to some extent, digging worms for bait from the riverbanks by recreational fishermen, can also cause riverbank erosion (Thurlow et al. 1986).

4.4. Eutrophication

The process by which nutrient pollutants cause riverine and estuarine ecosystems to change, is called eutrophication. In the south coast region, eutrophication is considered to be more severe in estuaries than rivers. This is because the rivers are generally completely flushed seasonally, where as estuaries on the south coast which are nearly all barrier estuaries, are generally poorly flushed. Under these conditions, the estuaries receive high nutrient loads in winter runoff which readily accumulate to excessive levels.

Excessive nutrients in estuaries cause accelerated growth by plants, increased growth of macrophytes (seagrasses and macroalgae) and phytoplankton. Increased biomass of algae within estuaries tends to smother existing seagrass and benthic microalgal communities. De-oxygenation of the water column can occur as the macrophytes and phytoplankton decay, resulting in fish kills and foul smelling decaying organics on the estuary's shoreline. If eutrophication is extreme, blue-green algal blooms may occur. Some blue-green algae release toxins that can poison both aquatic and terrestrial animals which are dependant on the estuary (LCSC 1990, WAWRC 1992, Hosja et al. 1994).

Soils of areas of low rainfall (<700 mm) are laterites, mottled clays and some sands. These areas have high runoff coefficients and have been identified as potential or existing high nutrient export regions (Weaver et al. 1994). Most of the larger catchments of the south coast region have their upper reaches in these low rainfall regions. In their water runoff, these regions have low losses of soluble phosphorus which are leached from applied agricultural fertilizers, medium sediment phosphorus losses as the soils lack reactive iron which binds phosphorus, and medium sediment export.

In areas of the south coast region with greater than 700 mm rainfall per annum, the soils tend to be either very sandy with no phosphorus adhesion or laterites with high phosphorus adhesion. These regions have high application rates of agricultural fertilizers and high soluble phosphorus export. The clearing of lands and the loss of riparian vegetation, have seen the increase in sediment export. This transports sediment bound phosphorus into the rivers and the estuaries which subsequently results in changes in trophic levels (Deeley et al. in prep).

Eutrophication results in the degradation of the estuarine ecosystem. It may contribute to health problems in fish and avian populations, produces unsightly and decaying algal mats washed up on shorelines, and the release of putrid and noxious gases (LCSC 1990).

Even though eutrophication is a major management problem for many of the south coast estuaries, little is known about their status and their risk of further degradation. Load estimates (Tables 4.1, 4.2, 4.3, 4.4), are very rough and have large errors which could be as high as ±200% (Deeley et al. in prep, Muirden in prep.-b, Muirden in prep.-a).

Only a few estuaries of the south coast region (Torbay, Princess Royal Harbour, Oyster Harbour and Beaufort Inlet) exhibit severe symptoms of eutrophication, however many of the other estuaries are moderately eutrophic and most are at risk from future eutrophication.

Table 4.1. Nutrient loads, nutrient status and observed symptoms of nutrient pollution or other environmental problems in the estuaries of the Broke Inlet to Torbay Inlet region.

ESTUARY	ANNUAL P LOADS (t)	NUTRIENT STATUS	SYMPTOMS OF NUTRIENT/ ENVIRONMENTAL PROBLEMS	SOURCES
BROKE INLET	2	low	Pristine	(LCSC 1990) (Deeley et al. in prep)
WALPOLE-NORNALUP INLET	24	moderate	Siltation, algal blooms, excessive macroalgae growth	(LCSC 1990) (EPAWA 1992)
IRWIN	~6-7	moderate	river salinity, siltation	(LCSC 1990) (EPAWA 1992)
PARRY	~7	moderate	Excessive macroalgae growth, siltation	(LCSC 1990) (Hodgkin & Clark 1988c)
WILSON	9-19	moderate	Excessive seagrass and epiphyte growth, algal blooms, siltation, river salinity	(LCSC 1990) (Bastyan 1996a) (Bastyan 1996c) (Bastyan 1996b)
TORBAY	~7	highly enriched	Blue/green algal blooms	(LCSC 1990) (Hodgkin & Clark 1990a)

Table 4.2. Nutrient loads, nutrient status and observed symptoms of nutrient pollution or other environmental problems in the estuaries of the Albany Environs region.

ESTUARY	ANNUAL P LOADS (t)	NUTRIENT STATUS	SYMPTOMS OF NUTRIENT/ ENVIRONMENTAL PROBLEMS	SOURCES
PRINCESS ROYAL HARBOUR	28.7-43	highly enriched	Macroalgae, seagrass loss	(LCSC 1990) (Deeley et al. in prep)
OYSTER HARBOUR	5-70	highly enriched	Macroalgae, seagrass loss, siltation	(LCSC 1990) (Hodgkin & Clark 1990a)
TAYLOR		moderate	siltation	(LCSC 1990) (Hodgkin & Clark 1990a)
ANGOVE/GARDNER				
KING CREEK				
NORMAN'S INLET		low		(LCSC 1990) (Hodgkin & Clark 1990a)
WAYCHINICUP INLET		low		(LCSC 1990) (Hodgkin & Clark 1990a)
BLUFF			siltation	(Hodgkin & Clark 1990a)
LITTLE BLUFF			siltation	(Hodgkin & Clark 1990a)
WONGERUP			siltation	(Hodgkin & Clark 1990a)
CORDINUP INLET		low		(LCSC 1990) (Hodgkin & Clark 1990a)
CHEYNE INLET		moderate	excessive algae growth, siltation	(LCSC 1990) (Hodgkin & Clark 1990a)
SWAN GULLY		low	siltation	(Hodgkin & Clark 1990a)
BEAUFORT INLET		highly enriched	Green algae blooms & associated fish deaths, siltation, river salinity	(LCSC 1990) (Hodgkin & Clark 1988a)

Table 4.3. Nutrient loads, nutrient status and observed symptoms of nutrient pollution or other environmental problems in the estuaries of the Fitzgerald Biosphere region.

ESTUARY	ANNUAL P LOADS (t)	NUTRIENT STATUS	SYMPTOMS OF NUTRIENT/ ENVIRONMENTAL PROBLEMS	SOURCES
WELLSTEAD INLET		moderate	Excess seagrass growth, siltation	(EPAWA 1990) (Hodgkin & Clark 1987)
HUNTER CK		low		(Hodgkin & Clark 1988a)
KELLY'S CK		low		(Hodgkin & Clark 1988a)
GORDON INLET		moderate	Algal blooms, river salinity and siltation	(EPAWA 1990) (Hodgkin & Clark 1988a)
BOONDADUP INLET		low	Pristine	(Hodgkin & Clark 1989b)
ST MARY'S INLET		low	Pristine	(Hodgkin & Clark 1989b)
LAKE NAMELESS		low	Pristine	(Hodgkin & Clark 1989b)
FITZGERALD INLET		moderate	Increased river salinity, nutrients and siltation	(Hodgkin & Clark 1990b) (EPAWA 1992)
DEMPSTER INLET		low	Pristine	(Hodgkin & Clark 1990b) (EPAWA 1992)
HAMERSLEY INLET		moderate	Increased river salinity, nutrients and siltation	(Hodgkin & Clark 1990b) (EPAWA 1992)
CULHAM INLET		moderate	Increased river salinity, nutrients and siltation	(Hodgkin & Clark 1990b) (EPAWA 1992)

Table 4.4. Nutrient loads, nutrient status and observed symptoms of nutrient pollution or other environmental problems in the estuaries of the Esperance Environs region.

ESTUARY	ANNUAL P LOADS (t)	NUTRIENT STATUS	SYMPTOMS OF NUTRIENT/ ENVIRONMENTAL PROBLEMS	SOURCES
JERDACUTTUP LAKES		moderate	River salinity and siltation	(Hodgkin & Clark 1990b)
OLDFIELD ESTUARY		moderate	River salinity and siltation	(Hodgkin & Clark 1990b)
TORRADUP INLET		moderate	River salinity and siltation	(Hodgkin & Clark 1990b)
STOKES INLET		moderate	River salinity, nutrients and siltation	(Hodgkin & Clark 1989b)
BARKERS INLET				(Hodgkin & Clark 1989b)
BANDY CREEK				(Hodgkin & Clark 1989b)
DAILY RIVER		low		(Hodgkin & Clark 1989b)
MUNGLIGINUP		low		(Hodgkin & Clark 1989b)
ALEXANDER INLET		low		(Hodgkin & Clark 1989b)
BLACKBOY CREEK		low		(Hodgkin & Clark 1989b)
THOMAS RIVER		low		(Hodgkin & Clark 1989b)
JORNDEE		low	Pristine	(Hodgkin & Clark 1989b)
POISON & FERN CREEKS		low	Pristine	(Hodgkin & Clark 1989b)

4.5. Commercial Fisheries

Commercial fisheries in the south coast estuaries are amongst the oldest fisheries in Western Australia. Many descendants of the original families who began fishing the southcoast estuaries around the late 19th century, still fish the same estuaries as their forebearers (SCEFWG 1995).

Of the estuaries between Broke Inlet and Israelite Bay, there a number that are not open to commercial fishing (Table 4.5.). There are currently 53 commercial fishermen licenced to operate in the south coast estuaries. Using methods such as gillnets, haul nets, seine nets, crab drop nets and hand lines, the fishermen take a suite of species.

Table 4.5. Commercial fishery seasons in south coast estuaries, from Broke Inlet to Israelite Bay (SCEFWG 1995). (NS = not specified)

ESTUARY	CLOSED	OPEN	CLOSED 23/12 - 2/1	CLOSED 20/12 - 6/1	CLOSED 31/10 - 1/5	FISH TRAPS	HAUL NETS
BROKE INLET		+	+	+	+		+
WALPOLE-NORNALUP INLET	+						
IRWIN INLET		+	+	+	+		+
PARRY INLET		+	+	+			+
WILSON INLET		+	+	+			+
TORBAY INLET	+						
PRINCESS ROYAL HARBOUR		+	+	+		+	+
OYSTER HARBOUR		+	+	+		+	+
TAYLOR INLET	+						
ANGOVE AND GARDINER LAKES		+	+	+			
KING CREEK	NS						
NORMAN'S INLET	+						
WAYCHINICUP INLET		+	+	+			+
CORDINUP INLET	NS						
CHEYNE INLET	+						
SWAN GULLY	NS						
BEAUFORT INLET		+	+	+	+		
WELLSTEAD INLET	+						
HUNTER CK	NS						
KELLY'S CK	NS						
GORDON INLET		+	+	+			+
BOONDADUP INLET	NS						
ST MARY'S INLET	+						
LAKE NAMELESS	NS						
FITZGERALD INLET		+	+	+			+
DEMPSTER INLET	+						
HAMERSLEY INLET		+	+	+			+
CULHAM INLET		+	+	+			+
JERDACUTTUP LAKES		+	+	+			
OLDFIELD ESTUARY		+	+	+			+
TORRADUP INLET		+	+	+			+
STOKES INLET		+	+	+	30/11-1/5		+
BARKERS INLET	+						
BANDY CK	NS						
DAILY RIVER	NS						
MUNGLIGINUP CK	NS						
ALEXANDER INLET	NS						
BLACKBOY CK	NS						
THOMAS RIVER	NS						
JORNDEE CK	NS						
POISON & FERN CK	NS						

The major commercial estuarine fish species are Estuarine Catfish (*Cnidoglanis macrocephalus*), Sea Garfish (*Hyporhamphus melanochir*), River Garfish (*Hyporhamphus regularis*), King George Whiting (*Sillaginodes punctatus*), Western Sand Whiting (*Sillago bassensis*), Tailor (*Pomatomus saltator*), Black Bream (*Acanthopagrus butcheri*), Silver Flounder (*Bigener brownii* & *Meuschenia freycineti*), Flounder (*Ammotretus rostratus* & *Pseudorhombus jenynsii*), Flathead (*Platycephalus* species), Sea Mullet (*Mugil cephalus*), Tarwhine (*Rhabdosargus sarba*), Yellow-eye Mullet (*Aldrichetta forsteri*), Mussel (*Mytilus edulis*), Blue Manna Crab (*Portunus pelagicus*), Skipjack (*Pseudocaranx dentex*), Squid (*Idiosepius notoides*), Australian Herring (*Arripis geogianus*) and Salmon (*Arripis esper*) (SCEFWG 1995).

Figures for the catch of the commercial fisheries at individual estuaries (not including Princess Royal Harbour), varied from year to year (Table 4.6.). The catch was variable, depending on the number of visits by professional fishermen, whether the bar was open to the ocean and for how

Table 4.6. Catch estimates of commercial fisheries (in tonnes) for south coast estuaries not including Princess Royal Harbour, 1991-1996 (*courtesy* Fisheries Department of Western Australia)

ESTUARY	1991	1992	1993	1994	1995	1996
BROKE INLET	12.3	12.5	14.7	4.5	14.0	9.9
IRWIN INLET	14.7	18.7	13.8	12.6	24.7	11.9
PARRY INLET	0.1	-	0.1	<0.1	0.3	0.4
WILSON INLET	199.2	108.7	150.2	103.5	159.5	192.3
OYSTER HARBOUR	105.6	79.9	69.0	63.2	60.7	65.6
BEAUFORT INLET	0.6	0.2	5.6	5.9	13.3	19.0
GORDON INLET	5.9	37.2	15.9	5.1	4.2	4.0
DEMPSTER INLET	-	-	0.8	0.3	-	n/a
HAMERSLEY INLET	3.2	2.4	2.5	2.4	3.0	n/a
CULHAM INLET	61.0	69.4	50.0	16.8	0.4	n/a
JERDACUTTUP LAKES	-	-	1.3	0.2	<0.1	n/a
OLDFIELD ESTUARY	0.4	1.1	0.07	0.1	4.2	1.2
TORRADUP INLET	0.1	-	-	-	-	-
STOKES INLET	7.9	42.6	14.7	13.6	9.6	15.0
OTHER INLETS (bulked)	5.1	2.1	4.5	0.3	2.6	7.4
SOUTH COAST TOTAL	416.5	374.8	343.2	228.6	296.5	326.7

long, catchment runoff and other environmental variables such as salinity and dissolved oxygen.

In the smaller estuaries of the south coast region, information is not available to determine trends, because of the variable nature of catch records, the irregularity of visits and the Privacy Legislation of the Fisheries Act (Lenanton & Hodgkin 1985).

The estuarine fishery on the south coast is small when compared to the state's total catch. The fishery yields an annual catch of approximately 200 to 450 tonnes.

Commercial fishermen have been known to manually open the bars of various south coast estuaries (e.g. Broke, Irwin, Wilson and Beaufort Inlets). Premature opening of an estuary's bar may result in the reduction of the scouring effect and shorten the period the bar would naturally stay open. In effect, this may lessen the recruitment of marine fishes into the estuary, affect the seasonal salinity changes and alter the water colour (Hodgkin & Clark 1988c, Hodgkin & Clark 1988a, Hodgkin & Clark 1989a).

4.6. Dieback

Dieback is spread by *Phytophora cinnamomi*, an introduced fungus whose spores spread laterally in the water table and with the movement of infected soil. This soil-borne fungus kills their host by damaging their fine roots that take up water, or by girdling primary roots of the tree trunk itself (EPAWA 1992). *P. cinnamomi* attacks over 900 species of native flora, including the Myrtaceae (e.g. Eucalypts, Bottlebrushes, Myrtles), Proteacae (e.g. Grevillea, Banksia) and the Epacridacae (heaths). The south coast region contains around 25% of Western Australia's known plant species. *Phytophora* represents a serious threat to floristics diversity is susceptible areas (CALM 1992a, SCRAP & SCRIPT 1996c).

The south coast is particularly at risk as it has the ideal climate for *Phytophora* to thrive. It has warm, moist conditions for most of the year. Environmental conditions are so favourable for fungi to grow, that even bushwalkers and animals can easily spread it (EPAWA 1992).

With the current level of knowledge, dieback cannot be eradicated from an infected area, however slowing its spread in areas already infected and preventing the spread into new areas, can help contain the fungus (CALM 1992a).

4.7. Exotic Weeds

Associated the clearing of the land, and introduction of non-indigenous animals and plants, is the importation of exotic 'weed' species. The weeds may be distributed by waterways, and in some cases into National Parks and Conservation Reserves. Species such as *Typha orientalis* (Bulrush), *Watsonia* species (Watsonia), *Cortaderia selloana* (Pampas Grass), *Arundo donax* (Giant Reed) and *Chasmanthe floribunda*, thrive in moist habitats and can overtake native bushland (CALM 1992a). Some grasses that are not a problem to agriculture (e.g. Velt Grass, African Love Grass, Umbrella Grass), can be a threat to natural vegetation in neighbouring public lands (EPAWA 1992, Pen 1994, Pen 1995, AgWA 1996).

In the south coast region, the main concern is the Blackberry, *Rubus fructicosus* which is widespread through the Porongurup National Park and other districts around Albany. Other 'declared weeds' include *Mentha pulegium* (Penny Royal), *Zantedeschia aethopica* (Arum Lily), *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Patersons Curse) and *Chondrilla juncea* (Skeleton Weed). 'Pest plants' which are usually prescribed by local authorities include the Afgan Thistle (*Solanum hystrix* & *S. holopetalem*), Angel's Trumpet (*Datura canida*), Boxthorn (*Lycium ferocissimum*), Raspistrium Weed (*Raspistrium rugosum*) and Umbrella Grass (*Digitaria* sp.) (CALM 1992a, EPAWA 1992).

4.8. Pesticides

Pesticides are used for the control of organisms that are considered as pests. Insecticides are used to control insects, herbicides for the control of weeds, and fungicides to control fungi. Pesticide usage in agricultural practices has increased over the last few years with the introduction of no tillage methods. One such method, spray seeding, seems to be the most popular modern sowing technique, introduced to help alleviate the erosion problem. This trend has resulted in a significant increase in herbicide usage in the catchments of the south coast estuaries.

Organochlorines and dieldrin were detected in quantities below health limits, in Albany's urban runoff in 1988 (EPAWA 1990). There has been no documentation of current levels of pesticides, in either the waters or sediments of the south coast estuaries, however there is community interest in pesticide levels in the south coast waterways, suggesting that investigations may be required.

5. REGIONAL ISSUES

5.1. Broke Inlet to Torbay Inlet

Much of the limited research on the estuaries of the south coast has been undertaken in this region, mainly at Wilson Inlet (Table 5.1). The management of the ocean bars is the major management issue in the Broke Inlet to Torbay Inlet region. Broke, Irwin, Parry, Wilson and Torbay Inlets, all have some degree of human intervention as to when the bar is opened. In Wilson Inlet, this has been a community debate for many years. The points of discussion have been whether to artificially open or not, to open on the east or the west, and to open permanently or not.

In the last couple of decades there has been significant population increases on the south coast. Associated with these increases is the need for housing development and, the disposal of wastewater and refuse.

In Walpole (Walpole-Nornalup Inlet), there has been significant foreshore development which has removed fringing vegetation and filled in rare perched wetlands. Septic systems in some of the new houses may add to the existing groundwater nutrient flux into Walpole Inlet. Wilson Inlet also has foreshore developments that have removed and land-filled ephemeral fringing wetlands. Developments have been proposed for Nullakai Point and Prawn Rock Channel.

Foreshore development is a major issue for Broke Inlet. The management of lands vested to the Shire of Manjimup at the gazetted townsite of Camfield, are under review. Presently there are a number of squatter huts and one freehold property, however various plans for development have been proposed.

Except for Broke Inlet, all of the estuaries in this region show some degree of eutrophication. Loss of nutrient and organic matter from agriculture in their catchments, is the source of the pollution.

Aquaculture ventures have been proposed in both Wilson and Walpole-Nornalup Inlets. Only Wilson Inlet has existing mussel farm leases.

The upper catchments of the Frankland, Kent, Denmark and Hay Rivers, are showing signs of salt stress. If remedial action is not undertaken, the effects of salinity on the remnant vegetation, the wetlands and pollution loads are likely to be significant.

SCRAP & SCRIPT (1996b) have highlighted Nornalup Inlet as having high conservation value because it is surrounded by near pristine bushlands and sedgelands.

Table 5.1. Eutophication state of the estuaries in the Broke Inlet to Torbay Inlet region. 1 = mild, 2 = moderate, 3 = severe.

ESTUARY	Broke	Walpole-Nornalup	Irwin	Parry	Wilson	Torbay
SYMPTOMS						
Excess macroalgae		1	1	3	1	1
Phytoplankton blooms		1	1	3	1	3
Seagrass loss		1	1			
Siltation		1	1	1	1	
Excessive epiphytes		1		2	2	
Foreshore development	1	1			1	
Exotic weeds		1	1	1	2	1
Increased catchment salinity		1	1		1	
NUTRIENT SOURCE						
Agriculture		1	1	2	2	3
Industry					1	
Urban					1	
HUMAN INTERACTION						
Bar Management	1		1	1	1	1
Algal Harvesting						
Riparian Revegetation		1	1		2	1
Community Groups or Government	*	*	*	*	*	*

Broke Inlet also has high conservation value because it is the only large near pristine estuary on the south coast, however it has high recreational value and has a commercial fishing season.

5.2. The Albany Environs

Princess Royal Harbour and Oyster Harbour have been degraded by nutrient pollution in catchment runoff, which was identified as the cause of the significant loss of seagrass and increase in macroalgae biomass (EPAWA 1990). The latest survey (Bastyan et al. 1996), showed an increase in seagrass distribution and a decrease in macroalgae biomass. Table 5.2 highlights the lack of knowledge regarding the health of the estuaries east of Albany. However most of the estuaries have cleared agricultural lands in their catchments which has been connected to estuary eutrophication and siltation elsewhere.

In the low rainfall areas east of Albany, there has been an increase in erosion and sediment transport. The soils may be more prone to erosion due to the sparseness of vegetation and the variable river flow. In January 1982, the Pallinup river in flood discharged approximately 100,000 t of sediment from the river bed and banks into the Beaufort Inlet. It is speculated that most of this sediment came from farmland catchment (Hodgkin & Clark 1988a).

The loss of nutrients and organic matter from cleared farmlands on poor soils, is polluting many of the estuaries in the Albany Environs region. Beaufort Inlet is showing symptoms of severe eutrophication. The Kalgan River has been targeted by the Albany Waterways Management Authority for riparian vegetation replanting and buffer zone fencing programmes (Pen 1994, Pen 1995, SCRAP & SCRIPT 1996c). In recent years aquaculture leases have been worked in Oyster Harbour. The Fisheries Department are currently undertaking a study into the expansion of aquaculture in Oyster and in nearby Princess Royal Harbour. Introduced marine species are a current topic of research by CSIRO. The Centre for Research of Introduced Marine Pests (CRIMP) have collected Sabellid worms (*Sabella spananzanii*) from Oyster Harbour. This exotic marine organism has been a concern to the aquaculture ventures and the environment.

Some species of dinoflagellates have been connected to Paralytic Shellfish Poisoning (PSP), Diarretic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP), and Neurotoxic Shellfish Poisoning (NSP). Only one case of PSP

Table 5.2. State of the estuaries in the Albany Environs region. 1 = mild, 2 = moderate, 3 = severe. (PRH = Princess Royal Harbour).

ESTUARY	PRH	Oyster	Taylor	Two Peoples, King, Norman	Waychinicup, Hassel Beach	Cordinup	Cheyne	Swan Gully	Beaufort
SYMPTOMS									
Excess macroalgae	3	3							
Phytoplankton blooms	1	1	2						3
Seagrass loss	3	2							
Siltation		1					1		3
Excessive epiphytes	3	3							
Foreshore development	1	1							
Exotic weeds	1	1							1
Increased catchment salinity		1				2			2
NUTRIENT SOURCE									
Agriculture	2	3				1			
Industry	3	1							
Urban	1	1							
HUMAN INTERACTION									
Bar Management		1							
Algal Harvesting	2								
Riparian Revegetation	1	1							1
Community Groups or Government	*	*							

has been recorded in Western Australia, however the toxic dinoflagellates of the genus *Alexandrium*, have been recorded in Oyster Harbour and Princess Royal Harbour (Hosja et al. 1994, Deeley et al. in prep). The spread of these exotic dinoflagellates to other estuaries is a major concern which may affect the endemic marine life and pose a threat to the south coast aquaculture industry.

Weed infestation is a serious problem in this region. Blackberry and Bridal Weed already have wide distribution in the major watercourses. Weed species are a threat to the survival of the remnant vegetation and to the integrity of National Parks.

SCRAP and SCRIPT (1996a) identified Oyster Harbour as being of outstanding environmental value because of the fringing mudflats and the large numbers of migratory birds that visit the estuary. Oyster Harbour also has cultural significance for its aboriginal fishtraps on its northern shore. It is also on the register of wetlands of national significance. Normans Inlet and Lake Angove were also identified for the scenic values. Waychinicup Inlet is also unique on the southcoast for its fjord-like gorge through the coastal granite of Mount Manypeaks.

5.3. Fitzgerald Biosphere

Increases in salinity, nutrient, organic and sediment loads in catchment runoff, have been observed in the estuaries of the Fitzgerald Biosphere region (Hodgkin & Clark 1987, Hodgkin & Clark 1988a, Hodgkin & Clark 1989b, Hodgkin & Clark 1990b, Deeley et al. in prep), while little revegetation of riparian zones has occurred (*pers comm.* Sanders 1997).

The Fitzgerald, Hamersley, Wellstead and Culham Inlets have areas showing symptoms of increased salinity in their upper catchments. The catchments of the latter two have significant areas of degraded land and all have shown symptoms of eutrophication (Table 5.3). Algal blooms have been observed in the Wellstead, Gordon and Fitzgerald Inlets.

Dieback has infected significant portions of the Fitzgerald Biosphere region, to the extent that the Fitzgerald River National Park is threatened by its spread. This would be the major management issue of the National Park. Wind erosion is a concern in years of low ground cover and strong winds.

Table 5.3. State of the estuaries in the Fitzgerald Biosphere region. 1 = mild, 2 = moderate, 3 = severe.

ESTUARY	Well-stead	Hunter	Kelly's	Gordon	Boon-dalup	St Mary	Lake Nameless	Fitz-gerald	Demp-ster	Hamers-ley	Culham
SYMPTOMS											
Excess macroalgae	1							1			
Phytoplankton blooms	1		1					1			
Seagrass loss								1			
Siltation	1		1					2		1	1
Excessive epiphytes	1										
Foreshore development											
Exotic weeds	1		1					1		1	1
Increased catchment salinity	2							1		1	2
NUTRIENT SOURCE											
Agriculture	2		1					1		1	1
Industry	3										
Urban	1										
HUMAN INTERACTION											
Bar Management											1
Algal Harvesting	1										
Riparian Revegetation	1		1					1			1
Community Groups or Government	*							*			

With the proposal of a marine reserve adjacent to the Fitzgerald River National Park and the inclusion of estuaries such as the St Mary, Fitzgerald, Dempster and Hamersley Inlets (MPRSWG 1994), an opportunity presents itself for the Biosphere Reserve to incorporate a marine component. This will place greater emphasis on the management of surface water quality and quantity entering the estuaries and the ocean. The upper catchments of the Fitzgerald and Hamersley Inlets are substantially cleared which threaten the integrity and function of the core zone of the biosphere (Watson 1994). The loss of riparian buffers allow for the increased nutrient and sediment inputs into the estuaries.

Little research has been undertaken on the ecology and the health of the smaller estuaries and their catchments. The catchments of Boondadup, St Mary and Dempster Inlets lie wholly within the Fitzgerald River National Park, therefore are considered as being pristine. These estuaries have high conservational value and would be ideal systems for comparative studies with nearby degraded estuaries.

5.4. Esperance Environs

There is a lack of information on the estuaries of the Esperance Environs region (Table 5.4). The catchments of the rivers and creeks, that have been cleared for agriculture all show signs of salinity stress and erosion. therefore it can be assumed that their coastal inlets are receiving increased loads of nutrients and silt.

However the extent of this pollution is largely unknown as many were highly saline prior to development. Stokes Inlet has experienced some minor events of excessive macroalgae growth.

Dieback has widely infected the coastal plain and has had considerable impacts of the *Banksia speciosa* heathlands. The coast between Hopetoun and Torradup, and Cape Arid National Park have been seriously affected.

The marine tube worm *Sabella spallanzanii* has recently been observed in Bandy Creek. Introduced marine pests are a major environmental concern which are currently being researched by CSIRO's Centre for Research on Introduced Marine Pests and the Australian Association of Port and Marine Authorities (*pers comm.* G. Clapin 1997).

The eutrophication of the estuaries of the Esperance Environs region, through the input of agricultural runoff and the loss of riparian buffer zones, will ultimately affect their ecological stability and integrity.

Table 5.4. State of the estuaries in the Esperance Environs region. 1 = mild, 2 = moderate, 3 = severe.

ESTUARY	Jerdacuttup	Oldfield	Torradup	Stokes	Barker	Bandy Creek	Dailey	Munglinup	Alexander	Blackboy	Thomas	Jorndee	Poison & Fern
SYMPTOMS													
Excess macroalgae				1									
Phytoplankton blooms													
Seagrass loss													
Siltation	1												
Excessive epiphytes													
Foreshore development	1												
Exotic weeds	1	1	1	1									
Increased catchment salinity	1			2									
NUTRIENT SOURCE													
Agriculture				1									
Industry													
Urban													
HUMAN INTERACTION													
Bar Management													
Algal Harvesting													
Riparian Revegetation													
Community Groups or Government													

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7. ACKNOWLEDGMENTS

This report was funded by a grant from the Marine Conservation Branch of the Department of Conservation and Land Management. The authors would like to acknowledge the contributions of the following persons;

Mark Cliff of the Fisheries Department, Peter Muiden, Luke Pen, Chris Gumby and Anthony Sutton of the Water & Rivers Commission, Ray Laurie, Angela Sanders and Greg Mair of CALM, David Weaver of Agriculture WA, and Ernest Hodgkin for valuable discussions and editorial input.