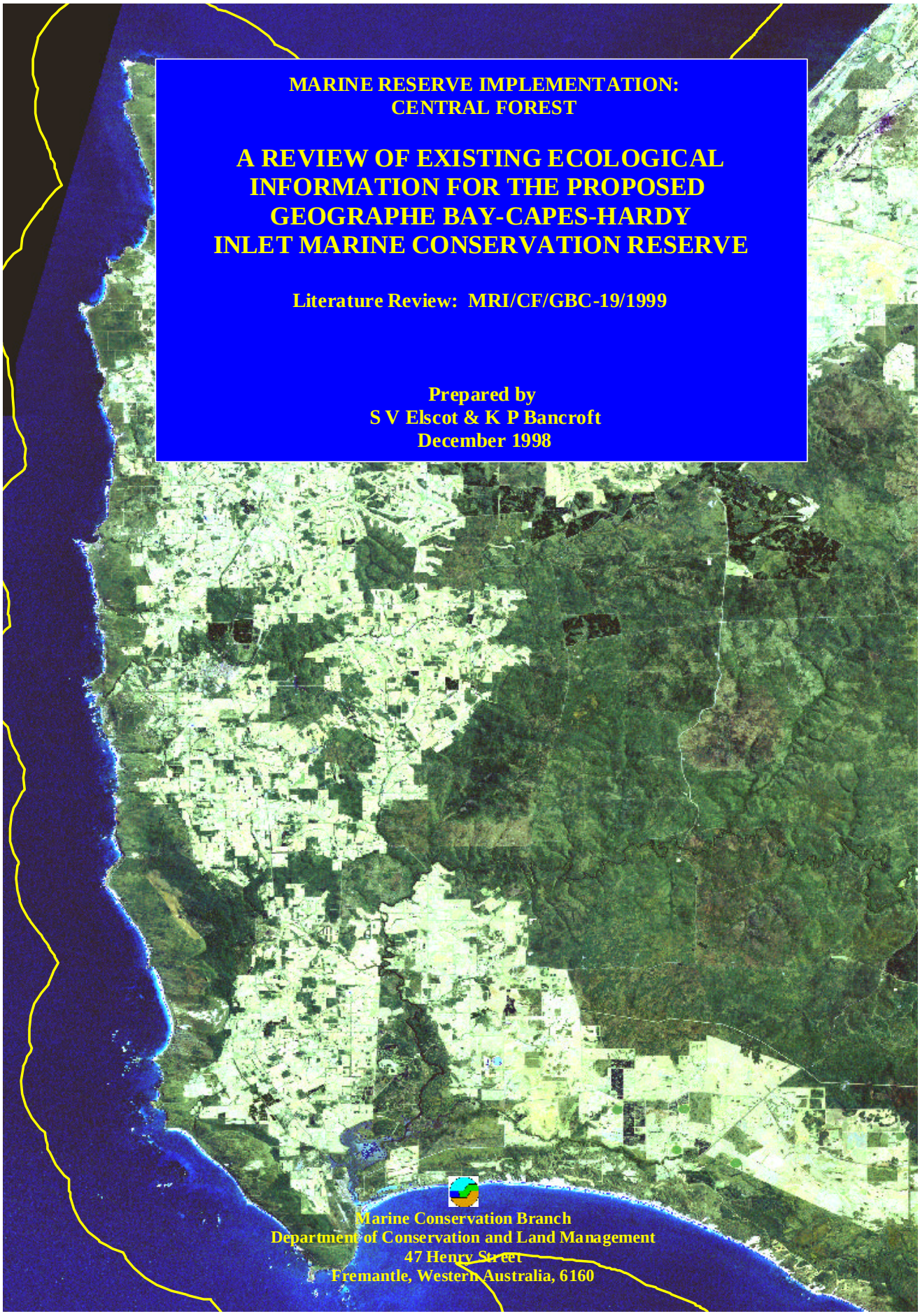

MARINE RESERVE IMPLEMENTATION:
CENTRAL FOREST

A REVIEW OF EXISTING ECOLOGICAL INFORMATION FOR THE PROPOSED GEOGRAPHE BAY-CAPES-HARDY INLET MARINE CONSERVATION RESERVE

Literature Review: MRI/CF/GBC-19/1999

Prepared by
S V Elscot & K P Bancroft
December 1998

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry Street
Fremantle, Western Australia, 6160

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A collaborative project between CALM's Marine Conservation Branch
and South West Capes District Office

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Coast and Clean Seas Marine Protected Area Program
Project No: WA9703

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Cover. Geographe Bay-Capes-Hardy Inlet region (Landsat satellite image *courtesy* Environment Australia)

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SUMMARY

In December 1997, The Western Australian Government following the advice provided by the Marine Parks and Reserves Authority announced that the Geographe Bay-Capes-Hardy Inlet region was one of three priority areas for the establishment of marine conservation reserves under the *CALM Act*. Reservation of the waters of the Geographe Bay-Capes-Hardy Inlet region was also recommended in the Leeuwin-Naturaliste Ridge Statement of Policy Report (Ministry for Planning, 1998).

Under the State Government's marine and conservation strategy detailed in *New Horizons-The way ahead in marine conservation and management* released by the Western Australian Government in 1998 (WA Government, undated), there is a requirement for:

> "Extensive assessment, community consultation and management planning before a new marine conservation reserve is established".

An essential component of this is that:

> "A comprehensive assessment of the area's biological and economic resources, and social values is carried out".

This review partially addresses this essential component by presenting a summary of existing ecological information for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve (Geographe Bay to Flinders Bay). It presents a general description of the physical characteristics and summarises the biological resources of the region.

The information that has been compiled in this review was collected mainly through literature searches, review of published materials, examination of CALM data for marine mammals and stranding events, and from anecdotal information.

This review collates information available for benthic habitats, marine flora and fauna, marine wildlife, estuarine coastal wetlands, and coastal terrestrial biota. It highlights the gaps in ecological information for the region, particularly:

1. the poor coverage of the existing benthic habitat mapping;
2. the lack of information on the marine flora and fauna in general and particularly between Cape Leeuwin to Cape Naturaliste;
3. the little information available on mobile marine invertebrate and macroalgae diversity and distribution, and;
4. the absence of information on sessile marine invertebrate diversity and distribution.

This review will be utilised as a resource document for the planning process in the implementation of the marine conservation reserve proposed for the Geographe Bay-Capes-Hardy Inlet region.

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1. INTRODUCTION

1.1. OVERVIEW

In recognition of the importance of conserving the State's marine biodiversity, the Minister for the Environment established the Marine Parks and Reserves Selection Working Group (MPRSWG) in 1986. The main aim of the MPRSWG was to identify representative and unique areas of Western Australia's marine waters for consideration as part of a statewide system of marine conservation reserves under the *Conservation and Land Management (CALM) Act* 1984. The MPRSWG's report was released in June 1994 and identified over seventy such candidate areas throughout the coastal waters of Western Australia (CALM 1994).

The State's vesting body for marine conservation reserves is the Marine Parks and Reserves Authority (MPRA) which was established in 1997. The MPRA has prioritised the candidate areas for implementation as marine conservation reserves. The proposed Geographe bay-Capes-Hardy Inlet marine conservation reserve encompasses the Geographe Bay-Cape Leeuwin and Hardy Inlet, is one of the MPRA's high priority candidate areas.

Under the State Government's marine and conservation strategy detailed in *New Horizons - The way ahead in marine conservation and management*, released by the Western Australian Government in 1998 (WA Government, undated), there is a requirement for:

> "Extensive assessment, community consultation and management planning before a new marine conservation reserve is established".

An essential component of this is that:

> "A comprehensive assessment of the area's biological and economic resources, and social values is carried out".

In view of the high standing that the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve has in the MPRA's priority list for new marine conservation reserves, CALM applied to Environment Australia for funding to assess the region's biological and economic resources. Partial funding of $72,000 for the project was obtained through Environment Australia's Natural Heritage Trust, via the Coast and Clean Seas Marine Protected Area Programme. CALM has contributed further resources to the project, valued at approximately $87,000.

This review contributes to the project by presenting a broad summary of existing ecological information for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve (Geographe Bay to Flinders Bay). It presents a general description of the physical characteristics and summarises the biological resources of the region. This review collates information available for benthic habitats, marine flora and fauna, marine wildlife, estuarine coastal wetlands, and coastal terrestrial biota. This information has been compiled mainly through literature searches, a review of published and unpublished materials, examination of CALM data for marine mammals and stranding events, and anecdotal information.

1.2. STUDY AREA

The study area for this review encompasses the CALM (1994) Leeuwin-Naturaliste and the Hardy Inlet recommended areas of the south west Western Australia (Figure 1). This study area extends

from the Vasse-Wonnerup Estuary in mid Geographe Bay to Black Point on the eastern edge of Flinders Bay, and extends seaward to the Limit of Western Australian State Waters, described as 3 nm from the Territorial Sea Baseline.

2. CLIMATE

The Geographe Bay-Capes-Hardy Inlet region enjoys a Mediterranean-type climate, which is characterised by cool, wet winters and hot, dry summers. Mean maximum temperatures in January and February range from 28°C at Busselton down to 23°C at Cape Leeuwin, and during July drop to 16°C at both Busselton and Cape Leeuwin (Bureau of Meteorology, online). Mean minimum temperatures range from 17°C at Cape Leeuwin down to 13°C at Busselton during January and February, and during July drop to 11°C at Cape Leeuwin and down to 7°C at Busselton (Bureau of Meteorology, online). Seasonal variation in temperature is more extreme in the northern part of the study area.

The average yearly rainfall experienced by the region ranges from 825 mm at Busselton up to 1000 mm at Cape Leeuwin, of which 55% falls between June and August, 23% during Autumn and 19% during spring (Bureau of Meteorology, online). A seasonal drought occurs during the summer months.

Weather patterns in Western Australia are controlled by the seasonal movement of a belt of dry anticyclonic high pressure cells which move west to east across Australia with a period of seven to ten days (Gentilli, 1972). During winter, this belt is centred around latitude 30° S and brings cool, moist westerlies to the south of the state. During summer, the belt moves south and is centred around latitude 40° S, bringing easterly winds and fine warm weather to much of the state. Superimposed on this general pattern is the occurrence of rain-bearing cyclonic low pressure systems and their associated fronts which move northward in winter bringing north westerly gales and heavy rain to the south-west corner followed by moderate to fresh south to south-west winds. During late spring and summer local winds are controlled primarily by the land seabreeze cycle, which arises from differential diurnal heating of the land and water, causing offshore easterly winds in the mornings followed by strong south-westerly seabreezes that often exceed 20-25 knots (Fahrner & Pattiaratchi, 1994). Anecdotal evidence suggests that this may result in very localised wind patterns in the Capes region, due possibly to the differing temperatures of the water bodies surrounding the Capes and the high topography of much of the coastline.

3. COASTAL GEOLOGY AND GEOMORPHOLOGY

The Geographe Bay-Capes-Hardy Inlet region encompasses three major distinctive coastal types: the low profile, low energy sandy shores of Geographe Bay; the high energy, rocky shores of the Leeuwin-Naturaliste Ridge; and the exposed, open ocean shores of Flinders Bay. The geology and geomorphology of these coasts has been well described in the Report of the Marine Parks and Reserves Selection Working Group (CALM, 1994):

> The Leeuwin Block is a raised horst, separated from the sunkland of the Perth Basin by the Dunsborough Fault. It has an elevation of up to 200 m and is also referred to as the Leeuwin-Naturaliste Ridge. The Leeuwin Complex consists of intensely deformed plutonic igneous rocks, mainly granite and gneiss. To the west of it lies the Yallingup Shelf, an area of shallow basement extending to the continental shelf.

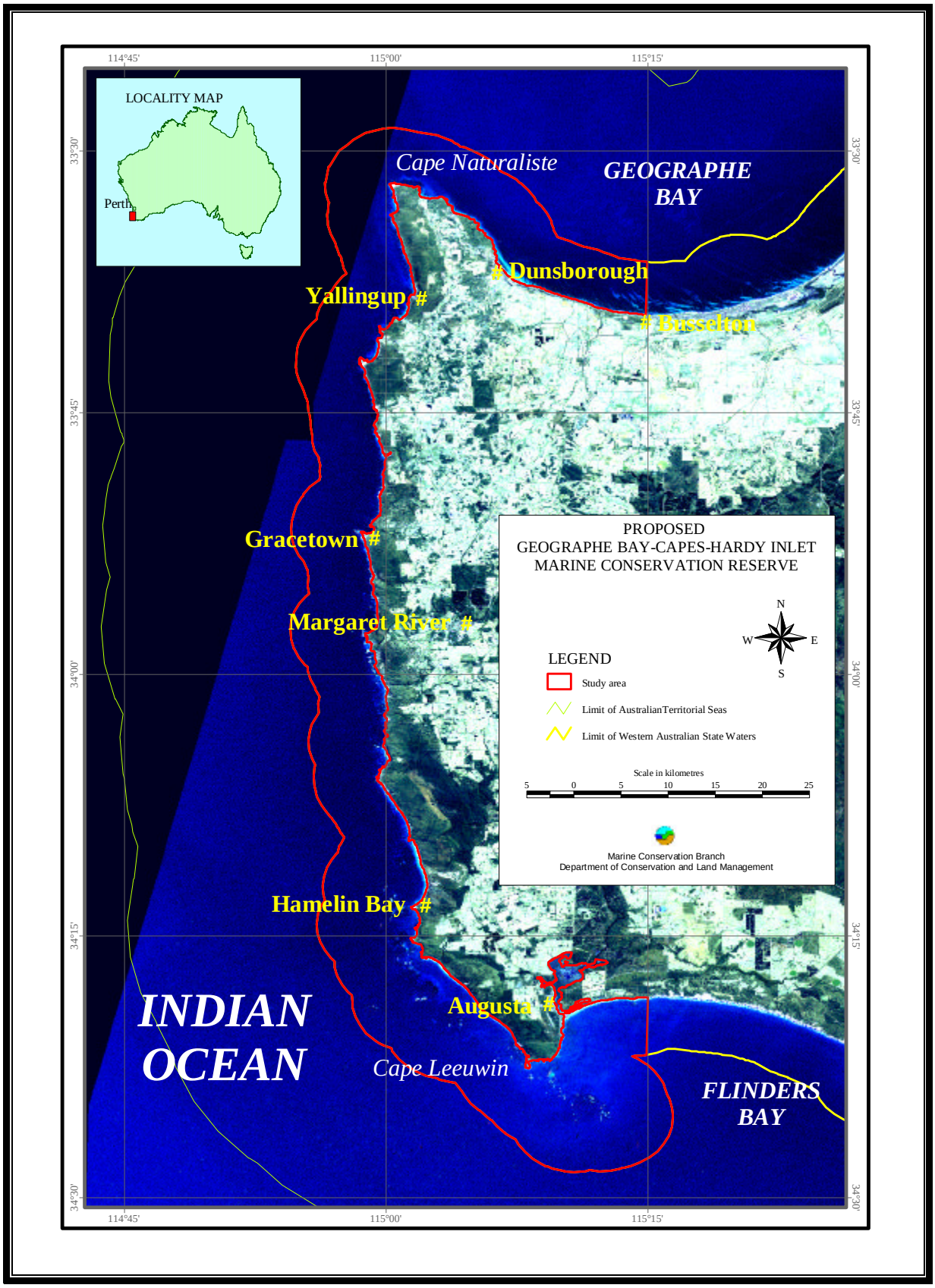

Figure 1. Study Area: The proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

At Dunsborough the Proterozoic granites and gneiss give way to the Quaternary calcareous sand beaches of Geographe Bay. The bay is gently arcuate with low foredunes (Quindalup Dunes) forming a barrier between the sea and a series of intertidal lagoons and marshes. A number of small rivers enter the lagoons but are barred from the sea by dunes. The Vasse-Wonnerup lagoons have locks at their outlets and are managed as freshwater wetlands although prior to 1930 they were barred estuaries.

At the western end of Geographe Bay, between Dunsborough and Busselton, the shore is relatively sheltered. East of Busselton, as the bay curves northward, the shore becomes progressively more exposed to the prevailing westerly winds and swells. The seabed is gently shelving (approximately 2 m/km) and consists of a Holocene sediment veneer (mean thickness 1m) overlying Pleistocene limestones and clays. A record of older Pleistocene shorelines is preserved as limestone ridges parallel to the present beach, both onshore and offshore.

A conspicuous feature is the Dunn Bay sandbar a few hundred metres offshore between Dunsborough and Quindalup. This structure is actively growing. It is now partly emergent at high tide and cuts off a shallow lagoon between it and the beach. Further east, by contrast, the beach is eroding and artificial groynes have been constructed to control regression of the shore.

The granites and gneisses of the Leeuwin Complex are eroded by the sea to form sloping rock faces on exposed headlands and rounder boulder fields in more sheltered situations. There are coarse sand beaches between the headlands. At several locations along the western side of the Leeuwin Block (Yallingup, Cowaramup Bay, Kilcarnup, and Hamelin Bay) Quaternary aeolianite limestones have been deposited over the granites and gneisses, sometimes with considerable thicknesses. These tend to form limestone cliffs across the shore, fronted with intertidal limestone rock platforms. Thus the shore of this sector is quite complex with a range of very different habitats.

There is one small estuary on the Leeuwin-Naturaliste coast at the mouth of the Margaret River. It is of the barred riverine type (Hesp, 1984). Elsewhere there are many freshwater springs along this coast where the aeolianite-granite junction occurs near shore level. Caves are also common in that situation.

Between Cape Leeuwin and Black Head the coast is formed by the southern boundary of the Scott Coastal plain. This is the southernmost portion of the Perth Basin. It is separated from the Leeuwin Block in the west by the Dunsborough and Busselton-Alexander Bridge Faults and from the Yilgarn Craton and Albany-Frazer Orogen in the east by the Darling Fault. The Darling Fault crosses the coast at Black Head.

The hinterland is relatively low-lying with Quaternary sands overlying Cretaceous sediments. The shore itself consists of a wide, curving beach, more than 80 km long and trending NW-SE. A Holocene dune field backs it. The beach is almost continuous, only being interrupted at Black Point, where there is a high headland of Bunbury Basalt. It is one of the most extensive outcrops of this rock type. At the shore the outcrop has eroded into high cliffs with narrow rock platforms, large tide pools and boulder fields at sea level. Columnar and pillar formations are both present. It is assumed that the rocks extend into the sublittoral zone (CALM, 1994).

A number of studies have examined the geomorphology of the Geographe Bay-Capes-Hardy Inlet region (Allison *et al.*, 1993; Bastian, 1977; Cockbain, 1990; McArthur, 1991; Myers, 1994; Myers and Hocking, 1990; Peers, 1975; Playford *et al.*, 1976; Tille & Lantzke, 1990; Valentine & Enright, 1975; Western Australian Geological Survey, 1975).

Bird (1987), Collins & Hamilton (1989), Davies (1983), Paul & Searle (1978), Riedel & Byrne (1988), and Semenuik *et al.* (1989) have discussed coastal processes and morphology.

Searle (1977), Searle & Logan (1978), Searle & Semenuik (1985), and Collins (1988) have studied the sedimentology of Geographe Bay in detail.

4. HYDROGEOLOGY AND GROUNDWATER

The largest aquifers in the region occur in the limestones of the Swan and Scott Coastal Plains of the southern Perth Basin, and only shallow aquifers occur along the older raised Leeuwin-Naturaliste Ridge (C. Jaques, Water and Rivers Commission, Bunbury, *pers. comm*.). Allen (1976), Hirchberg (1989), Iasky (1993), and Wharton (1981) have described the hydrogeology of the southern Swan Coastal Plain and Perth Basin.

The Water Authority of Western Australia have produced a management plan for the Busselton-Capel groundwater area (WAWA, 1995). Appleyard (1991), Baddock (1994), and Thorpe (1992) have discussed the hydrogeology between Cape Naturaliste and Cape Leeuwin. The geology and hydrogeology of the Scott Coastal Plain is described by Western Australian Geological Survey (1995).

There are four major estuaries and numerous coastal wetlands in the Geographe Bay-Capes-Hardy Inlet region. These are discussed in detail in the “Estuaries and Coastal Wetlands” section.

5. BIOGEOGRAPHY

Wilson & Allen (1987) state that "*the most striking feature of the Australian marine fauna is that it consists essentially of two very distinct latitudinal elements separated by zones of intermixing*". Wilson & Gillet (1971) referred to these faunal bioregions as the Northern Australian Region, the Southern Australian Region and the Eastern and Western Overlap Zones.

The Northern Australian Region forms part of the extensive tropical Indo-West Pacific Faunal Region and is characterised by high species diversity with the majority of species distributed widely throughout the tropical Indian and west Pacific Oceans. In contrast, the fauna of the Southern Australian Region is characterised by low species diversity and very high species endemicity due to a long history of geological isolation. The Eastern and Western Overlap Zones are zones of transition between the northern and southern regions where there is a gradual replacement of tropical fauna by temperate forms with a considerable proportion of endemic species occurring also (Wilson & Allen, 1987).

Wilson & Allen (1987), and Poore (1995) describe how the geological history of Australia has led to the present distribution of the major marine fauna. Wilson & Allen (1987) also review the current distribution of several major faunal groups (fish, molluscs, corals and echinoderms).

The Geographe Bay-Capes-Hardy Inlet region encompasses the theoretical boundary between the Southern Australian Faunal Region and the Western Overlap Zone. As such, the fauna is predominantly temperate in affinity, but is characterised by considerable endemicity of species that have their origin in the pan-Pacific Tethyan fauna (Wilson & Allen, 1987; Morgan & Wells, 1991).

Wilson & Allen (1987) noted that the biogeographic significance of the Leeuwin Current in Western Australia is profound, and suggest that it accounts for the occurrence of many tropical animals along the Leeuwin-Naturaliste coast. Several authors have discussed this further. Maxwell & Cresswell (1981) have shown that larvae of tropical animals can be dispersed as far as

the Great Australian Bight by the current. Hutchins (1991) discussed the dispersal of tropical fish as far as the Recherche Archipelago by the current. Wells (1980) found that nine (of 308) tropical prosobranch gastropods examined were distributed as far south as Cape Leeuwin, with five species extending around to the south coast. Veron & Marsh (1988) similarly found that nine (of 318) species of hermatypic corals were distributed beyond Cape Leeuwin and along the south coast.

Walker (1991) suggests that the direct effects of the Leeuwin Current on the marine flora of the region are less detectable than its effects on the marine fauna. Marine macroalgae of the region show only sporadic tropical influence, and the flora is dominated by southern temperate species which has one of the richest diversities in the world (400 genera, 1100 species) (Womersley, 1984; 1987). The seagrasses of the region are rich in both overall species (20 species in nine genera) and in local diversity, with up to ten species recorded within a 100 m^2 (Kirkman & Walker, 1989).

Hutchins (1994) investigated the distribution of nearshore reef fish at twelve regions along Western Australia's west and south coasts between 1977 and 1993. He described a "*faunal signature*" for each region based on the most commonly sighted fishes which indicated that endemic species form the greater proportion of fish seen between Shark Bay and Albany. This trend was very observable in the Cape Leeuwin to Cape Naturaliste area where six of the 10 most commonly sighted fishes were endemic to the region. Of the 150 species identified in the Geographe Bay-Capes-Hardy Inlet region, 76% were of warm temperate affinity, 19% were sub-tropical species (west coast endemics) and 5% were tropical species (which were mostly represented by one-off records). Hutchins (1994) has suggested that this endemism provides a "*uniquely West Australian flavour*" to the fauna, which is most obvious on the mid-lower west coast and is gradually being replaced to the north by fauna of wide-ranging tropical Indo-West Pacific species and to the east by the warm temperate species which range across Australia's southern coastline. This finding has led Hutchins (1994) to suggest that the area between Coral Bay and the Recherche Archipelago constitutes a distinct bioregion that he names '*The Leeuwin Province'*.

In 1995, the Commonwealth Government has funded a project to provide a single ecosystem level regionalisation of Australia's coastal and marine environments. This project, known as the *Interim Marine and Coastal Regionalisation of Australia* (IMCRA), was coordinated by Environment Australia (Biodiversity Group) and employed a collaborative approach between Commonwealth and State/Territory agencies. IMCRA uses a hierarchical structure to provide information and identify bioregions at two different levels: continental (*provinces*) and regional (*meso-scale regions*). The meso-scale regionalisation defines bioregions of the waters inshore of the continental shelf (out to the 200 m isobath) based on both biological and physical information. The Geographe Bay-Capes-Hardy Inlet region lies entirely within the Leeuwin-Naturaliste Bioregion, which stretches from Perth south to Black Point on the south coast. This bioregion is characterised by a high energy, heavy swell affected shore, a narrow continental coast, and a cold inshore current running counter to the warm offshore Leeuwin Current (IMCRA, 1998).

IMCRA (1998) also provides two provincial scale regionalisations for continental shelf waters, the demersal provinces and biotones regionalisation and the Pelagic Provinces and Biotones Regionalisation, which are defined by classifications of demersal and pelagic fish species diversity and richness. Biotones represent zones of transition between core provinces. The Geographe Bay-Capes-Hardy Inlet region falls entirely within the South Western Province of the demersal provinces and biotones regionalisation. This demersal province is characterised by two primary distribution types:

1. western warm temperate species whose range extends from the mid-west coast in the South Western Biotone, and across the south coast into the Great Australian Bight Biotone, and;

2. more widely distributed elements whose range extend from the South Western Biotone (SWB) eastward to Bass Strait (IMCRA, 1998).

There is also a smaller component of eurythermal species that extend as far north as North West Cape, and major disjunctions define the western and eastern boundaries of the South Western Province. The Geographe Bay-Capes-Hardy Inlet region forms the southern portion of the Western Pelagic Biotone in the pelagic provinces and biotones regionalisation. This is defined as a strong zone of faunal overlap representing the major termination zone for eastern tropical and temperate species, and is characterised by numerous disjunctions in species as occurs in the demersal regionalisation (IMCRA, 1998).

6. WATER QUALITY

The causes and consequences of loss of seagrasses in Australian coastal waters has been reviewed by Walker & McComb (1992), and threats to macroalgal diversity has been addressed by Walker & Kendrick (1998). Local concerns over the health of seagrasses in Geographe Bay (Geographe Bay Advisory Committee, 1992) prompted the Western Australian Water Authority to fund a series of studies, as an extension of the Perth Coastal Waters Study. These studies investigated the impacts of nutrient discharge on the benthic communities of Geographe Bay (Lord & Associates, 1995). This study, commonly known as the Geographe Bay Study, took place between December 1993 and February 1995. It was comprised of three concurrent interlinking studies:

(i) the physical oceanography and circulation patterns of Geographe Bay was investigated by Fahrner & Pattiaratchi (1994);

(ii) a comprehensive assessment of the total loading of all contaminants into Geographe Bay during 1992/1993 was undertaken by Holmes (1994), and;

(iii) the seagrasses, algae and water quality of Geographe Bay was investigated by McMahon (1994), Walker *et al.* (1994, 1995a, 1995b, 1995c, 1995d, 1995e), McMahon *et al.* (1997) and McMahon & Walker (1998).

Holmes (1994) assessment of the contaminant inputs into Geographe Bay gave a best estimate of pollutant levels derived from each source of industrial effluents, ground and surface water discharges into the Geographe Bay catchment. The total nutrient discharge into Geographe Bay was estimated to be 1,230 t of nitrogen (N) and 141 t of phosphorous (P) during winter 1992 and 158 tonne of N and 25 t of P during summer 1992/1993. In order of magnitude, this total was comprised of surface flows from rivers and drains, groundwater discharges, and discharges from coastal wastewater treatment plants and unsewered areas adjacent to the coast. The greatest portion of nutrients flowing into Geographe Bay was derived from Leschenault Inlet, which is beyond the northern boundary of the study area. Holmes (1994) also summarised the contaminants discharged from industrial processes in the area, however he stated that the mass of these substances is not significant because the major ions discharged are natural constituents of seawater.

The investigations into the seagrasses, algae and water quality of Geographe Bay, undertaken as part of the Geographe Bay Study, are the most detailed examination of the flora of the bay to date. Walker *et al.* (1994, 1995a, 1995b, 1995c, 1995d, 1995e; McMahon *et al.* 1997) surveyed the benthic primary producers to determine the nature and extent of any algal blooms, and the status of the seagrass meadows in Geographe Bay. Seven sites within the study area were sampled: five were chosen for their proximity to localised inputs (Toby's Inlet, Buayanup Drain, Vasse-Diversion Drain, Vasse-Wonnerup Estuary, Capel River), and two sites were used as reference sites (Dunsborough, Forrest Beach). The use of the Dunsborough site as a reference location, based on the fact that it appeared to have no terrestrial runoff, may be questionable. Dunsborough has

several large stormwater drains that discharge near this site, which is also adjacent to a residential area that was unsewered up to the time of the study.

Over the summers of 1993/1994 and 1994/1995 surveys were undertaken every fortnight. In April, July and September 1994 four sites (Buayanup Drain, Vasse-Diversion Drain, Vasse-Wonnerup Estuary and Dunsborough) were sampled more intensively (in conjunction with the study of McMahon, 1994; and McMahon & Walker, 1998). The information obtained from the seven sites sampled over the summers only was used for general habitat descriptions (a summary including site coordinates and species list is compiled in Appendix 1A, 1B and 1C).

The data from the four sites sampled throughout the year was used to compare physical and biological conditions. Parameters measured at each site included: topography, substratum, species composition and percentage cover noted every 10 m along a 300 m triangular transect; light attenuation; depth; temperature; salinity; pH; chlorophyll-*a*; phaeophytin; total nitrogen, inorganic nitrogen and total phosphorous; and the presence or absence of the eutrophication-indicating bacillariophytes, cyanophytes and the macroalgae *Cladophora*. Photographic records of each site were made.

This study concluded that seagrasses in Geographe Bay were mostly in a healthy condition (without exceptional epiphyte loads), excepting the inshore sites at Buayanup Drain and the Vasse-Diversion Drain. However it was also suggested that the accumulation of diatomaceous mucopolysaccharide slimes and blue-green algal aggregations on the seagrasses are of some concern and require further investigation.

McMahon (1994) and McMahon & Walker (1998) assessed the impact of the agricultural drains (which flow predominantly from July to September) on nutrient concentrations in the water column, sediment and the seagrass *P. sinuosa* in nearshore Geographe Bay. Four sites in southern Geographe Bay were sampled in conjunction with Walker *et al.* (1994) (discussed above). During winter, nearshore nutrient concentrations adjacent to the drains increased ten-fold compared to the reference site (Dunsborough - see above), however greater than 100 m offshore these nutrients were no longer detectable. The yearly input of nutrients from terrestrial sources could only account for two-thirds of the nutrients required to produce the maximum yearly standing biomass of *P. sinuosa* up to 10 m depth in the bay. McMahon suggests that other sources (particularly seagrass wrack decomposition) are likely to be important in maintaining productivity. Nitrogen was found to be the limiting nutrient for primary producers in Geographe Bay.

Two community-based water quality monitoring initiatives have recently received funding under the Natural Heritage Trust's Coast and Clean Seas Monitoring Program:

1. The Cowaramup Bay Chapter of the Surfrider Foundation, in conjunction with the Water and Rivers Commission, is conducting the *Baywatch* Program (Project Leader Dr. Justine Boouw). This program will sample four sites in Cowaramup Bay, three sites in Cowaramup Brook, and five town bores for nutrients, pesticides and herbicides, suspended solids, heavy metals and *E.coli* bacteria. The sampling is to occur in April, June and October each year from 1998 to 2001.

2. The Margaret River Chapter of the Surfrider Foundation, in conjunction with the Water and Rivers Commission is undertaking an associated project known as the *Margaret River-Gnarabup Community Water Quality Initiative* (Project Leader Rob Conneelley). Six oceanic sites and six town bores (Prevelly Park) will be sampled as described for the Baywatch Program. The sites are situated near the mouth of the Margaret River, at Gnarabup Beach (south of the rivermouth), and adjacent to the primary dune system at Grunters Beach, which receives effluent from the Gnarabup Estate sewage treatment system.

7. BENTHIC HABITATS

Broad-scale habitat mapping of seagrass coverage was undertaken by Walker *et al.* (1987), as part of the assessment of the impact of several development proposals on the benthic communities of Geographe Bay. Seagrass percentage cover was determined from a suite of 1986 aerial photographs. No systematic ground-truthing was undertaken, however many dives in the area by Walker and others, and dive log data, showed a good correlation to the areas defined in the mapping (Associate Professor D. Walker, University of Western Australia Aquatic Botany Department, *pers. comm.*).

Laurenson *et al.* (1993) undertook a visual assessment of trawling impact over a large area of Geographe Bay using a remotely operated vehicle underwater video system towed behind a trawling vessel. All transects were recorded on video cassette recorder (VCR) and positional input from the vessels' Global Positioning System (GPS) was also fed directly to the VCR via a portable computer. The computer was used by an observer to record a description of the seabed (a 5 m wide strip was visible) every 15 seconds along with the date, time, latitude and longitude entered automatically from the GPS. The data was produced as a text file containing benthic habitat descriptions and associated coordinates.

Geographical Information System data layers were created for Geographe Bay area by the University of Western Australia's Centre for Water Research, as part of the Geographe Bay Study, for the Water Authority of Western Australia. Three coverages were mapped:

1. nutrient input sites and data from Holmes (1994),

2. algae, seagrasses and water quality data from the sites of McMahon (1994), McMahon & Walker (1998), McMahon *et al.* (1997) and, Walker *et al.* (1994; 1995a; 1995b; 1995c; 1995d; 1995e), and;

3. Bathymetry data from Fahrner & Pattiaratchi (1994) and habitat mapping derived from Walker, Lukatelich & McComb (1987).

There is one electronic copy of the information layers held by Dr Pattiaratchi at the University of Western Australia's Centre for Water Research, however permission must be sought from the WAWA (through Lord & Associates) for access to the program (C. Pattiaratchi, Centre for Water Research, *pers. comm.*).

8. MARINE FLORA AND FAUNA

The benthic flora of Geographe Bay-Capes-Hardy Inlet region has been studied little. Kirkman & Walker (1989), Kirkman & Kuo (1990), Kirkman & Cook (1987), Kirkman (1985), Womersley (1982; 1984; 1987), Larkum & denHartog (1989) and Walker (1991) provide broad overviews of the seagrass and macroalgal communities of southwestern Australia.

8.1. SEAGRASSES

The seagrasses of Geographe Bay have been well described in Walker *et al.* (1994) and Kirkman & Walker (1989):

> Geographe Bay is dominated (about 70%) by monospecific stands of the seagrass *Posidonia sinuosa*, with smaller areas of other seagrasses, such as *P. angustifolia*, *Amphibolis griffithii* and *A. antarctica*, and several minor species, which have irregular distributions both spatially and temporally, and are generally found in sand patches.
>
> Ten seagrass species are found in Geographe Bay:
>
> (i) *Amphibolis antarctica* (Labill.) Sonder ex Aschers.
>
> (ii) *Amphibolis griffithii* (Black) denHartog
>
> (iii) *Halophila ovalis* (R.Br.) Hook.f.
>
> (iv) *Heterozostera tasmanicus* (Aschers.) Dandy
>
> (v) *Posidonia angustifolia* Cambridge and Kuo
>
> (vi) *Posidonia australis* Hook.f.
>
> (vii) *Posidonia coriacea* Kuo and Cambridge
>
> (viii) *Posidonia ostenfeldii* Ostenfeld
>
> (ix) *Thalassodendron pachyrhizum* denHartog
>
> The genera *Amphibolis* and *Posidonia* are most important, as they are large and structurally significant in the marine habitats of Geographe Bay. They can form continuous meadows, which are present from approximately 2 m to 14 m depth in Geographe Bay while below 14 m seagrasses become sparse and patchy in distribution, with plants present in small clumps. The lower limit of seagrass distribution is usually light dependent, and the offshore waters of Geographe Bay are particularly clear. The deepest seagrass record for the State of Western Australia is for *T. pachyrhizum*, which grows on rock, north-west of Busselton (32°34'20" S, 115°15'00" E) at 45 m. *Posidonia* spp. and *Amphibolis* spp. have been reported from 27 m (33°31'30" S, 115°28'30" E).
>
> *T. pachyrhizum* and *A. antarctica* are unusual among seagrasses as both can grow on rock. In Geographe Bay, both are found on scattered outcrops of limestone, which are particularly common in the western bay. They are often found with a variety of macroalgae, particularly *Scaberia agardhii*, as well as sessile invertebrates, particularly sponges. Below 14 m sediment pockets between rock strata are colonised by *P. sinuosa*, but these are sparse. Also present are *A. antarctica, A. griffithii, T. pachyrhizum*, and *P. augustifolia*.
>
> Seagrass meadows have within them scoured areas of bare sand, known as "blowouts", which have been eroded from the existing meadow. In Geographe Bay, they are generally of parabolic shape, varying in size from a few square metres to several hectares, oriented in a SW-NE direction, with an overhanging scarp of exposed rhizome fibres up to 0.6m high at the apex, tapering to the edges. The scour floor of unconsolidated sediment then rises gently to the level of the meadow. This far edge is usually recolonised by *Amphibolis* seedlings, which may fill the scour. If the area remains undisturbed there will be recolonisation both by *Posidonia* seedlings and regrowth from the edge of the meadow, so that *Amphibolis* is eventually shaded out. Recolonisation of damaged areas may never occur, as disturbance by storm events prevents the stabilisation of the seagrasses. If seagrass growth rates are reduced by pollution, or sediment dynamics are changed, the eroding edge will continue to migrate, but the recolonising edge does not grow fast enough and the blowout increases in size.

> Geographe Bay has a second type of feature, described by Searle & Logan (1978) as transverse furrows, 100 to 300 m wide, running at angles of 290° in the eastern bay to 340° in the west, at intervals of 500-1500 m, with increased spacing to the east. The change in spacing corresponds to a change in the refraction of swell wave trains around Cape Naturaliste. The furrows are similar in cross-section to the scours, but the eroding scarp face may be gently scalloped, with scallop amplitudes of 5-20 m. These appear to be the result of coalescence of smaller scours. Sand lobes are associated with the longitudinal scours, and form irregular fingers within the meadow, up to 40 m long and 30 m wide. These sand lobes terminate in shallow sandbars at their landward end. The furrows also appear to be migrating southwest in a similar way to the blowouts.

South of Cape Naturaliste, the predominant seagrass beds are protected by offshore reefs or by headlands with an aspect that shields the bays in which they grow (Kirkman & Kuo, 1990). The exceptionally clear waters of this coast also allow *Posidonia* spp. and *Amphibolis* spp. to form large beds at depths around 30 m, exposed to direct oceanic swell; this is not found on any coast elsewhere in the world (Kirkman & Kuo, 1990). Seagrasses of the "*Posidonia ostenfeldii*" complex, *P. robertsoniae, P. kirkmanii, P. denhartogii, P. coriacea* and *P. ostenfeldii*, predominate in this region (Walker & Kirkman, 1989). These are stronger leaved, more deeply rooted plants that are adapted to heavy swell conditions and are distinguished from the "*Posidonia australis*" complex, *P. australis, P. sinuosa* and *P. angustifolia*, which are mostly found in sheltered embayments (Kirkman & Walker, 1989). *A. antarctica, A. griffithii, Heterozostera tasmanica, Halophila ovalis* and some members of the *P. ostenfeldii* complex are found to occur on the periphery and in the blowouts of the seagrass beds in this area also (Kirkman & Kuo, 1990).

Two studies have been undertaken to determine the variability of seagrass cover in the southern portion of Geographe Bay. Both were conducted by comparing areas of seagrass that were ascertained from aerial photographs. In 1988, the Department of Transport (then the Department of Marine and Harbours) undertook an assessment of the potential effects of the Port Geographe canal-based residential development (Riedel & Byrne, 1988). The objectives of the study were to provide an appraisal of the seagrass meadows in the area, and assess the impact of the proposed groyne structure on the adjacent seagrass beds. This was achieved by documenting the extent of seagrass cover and determining the rates of change to cover over the 40 year period 1947-1987. Seagrass cover was measured at five sites along the Geographe Bay coast, from 2 km west to 5 km east of the Busselton Jetty. The mean percentage seagrass cover at each site decreased from 1947-1965 after which time the seagrass cover remained fairly constant (Riedel & Byrne, 1988).

In 1993, an independent study was undertaken on behalf of the Environmental Protection Authority to determine the changes in seagrass cover in southern Geographe Bay over the last 50 years (Conacher, 1993). Three sites of approximately one square kilometre (Busselton, Broadwater and Quindalup) were analysed using a suite of aerial photographs from 1941-1991. Excepting Quindalup, the sites showed a similar pattern of declining seagrass cover between 1958 and 1974, followed by a recovery to approximately 1958 levels. The Quindalup site did not show this recovery and nearshore seagrass cover has continued to decline since 1958. The decline observed between 1947 and 1965 coincides with the rapid expansion of agriculture in the catchment and construction of the drainage systems into the bay (Lord & Associates, 1995).

Walker *et al.* (1987) have assessed the potential impacts of subtidal sand mining, the Port Geographe development and the possible reopening of the Vasse-Wonnerup Estuaries on the dominant benthic communities of Geographe Bay for the Environmental Protection Authority.

In recognition of the fundamental ecological importance of meadows of long-lived perennial, deep-rooted seagrass species (particularly *Posidonia* and *Amphibolis*) the South Western Australian Seagrass Study (SWASS, 1996) nominated three seagrass areas within the Geographe Bay-Capes-Hardy Inlet region for listing on the Australian Heritage Commission's Register of the National Estate. These areas were Geographe Bay, Hamelin Bay and Flinders Bay.

8.2. MACROALGAE

There have been no intensive collections or taxonomic studies of macroalgae in the Geographe Bay-Capes-Hardy Inlet region, however Womersley (1984; 1987) suggests that the west coast has a reduced species diversity compared to the south coast. Walker (1991) suggests that the rocky limestone subtidal of the west coast has mixed macroalgal assemblages of foliose red, green and brown algae, dominated by the kelp *Ecklonia radiata* and S*argassum* species. Where the substrate changes from limestone to granite at Cape Naturaliste, cold temperate brown algae become dominant (Walker, 1991).

8.3. FISHES

The influence of the Leeuwin Current on the marine fauna of southwest Western Australia has been documented by several authors (Caputi *et al.*, 1996; Hatcher, 1991; Lenanton *et al.*, 1991; Maxwell & Cresswell, 1981; Pearce & Phillips, 1988; Phillips *et al.* 1991).

The fish fauna of the Geographe Bay-Capes-Hardy Inlet region has been studied in some detail. Scott (1981) sampled the fish fauna of the seagrass meadows in Geographe Bay. A small beam trawl sampled twelve nearshore sites between Capel and Dunsborough (only very rough locations given) and 19 species were recorded. The samples were dominated by the weed whiting *Neoodax radiatus*, which comprised 52% of all individuals captured (a complete species list is included in Appendix 2).

Walker (1979a; 1979b) created an inventory of the 'marine resources' of the Bunbury-Geographe Bay area using data collected from three research cruises undertaken in November 1975, April 1976, and November 1976. A comprehensive sampling method included the use of set lines, set nets, trawls, ring nets, beach seines, hand lines, trolling lines, traps and light attraction at night. The breeding state, size, weight and stomach contents of every fish caught were recorded. A checklist of all the species recorded in the study, combined with museum records was used to create an inventory of the fish species in the area coupled with notes on their distribution, preferred habitat, social behaviour, and feeding and breeding biology, that were obtained during this study. A total of 247 fishes were recorded for the area.

Lenanton (1982) investigated the use of nearshore marine and estuarine waters between Busselton and Hardy Inlet as nursery habitats by some commercially and recreationally important fish species. On six occasions between May 1976 and March 1977 juvenile fish were collected by seine net at three sites in Geographe Bay (East Toby's Inlet, Dunsborough, and Eagle Bay), two sites between Cape Naturaliste and Cape Leeuwin (Kilcarnup and Gnarabup, which are two sheltered embayments and not representative of conditions along most of the west coast), three sites in Flinders Bay (Ringbolt Bay, Granny's Pool and East Flinders Bay), and one site at the mouth of Hardy Inlet. The dominant flora and several physical variables were recorded at each site also. In all, 62 species of teleost and three species of elasmobranch were recorded (a species list is included in Appendix 3A). The relative abundance of 16 commercially and recreationally important species was determined for each site (Appendix 3B).

This work concluded that the inshore marine environment of the study area provides an alternative to estuaries as both a spawning and nursery area for 13 of the 16 important fishes studied, and that the major recruitment into the estuaries by these species is actively as 0+ class juveniles (<1 year old). Two species were found to have exclusively estuarine dependent 0+ class juveniles: sea mullet *Mugil cephalus*, and tarwhine *Rhabdosargus sarba*. As a result of Scott (1981) failing to collect any 0+ juveniles of the 16 commercially and recreationally important fish identified by

Lenanton in the seagrass beds of Geographe Bay, Lenanton suggested that the fauna of drift decaying seagrass and macroalgae provide an important food source for these juvenile fish. Lenanton estimated that within the area surveyed, all of the 26 km coastline (inshore 50 m) between Busselton and Dunsborough could provide an important nursery habitat. Furthermore, he estimates that the remaining 16 km (west) coastline of Geographe Bay, together with the 9 km of Flinders bay surveyed, collectively offer another 12 km of small embayment shoreline that is also an ideal nursery habitat. Lenanton was unable to estimate the area of nursery habitat on the coast between the Capes, however he suggests that many small areas comparable to those surveyed are likely to be important (Lenanton 1982; 1984).

Hutchins (1994) surveyed the nearshore reef fish fauna of Western Australia's west and south coasts between 1977 and 1993. Surveys were carried out at several locations in the Geographe Bay-Capes-Hardy Inlet region: several inshore and offshore reefs in Geographe Bay, including the Busselton Jetty and Naturaliste Reefs; Cape Naturaliste - Yallingup; Hamelin Bay and Cumberland Rock; St Alouarn, Flinders and Seal Islands; and Quarry and Ringbolt Bays in Flinders Bay. These surveys recorded a total of 150 species of reef fish. The faunas recorded for the Geographe Bay and Cape Leeuwin areas were very similar. Both areas were dominated by the warm-temperate species, with only a few subtropical species being well represented. One-off records mostly represented tropical species. A complete species list for the area is included in Appendix 4. The ten reef fish species most commonly sighted by Hutchins in the Geographe Bay-Capes-Hardy Inlet region were:

Chromis klunzingeri	Black headed puller
Pseudolabrus biserialis	Red banded wrasse
Pempheris klunzingeri	Rough bullseye
Halichoeres brownfeldii	Brownfield's wrasse
Trachinops noarlungae	Yellow headed hulafish
Coris auricularis	Western king wrasse
Austrolabrus maculatus	Black spotted wrasse
Opthalmolepis lineolatus	Maori wrasse
Parma mccullochi	McCulloch's scalyfin
Dotalabrus alleni	Wrasse sp.

Ayvasian & Hyndes (1995) investigated the species composition of the surf zone fish fauna at 23 sites distributed along 1,500 km of coastline between Geraldton and Esperance, south Western Australia between 1991 and 1992. The study aimed to demonstrate that the species composition, life history, trophic strategy and geographic ranges of fish in the surf zone differ between the west and south coasts, due to greater habitat complexity and the influence of the Leeuwin Current along the west coast. Three sites within the Geographe Bay-Capes-Hardy Inlet region were sampled by seine net: Busselton, Dunsborough and Black Point. Classification and multi-dimensional scaling was used to group sites into associated assemblages, and each site in the study area was classified into a different assemblage:

- Busselton was found to constitute a distinct assemblage of 21 species, of which none were exclusive to the assemblage;

- Dunsborough was grouped into an assemblage with similar embayment sites in Perth inshore waters, and also with Rottnest and Garden Islands, where a total of 49 species with five endemics were recorded (only a second assemblage identified for inshore Perth sites had a greater species diversity-66 species), and;

- Black Point was also found to constitute a distinct assemblage which was the most depauperate site sampled, producing only eleven species of which none were endemic to the assemblage.

It was concluded that composition of the surf zone fish assemblages on the west and south coast differed markedly with significantly greater diversity on the west coast. It was suggested that this was due to the more complex and heterogenous habitat types (particularly seagrass meadows and patchy limestone reef) in close proximity to the relatively sheltered sandy surf zones of the west coast, producing a more temporally stable environment than was previously thought. It was also suggested that the stability of the surf zones on the lower west coast allow for the presence of greater numbers of benthic invertebrates, which was reflected in the greater proportion of benthic invertevores on this coast. In contrast, the south coast assemblages that were subject to more exposed surf zones were dominated by zooplanktivores. A species list, including life history, trophic status and geographical range, for each assemblage identified in the study area is included in Appendix 5.

Valesini *et al.* (1997) undertook a comparison of the fish faunas of the shallows in Flinders Bay with those of different regions in Hardy Inlet to determine the relative role of marine and estuarine habitats as nursery areas for various species of marine fish found in the region. Three sites in Flinders Bay (within 3 km of the mouth of the inlet), three sites in the estuary channel, three sites in the deadwater lagoon (adjacent to the estuary mouth), and three sites in the main estuary basin were sampled by seine net (both day and night) at six weekly intervals between February and December 1994. Juveniles of some marine species (particularly *Pelates sexlineatus, Rhabdosargus sarba* and *Aldrichetta forsteri*) were either found only in the estuary or were in far higher densities in the estuary than in Flinders Bay. In contrast, the juveniles of some marine species (*Sillago schomburgkii*) were relatively abundant in both environments, while others (*Sillago bassensis, Pelsartia humeralis, Lesuerina platycephala* and *Spratelloides robustus*) were either far more abundant in, or entirely restricted to Flinders Bay. It was suggested that the marine species found in the inshore waters of Flinders Bay varied considerably in their preference for the estuary as a nursery area.

Classification and ordination revealed that the fish assemblages of Flinders Bay were markedly different from the assemblages of the estuary shallows, which was dominated by the estuarine spawning species *Leptatherina wallacei, Favonigobius lateralis, Leptatherina presbyteroides* and *Atherinosoma elongata*. The composition of the fish assemblages present in the estuary channel and basin underwent pronounced seasonal changes during winter, when freshwater input from rivers decreased estuarine salinities by seven fold, causing the emigration of marine straggler species and a reduction in the densities of marine-estuarine opportunist species such as *P. sexlineatus* and *R. sarba*. There was also a large immigration of 0+ juveniles of *A. forsteri* from the sea and *L. wallacei* from the river. The Deadwater Lagoon did not undergo the same seasonal changes as the estuary as there is no riverine input. The Deadwater Lagoon had considerably less numbers of marine straggler species as tidal exchange in this area was restricted compared to the estuary. Despite this, the overall density of fish in the Deadwater Lagoon was higher than in the estuary basin or channel due to large numbers of the estuarine species *A. elongata* and *L. wallacei*, and 0+ juveniles of the marine species *R. sarba*. The high densities of fish in the Deadwater Lagoon was attributed to the high level of productivity and protection that is provided by patches of the seagrass *Ruppia megacarpa*, that was not present in the estuary basin or channel sites (Valesini *et al.*, 1997). A species list, including relative densities, is tabled in Appendix 6.

The colonisation of the *HMAS Swan* dive wreck by both fish and encrusting marine life since its scuttling on the 14th December 1997 is currently being studied by Dr Peter Morrison (Dr P. Morrison, Sinclair Knight Mertz, *pers. comm.*). This study, undertaken on behalf of the Geographe Bay Artificial Reef Society, is ongoing (it will continue until 2002) and forms part of the Environmental Protection Authority compliance monitoring for the Sea Dumping Permit that was issued for the scuttling. Fish diversity and abundance has been quantified using visual surveys on scuba at five sites in Geographe Bay:

1. the *HMAS Swan* (33°33.153'S, 115°05.882'E);

2. a control site 1nm from the Swan (33°32.450'S, 115°o4.033'E);

3. Wrights Bank (33°30.083'S, 115> 00.529'E);

4. Geographe Ridge, also called the Four Mile reef (33°37.860'S, 115°11.720'E), and;

5. the Busselton Jetty (33°37.860'S, 115°20.200'E, all coordinates are AGD66 datum for GPS).

A complete species list for the *HMAS Swan* dive wreck is tabled in Appendix 7. Growth of marine encrusting life on the Swan has been assessed by video transect analysis every four months since scuttling. Each sampling occasion, four 25 m transects (one top deck and one lower deck on each side, producing a 125 sec video each) have been analysed using a quantitative video transect analysis system. Sediment analysis for key metals and total petroleum hydrocarbons has been undertaken at both the Swan and the control site quarterly since the scuttling to monitor possible pollution caused by the scuttling.

Suzi Ayvasian of the Fisheries WA Watermans Research Laboratories has been investigating the age, growth and reproduction of the Australian herring (*Arripis georgianus*) stocks in waters between Perth and Adelaide. The study, which is funded by the Fisheries Research and Development Council (FRDC), commenced in 1996 and is ongoing to 1999, and is in collaboration with Ian Potter (Murdoch University) and Dave Fairclough (South Australian Research and Development Council). Data is being collected via monthly seine netting and creel samples from recreational and commercial fishermen. Four sites within the Geographe Bay-Capes-Hardy Inlet region were sampled for juvenile herring:

1. Quindalup;

2. Toby's Inlet (Geographe Bay);

3. Hamelin Bay, and;

4. Dead Finish Anchorage (Flinders Bay).

The Margaret River Chapter of the Surfrider Foundation has recently received funding from the NHT Coast and Clean Seas Marine Species Protection Program to undertake the *Blue Groper Protection Strategy* (Project Leader Andrew McColl). The project aims to protect juveniles of the blue groper (*Achoerodus gouldii*) from inadvertent capture by people unaware that they are a protected species. The project will erect informative signs (aimed at inexperienced recreational divers and visiting fishers) at carparks and beaches that provide easy access to the breeding habitat of the territorial blue groper. The locations selected for signage are: the mouth of the Margaret River, the Margaret River Main Surfbreak, Gnarabup Beach boat ramp, Grunters Beach, and Redgate Reefs. The project also aims to monitor the populations of blue groper at the five sites through visual surveys, and to monitor the effectiveness of the signs by routinely watching recreational activity at the sites. This will be performed in conjunction with Fisheries WA Officers where possible, over two summers after the erection of the signage.

The great white shark (white pointer) *Carcharodon carcharius* is occasionally sighted in the nearshore areas of the Geographe Bay-Capes-Hardy Inlet region. They are usually sighted in southern Geographe Bay, where several fishing boats report attacks each year, and around the Cape Leeuwin-Flinders Bay area, where the sharks may feed on juvenile seals (Hutchins & Swainston, 1986). The shark is fully protected under the State Fish Resources Management Act and under Commonwealth legislation.

The Leafy Seadragon *Phycodurus eques* is totally protected under the Fish Resources Management Act. It is known to occur in the shallow, protected reef and seagrass areas of southern Western Australia (Geographe Bay is ideal), however they are not commonly seen and there have been no estimates of population size in the area (Hutchins & Swainston, 1986).

8.4. INVERTEBRATES

There have been few intensive collections of any marine invertebrates in the Geographe Bay-Capes-Hardy Inlet region. Several publications discuss the general distribution of some species:

1. Slack-Smith (1989) examines the distribution and biogeography of the bivalves of Shark Bay, some of which are found in Geographe Bay;

2. Morgan & Jones (1991) give records on the distribution and habitat of 115 species of decapod crustaceans from the south coast of Australia (between Cape Naturaliste and the South Australian border);

3. Jones (1991) describes and provides a key for 31 species of shallow water barnacles (*Cirripedia*) which have been collected between the Houtman Abrolhos Islands and Albany;

4. Britton *et al.* (1991) examine general relationships between topography, substratum, and surface temperature in determining the spatial distribution of intertidal fauna of the rocky shores of southwestern Australia;

5. the population biology and reproductive ecology of the greenlip abalone (*Haliotis laevigata*) populations at Augusta (and Esperance and Hopetoun) are described by Wells & Mulvay (1995), and;

6. Wells (1980) has discussed the distribution of shallow water marine prosobranch gastropod molluscs along the coastline of Western Australia.

A Fisheries WA Habitat Protection Order on Cowaramup Bay, encompasses all waters within a line drawn from North Point to South Point was recently approved. Shirley Slack-Smith of the Western Australian Museum provided the following comments on the invertebrate communities of Cowaramup Bay in support the community application.

> Within the coastal waters between Cape Leeuwin and Cape Naturaliste, notable for the diversity of their flora and fauna, Cowaramup Bay presents many unusual features. Important among these is the diversity of habitat available within a fairly small area in which a degree of shelter is combined with free access to oceanic waters.
>
> The deeper subtidal areas of the bay support impressive growths of a diverse range of algae, sponges and ascidians. The intertidal reefs and pools on the northern side of the bay support, in season, a variety of marine organisms. However, it is in the shallower waters on the southern side that the diversity and abundance of marine animal species of Cowaramup Bay is particularly striking.
>
> Along this southern shore are areas of loose rocks and boulders at and just below low tide level. These support groups of animals such as molluscs and echinoderms which, while undoubtedly present in other areas along the Leeuwin-Naturaliste coastline, are nowhere as abundant or accessible. Such animals seem to flourish here because the boulders provide protection from predator species and a greater surface area at the appropriate tidal level on which they and their food organisms can settle and grow. In addition, deposit-feeding organisms, including many species of brittle stars (*Ophiuroidea*), may be taking advantage of a

habitat in which detritus is trapped among the rocks and rubble. The boulder areas also provide a suitable habitat in which many species (notably nudibranchs or sea slugs) lay eggs during their breeding season. The extent to which the bay acts as a nursery area for the biota is not known.

Cowaramup Bay, particularly along its southern shores, provides an opportunity not elsewhere available for the general public to see examples of the marine life of the area, especially during the low tides of spring and summer. However the bay has also become known to professional and amateur collectors as a source of many desirable species of shells and other organisms which, in season, come into shallow waters to feed or breed (S. Slack-Smith, Western Australian Museum of Natural Science Aquatic Zoology Department, *pers. comm.*).

A study was undertaken by Laurenson *et al.* (1993) between 1991-1992 to assess the impacts of the southwest inshore trawl fisheries on the benthic communities in coastal waters between 31°20' S and 34°23' S latitudes. The specific objectives of the study were: to document the occurrence of commercially and recreationally important fish species in the trawl by-catch; study aspects of the biology of whiting species which dominate the by-catch; and to examine experimentally and visually the impact of trawling on the benthos (see Fishes section).

8.4.1. Corals

Veron & Marsh (1988) have published records and an annotated species list of the hermatypic corals of the Western Australian coastline (Species list in Appendix 8.). In summary:

Geographe Bay, sheltered from southwesterly swells by Cape Naturaliste, has a number of areas of low relief rocky substrate in depths of 5-20 m providing substrate for corals among small macroalgae and seagrasses. Coral communities are particularly well developed between Dunsborough and Cape Naturaliste where 14 species of seven genera are recorded. Off Eagle Bay, near Cape Naturaliste, *Turbinaria* species form very large tiered coralla c. 3 m in height while *Favites* and *Goniastrea* species also form large coralla. The endemic south Western Australian species *Symphyllia wilsoni* and *Coscinarea marshae* are abundant in some areas at 15-20 m.

The south coast of Western Australia has a succession of granite or gneiss headlands with sandy beaches between while carbonate platforms lie across some of the smaller bays. Coral communities are found in moderately sheltered waters on this coast. Seven species of four genera occur along the south coast. *Symphyllia wilsoni* and *Favites* species have been found as beach worn specimens on the south coast and *Montipora* sp. has been photographed near Cape Leeuwin, which is the southernmost record for this genus (Veron & Marsh, 1988).

8.4.2. Scallops

Heald (1977) examined the *Pecten* scallop stocks in Geographe Bay in February and September 1976, to assess the potential for a commercial fishery in the area. Numerous dredge surveys were undertaken in the southern portion of Geographe Bay (offshore of Dunsborough - Rocky Point), and the numbers and sizes of *Pecten* scallops and doughboy scallops (*Chlamys asperrimus*) was recorded for each haul. Smaller grab samples were made along transects which traversed areas where reasonable catches of *Pecten* were taken by dredge, and several stations in a grid pattern also. Information on the sediment type and grain size, and other benthic fauna (mostly molluscs) present was recorded.

There is considerable information on the benthic substrates of southern Geographe Bay recorded, as there was over 400 grab samples taken, however it is not clear how accurate the location of each

sample was recorded. A collection of molluscs, fish, echinoderms and sponges was also made for the Western Australian Museum. It was concluded that the scallop stocks of Geographe Bay were low, and that most of the Bay was unsuitable for scallop dredging due to the rocky nature of the substrate.

8.4.3. Epifauna

Cathie Derrington of the Water and Rivers Commission (Bunbury) has recently investigated the epifaunal communities of Geographe Bay. The study (not yet completed) is examining the biomass, distribution and filtration rate of epifauna communities in the *Posidonia* and *Amphibolis* seagrass meadows within southern Geographe Bay. Additionally the study aims to determine whether epifauna can control phytoplankton levels, and how epifauna is affected by point source pollution.

Four sites within Geographe Bay have been sampled:

1. 400 m offshore of Buayanup Drain (33°38.531' S, 115°14.933' E);
2. 400 m offshore of Toby's Inlet (33°37.797' S, 115°10.794' E);
3. 400 m offshore of Curtis Bay, Dunsborough (33°38.531' S, 155°14.933' E), and;
4. 200 m offshore of Eagle Bay (coordinates not available).

Water quality (DO, salinity, pH, temp, turbidity, TN, TP, FRP, NO_3, NH_4, tide, chlorophyll *a b c*, phaeophytin, phytoplankton) was monitored at each site on a fortnightly basis from July 1996 - June 1997. Sampling of epifauna was performed seasonally (July 1997, October 1997, January 1998 and April 1998). Filtration rates of epifauna on *P. sinuosa* and *A. antarctica* were determined in the laboratory. No results are currently available.

8.5. INTRODUCED MARINE PESTS

There has been no investigation of introduced marine pests in the Geographe Bay-Capes-Hardy Inlet region to date. The introduced fanworm *Sabella spallanzanii* has been identified in Bunbury Harbour (to the north of the study area). However, it is unlikely that the species is present in the study area (except possibly Hardy Inlet and the Busselton Jetty), as conditions are not suitably sheltered (G. Clapin, CSIRO Division of Marine Research, *pers. comm.*).

8.6. MARINE RESOURCES

Jones (1986) has created a series of four sets of 57th Royal Australian Survey Corps 1:250 000 topographic maps, with accompanying text, that broadly catalogues the marine resources of Western Australia. The four map sets specifically provide details on:

1. Coastal geomorphology and seagrasses;
2. Professional fishing;
3. Recreational fishing and fish nursery areas, and;

4. All other resources and activities including:

- Subsistence Aboriginal Fishing
- Seagrasses
- Crustaceans
- Macroalgae
- Molluscs
- Reefs
- Breeding Seabirds
- Coquina Beds
- Turtles
- Recreational Areas
- Seals
- Scientific and Educational Areas
- Shipwrecks
- Anchorages, Marinas and Ports

Copies of the map series are available for reference at the Fisheries WA Watermans Research Laboratories.

Bruce (1992) has produced a prototype fisheries and coastal resource inventory for the Western Australian coastline between Lancelin and Geographe Bay. This Honours thesis compiled information on the shoreline and bathymetry of the area (using RAN and Department of Marine and Harbours data), habitat features (using the data of Laurenson *et al.*, 1993), and coastal geomorphology (derived from Jones, 1986). Coastal resources with either natural, conservation, social or economic value between Geographe Bay and Margaret River were identified.

9. MARINE WILDLIFE

9.1. CETACEANS

Two species of whale, the humpback (*Megaptera novaeangliae*) and the southern right (*Eubalaena australis*) are frequent visitors to shores of the Geographe Bay-Capes-Hardy Inlet region (CALM, 1994). They are both listed as "*fauna that is rare or likely to become extinct*" under the Western Australian Wildlife Conservation (Specially Protected Fauna) Notice 1998, however since the cessation of commercial whaling both species appear to be recovering from their once perilously low numbers (Bannister, 1978; 1986; 1990; 1994a, 1995).

Humpback whales are the most common whale in the Perth Basin and pass by the Cape Leeuwin - Cape Naturaliste area twice a year on their migrations between their southern ocean feeding grounds and their winter breeding grounds off North-West Cape (Bannister, 1995). Jenner & Jenner (1993) assessed the migratory patterns of humpback whales in the Perth Basin using aerial surveys of both the northern and southern migrations. They found that the peak southern migration off the Cape Naturaliste - Bunbury region occurred during mid-October and the peak northern migration occurred at the end of June. Jenner & Jenner (1993) suggest that migrations proceed according to age, with sexually immature whales preceding the bulk migratory body and near-term females arriving up to two to four weeks later than the peak migration. Importantly, they note that identification of the peak migration as a single two to three week period when the majority of animals pass a given point is of limited use from a management perspective, as it does not include the most critical animals to a recovering population (Jenner & Jenner, 1993; 1994). Since 1976, aerial surveys off Carnarvon (Shark Bay, Berringer and Dorre Islands, and Dirk Hartog Island) during a ten day period in July have been used to determine the west coast Humpback population size (Bannister, 1985; 1994a). Between 1976 and 1991 sightings increased at around 10% per year and the west coast population is estimated to now number at least 3,000 animals and possibly considerably more (Bannister, 1995).

In winter and spring (particularly August and September) southern right whales can be found very close inshore along the southwest and southern coast of Australia where they calve and suckle young in sheltered bays. By summer they move south to Antarctic feeding grounds, and it is not presently known where successful mating occurs (Bannister, 1995). Since 1976, aerial surveys from Cape Leeuwin east to Cape Arid or Israelite Bay, and to Ceduna since 1993, have been used to determine the status of the southern right whale population (Bannister, 1985; 1994b). These surveys have shown a steady increase in numbers of animals, around 10% per year, however the total population is very small and probably numbers no more than 800 animals (Bannister, 1995). Some parts of the coast are frequented by southern right whales more often than other areas, and Bannister (1985) notes Flinders Bay, Augusta and Bremer Bay-Point Ann-Hopetoun as two particularly popular locations.

Naturaliste Charters have been operating whale-watching charters in both Flinders Bay and Geographe Bay since 1993. Jacq Willbond has worked on the charters for the last three years and has kept extensive logs detailing the coordinates of all sightings and also records of whale behaviour, depths, water temperatures, food and seabird presence, and other observations for each sighting over the last two years. Photographs and video footage of many animals has also been taken. Blue whales have been observed in the nearshore Geographe Bay area (but not in Flinders Bay) in increasing numbers each year, particularly during November, however in 1998 many animals were observed as early as September. Mothers with very young calves have also been observed. There are no published reports of humpbacks calving in this region, however they have been frequently observed with exceptionally small and pale calves in the Geographe Bay area, and occasionally in Flinders Bay. There has been one sighting of a pregnant female apparently in the process of giving birth, in the vicinity of the artificial tyre reef in Geographe Bay, during late September 1997 (recorded on video by J. Willbond, Naturaliste Charters). The numbers and size of many of the calves seen over the last three years suggests that Geographe Bay may indeed be an important calving and nursery region for the west coast humpbacks (J. Willbond, Naturaliste Charters, *pers. comm.*).

Other whales known to occur in the Geographe Bay-Capes-Hardy Inlet region but not commonly seen include sperm whales (*Physeter macrocephalus*), pygmy blue whales (*Balaenoptera musculus*), minke whales (*B. acutorostrata*), and the long-finned pilot whale (*Globicephala melas*), although there is little data on stocks or breeding ranges (D. Coughran, CALM Wildlife Protection Section, *pers. comm.*).

There is a large population of bottlenose dolphins (*Tursiops truncatus*) in the study area which often come close inshore and interact with surfers and swimmers at several locations (CALM, 1994).

Other cetaceans recorded as stranded by CALM Wildlife research officers in the Geographe Bay-Capes-Hardy Inlet region between 1981 and 1998 include:

Pygmy right whales	*Caparea marginata*
Scamperdown whales	*Mesoplodon grayi*
False killer whales	*Pseudorca crassidens*
Cuvier's whales	*Ziphius cavirostris*
Shepherds beaked whales	*Tasmacetus shepherdi*
Pygmy sperm whales	*Kogia breviceps*
Striped dolphins	*Stenella caeruleoalba*

Common dolphins *Delphinius delphis*

(D. Coughran, CALM Wildlife Protection Section, *pers. comm.*)

9.2. PINNIPEDS

Two species of pinniped, the Australian sea lion (*Neophoca cinerea*) and the New Zealand fur seal (*Arctocephalus forsteri*), are both frequently sighted along the shores of the Geographe Bay-Capes-Hardy Inlet region. They are both specially protected under the Western Australian Wildlife Conservation (Specially Protected Fauna) Notice 1998.

Gales *et al.* (1992) surveyed the distribution, abundance and breeding cycle of the Australian sea lion in Western and Southern Australia between 1987 and 1992. They found that the present range of the Australian sea lion extends from the Houtman Abrolhos Islands in Western Australia (28° S, 114° E) to The Pages in South Australia (35° S, 138° E). They are, however, sparsely distributed with a total population of between 9,300 and 11,700 animals. No breeding or haul-out sited were identified in the Geographe Bay-Capes-Hardy Inlet region, with the closest breeding sites to this region being the Beagle, Fisherman and Buller Islands (off the central west coast) to the north (30° S, 115° E), and Haul-off Rock to the east (34°42' S, 118°40' E).

Shaugnessy *et al.* (1994) examined the distribution and abundance of New Zealand fur seals in southern Western Australia between 1987 and 1991. In Western Australia their range was found to extend from the Recherche Archipelago (33° S, 124° E) to the islands off Cape Leeuwin. Although Flinders, St Alouarn and Seal Islands were identified as haul out sites of the New Zealand fur seal, there was no evidence that breeding occurred there. The nearest breeding site identified was at Eclipse Island, off Albany, which is to the east of the Geographe Bay-Capes-Hardy Inlet region. Gales & Lambert (1985) recorded the first recent sightings of New Zealand fur seals in the Cape Leeuwin area in 1982 and suggest that they have begun to reappear on the rocky outcrops south of Flinders Island after a possible absence of 140 years. Whilst numbers of fur seals off Cape Leeuwin are increasing, most animals are sub-adults and breeding adults are not commonly seen (Gales and Lambert, 1985). The current Australian population of New Zealand fur seals is estimated to number 34,600 with less than 10% occurring in Western Australia (over 80% occur in South Australia), as the seals of this region are widespread with more colonies of fewer animals each (Shaugnessy *et al.*, 1994).

There has been only one record of the sub-Antarctic fur seal (*Arctocephalus tropicalis*) in the Geographe Bay-Capes-Hardy Inlet region area since 1981 (stranded at Canal Rocks). Gales *et al.* (1992) suggests that the poor body conditions of most animals recorded at lower latitudes indicates that they were not foraging successfully and most probably represent vagrants beyond their normal range. Leopard seals (*Hydrurga leptonyx*) have also been recorded as stranded in the study area (D. Coughran, CALM Wildlife Protection Section, *pers. comm.*).

9.3. MARINE TURTLES

Since 1986, the Western Australian Marine Turtle Conservation Project (WAMTCP) has undertaken considerable fieldwork off the northwestern Australian coast to determine the distribution, abundance, breeding and feeding patterns of the Western Australian marine turtle populations (Prince, 1993). The most southerly turtle rookery in Western Australia is the loggerhead (*Caretta caretta*) rookery at Dirk Hartog Island (Shark Bay) (Prince, 1994). Adult and juvenile loggerheads are occasionally washed ashore in numbers around the southwest coasts after

storms in the winter and spring period. It appears that these are animals that have been washed southward by the Leeuwin Current and coastward by westerly storms (Prince, 1994).

A small-scale salvage program has been conducted as part of the WAMTCP to document the species and numbers of turtles found on the southwest and southern Western Australian coasts. Leatherbacks (*Dermochelys coriacea*) and loggerheads are the predominant species found in southwest waters, but some green turtles (*Chelonia mydas*) are also encountered. There have been reports of a hawksbill turtle (*Eretmochelys imbricata*) and juvenile flatback turtles (*Natator depressus*) being stranded in the region (Prince, 1993; 1996).

The Cape Naturaliste-Geographe Bay area may possibly represent the southernmost foraging range of sub-adult loggerhead and leatherback turtles. Leatherback turtles forage in the waters of the continental shelf, diving up to 80 m to feed on jellyfish and coelenterates. As leatherback turtles are regular visitors in Western Australian waters, but are known not to breed here, Prince (1994) suggests that the Leeuwin Current may provide an important leatherback feeding ground. Loggerhead turtles are benthic feeders and may forage in Geographe Bay for scallops, crabs and other crustaceans. Leatherbacks and loggerheads are caught in low numbers but regularly (May to June particularly) by scallop trawlers, shark and gill-netters, and crayfishermen in the area (B. Prince, CALM Science, *pers. comm*.). The loggerhead turtle is listed as a "*fauna that is rare or is likely to become extinct*" the Western Australian Wildlife Conservation (*Specially Protected Fauna*) Notice 1998.

9.4. SEABIRDS

There are several publications that examine the distribution, abundance and breeding patterns of seabirds in southwestern Australia (Dunlop & Wooller, 1986, 1990; Dunlop *et al.*, 1988; Wooller *et al.*, 1991). The seabird fauna of southwestern Australia has been described as a biogeographical paradox, because southern cool water species are found nesting sympatrically with tropical species forming unusual communities (Dunlop & Wooller, 1990). Dunlop & Wooller (1990) suggest that the Leeuwin Current has been the primary determinant of the seabird assemblages in the Capes region by allowing the southward penetration of tropical species along the west coast.

A number of these species breed at much higher latitudes than is found elsewhere in the world. Of particular note, is the breeding colony of the red-tailed tropicbird (*Phaethon rubricauda*) on Sugarloaf Rock (Cape Naturaliste). The rare red-tailed tropicbird has been recorded as successfully breeding on Sugarloaf Rock since 1966 (Dunlop & Wooller, 1986; Thompson & Williams, 1989; Wooller *et al.*, 1991). Burbidge *et al.* (1996) estimate that there may be as few as 5-12 breeding pairs of the bird remaining in Western Australia, and as the next nearest stable breeding colony of the bird is on Christmas Island (Wooller *et al.*, 1991), the Sugarloaf Rock colony is extremely important. Until 1997, the red-tailed tropicbird was a specially protected species under the Wildlife Conservation Act, however it was recently removed from the list because the status of the bird over its whole range (outside of Western Australia) was considered.

The bridled tern (*Sterna anethetus*) is another tropical species that reaches the southernmost limits of its breeding range on the islands off Cape Leeuwin (Dunlop *et al.*, 1988). This is a recent extension of their breeding range, which was recorded as no further south than the Houtman Abrolhos Islands in the 1840's, reached Safety Bay by 1920, and extended to Hamelin Island by 1955 and Seal Island (Cape Leeuwin) by 1957 (Wooller *et al.*, 1991). In addition to the unusual presence of tropical species, Dunlop and Wooller (1990) suggest that this region is depauperate in numbers of cool water species when compared to other regions of similar latitude and position.

There are several important seabird-breeding islands within the Geographe Bay-Capes-Hardy Inlet region. Burbidge and Fuller of CALM's Western Australian Threatened Species and Communities

Unit (WATSCU) have developed and maintained the *Seabird Breeding Islands Database* which compiles all records of breeding seabirds on islands in Western Australia since 1971. They recognise four important breeding island in the Geographe Bay-Capes-Hardy Inlet region:

1. Cape Hamelin (Islet);
2. Hamelin Island;
3. Seal Island, and;
4. Sugarloaf Rock.

This database does not include the surveys of Gillham (1961; 1963) which catalogued the breeding seabirds of Hamelin, St Alouarn and Seal Island, and examined the association of the nesting birds and the vegetation types of the islands. Gillham (1961) suggested that the use of a rookery by seabirds alters the composition of the vegetation and eventually degrades the vegetation to a point where suitable nesting sites can no longer be found. She claims that the cycle is dynamic, the birds will then move to other islands and the vegetation will undergo regeneration, eventually providing new rookery habitat. Appendix 9 lists the seabirds recorded as breeding on each of the islands, which have all been vested with the National Parks and Nature Conservation Agency (NPNCA) as Nature Reserves to protect the breeding birds.

In addition to the eleven species of seabird that breed in the area, Burbidge *et al.* (1996) identified another 44 species of seabird that are recorded as visiting the Geographe Bay-Capes-Hardy Inlet region. R. Wooller (School of Biological and Environmental Sciences, Murdoch University) and R. Payton (Royal Australasian Ornithologists Union, local seabird observer) have augmented this list with another 24 species (including ten species of shore birds) they have personally observed in the area. Appendix 10 provides a list of these species and their status. With the exception of the red-tailed tropicbird (discussed earlier) there are no rare or endangered seabird colonies in the area, and Burbidge *et al.* (1996) suggest that there is few significant threats to seabird abundance at present.

10. FISH RESOURCES MANAGEMENT

There are several locations within the Geographe Bay-Capes-Hardy Inlet region which have Fisheries WA Protection Notices gazetted under the *Fisheries Act* (1905) and the *Fisheries Resources Management Act* (1905), placed over them to restrict the taking of marine flora and fauna:

Yallingup Reef Protected Area has restrictions on the taking of molluscs, echinoderms, cnidarians, sygnathids, solenomstomids, crustacea (excluding rock lobsters and blue manna crabs), and all algae and seagrasses is prohibited within a 400 m radius of the mouth of the Yallingup Brook. Commercial abalone fishermen are exempt and are allowed to remove abalone (Yallingup Reef Protected Area Notice 1995).

Cowaramup Bay Protection Area, encompasses all waters within a line drawn from North Point to South Point was recently approved. Taking of the marine animals (see above) is prohibited at Cowaramup Bay, however abalone, blue manna crabs, cuttlefish, finfish, rock lobster and squid are exempt (*Prohibition on Fishing (Cowaramup Bay) Order 1998*).

***HMAS Swan* Wreck Site** has a total prohibition on the taking of any fish within 200 m of the *HMAS Swan* dive wreck (*Prohibition on Fishing ("HMAS Swan" Wreck Site) Order 1998*).

Quindalup Artificial Reef has a prohibition on the taking of any fish by commercial fishermen within 200 m of the Quindalup artificial reef (Steve Embling, Fisheries WA, Busselton, *pers comm.*).

There are recreational netting restrictions in some areas of the Geographe Bay-Capes-Hardy Inlet region (Steve Embling, Fisheries WA, Busselton, *pers comm.*):

Dolphin Road-Siesta Park: All waters within 400 m of HWM from Dolphin Rd to approx 1 km west of Siesta Park groyne, are closed to recreational netting from 15 December to 15 February, all weekends and public holidays from 16 February to 25 April.

Dunsborough: All waters within 400 m of HWM from Bird Rock to 450 m east of the intersection of Elmaore Rd and Geographe Bay Rd, are closed to recreational netting from 15 December to 15 February, all weekends and public holidays from 16 February to 25 April.

Yallingup: All waters within 400 m of HWM between the northern edge of Yallingup Bay and Yallingup Brook's entry into the ocean, are closed to recreational netting at all times.

Canal Rocks: All waters within 800 m radius from the centre of Canal Rocks, are closed to recreational netting at all times.

Cowaramup Bay: All waters within Cowaramup Bay, are closed to recreational netting at all times.

Hardy Inlet and Blackwood Estuary: Waters of the Blackwood River and Hardy Inlet downstream from Fisher Rd boat ramp and north of Point Irwin and Irwin St boat ramp are conditionally opened to recreational set netting.

Geographe Bay: All waters within 400 m of HWM between the mouth of the Capel River and Cape Naturaliste, are closed to recreational set netting at all times.

Busselton Jetty: All waters within 400 m of HWM between Guerin St and Dolphin Rd, and within 800 m of the jetty, are closed to recreational set netting at all times.

11. ESTUARIES AND COASTAL WETLANDS

The Geographe Bay-Capes-Hardy Inlet region is bordered by the Swan Coastal Plain in the north and by the Scott Coastal Plain in the south. Both are low-lying sumplands that contain numerous wetlands and swamps. Whilst many of the wetlands of the Swan Coastal Plain have been degraded by the adjacent land use, several wetlands retain highly significant waterbird habitat. The broad wetland systems of the Scott Coastal Plain are particularly significant as they retain much native fringing vegetation and are well connected to each other such that habitat and the concomitant biodiversity values are extremely high. These wetlands also contain a number of unique and rare species of flora and fauna in unique and uncommon habitats (Pen, 1997).

The Geographe Bay-Capes-Hardy Inlet region contains two major drainage basins, which are the Blackwood and the Geographe Bay catchments. The Blackwood River basin is the largest in the southwest and also includes the Scott River which drains the western Scott Coastal Plain. The Blackwood catchment has been extensively cleared for agriculture, whilst much of the Scott River retains natural vegetation and is reserved in the Scott National Park (Pen, 1997). Both rivers ultimately discharge into Hardy Inlet. The Geographe Bay catchment contains two estuaries, Vasse-Wonnerup and Toby's Inlet, which historically received the discharge of all the major streams in the area. Many of the creeks and rivers have now been either partially or entirely modified as artificial drainage systems to drain the very low-lying agricultural areas of the southern Swan Coastal Plain (Pen, 1997). Many minor creeks drain the Leeuwin-Naturaliste Ridge, and most are contained within remnant coastal vegetation (Pen, 1997). The only true river system to dissect the Ridge is the Margaret River which drains the northwest corner of the forested Blackwood Plateau, and has a small estuary at the mouth.

11.1. IMPORTANT COASTAL WETLANDS

The Water and Rivers Commission has recently undertaken the Busselton-Walpole Regional Allocation Study to guide sustainable future management of water resources in the region. As part of this study, the Water and Rivers Commission has published a comprehensive and systematic overview of the environmental values of the region's wetlands, rivers and estuaries (Pen, 1997). The report firstly describes the state of the individual wetlands, rivers and estuaries of the region using a new condition assessment method. Secondly, a regional identification and environmental evaluation of the important and valuable wetlands was made. Thirty-one coastal wetland groups within the Geographe Bay-Capes-Hardy Inlet region were identified, of which 15 were considered to have important values. Appendix 11 lists all coastal wetland groups in the Geographe Bay-Capes-Hardy Inlet region and identifies the outstanding values of the 15 important wetland groups of the region.

Two detailed reports have mapped (at 1:25 000) and classified the coastal wetlands of the Busselton-Walpole region based on geomorphology. Hill *et al.* (1996) have examined the wetlands of the Swan Coastal Plain, between Bunbury and Dunsborough, and the V & C Semenuik Research Group (1997) have mapped the wetlands of the Scott Coastal Plain, east of Augusta to Walpole.

Coastal wetlands between Augusta and Walpole were classified into consanguineous suites using an approach based on geology, geomorphology and hydrology, by the V & C Semenuik Research Group (1996). This study, funded by the Australian Heritage Commission's National Estate Program, recommended four wetland suites adjacent to Flinders Bay for inclusion on the Register of the National Estate. The Alamein Suite, including the Gingilup Swamps, is comprised of large undisturbed and relatively isolated sumplands that are surrounded by high quality native forest and sedgeland that contains many declared rare and priority plant species that have very restricted ranges. The D'Entrecasteaux Suite is comprised of undulating sumplands that have a very high biodiversity including several declared rare and priority plant species, and several endemic freshwater fish species. The Balgamup Suite is formed where coastal dunes have encroached over the Tertiary basement, and contains very isolated and pristine representatives of this type of wetland. The wetlands contain restricted and unusual flora, and have significant habitat value, particularly for invertebrates and fish. Bolghinup Lake is a unique wetland situated on Black Point at the base of a mobile dune, underlain by calcrete and limestone and surrounded by basalt batholiths (V & C Semenuik Research Group, 1996).

The Directory of Important Wetlands in Western Australia (ANCA, 1996) provides the best national compilation of Australia's important wetlands at present. It has been a collaborative project between Commonwealth and State Governments to promote the conservation and better management of Australia's wetlands. The criteria for determining important wetlands included

representativeness, rarity, biodiversity, wetland functions, and historic and cultural significance. Five important coastal wetlands within the Geographe Bay-Capes-Hardy Inlet region were identified by the directory: McCarley's Swamp (Ludlow Swamp); the Vasse-Wonnerup Wetland System (see below); the lower Blackwood River (see below); the Cape Leeuwin Wetland System; and the Gingilup-Jasper Wetland System. McCarley's Swamp is one of the few remaining good examples of a wooded swamp on the lower Swan Coastal Plain and contains significant waterbird habitat including several threatened species. The Cape Leeuwin Wetland System is a unique system adjacent to the waterwheel on Cape Leeuwin that has several threatened plant communities and the largest known population of the threatened and rare aquatic snail *Austroassiminea letha*. The Gingilup-Jasper Wetland System is an outstanding example of a near-pristine extensive system of freshwater lakes, marshes and shrub-swamps that have a very high biodiversity, and contain seven of the eight fish species that are endemic to the southwest (ANCA, 1996). The system lies entirely within the D'Entrecasteaux National Park and the Gingilup Swamps Nature Reserve.

11.2. ESTUARIES

11.2.1. Hardy Inlet and the lower Blackwood and Scott Rivers

The Blackwood River Estuary is one of only two large, seasonal, permanently open estuaries on the south coast of Western Australia. The main basin of the estuary, known as Hardy Inlet, covers an area of around 9 km^2 and extends over a distance of 5 km from the entrance channel to the mouths of the Blackwood and Scott Rivers. The estuarine reaches of these rivers extend a further 30 km and 8km upstream respectively. To the eastern side of the entrance channel are two lagoons, the Deadwater and Swan Lake where the entrance channel formerly wound its way to sea. Hodgkin (1976) has described the history of these lagoons.

The ecology of the Blackwood River Estuary has been studied in considerable detail. In the early 1970s there were several applications lodged with the Department of Environmental Protection for mineral and dredging claims in the lower Blackwood estuary and the surrounding area. The community, several Government departments and the National Parks Board lodged Strong objections to the claims. In response, the Environmental Protection Authority requested the Estuarine Marine Advisory Committee to undertake a detailed study of the estuary to predict the probable effects of mining and dredging in the estuary, and to understand the ecological functions of the estuary to aid effective management (Hodgkin, 1978). The study, undertaken during 1974-75, was a major collaborative project that was collectively known as "*The Environmental Study of the Blackwood River Estuary*".

The study, which was coordinated by Dr. E. P. Hodgkin, resulted in the publication of 14 technical reports:

1. Technical Report 1: Water characteristics, dynamics and sediment transport (Imberger *et al.* 1976).

2. Technical Report 2: Sedimentary history and granulometric analyses (Sas, 1974).

3. Technical Report 3: Ecology and nutrient dynamics of the aquatic flora (Congdon & McComb, 1976).

4. Technical Report 4: The macrobenthic invertebrate fauna (Wallace, 1976).

5. Technical Report 5: The food of the estuary fish (Wallace, 1976).

6. Technical Report 6: The birdlife of the estuary. (Lane, 1975).

7. Technical Report 7: The ecology of the fish and commercial crustaceans of the estuary (Lenanton, 1976).

8. Technical Report 8: An estimation of the catches of amateur and professional fishermen in the estuary during 1974-75 (Lenanton & Caputi, 1976).

9. Technical Report 9: Recreational usage of the estuary (Caputi & Lenanton, 1976).

10. Technical Report 10: Community perceptions of environmental changes around Augusta (Frawley, 1975).

11. Technical Report 11: Attitudes towards environmental change in the estuary (Wooller1976).

12. Technical Report 12: Tourism in the area (Bayley-Jones, 1975).

13. Technical Report 13: The economics of recreation versus mining in the area (Fulbrook, 1975).

14. Technical Report 14: The surface geology and economic mineral prospects in the estuary and surrounding area (Geological Survey of Western Australia, 1974).

The results of the study were synthesised into one volume that provides a comprehensive description of the physical, biological and social aspects of the Blackwood River Estuary (Hodgkin, 1978). Following the preparation of this document, the Estuarine Marine Advisory Committee published a report on the anticipated effects of dredging in the estuary that subsequently resulted in the refusal of the mining applications (EMAC, 1978).

The fish fauna of the estuary has been investigated several times. Lenanton (1974) compiled a preliminary checklist of the species found in the estuary in 1971-72 (Appendix; 12). The relative use of the estuary and nearshore marine areas as nursery habitat by fishes was examined by Lenanton (1982; 1984), and more recently by Valesini *et al.* (1997) (see also Fishes and Appendix 6). The foraminifera of Hardy Inlet have been described by Quilty (1976).

The flora of the estuary has also been well described. Following the Environmental Study of the Blackwood River Estuary, Congdon (1977) completed a PhD. on the productivity and seasonal nutrient turnover in the aquatic plants of the estuary. Congdon & McComb (1979) determined the productivity of *Ruppia* sp. in the estuary. Congdon & McComb (1981), and McComb (1984) have also described the biomass and productivity of plants in the Blackwood River Estuary. The first record of the seagrass *Halophila decipiens* in southwestern Australia was found in the channel of the Hardy Inlet in 1991 (Kuo & Kirkman, 1995). The seagrass, an annual, was not found in the Deadwater and Swan Lake lagoons, or in Flinders Bay.

The Estuarine Health Indicators Project included five sites in Hardy Inlet (Deeley *et al.*, in prep). The project collected data on the benthic macroinvertebrates, phytoplankton, zooplankton, and water and sediment characteristics and nutrient. Long term trends and predictive models of river flow and nutrient loading were also described (D. Deeley, Acacia Springs Environmental P/L, *pers. comm*.).

The Western Australian Agriculture Department, in conjunction with the Blackwood Catchment Coordinating Group, has recently completed a draft report on the water quality of the lower Blackwood River. The report is a compilation of all the data obtained during the Bunning's Watercare and Ribbons of Blue Blackwood Snapshot sampling program since its inception in 1991 (Margaret Scott, Bunning's Watercare Program Coordinator, *pers. comm*.).

The Water and Rivers Commission (Bunbury) has recently drafted a pilot monitoring program for the Hardy Inlet and the estuarine sections of the Blackwood and Scott Rivers. This program is the first examination of the water quality of the estuary that has been proposed since the Blackwood River Estuary Environmental Study, and forms part of a proposed larger monitoring program that will encompass flora and faunal surveys, sediment studies and habitat mapping (Latchford & Hardcastle, 1998). The program divides Hardy Inlet into seven separate regions in which random samples will be taken on a fortnightly basis. The following parameters will be measured: temperature; DO; pH; salinity; conductivity; turbidity; TOC, TN, TP, FRP, NH_3, NO_3, and silicate; colour; chlorophyll *a, b* and *c;* and phaeophytin. All data will be entered into the Water and Rivers Commission EDICT database and will be accessible via a formal data request.

11.2.2. Vasse-Wonnerup Estuary

The Vasse-Wonnerup Estuarine System extends in a northeasterly direction from the centre of Busselton to Forrest Beach over a distance of 14 km. Its principal components are the Vasse and Wonnerup estuaries, which are 9 km and 5 km long, up to 0.6 km wide and generally less than 1 m deep, even in winter, and the smaller Deadwater, and Swan Lake, which all discharge to the ocean via the Wonnerup Inlet. The mouth of the inlet is shallow and often closed by the formation of a sand bar, particularly during summer and autumn (Lane *et al.*, 1997). The Vasse-Wonnerup lagoons and their associated wetlands occupy an area of approximately 1500 ha and have formed in the depressions between the Spearwood and more recently formed Quindalup dune systems (McAlpine *et al.,* 1989).

Historically, the estuary system consisted of a complex of brackish seasonal lakes, marshland, estuarine forest and saline lagoons, receiving freshwater from most of the rivers between Dunsborough and Bunbury (McAlpine *et al.*, 1989). During the past 130 years the estuary's catchment has been largely cleared for agriculture (primarily milk and beef production) and extensive drainage networks have been constructed to prevent flooding of the low-lying land (Lane *et al.*, 1997). Several of the rivers that formerly discharged into the estuaries have been either partially (the Vasse and Sabina Rivers), or wholly (the Capel and Buayanup Rivers) diverted to sea, forming short canal-like estuaries of little habitat value (Pen, 1997). The system now receives flow from only four rivers: the Vasse, Sabina, and Abba Rivers discharge into the Vasse lagoon; and the Ludlow River flows into the Wonnerup lagoon (McAlpine *et al.*, 1989). In 1908, floodgates were installed on the estuaries' exit channels to allow outflow but preventing inflow of seawater (Lane *et al.,* 1997). These considerable changes to the hydrology of the system have greatly altered both the water levels and quality of the estuaries. Lane *et al.* (1997) and McAlpine *et al.* (1989) have reviewed these changes in detail. Both estuaries are highly enriched with nutrients, mainly of agricultural origin, which results in the frequent development of algal blooms in the lowest reaches of the Vasse Estuary during the summer and autumn (Lane *et al.,* 1997).

The Vasse-Wonnerup Estuary System is internationally recognised for its waterbird habitat. Surveys during the 1980s revealed more than 30,000 waterbirds of 60 species each year (Bamford & Bamford, 1995; Halse *et al.*, 1992; Halse *et al.*, 1993; Jaensch *et al.*, 1988; Lane, 1990). Eighty-five species have been recorded in total (Lane, 1990). Nationally, the estuaries are a major migration stop-over point for a number of species of small waders, and regionally it is a major breeding area of the black swan *Cygnus atratus* and several duck species. The area is also a post-breeding and moulting refuge for a very high diversity of waterbirds (ANCA, 1996). On this basis

the Vasse-Wonnerup Estuary System was listed in June 1990 as a *Wetland of International Importance* under the RAMSAR Convention (CALM, 1990). The system is also listed on the Register of the National Estate (Lane *et al.*, 1997).

Following major fish deaths in the channel of the Vasse arm of the estuary in 1988, a study to understand the causes of the problem was undertaken by the Environmental Protection Authority. The Estuarine Impacts Branch of the Department for Environmental Protection monitored river flows and nutrient loads to the Vasse-Wonnerup lagoons during 1987-1988. A comprehensive assessment of the environmental condition of the estuaries and a discussion of management issues and options was published (McAlpine *et al.*, 1989).

In March 1997, community concern over continued sudden, mass fish deaths in the Vasse Estuary exit channel, and the death of the fringing vegetation and adjacent pastures, led to the formation of the Vasse Estuary Technical Working Group. The Working Group's investigations revealed that mass fish deaths in the estuary have a history dating back to 1905. It was suggested that the principal cause of the summer fish deaths is temporary declines in dissolved oxygen concentrations to critical levels, primarily due to night-time respiration by algal blooms, algal bloom decay and high water temperatures. The Vasse Estuary Technical Working Group (VETWG) has reviewed the history of the management of the Wonnerup Inlet sand bar, and the Vasse and Wonnerup estuary floodgates. The VETWG documented the historical changes to water levels and quality, and the history of fish deaths and methods used previously to prevent them (Lane, *et al.*, 1997). The report also discusses management options for the estuaries and makes a number of recommendations to reduce the incidence of sudden, mass fish deaths.

The Water and Rivers Commission monitored the water quality in the Vasse-Wonnerup Estuary System has been during 1997-1998 (Lane *et al.*, 1997). Two sites in Vasse River, three sites in each of the estuary lagoons, two sites in the Deadwater and two sites between the floodgates and the sandbars were sampled for nutrients, phytoplankton, chlorophylls, BOD, pH, salinity, turbidity, pesticides, and heavy metals either monthly or quarterly. Continuous recordings of water levels, temperature and dissolved oxygen were also made. Data will be entered into the Water and Rivers Commission EDICT database and will be available via a formal data request.

As a condition of the EPA licence application to continue the discharge of treated effluent into the Vasse Diversion Drain, the Water Corporation, as part of its Environmental Improvement Initiative has provided funding for a study. This study which analysed the spatial movement of nutrients through the catchments of the Vasse-Wonnerup Estuaries and the Capel River using Geographical Information Systems was undertaken by David Deeley of Evangalisti and Associates, and commenced in late 1998 (D. Deeley, Acacia Springs Environmental P/L, *pers. comm.*).

The land surrounding the estuaries is substantially privately owned, whilst some is reserved as Nature Reserve (managed by CALM), and smaller areas are Recreation Reserve (managed by Busselton Shire Council). The open water of the estuaries is mostly vacant Crown land. CALM has been designated at the lead agency to draft a management plan for the estuaries, and work is expected to commence in 1998 following conservation of the vacant Crown land portions of the estuaries as Nature Reserves (Lane *et al.*, 1997).

11.2.3. Toby Inlet

Toby Inlet is a miniature version of the Vasse-Wonnerup Estuary, being about 4.5 km long and 50 m across. Historically, it received flow from the Carbunup River and Mary Brook systems via the Broadwater, a freshwater wetland that bends behind a narrow ridge just to the landward of the estuary (Pen, 1997). These streams have been diverted to sea as part of the agricultural drainage network, and form short canal-like estuaries. The catchment of Toby Inlet includes a golf course,

vineyards and potato farms, and adjacent to the lower lagoon is a high density, unsewered residential area.

In 1997, the Sussex Land Conservation District Committee (LCDC) obtained funding from the Gordon Reid Foundation to produce a draft management plan for the inlet and its associated wetlands. This was in response to increasing community concern over the health of the inlet following several years of severe algal blooms (Clay & Weston, 1997). The document has little value as a management plan (A. Sutton, Geocatch, *pers. comm*.), however it does provide consultant's reports on the aquatic macroinvertebrate fauna, terrestrial fauna and vegetation of the Inlet. Water quality, including DO, TN, TP and major cations, were sampled at 19 sites throughout the system (Sussex LCDC, 1996). The reports concluded that Toby Inlet is a nutrient enriched and degraded aquatic ecosystem with a macroinvertebrate fauna that is dominated by cosmopolitan species with low biodiversity.

The Toby Inlet Ocean Entrance Management Study is currently being coordinated by Geocatch in conjunction with the Busselton Shire Council and the Sussex LCDC. The project, funded by the NHT *Coast and Clean Seas* Monitoring Program, aims to achieve a detailed understanding of the inlet's form, hydrodynamics, and ecological functions through a review of available data, a detailed bathymetric and topographic study and ongoing hydrodynamic monitoring. Effective management options for the inlet will be developed in consultation with the community. The project, scheduled to begin in May 1998, has not yet commenced (C. Thorstensen, Geocatch, *pers. comm*.).

11.2.4. Margaret River Estuary

The main lagoon of the Margaret River Estuary is about 1 km long and around 200 m wide, thereafter tapering to about 10 m wide over a distance of 2 km. The lagoon, which has an area of about 20 ha, is connected to the ocean via a 500 m long and 50 m wide entrance channel that twists around a headland. The northwestern side of the estuary is adjacent to the Kilcarnup Reserve, which is managed by the Margaret River-Augusta Shire council. The estuary retains a good buffer of wetland and riparian vegetation along most of its length (Pen, 1997).

As part of the Bunning's Watercare Program, managed by Margaret Scott, students of the Margaret River High and Primary Schools have undertaken a water quality monitoring program in the Margaret river since 1992 (M. Scott, Bunning's Watercare Program Coordinator, *pers. comm*.). This program includes only one tidal site at the Margaret River mouth. Water quality at the Margaret River mouth is also being monitored by the Margaret River Surfrider Foundation (*see* Water Quality section).

12. COASTAL TERRESTRIAL BIOTA

12.1. COASTAL FLORA

The coastal vegetation of the west coast between Cape Leeuwin and Cape Naturaliste has been recorded by CALM Busselton's district botanist A. Webb. The plant communities of the primary dunes are dominated by the low spreading shrub *Rhagodia bacata*, the herb *Calocephalus brownii,* the fan flower *Scaevolia crassifolia*, the sedge *Isolepis nodosa*, and the sword sedge *Lepidosperma gladiatum*. Several introduced species are also common, these are the succulent *Tetragonia decumbens*, the daisy *Arctotheca populitholia*, pigface *Carpobrotus edulis*, and marram grass

Ammophila arenaria. Secondary dunes are colonised by the salt bush *Olearis axillaris,* the shrubs *Acacia littorea, Spyridium globulosum, Templetonia retusa* and *Boronia alata*. If undisturbed, these communities give way to a climax community of acacia-peppermint low woodland. Agonis flexuous (peppermint), the Acacia species *A. littorea, A. cyclops* and *A pulchella*, *Leucopogon* parviflorus, and some small marri Eucalytpus *calophylla* dominate this community. Further inland are communities of tall karri forest (*E. diversicolor*), tall tuart forest (*E. gomphocephalus*), jarrah-marri forest (*E. marginata* and *E. calophylla*), marri woodland (*E. calophylla*), low jarrah-banksia woodland (*E. marginata, Banksia menziesii* and *B. attenuata*), paperbark low woodland (*Melaleuca sp.*), and acacia thicket (*A. decipiens*) (Beard, 1981). Smith (1973) and more recently by Keating & Trudgeon (1985) have given a description of the coastal vegetation of the southern Swan Coastal Plain to Dunsborough. Grein (1997) describes the coastal vegetation of the Augusta-Margaret River Shire. Species lists for the coastal vegetation of the area are held at CALM Busselton.

As part of the Regional Forest Agreement there has been comprehensive mapping of the vegetation of the southwest region pre-1750 by Mattiske Consulting (Mattiske & Havel, 1998). The plant communities have been mapped at 1:25,000, whereas Beard's mapping was carried out at 1:250,000, so many smaller vegetation types are shown in the RFA data than was given by Beard (1980). This data is also available on an electronic database on the CALM Web page NatureBase CALM, online).

The Meelup Regional Park contains a number of rare and endangered coastal plant species, including the granite herb *Caladenia caesorea ssp. maritima,* and the spider orchids *C. longicauda* subspecies *Chivicola, C. heugelii,* and *C. excelsa.* The Meelup granite coastal heaths, containing the Priority 4 species *Calothamnus graniticus* subspecies. *C. graniticus* is listed by WATSCU as a Vulnerable Threatened Ecological Community. Two Critically Endangered plants, *C. viridescens* and the Meelup mallee *E. phylacis*, also occur. The Meelup mallee is particularly rare and unique, with only 18 individuals of the plant known. It is thought that these plants are actually all the same individual, each arising from vegetative propagation, and are believed to be more that 5,000 years old (A. Webb, CALM Busselton, *pers. comm*.).

The flora of the islands off Augusta is considerably different from that of the mainland due to the impact of the nesting birds (A. Webb, CALM Busselton, *pers. comm*.). The association between nesting birds and the vegetation of Hamelin, Seal, St Alouarn and Flinders Islands has been described by Gillham (1961; 1963). Gillham (1961) suggested that use of these islands as a rookery by seabirds has led to an alteration of the structure of the plant communities, from low sclerophyllous shrubs to succulents and ultimately to a community dominated by introduced grass species. Gillham suggest that the process is dynamic, and as the vegetation becomes altered and is no longer suitable as a nesting site, birds will move to another island, and the vegetation will undergo regeneration. Abbott (1978; 1980) has described the flora of Hamelin Island more recently.

12.2. COASTAL FAUNA

The coastal areas of the Capes region supports a variety of mammalian fauna, however populations are small and often isolated (How *et al.*, 1987). The western grey kangaroo *Macropus fuliginosus*, the dunnart *Sminthopsis griseoventer*, and the mardo *Antechinus flavipes* are the most abundant and commonly seen mammals in the area (G. Voight, CALM Busselton, *pers. comm*.). Several animals that are vulnerable and specially protected under the Western Australian Wildlife Conservation Act are known to occur in the area, including the brown bandicoot or quenda *Isoodon obesulus*, the chuditch *Dasyurus geoffroii* and the western ringtail possum *Pseudocheirus occidentalis*. The western ringtail possum and the brushtail possum *Trichosurus vulpecula* have both changed status considerably since settlement. Once abundant in peppermint (*Agonis flexuosa*) woodlands of the region, both species have declined alarmingly in their range, and nowhere in this region are dense

populations of either possum found (How *et al.*, 1987). Viable populations of the possums do occur within the towns of Busselton, Dunsborough and Quindalup however (Christenson *et al.*, 1985). The vulnerable and specially protected quokka *Setonix brachyurus*, and the tammar wallaby *Macropus eugenii*, have both been previously identified around the swamps and peppermint woodlands in the area, however recent trapping attempts have failed to produce either animal. An area at Boojidup has been identified as containing suitable habitat for the gazetted rare noisy scrub bird, and the area surrounding Quinninup Falls may support the critically endangered Gilbert's potoroo, however neither have been successfully trapped in the area in recent times. The bobtail *Tiliqua rugosa* and the bungarra *Varanus gouldii* are two of the larger, more commonly seen lizards of the coastal areas (G. Voight, CALM Busselton, *pers. comm.*). At least ten species of skink and eleven species of snake, including the venomous dugite *Pseudonaja afghanis*, and tiger snake *Notechis scutatus* also inhabit the coastal dunes. A list of the mammalian, amphibian and reptilian fauna of the region is recorded in Appendix 13A, 13B, 13C.

The fragmentation of native vegetation through clearing has probably had the greatest effect of all human induced changes to the native fauna (CALM, 1989). Most of the medium sized native mammals of the area have become locally extinct or scarcely depleted in numbers, due primarily to loss of habitat and also predation by exotic animals (How *et al.*, 1987). Habitat preservation was identified as a primary consideration in the Leeuwin-Naturaliste National Park Management Plan, and thus existing and potential habitats within the park are protected from prescribed burns, wildfires and management operations (CALM, 1989). The Leeuwin-Naturaliste Ridge Statement of Planning Policy seeks to address habitat fragmentation by linking the National Park with substantial areas of remnant vegetation by environmental corridors (Ministry for Planning, 1998). The Western Shield Project, initiated by CALM, has undertaken extensive control of introduced predators through trapping and the use of baits containing the poison 1080 (derived from the native plant *Gastrolobium* sp.).

Ten species of shorebirds have been identified along this coast by a local Royal Australasian Ornithologists Union (RAOU) bird observer. These birds, which include the sanderling *Calidris ruficollis*, two sandpipers *Calidris acuminata* and *Actitis hypoleucos*, the whimbrel *Numenuis phaeopus*, the red capped plover *Charadrius ruficapillus*, and the large sand plover *Charadrius leschenaulti*, are widely distributed but not commonly seen (*see* Appendix 10). The hooded plover *Thinornis rubricollis* is also known to occur in the area and this species is regarded as vulnerable by the RAOU (R. Payton, RAOU, *pers. comm.*).

The aquatic root mat communities of the caves of the Leeuwin Naturaliste Ridge have been listed as critically endangered by WATSCU. Extensive knowledge of the caves in this area exists within the Western Australian Speleological Group and the Speleological Research Group (CALM, 1989). Knowledge of the faunal communities of the caves of the region (both current and some paleontological) exists within the Western Australian Museum of Natural Science's Zoological Department.

12.3. TUFA

Tufa is a freshwater precipitate of calcium carbonate that occurs where groundwater percolates to the surface through limestone. Formation of tufa is thought to be the result of carbon dioxide diffusion from the water into the atmosphere leading to a dis-equilibrium that results in the deposition of the carbonate (Burne & Moore, 1987). Along the coastline of Cape Leeuwin there has been three distinct forms of tufa identified by Linda Moore (Water & Rivers Commission, Perth). Various microbes (cyanobacteria, green algae and diatoms) are associated with each form and influence their architecture. A fine, terraced-fan shaped deposit of tufa 16 m wide and 17 m long, with a height of 3.8 m is around 150-200 m northwest of the waterwheel on the Cape. This deposit consists of a series of rimstone pools, 2-4 cm wide and 3-5 mm deep, and occasionally

deeper pools with nodular incrustations which are botryoidal. A thin film of water that trickles from a spring 30 m above covers the deposit. Quarry Bay has massive crystalline tufa formations on the side of a vertical and overhanging small cliff face. The formations include drapes, curtains, small cylindrical stalactites and larger campanulate masses that are up to 2 m high and 1 m deep. Most of these formations are inactive (non-accreting and devoid of flowing water), however the northern 12 m section is still accreting. Botryoidal deposits are also a common feature of the freshwater pools fed by groundwater springs along this coastline. They have a smooth surface, are pink or brown in colour and occur about 5-30 cm below the water surface (L Moore, Water and Rivers commission, *pers. comm*.).

Whilst tufa occur in a wide variety of environments, their present day distribution is very restricted compared to Precambrian and Phanerozoic times (Moore, 1998). Modern microbiolites (tufa, stromatolites and thrombolites) occur in several areas in Western Australia, however the spectacular tufa formations of the Cape Leeuwin area are possibly unique to the State. The microbial flora associated with these tufa are unusual due to the scarcity of the filamentous cyanobacterium *Phormidium incrustatum* that is commonly associated with tufa deposits in Europe and the United States, and also the presence of an abundance of diatoms, particularly *Epithemia musculus* and *Mastogloia* sp. It appears that tufa may be particularly common along the shores of the Geographe Bay-Capes-Hardy Inlet region, where many groundwater springs seep to the surface, however an extensive identification of sites has not yet been made (L. Moore, WRC, *pers. comm*.). WATSCU have listed the tufa communities near the waterwheel at Cape Leeuwin, Augusta as a Threatened Ecological Community (A. Webb, CALM Busselton, *pers. comm*.).

12.4. NATURAL RESOURCES

The Spatial Resource Information Group of the WA Department of Agriculture has recently produced a Natural Resource Atlas for the Geographe Bay Catchment (Weaving, 1998). The Atlas, commissioned by the Geographe Catchment Council (Geocatch), provides a comprehensive review (including maps) of the current state of vegetation, fauna, soils, geology, and water resources in the catchment, and also collates details of all integrated catchment management and nature conservation projects within the region.

As part of the Regional Forest Agreement, the Commonwealth and Western Australian Regional Forest Agreement Steering Committee have identified several places of natural value adjacent to the Geographe Bay-Capes-Hardy Inlet region for listing on the Register of the National Estate (CWARFASC, 1998).

The Leeuwin-Naturaliste Ridge Statement of Planning Policy includes computer based mapping of land systems, landscape character units, remnant vegetation, geology and mineral resources, existing land tenure and land use, and areas of natural landscape significance (Ministry for Planning, 1998).

13. COASTAL NATIONAL PARKS AND NATURE RESERVES

Four national parks and five nature reserves are adjacent to the marine areas of the Geographe Bay-Capes-Hardy Inlet region. They are:

1. Leeuwin-Naturaliste National Park

2. Tuart Forest National Park
3. Scott River National Park
4. D'Entrecasteaux National Park
5. Seal Island Nature Reserve
6. St Alouarn Island Nature Reserve
7. Sugarloaf Rock Nature Reserve
8. Flinders Bay Nature Reserve
9. Hamelin Island Nature Reserve

National parks and nature reserves in Western Australia are vested in the National Parks and Nature Conservation Authority (NPNCA). The NPNCA and CALM is responsible for the preparation of management plans for all lands vested in the Authority. Only the Leeuwin-Naturaliste National Park and the D'Entrecasteaux National Park are currently managed according to gazetted management plans (CALM 1987; 1989). These management plans provide information on the land tenure, resources, conservation of flora and fauna, recreation management, and research and monitoring priorities. The Shannon-D'Entrecasteaux National Park Management Plan is currently undergoing revision, whilst the Leeuwin-Naturaliste National Park Management Plan is scheduled to be revised in 1999 (J. Williamson, CALM Planning Branch, *pers. comm*.).

The Leeuwin-Naturaliste National Park extends along the coastline from Bunkers Bay (east side of Cape Naturaliste) to Cape Leeuwin over a distance of about 100 km, covering an area of around 15,600 ha, and is made up of 28 separate reserves (CALM, 1989). The park is highly fragmented and in many places is a narrow foreshore reserve connecting more substantial blocks, which extend up to 5 km inland. Leeuwin-Naturaliste National Park is regarded as one of the primary coastal recreation areas in the southwest. With some of the best surfing conditions in Australia, and as a popular fishing destination, the park attracts around 500,000 visitors each year (Ministry for Planning, 1998). Leeuwin-Naturaliste National Park has some of the finest known cave systems in Australia. There are over 360 known caves in the park, and several contain extremely rare and threatened ecological communities (CALM, 1989).

Tuart Forest National Park reserves the last remaining forest of the tuart *Eucalyptus gomphocephala*, which is unique to the southwest of the State. A management plan for the Tuart Forest National Park is scheduled to be drafted soon (CALM, Tenure Information Branch, *pers. comm*.).

The Scott River National Park is an area of extremely high biodiversity due to the pristine and isolated nature of most of the area. It contains many important coastal wetlands (*see* Estuaries and coastal wetlands section).

Black Point, the eastern boundary of the study area, forms the westernmost point of the ***D'Entrecasteaux National Park***, which is the largest national park on the south coast.

All of the important seabird breeding islands in the Geographe Bay-Capes-Hardy Inlet region, including **Seal Island, St Alouarn Island, Flinders Island, Hamelin Island, Square Rock, SE Rocks,** and **Sugarloaf Rock** have been vested with the National Parks and Nature Conservation Authority as *Nature Reserves for the conservation of fauna*. No management plans for these reserves have been drafted.

The **Meelup Regional Park** is an 'A' class reserve vested in the Shire of Busselton and managed by a committee appointed by the Shire. The reserve, encompassing an area of 550 ha, contains a number of rare and restricted flora, including the critically endangered Meelup mallee, and a unique coastal granite community (*see* Estuaries and coastal wetlands section). A further 1770 ha of land adjacent to the coast is reserved for the purpose of recreation and vested with the relevant Shire Councils (CALM, Tenure Information Branch, *pers. comm.*).

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APPENDICES

APPENDIX 1A. SITES SURVEYED IN GEOGRAPHE BAY (Walker *et al.* 1994; 1995a; 1995b; 1995c; 1995d; 1995e; McMahon & Walker 1997)

	SITE	LOCATION	SUBSTRATE
1	Dunsborough	33°36.425 S 115°07.112 E	Flat sandy bottom
2	Toby Inlet	33°37.797 S 115°10.794 E	Flat sandy bottom
3	Buayanup Drain	33°38.531 S 115°14.933 E	Flat sandy bottom
4	Vasse Diversion Drain	33°38.339 S 115°19.303 E	Flat sandy bottom
5	Vasse-Wonnerup Estuary	33°36.116 S 115°25.401 E	Flat sandy bottom
6	Forrest Beach	33°34.265 S 115°31.362 E	Low and high rock and sand
7	Capel River	33°30.194 S 115°31.362 E	Low and high rocky ledges and sand

APPENDIX 1B. GENERAL DESCRIPTION OF THE BENTHIC COMMUNITIES IN GEOGRAPHE BAY (McMahon & Walker 1997)

The benthic substrata of Geographe Bay can be divided into three main categories; sandy substrata, a combination of sandy substrata and low relief reef, and a combination of low and high relief reef. Sandy substrata were present in the south-western portion of the bay between Dunsborough and the Vasse-Wonnerup Estuary. These areas were dominated by monospecific meadows of *Posidonia sinuosa*, with *Amphibolis antarctica* and *A. griffithii* on the periphery of the meadows. Closer to Dunsborough the cover of *Amphibolis* spp increased and a number of large meadows occurred. The brown macroalga, *Scaberia agardhii* was also present in patches.

Sites with sandy substratum and low relief were found both north of Wonnerup, around Forrest Beach, with a combination of seagrasses (*P. sinuosa, A. antarctica, A. griffithii* and *Halophila ovalis*) in small patches. Dominant macroalgae included *Osmundaria prolifera, Scaberia agardhii, Sargassum* spp., C*aulerpa* spp. and *Padina* spp. Plate corals and sponges were also present.

At Capel there was low and high relief reef and also small patches of the seagrasses *A. griffithii* and *A. antarctica. P. angustifolia* was found on sandy bottoms surrounding high relief reef further north. Most common benthic macroalgae were the kelp *Ecklonia radiata* and *Sargassum* spp. Many small red turf algae were present along with erect red and green algae such as *Caulerpa* spp.

Three main types of epiphytes were noted in the bay; macroalgal epiphytes, diatom aggregations and cyanobacterial aggregations. There was temporal variation in these epiphytes, with *Cladophora, Pachydictyon* and *Polycerea* dominant in summer and red algae such as *Metagoniolithon* more common in winter. *Amphibolis* bore a greater load of red algal epiphytes than did *Posidonia*. An extensive bloom of *Cladophora* occurred in December of 1993 and 1994 at Capel River and Forrest Beach. This disappeared after one month.

Mastogloia (Bacillariophyta) aggregations were found in the south-western portion of the bay. They increased in cover over summer. After a storm in summer the majority of the aggregations were gone and remained absent throughout the rest of the year. *Chroococcus* (Cyanophyta) aggregations were present at all sites. They increased in cover over summer, especially at Vasse Diversion Drain and Vasse-Wonnerup Estuary, but were not present during the rest of the year.

APPENDIX 1C. SPECIES RECORDED AT SEVEN SITES IN GEOGRAPHE BAY (Walker *et al*. 1994; 1995a; 1995b; 1995c; 1995d; 1995e; McMahon & Walker 1997)

SPECIES	1	2	3	4	5	6	7
SEAGRASS							
Posidonia sinuosa	✓	✓	✓	✓	✓	✓	✓
Posidonia angustifolia		✓				✓	
Amphibolis antarctica	✓	✓	✓	✓	✓	✓	✓
Amphibolis griffithii	✓	✓			✓	✓	✓
Halophila ovalis	✓				✓	✓	✓
MACROALGAE							
Chlorophyta							
Caulerpa sp.					✓	✓	✓
Caulerpa cactoides							✓
Halimeda cuneata							✓
Phaeophyta							
Caulocystis uvifera						✓	
Dictyopteris muelleri						✓	✓
Ecklonia radiata						✓	✓
Lobophora variegata	✓						
Padina sp.	✓					✓	✓
Scaberia aghardii	✓				✓	✓	✓
Sargassum sp.					✓	✓	✓
Rhodophyta							
Asparagopsis armata						✓	
Gelidium sp..							✓
Osmundaria prolifera						✓	
EPIPHYTIC ALGAE							
Cladophora montagneana			✓	✓	✓	✓	✓
Cladophora dalmatica	✓		✓	✓	✓	✓	✓
Polycerea nigrescens	✓	✓			✓	✓	
Pachydictyon paniculatum	✓	✓	✓	✓	✓	✓	✓
Pachydictyon polycladum	✓	✓	✓	✓	✓	✓	✓
Metagoniolithon chara	✓	✓		✓	✓	✓	
Lenormandia marginata					✓	✓	
MICROALGAE							
Bacillariophyta							
Mastogloia sp.	✓	✓	✓	✓	✓	✓	
Cyanophyta							
Chroococcus sp.	✓	✓	✓	✓	✓	✓	✓

APPENDIX 2. FISH SPECIES OF THE SEAGRASS MEADOWS IN GEOGRAPHE BAY (Scott, 1981)

SPECIES
Acanthaluteres spilomelanurus
Apogon rueppellii
Aseraggodes haackeanus
Aspaminae sp. 1
Aspaminae sp. 2
Aspaminae sp. 3
Atopomycterus nicthemerus
Brachaluteres jacksonianus
Cristiceps australis
Gymnapistes marmoratus
Heteroclinus adelaidae
Meushenia freycineti
Neoodax radiatus
Neoodax semifasciatus
Pseudolabrus aurantiacus
Scobinichthys granulatus
Siphamia cephalotes
Stigmatophora argus
Syngnathus poecilolaemus

APPENDIX 3A. FISH SPECIES COLLECTED FROM THE BLACKWOOD RIVER ESTUARY AND THE INSHORE MARINE ENVIRONMENT OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION DURING 1976-1977 (Lenanton, 1982)

SPECIES	COMMON NAME	ESTUARY	MARINE
Acanthopagrus butcheri	Black bream	✓	
Aldrichetta forsteri	Yellow-eye mullet	✓	✓
Ammotretis elongatus	Elongate flounder		✓
Amniataba caudavittatus	Yellow-tailed trumpeter		✓
Amoya bifrenatus	Bridled goby	✓	
Apogon rueppellii	Gobbleguts		✓
Aptychotremata vincentiana	Shovelnose ray		✓
Aracana aurita	Shaw's cowfish		✓
Arramphus sclerolepis	Garfish		✓
Arripis georgianus	Australian herring	✓	✓
Arripis trutta	Australian salmon	✓	✓
Atherinosoma elongata	Elongate hardyhead	✓	
Atherinosoma presbyteroides	Swan River hardyhead	✓	✓
Atopomycterus nichthemerus	Globe fish	✓	✓
Bigener brownii	Spiny-tailed leatherjacket		✓
Callionymus goodladi	Goodlad's stinkfish		✓
Caranx georgianus	Skipjack trevally	✓	✓
Cnidoglanis macrocephalus	Cobbler	✓	✓
Contusus richei	Prickly toadfish	✓	✓
Crapatalus arenarius	Sand fish		✓
Enoplosus armatus	Old wife		✓
Favonigobius lateralis	Long-finned goby	✓	✓
Favonigobius suppositus	Long-headed goby	✓	
Gymnapistes marmoratus	Devilfish		✓
Gymnothorax woodwardi	Woodward's reef eel	✓	
Gynoglossus broadhursti	Broadhurst's tongue sole		✓
Heteroclinus heptaeolus	Weedfish		✓
Heteroclinus sp.	Weedfish		✓
Histiogamphelus cristatus	Pipefish		✓
Histiogamphelus meraculus	Pipefish	✓	
Hypherlophus vittata	Sandy sprat	✓	
Hyporhamphus melanochir	Sea garfish		✓
Kyphosus cornelii	Western buffalo bream		✓
Meuschenia freycineti	Six-spined leatherjacket	✓	✓
Meuschenia. hippocrepis	Horseshoe leatherjacket		✓
Microcanthus strigatus	Footballer sweep	✓	
Mugil cephalus	Sea mullet	✓	✓
Neoodax radiatus	Weed whiting		✓
Neoodax semifasciatus	Blue weed whiting		✓
Paraquula melbournensis	Silverbelly		✓
Pelates sexlineatus	Striped trumpeter	✓	✓
Pelsartia humeralis	Sea trumpeter		✓
Platycephalus longispinis	Sand flathead		✓
Platycephalus laevigatus	Rock flathead		✓
Pomatomus saltatrix	Tailor		✓
Pranesus ogilbyi	Ogilby's hardyhead		✓
Pseudogobius olorum	Blue-spot goby	✓	
Pseudolabrus parilus	Brown-spotted wrasse		✓
Pseudorhombus jenynsii	Small-toothed flounder		✓
Rhabdosargus sarba	Tarwhine	✓	

SPECIES	COMMON NAME	ESTUARY	MARINE
Schuetta woodwardi	Woodward's pomfret		✓
Scobinichthys granulatus	Rough leatherjacket		✓
Scorpis georgianus	Banded sweep	✓	✓
Sillaginoides punctata	King George whiting	✓	✓
Sillago basensis	School whiting		✓
Sillago schomburgkii	Western sand whiting	✓	✓
Sillago sp.	Whiting		✓
Sphryaena novaehollandiae	Short-finned sea pike		✓
Spratelloides robustus	Blue sprat	✓	✓
Strophiurichthys inermus	Blue boxfish		✓
Strophiurichthys robustus	Robust boxfish		✓
Torquigener pleurogramma	Common blowfish	✓	✓
Trygonorhina fasciata	Southern fiddler		✓
Upeneichthus porosus	Goatfish		✓
Urolophus testaceus	Common stingaree		✓

APPENDIX 3B. RELATIVE ABUNDANCE OF 16 RECREATIONALLY AND COMMERCIALLY IMPORTANT FISHES IN THE NEARSHORE MARINE ENVIRONMENT OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION (Lenanton, 1982)

SPECIES	Hardy Inlet Mouth	East Flinders Bay	Granny's Pool	Ringbolt Bay	Gnarabup	Kilcarnup	Eagle Bay	Dunsborough	East Toby's Inlet
Aldrichetta forsteri	24	231	137					26	4
Ammotretis elongatus			187	25	6	6		3	4
Arripis georgianus		131	25	150	112		26	19	<1
Arripis trutta	<1						13	1	<1
Cnidoglanis macrocephalus						300			<1
Enoplosus armatus						106			
Hyperlophus vittatus	5								
Hyporhamphus melanochir	5		37	6	12	418	37		
Mugil cephalus	10								
Platycephalus longispinus			12	18	6	6		2	3
Pseudorhombus jenynsii								2	1
Rhabdosargus sarba	251								
Sillaginoides punctatus	42							31	6
Sillago bassensis		25	31				6	19	5
Sillago schomburgkii								14	<1
Spratelloides robustus	2	6	81	69		62	1055	10	147

NB Relative abundance at each site is the mean number of fish per hectare.

APPENDIX 4. REEF FISHES OF THE GEOGRAPHE BAY-CAPE LEEUWIN AREA (Hutchins, 1994)

SPECIES	DISTRIBUTION
Acanthaleuteres brownii	J
Acanthaluteres vittiger	I
Acanthistius serratus	G
Achoerodus gouldii	I
Anoplocapros lenticularis	I
Anoplocapros robustus	H
Apodactylus westralis	J
Apogon ruepellii	D
Apogon victoriae	E
Aracana aurita	H
Arripis georgianus	I
Arripis truttaceus	I
Aspasmogaster occidentalis	G
Aspasmogaster tasmaniensis	J
Aulopus pupurissatus	I
Austrolabrus maculatus	H
Batrachomoeus rubricephalus	G
Bodianus frenchii	I
Brachaluteres jacksonianus	J
Caesioscorpis theagenes	E
Callogobius depressus	J
Callogobius mucosus	J
Chaetodon assarius	E
Cheilodactylus gibbosus	F
Cheilodactylus rubrolabiatus	F
Chelmonops curiosis	H
Chironemus georgianus	J
Choerodon rubescens	E
Chromis klunzingeri	G
Cirripectes hutchinsi	E
Cnidoglanis macrocephalus	I
Cochleoceps bicolor	J
Conger wilsoni	I
Coris auricularis	F
Dactylophora nigricans	J
Dasyatis brevicaudata	H
Dermatopsis multiradius	I
Dinolestes lewini	J
Diodon nicthemerus	J
Dipulis caecus	E
Dotolabrus alleni	G
Dotolabrus aurantiacus	J
Enigmapercis reducta	H
Enoplosus armatus	I
Epinephelides armatus	F
Eubalichthys mosaicus	I
Eupetrichthys angustipes	J
Eviota bimaculata	F
Girella tephraeops	G
Girella zebra	I
Glaucosoma hebraicum	F
Gymnothorax prasinus	F

SPECIES	DISTRIBUTION
Gymnothorax woodwardi	E
Halichoeres brownfieldi	F
Helcogramma decurrens	H
Heraldia nocturna	J
Heteroclinus heptaeolus	J
Heteroclinus roseus	I
Heteroclinus sp.	I
Heterodontus portusjacksoni	I
Histiophryne cryptacanthus	I
Hypoplectodes wilsoni	G
Hypoplectrodes nigrorubrum	I
Kyphosus cornelli	E
Kyphosus sydneyanus	H
Lepidoblennius marmoratus	J
Limnichthys fasciatus	O
Lissocampus runa	J
Lotella fuliginosa	H
Lotella rhacinus	I
Maroubra perserrata	J
Meuschenia flavolieata	I
Meuschenia galii	I
Meuschenia hippocropis	I
Microcanthus strigatus	E
Muraenichthys australis	H
Myliobatis australis	I
Neatypus obliqus	F
Nemadactylus valenciennesi	J
Nesogobius sp.	J
Noosebastis bouganvilli	I
Noosebastis pandus	I
Norfolkia incisa	J
Notolabrus parilus	H
Odax acroptilis	I
Odax cyanomelas	I
Ogilbia sp.	E
Omegophora armilla	J
Omegophora cyanopunctata	J
Ophiclinus gracilis	J
Ophiclinus pectoralis	G
Opthalmolepis lineolatus	I
Orectolobus ornatus	I
Orectolobus sp.	E
Othos dentex	I
Parablennius postoculomaculatus	E
Parapercis haackei	H
Paraplesiops meleagris	I
Parapriacanthus elongatus	I
Parascyllium variolatum	I
Paristiopterus gallipavo	J
Parma bicolor	G
Parma mccullochi	G
Parma occidentalis	E
Parma victoriae	I
Parupeneus chrysopleuron	D
Parupeneus spilurus	D
Parvicrepis parvipinnis	J
Pempheris klunzingeri	H
Pempheris multiradiata	I
Pempheris sp.	I
Pentaceropsis recurvirostris	J
Pentapodus vitta	E
Phyllophyrne scortea	J

SPECIES	DISTRIBUTION
Phyllopteryx taeniolatus	I
Pictilabrus laticlavius	I
Pictilabrus viridis	G
Plagiotremus rhinorhyncos	D
Platax teira	D
Plectorhincus flavomaculatus	D
Pseudocaranx dentex	H
Pseudolabrus biserialis	G
Pseudophycis breviuscula	J
Rhabdosargus sarga	E
Schuettia woodwardi	F
Scobinichthys granulatus	H
Scorpaena sumptuosa	F
Scorpaenodes steeni	E
Scorpis aequipinnus	J
Scorpis georgianus	I
Seriola lalandi	H
Sillaginoides punctat	I
Siphamia cephalotes	I
Siphonognathus beddomei	J
Siphonognathus caninis	J
Sphyraena obtusata	D
Spratelloides robustus	H
Sticharium dorsale	J
Suezichthys cyanoleamus	E
Synchiropus papilio	H
Syphraena novaehollandiae	J
Thalassoeletris adela	J
Thysanophrys cirronasus	I
Tilodon sexfasciatum	J
Trachichthys australis	I
Trachinops brauni	G
Trachinops noarlungae	I
Trachurus novaezelandiae	H
Trygonoptera ovalis	I
Upenichthys lineatus	I
Vincentia badia	I
Vincentia puncata	G

DISTRIBUTION RANGE

H Warm temperate species, widely distributed south and east of Shark Bay to other States.
E Subtropical species that range from Coral Bay to Cape Leeuwin
I Warm temperate species, widely distributed south and east of the Houtman Abrohlos Islands or Port Denison to other States.
G Warm temperate species that range from the Houtman Abrohlos Islands to the Recherche Archipelago.
D Tropical species whose southernmost limit is usually Rottnest Island.
J Warm temperate species, widely distributed from Rottnest Island or Lancelin south and east to other States.
F Subtropical species that range from Shark Bay to the Recherche Archipelago.
- Unusual distribution.

APPENDIX 5. SPECIES COMPOSITION, RELATIVE DENSITY, LIFE HISTORY, TROPHIC LEVEL AND GEOGRAPHIC RANGE OF THE FISH ASSEMBLAGES OCCURRING IN THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION (Ayvasian & Hyndes 1995)

SPECIES	ASSEMBLAGE C	F	G	LIFE HISTORY	TROPHIC LEVEL	RANGE
Acanthalutes spilomelanurus		✓		R	O	Te
Aldrichetta forsteri	✓✓	✓	✓	N	O	Te
Allanetta mugiloides		✓✓		R	Z	Te
Ammotretis elongatus	✓	✓		R	BI/BM	Te
Amniataba caudavittatus		✓		T	BM	Tr
Apogon reuppellii	✓	✓		R	BI/BM	Te
Aptychotrema vincentiana		✓		T	BM/P	Te
Arripis georgianus	✓	✓		T	BM	Te
Atherinomorus oglibyi	✓✓	✓		R	Z	Tr
Atherinosoma elongata		✓✓		R	Z	Te
Callionymus goodladi		✓		R	BI/BM	Te
Centropogon latifrons		✓		R	BM/P	Te
Cnidoglanis macrocephalus		✓	✓✓	R	BI/BM	Te
Contusus brevicaudus		✓		N	O	Te
Cristiceps aurantiacus		✓		T	BM/P	Te
Diodon nicthemerus		✓		T	BM	Te
Enoplosis armatus		✓	✓	R	BM	Te
Favonigobius lateralis	✓	✓		R	BI	Te
Filocampus tigris		✓		R	BI	Tr
Gerres subfasciatus	✓			T	BM	Te
Haletta semifasciata		✓		R	O	Te
Halichoeres brownfeldi		✓		R	BI/BM	Te
Heteroclinus adelaidae		✓		T	BM/P	Te
Heteroclinus roseus		✓	✓	T	BM/P	Te
Histiogamphelus cristatus		✓		R	BI	Te
Hyperlophus vittatus	✓✓	✓		N	Z	Te
Hyporhamphus melanochir	✓			R	O	Te
Kyphosus sydneyanus		✓		N	H	Tr
Leptatherina presbyteroides		✓✓✓	✓✓	R	Z	Te
Lesuerina sp.	✓	✓	✓	R	BI/BM	Te
Leviprora inops		✓		N	BM/P	Te
Microcanthus strigatus		✓		T	BM	Tr
Mugil cephalus	✓✓	✓		N	O	C
Neoodax belteatus		✓		R	O	Te
Parequula melbournensis			✓	T	BM	Te
Pelates quadralineatus		✓		N	BM	Tr
Pelsartia humeralis		✓	✓	N	BM	Te
Penicipelta vittiger	✓			R	O	Te
Platycephalus speculator		✓		N	BM/P	Te
Polyspina piosae		✓		N	O	Te
Pomatomus saltatrix	✓			N	P	Te
Pseudocaranx dentex	✓	✓		T	P/Z	Te
Pseudolabrus parilus		✓		R	BI/BM	Te
Pseudorhombus jenynsi	✓	✓		R	BI/BM	C
Scobinichthys granulatus		✓		R	O	Te
Scorpis georgianus	✓			T	BM	Te
Sillaginoides punctata	✓	✓		N	BM	Te
Sillago bassensis	✓	✓	✓✓	N	BM	Te
Sillago burrus	✓✓	✓		N	BM	Tr

SPECIES	ASSEMBLAGE C	F	G	LIFE HISTORY	TROPHIC LEVEL	RANGE
Sillago schomburgkii	✓	✓	✓	R	BM	Te
Siphonognathus radiatus		✓		R	O	Te
Spratelloides robustus		✓	✓	N	Z	Te
Stigmatophora argus		✓		R	BI	Te
Torquigener pleurogramma	✓✓	✓✓		N	O	Te
Trioris republicae		✓		T	O	Tr

Assemblage
- **C** Busselton site only.
- **F** Dunsborough site grouped with inshore Perth sites and Rottnest and Garden Islands.
- **G** Black Point only.

Relative density
- ✓ low density (1-9 fish/100m^2);
- ✓✓ moderate density (10-99 fish/100m^2);
- ✓✓✓ high density (>100 fish/100m^2).

Life history categories
- **R** resident;
- **N** nursery juveniles;
- **T** transient.

Trophic level
- **Z** zooplanktivore;
- **BI** benthic microinvertivore;
- **BM** benthic macroinvertivore;
- **P** piscivore;
- **H** herbivore.

Geographic range
- **Te** temperate;
- **Tr** tropical;
- **C** circum Australia.

APPENDIX 6. FISH FAUNAS OF FLINDERS BAY AND THREE SITES IN HARDY INLET (Valesini *et al.*, 1997)

SPECIES	LIFE HISTORY	ESTUARY BASIN (% of total fish numbers)	ESTUARY CHANNEL (% of total fish numbers)	DEADWATER LAGOON (% of total fish numbers)	FLINDERS BAY (% of total fish numbers)
Afurcagobius suppositus	E	5.6	1	0.2	
Aldrichetta forsteri	O	2	1.7	1.8	1
Ammotretis elongata	S		<0.1		0.3
Amoya bifrenatis	E/M	0.2	<0.1	<0.1	
Apogon reuppellii	E/M		<0.1		
Arripis georgianus	O		<0.1	<0.1	0.3
Arripis truttaceus	O			<0.1	
Atherinomorus ogilbyi	O				0.1
Atherinosoma alongata	E	2.9	3.4	28.1	
Cnidoglanis macrocephalus	E/M	<0.1	0.1	<0.1	4.2
Contusus brevicaudatus	O		0.1	<0.1	0.1
Cristiceps australis	S	<0.1	<0.1		0.1
Engraulis australis	E/M	0.4	<0.1		
Enoplosus armatus	S	0.1	<0.1		
Favonigobius lateralis	E/M	21.2	17.4	11.6	
Gonorynchus greyi	O				<0.1
Haletta semifasciata	S	0.1	0.1		
Halichoeres brownfieldi	S	<0.1			
Hyprhamphus melanochir	E/M	<0.1			0.2
Kyphosus sydneyanus	S		<0.1		
Leptatherina presbyteroides	E/M	13.6	39.8	25.1	76
Leptatherina wallacei	E	35.5	8.1	24.2	
Leseurina platycephalus	SM				3.2
Mugil cephalus	O	0.1	<0.1	0.5	0.1
Pagrus auratus	S		<0.1		
Paraplagusia unicolor	SM				0.6
Pelates sexlineatus	O	11.5	21.3	0.5	
Pelsartia humeralis	SM				4.2
Penicipelta vittiger	S	<0.1			
Platycephalus laevigatus	S	<0.1			
Platycephalus speculator	E/M	<0.1	<0.1		0.3
Pseudocaranx dentex	S		<0.1		
Pseudogobius olorum	E	2.4	1.3	1.2	
Pseudolabrus parilus	S	0.1	<0.1	<0.1	
Pseudorhombus jenynsii	O	0.2	0.1	<0.1	0.2
Rhabdosargus sarba	O	3.8	4.9	5	0.1
Scobinicthys granulatus	S	0.1	<0.1		<0.1
Scorpis georgianus	SM				<0.1
Sillaginoides punctata	O	0.1	0.1	1.2	
Sillago bassensis	S	<0.1	0.3		4.6
Sillago burrus	O	<0.1			
Sillago schomburgkii	O	0.2	<0.1	0.2	1.5

SPECIES	LIFE HISTORY	ESTUARY BASIN (% of total fish numbers)	ESTUARY CHANNEL (% of total fish numbers)	DEADWATER LAGOON (% of total fish numbers)	FLINDERS BAY (% of total fish numbers)
Spratelloides robustus	S	0.1	0.2	<0.1	2.3
Stigmatophorus argus	S			<0.1	0.1
Torquigener pleurogramma	O	0.1	0.1	0.2	0.4
Trachurus mccullochi	S		<0.1		
Trygonorhina fasciata	SM				0.1
Upenichthys sp.	S		<0.1		
Urocampus carinirostris	E/M	<0.1		<0.1	0.1
TOTAL No. of SPECIES		**31**	**34**	**23**	**26**

Life History Category

E estuarine,
E/M estuarine and marine,
O opportunist,
S marine straggler,
SM solely marine.

Density of fish at each site is given as a percentage of the total number of individuals recorded for each site.

APPENDIX 7. FISH SPECIES RECORDED ON THE HMAS SWAN DIVE WRECK (Dr Peter Morrison, Sinclair Knight Mertz, Perth, *pers. comm*.)

SPECIES
Black banded sea perch
Black headed puller
Blackspot goatfish
Black spotted wrasse
Blue lined hulafish
Blue lined leatherjacket
Blue spotted goatfish
Breaksea cod
Brown spotted boarfish
Brown spotted wrasse
Common bullseye
Dusky morwong
Eagle ray
Estuary catfish
False tasmanian blenny
Fiddler ray
Footballer sweep
Fusilier sweep
Globe fish
King george whiting
Little rainbow wrasse
Long finned pike
Long snouted boarfish
Long snouted flathead
Masked stingaree
Moonlighter
Mosaic leatherjacket
Old wife
Pencil weed whiting
Pink snapper
Port jackson shark
Red lipped morwong
Ringed toadfish
Rough bullseye
Rough leatherjacket
Roughy
Round faced batfish
Samson fish
Sergeant baker
Shaw's cowfish
Silver trevally
Slender bullseye
Southern blue spotted flathead
Southern silverbelly
Spiny tailed leatherjacket
Spotted grubfish
Striped seapike
Striped stingaree
Swallowtail
Tarwhine

SPECIES
Wavy grubfish
West Australian jewfish
Western blue devil
Western butterfish
Western king wrasse
Western smooth boxfish
Western talma
White barred boxfish
Yellow headed hulafish
Yellow striped leatherjacket
Yellowtail kingfish

APPENDIX 8. HERMATYPIC CORALS OF THE THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION (Veron & Marsh, 1988)

SPECIES	GEOGRAPHE BAY	SOUTH OF CAPE NATURALISTE
Coscinaraea marshae	✓	✓
Coscinaraea mcneilli	✓	✓
Favites abdita	✓	
Favites complanata	✓	
Goniastrea aspera	✓	
Goniastrea australensis	✓	
Montipora mollis	✓	
Plesiastrea versipora	✓	✓
Scolymia australis	✓	✓
Symphyllia wilsoni	✓	✓
Turbinaria frondens	✓	✓
Turbinaria mesenterina	✓	✓
Turbinaria reniformis	✓	✓
Turbinaria peltata	✓	

APPENDIX 9. THE BREEDING SEABIRDS AND SHOREBIRDS OF THE ISLANDS IN THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION

SPECIES	COMMON NAME	CAPE HAMELIN	HAMELIN ISLAND	SEAL ISLAND	ST. ALOUARN ISLAND	SUGARLOAF ROCK
Eudyptula minor	Fairy penguin		2	2		
Hydroprogne caspi	Caspian tern			2		
Larus novaehollandiae	Silver gull		1, 2	2	2	1
Neophemea petrophila	Rock parrot		2	2	2	
Pelagodroma marina	White faced storm petrel	1			2	
Phaethon rubricauda	Red tailed tropicbird					1
Puffinus assimilis	Little shearwater				2	
Puffinus carniepes	Flesh footed shearwater	1		1, 2		
Sterna anethetus	Bridled tern		1, 2	1, 2		
Sterna bergii	Crested tern		1	1, 2		
Sterna nereis	Fairy tern			1, 2		

Source: (1) Burbidge & Fuller, CALM Seabird Breeding Islands Database
(2) Gillham (1961, 1963)

APPENDIX 10. SEABIRDS OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION

SPECIES	COMMON NAME	STATUS	SOURCE
Actitis hypoleucos	Common sandpiper	Uncommon *	3
Anous stolidus	Common noddy	Uncommon	1
Anous tenuirostris	Lesser noddy	Uncommon	1
Aptenodytes patagonicus	King penguin	Very Rare	1
Calidris acuminata	Sharp tailed sandpiper	Uncommon *	3
Calidris alba	Sanderling	Uncommon *	3
Calidris ruficollis	Red necked stint	Uncommon *	3
Calonectris leucomelas	Streaked shearwater	Rare	3
Catharacta skua	Great skua	Scarce	1
Charadrius leschenaulti	Large sand plover	Uncommon *	3
Charadrius ruficapillus	Red capped plover	Uncommon *	3
Daption capens	Cape petrel	Uncommon	1
Diomedia cauta	Shy albatross	Scarce	1
Diomedia chlororhyncos	Yellow nosed albatross	Rare	1
Diomedia chrysostoma	Grey headed albatross	Uncommon	1
Diomedia epomophora	Royal albatross	Rare	1
Diomedia exulans	Wandering albatross	Moderately Common	1
Diomedia melanophrys	Black browed albatross	Common	1
Diomedia salvini	Unnamed albatross	Scarce	1
Eudyptes chrysocome	Rockhopper penguin	Common	1
Eudyptes chrysolophus	Macaroni penguin	Very Rare	1
Eudyptes pachyrhincos	Fiordland penguin	Uncommon	1
Eudyptula minor	Little penguin	Common	1
Fregata minor	Great frigate bird	Very Rare	1
Fulmaris glacialoides	Southern fulmar	Scarce	1
Haliaetus leucogaster	White bellied sea eagle	Uncommon	3
Halobaena caerulea	Blue petrel	Rare	1
Hematopus fuliginosus	Sooty oystercatcher	Uncommon	3
Hematopus longirostris	Pied oystercatcher	Uncommon	3
Larus novaehollandiae	Silver gull	Common	1
Larus pacificus	Pacific gull	Uncommon	1
Limosa laponica	Bar tailed godwit	Uncommon *	3
Lugensa brevirostris	Kerguelen petrel	Rare	1
Macronectes giganteus	Southern giant petrel	Common	1
Macronectes halli	Northern giant petrel	Scarce	1
Morus capensis	Cape gannet	Very Rare	1
Morus serrator	Australian gannet	Common	1
Numenuis phaeopus	Whimbrel	Uncommon *	3
Oceanites oceanicus	Wilson ϧ storm petrel	Common	1
Oceanodroma leucorhoa	Leach ϧ storm petrel	Rare	1
Pachyptila belcheri	Slender billed prion	Common	1
Pachyptila desolata	Antarctic prion	Rare	1
Pachyptila salvini	Salvin ϧ prion	Common	1
Pachyptila turtur	Fairy prion	Moderately Common	1
Pachyptila vittata	Broad billed prion	Rare	3
Pandion haliaetus	Osprey	Common	3
Pelagodroma marina	White faced storm petrel	Common	1
Pelecanoides urinatrix	Common diving petrel	Scarce	1
Pelicanus conspicillatus	Australian pelican	Common	3
Phaethon rubricauda	Red tailed tropicbird	Rare and Endangered	1

SPECIES	COMMON NAME	STATUS	SOURCE
Phalacrocorax carbo	Great cormorant	Uncommon	3
Phalacrocorax melanoleucos	Little pied cormorant	Common	3
Phalacrocorax sulcirostris	Little black cormorant	Common	3
Phalacrocorax varius	Pied cormorant	Moderately Common	1
Pheobetria fusca	Sooty albatross	Scarce	1
Pheobetria palpebrata	Light mantled sooty albatross	Rare	1
Procellaria aequinoctialis	White chinned petrel	Rare	1
Procellaria aequinoctialis	White chinned petrel	Uncommon	3
Procellaria cinerea	Grey petrel	Uncommon	1
Pterodroma gouldi	Unnamed petrel	Rare	1
Pterodroma lessonii	White headed petrel	Uncommon	1
Pterodroma macroptera	Great winged petrel	Common	1
Pterodroma mollis	Soft plumaged petrel	Common	1
Puffinus assimilis	Little shearwater	Common	1
Puffinus carniepes	Flesh footed shearwater	Common	1
Puffinus griseus	Sooty shearwater	Rare	1
Puffinus huttoni	Hutton ȿ shearwater	Uncommon	3
Puffinus pacificus	Wedge tailed shearwater	Common	1
Puffinus tenuirostris	Short tailed shearwater	Uncommon	1
Stercorarius parasiticus	Arctic jaeger	Uncommon	1
Stercorarius pomarinus	Pomarine jaeger	Uncommon	3
Sterna albifrons	Little tern	Uncommon	2
Sterna bergii	Crested tern	Common	1
Sterna caspia	Caspian tern	Moderately Common	1
Sterna fuscata	Sooty tern	Rare	1
Sterna hirundo	Common tern	Very Rare	1
Sterna paradisea	Arctic tern	Very Rare	1
Thinornis rubricollis	Hooded plover	Uncommon *	3
Tringa nebularia	Common greenshank	Uncommon *	3

***** Shore birds.

Source: **1** Burbidge, Johnstone and Fuller (1996);
2 R.Wooller (*pers. comm.*)
3 R. Payton (*pers. comm.*). Status refers to occurrence in the Geographe Bay-Capes-Hardy Inlet region area only.

APPENDIX 11. COASTAL WETLANDS OF THE CAPES-GEOGRAPHE BAY-HARDY INLET REGION

WETLAND GROUP	AREA (ha)	DESCRIPTION	OUTSTANDING VALUES
Capel River Marshes	220	Coastal floodplain marshes, medium in size, at the bottom of the Capel River.	
Layman Gully Lakes	50	Medium sized lakes south-west of Capel, on private land.	
Capel Swamps	180	Scattered medium sized swamps between the Capel and Ludlow Rivers, mostly private land, but some reserved land also. Considerable remnant vegetation, including the rare aquatic plant *Aponogeton hexatepalus.*	
Ludlow Wetlands and McCarley's Swamp	30	Area of small lakes, swamps and flooplain east of Bussel Hwy, on private land. McCarleys swamp is an important waterbird breeding habitat, and contains the rare aquatic plant *A. hexatepalus.*	Naturalness Faunal Habitat/Sanctuary
Tutunup Rd Lake		Small lake north of the Ludlow River on private land.	Representative Naturalness
Tutunup Rd Swamps		Two small swamps east of Tutunup Rd on private land.	
Wonnerup Rd Swamp		Small swamp on the headwaters of the Ludlow River.	
Princefield Rd Floodplain	200	Large floodplain on a tributary of the Vasse Estuary on private land	
Ludlow-Abba Wetland	10	Small lakes, swamps and floodplain between the Ludlow and Abba Rivers. Mostly private land. Rare wetland plants, including *A. hexatepalus* and the sedge *Schoenus natans*.	Naturalness
Vasse-Wonnerup Estuary and associated wetlands	2000	Large estuarine marshland and tidal floodplain around the Vasse-Wonnerup wetland. Very important waterbird habitat.	Faunal Habitat/Sanctuary
Broadwater Floodplain and Toby's Inlet	700	Large tidal floodplain and lagoons on the original Vasse and Carbanup Rivers, mostly private land. Significant waterbird habitat, and contains the rare aquatic plant *Villarsia submersa*.	Faunal
Williamson Rd Swamp	40	Small seasonal swamp on private land	

WETLAND GROUP	AREA (ha)	DESCRIPTION	OUTSTANDING VALUES
Bunkers Bay Lake (Lake Jingi)	4	Small lake behind foredune on private land. Significant tree cover remains around the lake. Very pretty.	
Naturaliste Lake Wetlands		Small lake at the headwaters of the Eagle Bay Creek on private land. Located on the edge of a large area of coastal vegetation.	Representative Faunal
Quininup Rd Lake Wetlands		Small lake and swamp on the headwaters of the Wyadup Brook.	
Moses Rock Rd Swamp		Medium sized swamp on private land.	
Silverwood Swamp		Small swamp on private land.	
Ablett Rd Swamp		Small swamp on private land.	
Margaret River Swamps		Medium sized permanent and seasonal swamps and floodplains along the upper reaches of the Margaret River. All in State Forest. Important wetland habitat.	Representative Naturalness
Kilcarnup Rd Swamps		Small coastal swamps on private land.	
Wilderness Drive Swamps		Small swamps on private land.	
Devils Pool		Small pool on Boodjidup Bk adjacent to public land. Surrounded by very high quality native vegetation.	Naturalness
Lake Davies Wetlands		Three small swamps and a small lake in the Leeuwin-Naturaliste NP. Very pristine condition.	Naturalness
Turner Brook Wetlands	220	Areas of floodplain on private land.	
West Bay Creek Floodplain	110	Floodplains with seasonal swampland on the West Bay Creek, private land.	
Glenarty Creek Floodplains	600	Large floodplains and seasonal swamps on the Glenarty Creek, private land.	
Pt Pedder Swamps	400	Small and large swamps and floodplain around Pt Pedder, near Molloy Island, on private land. Surrounded by considerable remnant vegetation.	Representative Naturalness
Lower Blackwood Wetlands	1 700	Extensive areas of seasonal swamp and floodplain, mostly on cleared land. A large wetland is in the Scott NP.	Representative Naturalness
Scott River Wetland System	20 000	Huge areas of seasonal swamp, floodplain and small to large permanent lakes. Mostly cleared but some areas in Scott NP and nature Reserves. 7 of the southwest § 8 endemic fish species occur. Two rare plant species also.	Representative Naturalness

WETLAND GROUP	AREA (ha)	DESCRIPTION	OUTSTANDING VALUES
Gingilup Swamp Wetlands	2 000	Large permanent swamps amongst seasonal swampland, mainly within Gingilup Nature Reserve. There are seven rare wetland plants recorded in the area and numerous rare terrestrial plants. This is an important wetland habitat due to its pristine condition and isolation.	Representative Naturalness Habitat/Sanctuary
Bolghinup Lake Swamp		Small lake on Black Point in the D Entrecasteaux NP. This is a unique wetland in coastal limestone underlain by calcrete.	Naturalness

Source: Pen (1997)
Important wetlands with outstanding value are shown in bold.

APPENDIX 12. FISH AND CRUSTACEA OF HARDY INLET AND THE LOWER BLACKWOOD RIVER (Lenanton, 1974)

SPECIES
ELASMOBRANCHII
Parascyllium variolatum
PETROMYZONES
Geotria australis
TELEOSTOMI-Commercial species
Aldrichetta forsteri
Arripis georgianus
Australuzza novaehollandiae
Chrysophrys unicolor
Cnidoglanis macrocephalus
Mugil cephalus
Mylio butcheri
Navodon multiradiatus
Pomatomus saltater
Pseudomonacanthus sp.
Pseudorhombus jenynsii
Rhabdosargus sarba
Sillago punctata
Sillago schomburgkii
TELEOSTOMI - Non-commercial species
Atherinosoma sp.
Contusus richei
Ellogobius olorum
Galaxias occidentalis
Glossogobius supposititus
Gonorhyncus greyi
Gymnothorax woodwardi
Helotes sexlineatus
Melambaphes zebra
Ophisurus serpens
Sphaeroides pleurogramma
Therapon humeralis
Upeneichthys porosus
TELEOSTOMI-Freshwater introduced species
Crassius carassius
CRUSTACEA
Apheus sp.
Cyclograpsus audouinii
Heteropanope serratifrons
Leptograpsodes octodentatus
Ovalipes australiensis
Palaemonetes australis
Portunus pelagicus

APPENDIX 13A. MAMMALIAN FAUNA OF THE COASTAL SCRUB OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION

SPECIES	COMMON NAME	STATUS
Antechinus flavipes	Mardo	Common-rarely seen
Canis familiaris	Dog	Introduced
Cercartetus concinnus	Western Pygmy Possum	Common
Chalinolobus gouldii	Gould's Wattled Bat	
Chalinolobus morio	Chocolate Wattled Bat	
Dasyurus geoffroii	Chuditch	Vulnerable
Eptesicus regulus	King River Eptesicus	
Felis catus	Feral Cat	Introduced
Hydromys chrysogaster	Water Rat	In need of monitoring
Isoodon obesulus	Brown Bandicoot or Quenda	In need of monitoring
Macropus eugenii	Tammar Wallaby	In need of monitoring*
Macropus fuliginosus	Western Grey Kangaroo	Common
Macropus irma	Western Brush Wallaby	In need of monitoring
Mus musculus	House Mouse	Introduced
Nyctophilus geoffroyi	Lesser long-Eared Bat	
Nyctophilus major	Long-Eared Bat	
Oryctolagus cuniculus	Rabbit	Introduced
Phascogale tapoatafa	Brush-Tailed Phascogale	Unknown
Pseudocheirus occidentalis	Western Ringtail Possum	Vulnerable
Rattus fuscipes	Western Bush Rat	
Rattus rattus	Black Rat	Introduced
Setonix brachyurus	Quokka	Vulnerable*
Sminthopsis griseoventer	Dunnart	Common
Tachyglossus aculeata	Echidna	Common-rarely seen
Tarsiepes rostratus	Honey Possum	Common-rarely seen
Trichosurus vulpecula	Common Brushtail Possum	Common
Vulpes vulpes	Fox	Introduced

* Has not been trapped in the area for several years.

Status: **Vulnerable**-IUCN Rankings for specially protected fauna under the WA Wildlife Conservation (Specially Protected Fauna) Notice 1998.

Source: How *et al.* (1987) and G.Voight (CALM Wildlife, Busselton, *pers. comm.*)

APPENDIX 13B. COASTAL AMPHIBIANS OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION (How *et al.*, 1987)

SPECIES	COMMON NAME
Crinia georgiana	
Geocrina leai	
Helioporus eyeri	Moaning frog
Helioporus inornatus	Burrowing frog
Helioporus psammophilus	
Limnodyastes dorsalis	Western banjo frog
Litoria adelaidensis	Slender tree frog
Litoria moorei	Western green tree frog
Neobatrachus pelabatoides	Humming frog
Pseudophyrne guentheri	Guenther's toadlet
Pseudophyrne nichollsi	
Ranidella insignifera	
Ranidella glauerti	

APPENDIX 13C. TERRESTRIAL REPTILES OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION

SPECIES	COMMON NAME
Apraisia repens	Legless lizard
Cryptoblepharus plagiocephalus	Wood skink
Ctenotus catenifer	
Ctenotus delli	
Ctenotus impar	
Ctenotus labillardieri	Red-legged skink
Egernia kingii	King's skink
Egernia luctuosa	Mourning skink
Egernia napoleonis	Smith's skink
Egernia pulchra	Fry's skink
Hemiergis peroni	Burrowing skink
Hemiergis quadrilineata	
Leiolopisma trilineatum	New holland skink
Lerista distinguenda	
Lerista elegans	
Lerista microtis	
Lialis burtonis	Burton's snake lizard
Menetia greyii	Grey's skink
Morelia spilota	Carpet python
Morethia lineoocellata	Sandhill skink
Notechis coronatus	
Notechis curtus	
Notechis minor	
Notechis scutatus	Tiger snake
Phyllodactylus marmoratus	Marbled gecko
Pogona minor	Dragon lizard
Psuedonaja affinis	Dugite
Pygopus lepidopus	Common scaly-foot
Ramphotyphlops australis	Blind snake
Rhinoplocephalus bicolor	Meuller's snake
Rhinoplocephalus gouldii	
Rhinoplocephalus nigriceps	
Sphenomorphus australis	
Tiliqua rugosa	Bobtail
Varanus gouldii	Bungarra
Varanus rosenbergi	
Varanus tristis	Racehorse goanna
Vermicella semifasciata	

Source: How, Dell & Humphreys (1987) and G.Voight (CALM Wildlife, Busselton, *pers. comm.*).