MARINE RESERVE IMPLEMENTATION:
CENTRAL FOREST

RESOURCE ASSESSMENT SUMMARY FOR THE PROPOSED GEOGRAPHE BAY-CAPES- HARDY INLET MARINE CONSERVATION RESERVE

VERSION 1

Report: MRI/LNE/GBC-54/2001

A project funded through the Natural Heritage Trust, Coast and Clean Seas, Marine Protected Areas Program.
Project Number: WA9801

Prepared by
A K Hill & K A Ryan
Marine Conservation Branch

February 2002

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

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Cover. Busselton Jetty, courtesy of Mick Eidam

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CONTENTS

A INTRODUCTION **1**

B PROCEDURAL GUIDELINES **2**

1 STUDY AREA **2**

ECOLOGICAL VALUES

2 GEOLOGY AND GEOMORPHOLOGY **3**

3 DRAINAGE AND GROUNDWATER **15**

4 CLIMATE **27**

5 OCEANOGRAPHY **30**
WATER LEVEL 30
WAVES/SWELL 32
CURRENTS 35
WINDS 40
TEMPERATURE & SALINITY 42

6 BATHYMETRY **46**

7 MARINE AND COASTAL COMMUNITIES **48**

8 MARINE FAUNA **81**

9 MARINE FLORA, PROTISTS AND BACTERIA **114**

10 COASTAL TERRESTRIAL BIOTA **119**

SOCIAL VALUES

11 CULTURAL HISTORY **123**
ABORIGINAL 123
MARITIME 127
MILITARY 131

12 TENURE **132**

13 INFRASTRUCTURE AND FACILITIES **135**
COASTAL ACCESS 136
SHIPPING AND BOATING 138
SEWAGE 141

14 WATER QUALITY **146**

15 COMMERCIAL FISHING **160**

16 AQUACULTURE AND PEARLING **161**

17 TOURISM **162**

18 MINING AND PETROLEUM **169**

19 RECREATIONAL FISHING **171**

20 NON-EXTRACTIVE RECREATIONAL ACTIVITIES **173**

21 EDUCATION **179**

C RANKING VALUES AND PRIORITIES FOR MANAGEMENT **182**

D REFERENCES **183**

E MAP PRODUCTS FOR THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION **191**

* Figure 1 Locality map of the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 2 Tenure of the Geographe Bay-Capes-Hardy Inlet region
* Figure 3 Major benthic and coastal habitats of the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal

* Figure 4 Wildlife distribution of the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 5 Paddle boating in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 6 Diving (SCUBA and snorkelling) in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 7 Jetskiing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 8 Windsurfing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 9 Wildlife interaction in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 10 Waterskiing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 11 Swimming in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 12 Surfing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 13 Sailing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 14 Recreational line fishing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 15 Recreational crayfishing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 16 Recreational abalone fishing proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 17 Recreational crabbing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 18 Recreational netting in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 19 Recreational spear fishing in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal
* Figure 20 Commercial fishing zones in the proposed study area for the Geographe Bay-Capes-Hardy Inlet marine conservation reserve proposal

LIST OF TABLES

Table 1. Percentages of the major marine habitats in the study area 6
Table 2 Percentages of the coastal habitats in the study area 6
Table 3 Major estuaries within/adjacent to the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 18
Table 4 Wetlands adjacent to the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 20
Table 5 Major rivers which flow to the coast or to an inlet of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 21
Table 6 Tidal elevations at Busselton 30
Table 7 Geographe Bay flushing times for a constant wind speed of 5.5m/s 41
Table 8 Percentages of the seagrass habitat in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 50
Table 9 Seagrass species of the Geographe Bay-Capes-Hardy Inlet region 52
Table 10 Population size and relevant surveys of the cetaceans of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 82

Table 11 Cetaceans which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. 84
Table 12 Distribution, seasonality of occurrence and behavioural patterns of cetaceans of special conservation status which occur in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 85
Table 13 Population size and relevant surveys of the pinnipeds of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. 86
Table 14 Pinnipeds which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. 87
Table 15 Distribution, seasonality of occurrence and behavioural patterns of pinnipeds of special conservation status which occur in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 88
Table 16 Birds which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. 91
Table 17 Echinoderms which may occur in the study area of the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 98
Table 18 Echinoderms which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 100
Table 19 Distribution of endemic echinoderms of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 100
Table 20 Hermatypic corals of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 106
Table 21 Distribution of endemic corals of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 107
Table 22 Ascidians of the Geographe Bay-Capes-Hardy Inlet region 109
Table 23 Sponges of the Geographe Bay-Capes-Hardy Inlet region 110
Table 24 Declared rare flora and threatened ecological communities of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 120
Table 25 The breeding seabirds and shorebirds of the islands in the Geographe Bay-Capes-Hardy Inlet region 121
Table 26 Details of the shipwrecks of the study area for the the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 130
Table 27 Median and 90th percentile (in parentheses) background levels for selected water qualtiy parameters for the 'nearshore' and 'offshore' south Western Australian coastal waters in summer and winter 147
Table 28 Major nutrient sources to the southern part of Geographe Bay 150
Table 29 Cyanobacteria recorded in Vasse-Wonnerup estuaries, 1996-1997 153
Table 30 South West Region's tourism industry: Domestiv visitor profile 163
Table 31 South West Region's tourism industry: All visitors 164
Table 32 Participants in shoreline activities in the study area for the the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 173
Table 33 Leeuwin-Naturaliste region: Private boat distribution by postcode 175
Table 34 Coastwest/Coastcare projects in the study area for the the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve which received funding in the 1999/2000 year 180
Table 35 Coast & Clean Seas projects in the study area for the the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve 180

A INTRODUCTION

The Western Australian Government is committed to establishing a statewide representative system of multiple use marine conservation reserves under the *Conservation and Land Management (CALM) Act 1984* to protect the diverse and valuable natural heritage values of our nearshore marine environment. The *CALM Act* provides the framework for sustainable commercial and recreational use of these resources. In 1986, a Marine Parks and Reserves Selection Working Group (MPRSWG) was established to identify marine areas that where thought to be worthy of consideration for marine reserve status. The MPRSWG identified 70 areas around the Western Australian coast (The Department of Conservation and Land Management, 1994) which, if reserved, would provide a system of marine conservation reserves that would be representative of all the major ecosystems of the State.

In December 1997, the Western Australian Government, following advice provided by the Western Australian Marine Parks and Reserves Authority, announced the Geographe Bay/Leeuwin-Naturaliste/Hardy Inlet region was a priority area for establishment as a marine conservation reserve. Subsequently, the Department, through the Marine Conservation Branch (MCB), has initiated the planning process for implementing this marine conservation reserve.

Under the State Government's marine 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".

The Resource Assessment Summary of the Geographe Bay/Leeuwin-Naturaliste/Hardy Inlet region has been developed to ensure that there is adequate information to support the planning process. The resource assessment has relied on information (written and spatial) from both the Department and external sources including other Government agencies, non-Government agencies and the local community to document and assess the region's ecological and social values. It has direct links with the Department's Geographic Information Services data acquisition program.

The planning process for marine conservation reserves can take up to five years, and during this period new information will become available. As such, the Resource Assessment Summary for the Geographe Bay/Leeuwin-Naturaliste/Hardy Inlet region will be dynamic and continually updated as required throughout the planning process of the marine conservation reserve. It will therefore maintain an up-to-date reference for the Department during the planning process, and provide the basis for the preparation of the Indicative Management Plan. In the longer term, the information gathered throughout the resource assessment phase will be transferred to the managers of each reserve and provide a reference for ongoing management.This report provides all information which has been made available as at February, 2002.

B PROCEDURAL GUIDELINES

1 STUDY AREA

1.1 Why was the study area identified for consideration as a marine conservation reserve by the Marine Parks and Reserves Selection Working Group in their 1994 report?

The following values and pressures were identified by the Working Group in support of their recommendation for declaration of a marine reserve for the coast from Geographe Bay to Cape Leeuwin:

- the wide range of habitats (eg the sandy beaches and vast seagrass meadows of Geographe Bay the spectacular underwater scenery and prolific growth of tropical corals at the near-shore sublittoral area between Bunker Bay and Dunsborough);
- high recreation values, and its outstanding public recreational use potential; and
- the importance of commercial fishing in the area
  (The Department of Conservation and Land Management, 1994)

The following values and pressures were identified by the Working Group in support of their recommendation for declaration of a marine reserve for the Hardy Inlet:

- it supports a relatively large diversity of aquatic species of plants and animals;
- high recreational values; and
- the small volume of the basin and increasing human usage in the area
  (The Department of Conservation and Land Management, 1994)

2 GEOLOGY AND GEOMORPHOLOGY

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2.1 What are the key events in the geological history of the study area?

1. History of rock formation - the movements of plate tectonics has been proposed to be responsible for sea-level fluctuations and other oceanographic processes caused by volcanic and seismic activity, which has subsequently resulted in the present day geological framework.

   The WA coast is in contact with very old crystalline granites and recrystallised volcanic and sedimentary rocks which formed more than 600 million years ago. Younger sedimentary rocks (mainly sandstones and limestones) flank these older rocks, and in places extend offshore as a continental shelf.

   The nature of rocks will determine their susceptibility to the weathering and erosive processes and, in addition to the types of materials deposited on the coast, will ultimately determine their landform. This provides a basis for the variation of coastal features in the proposed study area (for example the limestone reef at Yallingup; the sandy shores of Geographe Bay; and the granite rocky shores at Cape Naturaliste).

2. Changes in sea level – the WA coast is the result of a relatively recent major rise in sea level over the past 20,000 years, related to melting of the northern hemisphere ice sheets. There was an initial rapid rise in global sea level, which subsequently declined significantly from about 8000 BP. Global sea level is then believed to have risen more slowly to about 2m above present sea level around 5000 BP, before declining and stabilising to present levels in the period from 4,500 years ago to the present.

   As sea levels rose to present levels, eroded areas/valleys were flooded forming bays and inlets whilst old dunes, high spots and ridges of resistant rock formed reefs, islands, promontories and headlands. Vast quantities of unconsolidated sedimentary material were swept ashore from the drowned continental shelf and deposited in bays between resistant headlands or behind islands and reefs. This led to a major phase of dune building and beach ridge development. This process is exemplified in the formation of the primary dune ridge along much of Geographe Bay, which has created features such as the Deadwater and the elongated inlets to the rear barrier estuaries.

   The history of sea level change influenced the formation of the Hardy Inlet and other estuaries of the proposed study area. The estuaries were formed when glacio-eustatic marine transgression reached present sea-level c.7000 BP. The free exchange between ocean and estuary following the post-glacial rise of sea level permitted establishment of a diverse fauna characteristic of sheltered marine embayments. This condition persisted until about 4000 BP, after which there was a

reduction in faunal diversity, a disappearance of a number of dominant marine species and a replacement with an impoverished, predominantly true estuarine fauna. This implies a reduced exchange with the ocean and a considerable increase in the salinity extremes, and is primarily speculated to be a retreat of relative sea level from a mid-Holocene high up to 2m above the present. However, other possible attributing factors could be a change in sea water temperature; geomorphic change; and/or a climatic change affecting the pattern of rainfall (Hodgkin and Kendrick, 1984)

3. Weathering and erosive processes – since the stabilisation of sea level, physical (salt) and chemical weathering; wind, wave and biological erosion; and depositional processes have shaped WA's coast. For example, the Leeuwin-Naturaliste coast has been particularly subject to wind and wave attack, so that resistant rocks now stand out as headlands. Geographe Bay, in contrast, has a lower wind and wave energy environment, and as such is characterised by depositional forms (beaches). Geographe Bay is characterised by a sinuous appearance, due to the location of alternating erosion and accretion zones (Searle and Logan, 1978).

4. Past and present sediment supplies - The continuous south-west swell and prevailing wind waves have favoured the movement of sediment away form the south-west corner by littoral currents to be deposited as dune and beach ridge systems in sheltered bays to the north and to the east (Department of Conservation & Environment, Bulletin No 49).

2.2 Is the geology/geomorphology of the study area generally uniform, or does the study area consist of distinct coastal zones?

The Geographe Bay-Capes-Hardy Inlet region encompasses three major distinctive coastal zones:

- the low profile, low energy sandy shores of Geographe Bay
- the high energy, rocky shores of the Leeuwin-Naturaliste Ridge
- the exposed, open ocean shores of Flinders Bay
  (Elscot and Bancroft, 1998)

2.3 What are the rock and sediment types of the coastline of the study area (eg granite, gneiss, limestone) and when were they formed/deposited?

Suggested references: The Department of Conservation and Land Management (1994); Weaving (1998); and Hassan (1998)

Basin type

- The proposed study area is predominantly classified as the Leeuwin Complex. The Leeuwin Complex consists mainly of deformed granitoid rock and granitic gneiss, with minor anorthosite and mafic granulite. The age of the complex is poorly constrained, with dates between c. 1480 and c.560 Ma being recorded (Hassan, 1998).
- East of the Dunsborough areas and east of the Hardy Inlet region, the geology is classified as Albany – Fraser Oregon (waters) and Perth Basin (land). The Albany-Fraser Oregon trends in an easterly direction along much of the south coast of the

Southwest. At the western end, the trend of the Oregon turns abruptly southward and is partly truncated by the Darling Fault.

- The Perth Basin developed over the Pinjarra Oregon as a result of major rifting that was initiated during the Silurian, at about 420 Ma, and continued intermittently until the Early Cretaceous at about 136 Ma (Hassan, 1998).

Basement type

- The study area is predominantly classified as Precambrian basement.
- East of Cape Naturaliste and east of the Hardy Inlet region, the classification is Phanerozoic basement (GIS geological units dataset, DME).

Geographe Bay

- recent Quaternary sand dunes and beach ridges: fixed and mobile calcareous sand containing heavy mineral deposits in some areas (Hassan, 1998);
- predominantly Quindalup System – coastal dunes of the Swan coastal Plain with calcareous deep sands and yellow sands;
- becoming Kilcarnup Dunes at the western end; and
- sections of Precambrian granite gneiss at the western end: mainly potassic, strongly to weakly foliated usually concordant; always present between basic granulite and coarse-grained granulite (Hassan, 1998).

Leeuwin-Naturaliste

- deposited during the Proterozoic period, about 2,500 million years ago;
- sections of intensely deformed plutonic igneous rocks, mainly granite and gneiss: mainly potassic, strongly to weakly foliated usually concordant; always present between basic granulite and coarse-grained granulite (Hassan, 1998);
- the Leeuwin-Naturaliste Ridge is separated from the Perth Basin by the Dunsborough Fault;
- at several locations (including Yallingup, Cowaramup Bay, Kilcarnup, and Hamelin Bay) Quaternary (late Pleistocene) aeolianite limestones with minor occurrences of fossil soil and beach conglomerate have been deposited over the granites and gneisses, sometimes with considerable thicknesses (Hassan, 1998; The Department of Conservation and Land Management, 1994);
- Yallingup Shelf, an area of shallow basement, extends to the continental slope;
- predominantly Kilcarnup Dunes – coastal dunes overlying limestone and rocky headlands in the Leeuwin Zone with calcareous deep sand, calcareous shallow sand and calcareous stony soil; and
- sections of Gracetown Ridge – limestone ridge in the coastal edge of the Leeuwin Zone with yellow deep sand and red deep sand.

Flinders Bay and Hardy Inlet

- Quaternary sands overlying Cretaceous sediments;
- a Holocene dune field backs the shore;
- between Cape Leeuwin and Israelite Bay the coast is underlain by tough granite rocks (The Department of Conservation and Land Management, 1994);
- the Hardy Inlet opens against the Precambrian rocks of the Naturaliste-Leeuwin ridge, but most of the estuary is bordered by Quarternary sediments and late Pleistocene (coastal limestone) and Holocene dunes in its lower part;

- the Blackwood River drains an area underlain predominantly by early Precambrian rocks. These rocks consist of granites and granitic gneisses with remnants of high-grade metamorphic rocks; and
- to the east of the opening of the Hardy Inlet, the coast consists mainly of recent quaternary sand dunes and beach ridges: fixed and mobile calcareous sand containing heavy mineral deposits in some areas.

2.4 What are the major landforms/habitats of the coastline of the study area?

Suggested references: Bancroft and Shattock (2000)

Table 1: Percentages of the major marine habitats of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Habitat type	Percentage (%)
Sand shoal	0.2
Shoreline reef platform	0.4
Offshore intertidal reef	0.1
Macroalgae (limestone reef/low relief)	10.9
Macroalgae (limestone reef/high relief)	0.4
Macroalgae (granite reef/low relief)	10.6
Macroalgae (granite reef/high relief)	6.5
Perennial seagrass (dense)	6.1
Perennial seagrass (medium)	10.9
Perennial seagrass (sparse)	18.7
Ephemeral seagrass	2.9
Sand	30.4
Silt	0.6
pelagic	1.3

(Bancroft and Shattock, 2000)

Table 2: Percentages of the coastal habitats of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Habitat classification	Percentage (%)
Beach	36.0
Beach/rocky shore	14.3
Rocky shore	40.2
Inlet closure	9.1
Unclassified	0.4

(Bancroft and Shattock, 2000)

Geographe Bay

- Geographe bay is a wide, gently arcuate, north-facing embayment. consisting mainly of beach fronted by gently sloping shallows and backed by a narrow plain of low foredune ridges. Sea level retreat over the past 5 million years has left a series of dune systems (on the Swan coastal Plain) of different ages generally parallel to the coastline of which the oldest is the Bassendean, then the Spearwood and the most recent, the frontal ridge of small, parabolic dunes called the Quindalup formation. (The Department of Conservation and Land Management, 1994).
- The Quindalup Formation occurs as two stratigraphic units as a sand sheet and a beach ridge wedge. The Sand Sheet forms the ocean floor from the intertidal zone to approximately 7km offshore (approximately 14m isobath), with an average thickness of 1m and a maximum thickness of 2.5m. In place, the sand sheet thins out to expose the underlying Tamala limestone. The Beach Ridge Wedge unit

forms the beach, the low dunes, and the sand sediments which extend to an average 500m inland, The sands are thinnest inshore, but reach a maximum thickness of 5m along the upper beach. The sands overlie limestones of the Tamala Formation and sandy clays of the Leschenault Formation (Coastwise, 2000)

- Immediately to the east of Cape Naturaliste there are narrow intertidal areas, located on small rocky outcrops of granite. These are interspersed with small sandy beaches. The wireweed seagrass *Amphibolis antarctica* grows patchily at the lower tide level. Off shore the water depth is shallow (<2m), with mobile unvegetated sand. Seagrasses are found further offshore (Kendrick et al., 1999).
- At Dunsborough the rocky shore gives way to a long sandy beach with vast seagrass meadows (Kendrick *et al.*,1994) in the shallow offshore waters.
- The Dunn Bay sandbar is a conspicuous feature a few hundred metres offshore between Dunsborough and Quindalup.
- Rivers draining the coastal plain have, in the past, been partially impounded by the Quindalup dune system, forming a series of wetlands within 1km of the shoreline. A system of drains (constructed prior to 1931) cuts through the sand dunes and has altered the original drainage regime. Large areas remain seasonally wet, and as is the case with the Vasse-Wonnerup wetland system, some areas remain permanently inundated (note the Vasse-Wonnerup lagoons have locks at their outlets and are managed as freshwater wetlands) (The Department of Conservation and Land Management, 1994).

Cape Naturaliste to Cape Leeuwin

- The dune systems form three distinct units. parabolic dunes overlie many limestone areas of the coast; unstable blowout areas which can amalgamate to form mobile dune sheets which frequently migrate inland eg Cape Naturaliste; and foredunes which occur along stretches of sand beaches. The type of foredune is dependent on wave energy, wind energy and the amount of sediment transported onshore (The Department of Conservation and Land Management, 1987).
- Granites and gneisses are eroded by the sea to form steep sloping rock faces on exposed headlands, with a small intertidal area subjected to oceanic swells (for example, Sugarloaf Rock, Canal Rocks, North Point Cowaramup, Cape Freycinet and Cape Leeuwin).
- Granites and gneisses form rounder boulder shores and large tide pools in sheltered situations, with large “gutters” and fissures between granite boulders creating protected habitats, which often accumulate large amounts of wrack (for example, Canal Rocks, Quarry and Ringbolt Bay Cape Leeuwin).
- In more protected areas, granites form boulder fields (Smiths Beach, Canal Rock Beach) and may lie on a on limestone basement or may be incorporated into the limestone matrix (Cowaramup and Moses Rock).
- At several locations Quaternary aeolianite limestones form steep limestone cliffs across the shore (10 - 20m width), with the largest intertidal limestone platforms at Yallingup, Cowaramup, Gnarabup, surrounding Hamelin Island and the islands off Cosy Corner.
- NNW trending rock outcrops (Canal Rocks, Cowaramup, Cape Mentelle) form the only bays of any size.
- There are coarse arcuate sand beaches between the headlands.
- 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).

- Where the aeolianite-granite junction occurs near shore level, there are freshwater springs along the coast, and caves are also common in this situation (The Department of Conservation and Land Management, 1994, Kendrick et al., 1999).
- The Yallingup Shelf is an area of shallow basement extending to the continental shelf.

Flinders Bay and Hardy Inlet

- Flinders Bay is a large crescent shaped bay SE from Cape Leeuwin.
- Within Flinders Bay, smaller crescent shaped bays pivoted on headlands are open to the east.
- Between Cape Leeuwin and Black Head the shore consists of a wide, curving beach, more than 80 km long and trending NW-SE, with a Holocene dune field backing it.
- Hardy Inlet is the wide lower basin of the Blackwood, and it opens to the sea via a rather long and narrow entrance channel which breaches a barrier dune at the mouth of the estuary. The estuary of the Blackwood may be classified as a seasonal, permanently open estuary (Hesp, 1984).
- Much of the area of Hardy Inlet consists of shallow banks or 'marginal platforms' at less than 1m depth. Large areas of these are exposed at low tide and there are rush islands in the highest parts of them.
- There are clearly defined channels 2-8m deep in the Hardy Inlet, with the main channel extending into Molloy Basin, around the west side of Molloy Island and up the riverine part of the estuary as far as Warner Glen Bridge.
- Two lagoons, the Deadwater and Swan Lake, open into the eastern side of the entrance channel near the mouth (The Department of Conservation and Land Management, 1994). These are separated from each other and the ocean by Holocene sand barriers. The seaward, outer barrier is subject to planation following severe flooding of the Blackwood River (Elliot, *pers.comm.*).

2.5 What are the main processes that currently influence the geology/geomorphology of the study area?

Weathering and erosive processes – since the stabilisation of sea level, physical (salt) and chemical weathering; wind, wave and biological erosion; and depositional processes have shaped the coast of the study area. The south-west swell action and the prevailing winds are often seen as the dominating factors which influence the geology/geomorphology of the study area.

Rocky bays of the Naturaliste-Leeuwin coast have been created by wind and wave erosion of the granulites, while resistant rocks now stand out as headlands (Coastwise, 2000). The rocky limestone and granite shores of the Naturaliste-Leeuwin ridge consist of cliffs and often intertidal platforms which are formed by a combination of wave attack, biological erosion, undercutting and rock falls. Granitic cliffs are relatively resistant to erosion, but the soil cover above the cliffs tends to be very thin and is easily eroded. However, limestone shores are much more easily eroded, with the base of the cliffs subject to wave attack, whilst the softer parts of the cliff face are subject to localised deflation by wind. The cliff develops through strong attack by weathering and/or erosion at and close to sea-level, after which the rock above is undermined and collapses. At the shoreward limit of the platform, a characteristic notch is eroded, where wave action has undercut the rock on the seaward edge. Chemical and biotic processes are active on the platform surface and form 'micro-habitats' in rock pools.

Between Dunsborough and Busselton, the shore is relatively sheltered, so that swell does not play a significant part in shaping the beach profile. Geographe Bay beaches are protected from the prevailing south westerly swell direction by Cape Naturaliste and by the broad, shallow inner continental shelf. As such, the bay is characterised by depositional forms (beaches). However, the dominance of offshore winds has resulted in limited construction of coastal dunes. This explains the low relief that characterizes the Busselton Holocene barrier (Resource Assessment Commission, 1993).

Dating from the first survey in 1940, the shoreline between Dunsborough and Wonnerup Inlet has displayed alternating phases of erosion and accretion. This has been attributed to the depletion of seagrass meadows between 1947 and 1965 and the subsequent increase in sediment available for transport and increase in energy levels in the immediate shore zone, which has in turn been ascribed to increased sediment and nutrient input caused by bush clearing for agricultural development and the construction of large drains (Lord and Associates, 1995). A number of giant cusps have formed, giving the bay a sinuous appearance. Artificial groynes have been constructed in an attempt to control regression of the shore. This issue is of particular interest because of the management implications, and so will be discussed further.

Studies of coastal movement show that the sinuous form of the Geographe Bay shoreline is highly variable. Some areas have accreted at a rate of 2-3m per year and others have eroded at the same rate, over the past 60 years. In general, the beaches of Geographe Bay are currently subject to a long term accretion period (although long-term erosion in Holocene, Elliot, *pers.comm.*). Searle and Logan (1978) have shown that accretion has been taking place in the Bay for some 4600 years at an average rate of 0.3ha per year, whilst over the past 60 years this has increased to a rate of 1.1ha per year. This rate is not constant since storm events tend to erode the coastline and calm summer conditions allow it to rebuild. However, certain isolated areas are subject to erosion and this gives rise to the sinuous configuration (Coastwise, 2000). Interestingly, erosion is highest where strong groundwater outflow occurs eg Siesta Park (Elliot, *pers.comm.*)

The location of erosion and accretion zones is related to four principal sources of sediment: inputs from the estuaries, littoral drift from the west, offshore stores of sand freed as a result of depletion of seagrass beds; and natural onshore movement of sand moved offshore during major erosion events (Department of Planning and Urban Development, 1992). The zones have been attributed primarily to the occurrence of offshore seagrass meadows, where the general accretion being experienced is a result of a decrease in seagrass meadow area, whilst erosion loci are associated with unbroken seagrass meadows directly offshore. (Searle and Logan, 1978).

Searle (1977) suggested that beach erosion was occurring on three time scales: the seasonal exchange of sand between the beach and near shore bars and sand patches; a cycle of about three hundred years associated with the long linear scours transverse to the shoreline; and the permanence of the seagrass cover and its effect on the long term equilibrium of the bay in respect of sediment supply and loss. Continued seagrass decline may cause the coastal systems at Geographe Bay to become dominated by coastal erosion (Searle and Logan, 1978).

The coast of Flinders Bay is wave dominated. On the eastern side of Cape Leeuwin there is less exposure to ocean swells and more sheltered conditions prevail. More eastwards, the coast is subject to heavy south west swell and easterly littoral currents which remove sediments which are then accumulated in the Great Australian Bight near Israelite Bay (Short, 1979).

Currents and sediment movement - littoral currents of the Naturaliste-Leeuwin region have favoured the movement of sediment away to the north and to the east. For example, easterly littoral currents of Flinders Bay remove sediments which are then accumulated in the Great Australian Bight near Israelite Bay (Short, 1979).

The total land area of Geographe Bay continues to grow under the natural regime, because it receives sediment from both alongshore and offshore. The four principal sources of sediment are inputs from the estuaries; net eastward littoral sand drift (the alongshore supply is thought to be the erosion product of the Leeuwin-Naturaliste ridge shore, which experiences very heavy sea and swell action throughout the year that is subsequently refracted around Cape Naturaliste, and also contains relic material from the Pleistocean land surface); offshore stores of sand freed as a result of depletion of seagrass beds (comprise both relic material and contemporary calcareous products); and natural onshore movement of sand moved offshore during major erosion events (Department of Planning and Urban Development, 1992; GBAC and Ministry for Planning, 1995).

Seasonal events - beach erosion in Geographe Bay is mainly due to the accentuation of the concavities during particularly stormy winters. The actual beach width at any time is a function of seasonal cycles where winter storms sweep sediment off the beach face making it narrower; longer term (11-12 year) storm cycles where severe storms can cause considerable erosion to beaches (such as the 1998 storms); and shore term cyclone cycles which can produce intense storms capable of extensive damage (Coastwise 2000).

Littoral currents of the Naturaliste-Leeuwin region have favoured the movement of sediment away to the north and to the east. This littoral sand drift is reversed by wind waves associated with winter gales on a few occasions in most years and easterly winds.

Human intervention - has also had a marked affect on shoreline dynamics. Clearing, grazing and agricultural practices following European settlement undoubtedly changed groundwater levels (which affect shoreline movement) and may have directly impacted on the coast itself. For example, settlements and building of jetties and groynes at Geographe Bay have changed patterns of erosion and accretion, as have five new 'river mouths' created as part of major drainage works from the 1930s onwards (GBAC and Ministry for Planning, 1995). At Naturaliste-Leeuwin, pedestrian tracks are common down limestone cliffs having a sandy beach apron. These act as a focus for water run-off and wind erosion (The Department of Conservation and Land Management, 1987). The dune systems are unstable, some being mobile and forming severe blowouts. Where vehicle tracks breach vegetated dunes they cause accelerated erosion (The Department of Conservation and Land Management, 1987)

2.6 What are the past/current/potential uses and pressures on the geology/geomorphology of the study area?

Uses and pressures

- recreational use of coastal landforms;
- coastal development;
  There is presently a high rate of proposed urban development, particularly for residential and tourist development. Land use pressures along the coast are intensifying (Coastwise, 2000). Sand accumulation in front or rock revetments and other hard landscaping areas is already a major problem. Disturbance of the coastal and foredune vegetation has come from encroachment into vegetated areas from car parks and camping sties; clearing for new coastal developments (eg for some of the resort developments along Geographe Bay coastline); landscaping with exotic vegetation along the foreshore; fire damage; rabbit foraging; invasion by environmental weed species; and the creation of tracks by vehicles and pedestrians (Coastwise, 2000). In these areas the erosion impact during high storm surge events is amplified owing to the lack of plant cover which serves to bind the sand with its roots. Storm surges are also able to penetrate further up the beach since, in these areas, the foredune has been eroded as a result of frequent traffic;
- extensive clearing for agriculture, which causes increased sediment and nutrient input (WRC, 1997);
- grazing pressure and intensified agricultural use (WRC, 1997);
- weed infestation (WRC, 1997);
- impacts associated with increasing numbers of tourists and recreational pursuits (WRC, 1997);
- sand mining (refer to section 17.1);
- commercial and recreational fishing activities (refer to sections 15 & 19);
  For example, shell collectors target the endemic species of Cypraea found in the study area (The Marine Parks and Reserves Selection Working Group, 1994). These are not truly intertidal species but are accessible in many areas during Spring tides when the boulders they shelter under are exposed (Kendrick et al., 1999). Collection of cryptic species such as *Notocypraea* spp. also disturbs the habitats. Digging for 'bait worms" at the high tide level may at times disturb the base of dunes (Kendrick et al., 1999).
- trampling;
  For example, accessible intertidal areas such as the limestone platforms of Yallingup, Kilcarnup, and Prevelly are likely to be disturbed by people walking on them to collect rock lobster pots and abalone (Kendrick *et al.,* 1999).
- depletion of seagrass meadows;
  Depletion of seagrass causes erosion and accretion zones (refer to section 2.5). If the seagrass meadows continue to decrease in coverage then it follows that accretion will continue until the sediment supply is exhausted. At this point sediment removal along the shore would be faster than sediment replacement and erosion would become extreme. Continued seagrass decline may cause the coastal systems at Geographe Bay to become dominated by coastal erosion (Searle and Logan, 1978).
- groundwater quality, which affects the caves of the area (Kirrily White, Shire of Busselton, *pers.comm.)*;

- diversion of flows - several of the rivers that flow into the study area have formerly discharged into the estuaries (eg Vasse Wonnerup, Toby Inlet), but have been either partially or wholly diverted to sea (eg diversion of the Vasse River to the Vasse Diversion Drain) (Pen, 1997). Floodgates have also been installed on the estuaries' exit channels (eg Vasse Wonnerup) to allow outflow but preventing inflow of seawater. The considerable changes to the hydrology of the estuary system (ie clearing, installation of drainage networks, diversion of flows) have greatly altered both the water levels and quality of the estuaries. For example, diversion of flows has caused a significant reduction in the velocity of the flow of water downstream of the diversion and thus the settlement of suspended sediments (WRC, 1997). Lane et al. (1997) and McAlpine et al. (1989) have reviewed these changes in detail;
- dredging and blasting of shipping channels;
- sea-level rise and climatic change;
  The coastline of Geographe Bay is one of Australia's most vulnerable to the future potential impacts of sea-level rise and climate change. Two major impacts have been highlighted, including increased erosion and loss of shoreline and increase in sea levels. No conclusive evidence is available on the extent of impacts, but some preliminary studies have suggested that if sea level rise is in the order of 1m then the shoreline retreat will be approximately 100 metres (Geographe Catchment Management Study);
- installation of telecommunication cables;
- navigation – installation of markers and removal of hazards; and
- aquaculture? (refer to section 16). Need correspondence from Fisheries WA to determine if this is a current or potential issue in the study area.

2.7 Is there any evidence of environmental impact on the geologic/geomorphic values of the study area?

- Shoreline accretion and recession;
  Searle and Logan (1978) have shown that accretion has been taking place in the Bay for some 4600 years at an average rate of 0.3ha per year, whilst over the past 60 years this has increased to a rate of 1.1ha per year. This has been primarily attributed to the loss of seagrass meadows (could be natural causes and/or man-induced). Areas of high accretion have impounded local water bodies forming lagoons that emit foul odours (Department of Planning and Urban Development, 1992). Shoreline fluctuations have prompted a number of engineering responses in the form of the construction of various seawalls and groynes eg Dunsborough, Busselton Main Beach.

  Sand accumulation in front or rock revetments and other hard landscaping areas is a major problem. For example, there has been accretion of drifting sand on the western side of the groyne constructed at Siesta Park, and to the west of the groyne the beach has prograded up to 80m. There has been a corresponding erosion to the east of the groyne where the beach is backed by cliffs up to 2m high cut into the backshore dunes and Peppermint forest. A similar sequence of events has occurred at the groyne built east of Guerin Street in 1974 (Bird, 1987). The Dunn Bay car park has been constructed over the coastal dunes and the laterite retaining wall has resulted in removal of beach sand and erosion of the adjacent dunes (Coastwise, 2000).The Geographe Bay Yacht Club boat ramp has recently been extended and has resulted in erosion of the beach (Coastwise, 2000).

- Degradation of the foredune vegetation; and
  This has occurred at many places, eg Quindalup and Mitchell Street (landowners have encroached onto the coastal reserves and there has been clearing of natural vegetation and replacement with lawns and exotic trees (Coastwise, 2000)). Pedestrian and vehicular access to the beach is impacting the coastal vegetation in many places in Geographe Bay.
- Reduction in water levels and quality of the estuary systems.
  Several of the rivers that flow into the study area have formerly discharged into the estuaries (eg Vasse Wonnerup, Toby Inlet), but have been either partially or wholly diverted to sea (Pen, 1997). Floodgates have also been installed on the estuaries' exit channels (eg Vasse Wonnerup) to allow outflow but preventing inflow of seawater. The considerable changes to the hydrology of the estuary system (ie clearing, installation of drainage networks, diversion of flows) 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.

2.8 What is the current condition of the geology/geomorphology of the study area?

The current condition of the coast from Busselton to Dunsborough is very poor as a result of sustained and significant interference associated with construction of engineering works. The remainder of the study area is generally very good with most of the actual features intact (Ian Elliot, Head of Geography, The University of Western Australia, *pers.comm.*).

2.9 What strategies are the relevant management authorities using/proposing to minimise the environmental impact on the geologic/geomorphic values?

- Departmental activities eg rehabilitation, access projects and public education programs, governed by the *CALM Act* 1984 and *Wildlife Conservation Act* 1950;
- Numerous Coastwest/Coastcare and Coast and Clean Seas projects (see section 20.3). For example, in 1999, the Shire of Busselton, in partnership with the Geographe Catchment Council, was given a Coastcare Grant to assist with the preparation of an overall foreshore management plan for the Geographe Bay coast. Coastwise was commissioned to prepare The Geographe Bay Foreshore Management Plan in October, 1999 (available in draft format). The Plan includes recommendations relating to rehabilitation, revegetation, access, boat launching facilities, dual use paths, recreational activities, community involvement and community ownership. The implementation of the proposals set out will involve a considerable amount of work and cost over many years. Once the priority issues have been identified and programmed, they will need to be costed and budgeted for by the Shire.
- Research - there have been a number of studies of Geographe Bay coast in the past which have examined foreshore movements, seagrass, boat launching and building setbacks. For example, Riedel & Byrne (1988) were commissioned to undertake a series of studies designed to asses the impact of Port Geographe, a canal-based residential subdivision with an associated public boat harbour, on the near shore coastal process in Geographe Bay (it was concluded that the breakwaters for the Port Geographe development would hardly impinge on the near shore bar and scour system and would have no influence on the seagrass meadows)

- Ministry for Planning publications eg Leeuwin Naturaliste Ridge Statement of Planning Policy (Ministry for Planning, 1998), which is yet to be gazetted; Augusta-Margaret River and Busselton-Dunsborough Land Release Plans 2000-01 to 2004-05; Geographe Bay: Recommendations for Foreshore Reserves, Building Setbacks and Development Controls (DPUD, 1992).
- Shire plans and policy eg the Shire of Busselton Planning Scheme No. 20 gives the Shire full discretionary powers with respect to development in the coastal zone. The Shire of Augusta-Margaret River Coastal Management Policy (1998) describes various management strategies to be undertaken by the Shire eg monitoring, the development and implementation of management or development plans for each of the coastal sectors within its jurisdiction (there is currently a Prevelly foreshore Management Plan); the development of formalised recreational, infrastructure and services facilities to be restricted to the existing activity nodes of Prevelly/Gnarabup, Gracetown and Flinders Bay; and the commencement of bi-annual meetings with the Department in order to liaise on management and jurisdiction issues.
- Coastal planning and management principles were developed for the WA coastline in the 1980s. They were included in a Cabinet Endorsed Government Position Paper in 1983, in the Country Coastal Planning Policy in 1986 and in Coastal Planning and Development in Western Australia: towards a Policy Framework (1996) (the latter is yet to be finalised). Coastal zone management policy for Western Australia (Western Australian Planning Commission, 2001) has just been released for public comment.
- West Australian Country Coast Policy (1997);
- Busselton Foreshore Environs Management of Residential Development (DoT, 1995);
- Busselton Foreshore Development Study in 1989; and
- Australian Oceans Policy.

3 DRAINAGE AND GROUNDWATER

AWAITING CORRESPONDENCE FROM WAYNE TINGEY – ON LEAVE UNTIL 29/1

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3.1 What are the size and nature (eg agricultural; urban) of the drainage basins of the study area, and what areas do these systems drain?

Blackwood river basin

- the largest in the southwest, having a catchment of about 23 000km^2
- Blackwood river drains the Yilgarn Plateau
- includes the Scott River which drains the western Scott Coastal Plain. Much of the Scott River retains natural vegetation and is reserved in the Scott National Park (Pen, 1997)
- both the Blackwood and Scott rivers ultimately discharge into Hardy Inlet (Elscot & Bancroft, 1998)
- has been extensively cleared for agriculture

Busselton Basin

- covers an area of 2560km^2
- consists of 26 river and creek systems that discharge to the coast between Bunbury and Augusta
- between Bunbury and Cape Naturaliste 9 short rivers and major creeks drain the Whicher Range and/or the Swan coastal Plain and discharge into Geographe Bay - the Capel. Ludlow, Abba and Sabina are the most substantial
- there are two estuaries between Bunbury and Cape Naturaliste: Vasse-Wonnerup and Toby's Inlet. These 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
- 17 minor creeks occur along Leeuwin-Naturaliste Ridge, three of which flow to Geographe Bay on the western side of Cape Naturaliste. Many are either partially or wholly contained within remnant coastal vegetation
- one small river, three creek and 11 minor creek systems drain to the coast between the Capes. All but one drain farmland or are subject to some form of degrading land use, and most pass through a narrow belt of reserved coastal vegetation before reaching the ocean

- 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

3.2 Estuaries of the study area

Refer to table 3

Blooms of potential toxic cyanobacteria have been a regular occurrence in the Vasse-Wonnerup Estuary and Toby Inlet for some years. Harmful species of blue-green algae including *Nodularia, Mycrocystis* and *Anabaena* occur frequently in the Vasse Estuary. Blooms of diatoms and dinoflagellates are also common. Sudden mass fish deaths in the Vasse-Wonnerup system have been recorded since 1905, with results of monitoring suggesting that low oxygen conditions resulting from decaying algal blooms were a likely cause. There have been two blooms of *Prymnesium* species, which have caused fish deaths in the Vasse. Fish kills are now being documented as part of the WRC Vasse0Wonnerup monitoring program (State of the Environment Report).

No estuaries of the study area are of national/international significance.

3.3 Major coastal wetlands adjacent to the study area

Thirty-one coastal wetland groups within the Geographe Bay – Capes – Hardy Inlet region were identified in a study by Pen (1997). Table 4 lists the 15 which were considered to have important values.

Despite the high rainfall of the catchment, the wetlands are subject to siltation and high nutrient loading due to large scale clearing and drainage modifications (the construction of a wide-spread network of artificial drains) on the coastal plain (Bradby, 1997).

The following wetlands of the study area have National/International significance:
Vasse-Wonnerup Wetland System – Ramsar International Significance and National Estate System 6 (ANCA 1996). It has recently been extended from 750ha to a total area of 1115ha (Department of Conservation and Land Management & Natural Heritage Trust, 2000).
McCarley's Swamp (Ludlow Swamp) (ANCA, 1996)
Cape Leeuwin Wetland System (ANCA, 1996)
Blackwood River (Lower Reaches) and Tributaries (ANCA, 1996)
Gingilup-Jasper Wetland System – National Estate (ANCA, 1996)
Broadwater Floodplain – National Estate (AHC, Register, May 1992)
Scott River Wetland System – National Estate (AHC, Register, May 1992)
Lake Davies – in National Park
(verified by Jim Lane, The Department of Conservation and Land Management, *pers.comm.*)

The Vasse-Wonnerup Wetland System is acknowledged to be of international significance; it was listed in June 1990 as a Wetland of International Importance under the RAMSAR Convention (The Department of Conservation and Land Management, 1990), and is also listed on the Register of the National Estate (Lane et al., 1997). Up o

33 000 birds have been counted there (ANCA, 1996) Eighty-five species have been recorded in total (Lane, 1990). Nationally, the wetlands are a major migration stop-over point for a number of species of small waders,

Table 3: Major estuaries within/adjacent to the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Estuary	Basin Area (ha)	Major drainage systems	Catchment Area (km2) (discharge ML and time)	Values	Surrounding land use	Condition
Vasse-Wonnerup	1000	Capel (now diverted directly to sea) Ludlow Abba Sabina Vasse (now diverted directly to sea)	1500 (210 000; seasonal)	Floodplain Faunal pops, esp waterbird Sanctuary	Farming and residential	Surrounded in cleared land/cleared and m channels not within vegetated corridors; modified ocean connection (installation o floodgates prevents the inflow of tidal wa creating fresh or brackish lagoons from th estuary; the Capel and Vasse Rivers have drained into this estuary, but have been d directly to the sea to prevent winter flood highly nutrient-enriched (State of the Environment Report)
Toby's Inlet	20	Carbunup (now diverted to the sea), Mary (now diverted to the sea)	260 (48 000, seasonal)		Residential mainly	As above
Hardy Inlet	900	Blackwood, Scott	22000 (1058000; seasonal)	Unique Representative Floodplain Natural Faunal pops Sanctuary		Partially connected to a large area of natu veg/mostly cleared and main channels no within vegetated corridors
Wilyabrup Brook estuary	2	Wilyabrup	90 (30700, seasonal)	Unique Represent-ative Natural	Private bushland	Contained within a small areas of natural veg/mostly cleared and main channels no within vegetated corridors; modified oce connection
Margaret River estuary	20	Margaret	470 (120 000; seasonal)	Unique Represent-ative Natural	Farming and National Park	Contained within a small area of natural vegetation/mostly naturally vegetated

(Pen, 1997)

Table 4: Wetlands adjacent to the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Wetland group	**Named wetlands**	**Appprox. area (ha)**	**Condition**	**Outstanding values (Pen, 1997)**			
				Represent-ativeness	Natural	Faunal	Sanctuary
Bussell Hwy Swamp		630	B		*		
Ludlow Wetlands		30	B-Dc		^	^	^
	McCarley's Swamp				*	*	*
Tutunup Rd Lake			B	*	*		
Ludlow-Abba Wetland		10	B-D1-c		*		
Vasse-Wonnerup Wetland System	Vasse-Wonnerup Estuary The Deadwater	2000	D1-c, Ds			*	*
Broadwater Floodplain	Broadwater Toby's Inlet	700	C, D1-c			*	
Naturaliste Lake Wetlands			B	*		*	
Margaret River Swamps			A	*	*		
Devils Pool			B		*		
Lake Davies Wetlands	Lake Davies		A		*		
Pt Pedder Swamps		400	B	*	*		
Lower Blackwood Wetlands		1700	B-Dc	^	^		
Scott River Wetland System		20000	B-Dc	^	^		
	Bulrush Swamp			*	*		
Gingilup Swamp Wetlands		2000	A-Dc	+	+		+
	Gingilup Swamp			*	*		*
Bolghinup Lake Swamp			A		*		

(Pen, 1997)

*Entire wetland or wetland group is important
+Most of the wetlands within the group are important
^Some of the wetlands within the group are important
A=wetland within a large area of healthy bushland
B=wetland within a small healthy bushland block
C=wetland connected to healthy bushland
D=wetland surrounded by cleared land
1=cleared lake
s=swamp/floodplain with remnant veg
c=cleared wetland
s-c=transitional

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. However, nutrient loads in the Vasse-Wonnerup Wetlands System from the surrounding catchment area are the largest measured in any waterbody in south-west WA. This nutrient enrichment comes from animal waste and soluble fertilisers, exacerbated by the floodgates. Algal blooms frequently develop in the lowest reaches of the Vasse Estuary during the summer and autumn (Lane *et al.,* 1997: ANCA, 1996).

3.4 Major rivers which flow to the coast or to an inlet of the study area (≥350km2):

Table 5: Major rivers which flow to the coast or to an inlet of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

System	Estuary	Catchment area (km2)	Mean annual flow (ml)	Salinity at mouth	General condition (pen, 1997)	Values (pen, 1997)
Blackwood	Hardy	21400	940000	Brackish	Multiple use river	Some habitat value
Capel		620	88600	Fresh	Multiple use river, polluted	Habitat and landscape
Margaret		470	120 300	Fresh	Natural resource river reaches	Natural and habitat
Scott	Hardy	630	113900	Fresh	-	Some habitat, National Park

A comprehensive environmental evaluation of streamlines has never been carried out in the south-west Western Australia. Pen (1997) nominated several streamlines as being important on the basis of representativeness and naturalness (this list included the Margaret River).

Despite the high rainfall of the catchment, the rivers are subject to siltation and high nutrient loading due to large scale clearing and drainage modifications (the construction of a wide-spread network of artificial drains) on the coastal plain (Bradby, 1997). According to Pen (1997), 79% of streams within the Geographe Bay catchment are defined as multiple use, being heavily impacted upon by upstream and adjacent land use.

The State of the Environment Report details the condition of various water courses of Geographe Bay Catchment (eg Cape;, Carbanup, Wass, Wasse Diversion Drain), and presents a table and figures showing average nutrient (total Nitrogen and phosphorous) concentrations in 1999 (derived from WRC unpublished data).

3.5 What are the characteristics of groundwater (eg water table level, quality, salinity)?

- Water table
  The seasonal variation of the water table is generally between 0.5 and 2 metres over most of the Geographe Bay area (WAWA, 1995a)

- Quality, Salinity & Use
  WAWA(1995a) state that groundwater pollution in the Busselton-Capel area is currently limited. However, the competition for domestic use in the Geographe Bay

area has reached a level in some areas where the long term quality of the groundwater system is at risk. Already, several areas on the coastal barrier system have experienced increased salinity levels which have not dropped following good winter rainfall (Coleman, R 1993 *Pers. comm*. In Geographe Bay Advisory Committee and Ministry for Planning, 1995).

Existing and potential point sources of pollution in the Busselton-Capel area have been identified. Potential pollution sites in the catchment include sand mines, landfill sites, sewage treatment facilities and holiday resorts. Pollution from fertilisers in the areas around Busselton and Donnybrook which are used for intensive horticulture, is also of concern (WAWA, 1995a; WAWA, 1995b). Water quality monitoring of the superficial aquifer of Geographe Bay is currently carried out twice yearly by the Water Corporation.

Groundwater salinity varies with distance from the coast, with the highest salinity levels being recorded near the coast. The average groundwater salinity for the region is 1000 mg/L or 1.818 mS/cm. The dominant ions in the shallow wells are sodium and chloride. Calcium and magnesium are significant in the limestone environment near the coast. High sulphate values are in some Busselton Shallow wells (possibly due to fertiliser) and silica attains high values. Several high values of nitrate concentrations indicate point source pollution. The unconfined aquifer tends to be too saline for domestic use and is primarily used for stock-watering. (WAWA, 1995a; WAWA, 1995b; Kinhill, 1998; Ministry for Planning, 1995).

- Shallow aquifers occur along the older raised Leeuwin-Naturaliste Ridge. The largest aquifers in the region occur in the limestones of the Swan and Scott Coastal Plains of the southern Perth Basin. The aquifers are, in increasing order of depth, the superficial (unconfined), the Leederville and the Yarragadee or Sue Coal Measures (all confined) (WAWA, 1995a).

  <u>Leederville aquifer</u>
  The groundwater salinity in the top 100 metres of the Leederville aquifer in the coastal plain has a salinity of less than 500mg/L TDS. Salinity increases gradually in the direction of groundwater flow, towards the coast where a saltwater interface is found. Groundwater is of the sodium chloride type. Iron, manganese and silica are present in high concentrations. The Leederville formation is the most important in the area, being the most easily accessed and heavily utilised aquifer, providing potable water supplies for Busselton and Dunsborough. Currently around 71% of the total groundwater availability from the Leederville aquifer has been allocated to private and public users (WAWA, 1995a; WAWA, 1995b).

  <u>Yarragadee Formation</u>
  The Yarragadee Formation is one of the largest known aquifers in Australia. It extends to a depth of up to 1500m and reaches a thickness of over 1200m in some places. Groundwater salinity varies between 180mg/L and 900 mg/L TDS in the Yarragadee aquifer, and the percentages of the major ions are similar to those in the Leederville aquifer. However, its greater depth has so far limited the extraction of groundwater to about 30% of the available resource. The groundwater is used for horticulture, pasture irrigation and public water supplies (WAWA 1995a, WAWA 1995b).

Sue Coal Measures

Information on the Sue Coal Measures Formation is limited. The aquifer contains fresh groundwater inland, but brackish or saline water along the coast. The aquifer has been intruded by seawater. The majority of groundwater use in the catchment is from the confined aquifers; it is used extensively for domestic, horticultural and other agricultural purposes(WAWA, 1995).

3.6 What is the relationship of groundwater with the geological structures of the study area (eg formation of caves)?

The Leeuwin-Naturaliste Ridge has some of the finest cave systems in Australia. There are several groundwater outflows or springs into or near the study area which are linked to cave systems. Examples include the Lake Cave system which outflows at Conto Spring, the Calgardup/Connolly's cave system which outflows at Bob's Hollow and the water table caves of the Jewel/Easter cave system at the waterwheel near Augusta. There are also a number of 'sea-caves', some of which are developed in granite in the study area. Sea caves in cliffs are caused by oscillations in sea level. When sea level was higher, waves eroded major joints and contacts in the basement rock. For example at Yallingup, the 'sea-caves' can be as large as 60m in length, 20m wide and 5m high. Both infiltration by seawater and groundwater influence the dynamics of these structures. Above the limestone/basement rock contact relict caves are also present eg Bunker Bay. There are examples of submarine caves in the offshore limestone reefs and islands eg Margaret River mouth Extensive knowledge of caves exists within the Western Australian Speleological Group and the Speleological Research Group (Rauleigh Webb, Western Australian Speleological Group, *pers.comm.;* The Department of Conservation and Land Management 1987).

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.(Elscot and Bancroft, 1998).

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, Water & Rivers Commission, Perth, *pers. comm*. In Elscot & Bancroft 1998). Along the coastline of Cape Leeuwin there has been three distinct forms of tufa identified by Linda Moore (WRC, 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. WATSCU

have listed the tufa communities near the waterwheel at Cape Leeuwin, Augusta as a Threatened Ecological Community (A. Webb, The Department of Conservation and Land Management Busselton, *pers. comm*. In Elscot & Bancroft, 1998).

- 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*. In Elscot & Bancroft, 1998)

3.7 What are the characteristics of the rainfall of the study area in terms of its relationship to groundwater? Detail the rate, reliability, drainage and surface runoff. Does periodic flooding occur in the study area?

- Recharge

  The rate of recharge varies considerably with vegetation cover (State of the Environment Report).

  The unconfined aquifer is mainly being recharged directly by rainwater or infiltration of surface water and upward leakage from the underlying Leederville Formation.

  The Leederville Formation is recharged through rain and surface water infiltration.

  The Yarragadee Formation is being recharged to some extent by direct rainfall and leakage from the Leederville Formation, however, detailed recharge studies are still to be finalised.

  Information on the Sue Coal Measures Formation is limited. It is believed to be recharged by leakage from the Leederville Formation (WAWA, 1995).

- Runoff

  The community of the Geographe Bay catchment have noted that more surface water is moving off the catchment more quickly. Deep-rooted perennial vegetation has been removed from 80.5% of the catchment, and soil compaction over many years has reduced water absorption and increased run-off. Landholders have noted rising watertables, more frequent flooding, and longer inundation of paddocks (Scott *et al.*, 2000).

  Nearly all of the runoff into the Blackwood estuary occurs between June and November, inclusive. During winter, total runoff to the Blackwood estuary typically peaks at about 20 X 10^6 m^3 per day during August. Although the Hardy inlet is wide, it actually holds little water compared with the other basin estuaries on the South Coast (D'Adamo & Mamaev, 1999)

- Flooding
  Major flooding of the Busselton townsite in August 1997 highlighted that the town does not have 100-year flood protection. Significant areas were also flooded in 1999.

  The waterways of Geographe Bay have been subjected to extensive engineering in an effort to control the level of water in the inland waterways. In the early nineteen hundreds tidal gates were constructed at the outlets of the Vasse and Wonnerup Estuaries (to limit the inundation of pastures and to control the level of fresh water behind the gates) and the Vasse Diversion Drain was built to avoid the flooding of Busselton Town by the Vasse River (WRC, 1997).

  An established Busselton Flood Management Steering Committee has determined that the preferred key flood management option is the construction of a network of detention basins in the upper catchment to attenuate peak flows in the Vasse River Diversion, and is resolved to seek implementation of this option (Ministry for Planning, 2000a; Water and Rivers commission, 1998). Many of the rivers of the area have been diverted to reduce winter flooding (eg most of the rivers between Busselton and Bunbury).

  For additional information on rainfall, refer to section 4.

3.8 What is the relationship of groundwater with seawater (ie flux)? Do groundwater discharge and other freshwater inputs affect the hydrodynamics of the study area (state direction and distance)?

Groundwater flow in the Geographe Bay region discharges into rivers, coastal wetlands and estuaries and into the nearshore coastal waters. Flow directions are predominantly to the north west in the eastern part, and to the north and north east in the western part of the region (WAWA, 1995). Groundwater flow is seasonal with a volume of $5x10^3m^3$ in summer and $50x10^3m^3$ in winter (Holmes, 1994). However, contradictory evidence suggests that groundwater flow from land to sea is negligible in summer. Water is prevented form flowing to sea in summer due to the pumping of water from groundwater bores (Coleman, 1994). This results in salt water moving landward and no fresh, groundwater flow into the bay (McMahon, 1994).

Groundwater flow in the unconfined aquifer is generally in a westerly direction and discharges over a saltwater wedge near the coast into the ocean (Dames and Morre, 1992). A saltwater interface is found towards the coast in the Leederville aquifer. Water flow within the Yarragadee aquifer is very slow – approximately one and a half million years from entry to exit. The basin flows to both the north and south, resulting in discharge into the Southern Ocean and Geographe Bay. Basin water seeps into the ocean across a wide area some distance offshore. The Sue Coal Measures Formation has been intruded by seawater (Water Authority, 1995; Geographe Bay Advisory Committee and Ministry for Planning, 1995).

- Hydrodynamics

  Submarine groundwater discharge and other freshwater inputs from drains and rivers have secondary influences on net circulation in Geographe bay when compared to wind-driven circulation (Fahrner and Pattiaratchi, 1994).

  The introduction of freshwater via rivers, drain and groundwater into the semi-enclosed embayments and inner reef and lagoonal areas between Cape Naturaliste and Cape Leeuwin raises the possibility of vertical and horizontal stratification of salinity and therefore density. This type of stratification can influence circulation and mixing by assisting flushing in some cases (due to horizontal density gradients) or restricting vertical mixing due to the formation of a vertically stable water column (ie stratified in density). These research areas are yet to receive detailed attention for this section of coast (D'Adamo and Mamaev, 1999).

  One of the most important influences on the dynamics of the Blackwood estuary is freshwater flows form the Blackwood and Scott rivers. The Hardy Inlet and Molloy Basin going from essentially marine (greater than 30 ppt) to fresh when these rivers begin the flow strongly in winter. Flushing begins about May, and is complete (all the way to the entrance channel) typically by about mid-winter. River flow has a negligible effect on the dynamics of the estuary when it falls to below about 0.25 x 10^6 m^3 per day (during summer and autumn). Vertical stratification is extreme during this period.

  Freshwater outflow into the Blackwood estuary also influences currents. Discharge causes outflow speeds up to about 1 m/s through the basin, inlet and channel as freshwater escapes to the ocean (compared to tidal current speeds up to about 0.5 m/s during summer) (D'Adamo and Mamaev, 1999).

  The Blackwood Estuary discharges significant amounts of freshwater to the coastal zone near Augusta during the winter-spring rainfall/runoff period. Buoyant freshwater inputs to the bay from the estuary will initially spread close to the shore as buoyant plumes, creating a *Region of Freshwater Influence* (ROFI) (Simpson, 1997). The entry of buoyant freshwater plumes into the nearshore coastal zone will set up vertical and horizontal density gradients and frontal zones between the plumes and receiving oceanic water. The dynamics of the ROFI will be significantly influenced by the presence of these gradients. Coastal circulation pattern and vertical mixing eventually disperses buoyant estuarine outflows (D'Adamo and Mamaev, 1999).

4 CLIMATE

4.1 Outline the climate type of the study area

The region enjoys a Mediterranean-type climate that is characterised by cool, wet winters and hot, dry summers (www.bom.gov.au).

4.2 What are the offshore and localised wind patterns of the study area (eg direction, seasonality, speeds)?

During winter, the subtropical ridge axis (ie the west-east axis of the belt of high pressure systems that encircle and continually move around the globe in an eastward direction) is located at its northern most latitude (25-30º S), resulting in a westerly prevailing wind stream acting over the southwest of the State. This enables cold fronts and strong westerly winds from the Roaring Forties to regularly penetrate the southwest, with cold fronts crossing the coast every week or so, on average (D'Adamo and Mamaev, 1999). Winter westerly winds average a velocity of 36km/hr and can exceed 50km/hr (storms associated with these fronts typically last for about one day or less). Apart from the passage of storms, the weather is otherwise relatively mild in winter with winds variable and relatively weak (D'Adamo and Mamaev, 1999).

With the change of season in summer, the ridge axis moves to its southern extremity (about 40ºS) and cold fronts rarely penetrate into the south of the State with any strength. Hot east-southeasterly winds prevail over the southern half of the State in summer (D'Adamo and Mamaev, 1999). Easterly winds have an average velocity of 28km/hr and occur with a frequency of 12% in summer. (Searle and Logan, 1978). This prevailing pattern is modulated on almost a daily basis from mid-spring to late summer, by strong afternoon south-southwesterly sea-breezes that often exceed 20-25 knots along the west coast and strong southwest-southeasterly seabreezes along the south coast (Fahrner & Pattiaratchi, 1994). During January sea breeze frequency is 45%, with average velocities of 37km/hr, and peak velocities greater than 50km/hr (Searle and Logan, 1978).

The wind fields during the changeover seasons of spring and autumn are characterised by mild variable winds, with relatively few strong storms or sea-breezes (D'Adamo and Mamaev, 1999).

4.3 What are the mean maximum temperatures for the hottest months and the coldest months?

Mean daily maximum temperatures in January and February range from 28.4°C to 28.5°C at Busselton; from 25.2°C to 25.6°C at Cape Naturaliste; and from 23.1°C to 23.3°C at Cape Leeuwin. During July, mean daily maximum temperatures drop to 16.3°C at both Busselton and Cape Leeuwin and 16.2°C at Cape Naturaliste (www.bom.gov.au).

4.4 What are the mean minimum temperatures for the hottest months and the coldest months?

Mean daily minimum temperatures in January and February range from 13.8°C to 14.0°C at Busselton; from 15.2°C to 15.6°C at Cape Naturaliste; and from 16.9°C to 17.2°C at Cape Leeuwin. During July, mean minimum temperatures drop to 7.5°C at Busselton; 10.4°C at Cape Naturaliste and 11.3°C at Cape Leeuwin (www.bom.gov.au).

4.5 What is the average annual precipitation, and at what time of the year does this precipitation fall?

The mean annual rainfall experienced by the region ranges from 822.9 mm at Busselton of which 56% falls during winter, 22% during autumn and 18% during spring; 824.8mm at Cape Naturaliste of which 55% falls during winter, 22% during autumn and 19% during spring; and up to 998mm at Cape Leeuwin, of which 51% falls during winter, 24% during autumn and 20% during spring (www.bom.gov.au). A seasonal drought occurs during the summer months. Very occasionally, widespread heavy rain may occur during the southward passage of a decaying tropical cyclone (Pen, 1997).

4.6 What is the average daily humidity of the study area?

Mean annual relative humidities are 72% (9am) and 59% (3pm) at Busselton; 73% (9am) and 65% (3pm) at Cape Naturaliste; and 78% (9am) and 73% (3pm) at Cape Leeuwin (www.bom.gov.au).

4.7 Outline any available evaporation data of the study area (eg annual mean, times of highest and lowest occurrence)

Evaporation isopleths from Australian Bureau of Statistics (1989) show evaporation to be about 1000 mm per year over the southwest corner of the State. Evaporation is highest in summer and lowest in winter (*In* D'Adamo and Mamaev, 1999).

4.8 Do any extreme climatic events occur in the study area (eg cyclones)? If so, what has been the environmental and social impact of these events?

Rain bearing depressions evolve from cyclones, which generate in the State's northwest. Each year, from November to May an average of about two cyclones cross the northwest coast. These systems occasionally travel southwards (once every four years, on average), and pass over the southwest of the State during Summer and Autumn, bringing unseasonally heavy rainfall events and associated gale force winds (D'Adamo and Mamaev, 1999). Cyclones, although rare, can raise water levels by up to approximately 4m off the North West coast (D'Adamo, *pers.comm.*) and significantly change shoreline shapes and profiles through erosion and/or accretion.

<u>Geographe Bay</u>
There are three distinctive levels of storm activity that affect the Geographe Bay coast, namely:

- Annual winter storms
- Cyclical storms related to periods of higher wind movement with an approximate 11-year period
- Random storms related to dissipating tropical cyclones

Significant erosive events in Geographe Bay tend to be infrequent. Storms result in strong northwesterly winds, high energy waves and raised water elevations, which can lead to erosion of the beach and deposition of sediment in an offshore bar (because of raised sea level, high energy waves ride over seagrass meadows which usually have a dampening effect on the incident waves) (Resource Assessment Commission, 1993). As winds turn westerly, they generate strong alongshore currents and easterly littoral drift within Geographe Bay. Variations in storminess translate into variations in geomorphic processes acting on the shoreline and hence explain inter- and intra-seasonal shoreline movements. Any given section of the Geographe Bay shoreline will display fluctuations of erosion and accretion which can last upward of ten years (Dept Planning and Urban Development, 1992).

In April 1978, Cyclone Alby caused a storm surge that led to severe erosion in Geographe Bay. The storm surge produced reached 1.94 metres AHD, far exceeding the 0.6m tide predicted. This is marked by a formerly cliffed dune margin behind several subsequently prograded sectors. Significant erosion events such as Cyclone Alby are infrequent. There have only been 10 cyclones recorded in the area of Geographe Bay since 1915 (Resource Assessment Commission, 1993).

5 OCEANOGRAPHY

Water level

5.1 What are the tidal patterns and ranges of the study area?

- Tides along the southwest coast are typically less than 1m, and have a maximum of no more than about 1m.
- The tides are mixed (ie diurnal and semi-diurnal), with diurnal fluctuations more common. The daily range is typically about 0.7m during spring tides and about 0.5m during neap tides (Fahrner and Pattiaratchi, 1994).
- The main tidal characteristics are shown in table 6:

Table 6: Tidal elevations at Busselton

Item	Tidal level (ref. to lowest astronomical tide)	Tidal level (ref. to Australian height datum)
Mean High High Water	+1.0 metres	+0.5 metres
Mean Sea Level	+0.6 metres	+0.1 metres
Mean Low Low Water	+0.3 metres	-0.2 metres

(Rogers & Associates 2000)

- Tidal exchange in the Blackwood estuary is dampened by the entrance bar. Astronomic tides in the inlet have a maximum range of 0.7m.

5.2 What is the influence of tides on the hydrodynamics of the study area (eg net water movement, estuary hydrodynamics)?

Geographe Bay and Naturaliste-Leeuwin region

The tides along the coast of these regions are small and produce only weak mean currents compared to wind and wave driven flows. Water level variations become important for circulation in Geographe Bay only during intense storms and cyclonic depressions (D'Adamo & Mamaev, 1999).

Hardy Inlet

In contrast to the more open expanses of the study area, tides play an important role in water circulations and mixing in the Hardy Inlet. The dynamics of the Blackwood estuary are influenced by tidal pumping of seawater into and out of the estuary via the entrance channel and lower reaches. Until the Blackwood and Scott rivers begin to flow strongly in winter, the estuary remains saline (greater than 30ppt), with the dynamics of the lower reaches characterised by the cyclic upstream and downstream movement of seawater as a salt wedge, in response to the diurnal cycle of the tide (D'Adamo & Mamaev, 1999)..

During ebbs, there is intense vertical mixing above the sills and in the shallow basins, forming regions of medium salinity water which, upon the turn of the tide to flood, make their way upstream as intrusive jets, above the bottom-penetrating salt wedge. Agnew *et al* (1976) found these jets to transport water up to 10 km upstream during flood tides. Because of the presence of relatively dense water upstream of the sills, some of this water remains trapped at the bottom during ebbs as the more buoyant water near the surface heads downstream, out to sea. A strong halocline (zone of intense salinity change) is formed between the outflowing water and more saline water of the

salt wedge below. This assists in the retention of sea water within the estuary over successive tidal cycles (D'Adamo & Mamaev, 1999).

The pooling of dense (high salinity) water in the depressions along the length of estuary has been found to promote deoxygenation below the halocline. For example, oxygen levels recorded at Alexandra Bridge during 1945-52 were low below the halocline (Hodgkin (1976). This is typical in nutrient-enriched estuaries such as the Blackwood. The seasonal introduction of a salt wedge in a nutrient-enriched system can lead to the depletion of oxygen near the bottom to concentrations at which fish cannot survive (< 3 mg l-1) (D'Adamo, 1995)

5.3 What are the implications of tides on physical characteristics of the study area (eg influence of tides on coastal geomorphology)?

- As previously discussed (section 2.1), water level fluctuation helped shape the geomorphology of the coastline of the study area.
- Currently, tides do not have a relatively significant influence on the geomorphic characteristics of the study area as they are relatively small along the south west coast. However, changes in water level which arise from storms/cyclonic events influence erosion/accretion events.
- The most important current influence of water level is probably its effect on the hydrodynamics of the Hardy Inlet (discussed in 5.2). The two most important influences of the dynamics of the estuary are freshwater flows and tidal pumping of seawater into and out of the estuary via the entrance channel and lower reaches.

5.4 What are the implications of tides on biological characteristics of the study area (eg zonation patterns)?

In general, rocky shores are characterised by vertical zonation, with many of the plants and animals that live there restricted to a narrow horizontal band according to their tolerance to exposure at low tide. Many animals exhibit adaptations which allow them to survive an environment which experiences fluctuations in tides, and subsequently exposure to sun/air/predators, fluctuating salinity conditions and other stresses. Zonation patterns of the study area were not studied in detail by Kendrick *et al.* (1999), although this report can be used to determine what species were present. However,note that the area defined as intertidal in the study area is not large due to the small tidal range (less than one metre).

5.5 Are there any other meteorological influences on water level?

- Meteorological effects in Geographe Bay are thought to be significant and of the same order as astronomic tides.
- Wind can raise or lower coastal sea levels depending on whether water is being forced towards or away from the shore by onshore or offshore winds, respectively.
- Barometric pressure induces isostatic changes in water level due to the 'inverse barometer effect', under which an increase (or decrease) in barometric pressure of 1 millibar lowers (or raises) water level by approximately 1 cm.
- In winter, storm surges generated by strong northwesterly winds can sometimes mask tidal movements.

- 'Bulges' of water termed Continental Shelf Waves can propagate down the Western Australian coastline producing water level changes of up to about 30cm off Western Australia (Hamon, 1966; Harrison, 1983, Webster, 1983).
- Meteorological effects were found to change water levels by up to 0.6m over and above predicted tidal water levels in the Hardy Inlet (D'Adamo and Mamaev, 1999)

Waves

5.6 What are the oceanic swell patterns and local sea patterns which affect the study area (eg formation, direction, typical wave height and period as per season)?

In general, measurement of waves off southwest show that swells have a period of about 12 seconds and heights typically of up to 2m, while sea generated by local wind is short crested with periods of 5-10 seconds (Fahrner and Pattiaratchi, 1994).

Southwesterly swells

- Prevailing swell arrives from the south-west, developed in the Roaring Forties of the Indian and Southern oceans
- Southwesterly swell is refracted by the shallow shelf of Geographe Bay and around Cape Naturaliste to approach the shoreline of southern Geographe Bay from the west-northwest. (D'Adamo and Mamaev, 1999)
- Swells have heights typically of up 2 m and a long period of about 12 seconds (Fahrner and Pattiaratchi, 1994)

Westerly Seas

- Generated by local, mainly winter, disturbances off the Western Australian coast (Coastwise, 2000)
- Have a shorter period (about 7 seconds) and are smaller than the Westerly swells but often arrive in conjunction with the swells (Coastwise, 2000)

South-westerly seas

- Generated by summer sea breezes (Coastwise, 2000)
- The height and period of these waves varies with wind velocity, duration and fetch (Coastwise, 2000)

Easterly seas

- Created by easterly winds blowing across Geographe Bay and Flinders Bay in summer (Coastwise, 2000)
- Wave heights and periods are similar to those generated by sea breezes (Coastwise, 2000)

North-westerly swells and seas

- Generated by the north-westerly gales that blow in winter (Coastwise, 2000)
- The location of the storm centre determines the period of the waves (Coastwise, 2000)

Long period waves

- The role played by long period waves such as shelf waves, seiches and edgewaves in the study area has not been studied.

5.7 Does the study area have a high, medium or low energy coast?

- Because of refraction, Geographe Bay has a low energy shore (Resource Assessment Commission, 1993).
- The coastal region between Cape Naturaliste and Cape Leeuwin has a high profile; rocky shoreline subjected to highly energetic seas and swells. Waves arrive from the open ocean and impinge along many parts of the coastline unimpeded (The Department of Conservation and Land Management, 1994).
- The coast east of Cape Leeuwin encompassing Flinders Bay is a high energy coast, subjected to heavy swells generated in the Roaring Forties wind belt in the Southern Ocean. Along its shores, south-facing headlands and beaches are exposed to strong wave action for much of the time (The Department of Conservation and Land Management, 1994).

5.8 How do waves affect the hydrodynamics of the study area (circulation/flushing/net water movement)?

Geographe Bay
Although Geographe Bay is relatively protected from the direct impact of prevailing southwesterly swells by Cape Naturaliste, wave-induced circulation has a secondary influence on net circulation (see Fahrner and Pattiaratchi, 1994). The shore of Geographe Bay is known to experience a net eastward littoral sand drift, in response to a dominant swell wave which is reversed by wind waves associated with winter gales on a few occasions in most years (D'Adamo & Mamaev, 1999).

Naturaliste-Leeuwin
Wave-induced circulation can be important influences on the hydrodynamics in nearshore semi-enclosed micro-tidal embayments and lagoonal systems of the Naturaliste-Leeuwin coast (D'Adamo & Mamaev, 1999).

Flinders Bay
In Flinders Bay, the swell is responsible for a net eastward littoral drift. Along its shores, south-facing headlands are exposed to strong wave action for much of the time (D'Adamo & Mamaev, 1999).

5.9 What is the effect of geomorphology (eg bathymetry, islands, reefs) on local wave patterns as ocean swells impact the coastline?

Bathymetry and seabed topography influence wave patterns. Waves moving from deep to shallower water are modified in both their height and direction by refraction, diffraction, shoaling and attenuation due to seabed. In Geographe Bay, the southwesterly swell is refracted by Cape Naturaliste, the shallow shelf of Geographe Bay and the seagrass meadow, thus attenuating the incident wave energy. Note that the seagrass meadow of Geographe Bay is capable of absorbing the wave energy of a 60cm wave. The result is low wave energy at the shoreline and a gradually increasing exposure to swell along the Geographe Bay coastline from south to north (Westralian Sands Limited, 1988). Wave heights are likely to be higher under west and north-westerly swell and wind regimes (PWD, 1981). Between the Capes, the Yallingup Shelf and subtidal reefs modify wave patterns.

5.10 What is the interaction between waves and sedimentation processes?

The amount of sediment being deposited on beaches is dependent to a large degree on the incident wave energy and the extent of offshore reefs. Under prevailing swell conditions, littoral current move sediments to the east along the southern coast (Flinders Bay) and to the north along the western coast (Naturaliste-Leeuwin). The prevailing drift is interrupted by storms, during which the direction of sediment movement can change markedly in response t changing swell and/or sea directions (D'Adamo and Mamaev, 1999).

Geographe Bay

Sediment movement in the nearshore zone is determined by the wave climate. Sediment movement occurs in both cross-shore and longshore directions. Cross-shore movement occurs during winter storms and dissipating tropical cyclones, which is the only time when direct onshore winds may be experienced. Storms lead to erosion of the beach and deposition of sediment in an offshore bar. The documented advance and retreat of the coastline is evidence of sediment transport to and from the sea floor. It has been suggested that this sand is provided by a submerged bar off the Dunsborough coast. In addition, shelf sands may be carried round Cape Naturaliste by the prevailing south-westerly ocean swell (Bird, 1987).

Longshore drifting is produced by both the background ocean swell which is refracted around Cape Naturaliste and approaches the shore of Geographe Bay from the north-west, and by wind generated waves. The net longshore sediment transport in Geographe Bay occurs mainly from west to east. It is carried out to sea or included in the north-eastward longshore sediment transport past Peppermint Grove towards Bunbury (Bird, 1987)

Riedel & Byrne (1983) have observed an average net littoral drift of sediment, from west to east, past the Busselton Jetty of between 40,000 and 60,000 m^3 per year. Further work by Riedel & Byrne (1989) estimated the littoral transport rate past the Port Geographe site, form west to east, to be 50,000m^3 per year during normal years and 80,000m^3 per year during stormy years.

Note that the seagrass meadow of Geographe Bay is capable of baffling a bed current of 0.5m/s and absorbing the wave energy of a 60cm wave. As a result of this baffling, the meadow is capable of trapping significant volumes of sediment moving both onshore and offshore, thereby having an impact on the characteristics of sediment supply to beaches of the bay (Department of Planning and Urban Development, 1992).

5.11 What are the implications of waves on physical characteristics of the study area (eg effect of swell on coastal geomorphology)?

- In Geographe Bay, the interaction with waves and seagrass meadows determines accretion and recession zones, as described in section 2
- Intertidal platforms are formed by a combination of wave attack, biological erosion, undercutting and rock falls. Erosion is also a major contributor in the development of limestone pavements where the limestone has an internally honey-combed

structure and the surface is degraded to an irregular or hummocked shape that is covered by a sand/gravel veneer.

To the west of Dunsborough fault is a series of rocky bays created by wave erosion of the granulites which form the Leeuwin/Naturaliste ridge. The coastal region between Cape Naturaliste and Cape Leeuwin has a high profile, rocky shoreline subjected to highly energetic seas, so that resistant rocks now stand out as headlands. The shore east of Cape Leeuwin is also a high energy coast, with south-facing headlands and beaches exposed to strong wave action for much of the time (Coastwise, 2000).

- Hydrodynamics – see section 5.8
- Sediment dynamics - the varying sizes and energy levels of waves caused by topographic effects causes sedimentation rates to vary for place to place and sorts or separates out sedimentary particles of different sizes (refer to section 5.10)

5.12 What are the implications of waves on biological characteristics of the study area?

- Distribution of organisms - reflects their adaptations to withstand high energy zones along habitats such as exposed rocky shores. This has not been studied in detail for the study area.
- Inhibition of growth - Benthic communities can be damaged by the resuspensions of large amounts of fine sediment by waves. This inturn can smother organisms and reduce light penetration which may inhibit the growth of marine plants

Currents

5.13 What are the major regional currents of the study area? Include formation, speed, direction and seasonality

The Leeuwin Current

- transports warm, buoyant, low-salinity, nutrient-poor tropical water down the Western Australian coastline from the northwest waters of Australia;
- driven from the northwest to southwest of the State by a poleward sea-level height gradient (which overwhelms the opposing effect of prevailing south-southwesterly winds);
- current speeds can exceed 1.5ms^{-1}, with the current reaching a maximum speed just beyond the continental shelf edge (Cresswell, 1991)
- fed by the tropical waters of the Pacific-Indian Throughflow and large-scale eastward-flowing currents which bring tropical and sub-tropical waters in towards the mainland from the Indian Ocean;
- during mid-autumn to mid-spring the absence of sustained opposing equatorward winds, in conjunction with the effect of the earth's rotation, enables the Leeuwin Current to flow fairly consistently over the continental slope and mid-shelf;
- onshore winds (from the northwest quadrant) associated with frontal systems, which occur a few times per month, occasionally force water derived from the Leeuwin Current to encroach onto the shelf and closer to the shore (Mills *et al*, 1996);
- effectively bypasses Geographe Bay on its approach to Cape Naturaliste (however small current eddies do extend shorewards into Geographe Bay), but then travels

closer to the mainland between the two capes and along the south coast en-route to South Australia (Cresswell and Peterson, 1993). To what extent the Leeuwin Current flows into the nearshore zone close to the coast is unknown;
- the area east of Flinders Bay is also within the path of the Leeuwin Current during autumn/winter. The extent to which the waters of the Leeuwin current penetrates close to shore, and becomes entrained in exchange currents for the Hardy Inlet for example, is unclear and requires further investigation;
- driven offshore by the onset and persistence of strong south-southwesterly winds during spring and summer and is replaced closer to the mainland by the Capes Current.

The Capes Current
- is a narrow (<20 km wide) northward flow of relatively cold water with high chlorophyll "a";
- driven by south-southwesterly winds;
- the few satellite-tracked buoys which have drifted onto the southwestern continental shelf during the summer months recorded daily mean current speeds of 30-50 cms^{-1}; (Cresswell and Vaudrey 1977 *in* Pearce and Pattiaratchi, 1999).
- fed by nutrient-rich upwelled water from the region between Cape Mentelle and Point D'Entrecasteaux (Gersbach *et al*, 1999 and Pearce and Pattiaratchi, 1999). The upwelling is driven by winds with a westward component off the south coast and northward component between the capes. The upwelled water is believed to be drawn from over the outer shelf and from just beneath the thermocline at depths of about 50 m or more;
- replaces the Leeuwin Current between Cape Naturaliste and Cape Leeuwin from about mid-Spring to mid-Autumn;
- the action of onshore winds during spring and summer appears to enable the Capes Current to spread into Geographe Bay, with field evidence reviewed by Fahrner and Pattiaratchi (1994) suggesting that it has the propensity to reach into Geographe Bay as far as Busselton;
- the extent to which the waters of the Capes current penetrates close to shore between Cape Naturaliste and Cape Leeuwin, and becomes entrained in exchange currents for areas of Flinders Bay, the Hardy Inlet for example, is unclear and requires further investigation.

5.14 What are the local currents of the study area? Include formation, speed, direction and seasonality

A combination of factors including the prevailing wave conditions, wind strength and direction, existence of nearshore sand bars, and the extent of the beach rock and nearshore reefs, determines the presence and strength of nearshore currents. The more exposed beaches will typically be subject to stronger longshore currents while circulation cells and offshore rip currents may occur between areas of beach rock.

Geographe Bay
- The interaction of variable wind directions, refraction of westerly swells around Cape Naturaliste and the effect of the inner continental shelf result in three main current directions: easterly, westerly and north-westerly. In the nearshore zone, the predominant current is easterly and is responsible for the 'longshore drift' sediment transport regime (Coastwise, 2000);

- mean long-term current speeds in the nearshore zone of Geographe bay are typically of order 0.05-0.1 m/s and driven principally by winds (D'Adamo and Mamaev, 1999);
- storm events can increase current speeds to 0.1-0.2 m/s or more (D'Adamo and Mamaev, 1999);
- tides cause currents with speeds of less than about 0.025 m/s (D'Adamo and Mamaev, 1999); and
- density differences set up by differences (or gradients) in temperature and salinity across and along the bay may be capable of inducing, at best, mean currents of about 0.01 m/s (Fahrner and Pattiaratchi, 1994)

Naturaliste-Leeuwin

- relatively strong nearshore currents occur south of Cape Naturaliste under typical wind conditions (refer to sample hydrodynamic model outputs for wind-driven flows in Fahrner and Pattiaratchi, 1994);
- in nearshore semi-enclosed micro-tidal embayments and lagoonal systems it is known that wave-induced circulation, density currents, and internal recirculation patterns can be important influences on the hydrodynamics (tides are small on this coast and are likely to produce only relatively weak currents); and
- there have been no definitive studies on the finer scale processes for the protected inner waters of this coast

Flinders Bay/Hardy Inlet

- it is known that wind plays a dominating influence on broad coastal water circulation;
- the fine scale oceanography of the Flinders Bay is yet to be studied in any great detail; and
- during summer, in the absence of freshwater discharge, tidal current speeds up to about 0.5 m/s were typical in the Hardy inlet channel, compared to about 0.3 m/s or less in the inlet and basin. In contrast, freshwater discharge causes outflow speeds up to about 1 m s-1 through the basin, inlet and channel as freshwater escapes to the ocean (D'Adamo and Mamaev, 1999)

5.15 Outline the formation of eddies and the occurrence of upwelling

- The presence of the Leeuwin Current over the continental slope and shelf effectively suppresses any tendency for broad-scale upwelling of deeper nutrient-rich waters up onto the shelf, that would otherwise normally be forced by typical upwelling-favorable equatorward winds.
- Occasionally eddies are generated by the Leeuwin Current which introduce warmer water during late winter (Coastwise, 2000)
- The area east of Cape Leeuwin is believed to be within the source zone for the Capes Current, where spring/summer winds with a westward component lead to upwelling of relatively cold, nutrient-rich waters up from depths below about 50 m. This upwelled water is then driven around Cape Leeuwin and northwards as a near-coastal flow.

5.16 How do currents affect the other hydrodynamic characteristics of the study area (net water movement/circulation/flushing)?

Geographe Bay

- The extent to which the Leeuwin and Capes currents influence the hydrodynamics and/or water quality of Geographe Bay is as yet not fully understood. However, the available satellite imagery on this issue suggests that the Leeuwin Current generally bypasses the area, due to the restricting nature of the bathymetry, with bottom friction coming into play as a major opposing force on the current as it tries to encroach into the shallowing bay
- The extent to which the Capes current influences the hydrodynamics of the study area is as yet not fully understood. However, the action of onshore winds during spring and summer appears to enable the Capes Current to spread into Geographe Bay, with field evidence reviewed by Fahrner and Pattiaratchi (1994) suggesting that it has the propensity to reach into Geographe Bay as far as Busselton. Further investigation would be required to clarify the characteristics of intrusion of Capes Current water into Geographe Bay. However, the cooler water introduced by the Capes Current is thought to serve an important role in the flushing of Geographe Bay
- Currents formed by wind are the principle force which drives circulation and mixing throughout the bay for most of the time. The net transport of water through the bay is in a northerly direction reflecting the predominance of northward-directed winds for a large percentage of the time. Refer to hydrodynamic model results of Fahrner and Pattiaratchi (1994) (reproduced in D'Adamo & Mamaev, 1999)

Naturaliste-Leeuwin

- To what extent the Leeuwin Current flows into the nearshore zone close to the coast is unknown and the same can be said for the Capes Current. Anecdotal reports by residents and visitors who regularly swim and surf in the area indicate that the coastal waters are particularly warm in winter and particularly cold in summer, this perhaps suggesting that the Leeuwin and Capes currents, respectively, are driven very close to shore during these respective periods.
- It can be presumed that wind forcing will be dominant along this coastline. However, in nearshore semi-enclosed micro-tidal embayments and lagoonal systems it is known that density currents, wave-induced circulation and internal recirculation patterns can be important influences on the hydrodynamics. Tides are small and likely to produce only relatively weak currents.
- There appears to have been no definitive studies on theses finer scale processes for the protected inner water of the Leeuwin-Naturaliste coast.

Flinders Bay/Hardy Inlet

- The area east of Cape Leeuwin is believed to be within the source zone for the Capes Current, where spring/summer winds with a westward component lead to upwelling of relatively cold, nutrient-rich waters up from depths below about 50 m. This upwelled water is then driven around Cape Leeuwin and northwards as a near-coastal flow. The area is also within the path of the Leeuwin Current during autumn/winter. The extent to which the waters of the Capes and Leeuwin currents penetrate close to shore, and become entrained in exchange currents for the Hardy Inlet for example, is unclear and requires further investigation.

5.17 How do currents interact with geology/geomorphology of the study area?

Interaction of currents with the nearshore continental shelf bathymetry, and shape of the coastline will influence the hydrodynamics of the study area. For example, restricted flushing may occur in the semi-enclosed embayments of the Naturaliste-Leeuwin coast due to the shape of the shoreline and interference to exchange by alongshore reef lines, islands, promontories, headlands and bottom undulations (D'Adamo and Mamaev, 1999).

5.18 How do currents interact with sedimentation processes in the study area (eg littoral drift)?

Under prevailing swell conditions, littoral currents move sediments to the east along the southern coast and to the north along the western coast. The prevailing drift is interrupted by storms, during which the direction of sediment movement can change markedly in response to changing swell and/or sea directions. Department of Conservation and Environment (1980) contains further details on littoral drift patterns for Western Australia.

The effect of the Leeuwin and Capes currents on sedimentation processes has not been studied in detail.

5.19 What are the implications of currents on the physical characteristics of the study area (eg spread of oil spills)?

- The Leeuwin Current has a major impact on the marine environment of the Leeuwin-Naturaliste coast. It transports warm, buoyant, low-salinity, nutrient-poor tropical water down the coastline. Its presence over the continental slope and shelf effectively suppresses any tendency for broad-scale upwelling of deeper nutrient-rich waters up onto the shelf. Subsequently, Autumn and winter sea temperatures at Cape Naturaliste are usually 2-3 degrees higher than in Geographe bay (The Department of Conservation and Land Management, 1994).
- The cooler water introduced by the Capes Current is thought to serve an important role in the flushing of Geographe Bay
- Currents can also influence local geomorphology eg lobate bodies of sand in Geographe Bay are likely to be caused by the easterly longshore current (Coastwise, 2000).

5.20 What are the implications of currents on the biological characteristics of the study area (eg spread of larvae)?

- The Leeuwin Current carries tropical flora and fauna southward to the temperate coastal regions of the State, acting as a strong vehicle for the transport of eggs, larvae, flora, juvenile and adult fishes and marine mammals. For example, 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.
- As pointed out in Pearce and Pattiaratchi (1999), the Leeuwin Current also has a major influence on the life histories and fisheries associated with a number of fish

species (Lenanton *et al*, 1991), including the southern bluefin tuna (Davis and Lyne, 1994) and western rock lobster (Pearce and Phillips, 1988)

- The Leeuwin Current also influences the distribution of some sea birds (Wooler *et al*, 1991).
- 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
- An important ecological characteristic of the Capes Current is that has relatively high levels of chlorophyll *a*, and is relatively rich in nutrients derived from deep sub-thermocline waters, thereby promoting the growth of phytoplankton as the upwelled water is driven along the coast and exposed to photosynthetically active radiation in the photic zone. It therefore has an import influence on the productivity of the area (D'Adamo and Mamaev, 1999)
- It has been suggested that the Capes Current may have important implications for the salmon fisheries off Western Australia as it may affect the migration of adult salmon around Cape Leeuwin (Gersbach *et al*, 1999)

Winds

5.21 What is the influence of winds on the hydrodynamics of the study area (eg net water movement/circulation/flushing)?

Geographe Bay

The wind (particularly the sea breeze effect) is the principle agent which drives circulation and mixing throughout Geographe Bay for most of the time. Circulation patterns in the southern portion are the weakest in the bay. Circulation patterns are weakest in summer. The inferred wind-driven circulation patterns for Geographe Bay are based on historical field data and on the hydrodynamic model results of Fahrner and Pattiaratchi (1994). In the following precis 'strong' currents refer to those with speeds greater than 0.1 m s^{-1} and 'weak' currents to those with speeds less than 0.1 m s^{-1} (Note that these results are in conjunction with the model output in Fahrner and Pattiaratchi, 1994):

- The current response to winds depends very much on the strength of the wind and also on the local relative alignments of the coast and wind.
- The net transport of water through the bay is in a northerly direction reflecting the predominance of northward-directed winds for a large percentage of the time- westerly, south-westerly and southerly winds with relatively strong nearshore currents following the perimeter of the bay in the direction from Cape Naturaliste to Myalup. Southerly winds produce relatively weak variable currents in the nearshore zone between Cape Naturaliste and Busselton.
- Southeasterly winds result in predominantly offshore transport of water with strong northward currents in the nearshore zone north off Koombana Bay, weak variable currents in the nearshore zone between Busselton and Bunbury and moderate to strong westward currents in the nearshore zone between Cape Naturaliste and Busselton.
- Easterly winds also result in an offshore transport of water but in a predominantly southwestward direction, with weak currents in the nearshore zone north of Koombana Bay and strong nearshore currents south of Koombana Bay that follow the perimeter of Geographe Bay towards Cape Naturaliste.
- During winter, north-westerly winds result in predominantly onshore transport of water with relatively weak and variable currents in the nearshore zone between Busselton and Bunbury, but stronger eastward currents in the nearshore zone west of Busselton.

- Under all the wind directions that were used in the simulations currents greater than 0.2 m s^{-1} were predicted for the area over and around Naturaliste Reefs, a result of the relatively shallow bathymetry of that reef area.

The flushing times for southern Geographe Bay are shown in Table 6. Note that this model has been identified to have its limitations (Fahrner & Pattiaratchi, 1994).

Table 7: Geographe Bay flushing times for a constant wind speed of 5.5m/s:

Wind direction	Degrees form south (clockwise)	Flushing time (days)
Easterly	270	5.3
South-easterly	315	15.4
Southerly	0	3.9
South-westerly	45	3.7
Westerly	90	3.6
North-westerly	135	13.3

(Fahrner & Pattiaratchi, 1994)

Naturaliste-Leeuwin

Although the fine scale oceanography of the area is yet to be studied in any great detail, it can be presumed that wind forcing will be as equally dominant along the Naturaliste-Leeuwin coastline as along the Geographe Bay and southern coasts. Fahrner & Pattiaratchi's (1994) modelling of wind-driven flows south of Cape Naturaliste shows relatively strong nearshore currents south of Cape Naturaliste under typical wind conditions (note that this model was reproduced in D'Adamo and Mamaev, 1999).

Flinders Bay/Hardy Inlet

Although the fine scale oceanography of the area east of Cape Leeuwin is yet to be studied in any great detail, it is known that the wind plays a dominating influence on broad coastal water circulation along the south coast throughout the year.

The dynamic behaviour of the Hardy Inlet is influenced by a number of factors typical of estuarine systems. Wind stress, generating wave action, is an effective mixing agent in the large expanse of open water of the basin. Here the water is often stirred to the bottom, with resuspension of fine sediment. Elsewhere in the estuary, wind probably has little effect in mixing the water (Hodgkin, 1976).

5.22 What are the implications of winds on the physical characteristics of the study area (eg water quality)?

Refer to 5.21 and section 2

The prevailing winds and south-west swell action are often seen as the dominating factors which influence the geology/geomorphology of the study area. The alignment of Geographe Bay means that the southerlies of winter, and the easterlies and south-westerly sea breeze of summer, all tend to blow offshore. This feature has three consequences, which have resulted in the low relief which characteristic of the Busselton Holocene barrier:

1. the incidence of onshore waves is very low, and further, the offshore vector of these waves reduces the energy of the refracted swell

2. where there is an onshore component of the winds, the fetch across which waves can form is limited, which results in the formation of very low amplitude waves which have a low capacity for sediment transport
3. the general absence of onshore breezes reduces the construction of substantial coastal dunes

(Dept Planning and Urban Development, 1992)

Leeuwin-Naturaliste coast has been particularly subject to wind and wave attack, so that resistant rocks now stand out as headlands. The dune systems form three distinct units. parabolic dunes overlie many limestone areas of the coast; unstable blowout areas which can amalgamate to form mobile dune sheets which frequently migrate inland eg Cape Naturaliste; and foredunes which occur along stretches of sand beaches. The type of foredune is dependent on wave energy, wind energy and the amount of sediment transported onshore (The Department of Conservation and Land Management, 1987).

5.23 What are the implications of winds on the biological characteristics of the study area (eg spread of larvae)?

As winds are major driving forces of water level, waves, currents and temperature and salinity gradients, the implications of winds on the biological characteristics of the study area is shown in 5.4, 5.12, 5.20 and 5.26.

Temperature and Salinity

5.24 Where and why do temperature and salinity gradients form? Outline the interaction of these gradients with local conditions (eg river runoff, winds, current, tides)

The shallow nearshore zones of Geographe Bay and the Naturaliste-Leeuiwn coast are strongly influenced by diurnal variations in heating and cooling and freshwater input through rivers, drains and submarine groundwater discharge. These processes generate vertical and horizontal stratification of salinity which may subsequently drive a thermohaline circulation (Fahrner & Pattiaratchi, 1994).

Until the Blackwood and Scott rivers begin to flow strongly in winter, the Blackwood Estuary remains saline, with the dynamics of the lower reaches characterised by the cyclic upstream and downstream movement of seawater as a salt wedge, in response to the diurnal cycle of the tide. During ebbs there is intense vertical mixing above the sills and in the shallow basins, forming regions of medium salinity water which, upon the turn of the tide to flood, make their way upstream as intrusive jets, above the bottom-penetrating salt wedge. Agnew *et al* (1976) found these jets to transport water up to 10 km upstream during flood tides. Because of the presence of relatively dense water upstream of the sills, some of this water remains trapped at the bottom during ebbs as the more buoyant water near the surface heads downstream, out to sea. A strong halocline (zone of intense salinity change) is formed between the outflowing water and more saline water of the salt wedge below. This assists in the retention of sea water within the estuary over successive tidal cycles.

The Blackwood Estuary discharges significant amounts of freshwater to the coastal zone near Augusta during the winter-spring rainfall/runoff period. Buoyant freshwater inputs to the bay from the estuary will initially spread close to the shore as buoyant plumes, creating a *Region of Freshwater Influence* (Simpson, 1997), until dispersed by local currents etc. This will set up vertical and horizontal density gradients and frontal zones between the plumes and receiving oceanic water. Coastal circulation patterns and vertical mixing eventually disperses buoyant estuarine outflows

5.25 Are there any salinity/temperature changes which cause density differences and subsequently drive circulation? What strengths are these circulations?

The creation of salinity and temperature changes may generate horizontal density gradients. For example, heating of the nearshore zone leads to horizontal density contrasts arising between nearshore and offshore areas. The effect of simple thermal expansion due to heating of a vertically mixed nearshore water column would be an alongshore current in the downcoast direction which is maximum near the surface and zero at the bottom. Hence a net alongshore transport could be generated (Pettigrew and Murray, 1986). The strength of the circulations is unknown

Baroclinic circulation is only of minor importance in Geographe Bay, except for Koombana Bay, as vertical and horizontal density gradients appear to be small and the waters are generally well mixed (Fahrner & Pattiaratchi, 1994). The strength of the circulations is unknown.

Refer to section 5.24 for a discussion of salt wedge dynamics of the Blackwood estuary, and the effects of the discharge of significant amounts of freshwater to the coastal zone near Augusta during the winter-spring rainfall/runoff period.

5.26 What is the impact of temperature and salinity on the marine communities of the study area?

Refer to section 2.1 – notes on the influence of salinity gradients on the fauna of estuaries.

Benthic (bottom dwelling) communities may be adversely affected in periods of temperature stratification. Water may cool to form cold and dense water pools in lagoons. Cold water can sink to the bottom of depressions creating vertically layered conditions where the bottom layers of water are trapped. Poor flushing over sustained periods may cause temperature stress to benthic communities (usually prevented by tidal and current mixing). This may be an issue in the near-shore embayments of Naturaliste-Leeuwin and the Hardy Inlet.

The formation of salinity layers can lead to prolonged residence times and associated accumulations of contaminants, which could subsequently affect marine communities. This could be a potential impact on the marine communities of the study area, although no significant events have been reported to date.

Prolonged exposure to direct sunlight, high temperatures and desiccation (drying) at low tide can cause damage to intertidal communities. Tidal pools remaining on rocky platforms at low tide may act as refuges from desiccation. However, if sufficient

heating occurs, evaporation causes these pools to deoxygenate and increase in salinity, causing stress to any inhabitants. Many animals and plants in tidal in these communities exhibit adaptations to cope with the environments subject to tidal conditions. This is a general principle which can be applied to the study area.

6 Bathymetry

CONTACTS:
NICK D'ADAMO (The Department)

6.1 Outline the bathymetry of the study area

Geographe Bay

- relatively simple bathymetry with gentle gradients
- nearshore zone is characterised by a series of submarine sandbars which rise up to 2m above the surrounding sea floor
- water depth increases to about 3 to 4 m within several hundred metres of the shore
- a gentle offshore gradient (approximately 2m/km) deepens the profile gradually: the seabed then slopes away gently to the 30 metre isobath some 15 km offshore
- beyond the 30m isobath the seafloor forms a very gently sloping platform ('the inner shelf'), with an average depth of about 40m, that meets the 50m isobath some 75km offshore from Koombana Bay
- the seafloor then slopes rapidly away to the edge of the continental shelf over an area which is termed 'the outer shelf'
- Naturaliste Reefs, about 35 km due north of Cape Naturaliste, form a major bathymetric feature in the outer part of the bay
- the distinctive feature of the bathymetry is the partitioning of the continental shelf into upper and lower shelves, a terrace-like structure. The upper shelf is bounded by the 50m isobath and the continental shelf break by the 200m isobath
- refer to Gersbach (1999) – three dimensional oblique perspective plot (reproduced in D'Adamo & Mamaev, 1999)
  (Fahrner and Pattiaratchi, 1994; D'Adamo and Mamaev, 1999)

Naturaliste-Leeuwin

- characterised by the two terrace-like shelves within the 50 m and 200 m isobaths
- to the west lies the Yallingup Shelf, an area of shallow basement extending to the continental shelf
- refer to Gersbach (1999) – three dimensional oblique perspective plot (reproduced in D'Adamo & Mamaev, 1999)
  (D'Adamo and Mamaev, 1999)

Flinders Bay

- the offshore bathymetry is characterised by the two terrace-like shelves within the 50 m and 200 m isobaths, respectively
- refer to Gersbach (1999) – three dimensional oblique perspective plot (reproduced in D'Adamo & Mamaev, 1999)
  (D'Adamo and Mamaev, 1999)

Blackwood Estuary

- upstream of the mouth of the Hardy Inlet, the channel bathymetry undulates between about 2 and 8 m depth en-route to the Hardy Inlet
- Hardy inlet has a deep central channel 2-8 m deep, flanked by wide shallow margins less than about 1 m in depth
- the basin bathymetry around Molloy island is relatively shallow, except for a channel running along its northwest perimeter
  (D'Adamo and Mamaev, 1999)

6.2 What is the interaction of bathymetry with the oceanographic processes of the study area?

- The Leeuwin Current is located over the continental shelf break and is bounded on the shoreward side by the inner shelf break. The peak sea surface temperature generally moves shoreward during the winter months and seaward during the summer months. The presence of the Leeuwin Current over the continental slope and shelf suppresses broad-scale upwelling of deeper nutrient-rich waters up onto the shelf. The Capes Current is located inshore of the Leeuwin Current, extending from the shore to the region over the inner shelf break where it is bounded by the Leeuwin Current. Sporadic upwelling has been established as a supplier of cold nutrient-rich waters to the coastal region off the south-west corner of the WA. This mechanism feeds the Capes Current between Cape Leeuwin and Cape Naturaliste (The Department of Conservation and Land Management, 1994; Gersbach, 1999).
- Waves moving from deep to shallower water are modified in both their height and direction by refraction, diffraction, shoaling and attenuation due to seabed friction eg the influence of the Yallingup shelf, the effect of subtidal reefs and the effect of seagrass meadows in Geographe Bay.
- Restricted flushing may occur in the semi-enclosed embayments of the Naturaliste-Leeuwin coast due to the shape of the shoreline and interference to exchange by alongshore reef lines, islands, promontories, headlands and bottom undulations (D'Adamo and Mamaev, 1999).

6.3 Do any seasonal changes occur to the bathymetry of the study area (eg as a result of storm events, algal life cycles)?

- Estuarine bars – all of the estuaries of the study area have sand bars at their mouths and are effectively seasonally closed when stream flow is minimal (Pen, 1997)
- Under prevailing swell conditions, littoral currents move sediments to the east along the southern coast and to the north along the western coast. The prevailing drift is interrupted by storms, during which the direction of sediment movement can change markedly in response to changing swell and/or sea directions (D'Adamo and Mamaev, 1999).

7 Marine and coastal communities

CONTACTS:
KEVIN BANCROFT (The Department of Conservation and Land Management)

7.1 In what IMCRA biogeographical province and region(s) does the study area occur, and what are the defining features of the biota and the marine and coastal communities?

- 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:
  - 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;
  - more widely distributed elements whose range extend from the South Western Biotone 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 (IMCRA, 1998).

  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).

  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).
- According to the classification of Wilson & Allen (1987), 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)
- Hutchins (1994) investigated the distribution of nearshore reef fish at twelve regions along Western Australia's west and south coasts between 1977 and 1993. In the Cape Leeuwin to Cape Naturaliste area, 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'*.

7.2 What are the major marine and coastal communities of the study area? For each community, state:

a) distribution and area covered within the study area;

b) structure (eg rock type, sediment type, relief);
c) distribution and diversity of predominant flora and fauna;
d) the occurrence of any species of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauan) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999*?), rare or endemic species;
e) the influence of the physical environment on structural morphology, and flora and fauna distribution and adaptations;
f) the influence of biological processes on structural morphology, and flora and fauna distribution and adaptations;
g) productivity/food webs/community structure;
h) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);
i) current condition/degree of naturalness (eg degraded; healthy); and
j) current/proposed management strategies and future implications.

NB: The following responses to question 7.2 a are in relation to the study by Bancroft and Shattock (2000), whereby the study area for the habitat mapping exercise covered an area of approximately 1096km^2.

SEAGRASS (perennial and ephemeral)

(a) Distribution and area covered:

- Refer to broadscale map of the major marine habitats in the Geographe Bay-Capes-Hardy Inlet region (Bancroft and Shattock, 2000)
- Perennial seagrass – typically present upon sand substratum, however seagrasses (eg *Thalassodendron pachyrhizum*) commonly occur in sand patches on reef pavement (Bancroft and Shattock, 2000).
- Ephemeral seagrass – typically present upon sand substratum, however seagrasses commonly occur in sand patches on reef pavement (Bancroft and Shattock, 2000)

Table 8: Percentage of the seagrass habitats in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

HABITAT TYPE	PERCENTAGE OF THE SEAGRASS HABITATS IN THE STUDY AREA
perennial seagrass (dense)	6.1%
perennial seagrass (medium)	18.7%
perennial seagrass (sparse)	10.9%
ephemeral seagrass	2.9%

(Bancroft and Shattock, 2000)

- Note that Wilson (1994) states that the Geographe Bay meadows are the most extensive on the west coast apart from Shark Bay; monospecific strands of *Posidonia sinuosa* cover approximately 70% of Geographe Bay (Lord & Associates, 1995)

(b) Structure:

- Perennial seagrass – typically an area of seagrass meadow, which consists o species that are present throughout the year. This habitat can be divided into three sub-categories:
  1. dense – where the seagrass coverage is greater than the area of exposed substrate
  2. medium – where the seagrass cover approximates the area of exposed substrate, and
  3. sparse – where the seagrass cover is less than the area of exposed substrate (Bancroft and Shattock, 2000).
- Ephemeral seagrass – typically an area of seagrass meadow, which consists of species that are short-lived or has high seasonal variation in coverage (Bancroft and Shattock, 2000)
- The seagrasses of the genera *Amphibolis* and *Posidonia* form continuous meadows from approximately 2m to 14m depth in Geographe Bay. Below 14m seagrasses become sparse and patchy in distribution, with plants present in small clumps.
- Seagrass meadows have associated with them sand areas known as “blowouts”, sand lobes, transverse furrows and sand bars. "Blowouts" are generally of parabolic shape, varying in size from a few square metres to several hectares, with the long axes of the parabolic scours oriented in a SW-NE direction and the parabolic apex convex to the south-west, with an overhanging scarp of exposed rhizome fibres up to 0.6m high at the apex, tapering to the edges. The scour floors gently rise to the level of the seagrass meadows. The distal margins are colonized by *Amphibolis antarctica*, a species known to colonise mobile sand substrates. At greater distance from the scour *Posidonia* species begin to re-establish (Walker *et al.*, 1994 and Kirkman & Walker, 1989). Transverse furrows, 100 to 300 m wide, running at angles of 290 degrees in the eastern bay to 340 degrees in the west, at intervals of 500-1500 m, with increased spacing to the east. The furrows are similar in cross-section to the scours, but the eroding scarp face may be gently scalloped, with scallop amplitudes of 5-20m. On the south-west margin there is an over-hanging scarp and there is a gently slope up to meadow level on the north-east margin. This north-east margin is colonized by *Amphibolis* while the scarp is cut in *Posidonia* rhizome mesh. The furrows also appear to be migrating southwest in a similar way to the blowouts. They extend seaward until a depth of 14m where they become discontinuous and poorly defined (Kirkman & Walker, 1989; Searle and Logan, 1978). 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 sand lobes extend out from the north-eastern margins of traverse furrows. Sand lobes only occur in depths of less than 6m. They rise gently to a height of about 1m above the seagrass meadow (Kirkman & Walker, 1989; Searle and Logan, 1978). Sand bars are developed at the landward edge of furrows. They are created by the shoreward deposition of sediment along the furrows. The bars have a maximum elevation of 2m and they are not normally emergent, however, sand islands have been reported at Siesta Park. Migration of the furrow and the eastward

longshore current causes these bars to lie at a more acute angle to the shore than the furrows. The north-east margins of the bars are colonized by *Amphibolis* while the south-west margins support small discontinous erosion scarps in the *Posidonia* meadow. This suggest that the bars migrate in conjunction with their parent furrows (Searle and Logan, 1978).

(c) Distribution and diversity of predominant flora and fauna:

- 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. Seagrasses of the "*Posidonia ostenfeldii*" complex predominate in the Naturaliste-Leeuwin region, as their strong leaves and deep roots are adapted to heavy swell conditions.
- Macroalgae (particularly *Scaberia agardii*), sessile invertebrates such as ascidians (e.g. *Pyura* spp., *Botrylloides* spp.), sponges (e.g. *Oceanapia* sp.), and mobile invertebrates such as seastars (*Fromia* sp.), seaurchins (*Amblypneustes* sp.) and crustaceans (*Portunus pelagicus*), are associated with perennial seagrass habitat (Bancroft and Shattock, 2000).

Table 9: Seagrass species of the Geographe Bay-Capes-Hardy Inlet region

SPECIES	Occurrence	Distribution (Murdoch University, 1996)
Amphibolis antarctica (Labill.) Sonder ex Aschers.	Geographe Bay Naturaliste-Leeuwin (on periphery and in the blowouts) Flinders Bay	Wide distribution: Exmouth southwards to Wilson's Promontory
Amphibolis griffithii (Black) denHartog	Geographe Bay Naturaliste-Leeuwin (on periphery and in the blowouts) Flinders Bay	Kalbarri southwards to Victor Harbour, SA
Halophila ovalis (R.Br.) Hook.f.	Geographe Bay Naturaliste-Leeuwin (on periphery and in the blowouts) Flinders Bay	Tropical and temperate, south to Cowaramup Bay in WA. Common in estuaries
Heterozostera tasmanica(Aschers.) Dandy	Geographe Bay Naturaliste-Leeuwin (on periphery and in the blowouts) Flinders Bay	Dongara southward around to Jervis Bay
Thalassodendron pachyrhizum denHartog	Geographe Bay	Kalbarri southwards to Twilight Cove Endemic to area
Posidonia sinuousa	Geographe Bay (debatable) Naturaliste-Leeuwin (more sheltered areas)	Geraldton to Victor Harbour, SA
P. angustifolia Cambridge and Kuo	Geographe Bay Naturaliste-Leeuwin (more sheltered areas)	Geraldton to Victor Harbour, SA
P. australis Hook.f.	Geographe Bay Naturaliste-Leeuwin (more sheltered areas)	Shark Bay to Lake Macquarie, NSW
P. coriacea Kuo and Cambridge	Geographe Bay Naturaliste Leeuwin (more exposed areas)	Ningaloo to South Australia
P. ostenfeldii Ostenfeld	Geographe Bay Naturaliste Leeuwin (more exposed areas and on the periphery and in the blowouts of the seagrass beds)	Cape Leeuwin to Israelite Bay *Endemic to the area
P. robertsoniae	Naturaliste Leeuwin (more exposed areas)	Cape Leeuwin to Israelite Bay *Endemic to the area
P. kirkmanii	Naturaliste Leeuwin (more exposed areas)	Cape Leeuwin to Israelite Bay *Endemic to the area
P. denhartogii	Naturaliste Leeuwin (more exposed areas)	Perth to South Australia

(Bancroft, *pers.comm.*; Kirkman & Walker, 1989; Walker *et al.*, 1994; and Murdoch University, 1996).

- Few fauna and flora species are associated with ephemeral seagrass habitat (Bancroft and Shattock, 2000).
- Seagrass meadows are also known as important nursery grounds for many fish species. For example, the seagrass meadows in Geographe Bay are home to at least 19 species of fishes, with the pencil wee whiting *Neoodax radiatus* the most common (see Scott, 1981 in Elscot and Bancroft (1998) for species list).

- Seagrasses also carry populations of epiphytes: macroalgal epiphytes, diatom aggregations and cyanobacterial aggregations. There are temporal variation in these epiphytes, with *Cladophora*, *Pachydictyon* and *Polycerea* dominant in summer and red algae such as *Metagoniolithon* more common in winter. *Mastoglois* (Bacillariophyta) aggregations are found in the south-western portion of Geographe Bay, increasing in cover over summer and mostly disappearing after a storm in summer. *Chroococcus* (Cyanophyta) aggregations were present, increasing over summer, especially at Vasse Diversion Drain Vasse-Wonnerup Estuary (McMahon and Walker, 1997).
- 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.
- Seagrasses of the *Posidonia* complex predominate in the Naturaliste-Leeuwin region, as their strong leaves and deep roots are adapted to heavy swell conditions:

(d) No endemic, rare or species of special conservation status (John Huisman, Murdoch University, *pers.comm.*).

However: *P. ostenfeldii, P. robertsoniae* and *P. kirkmanii* occur from Cape Leeuwin to Israelite Bay and are endemic to the area (Murdoch University, 1996). *Thalassodendron pachyrhizum* occurs from Kalbarri to Twilight Cove, and is endemic to the area (Murdoch University, 1996)

(e) Influence of the physical environment:

- In general, benthic macrophytes require light, adequate temperature and nutrients for growth. The upper limit of seagrass distribution is determined partially by the tidal amplitude, as the larger seagrasses are unable to tolerate emersion, and also by the surf zone, as they are unable to withstand high energy environments. 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. Seagrasses of the "*Posidonia ostenfeldii*" complex predominate in heavy swell conditions due to their strong leaves and deep roots, while the "*Posidonia australis"* complex are mostly found in sheltered embayments (Kirkman & Walker, 1989).
- The lower limit of seagrasses is usually light dependent, and the offshore waters of Geographe Bay are particularly clear (Walker *et al.*, 1987). The clear waters of the Geographe Bay region allows the area to have the deepest seagrass record for the State: *T. pachyrhizum*, north-west of Busselton (3234'20" S, 11515'00" E) at 45 m. *Posidonia* spp. and *Amphibolis* spp. have been reported from 27 m (3331'30" S, 11528'30" E) (Walker *et al.*, 1994 and Kirkman & Walker, 1989). The clear waters south of Cape Naturaliste allow *Posidonia* sp. and *Amphibolis* app. to form large beds at depths round 30 m exposed to direct oceanic swell; this is not found on any coast elsewhere in the world (Kirkman & Kuo, 1990)

  The seagrasses of the genera *Amphibolis* and *Posidonia* form continuous meadows from approximately 2m to 14m depth in Geographe Bay. Below 14m seagrasses become sparse and patchy in distribution, with plants present in small clumps. Below 14m 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* (Walker *et al.*, 1994 and Kirkman & Walker, 1989).

- 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: 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).
- Examination of the N:P ratio of the nutrient load entering Geographe Bay, the N:P ratio of water column total nitrogen and phosphorus and the C:N:P ratio in *P.sinuosa*, indicates nutrient limitation, especially by nitrogen, in April, July and September. In January, phosphorus limitation is implied. Nutrient limitation may minimise algal growth in summer. In winter when nutrients are available but turbid conditions prevail at sites with drains, algal and seagrass growth are likely to be limited by light (McMahon, 1994)
- Nutrient input into Geographe Bay from drains was readily absorbed by the system: dilution and uptake of nutrients by seagrasses is implied (McMahon, 1994).
- Seagrass cover decreased between 1947 and 1965, a time when intensive land clearing in the catchment and construction of drainage systems to the sea occurred

(f) Influence of biological processes:

- Competition
- Predation eg grazing by sea urchins
- dispersal and recruitment
- Seagrasses carry populations of epiphytes as described in c). Epiphytes can potentially smother the seagrasses, and affect growth by limiting light.
- It has been suggested that transverse furrows are formed by an amalgamation of parabolic scours, and it is possible that furrows occur when a seagrass meadow had begun to build up stagnant root and rhizome material and hence loses its resistance to erosion (Searle and Logan, 1978).

(g) Productivity/food webs/community structure:

Seagrasses are ecologically vital in the long-term sustainability of the coastal zone. Seagrasses are important primary producers in coastal environments – there are an important food source for may marine organisms via direct consumption and as a part of the detritus.

Seagrass meadows in the study area are extremely important as habitat and nursery areas for many species, included some of which are targeted by recreational and commercial fishers, such as the western rock lobster, *Panulirus cygnus.*

(h) Past, present and potential uses and/or pressures, evidence of impact and research programs:

- Pressures
  - Nutrient inputs from diffuse (eg Geographe Bay catchment) and point sources (eg wastewater treatment plants; agricultural drains)
  - Groundwater discharges (eg nutrient sand pesticides)
  - Mooring and anchoring
  - Propellor scour
  - Sand mining
  - Industrial discharges (although note that nutrients and other contaminants discharged into Geographe Bay from industrial processes are not considered to be important since the major components in these discharges include the natural constituents of sea water (Holmes, 1994))

- Aquaculture? Awaiting correspondence from Fisheries WA

- Evidence of impact and associated research
  - In 1993, an independent study was undertaken on behalf of the Environmental Protection Authority to determine the changes in seagrass cover at Busselton, Broadwater and Quindalup over the last 50 years. Between 1958 and 1976 seagrass cover in Geographe Bay decreased by up to 45%. 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- i.e. the increased sediment and nutrient input caused by bush clearing for agricultural development and the construction of large drains. Over the last 20 years, the total of the areas of southern Geographe Bay occupied by seagrass has remained relatively constant. (Lord & Associates, 1995; Coastwise, 2000).
  - These results were supported by a study in 1988 by the Department of Transport (then the Department of Marine and Harbours) to assess the potential effects of the Port Geographe canal-based residential development. Regional seagrass cover decreased by 20% between 1958 and 1965, by only 3% between 1965 and 1979 and by a further 9% between 1979 and 1983. During the period 1983 to 1987 seagrass cover increased by 14%. It was noted that such variation may have been the result of natural factors (Riedel & Byrne, 1988) (Riedel & Byrne, 1988).
  - Research has suggested that the general shoreline accretion of Geographe Bay is a result of a decrease in seagrass meadow area, whilst erosion loci are associated with unbroken seagrass meadows directly offshore. Refer to section 2.5 for more information. Seagrass decline is of major concern as it leads to coastal accretion that will continue until the sediment supply is exhausted, at which point coastal erosion rates will become very high (Lord and Associates, 1995; Coastwise, 2000).
  - Lord and Associates (1995) noted that inshore areas around several of the agricultural drains (particularly the Vasse Diversion Drain and the Buayanup Drain) had excessive epiphyte loads from the increased nutrient runoff in these areas. This study also noted the presence of green algal slime occurring in seagrass meadows and that it may be of importance, but that the persistence and significance of it was not known.
  - In Geographe Bay, "blowouts" are generally of parabolic shape, varying in size from a few square metres to several hectares. Recolonisation of blowouts 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 (Walker *et al.*, 1994 and Kirkman & Walker, 1989).
  - Professional fishers who operate in Geographe Bay noted that seagrass was being degraded and replaced with wireweed (Coastwise, 2000)
  - 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.

(i) Current condition:

- Healthy, with localised areas of degradation around point sources of nutrient input.
- 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 (known collectively as "The Geographe Bay Study, 1993-1995") as an extension of the Perth Coastal Waters Study (Lord & Associates, 1995). The seagrasses, algae and water quality of Geographe Bay were investigated by McMahon (1994), Walker *et al.* (1994, 1995a, 1995b, 1995c, 1995d, 1995e), McMahon *et al.* (1997) and McMahon & Walker (1998). It was concluded that seagrasses in Geographe Bay were mostly in a stable and healthy condition. Overall, epiphyte loads were low and comparable to healthy meadows elsewhere in local coastal waters. However, inshore areas around several of the agricultural drains (particularly the Vasse Diversion Drain and the Buayanup Drain) had excessive epiphyte loads from the increased nutrient runoff in these areas. Note that the use of Dunsborough as a reference location was questionable (Elscot and Bancroft, 1998; Lord and Associates, 1995)
- It was suggested that nutrient concentration (particularly phosphorous) may be limiting filamentous algal growth. The presence of blue-green algal and diatom aggregations did not appear to be an indication of nutrient enrichment. Nitrogen appeared to be the limiting nutrient for growth of primary producers. It was suggested that the accumulation of diatomaceous mucopolysaccharide slimes and blue-green algal aggregations on the seagrasses are of some concern and require further investigation (Lord and Associates, 1995).

(j) Current/proposed management strategies:

- 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.
- Proposed marine conservation reserve (The Department of Conservation and Land Management)
- Fisheries WA management and legislation, eg bag and size limits, to help conserve the fish stocks which inhabit the seagrass communities

<u>SAND</u>

(a) Distribution and area covered:

- Refer to broadscale map of the major marine habitats in the Geographe Bay-Capes-Hardy Inlet region (Bancroft and Shattock, 2000)
- Subtidal zone
- 30.4% of the total marine habitat of the study area (Bancroft and Shattock, 2000)

(b) Structure:

- Predominantly white carbonate sands as a substrate, however the sand may overlay reef platform or have patches of other habitats present (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna:

- May have seasonal vegetation or permanent patches of seagrass or macroalgae, and invertebrate infauna may also be present (Bancroft and Shattock, 2000)

(d) Endemic species/special conservation status:

Lack of information available

(e) The influence of the physical environment:

- Salinity – influences community structure
- Temperature – influences community structure
- The nature of the sediment (sediment size and organic content) – this will determine the distribution of organisms which live on the sediment surface and buried within the sediment because sediments provide a buffer against physical stress. They retain moisture, slow temperature and salinity changes and block out UV light. The movement of oxygen and nutrients is more rapid in coarser sediments, but these tend to be less rich in organic detritus, which provides food for many animals.
- Wave action – eg local erosion of the seagrasses by storms is the probable origin of parabolic scours or 'blowouts'. Once the depression is formed it is shaped into the parabolic form by prevailing south-westerly seas. Erosion occurs on the south-west margin and redeposition occurs among the grasses on the north-east margin. The net effect is movement of the parabolic scour to the south-west (Searle and Logan, 1978).
- Currents – for example, sand lobes are probably produced by the easterly longshore current flow. As wave refraction increases, the current vector parallel to the shore (i.e. across the furrow) increases. Sand being transported in the furrows is deflected eastward. The amount of sediment being deposited on the north-east margins of the furrow is too much for the seagrass to cope with and subsequently the seagrass is buried. The easterly current experiences an increase in flow because of the creation of a smooth sand surface. This increase inflow brings more sediment and more of the meadow is buried. Sand bars are developed at the landward edge of furrows by the shoreward deposition of sediment along the furrows.

(f) Influence of biological processes:

- Competition for food
- Predation
- Dispersal and recruitment
- Biological disturbance which occurs in the form of bioturbation, whereby burrow builders can limit the abundance and distribution of certain sedentary species. However, burrow builders also create the 3D structure that is home to commensal species

(g) Productivity/food webs/community structure:

- Sand communities are generally characterised by a diverse range of infauna. The majority of animals in soft substrata live below the surface. Deposit feeders are more often found in finer sediments where the organic content is great, while suspension feeders such as mussels are more common in coarser sediments where faster currents renew food supplies more quickly. Meiofauna (between 0.1mm and 1mm) live between the sand and mud particles, and include polychaetes and other types of worms. Other burrowers include crustaceans such as crabs, amphipods and burrowing shrimps. Macrofauna include molluscs, echinoderms, bivalves, worms, crabs etc.

(h) Past, present and potential uses and/or pressures:

- Input of nutrients and pollutants, eutrophication and algal blooms
- Dredging
- Spoil dumping
- Commercial and recreational fishing
- Tourism

(i) Current condition

Healthy (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies

- *HMAS Swan* Wreck Site has a total prohibition on the taking of any fish within 200m of the *HMAS Swan* dive wreck (*Prohibition on Fishing ("HMAS Swan" Wreck Site) Order 1998* of the *Fish Resources Management Act, 1994*).
- Proposed marine conservation reserve

SAND SHOAL

(a) Distribution and area covered within the study area:

- Refer to broadscale map of the major marine habitats in the Geographe Bay-Capes-Hardy Inlet region (Bancroft and Shattock, 2000)
- Occur in the Hardy Inlet in the study area.
- In general, sand shoals are located in the lower intertidal zone, generally seaward of the coastline habitats and is typically found in macrotidal (>2m tidal range) areas where strong currents and wave action create offshore banks and shoals. These banks and shoals can also be connected to islands or the mainland (Bancroft Shattock, 2000).
- 0.2% of the major marine habitats in the study area (Bancroft and Shattock, 2000)

(b) Structure:

Consists of mobile, medium to coarse sands, and is typically unvegetated (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna:

- Support bivalves (*Arthritica* sp., *Katelysia sclarina*), gastropods (*Potamopyrgus* sp., *Hydrococcus* sp.) and contains a low diversity of infauna such as polychaetes and nematodes. Sand shoals are important feeding grounds for migratory wading birds such as bar-tailed godwits (*Limosa lapponica*), curlew sandpipers (*Callidris ferruginea*) and white-faced heron (*Egretta novaehollandiae*) (Bancroft and Shattock, 2000).
- For more information, refer to Hodgkin (1976) – An Environmental Study of the Blackwood River Estuary
- For more information regarding estuarine communities, refer to "silt" community of section 7.2

(d) Endemic species/special conservation status:

- Migratory wading birds utilise sand shoals for feeding (refer to section 8.2 for more information)
- Lack of information available regarding invertebrates (refer to section 8)

(e) The influence of the physical environment:

- Wave action - in general, sand shoals are typically found in macrotidal (>2m tidal range) areas where strong currents and wave action create offshore banks and shoals
- Currents - In general, sand shoals are typically found in macrotidal (>2m tidal range) areas where strong currents and wave action create offshore banks and shoals
- Sediment transport – influences community structure
- Temperature – influences community structure
- Salinity – influences community structure
- The nature of the sediment (sediment size and organic content) will determine the distribution of organisms which live on the sediment surface and buried within the sediment
- For more information regarding estuarine communities, refer to "silt" community of section 7.2

(f) Influence of biological processes:

- Competition for food
- Predation
- Dispersal and recruitment
- Biological disturbance which occurs in the form of bioturbation, whereby burrow builders can limit the abundance and distribution of certain sedentary species. However, burrow builders also create the 3D structure that is home to commensal species
- For more information regarding estuarine communities, refer to "silt" community of section 7.2

(g) Productivity/food webs/community structure:

The majority of animals in soft substrata live below the surface. Deposit feeders are more often found in finer sediments where the organic content is great, while suspension feeders such as mussels are more common in coarser sediments where faster currents renew food supplies more quickly. Meiofauna (between 0.1mm and 1mm) live between the sand and mud particles, and include polychaetes and other types of worms. Other burrowers include crustaceans such as crabs, amphipods and burrowing shrimps. Macrofauna include molluscs, echinoderms, bivalves, worms, crabs etc.

(h) Past, present and potential uses and/or pressures

- Input of nutrients and pollutants, eutrophication and algal blooms
- Dredging
- Spoil dumping
- Commercial and recreational fishing
- Tourism

(i) Current condition

Healthy (Bancoft, *pers.comm.*)

(j) Current/proposed management strategies

- Proposed marine conservation reserve

SHORELINE REEF PLATFORM

(a) Distribution and area covered within the study area:

- Refer to broadscale map of the major marine habitats in the Geographe Bay-Capes-Hardy Inlet region (Bancroft and Shattock, 2000)
- typically located in the lower intertidal or nearshore subtidal zones (<1m below LAT) (Bancroft and Shattock, 2000)
- 0.4% of the major marine habitats in the study area (Bancroft and Shattock, 2000)

(b) Structure:

- occurs as low relief reef platforms of sedimentary (limestone or sandstone) substratum that are contiguous with the shoreline (Bancroft and Shattock, 2000)
- limestone outcrops are generally small and narrow (10-20m width) interspersed with small sandy beaches and follow the line of the dune behind. The incessant onshore waves move across the reef and sand may be trapped in depressions or amongst algae (Kendrick *et al*., 1999).
- the largest limestone platforms are found at Yallingup, Cowaramup, Gnarabup, surrounding Hamelin Island and the islands off Cosy Corner (Kendrick *et al*., 1999).

(c) Distribution and diversity of predominant flora and fauna:

- Supports turf algae (*Galeolaria* sp., *Scytosiphon* sp.) and invertebrates such as gastropods (turban shells *Turbo* spp., dogwhelks *Thais orbita,* abalone *Haliotis* spp.), seaurchins (*Heliocidaris erythrogramma*), anemones (*Actinia tenebrosa*), seastars (*Patiriella* spp.) and sponges (*Haliclona* sp.) (Bancroft and Shattock, 2000)
- In general the fauna on the intertidal rock platforms sampled in the study by Kendrick *et al.* (1999) had a low diversity as the design did not adequately reflect the high diversity of species in the area. The intertidal fauna consisted predominantly of molluscs with good numbers of crustaceans and cnidarians, and occasional echinoderms, sponges and fish. The most common and ubiquitous species were the pulmonate limpet *Siphonaria jeanae*, the acmaeid limpet *Patelloida alticostata*, the trochid *Austrocochlea rudis* and the nerite *Nerita atramentosa.* Other notable species included the serpulid *Galeolaria caespitosa*, the chiton *Clavarhizoma hirtosa* and the whelk *Thais orbita.* All other species were in much smaller numbers and more patchily distributed.

(d) Endemic species/special conservation status:

- Lack of information available (refer to section 8)

(e) The influence of the physical environment:

- In WA, the continuous south-west swell has been dominant in moulding the shape of softer parts of the coast
- Currents – eg distributes food to inhabitants of the reef
- Tidal action – influences community structure via exposure
- Tubidity – influences community structure
- Light – influences community structure eg growth of plants
- Temperature – influences community structure via exposure to heat stress and desiccation
- Nutrient input – influences community structure

- Chemical processes – eg weathering, these are active on the platform surface and form 'micro-habitats' in rock pools.
- Microtopography and the degree of habitat diversification influences biological assemblage. For example, pools in the platform may contain seagrass and algae with an associated fauna of small grazing organisms (Kendrick *et al.*, 1999

(f) Influence of biological processes:

- Competition
- Predation
- Dispersal and recruitment
- Biological agencies contribute to coastal erosion. Chitons in search of algae for food scrape off particles of rock with their teeth, digest the algae and then expel the rock. In this way, they smooth the rock surface. Various molluscs actively bore into the rock, as do some plants, giving rise to special forms, such as the characteristic notches of WA shores. Biological agencies weaken the rock fabric and facilitate other forms of weathering and erosion.

(g) Productivity/food webs/community structure:

Algae are the main primary producers of this ecosystem. Generally, a diverse range of invertebrates occupy shoreline reef platforms, and predators may include 'top-down' predators such as shore-birds and 'bottom-up' predators such as fish, whose predatory range on the shoreline reef increases as the tide rises.

(h) Past, present and potential uses and/or pressures

- Commercial and recreational fishing, and physical disturbance (trampling)- the few well developed platforms in the study area are mostly easily accessible from the shore making the larger fauna such as the abalone *Haliotis roei* and the turban shells *Turbo pulcher* and *T. torquata*, particularly at risk. This impact is expected to increase with the growing population. Accessible intertidal areas such as the limestone platforms of Yallingup, Kilcarnup, and Prevelly are also likely to be disturbed by people walking on them to collect rock lobster pots and abalone (Kendrick *et al.*, 1999). It is expected that pressure on invertebrates that are not targeted at this time will increase, for example the black nerite (*Nerita atramentosa)*, the giant limpet (*Patella laticostata)*, small limpets (*Siphonaria jeanie* and *Pateloida alticostata*), the giant barnacle (*Austrobalanus nigrescens)* and sea urchins (Kendrick *et al*., 1999)
- Nutrient input and pollutants - it can be expected that the nutrient loads in the numerous small freshwater steams and seeps will increase as urbanisation of the areas grows. These may have some impact on the intertidal areas in protected areas such as Cowaramup Bay, and Prevelly and Kilcarnup. (However in many areas the high water movement experienced on this exposed coast will disperse nutrients) (Kendrick *et al*., 1999)
- Educational tours
- Tourism
- Scientific research

(i) Current condition

- Very good, with the exception of high usage areas such as Gnarabup (water quality issues regarding sewage treatment plant) and Yallingup (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies

- Fisheries WA Management and legislation:
  - 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 400m 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* of the *Fish Resources Management Act, 1994*)
  - Cowaramup Bay Protection Area encompasses all waters within a line drawn from North Point to South Point. Taking of marine animals is prohibited, however abalone, blue manna crabs, cuttlefish, finfish, rock lobster and squid are exempt (*Prohibition on Fishing (Cowaramup Bay) Order 1998* of the *Fish Resources Management Act, 1994*)
- Proposed marine conservation reserve
- Limestone intertidal reef areas of Yallingup, Kilcarnup and Prevelly are warranted special protection because of their accessibility and high diversity of species (Kendrick *et al.*, 1999)

OFFSHORE INTERTIDAL REEF

(a) Distribution and area covered:

- See broadscale map of the major marine habitats in the Geographe Bay-Capes-Hardy Inlet region (Bancroft and Shattock, 2000)
- typically in the intertidal or shallow waters, and in the study area this habitat is obvious in high swell conditions (Bancroft and Shattock, 2000)
- 0.1% of the major marine habitats in the study area (Bancroft and Shattock, 2000)

(b) Structure:

- occurs as offshore low relief (<1m high) reef platforms of sedimentary (limestone) or high relief (>1m high) igneous (granites) or metamorphic (gneiss) substratum (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna:

- Supports turf algae (*Galeolaria* sp., *Scytosiphon* sp.) and invertebrates such as gastropods (turban shells *Turbo* spp., dogwhelks *Thais orbita*, abalone *Haliotis* spp.), and arthropods (barnacles *Austrobalanus* sp.) (Bancroft and Shattock, 2000)

(d) Endemic species/special conservation status:

- Lack of information available (refer to section 8)

(e) The influence of the physical environment:

- Swell - In WA, the continuous south-west swell has been dominant in moulding the shape of the coast. A rocky shore generally consists of a cliff, a notch at the base and a shore platform. The cliff develops through strong attack by weathering and/or erosion at and close to sea-level, after which the rock above is undermined and collapses. At the shoreward limit of the platform, a characteristic 'notch' is eroded, where wave action has undercut the rock on the seaward edge. Erosion of limestone areas forms horizontal rock platforms.

- Currents
- Tidal action
- Turbidity
- Light
- Nutrient input
- Chemical processes – eg weathering, these are active on the platform surface and form 'micro-habitats' in rock pools.
- Microtopography and the degree of habitat diversification influences biological assemblage. For example, pools in the platform may contain seagrass and algae with an associated fauna of small grazing organisms (Kendrick *et al.*, 1999)

(f) Influence of biological processes:

- Competition
- Predation
- Dispersal and recruitment
- Biological processes are active on the platform surface and weaken the rock fabric and facilitate other forms of weathering and erosion. These processes contribute to the formation of 'micro-habitats' in rock pools.

(g) Productivity/food webs/community structure:

Algae are the main primary producers of this ecosystem. Generally, a diverse range of invertebrates occupy shoreline reef platforms, and predators may include ‘top-down’ predators such as shore-birds and ‘bottom-up’ predators such as fish.

(h) Past, present and potential uses and/or pressures

- Over-collecting - the few well developed platforms in the study area are mostly easily accessible making the larger fauna such as the abalone *Haliotis roei* and the turban shells *Turbo pulcher* and *T. torquata*, particularly at risk. This impact is expected to increase with the growing population.
- Commercial and recreational fishing, and physical disturbance (trampling) - accessible intertidal areas are also likely to be disturbed by people walking on them to collect rock lobster pots and abalone (Kendrick *et al.*, 1999). It is expected that pressure on invertebrates that are not targeted at this time will increase, for example the black nerite (*Nerita atramentosa)*, the giant limpet (*Patella laticostata)*, small limpets (*Siphonaria jeanie* and *Pateloida alticostata*), the giant barnacle (*Austrobalanus nigrescens)* and sea urchins (Kendrick *et al*., 1999)
- Nutrient input and pollutants - it can be expected that the nutrient loads in the numerous small freshwater steams and seeps will increase as urbanisation of the areas grows. These may have some impact on the intertidal areas. (However in many areas the high water movement experienced on this exposed coast will disperse nutrients) (Kendrick *et al*., 1999)
- Tourism

(i) Current condition

- Very good (Bancroft, *pers. com.*)

(j) Current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA Management and legislation, eg bag and size limits

<u>MACROALGAE DOMINATED LIMESTONE REEFS</u>

(a) Distribution and area covered:

- Refer to broadscale map of major marine habitats in the Geographe Bay-Capes-Hardy Inlet region
- subtidal
- macroalgae (limestone reef/low relief) is 10.9% of the major marine habitats in the study area
- macroalgae (limestone reef/high relief) is 0.4% of the major marine habitats in the study area
  (Bancroft and Shattock, 2000)

(b) Structure

- macroalgae (limestone reef/low relief) – subtidal limestone substratum of low relief (<1m high). In the study area, this habitat may also incorporate mobile sand patches or patches of seagrass (Bancroft and Shattock, 2000)
- macroalgae (limestone reef/high relief) – typically subtidal limestone substratum of high relief (>1 m high). In the study area, this habitat also may incorporate sand patches or patches of seagrass (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna:

- macroalgae (limestone reef/low relief) generally is covered in large fleshy macroalgae (e.g. bull kelp *Ecklonia radiata*, *Cystophora* spp.) and macroalgal turf (red, green and brown algae). In sheltered areas, *Sargassum* spp. is the dominant macroalgae. This habitat is associated with a wide range of invertebrate life such as ascidians (*Pyura* spp.), calcareous sponges and gastropods (Bancroft and Shattock, 2000)
- macroalgae (limestone reef/high relief) is generally covered in a wide range of fleshy macroalgae (e.g. bull kelp *Ecklonia radiata*, *Scytothalia* sp., *Platythalia* sp., *Cystophora* spp.) and macroalgal turf (red, green and brown algae). This habitat is characterised by caves and overhangs, which support a diverse range of sessile invertebrate life such as colonial ascidians (*Aplidium* spp., *Clavelina* spp., *Herdmania* spp., *Didemnum* spp.), sponges (*Echinoclathria* spp., *Thorecta* spp., *Mycale* spp.), octocorals (*Mopsella* sp.) and soft corals (*Capnella* spp., *Sinularia* sp.). Mobile invertebrates such as seastars (*Nectria* spp., *Echinaster* spp.), seaurchins (*Heliocidaris erythrogramma*, *Holopneustes* sp.), crustaceans (*Panulirus cygnus*) and many gastropods are associated with this habitat (Bancroft and Shattock, 2000).
- assemblages of marine algae in the subtidal study sites of Kendrick *et al.* (1999) were species rich and many were rare and were surveyed infrequently. Abundant understorey algal species under kelp dominated subtidal limestone reefs are : *Amphiroa anceps, Jania pulchella, Callophillis* sp., and *Pterocladia lucid.* Sponges and ascidians also showed high diversity and high species turnover within and between subtidal sites of the study area. Species lists for fishes, flora, sponges and ascidians of the subtidal reefs of the study area can be found in Kendrick et al (1999).

(d) The occurrence of any endemic species/special conservation status

- Lack of information available
- Note that *Ecklonia brevipes* is a New Zealand species which has two stipes and occurs in Hamelin Bay. One population in south western Australia has been observed reproducing vegetatively by the production of secondary holdfasts from the apices of lateral branches. These holdfasts attach to the substratum and, along with a portion of the lateral branch, become detached from the parent thallus. This types of vegetative propagation is also found in the New Zealand *Ecklonia brevipes* and the Australian population is tentatively assigned to the species (Huisman, 2000).
- The corals *Symphyllia wilsoni*, *Turbinaria mesenterina*, and *Coscinarae marshae* are typically found in Macroalage (high relief/limestone). However, *Turbinaria mesenterina and Coscinarae marsha* may be found as isolated colonies on Macroalage (low relief/limestone).

(e) The influence of the physical environment

- Swell
- Currents
- Tides
- Light
- Turbidity
- Temperature
- Nutrient input
- The following results are drawn from Kendrick *et al.*, (1999):
  - The distribution of marine algae was significantly influenced by subtidal reef type (limestone or granite) at shallow sites

- Algal assemblages on high relief reef were not significantly different from low relief reef, but this more likely reflects the sampling intensity of the survey.
- There were more species of fish occurring in offshore versus onshore sites, however fish density seemed to be more site specific (there were high levels of observer bias in this study)

(f) The influence of biological processes:

- Competition
- Predation
- Dispersal and recruitment
- The most species rich sites of marine algae at subtidal reefs did not have kelp canopies

(g) Productivity/food webs/community structure:

Marine algae are the primary producers of this ecosystem. Sponges and ascidians are diverse components of the sessile benthos. Many large demersal fish are associated with the macroalgae habitat.

(h) Past, present and potential uses and/or pressures:

- Commercial and recreational fishing - many recreationally targeted large demersal fish such as the Western Australian jewfish, western blue groper and harlequin fish are associated with the macroalgae (Bancroft and Shattock, 2000).
- Nutrient and pollutant input
- Collection as algal wrack as a soil conditioner for gardens (does this currently occur in the study area?)

(i) Current condition:

Very good (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies:

- Proposed marine conservation reserve
- Fisheries WA Management and legislation, eg bag and size limits
- The following recommendations were made by Kendrick *et al.* (1999):
  - The distribution of marine algae was significantly influenced by subtidal reef type (granite or limestone) at shallow sites. This stratum should be included in any zoning strategy within regions
  - Algal assemblages on high relief reef were not significantly different from low relief reef, but this more likely reflects the sampling intensity of the survey, and including this stratum in a zoning strategy is recommended
  - as a result of fish density, it was recommended that an offshore versus onshore stratum be included in the future zoning strategy
  - Algal assemblages should be a key component of further subtidal studies as they are major components of the biodiversity
  - sponges and ascidians are candidates for future surveys

<u>MACROALGAE DOMINATED GRANITE REEF</u>

(a) Distribution and area covered:

- See broadscale map of major marine habitats in the Geographe Bay-Capes-Hardy Inlet region
- Subtidal
- Macroalgae (granite reef/low relief) is 10.6% of the major marine habitats in the study area
- Macroalgae (granite/high relief) is 6.5% of the major marine habitats in the study area (Bancroft and Shattock, 2000)

(b) Structure:

- macroalgae (granite reef/low relief) – typically subtidal granite or gneiss substratum of low relief (<1m high). IN the study area this habitat is typically either the surface of large buried boulders or fields of small boulders, which may also incorporate sand patches (Bancroft and Shattock, 2000)
- macroalgae (granite reef/high relief) – typically subtidal granite or gneiss substratum of high relief (>1m). In the study area this habitat is typically either the surface of large buried boulders or fields of small boulders, which may also incorporate sand patches (Bancroft and Shattock, 2000)
- Granite and gneiss outcrops with steep slopes to seawards usually abut deeper waters, with a small intertidal area subjected to oceanic swells (Sugarloaf Rock, Canal Rocks, North Point Cowaramup, Cape Freycinet and Cape Leeuwin). Large "gutters" and fissures between granite boulders create more protected habitats (Canal Rocks, Quarry and Ringbolt Bay Cape Leeuwin) which often accumulate large amounts of wrack. In more protected areas, granites form boulder fields (Smiths Beach, Canal Rock Beach) and may lie on a on limestone basement or may be incorporated into the limestone matrix (Cowaramup and Moses Rock) (Kendrick et al., 1999).

(c) Distribution and diversity of predominant flora and fauna:

- macroalgae (granite reef/low relief) - this habitat generally is covered in large fleshy macroalgae (e.g. bull kelp *Ecklonia radiata, Cystophora* spp.) and macroalgal turf (red, green and brown algae). A wide range of invertebrate life such as ascidians (*Pyura* spp.), calcareous sponges, ascidians and gastropods are associated with this habitat (Bancroft and Shattock, 2000)
- macroalgae (granite reef/high relief) - this habitat generally is covered in large fleshy macroalgae (such as *Ecklonia radiata, Scytothalia* sp., *Platythalia* sp and *Cystophora* spp.), macroalgal turf (red, green and brown algae) and crustose coralline algae. This habitat is characterised by caves and crevices, which support a diverse range of sessile invertebrate life such as colonial ascidians (*Aplidium* spp., *Clavelina* spp., *Didemnum* spp.), sponges (*Echinoclathria* spp., *Thorecta* spp., *Mycale* spp.), octocorals (*Mopsella* sp.), soft corals (*Capnella* spp., *Sinularia* sp.). Mobile invertebrates such as seastars (*Fromia* sp.), seaurchins (*Phyllacanthus irregularis*) and gastropods (*Turbo jordani, Haliotis laevigata*) are also present. Many recreationally targetted large demersal fish such as the Western Australian jewfish (*Glaucosoma hebraicum*), western blue groper (*Achoerodus viridis*) and harlequin fish (*Othos dentex*) are associated with this habitat (Bancroft and Shattock, 2000)
- Species lists for fishes, flora, sponges and ascidians of the subtidal reefs of the study area can be found in Kendrick et al (1999). Assemblages of marine algae in the subtidal study sites were species rich and many were rare and were surveyed infrequently. The diversity of algal species, species distributions and species turnover suggest that marine algae in the study area are major components of the subtidal biodiversity (Kendrick *et al.*, 1999).

- The kelp, *Ecklonia radiata* and the large brown alga, *Scytothalia dorycarpa* are dominant canopy on deeper granite reefs. The understorey under these canopies is depauperate, with mostly smaller foliose and filamentous algae occurring in patches in the canopy. The foliose red algae *Dictymenia sonderi* and the bladed brown alga, *Lobophora variegata* occur in patches with little or no kelp canopies (Kendrick *et al.*, 1999). Shallow granite reef and boulder fields are characterised by species rich canopies of *Ecklonia radiata* and species of *Sargassum, Cystophora, Platythalia* and *Scytothalia* and other large brown algae (Womersley, 1987 *In* Kendrick *et al.*, 1999). Sponges and ascidians showed high diversity and high species turnover within and between subtidal sites of the study area (Kendrick *et al.*, 1999)

(d) Endemic species/special conservation status

- Lack of information
- Note that *Ecklonia brevipes* is a New Zealand species which has two stipes and occurs in Hamelin Bay. One population in south western Australia has been observed reproducing vegetatively by the production of secondary holdfasts from the apices of lateral branches. These holdfasts attach to the substratum and, along with a portion of the lateral branch, become detached from the parent thallus. This types of vegetative propagation is also found in the New Zealand *Ecklonia brevipes* and the Australian population is tentatively assigned to the species (Huisman, 2000).
- The corals *Symphyllia wilsoni, Turbinaria mesenterina,* and *Coscinarae marshae* corals are typically found in Macroalgae (high relief/granite).

(e) Influence of the physical environment:

- Currents
- Tides
- Turbidity
- Light
- Temperature
- Nutrient and pollutant input
- The following results are drawn from Kendrick *et al.*, (1999):
  - The distribution of marine algae was significantly influenced by subtidal reef type (limestone or granite) at shallow sites
  - Large gutters and fissures between granite boulders create protected habitats which often accumulate large amounts of wrack
  - Faunal assemblage on granitic boulder fields differed from limestone platforms due to differences in their microtopography and on the presence of limpets and a suite of species which were only found on the platforms
  - Within boulder field sites there was no significant separation of intertidal fauna by either region or exposure
  - The distribution of marine algae was significantly influenced by subtidal reef type at shallow sites and depth (<10m, 10-20 m)
  - Regional differences were observed between sites on the northern shore of Cape Naturaliste and the western and southern regions of the survey area. This probably reflects different wave exposure regimes, as the northern shore is well protected against prevailing western and southern winds and ocean swells.
  - Algal assemblages on high relief reef were not significantly different from low relief reef, but this more likely reflects the sampling intensity of the survey.
  - There were more species of fish occurring in offshore versus onshore sites, however fish density seemed to be more site specific (there were high levels of observer bias in this study)

- On subtidal reefs, the spatial patterns of fish abundance and size and of sponges and ascidians were not clearly shown (Kendrick et al, 1999).

(f) The influence of biological processes:

- Competition
- Predation – eg it has been proposed that molluscs and echinoderms flourish at Cowaramup Bay because, in addition to the influence of physical processes, the boulders provide protection from predators. 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. (S. Slack-Smith, Western Australian Museum of Natural Science Aquatic Zoology Department, *pers. comm*. In Elscot & Bancroft, 1999)
- Dispersal and recruitment
- The most species rich sites of marine algae at subtidal reefs did not have kelp canopies (Kendrick *et al.*, 1999)

(g) Productivity/food webs/community structure:

Marine algae are the primary producers of this ecosystem. Sponges and ascidians are diverse components of the sessile benthos. Many large demersal fish are associated with the macroalgae habitat.

(h) Past, present and potential uses and/or pressures:

- Commercial and recreational fishing - many recreationally targeted large demersal fish such as the Western Australian jewfish, western blue groper and harlequin fish are associated with the macroalgae (granite reef/high relief) habitat (Bancroft and Shattock, 2000).
- Nutrient and pollutant input
- Collection as algal wrack as a soil conditioner for gardens (does this currently occur in the study area?)

(i) Current condition

Very good (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies:

- Proposed marine conservation reserve
- Fisheries WA Management and legislation
- Cowaramup Bay Protection Area encompasses all waters within a line drawn from North Point to South Point. Taking of marine animals is prohibited, however abalone, blue manna crabs, cuttlefish, finfish, rock lobster and squid are exempt (*Prohibition on Fishing (Cowaramup Bay) Order 1998* of the *Fish Resources Management Act, 1994*)
- The following recommendations were made by Kendrick *et al.* (1999):
  - The distribution of marine algae was significantly influenced by subtidal reef type at shallow sites and depth (<10m, 10-20 m). These strata should be included in any zoning strategy within regions
  - Algal assemblages on high relief reef were not significantly different from low relief reef, but this more likely reflects the sampling intensity of the survey, and including this stratum in a zoning strategy is recommended

- as a result of fish density, it was recommended that an offshore versus onshore stratum be included in the future zoning strategy
- Algal assemblages should be a key component of further subtidal studies as they are major components of the biodiversity
- sponges and ascidians are candidates for future surveys
- Granitic boulder fields in sheltered habitats such as Cowaramup and Sugar Loaf should be protected because of the high diversity of species found in the immediate subtidal (Kendrick et al., 1999).

SILT

(a) Distribution and area covered:

- Refer to broadscale map of the major marine habitats of the Geographe Bay-Capes-Hardy Inlet region
- Subtidal
- Occurs in the sheltered areas in the Hardy Inlet
- 0.6% of the major marine habitats in the study area (Bancroft and Shattock, 2000)
- The main basin of the Blackwood River estuary, known as Hardy Inlet, covers an area of around 9km2 and extends over a distance of 5km from the entrance channel to the mouths of the Blackwood and Scott Rivers. The estuarine reaches of these rivers extend a further 30km and 8km upstream respectively.

(b) Structure:

- Silt – mud or silt substratum, with a significant terrigenous fraction, and are usually unvegetated (Bancroft and Shattock, 2000)
- The Blackwood River Estuary is one of only two large, seasonal, permanently open estuaries on the south coast of Western Australia. Hardy Inlet extends from the entrance channel to the mouths of the Blackwood and Scott Rivers. 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.

(c) Distribution and diversity of predominant flora and fauna:

- Supports a rich variety of infauna such as polychaete and nematode worms, molluscs (*Nassarius* spp.) and crustaceans (estuarine shrimp *Palaemonetes australis*) (Bancroft and Shattock, 2000)
- 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. 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)
- The foraminifera of Hardy Inlet have been described by Quilty (1976)
- Phytoplankton makes only a small contribution to primary production in the Blackwood. It is thought that this is attributable principally to the relatively low nutrient levels and the large tidal volume of the lower estuary. Zooplankton were also sparse in the estuary. The only species at all common was *Gladioferens imparipes*. The number of species of macroscopic algae occurring in the estuary was small. Only two species were abundant: the filamentous green alga *Rhizoclonium* and the charophyte *Lamprothamnium*, both of which belong predominantly to freshwater groups. Diatoms and other microscopic algae of the surface sediments are important primary producers in shallow water and are eaten both by benthic invertebrates and some species of fish. In the Blackwood, the very

euryhaline species *Ruppia maritima* dominates the lower estuary, but it is replaced by the less salt tolerant *Potamogeton pectinatus* in the upper estuary and around Molloy Island during the fresh phase. The plants are confined to shallow water and the best growth is in situations of relatively restricted flow such as Swan Lake, the Deadwater and embayments along the tidal river. Rush beds form a large part of the margin of the lower estuary, dominated by *Juncus krausii* but with the sedge *Baumea juncea* also present near the water's edge. Bacteria, fungi, spirochaetes, flagellates, diatoms, ciliates and other Protista are present in vast numbers. There were about forty species of Foraminifera in the inlet region, but only three species in an area measured in the tidal river. True estuarine macrofauna – of 55 benthic invertebrate species found living in the estuary, some 40 are probably confined mainly to estuarine environments. Only 13 species formed the great bulk of the invertebrate fauna: 3 polychaete worms, 4 bivalve and 3 gastropod molluscs, 2 crustaceans and one insect. There are six species of true-estuarine fish. Non-resident macrofauna- the great majority of the fish that use the estuary spawn in the sea, and they enter the estuary as juveniles or adults. About half of the non-resident fish species are believed to be stenohaline-marine species which do not tolerate salinities less than 30ppt. The rest (24 species) can be regarded as euryhaline marine species, in that they are observed to tolerate lower salinities, at least to 15ppt, and 18 species down to 3ppt. A number of waterbirds use the estuary, including pelicans, cormorants, ducks, waders and gulls.

- Refer to the Estuarine Health Indicators Project – an exhaustive macroinvertebrate study which included five sites in Hardy Inlet (D. Deeley, 1999).
- Refer to An Environmental Study of the Blackwood River estuary, WA (Hodgkin, 1978)

(d) Occurrence of any endemic species or species of special conservation status

Lack of information available

(e) Influence of the physical environment

- Reduced salinity and a gradient of this from sea water to fresh water, is probably the most important environmental characteristic determining composition of the biota and controlling the distribution of organisms within estuaries. There is a change in composition of the biota along the length of the estuary, a gradient in relation to salinity – in general, species richness and diversity are normally greatest at the marine end of estuaries and decrease upstream, although seasonal patterns may confound these relationships as physical processes and biotic interactions influence the growth and survival of organisms (Deeley, 1999). For example, the Foraminifera reflect dramatically the effect of salinity on species diversity and faunal composition. There were about forty species of these predominantly marine Protozoa in the inlet region, but only three species in an area measured in the tidal river.
- runoff and nutrient inputs
- turbidity (which varies with river flow and consequently there is seasonal variation)
- light
- water flow (affects supply of nutrients and loss of them and suspended matter to the sea);
- temperature (for example, the thermocline asssociated with halocline in the tidal river in summer may affect fish movements);
- tidal range and exchange of the Blackwood estuary;
- strength of currents (may influence the composition and distribution of the mobile fauna (shrimp and fish) during the period of major discharge);

- nutrient supply (particularly nitrogen and phosphorous); sediment size and organic content; and
- wave action.

(f) Influence of the biological environment

- Competition
- Predation
- Dispersal and recruitment
- Biological disturbance which occurs in the form of bioturbation, whereby burrow builders can limit the abundance and distribution of certain sedentary species. However, burrow builders also create the 3D structure that is home to commensal species
- Information on inter-specific relationships is limited to some quantitative data on the kinds of food taken by fish and we know virtually nothing of the effects of predation pressure on the populations or of competition for resources. Predation pressure on the benthic fauna is likely to vary seasonally, being greater during the saline phase than during the fresh phase (Hodgkin, 1978).

(g) Productivity/food webs/community structure

- Food web-see Hodgkin (1978).
- Phytoplankton makes only a small contribution to primary production. It is thought that this is attributable principally to the relatively low nutrient levels and the large tidal volume of the lower estuary. Zooplankton are also sparse in the estuary. Diatoms and other microscopic algae of the surface sediments are important primary producers in shallow water and are eaten both by benthic invertebrates and some species of fish. The number of species of macroscopic algae occurring in the estuary was small. . Rush beds form a large part of the margin of the lower estuary, dominated by *Juncus krausii* Bacteria, fungi, spirochaetes, flagellates, diatoms, ciliates and other Protista are present in vast numbers. Sea grasses are quantitatively the most important macroscopic plants, although only a small variety of fauna is directly dependent on them. 13 species on benthic invertebrates form the bulk of estuarine macrofauna. Probably the principal input is from detritus derived from a variety of sources eg marginal vegetation. Predators include fish, which primarily use the estuary spawn in the sea and enter the estuary as juveniles or adults, and a number of waterbirds which use the estuary, including pelicans, cormorants, ducks, waders and gulls.
- 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.

(h) Past, present and potential uses and/or pressures

- Nutrient inputs, eutrophication and algal blooms
- Dredging
- Commercial and recreational fishing
- Tourism and recreation (eg waterskiing)

(i) Current condition

- Good, primarily because of the high flushing rate of the estuary during winter (Bancroft, *pers.comm.*)
- Refer to section 14 – Water quality eg 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 Estuarine Health Indicators Project included five sites in Hardy Inlet (D. Deeley, Acacia Springs Environmental P/L, *in prep*.).

(j) Current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA management and legislation, eg bag and size limits
- Refer to section 14.8 eg 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). All data will be entered into the Water and Rivers Commission EDICT database and will be accessible via a formal data request.

PELAGIC

(a) Distribution and area covered

- See broadscale map of the major marine habitats of the Geographe Bay-Capes-Hardy Inlet region
- Pelagic are areas that are greater than 50m in depth
- 1.3% of the major marine habitats of the study area
  (Bancroft and Shattock, 2000)

(b) Structure

- May have various substrates (the focus is on the macrobiology of the water column) (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna

- Pelagic fish and invertebrates, and larval stages of various phyla (Bancroft and Shattock, 2000)

(d) Occurrence of any endemic species or species of special conservation status

- Humpback and Southern Right whales, Australian Sea Lion and New Zealand Fur Seal
- Fish species – see section 8
- Lack of adequate information available

(e) Influence of the physical environment

- The depths of the surface mixed layer
- Hydrological features such as currents and eddies
- Turbidity
- Salinity
- Light
- Temperature
- nutrients

(f) Influence of the biological environment

- Predation
- Competition
- Dispersal and recruitment

(g) Productivity/food webs/community structure

Photosynthetic planktonic plants and bacteria are the basis of the ocean's primary productivity. The ocean around WA is generally low in nutrients. Significant upwellings are lacking and nutrient inputs from land run-off are also limited because of the poor nutrient status of the continent's ancient leached soils and low rainfall. Consequently, WA waters have a low biological and fisheries productivity and large areas of the oceans are virtual deserts.

(h) Past, present and potential uses and/or pressures

- Deep water communities are subject to trawling and other fishing
- Human activities contributing fertilisers and other high-nutrient wastes can speed up the process of eutrophication, leading to excessive algal blooms and deterioration of water quality

(i) Current condition

Very good (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA management and legislation, eg commerical fisheries licences

<u>BEACH</u>

(a) Distribution and area covered

- See broadscale map of the major coastal habitats of the Geographe Bay-Capes-Hardy Inlet region
- located in the upper intertidal and supratidal zones
- 36% of the major coastal habitats in the study area
- 14.3% of the major coastal habitats is classified as beach/rocky shore (Bancroft and Shattock, 2000)

(b) Structure

- typically consists of unconsolidated carbonate sands (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna

The *beach* habitat is mostly unvegetated however flora such as spinifex (*Spinifex longifolius*) may be present above HAT. The intertidal sands of beach habitats in the Geographe Bay-Capes-Hardy Inlet region typically support a range of invertebrates including bivalve shells and seaurchins (Bancroft and Shattock, 2000)

(d) Occurrence of any endemic species or species of special conservation status

- Lack of information available

(e) Influence of the physical environment

- The sandy beaches of the Naturaliste-Leeuwin coast are often exposed to incoming swell and the coarse sands are highly mobile (Kendrick et al., 1999)
- Tides
- Currents
- Sediment transport
- Nutrient and pollutant input

(f) Influence of the biological environment

- Wrack accumulations in the protected areas of sandy beaches create habitat for worms and insects (Kendrick et al., 1999).
- Source of calcium carbonate from articulate beds and shells

(g) Productivity/food webs/community structure

Flora above high astronomical tide is responsible for the primary production in this habitat. Predators such as bivalve shells and urchins generally consume detritus and algae.

(h) Past, present and potential uses and/or pressures

- Refer to section 2.7 for more information. Note that there is presently a high rate of proposed urban development, particularly for residential and tourism and the Geographe Bay coast is the focus. Land use pressures along the coast are intensifying (Coastwise, 2000)
- Digging for 'bait worms" at the high tide level may at times disturb the base of dunes (Kendrick et al., 1999)
- Searle and Logan (1978) have shown that accretion has been taking place in the Bay for some 4600 years at an average rate of 0.3ha per year, whilst over the past 60 years this has increased to a rate of 1.1ha per year. This has been attributed to the depletion of seagrass meadows between 1947 and 1965 and the subsequent increase in sediment available for transport and increase in energy levels in the immediate shore zone, which has in turn been ascribed to increased sediment and nutrient input caused by bush clearing for agricultural development and the construction of large drains (Lord and Associates, 1995). Refer to section 2 for more information
- Commercial and recreational fishing, eg netting
- Tourism activities

- Recreational use of coastal landforms

(i) Current condition

Busselton to Dunsborough – the current condition is very poor as a result of sustained and significant interference associated with construction of engineering works. The rest is generally very good with most of the actual features intact (Elliot, *pers.comm.*).

(j) Current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA Management and legislation, eg commerical netting restrictions (eg closure to rec fishing and boating at Smiths Beach)
- Leeuwin-Naturaliste National Park

ROCKY SHORE

(a) Distribution and area covered

- See broadscale map of the major coastal habitats of the Geographe Bay-Capes-Hardy Inlet region
- Upper intertidal zone
- 40.2% of the major coastal habitats in the study area
- 14.3% of the major coastal habitats is classified as beach/rocky shore (Bancroft and Shattock, 2000)

(b) Structure

- includes low cliffs (<5m), boulder or pavement of igneous, metamorphic or sedimentary substratum located along the shoreline. For convenience, shoreline high cliffs (>5m) are included in this category. In the study area, rocky shores are typically wave-cut or undercut, unvegetated limestone cliffs (Bancroft and Shattock, 2000)
- a rocky shore generally consists of a cliff, a notch at the base and a shore platform. The cliff develops through strong attack by weathering and/or erosion at and close to sea-level, after which the rock above is undermined and collapses. At the shoreward limit of the platform, a characteristic 'notch' is eroded, where wave action has undercut the rock on the seaward edge. Erosion of limestone areas forms horizontal rock platforms.

(c) Distribution and diversity of predominant flora and fauna

- variety of mollusc species including barnacles (e.g. *Austromegabalanus nigrescens*), top shells (*Austrocochlea* spp.) and other invertebrates such as crabs (*Pagurus* sp.) (Bancroft and Shattock, 2000)

(d) Occurrence of any endemic species or species of special conservation status

- Lack of information available. Refer to section 8 for more information

(e) Influence of the physical environment

- Temperature - flora and fauna are distributed according to their tolerance to exposure to desiccation and heat stress at low tide. Note that conditions for growth

and survival of organisms are often better lower on the shore as physical conditions are less harsh and submersion times are longer

- Wave action – granitic rock weathers into relatively smooth slopes descending into the sublittoral zone in areas exposed to heavy wave action, or to form boulder zones where wave action is less severe. Vertical zonation patterns are not as clear at areas on intertidal boulder slopes with rock pools, as these provide a much greater variety of micro-habitats and a richer fauna and flora
- Tidal frequency
- Currents and relative speed of water movement
- Light
- Nutrient and pollutant input

(f) Influence of the biological environment

- Competition
- Predation
- Grazers eg the permanent molluscan and echinoderm grazers, and the transient fish and crustacean grazers which invade the intertidal zone at high tide
- Dispersal and recruitment
- Biological agencies also contribute to coastal erosion. Chitons in search of algae for food scrape off particles of rock with their teeth, digest the algae and then expel the rock. In this way, they smooth the rock surface. Various molluscs actively bore into the rock, as do some plants, giving rise to special forms, such as the characteristic notches of WA shores. Biological agencies weaken the rock fabric and facilitate other forms of weathering and erosion.

(g) Productivity/food webs/community structure

Algae are the predominant primary producers in this habitat. Grazers include the molluscs and echinoderms, and the transient fish, crustaceans and shorebirds are the predators of the system.

(h) Past, present and potential uses and/or pressures

- Commercial and recreation fishing, eg Overcollecting - the few well developed platforms in the study area are mostly easily accessible from the shore making the larger fauna such as the abalone *Haliotis roei* and the turban shells *Turbo pulcher* and *T. torquata*, particularly at risk. This impact is expected to increase with the growing population. Accessible intertidal areas such as the limestone platforms of Yallingup, Kilcarnup, and Prevelly are also likely to be disturbed by people walking on them to collect rock lobster pots and abalone (Kendrick *et al.*, 1999). It is expected that pressure on invertebrates that are not targeted at this time will increase, for example the black nerite (*Nerita atramentosa)*, the giant limpet (*Patella laticostata)*, small limpets (*Siphonaria jeanie* and *Pateloida alticostata*), the giant barnacle (*Austrobalanus nigrescens)* and sea urchins (Kendrick *et al.*, 1999)
- Coastal development – refer to section 2 for more information
- Nutrient and pollutant input - it can be expected that the nutrient loads in the numerous small freshwater steams and seeps will increase as urbanisation of the areas grows. These may have some impact on the intertidal areas in protected areas such as Cowaramup Bay, and Prevelly and Kilcarnup. (However in many areas the high water movement experienced on this exposed coast will disperse nutrients) (Kendrick *et al*., 1999)

(i) Current condition

- Generally very good (Elliot, *pers comm.*)

(j) Current/proposed management strategies

- Proposed marine conservation reserve
- Leeuwin-Naturaliste National Park

ISLAND

(a) Distribution and area covered

- See broadscale map of the major coastal habitats of the Geographe Bay-Capes-Hardy Inlet region
- land over 0.05ha that is surrounded by sea and is permanently about Highest Astronomical Tide
  (Bancroft and Shattock, 2000)

(b) Structure

- sand, igneous and sedimentary rock (limestone and sandstone), and may be bare, vegetated or have seasonal vegetation (Bancroft and Shattock, 2000)

(c) Distribution and diversity of predominant flora and fauna

- the larger islands (eg. St Alouarn, Hamelin) in the Geographe Bay-Capes-Hardy Inlet region are typically vegetated by coastal heath which includes spinifex (*Spinifex* sp.), however the smaller islands tend to be bare limestone, gneiss or granite rock. The island habitat of the region is known to be important for haul out, breeding and nesting areas for seabirds (red-tailed tropicbird *Paethon rubricauda*, rock parrot *Neophemea petrophila* fairy penguin *Eudyptula minor*), and marine mammals (Australian sea lion *Neophoca cinerea*, New Zealand fur seal *Arctocephalus fosteri*) (Bancroft and Shattock, 2000)

(d) Occurrence of any endemic species or species of special conservation status

- Australian sea lion
- New Zealand fur seal

(e) Influence of the physical environment

- Wave action
- Tidal action
- Currents and sediment transport

(f) Influence of the biological environment

- Competition
- Predation

(g) Productivity/food webs/community structure

- Coastal heath is a primary producer of this habitat. Many of the predators which use this habitat utilise food resources from the surrounding pelagic habitat.

(h) Past, present and potential uses and/or pressures

- Commercial and recreational fishing, eg abalone
- Nutrient and pollutant inputs
- Tourism

(i) Current condition

Very good (Bancroft, *pers.comm.*)

(j) Current/proposed management strategies

- All of the important seabird breeding islands in the study area, 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.

8 Marine Fauna

AWAITING RESEARCH OF KEVIN BANCROFT, THE DEPARTMENT'S MARINE CONSERVATION BRANCH - mammal, birds and reptiles

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8.1 For the mammals found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

CETACEANS

(a) Species diversity and the relative importance of the faunal group

Three species of cetaceans are commonly seen in the study area - Humpback *Megaptera novaeangliae;* Southern right whale *Eubalaena australis*; and Bottlenose dolphin *Tursiops truncatus.* Thirteen other species of cetaceans have been recorded in the area as being stranded or uncommonly seen (see b).

Cape Naturaliste and Geographe Bay have been identified as breeding and resting areas for Humpbacks. The Capes form an important reference point for the migration patterns of Humpbacks and Southern Rights. The study area is of particular importance to Blue whales as a feeding area. Very little is known about these cetaceans, who were almost wiped out as a result of whaling. A study is currently underway in Victoria, which has identified an important aggregation area associated with cold-water upwelling in the Otway basin. As increases in sightings occur with Geographe Bay, it will be important to identify the factors accounting for the blues presence and perhaps identify the area as a special management zone. Therefore, in general, the study area is of great importance for cetaceans, in both a regional and statewide context (Holley, *pers.comm.*).

(b) Size of significant populations(s) and details of most recent survey

Table 10: Population size and relevant surveys of the cetaceans of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Population size	Surveys and source
Humpback *Megaptera novaeangliae*	West coast population is at least 3,000 expected to double in 10 years	Aerial surveys off Carnarvon (Shark Bay, Berringer and Dorre Islands, and Dirk Hartog Island) for a ten day period in July since 1976 (Bannister, 1995); Nick Gales (pers. comm.)
Southern right whale *Eubalaena australis*	Total population of 800 increasing around 10%/year (Bannister, 1995)	Aerial surveys from Cape Leeuwin east to Cape Arid or Israelite Bay since 1976, and to Ceduna since 1993 (Bannister, 1985; 1994b)
Blue Whales	There is little data available on stocks	A study is currently underway in Victoria, which has been identified as an important aggregation area associated with a cold-water upwelling in the Otway basin. See David Holley (The Department).
Sperm whales *Physeter macrocephalus*	There is little data available on stocks, not commonly seen in the study area	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Pygmy blue whales *Balaenoptera musculus*	There is little data available on stocks, not commonly seen in the study area	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Minke whales *B. acutorostrata*	There is little data available on stocks, not commonly seen in the study area	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Long-finned pilot whale *Globicephala melas*	There is little data available on stocks, not commonly seen in the study area	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Bottlenose dolphin *Tursiops truncatus*		The Department of Conservation and Land Management, 1994
Pygmy right whales *Caparea marginata*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Scamperdown whales *Mesoplodon grayi*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
False killer whales *Pseudorca crassidens*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Cuvier's whales *Ziphious cavirostris*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Shepherds beaked whales *Tasmacetus shepherdi*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Pygmy sperm whales *Kogia breviceps*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.
Striped dolphins *Stenella caeruleoalba*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.

Common dolphins *Delphinius delphis*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.

- Naturaliste Charters have been operating whale-watching charters in both Flinders Bay and Geographe Bay since 1993. Extensive logs detailing the coordinates of all sightings and recording 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. (J. Willbond, Naturaliste Charters, *pers. comm*.).

(c) Table 11: Cetaceans which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Status
Humpback whale *Megaptera novaeangliae*	Listed as "fauna that is rare or likely to become extinct" under the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act 1950 Listed as "species that are vulnerable" under Schedule 2 of the Endangered Species Protection Act 1992
Southern right whale *Eubalaena australis*	Listed as "fauna that is rare or likely to become extinct" under the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act 1950 Listed as "species that are endangered" under Schedule 1 of the Endangered Species Protection Act 1992
Blue whale *Balaenoptera musculus*	Listed as "fauna that is rare or likely to become extinct" under the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act 1950 Listed as "species that are endangered" under Schedule 1 of the Endangered Species Protection Act 1992

(d) Refer to table 12

(e) Past/current/potential uses and pressures

- Physical disturbance
  - Boat collisions and boat noise-
  - Commercial whale-watching tours
- Entanglement (eg in litter, ropes, discarded fishing gear)

(f) Past/current/proposed management strategies

- Legislation which protects species of special conservation status
- Departmental licenses and guidelines for tourism operators and interaction with wildlife

Table 12: Distribution, seasonality of occurrence and behavioural patterns of Cetaceans of special conservation status which occur in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Biogeographical and local distribution	Seasonality of occurrence	Behavioural patterns
Humpback *Megaptera novaeangliae*	Flinders Bay, Capes and Geographe Bay (J.Willbond, Naturaliste Charters, *pers.comm.*)	Peak southern migration off the Cape Naturaliste – Bunbury region occurs during mid-October and the peak northern migration occurred at the end of June (Jenner & Jenner, 1993)	Migrate between southern ocean feeding grounds and winter breeding grounds off North-West Cape. It has been suggested 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 (Jenner & Jenner, 1993). Migrate around 2500 km 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 (J. Willbond, Naturaliste Charters, *pers. comm.*). It has been suggested that Geographe Bay is an important calving and nursing region (J Willbond, Naturaliste Charters, *pers.comm.)*
Southern right whale *Eubalaena australis*	Southwest and southern coast of Australia. 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-Hopetown as two particularly popular locations.	Winter and spring (particularly August and September) (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) Migrate between southern ocean feeding grounds and winter breeding grounds. Calve and suckle young in sheltered bays very close inshore
Blue Whales	Geographe Bay	Particularly during November, however in 1998 many animals were observed as early as September.	

PINNIPEDS

(a) Species diversity and the relative importance of the faunal group

Two species of pinnipeds are commonly seen in the study area: Australian sea lion *Neophoca cinerea*, and New Zealand fur seal *Arctocephalus forsteri.* T*wo* species of pinninpeds have been sighted on occasions: sub-Antarctic fur seal *Arctocephalus tropicalis* and the leopard seals *Hydrurga leptonyx*.

The study area is not important for breeding Australian sea lions, because they do not breed or haul-out in the study area; the area lies between the two distinct west and south coast populations; because males can move great distances; and because the Australian sea lion has an asynchronous breeding cycle, so that animals can be found there all year round. Females exhibit natal site fidelity, ie they only return to the island they were born on to breed, so that recruitment of new areas is unlikely. (Holley, *pers.comm.*).

The study area is not of significant importance to stocks of the New Zealand fur seal. Flinders, St Alouarn and Seal Islands have been identified as haul-out sites, although there is no evidence of breeding there. Numbers of the New Zealand fur seals are increasing, with animals being sighted at new locations. Flinders Bay near Augusta has been identified as the most western breeding colony of New Zealand fur seals. Geographe Bay may become an important area for New Zealand fur seals if the population continues to expand (Holley, *pers.comm.*).

(b) Size of significant population and details of most recent survey

Table 13: Population size and relevant surveys of the pinnipeds of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Population size	Surveys and source
Australian sea lion *Neophoca cinerea*	Total population of between 9,300 and 11,700 animals (Gales *et al.* 1992). The population is stable to declining (Gales, *pers. comm*.)	Gales *et al.* (1992) surveyed the distribution, abundance and breeding cycle between 1987 and 1992
New Zealand fur seal *Arctocephalus forsteri*	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).	Shaugnessy *et al* (1994) examined the distribution and abundance of New Zealand fur seals in southern WA between 1987 and 1991
Sub-Antarctic fur seal *Arctocephalus tropicalis*	Only one sighting in the study area since 1981, stranded at Canal Rocks	
Leopard seals *Hydrurga leptonyx*	Recorded as stranded	D. Coughran, The Department's Wildlife Protection Section, *pers. comm*.

Note that there are two distinct stocks of Australian sea lions in WA – the south coast population and the west coast population.

(c) Rare/endemic/special conservation status

Table 14: Pinnipeds which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	**Status**
Australian sea lion *Neophoca cinerea*	Listed as "Other specially protected fauna" under Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act, 1950
New Zealand fur seal *Arctocephalus forsteri*	Listed as "Other specially protected fauna" under Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act, 1950

(d)

Table 15: Distribution, seasonality of occurrence and behavioural patterns of the pinnipeds of special conservation status which occur in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Biogeographical and local distribution	Seasonality of occurrence	Behavioural patterns
Australian sea lion	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). Sighted throughout the marine waters of the study area (Gales, *pers.comm.*)	Occur in the study area all year round (Holley, *pers.comm.*)	Do not breed or haul-out in the study area, with the closest breeding sites being the Beagle, Fisherman and Buller Islands to the north and Haul-off Rock to the East (Gales *et al.*, 1992) Asynchronous breeding cycle
New Zealand fur seal	In WA extend from the Recherche Archipelago (33 S, 124 E) to the islands off Cape Leeuwin (Sahugnessy *et al.*, 1994). Flinders Island near Augusta is the western most breeding colony (Holley, *pers.comm.*)		Flinders, St Alouarn and Seal Islands have been identified as haul-out sites, although no evidence of breeding there (*Shaugnessy et al*, 1994) Breed on an annual basis, with pupping in December and January (Holley, *pers.comm.*)

(e) Past, present and potential uses and/or pressures

- Human disturbance through boating activities, recreational activities on or near breeding islands and haul-out sites and feeding
- Entrapment in lobster pots and nets
- Litter (eg entanglement in bait bands, discarded fishing line)
- Competition for marine resources (ie food)
- Oil spill/pollution

(f) Past/current/proposed management strategies

- Legislation which protects species of special conservation status
- Departmental licenses and guidelines for tourism operators and interaction with wildlife
- Proposed marine conservation reserve

8.2 For the birds (seabirds and shorebirds) found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999*, the

Endangered Species Protection Act 1992 **and/or the** ***Threatened Australian Fauna (ANZECC List) 1999?*****);**

d) If c), state:
- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

(a) Species diversity and the relative importance of the faunal group

Refer to Elscot and Bancroft (1998) for a list of the breeding seabirds and shorebirds of the islands of the study area, and for a list of the seabirds and shorebirds of the study area, with status.

Seabirds
- None of the breeding seabirds which occur in the study area are unique to the study area, and are more abundant in other parts of the Western Australian coast (Phil Fuller, *pers.comm.*). However, note the occurrence of species of special conservation status in c).
- Note that St Alouarn Island is the only island in the study area where the little penguin is known to occur. The population is estimated between 11 to 100 birds (Cannell, 2001). This is therefore an important population in a regional context, but not in a statewide context (there are more substantial populations elsewhere along the coast eg Penguin Island).

Shorebirds
- The Hardy Inlet is an important winter refuge for migrating shorebirds (Grant Pearson, *pers.comm.*).
- The relative importance of the proposed marine conservation reserve area varies from one species to another. At the State level, it might be considered high for Hooded Plover (confirm with Julie Raines at austecol@cygnus.uwa.edu.au) but it's probably fair to say that it is low for most if not all other species. At the regional level (SW: Kalbarri to Cape Arid) I would say it is moderate-low for most species other than Hooded Plover - but seek an opinion from WA Wader Study Group.
- Look at Watkins, W. (1993). A national plan for shorebird conservation in Australia. RAOU Report No. 90. (in the Woodvale Library).

(b) Size of population, and details of most recent survey

Seabirds
There are no population figures available for the seabirds of the area. No recent surveys have been performed. There has been some opportunistic collection of figures of the number of breeding seabirds of the area - contact Phil Fuller (The Department) for database (Fuller, The Department, *pers.comm.*).

Shorebirds
- Hooded Plover surveys are being conducted at many points along the of the study area. Contact Julie Raines at austecol@cygnus.uwa.edu.au
- There might be some data from "Australia-wide" shorebird surveys that are conducted in February each year. Contact WA Wader Study Group via Julie Raines or Mike Bamford

at mabce@ca.com.au. WA Wader Study Group might also be aware of other work done in the area over the years.

- There are some early 1970s shorebird data for Hardy Inlet in a technical report written by Jim Lane (the Department) which was part of the interdisciplinary study of the ecology of the estuary at that time (Hodgkin, Imberger, Lenanton and others led/participated). Copy at Woodvale Library.
- Grant Pearson, Alan Clarke and Jim Lane (the Department) conducted systematic surveys of shorebirds on Vasse-Wonnerup a few summers ago, but note this is not party of the proposed study area.
  (Jim Lane, the Department, *pers.comm.*)

(c) Rare/endemic/special conservation status

- Species which are rare are listed in Elscot and Bancroft (1998)
- There are no species which are endemic to the study area (Phil Fuller, the Department Woodvale, *pers.comm.*)
- Refer to table 16

Table 16: Birds which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Special conservation status
Anous tenuirostris Lesser Noddy	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992 Listed as 'Fauna that is rare or is likely to become extinct" under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 1999 of the Wildlife Conservation Act 1950
Diomedia chrysostoma Grey headed albatross	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992
Diomedia epomophora Royal albatross	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992 Listed as 'Fauna that is rare or is likely to become extinct" under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 1999
Diomedia exulans Wandering albatross	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992 Listed as 'Fauna that is rare or is likely to become extinct" under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 1999
Halobaena caerulea Blue petrel	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992
Pachyptila turtur Fairy prion	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992
Pheobetria fusca Sooty albatross	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992
Pterodroma mollis Soft plumaged petrel	Listed as 'species that are vulnerable" under Schedule 2 of the Endangered species Protection Act 1992

- Until 1997, the red-tailed tropicbird (*Phaethon rubricauda*) 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 rare red-tailed tropicbird has been recorded as successfully breeding on Sugarloaf Rock (Cape Naturaliste) 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.
- Of interest, although not in the study are, the Vasse-Wonnerup estuary is inhabited by 21 waterbird species which are protected under a Japan-Australia Migratory Bird Agreement and protection exists under a China-Australia Migratory Bird Agreement (Weaving, 1998)

(d) Information regarding the distribution, seasonality and behavioural patterns can be found in'Handbook of Australian and New Zealand birds". It will be a time-consuming task to summarise this information (Fuller, the Department Woodvale, *pers.comm.*) – complete at a later stage of the planning process if necessary.

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. 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 (Dunlop & Wooller, 1990). Of particular note, is the breeding colony of the red-tailed tropicbird (*Phaethon rubricauda*) on Sugarloaf Rock (Cape Naturaliste). 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). 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 the Department'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 islands 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.

(e) Past, present and potential uses and/or pressures

- Burbidge *et al.* (1996) suggest that there is few significant threats to seabird abundance at present
- Boating activities close to islands within the park
- Entanglement in fishing gear
- Oil spills/pollution
- 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.

(f) Past/current/proposed management strategies

There are several important seabird-breeding islands within the Geographe Bay- Capes-Hardy Inlet region: Cape Hamelin (Islet); Hamelin Island; Seal Island; and Sugarloaf Rock. These have all been vested with the National Parks and Nature Conservation Agency (NPNCA) as Nature Reserves to protect the breeding birds.

8.3 For the reptiles found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context ;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) **past/current/proposed management strategies (eg codes of practice, monitoring programs).**

TURTLES

(a) Species diversity and the relative importance of the faunal group

No species of turtle are common in the study area, and subsequently any individuals are of negligible importance to the poulation.

- Leatherbacks (*Dermochelys coriacea*) – occasionally stranded
- loggerheads - adults and juveniles 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).
- green turtles (*Chelonia mydas*) occasionally stranded
- hawksbill turtles (*Eretmochelys imbricata*) have been stranded in the region (Prince, 1993; 1996).
- juvenile flatback turtles (*Natator depressus*) have been stranded in the region (Prince, 1993; 1996).

(b) Size of significant population and details of most recent survey

Not applicable

(c) Rare, endemic and special conservation status

Green, hawksbill and leatherback turtles are listed as *vulnerable* under the *Commonwealth Endangered Species Protection Act 1992*. The loggerhead is listed as *endangered* under the *Endangered Species Protection Act 1992*. The flatback is listed as *vulnerable* under Commonwealth legislation and is treated as *rare or insufficiently known* in the National Action Plan. Under WA legislation, the loggerhead and leatherback are listed as *fauna that is rare or is likely to become extinct* under *Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice* 1999 under the Western Australian Wildlife Conservation Act 1950.

(d)

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).

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.

(e) Past, present and potential uses and/or pressures

- 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 Geographe bay area (B. Prince, the Department, *pers. comm*.).
- Physical disturbance – boat collisions and boat noise
- Entanglement (eg in litter, ropes, discarded fishing gear)

(f) Past/current/proposed management strategies

- Legislation which protects species of special conservation status
- Departmental licenses and guidelines for tourism operators and interaction with wildlife

8.4 For the fishes found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state:

- **biogeographical and local distribution;;**
- **seasonality of occurrence (if applicable); and**
- **behavioural patterns (if applicable);**

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

AWAITING CORRESPONDENCE FROM FISHERIES WA

(a) Species diversity and the relative importance of the faunal group

- Several surveys have been performed to determine the species diversity of the fish assemblages of the study area. All of the following species lists can be found in Elscot and Bancroft (1998):
  - 55 species were sampled in the Geographe Bay-Capes-Hardy Inlet region by Ayvasian & Hyndes (1995) (See Elscot & Bancroft for species list, life history, trophic status and geographical range). Busselton constitutes a distinct assemblage of 21 species, of which none are exclusive to the assemblage. Dunsborough has an assemblage similar to embayment sites in Perth inshore waters, Rottnest and Garden Islands. Dunsborough has a very high species diversity: a total of 49 species with five endemics have been recorded (only a second assemblage identified for inshore Perth sites has a greater species diversity-66 species). Black Point constitutes a distinct assemblage. In this study, it was the most depauperate site sampled, producing only eleven species of which none were endemic to the assemblage (Ayvasian & Hyndes, 1995).
  - 150 species of reef fish were recorded in surveys of the Geographe Bay-Capes-Hardy Inlet region by Hutchins (1994). Species list and distribution range are provided in the list in Elscot and Bancroft (1998). 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.

- The seagrass meadows in Geographe Bay are home to at least 19 species, with the pencil weed whiting *Neoodax radiatus*, comprising 52% of all individuals captured (Scott, 1981).
- A total of 61 species of fishes have been recorded on the HMAS Swan dive wreck, since its scuttling on the 14th December 1997 (Morrison, *pers comm*)
- Fish collected form the Blackwood River Estuary and the inshore marine environment of the Geographe Bay-Capes-Hardy Inlet region during 1976-77 (Lenanton, 1982)
- Species list, life history and abundances percentages of the fish of Flinders Bay and three sites in Hardy Inlet (Valesini *et al.*, 1997). The overall density of fish in the Deadwater Lagoon is 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 is attributed to the high level of productivity and protection that is provided by patches of the seagrass *Ruppia megacarpa* (Valesini *et al.*, 1997).
- The relative abundance of 16 recreationally and commercially important fishes in the nearshore marine environment of the study area (Lenanton, 1982)

- In addition,
  - A total of 110 fishes were encountered during all fish census transects of Kendrick et al (1999). Species lists in Kendrick et al (1999). Three species of fish were considerably more abundant than the other 79 species of fish recorded along large transects: Black headed puller (*Chromis klunzingeri*), Blue lined Hulafish (*Trachinops brauni*) and Noarlunga Hulafish (*T. noarlungae*) were the most common species (refer Kendrick *et al.* (1999) for species list). Note that both species richness and fish density were shown to have high levels of observer bias in this particular study.
  - A total of 247 fishes were recorded for the Bunbury-Geographe Bay area (Walker 1979a; 1979b).
  - The composition of the fish assemblages present in the Blackwood estuary channel and basin undergo pronounced seasonal changes during winter, when freshwater input from rivers decrease 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 is also a large immigration of 0+ juveniles of *A. forsteri* from the sea and *L. wallacei* from the river. The Deadwater Lagoon does not undergo the same seasonal changes as the estuary as there is no riverine input (Valesini *et al.*,1997)
  - The fish assemblages of Flinders Bay are markedly different from the assemblages of the estuary shallows, which are dominated by the estuarine spawning species *Leptatherina wallacei*, *Favonigobius lateralis*, *Leptatherina presbyteroides* and *Atherinosoma elongata*. Valesini *et al.*

(1997) 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 (juveniles of some marine species were either found only in the estuary or were in far higher densities in the estuary than in Flinders Bay; juveniles of some marine species were relatively abundant in both environments; while others were either far more abundant in , or restricted to Flinders Bay).

(b) Size of significant populations and details of most recent survey

- Fish were identified in Kendrick *et al.* (1999)
- See a) and Elscot and Bancroft (1998) for a list of recent surveys

(c) Rare/endemic/special conservation status

There are no species which are of special conservation status or are endemic to the area. Some species which inhabit the study area may be endemic to the south west of WA – see Hutchins (1994) (Hutchins, WAM, *pers.comm.*), for example Dunsborough has five endemics (Ayvasian & Hyndes, 1995).

However, note the occurrence of the great white shark (white pointer) *Carcharodon carcharius*, which is listed under the *Schedule 1 – Fauna that is rare or is likely to become extinct of the Wildlife Conservation (Specially Protected Fauna) Notice 1999.* The leafy Seadragon *Phycodurus eques* is totally protected under the Fish Resources Management Act.

(d) Special conservation status

- The great white shark (white pointer) *Carcharodon carcharius* is listed under the *Schedule 1 – Fauna that is rare or is likely to become extinct of the Wildlife Conservation (Specially Protected Fauna) Notice 1999*. It 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).

(e) Past, present and potential uses and/or pressures

- Incidental recreational and commercial extraction (i.e. by-catch)
- Activities which degrade critical habitats
- Trophic interactions
- pollution

(f) Past/current/proposed management strategies

- Fisheries WA management and legislation
- Proposed marine conservation reserve
- Legislation which protects species of special conservation status

- Coastcare and Fishcare programs (eg Yallingup LCDC; Dunsborough primary school – fish surveys)
- The Margaret River Chapter of the Surfrider Foundation has 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, Grunters Beach, and Redgate Reefs. The project also aims to monitor the populations of blue groper at the five sites through visual surveys at 5 sites, 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.
- Note that Lenanton estimated that all of the 26 km coastline (inshore 50 m) between Busselton and Dunsborough could provide an important spawning and nursery habitat for at least 13 recreationally and commercially important fish, including the prized sportfish Western Australian salmon *Arripis trutta,* herring *Arripis giorgianus,* and King George whiting *Sillaginoides punctatus*. 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).

8.5 For the echinoderms found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state biogeographical and local distribution;

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

(a) Species diversity and the relative importance of the faunal group

A fair estimate of the species of echinoderms from this area is 96 species - without going through museum collections it is not possible to get a more accurate figure. This number is compiled from lists for Albany and Rottnest Island of species known to be in the SW corner (see below). A geographical breakdown is 56 (59%) with a temperate distribution, 21 (22%) with a tropical distribution and 18 (19%) endemic species, several of which have their southern limit at Cape Naturaliste.

While no figures are available, the area of highest species diversity, particularly of seastars, appears to be the rocky shores and offshore reefs (10-20m+ depth) between Dunsborough and Cape Naturaliste (Loisette Marsh, WAM, *pers comm.*).

Table 17: Echinoderms which may occur in the study area of the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	General Distribution	Species	General Distribution
Euretaster insignis	Tropical South to Cape Naturaliste On the Continental shelf	*Nectria macrobrachia*	temperate
Metrodira subulata	South to Cape Leeuwin On the Continental shelf	*N. saoria*	temperate
Nepanthia crassa	Endemic, west coast, south to Cape Naturaliste, shallow water	*N. wilsoni*	temperate
Cenolia tasmaniae	temperate	*Petricia vernicina*	temperate
Oxycomanthus muelleri	endemic	*Austrofromia polypora*	temperate
Comatulella brachiolata	endemic	*Bunaster variegatus*	endemic
Ptilometra macronema	temperate	*Patiriella gunnii*	temperate
Aporometra occidentalis	endemic	*Paranepanthia rosea*	Endemic
Tosia australis	temperate	*Manasterina longispina*	endemic
Nectria ocellifera	endemic	*Nepanthia troughtoni*	temperate
Patiriella brevispina	temperate	*Echinaster arcystatus*	temperate
Paranepanthia grandis	temperate	*E. glomeratus*	temperate
Echinaster varicolor	endemic	*Plectaster decanus*	temperate
Uniophora dyscrita	endemic	*Allostichaster polyplax*	temperate
Astrogymnotes catasticta	endemic	*Coscinasterias muricata*	temperate
Ophiomyxa australis	Tropical	*Astroboa ernae*	temperate
Astrobrachion adhaerens	temperate	*Conocladus australis*	temperate
Euryale aspera	tropical	*Ophiacantha alternata*	temperate
Ophiothela danae	tropical	*Amphipholis squamata*	
Clarkcoma pulchra	temperate	*Amphiura microsoma*	tropical
Ophionereis semoni	tropical	*A. constricta*	
Ophiopeza cylindrica	temperate	*A. micra*	Tropical
Ophiopsammus assimilis	temperate	*Amphioplus (Unioplus) ochroleuca*	Tropical
Goniocidaris	temperate	*Amphistigma*	temperate

tubaria	
Amblypneustes pallidus	endemic
Peronella lesueuri	tropical
Lipotrapeza vestiens	temperate
Stichopus ludwigi	temperate
Ceto cuviera	temperate
Psoledium granulyenum	endemic
Comanthus gisleni	Tropical
Cenolia trichoptera	temperate
Antedon incommoda	temperate
Luidia australiae	temperate
Astropecten preissi	temperate
A. triseriatus	Tropical
Archaster angulatus	Tropical
Pentagonaster duebeni	temperate
Goniodiscaster seriatus	endemic
Anthaster valvulatus	temperate
Ophiura kinbergi	tropical
Phyllacanthus irregularis	temperate
Centrostephanus tenuispinus	temperate
Temnopleurus michaelseni	temperate
Amblypneustes leucoglobus	Endemic
Holopneustes porosissimus	temperate
Nudechinus scotiopremnus	Tropical
Tripneustes gratilla	Tropical

minuta	
Ophiactis resiliens	temperate
O. savignyi	Tropical
O. tricolor	temperate
Ophiothrix caespitosa	temperate
O.ciliaris	Tropical
Macrophiothrix michaelseni	Endemic
Ophiothrix (Placophiothrix) spongicola	Temperate
Ophiocoma dentata	Tropical
O. occidentalis	Endemic
Clarkcoma canaliculata	temperate
Ophionereis schayeri	temperate
Opphiarachnella ramsayi	temperate
Ophioconis opacum	temperate
Ophioplacus imbricatus	tropical
Heliocidaris erythrogramma	temperate
Clypeaster telurus	Endemic
Protenaster australis	temperate
Breynia desorii	Endemic
Holothuria hartmeyeri	temperate
Stichopus mollis	temperate
Stichopus siludwigi	temperate
Australocnus occiduus	temperate
Cucumella mutans	temperate
Leptosynapta dolabrifera	temperate

(Source: Loisette Marsh, WAM of Natural Science, *pers.comm.*, Marsh, 1991; Marsh and Pawson, 1993; Marsh, 1976)

(b) Size of population and details of most recent survey

Figures are not available to indicate the size of population.
Echinoderms were sampled in Kendrick *et al.* (1999)

(c) Rare/endemic/special conservation status:

There is a general lack of information regarding the status of echinoderms. The table below indicates which species are endemic to the study area.

Table 18: Echinoderms which are rare/endemic/special conservation status in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Paranepanthai rosea	*Aporometra occidentalis*	*Goniodiscaster seriatus*
Manasterina longispina	*Nectria ocellifera*	*Bunaster variegatus*
Protenaster australis	*Echinaster varicolor*	*Macrophiothrix michaelseni*
Oxycomanthus muelleri	*Uniophora dyscrita*	*Ophiocoma occidentalis*
Psoledium granalyenum	*Astrogymnotes catasticta*	*Amblypneustes leucoglobus*
Breynia desorii	*Amblypneustes pallidus*	*Clypeaster telurus*

(Source: Loisette Marsh, WAM of Natural Science, *pers.comm.*, Marsh, 1991; Marsh and Pawson, 1993; Marsh, 1976)

(d) Table 19: Distribution of endemic echinoderms of the study area for the proposed Geographe Bay-Capes-Hardy-Inlet marine conservation reserve

Species	**Status**	**Distribution**
Paranepanthai rosea	Endemic	Southern limit at Cape Naturaliste, found among boulders between Dunsborough and Cape Naturaliste, at Rottnest Island and the Houtman Abrolhos
Manasterina longispina	Endemic	Abrolhos Is, south to south coast WA
Protenaster australis	Endemic	Confined to a restricted habitat – sand pockets on shallow reefs, and so is vulnerable to disturbance
Oxycomanthus muelleri	Endemic	Geraldton – southwest Australia
Aporometra occidentalis	Endemic	SW Australia
Nectria ocellifera	Endemic	Geraldton – southwest Australia
Echinaster varicolor	Endemic	NW Australia – SW Australia
Uniophora dyscrita	Endemic	SW Australia
Astrogymnotes catasticta	Endemic	SW Australia
Amblypneustes pallidus	Endemic	Shark Bay-South Australia
Psoledium granalyenum	Endemic	
Goniodiscaster seriatus	Endemic	Pt Maud (c. 23°S); south to Cape Naturaliste
Bunaster variegatus	Endemic	Shark Bay, south to Cape Leeuwin
Macrophiothrix michaelseni	Endemic	Shark Bay, south to south coast, WA
Ophiocoma occidentalis	Endemic	Shark Bay, south to Cape Naturaliste
Amblypneustes leucoglobus	Endemic	Geraldton, south to Eucla
Clypeaster telurus	Endemic	Northern Australia, south to south coast
Breynia desorii	Endemic	Kimberley south to Lucky Bay

(Source: Loisette Marsh, WAM of Natural Science, *pers.comm.*, Marsh, 1991; Marsh and Pawson, 1993; Marsh, 1976)

(e) Past, present and potential uses and/or pressures

- Harvesting of the purple sea-urchin *Heliocidaris erythrogramma* and possibly *Centrostephanus tenuispinus* for food may take place but I have no knowledge of any, so it could be a potential rather than a current threat (Loisette Marsh, WAM, *pers.comm.*)
- Natural impacts are extreme low tides in summer which expose rock platform organisms to heat stress and winter storms which sometimes dislodge animals and cast them up on the beach. Of these two impacts the former is likely to be the more damaging but extreme events are rare (Loisette Marsh, WAM, *pers.comm.*)

- The greatest pressures are likely to come from unfettered tourist and resident developments which may cause habitat destruction and the insidious impact of nutrient enrichment, pesticide residues and other pollution of groundwater which eventually reaches the shoreline (Loisette Marsh, WAM, *pers.comm.*)
- NB: the area of highest species diversity, particularly of seastars, appears to be the rocky shores and foreshore reefs (10-20m+ depth) between Dunsborough and Cape Naturaliste. The same area is also the most important habitat for corals. Hence it is vital that every effort must be made to restrict habitat damage to this par of the coast and offshore reefs.
- Incidental recreational and commercial extraction (ie by-catch)
- Activities which degrade critical habitats
- Trophic interactions
- pollution

(f) Past/current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA management and legislation

8.6 For the crustaceans found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state biogeographical and local distribution;

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

(a) Species diversity and relative importance of the faunal group

WA Museum collections from much of the south-western and southern Western Australian coast are poor, and therefore our knowledge of the fauna must be regarded as incomplete. Certain taxa are poorly represented (eg caridean shrimps) and even less work has been undertaken on most non-decapod crustacean groups, apart from the barnacles (Diana Jones' work).

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). Using information from this survey in the Albany area and using WA Museum collections from the south-western and southern Western Australian coasts, it was found that in south-western and southern WA, generally 75% of the known crustacean species show temperate rather than tropcial afffinities; 43% occur only in southern Australia (from Shark Bay to northern NSW in the east) and 6% are endemic to WA. Due to the influence of the Leeuwin Current, 24% of the crustacean species range from tropical waters into south-western and southern Western Australian waters (Morgan and Jones, 1991). It is expected that such percentates and scenarios apply for the area of the proposed marine reserve (Jones, WAM, *pers.comm.*).

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.

(b) Size of population(s) and most recent survey

- There have been no studies conducted in the study area on population size or on genetically distinct populations (Jones, *pers.comm.*).
- The only research that has been conducted in this area is Jones' barnacle surveys (purely collecting and documentation) and the Department's recent marine survey (Kendrick *et al.*, 1999). Five crustaceans were sampled in this intertidal survey, although it was noted the method of sampling did no reflect the high diversity of species in the study area.

(c) Rare, endemic and special conservation status

Endemic
Tetrapachylasma ferrugomaculosa
Palaemonetes australis
Panulirus cygnus
Calcinus dapsiles
Paguristes longisetosus
Paguristes purpureantennatus
Ocypode convexa
(Jones, WAM, *pers.comm.*)

Rare
unable to comment
(Jones, WAM, *pers.comm.*)

Special conservation status
unable to comment
(Jones, WAM, *pers.comm.*)

(d)

Tetrapachylasma ferrugomaculosa - Rottnest Island to King George Sound
Palaemonetes australis - Hill River to Esperance
Panulirus cygnus - Onslow/NW Cape to Cape Leeuwin
Calcinus dapsiles - Shark Bay to East of Albany
Paguristes longisetosus - Albany to Hopetoun
Paguristes purpureantennatus - Geraldton to Albany
Ocypode convexa - Barrow Island & NW Cape to Yallingup
(Jones, WAM, *pers.comm.*)

(e) Past, present and potential uses and/or pressures

- Commercial and recreational fishing (eg Blue Manna Crab (*Portunus pelagicus*) and the Western Rock Lobster (*Panulirus cygnus*)
- Activities which degrade critical habitats
- Trophic interactions
- pollution

(f) Past/current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA management and legislation

8.7 For the molluscs found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state biogeographical and local distribution;

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

Reference books:

Seashells of Western Australia: Wells and Bryce 1988. Pub: W A Museum.
Covers all major groups: chitons, gastropods, opisthobranchs and bivalves.

Australian Marine Shells: Barry Wilson 1993. Pub: Odyssey
Covers gastropods only.

A guide to Common Molluscs of South-western Australian estuaries: Wells and photos by Bryce. WA Museum 1984.
Covers gastropods and bivalves

(a) Species diversity and relative importance of the faunal group

- A species list for the region is not readily available, and would take approximately two months work to put together (Wells, WAM, *pers.comm.*).
- The mollusc species which characterise the region have a planktonic larval phase, so that they generally have a widespread temperate distribution. The region also contains species of tropical affinity (approximately 2%), which occasionally reach as far south as Margaret River and beyond as a result of the Leeuwin Current (Wells, WAM, *pers.comm.*).
- Wells (1980) has discussed the distribution of shallow water marine prosobranch gastropod molluscs along the coastline of Western Australia.
- 34 molluscs were sampled in the intertidal survey of Kendrick et al. (1999), although it was noted the method of sampling did no reflect the high diversity of species in the study area.
- Slack-Smith (1989) examines the distribution and biogeography of the bivalves of Shark Bay, some of which are found in Geographe Bay;
- 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;
- Along the southern shore of Cowaramup Bay 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 Naturaliste-Leeuwin coastline, are nowhere as abundant or accessible. 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 (S. Slack-Smith, Western Australian Museum of Natural Science Aquatic Zoology Department, *pers. comm*. In Elscot & Bancroft, 1999)

(b) Size of population and most recent survey

- Figures are not available to indicate the size of population (Bryce, *pers.comm*).
- Molluscs were surveyed in Kendrick *et al.* (1999)

(c) Rare, endemic and special conservation status

There are no species in the Geographe Bay-Capes-Hardy Inlet region which are considered to be rare, threatened or endemic. Some species found in the area may be endemic to the south-west region eg *Campanile symbolicum* (lighthouse shell) has a distribution ranging from Esperance to Geraldton and is endemic to the SW of Western Australia(Wells, WAM, *pers.comm.*).

(d) Not applicable

(e) Past, present and potential uses and/or pressures

- Commercial and recreational fishing eg Commercial species of Haliotidae are *Haliotis conicopora* (brown lipped abalone), *H. laevigata* (green lipped abalone)and *H. roei* (blacklipped abalone). The first two inhabit the deeper subtidal zones and can only be collected by scuba diving; H conicopora prefers dark caves (Wells, WAM, *pers.comm.*).

  Amateur shell collectors may pose a potential threat to the molluscs of the proposed marine conservation reserve. Shell collectors target many different groups but primarily the species of the families Cypraeidea and Volutidae found in the study area (The Department of Conservation and Land Management, 1994; Bryce WAM *pers. comm.*). These are not truly intertidal species but are accessible in many areas during spring tides when the boulders they shelter under are exposed. Collection of cryptic species such as *Notocypraea* spp. also disturbs the habitats (Kendrick et al., 1999).

  The few well developed platforms in the study area are mostly easily accessible from the shore making the larger fauna such as the abalone *Haliotis roei* and the turban shells *Turbo pulcher* and *T. torquata*, particularly at risk. This impact is expected to increase with the growing population. It is expected that pressure on invertebrates that are not targeted at this time will increase, for example the black nerite (*Nerita atramentosa)*, the giant limpet (*Patella laticostata)*, small limpets (*Siphonaria jeanie* and *Pateloida alticostata*), the giant barnacle (*Austrobalanus nigrescens)* and sea urchins (Kendrick *et al*., 1999)

  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. It was concluded that the scallop stocks of Geographe Bay were low.
- Activities which degrade critical habitats
- Trophic interactions
- pollution

(f) Past/current/proposed management strategies

- Proposed marine conservation reserve

- Fisheries WA management and legislation

8.8 For the corals found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state biogeographical and local distribution;

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

(a) Species diversity and the relative importance of the faunal group

- 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 (Veron & Marsh, 1988). Geographe Bay 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. Of the 14 species, 10 are tropical, 2 are temperate and 2 are endemic. Of the 10 tropical species, five have their southern limit near Cape Naturaliste and are all fairly abundant on the offshore reefs in Geographe Bay. Rare giant colonies of *Turbinaria* spp off Eagle Bay are a unique feature of the reefs at c10 m depth.

  Refer to Table 20

(b) Size of population and details of most recent survey

- Figures are not available to indicate size of population
- Corals were surveyed in Kendrick *et al.* (1999)

(c) Rare/endemic/special conservation status

- *Coscinaraea marshae* and *Symphyllia wilsoni* are endemic to south-western Australia (Loisette Marsh, WAM, pers.comm.).
- Rare giant colonies of *Turbinaria* spp off Eagle Bay are a unique feature of the reefs at c10 m depth.
- Refer to table 20

Table 20: Hermatypic corals of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

SPECIES	GEOGRAPHE BAY	SOUTH OF CAPE NATURALISTE	DISTRIBUTION
Coscinaraea marshae	3	3	Endemic to south-western Australia. South Australia north to Abrolhos. Abundant in Geographe Bay at 15-20m
Coscinaraea mcneilli	3	3	East and southern coast of Australia, north to Abrolhos
Favites abdita	3		Geographe Bay to tropics. Form large coralla
Favites complanata	3		Geographe Bay to tropics. Form large coralla
Goniastrea aspera	3		Geographe Bay to tropics. Form large coralla
Goniastrea australensis	3		Geographe Bay to tropics. Form large coralla
Montipora mollis	3		Tropical, southern limit Geographe Bay
Plesiastrea versipora	3	3	Circum Australia to tropics
Scolymia australis	3	3	East and southern coast of Australia, north to Rottnest. Flinders Bay (museum spec.)
Symphyllia wilsoni	3	3	Endemic to south-western Australia. Bremer Bay to Shark Bay. Abundant in Geographe Bay at 15-20m
Turbinaria frondens	3	3	Duke of Orleans Bay to tropics
Turbinaria mesenterina	3	3	Recherche Archipelago to tropics. At Eagle Bay colonies consist of tiers of plates up to 3m high and 3m across; common.
Turbinaria reniformis	3	3	Recherche Archipelago to tropics; common in Geographe Bay
Turbinaria peltata	3		Geographe Bay to tropics. Colonies are abundant in Geographe Bay and occur in colonies of more than 1m in diameter.

(Species list from Veron & Marsh, 1988; distribution information provided by Loisette Marsh, WAM, *pers.comm.*)

(d)

Table 21: Distribution of endemic corals of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Species	Distribution
Coscinaraea marshae	Endemic to south-western Australia. South Australia north to Abrolhos. Abundant on the low profile reefs off the coast between Dunsborough and Cape Naturaliste at around 15-20m, but is not known from the Cape Naturaliste to Leeuwin Coast. It is uncommon to rare through most parts of its distribution.
Symphyllia wilsoni	Endemic to south-western Australia. Bremer Bay to Shark Bay. Abundant on the low profile reefs off the coast between Dunsborough and Cape Naturaliste at around 15-20m, but is not known from the Cape Naturaliste to Leeuwin Coast. It is uncommon to rare through most parts of its distribution.
Turbinaria mesenterina	Recherche Archipelago to tropics. At Eagle Bay colonies consist of tiers of plates up to 3m high and 3m across; common.

(e) Past, present and potential uses and/or pressures

- Anchor damage is a threat to species on the deeper reefs as these are favoured fishing locations.
- Coastal development is a potential threat through disturbance of the coast and the seepage of groundwater form residential and tourist development. High water quality is essential for healthy coral growth, hence water quality needs to be monitored if there is further development on this area of the coast

  (Loisette Marsh, WAM, *pers.comm.*)
- Incidental commercial and recreational extraction (ie bycatch)
- Activities which degrade critical habitats
- Trophic interactions
- pollution

(f) Past/current/proposed management strategies

- Proposed marine conservation reserve
- Fisheries WA management and legislation

8.9 For any other invertebrates (eg sponges, bryozoans, tunicates) found in the study area, state:

a) species diversity and the relative importance of the faunal group in a statewide and regional context;

b) size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

c) species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

d) If c), state biogeographical and local distribution;

e) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

f) past/current/proposed management strategies (eg codes of practice, monitoring programs).

(a) Species diversity and the relative importance of the faunal group

Ascidians

- There has been no systematic and quantitative research regarding ascidians in WA. To compile a comprehensive species list would be a very time consuming task – the best avenue for this would be Pat Kott's Ascidian Monographs -memoirs of the Qld museum vol 23:1985, vol20:1980; vol32:1992, vol29:1990 OR in the Zoological Catalogue of Australia vol 34 1998 (Jane Fromont, WAM, *pers.comm.*; Stocker, Murdoch Uni, *pers.comm.*)
- In the subtidal studies of Kendrick et al. (1999) ascidians were poorly studied, but showed high diversity and high species turnover within and between sites. Ascidians were identified as candidates for future surveys. A possible 44 species of ascidians were identified in the subtidal areas of the study area.
- Refer to table 22

Brachiopods

Brachiopods have no known economic or realised scientific importance. They are however, living creatures with a 500 million year old history (Robert Craig WAM, *pers.comm.*).

Table 22: Ascidians of the Geographe Bay-Capes-Hardy Inlet region
(Identified by Dr Laura J. Stocker form the Institute for Science and Technology Policy, Murdoch University, WA 6163)
Source: Kendrick *et al.*, 1999

FAMILY CLAVELINIDAE
Genus *Clavelina*
Clavelina cylindrica
Clavelina moluccensis

Genus Neptheis
Neptheis fascicularis

FAMILY PYCNOCLAVELLIDAE
Genus *Euclavella*

FAMILY HOLOZOIDAE
Genus *Distaplia*
Distaplia pallida

FAMILY POLYCITORIDAE
Genus *Eudistoma*
Eudistoma maculosum

Genus *Polycitor*
Polycitor nubilus

FAMILY RITTERELLIDAE
Genus *Ritterella*
Ritterella sigillinoides

FAMILY PSEUDODISTOMIDAE
Genus *Pseudodistoma*
Pseudodistoma australe
Pseudodistoma candens
Pseudodistoma sp. CC1

FAMILY POLYCLINIDAE
Genus *Aplidiopsis*
Aplidiopsis mammillata

Genus *Sydneiodes*
Sydneiodes tamaramae

Genus *Synoicum*
Synoicum sacculum

Aplidium sp. CC3

Genus *Aplidium*
Aplidium altarium
Aplidium benhami
Aplidium clivosum
Aplidium cratiferum
Aplidium filiforme
Aplidium petrosum
Aplidium rubricollum
Aplidium triggsense
Aplidium sp. CC1
Aplidium sp. CC2
Euclavella claviformis

Family Didemnidae
Genus *Didemnum*
Didemnum albidum
Didemnum sp. CC1
Didemnum sp. CC2
Didemnum sp. CC3
Didemnum sp. CC4
Didemnum sp. CC5 (candidum?)
Didemnum sp. CC6 (augusti?)
Didemnum sp. CC7

Genus *Leptoclinides*
Leptoclinides sp. CC1
Leptoclinides sp. CC2
Leptoclinides sp. CC3
Leptoclinides sp CC4 (c.f. Leptoclinides sp 4, P. Kott, 1997)

Genus *Polysyncraton*
Polysyncraton aspiculatum

FAMILY PEROPHORIDAE
Genus *Perophora*
Perophora hutchisoni
Perophora multiclathrata

FAMILY STYELIDAE
Genus *Cnemidocarpa*
Cnemidocarpa sp. CC1 (pedata?)

Genus *Oculinaria*
Oculinaria australia

Genus *Botrylloides*
Botrylloides leachi

FAMILY PYURIDAE
Genus *Pyura*
Pyura gibbosa

Sponges

- As with ascidians, there is insufficient knowledge regarding the sponges of the area to determine their relative significance. In the subtidal studies of Kendrick et al. (1999), sponges were poorly studied, but showed high diversity and high species turnover within and between sites. Species that were influential were *Clathrina* sp1, *Mycale* sp1 and *Echinoclathria.* Sponges were identified as candidates for future surveys. A possible 110 sponge species were identified in the subtidal areas of the study area

Table 23: Sponges of the Geographe Bay-Capes-Hardy Inlet region

Order	Family	Genus	Species
Class Calcarea			Calc Sp 1
Class Calcarea			Calc Sp 2
Class Calcarea			Calc Sp 3
Class Calcarea			Calc Sp 4
Class Calcarea			Calc Sp 5
Class Calcarea			Calc Sp 6
Class Calcarea			Calc Sp 7
Class Calcarea			Calc Sp 8
Class Calcarea			Calc Sp 9
Class Calcarea			Calc Sp 11
Class Calcarea			Calc Sp 12
Class Calcarea			Calc Sp 13
Class Calcarea			Calc Sp 14
Class Calcarea			Calc Sp 12
Class Calcarea			Calc Sp 15
Class Calcarea			Calc Sp 16
Class Calcarea			Calc Sp 17
Class Calcarea			Calc Sp 18
Class Calcarea			Calc Sp 19
Clathrinida	Clathrinidae	*Clathrina*	*Clathrina* Sp
Dendroceratida	Dysideidae		Dysideidae Sp 1
Dictyoceratida			Dictyoceratida Sp 1
Dictyoceratida			Dictyoceratida Sp 2
Dictyoceratida	Irciniidae		Irciniidae Sp 1
Dictyoceratida	Spongiidae		Spongiidae Sp 1
Dictyoceratida	Spongiidae		Spongiidae Sp 3
Dictyoceratida	Spongiidae		Spongiidae Sp 5
Dictyoceratida	Spongiidae		Spongiidae Sp 6
Dictyoceratida	Spongiidae		Spongiidae Sp 3
Dictyoceratida	Spongiidae		Spongiidae Sp 7
Dictyoceratida	Spongiidae		Spongiidae Sp 8
Dictyoceratida	Spongiidae		Spongiidae Sp 9
Dictyoceratida	Spongiidae	*Hippospongia*	*Hippospongia* Sp 1
Dictyoceratida	Spongiidae	*Phyllospongia*	*Phyllospongia* Sp 1
Dictyoceratida	Spongiidae	*Strepsichordaia*	*Strepsichordaia* Sp 10
Dictyoceratida	Irciniidae	*Thorectandra*	*Thorectandra* Sp 1
Halichondrida			Halichondrida Sp 1
Halichondrida			Halichondrida Sp 2
Halichondrida	Axinellidae		Axinellidae Sp 1
Halichondrida	Axinellidae		Axinellidae Sp 2
Halichondrida	Axinellidae		Axinellidae Sp 3
Halichondrida	Axinellidae		Axinellidae Sp 5
Halichondrida	Axinellidae		Axinellidae Sp 6
Halichondrida	Axinellidae		Axinellidae Sp 7
Halichondrida	Axinellidae		Axinellidae Sp 8
Halichondrida	Axinellidae		Axinellidae Sp 9
Halichondrida	Axinellidae		Axinellidae Sp 10
Halichondrida	Axinellidae		Axinellidae Sp 12

Order	Family	Genus	Species
Halichondrida	Axinellidae		Axinellidae Sp 13
Halichondrida	Axinellidae		Axinellidae Sp 14
Halichondrida	Axinellidae	*Cymbastela*	*Cymbastela* Sp 1
Halichondrida	Axinellidae	*Cymbastela*	*Cymbastela* Sp 2
Haplosclerida			Haplosclerida Sp 1
Haplosclerida			Haplosclerida Sp 2
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 1
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 2
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 3
Poecilosclerida	Microcionidae		Microcionidae Sp 1
Poecilosclerida	Microcionidae		Microcionidae Sp 2
Poecilosclerida	Microcionidae		Microcionidae Sp 3
Poecilosclerida	Microcionidae		Microcionidae Sp 5
Poecilosclerida	Microcionidae		Microcionidae Sp 7
Poecilosclerida	Microcionidae		Microcionidae Sp 8
Poecilosclerida	Microcionidae		Microcionidae Sp 13
Poecilosclerida	Microcionidae		Microcionidae Sp 15
Poecilosclerida	Microcionidae		Microcionidae Sp 16
Poecilosclerida	Microcionidae	*Clathria*	*Clathria styloprothesis*
Poecilosclerida	Microcionidae	*Clathria*	*Clathria* Sp 2
Poecilosclerida	Microcionidae	*Clathria*	*Clathria* Sp 3
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 1
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 2
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 3
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 4
Poecilosclerida	Raspailiidae	*Echinodictyum*	*Echinodictyum* Sp 1
Poecilosclerida	Mycalidae	*Mycale*	*Mycale* Sp 1
Poecilosclerida	Mycalidae	*Mycale*	*Mycale* Sp 2
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 1
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 2
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 3
Poecilosclerida	Tedanidae		Tedanidae Sp 1
Poecilosclerida	Tedanidae		Tedanidae Sp 2
Verongida	Aplysinidae		Aplysinidae Sp 1
Verongida	Aplysinidae		Aplysinidae Sp
Homosclerophorida	Plakinidae		Plakinidae Sp 1
Homosclerophorida	Plakinidae		Plakinidae Sp 2
Astrophorida			Astrophorida Sp 1
Astrophorida			Astrophorida Sp 2
Astrophorida			Astrophorida Sp 3
Astrophorida			Astrophorida Sp 4
Astrophorida			Astrophorida Sp 5
Astrophorida			Astrophorida Sp 6
Astrophorida	Anchoriniidae		Anchoriniidae Sp 1
Astrophorida	Anchoriniidae		Anchoriniidae Sp 2
Astrophorida	Anchoriniidae		Anchoriniidae Sp 3
Astrophorida	Geodiidae	*Geodia*	*Geodia* Sp 1
Astrophorida	Geodiidae	*Geodia*	*Geodia* Sp 2
Hadromerida			Hadromerida Sp 1
Hadromerida			Hadromerida Sp 2
Hadromerida			Hadromerida Sp 3
Hadromerida	Chondrillidae	*Chondrilla*	*Chondrilla australiensis*

Order	Family	Genus	Species
Hadromerida	Latrunculiidae		Latrunculiidae Sp1
Hadromerida	Polymastidae	*Polymastia*	*Polymastia* Sp 1
Hadromerida	Polymastidae	*Polymastia*	*Polymastia* Sp 2
Hadromerida	Spirostrellidae		Spirostrellidae Sp 1
Hadromerida	Suberitidae	*Caulospongia*	*Caulospongia* Sp 1
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 1
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 2
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 3
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 4
Lithistida			Lithistida Sp 1

(Source: Kendrick *et al.*, 1999)

Brachiopods

The numbers are unknown. There are probably 12 species found along the WA coast, with a least three species found in the proposed marine park. Most common species found are *Magellania flavescens*, which is found on piles near Bunbury to Busselton and along the southern coast of Australia, and *Cancellothyris hedleyi*, which has been recorded from the Abrolhos to NSW. No specific surveys for brachiopods has ever been done, so their relative significance is unknown. They appear in collections from time to time as 'unknowns" (Rob Craig, WAM, *pers.comm.*).

(b) Size of population and most recent survey

- Figures are not available to indicate size of population
- Invertebrates were sampled in Kendrick *et al.* (1999)

(c) Endemic/rare/special conservation status

Ascidians

As no systematic and quantitative surveys have been done, it is unknown if ascidians are threatened, rare or plentiful (Stocker, Murdoch Uni, *pers.comm.*)

Sponges

As no systematic and quantitative surveys have been done, it is unknown if sponges are threatened, rare or plentiful

Brachiopods

As no specific surveys have been done, it is unknown if brachiopods are threatened, rare or plentiful. Brachiopods first appeared in the fossil record some five hundred million years ago when they outnumbered bivalves. Since that time they have suffered major extinctions and with environmental changes have become a much less abundant group of living organisms (Rob Craig, WAM, *pers.comm.*).

(d) Not applicable

(e) Past, present and potential uses and/or pressures

- Incidental commercial and recreational extraction (ie bycatch) eg 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 3120' S and 3423' S latitudes.
- Activities which degrade critical habitats
- Trophic interactions

- pollution

(f) Past/current/proposed management strategies:

- Proposed marine conservation reserve
- Fisheries WA management and legislation
- Although bryozoans and sponges are important sessile benthic groups, they have been poorly studied in the study area (and in many other areas of WA) and are subsequently poorly known. As such, they need to be protected to safeguard these unknown components of biodiversity (Jane Fromont, WAM, *pers.comm.*).
- Recommendation 6 (Kendrick *et al.*, 1999): Both sponges and ascidians were poorly studied during the study of Kendrick *et al.*(1999), but show high diversity and high species turnover within and between sites. Both sponges and ascidians are candidates for future studies
- As no recent research has been done of the phylum Brachiopoda, our understanding of their value as environmental indicators, economic potential for drugs etc is not known. Brachiopods are susceptible to disturbance: they are sedentary, attached tot he sea floor and hard surfaces, and if disturbed will usually die. No management plan has ever been established anywhere in Australia for this whole phylum (Rob Craig, WAM, *pers.comm.*)

9 Marine Flora, Protists & Bacteria

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9.1 For any seagrass populations in the study area, state:
- **a) species diversity (give details of most recent survey);**
- **b) biogeographical and local distribution and endemism;**
- **c) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);**
- **d) current condition; and**
- **e) management strategies currently used and/or proposed.**

(a) Species diversity and details of most recent survey

- Refer to section 7.2 for species list
- Refer to Kendrick *et al.* (1999), Bancroft (2000) and Bancroft and Shattock (2000) for recent survey information. Two seagrass species were sampled in the subtidal areas of the study area (Kendrick *et al*.,1999) - *Amphibolis griffthiii* and *Thalassodendron pachyrhizum*

(b) Biogeographical and local distribution and endemism

- Refer to section 7.2

(c) Past, present and potential uses and/or pressures, evidence of impact and the relevant research programs

- Refer to section 7.2

(d) Current condition

- Refer to section 7.2

(e) Management strategies currently used and/or proposed

- Refer to section 7.2

9.2 For any mangroves in the study area, state:
- **a) species diversity (give details of most recent survey);**
- **b) biogeographical and local distribution and endemism;**
- **c) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);**
- **d) current condition; and**
- **e) management strategies currently used and/or proposed.**

Not applicable

9.3 For any macroalgal populations in the study area, state:
- **a) species diversity (give details of most recent survey);**
- **b) biogeographical and local distribution and endemism;**
- **c) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);**

d) current condition; and
e) management strategies currently used and/or proposed.

(a) Species diversity and details of most recent survey

- Refer to section 7.2 for species list
- Refer to Kendrick *et al.* (1999), Bancroft (2000) and Bancroft and Shattock (2000) for recent survey information.

A total of 150 algae were sampled in the subtidal areas of the study area, and 26 in the intertidal areas (Kendrick *et al*., 1999). One collection of algae and seagrasses from the northern side of Cowaramup Bay, made adjacent to the boat ramp in the low intertidal, a zone exposed at extreme spring tides, resulted in 27 species of macroalgae and serves as an indication of the high diversity of species in this area (species list in Kendrick et al., 1999).

(b) Biogeographical and local distribution and endemism

- Refer to section 7.2
- Biogeographical distribution information and endemism can be found in Huisman (2000), or other suitable botanical texts
- Of the 150 algal species sampled by Kendrick *et al.* (1999), many species were rare and were surveyed infrequently. Only six algae occurred at >15 survey sites. Approximately 75% of the total species recorded occurred at less than five sites.

Of the sites studied by Kendrick et al. (1999), the most algal species were recorded at Fould Bay inshore, Bunker Bay and Canal Rocks inshore: these sites were characterised by granite substrata, shallow depths and lacked a kelp canopy. Between 40 and 50 species of macroalgae were identified at each of these sites (Kendrick et al., 1999).

Assemblages of marine algae varied across the study region and were significantly different among regions, between granite and limestone reefs and between depths <10 m and 10-20 m. Regional differences were observed between sites on the northern shore of Cape Naturaliste and the western and southern regions of the survey area. This probably reflects different wave exposure regimes, as the northern shore is well protected against prevailing western and southern winds and ocean swells (Kendrick et al., 1999).

In general, for deep granite and shallow limestone reefs, few species characterise algal assemblages whereas for shallow granite reefs many species and high species turnover characterised alga assemblages. Where the substrate changes from limestone to granite at Cape Naturaliste, cold temperate brown algae become dominant (Walker, 1991).

For deep granite reefs the canopy brown algae, *Ecklonia radiata* and *Scytothalia dorycarpa* and the understorey red alga *Rhodopeltis australis* characterise the algal assemblage. The understorey under these canopies were depauperate, with most smaller foliose and filamentous algae occurring in patches in the canopy. The foliose red algae *Dictymenia sonderi* and the bladed brown alga, *Lobophora variegat*a occurred in patches with little or no kelp canopies (Kendrick *et al*., 1999).

Shallow granite reef and boulder fields were characterised by species rich canopies of *Ecklonia radiata* and species of *Sargassum, Cystophora, Platythalia* and *Scytothalia* and other large brown algae (Womersley, 1987). The main canopy brown algae were *Cystophora harveyii, C. racemosa, Platythalia angustifolia* and *Sargassum varians.* Understorey assemblages were also more diverse, with high species turnover between replicate quadrats within sites. The abundant understorey species of limestone reefs were the coralline algae *Amphiroa anceps* and *Jania pulchella* and other red algae *Callophillis* sp. and *Pterocladia lucida* under kelp dominated limestone reefs in the southwest of the study region, from near Hamelin Bay to Augusta (Kendrick *et al.*, 1999).

(c) Past, present and potential uses and/or pressures, evidence of impact and the relevant research programs

Refer to section 7.2

(d) Current condition

Refer to section 7.2

(e) Management strategies currently used and/or proposed

Refer to section 7.2

9.4 For any populations of cyanobacteria (non-bloom populations, eg stromatolites) in the study area, state:

a) species diversity (give details of most recent survey);
b) biogeographical and local distribution;
c) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);
d) current condition; and
e) management strategies currently used and/or proposed.

(a) Species diversity and details of most recent survey:

The microbial flora associated with the tufa deposits of the area 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. (L.Moore, WRC, *pers.comm. In* Elscot & Bancroft, 1998)

An extensive survey has not yet been undertaken (L. Moore, Water & Rivers Commission, Perth, *pers. comm*. In Elscot & Bancroft 1998).

(b) Biogeographical and local distribution and endemism:

- 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. More research is needed to determine distribution and endemism
- Refer to the Department's Marine Conservation Branch official planning file for map of the tufa communities (this is also available by contacting Meredith Soutar, The Department, Busselton). Locations are Cape Naturaliste, Sugarloaf, 3 Bears, Canal Rocks, Meekadarabee, Kilcarnup, Contos, Foul Bay and Quarry Bay
- 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, Water & Rivers Commission, Perth, *pers. comm*. In Elscot & Bancroft 1998). Along the coastline of Cape Leeuwin there has been three distinct forms of tufa identified by Linda Moore (WRC, 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*. In Elscot & Bancroft, 1998)

(c) Past, present and potential uses and/or pressures, evidence of impact and the relevant research programs:

- Used as a recent analogue of fossil structures in the geological record that may provide some insights into palaeoenvironments
- There is evidence of "people pressure" in the area near the Water Wheel through direct damage from trampling
- During a period the town of Augusta was using the groundwater feeding the area as a source of public water supply, depriving the area of adequate spring flows. It is

thought they the town of Augusta now gets its water from a borefield in another area.

- Report from Linda Moore – pending
  (Linda Moore, WRC, *pers.comm.*)

(d) Current condition:

Variable.
Where spring water is still flowing, the tufa continues to accrete due to the growth of the associated microbes. However, there are many areas along the coast in this area where the tufa deposits are dry and are slowly eroding, especially those which are adjacent to the sea and are impacted by waves (Linda Moore, WRC, *pers. comm.*)

(e) Management strategies currently used and/or proposed:

- WATSCU have listed the tufa communities near the waterwheel at Cape Leeuwin, Augusta as a Threatened Ecological Community (A. Webb, The Department, Busselton, *pers. comm.* In Elscot & Bancroft, 1998).
- Education – the Cape to Cape walk trail refers to the tufa deposits and makes people aware of their significance
- Leeuwin-Naturaliste National Park?

10 Coastal terrestrial biota

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10.1 What are the major coastal terrestrial plant assemblages of the study area? Include dominant species and conservation status

- The coastal vegetation of the west coast between Cape Leeuwin and Cape Naturaliste has been recorded by the Department's district botanist A. Webb (Busselton). 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).
- Keating & Trudgeon (1985) have given a description of the coastal vegetation of the southern Swan Coastal Plain to Dunsborough.
- Refer to Coastwise (2000) Appendix 3: List of plant species occurring on the Sandy Geographe Bay coastline
- Grein (1997) describes the coastal vegetation of the Augusta-Margaret River Shire. Species lists for the coastal vegetation of the area are held at the Department's Busselton office.
- Abbott (1978; 1980) has described the flora of Hamelin Island more recently. Note that 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, the Department, *pers. comm.*).

Table 24: Declared rare flora and threatened ecological communities of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Declared Rare Flora	Threatened Ecological Communities	Priority
Caladenia caesarea subsp maritima	Cave Aquatic Root Mat Communities	Cotact Meredith Soutar (the Department, or refer to official file)
Caladenia excelsa ms	TUFA microbial community	
Caladenia huegelii	Meelup granites (*Calothamnus graniticus* heath on south west coastal granites (Meelup)	
Caladenia viridescens		
Eucalyptus phylacis		
Kennedia macrophylla		
Wurmbea calcicola		

(Meredith Soutar, the Department, *pers.comm.*)
NB: refer to Department's Marine Conservation Branch official planning file for maps of Declared Rare and priority flora and threatened ecological communities (note that the TUFA community and the Meelup Granites communities are coastal)

- 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, the Department, *pers. comm.*).
- Note that a recent study (Connell *et al.*, 2000) classified over 82% of native vegetation remnants in the Geographe Bay catchment as being poor or very poor condition.

10.2 What are the major groups of land mammals, birds and reptiles? Include number of species, dominant species and conservation status

- Species list and status of the mammalian fauna of the coastal scrub of the study area can be found in Elscot & Bancroft (1998). 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, the Department, *pers. comm.* In Elscot & Bancroft, 1998).

  Several animals that are vulnerable and specially protected under the Western Australian *Wildlife Conservation Act* are known to occur in the Capes 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. 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 (Elscot & Bancroft, 1998)

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Table 25: 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, U					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, the Department's Seabird Breeding Islands Database
(2) Gillham (1961, 1963)

NB: All of the above are common, except the red tailed tropicbird (uncommon) and the fairy tern (moderately common), as advised from Phil Fuller (*pers.comm.*)

- See Elscot and Bancroft (1998) for species lists of the seabirds and shorebirds and conservation status in the study area
- Refer to Elscot & Bancroft for species list of terrestrial reptiles. The bobtail *Tiliqua rugosa* and the bungarra *Varanus gouldii* are two of the larger, more commonly seen lizards of the coastal areas (G. Voight, the Department, *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
- Refer to Elscot & Bancroft (1998) for species list of coastal amphibians of the Geographe Bay-Capes-Hardy Inlet
- 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 (The Department of Conservation and Land Managment, 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.
- Note that the Department's Wildlife Branch maintains a databases of declared fauna occurrence in the Department's regions, so that information can be obtained for the Central Forest Region.

10.3 What strategies are the relevant management authorities utilising/proposing to determine and/or minimise any potential environmental impact on the coastal terrestrial biota of the study area?

- There are many coastal rehabilitation projects underway by the Department and community groups, such as those listed in section 21.3. For example, coastal rehabilitation is currently occurring at Cowaramup Bay, Hamelin Bay, Redgate, Big Rock in Gracetown, Lefthanders, Moses Rock, Injidup, Yallingup and Meelup.
- The fragmentation of native vegetation through clearing has probably had the greatest effect of all human induced changes to the native fauna (The Department of Conservation and Land Management, 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 (The Department of Conservation and Land Management, 1989).
- In April 1997 the Memorandum of Understanding for the Protection of Remnant Vegetation on Private Land in the Agricultural Region of Western Australia came into being
- 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 the Department, 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.).
- Shire of Augusta-Margaret River Coastal Management Policy, 1998
- *Wildlife Conservation Act 1950*
- Geographe Bay Foreshore Management Plan *Draft* (Coastwise, 2000)
- The Peppermint forest is of great value to Busselton and imparts to it a special character. It defines and forms an avenue between Busselton and Dunsborough along Caves road and it screens many of the large developments on the seaward side. It also provides an attractive backdrop to the dune scrub and beach areas when viewed from the ocean or the beach. As development occurs along the coastline, increasing pressure will be placed on this vegetation. To avoid this situation, all coastal reserves should be the subject of a planning exercise that endeavours to maximise the quality of the native vegetation (Coastwise, 2000).

11 Cultural history

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Aboriginal

11.1 Outline the historical occupation of the study area by Aboriginal groups

Aboriginal people have occupied southwest Western Australia for around 40,000 years. Archaeological investigations near the Geographe Bay foreshore at Dunsborough date Aboriginal occupation sites to 12,000 years ago (Dortch and Dortch 1997). Other studies at Devil's Lair, near Cape Leeuwin 100 km to the south show that people lived there 33,000 years ago (Dortch, 1979). Excavations in nearby Mammoth Cave found charred bones, possible caused by man mad fires, estimated to be at least 37,000 years old (Merrilees *et al.*, 1973).

The south-west of Western Australia is considered to form a distinct cultural bloc defined by the distribution of the *Nyungar* ('man' or 'person') language. The south-west people recognised themselves, their language and culture as "*Bibbulman*" before Nyungar was used as a group or linguistic name (Bates, 1985). Land of the Bibbulman people extended from everything to the west of a line drawn from Jurien Bay on the west coast to Esperance on the south coast (Bates, 1966). The name of the dialect between Augusta and Vasse was *Burrong wongi*. All coastal Bibbulman were *Waddarn-di* – sea people, and called themselves *Waddarn-di Bibbulmun* (Bates, 1985).

Note- spelling of Bibbulman/mun/mum varied in this document

Thirteen "tribal groups" in the south-west have been identified based on socio-linguistic boundaries and minor dialect differences. The Wardandi Bibbulmum territory encompasses the coast from Koombanup (Bunbury) to Talanup (Augusta) following the Blackwood river inland to Nannup (Tindale, 1974).The Wardandi moved throughout their territory in nuclear families and larger bands, coming together for social and ceremonial purposes. They practiced elaborate oral traditions and maintained complex social arrangements and spiritual beliefs. They made periodic moves throughout the year within relatively small areas as well as between larger, distinct ecological zones (Coastwise, 2000).

At the time of European occupation, there were approximately 6,000 Aboriginal persons living in the south –west (The Department of Conservation and Land Management, 1987). The early settlers used many of the tracks created by the Nyungar people, the Nyungar people showed the settlers to water sources and the Europeans shared game shot while being guided by the Nyungar men (Goode, 2000). The Nyungars were often emplyed as farm labour and domestic help. Good relations between the local Aborigines and the first settlers soon degenerated. Aborigines killed cattle and sheep for food and the military garrison, which had been established to protect the settlers, carried out repraisal raids in which an

unrecorded number of Aborigines perished. Attacks by Aborigines on settlers appear to have started in the Vasse River settlement soon after the arrival of the Europeans, increasing in intensity after 1836. On 21 February 1841, George Layman, a twenty-nine year old settler, was speared by a local elder named Gaywal as a result of an argument over Layman giving food to another Aborigine. The Vasse River group was pursued by a reprisal party, who massacred them at Wonnerup. Although at least eight Aborigines were killed, Gaywal escaped the slaughter, to be shot seven days later. (O'Connor *et al.* 1995).

In 1851, the Bussells set up a pastoral/farming property at the Ellensbrook River. Sam Isaacs, known to his people as Yebulbis, moved to Margaret River with the Bussells in 1864. He is best remembered by history for the part which he played with Grace Bussell in the renowned sea rescue, as a result of which he was awarded one hundred acres of land by the WA Government. Isaacs descendants are now in the Busselton area – his grandson Mr G. Webb and great-grandson Mr W. Webb, so tat there lies an unbroken link with the past (O'Connor *et al.*, 1995).

Until the early 1900s, Nyungar people were dispersed, dispossessed of their lands, their culture changed and population reduced. Significant changes occurred from 1903 with major agricultural developments by the Government in the Avon, Midlands and Great Southern districts. Before 1900, Nyungars relied on both employment at pastoral stations in the south-west and hunting traditional foods. As more land was cleared and traditional food harder to gather, they increasingly relied on employment with non-Aboriginal farmers and rations distributed by the Government and mission stations. The cultural lifestyle of these people was severely disrupted by widescale clearing of natural habitat and relocation to mission stations and Government settlements under the 1905 Aborigines Act and 1936 Native Administration Act (The Department of Conservation and Land Management, 1991).

Note: for more detail regarding the history of European settlement and Indigenous occupation, refer to Goode (2000) – Ethnographic Survey of Hamelin Bay, Leeuwin-Naturaliste National Park, WA. A report produced for the Department. MCB has a copy.

11.2 What sacred/significant sites have been registered with the Aboriginal Affairs Department under the Aboriginal Heritage Act 1972? What is the significance of these sites in a regional context?

There are a total of 45 sites identified as having Aboriginal significance in and adjacent to the study area which have been mapped by DOLA from information of the Aboriginal Sites Register System, Aboriginal Affairs Department. Most of these sites contain artefacts, and several are burial sites. The majority of these sites have open access, although the sites where access is closed are the Hamelin Bay Burial Grounds, the Broadwater Burial Grounds, Gracetown Burial Grounds, King Bundaitch's Grave site and the Busselton Fringe Camp site. All sites are registered under the Aboriginal Heritage Act 1972. Note that all sites have not necessarily been reported, the Aboriginal Sites Register System is a work in progress, and not all sites from this System have necessarily been mapped by DOLA (Land Claims Mapping Unit, DOLA; Richard Riordan, Aboriginal Affairs Department, *pers comm.).*

11.3 What was the historical Aboriginal use of the study area and its resources? Outline any evidence of Aboriginal occupation and use of the study area (eg rock paintings, shell middens).

The seasonal movement of Aboriginal groups relates to the exploitation of various resources available in the different environmental situations. The Wardandi maintained a number of paths between the Vasse/Wonnerup area in the north and Augusta to the south, and as far as Nannup to the east, that followed the coast and the Blackwood River. The coastal path

passes directly through the Hamelin Bay-Margaret River-Kilcarnup area and many of the Nyungar names for camping places are still in common use (Goode, 2000).

Traditionally, the Bibbulmun Nyungar people recognised six different seasons in the year, each coinciding with a particular seasonal abundance of a wide variety of food resources. Aboriginals tended to congregate around waterways during the summer to fish, and move inland during the winter months to hunt kangaroo and other game and gather roots. Spears *Gidgie-garbel* and *Gidgie-borryl*, axes *Kadjo* and digging sticks *Wonna*, were among the implements used (Berndt 1979, Tilbrook 1983). The use of low intensity controlled firing of the vegetation enabled the Aboriginal people to modify their environment and maximise economic resource exploitation (O'Conner *et al.*,1995).

The calm, shallow, inshore marine waters and the small estuarine channels entering Geographe Bay offered marine fish, while the fresh-water streams and the lakes and wetlands behind the foreshore provided wildfowl, turtles, frogs, crustaceans and edible rhizomes (reed roots) (Dortch 1997). Mainly eye-witness accounts, mostly dating to the first decades of British settlement in the early nineteenth century, make it clear that estuarine/inshore marine fishing, mainly of schooling species, was a key subsistence activity in the traditional economy of southwestern Aboriginal communities (Dortch, 1997).

Fishing was mainly restricted to the lakes and rivers, as the south west Aborigines were not a seafaring people (O'Connor *et al.*, 1995). Predominant techniques in catching fish in estuaries and coastal waters were spearing of fish by individuals, tidal weirs, traps and fish drives. During the early Holocene when estuaries were more marine than they are now, Aborigines may have also eaten oysters and other shellfish. There are accounts from early explorers and settlers at Busselton that mention indigenous people fishing and hunting in and around Geographe Bay (Bussell n.d. [1834], Marchant 1982).

Searches for weirs and other fishing sites have not been carried out at most of the estuaries and former marine lagoons of south-western Australia. (Dortch, 1997). The only evidence of fish traps found in the study area to-date is at the Abba River (Land Claims Mapping Unit, DOLA). There is also little evidence to suggest that Aborigines fished along the open beaches and exposed cliffed or rocky shores constituting the south west's predominantly high-energy coasts. . The archaeological evidence for marine and fresh water mollusc exploitation, though not negligible, is very sparse (Dortch,1997). Middens including those of edible species found in or adjacent to the study area have been found at Aboriginal coastal occupation sites at Cowaramup Point, Ellen Brook Complex, Gnarabup Swamp, Willanup Spring and Jingiee Lake (Land Claims Mapping Unit, DOLA).

Coastal and marine resources were a prominent feature of the Dreaming. The Dreaming is an ideological and philosophical basis for a close emotional connection between Aboriginals and their land, referring to a distant past when the world had yet to be fully created. Between Cape Leeuwin and Bunbury the local peoples held the whale as a totem (*mammang borungur*). The whale in the southwest of WA was collectively known as *Mimange.* Whaling also provided Aboriginal peoples with employment, economic stability, equality, independence and food. The Geographe Bay foreshore and hinterland may have had a ceremonial focus, as suggested by a semi-circular earthwork seen near Wonnerup by Francois Peron, a member of the 1801 Baudin expedition from France (Marchant 1982).

Trade was also an important factor in traditional Aboriginal society. The Nyungar traded wilgi (ochre) in return for such items as ground axes, pearl shell ornaments, meteorites and carved initiation boards (O'Connor *et al.*, 1991). Artefacts containing chert have been found at Devil's Lair, with the nearest possible source of this material being greater than 500 km south-east of the Swan River (Hallam, 1981).

There are a total of 45 sites identified as having Aboriginal significance in and adjacent to the study area which have been mapped by DOLA from information of the Aboriginal Sites Register System, Aboriginal Affairs Department. Refer to section 11.2.

11.4 What is the current use of the study area by Aboriginal groups (eg subsistence uses, commercial uses)?

Expansion of the British settlements at Wonnerup and Busselton led to ever-greater use of resources and land, resulting in the displacement of indigenous people and eventually, from *c*.1900, their relocation to missions and fringe-camps (Haebich 1988). Despite these upheavals, indigenous people have maintained their cultural, spiritual, and familial connections with Geographe Bay throughout the 20th century and to the present day. The interests maintained by Aboriginal people include: the identification and management of Aboriginal heritage sites, native title claims, research and community education, and recreation. (Geographe Catchment Management Strategy).

The Department undertook a research project in 1991 to identify the aboriginal activities which currently occur in the south west. Hunting was the most common Nyungar activity. Animals taken from the land adjacent to the study area are the Western Grey Kangaroo, the feral big, rabbit, emu, black cockatoo, bardee, parrots, echidna and racehorse goanna. Hunting forms an important part of teaching Nyungar ways and culture to young people. Numerous plants are collected for foodstuff, including the grasstrees and bull banksias. Camping is regarded a s a major activity (The Department of Conservation and Land Management, 1991).

The Commonwealth Government recognises some rights of Aboriginal people in legislation such as the *National Parks and Wildlife Conservation Act 1975*. Western Australia recognises the rights of Aboriginal people to hunt, fish and gather through the *Wildlife Conservation Act 1950* and the *Fisheries Act 1905.*

11.5 Applications on the Register of Native Title Claims under the *Native Title Act 1993* and details

There are presently two Native Title claims on parts of the study area that are on the Register of Native Title Claims under the *Native Title Act 1993*, according to Land Claims Mapping Unit (DOLA):

WC 96/41
Harris Family
1762 km^2
Claimant: Minnie van Leeuwen
C/-M.E. van Leeuwen
18 Jennings Way
Lockridge WA 6054
Status: "Registered" i.e. a registered claim on the Tribunal's register and has the right to negotiate
File last updated by LCMU (DOLA) on 20/10/1999

WC 98/63
South West Boojarah
10070 km^2
Claimants: Donald Corbett and others
C/-Noongar Land Council
GPA Box 8432
Perth WA 6849

Ph: (08) 9225 4111
Fax: (08) 9225 4133
Status: "Registered" i.e. a registered claim on the Tribunal's register and has the right to negotiate
File last updated by LCMU (DOLA) on 1/11/2000

(Land Claims Mapping Unit, DOLA)

Status as at 2/2/00
Harris (96/41), Isaacs (98/42), South-West Boojarah (98/63) and part of Gnaala Karla Booja (98/58) have been consolidated into the one trial area and are now referred to as 'South-West Trial Area Number One'. The claim has been filed with the Federal Court, passed through the Administrative, Regulatory and Notification stages, and was accepted for mediation by the National Native Title Tribunal. It has now been programmed to trial and allocated a judge. Orders state it can go to trial no earlier than February 2002 (Richard Hunt-Smith, National Native Title Tribunal, *pers.comm*).

WC 98/58
Gnaala Karla Booja
30750 km^2
Claimants: Lorraine Belloti and others
C/-Noongar Land Council
GPO Box 8432
Perth WA 6849
Ph: (08) 9225 4111
Fax: (08) 9225 4133
File last updated by LCMU (DOLA) on 31/10/2000
Status: "Registered" i.e. a registered claim on the Tribunal's register and has the right to negotiate

WC 98/42
Isaacs
Details available from National Native Title Tribunal, and when the Department's GIS section obtains most recent information from Land Claim Mapping Unit, Geographic Servcies, DOLA

Maritime

11.6 Outline the significant aspects of the maritime history and European settlement of the study area and any remaining evidence of this history

- Cape Leeuwin, the south-west extremity of Australia, and a portion of the coast north of the south of the Cape ranging from about Hamelin Bay to Point D'Entrecasteaux, were discovered and named by the Dutch ship 'Leeuwin' in 1622.
- A second recording was made in 1685 by J.P. Poereboom, who anchored in what is thought to be Flinders Bay. Poreboom made the first, brief description of Aboriginal culture (The Department of Conservation and Land Management, 1987)
- Several French explorers followed in the later half of the 18th century. De ST Allouarn, reported sighting the south-west coast in 1772, and is said to have anchored close to a small island near Cape Leeuwin (The Department of Conservation and Land Management, 1987)
- Matthew Flinders sailed along the coastline of "Leeuwin's Land" in 1801, and named Cape Leeuwin (The Department of Conservation and Land Management, 1987)

- Sealers and whalers, mostly American, French and British visited Australian shores in the early 1800s, but did not set up permanent settlements on the west coast.
- The earliest accounts of certain exploration in the Busselton area date to 1801, when two French ships, the 'Geographe' under the command of Nicholas Baudin and the 'Naturaliste' under Emmanuel Hamelin, visited Geographe Bay and explored the coastline from Cape Hamelin northwards to the area at the mouth of the Swan River and Rottnest Island. The Baudin expedition charted and named many geographical features in the area, including Cape Naturaliste and Geographe Bay, Point Picquet, Hamelin and Depuch Bays. It is believed that during Baudin's departure from Geographe Bay, a young officer named Vasse fell overboard and, having been left behind, lived for some months with the Aboriginals before dying on the banks of the river now bearing his name, after refusing to travel inland with the Aboriginals.
- Matthew Flinders arrived off Cape Leeuwin in HMS *Investigator* on 6 December, 1801 to begin charting the Australian coast. He discovered that the largest of the supposed Isles of St Alouarn was joined to the mainland and he gave it the name Cape Leeuwin, taking the name of the adjoining area which had been called 'Leeuwin's Land' by Dutch navigators after the *Leeuwin* ('lioness') had rounded the cape in March 1622.
- The British settlers came to the Swan River in 1829. As a result of the expeditions of the French, the British sent Captain James Stirling in *HMS Success* to investigate the colonisation potential of the south-west corner of Australia. Stirling favoured the idea of an early southerly extention of the Swan River Colony. Stirling observed in March 1827 that excellent shelter was afforded in the bay extending from Castle rock to the Vasse Inlet (Feilman and Associates, 1977).
- The first group of settlers in the southwest of the colony arrived on the brig *Emily Taylor* with Captain James Stirling, who intended to explore the area and determine the possibility of settlement. The party landed at Flinders Bay, near the mouth of the Hardy Inlet on 2 May 1830 and established the settlement of Augusta (originally known as Port Augusta), and three land grants (to the Molloy, Bussells and Turners) were taken up in the Augusta area. Settlers suffered many hardships in the early days because of its isolation and the difficulty faced with clearing of land (Laurence *et al.*, 1992). Within two years it was found that the site was too difficult; Captain Molloy left Augusta to take up a grant of 12,400 acres at the Vasse River, to be followed by the Bussell Brothers, who took up 5,573 acres. The Augusta settlement lapsed until the 1870s, when M. Davies began exploiting timber thereunder Government licence and established a permanent settlement in June 1879 (O'Connor *et al.*, 1995).
- As such, the settlement of Geographe Bay by Europeans began shortly after 1829 in a search for arable land. Earliest known European settlers were the Molloy, Turner and Bussell families who settled in the area in 1832. The town site for Busselton was surveyed and gazetted in 1837 (Gutteridge Haskin & Davey, 1989).
- When the early settlers of Augusta moved north to the Vasse region , conflicts between the Aboriginal inhabitants arose, and after that disease, tribal vendettas and forceable shifts to schools and 'native camps' remote from the traditional areas led to a rapid decline of the traditional Aboriginal culture (Ministry for Planning, 1997)
- Whaling was one of the early industries in the south-west. The area was frequently visited by a number of American Whaling ships. Works for processing whale meat were established as early as 1839 at Augusta by J.W. Child, who formed the AWA Whaling Co. in 1843. R. Heppinstone built a whaling Station at Castle Rock near Cape Naturaliste which operated for several years in the 1850s. The flourishing whaling activity in the 1940s is said to have been a major attraction for early settlement into the area (Coastwise, 2000). (The Department of Conservation and Land Management, 1987)
- On 21 February 1841, George Layman, a 29 year old settler was speared by a local Aboriginal elder named Gaywal, as detailed in section 11.1.

- Early pastoralists of the area included Bussell, Brady, Heppingston, Knight, Layman and Payne.
- Early colonists harvested jarrah which was exported to markets in England, India and South Australia. Some logging was carried out in the Busselton district and jetties were built in Geographe Bay. William Eldridge established a timber exporting firm in the 1850s based at Augusta. M.C. Davies started to build a saw mill at Coodardup. Jetties in both Flinders and Hamelin Bays, were completed in 1885 as these areas were the shipping points. A new mill was built at Arumvale, Boranup and later Jarrahdene to cope with the demand for timber. The company expanded rapidly and by 1890 was responsible for over 32% of all timber exports from the colony (The Department of Conservation and Land Management, 1987). In 1900 the company amalgamated with its major opposition and several others to become Millars' Karri and Jarrah Forests Limited. By 1907, the timber resources at Karridale had dwindled and Hamelin Bay port was closed (The Department of Conservation and Land Management, 1987)
- The first stage of the Busselton jetty was constructed in 1865 to provide for the growing quantities of timber that were being exported. It served as a shipping port up until 1973.
- Dunsborough township was gazetted in 1879 (State of the Environment Report).
- In 1884 Davies approached the local authorities and requested support to build a direct route from Busselton to Augusta. This road, originally known as Karridale Road, is today known as the Bussell Highway. A year later, the Cape Leeuwin Lighthouse was built by Davies' firm, Davies and Wishart. A waterwheel was built nearby to supply water to the lighthouse keepers and their families.
- Settlement in the Geographe Bay area was accelerated by Government programs, including the Estates Settlement Scheme in the 1820s and 1830s; the construction of the road and rail network between 1889 and 1918; the Group Settlement and Returned Soldiers Scheme in the 1920s and 1930s and the establishment of irrigation and drainage facilities under Government Works Programs. These programs opened up previously unused land and provided incentive to establish community and servicing infrastructure, thus enabling urban growth around the established nodes (Coastwise, 2000).
- The timber industry played a very important role in the early development of the region, and road, rail and communication links ere established to support the industry. The relative importance of the timber industry in certain areas declined with the subsequent growth of the dairy industry.
- On the coast Busselton grew from a timber port to fledgling coastal resort and an early centre of the South west's potato industry
- The discovery of caves near Margaret River and Augusta and their exploration about 1900 first brought tourists to the area (Hodgkin, 1978).

Evidence

Various physical remains of the various phases of European settlement can be found. The most notable structure in the study area is the Busselton railway jetty. The first stage of the jetty was built in 1865 but the structure was extended several times with the most recent being in 1911. At present, the jetty structure stretches over 2 kilometres offshore. A lighthouse was built in 1873 and operated in the study area until its demolition in 1933 (Coastwise, 2000).

The Augusta-Busselton Heritage Trail is part of a statewide network of trails established to commemorate the Bicentenary in 1988. Approximately 100 km long, the trail retraces the pioneer route from Augusta to the Vasse and includes:

- The historic Augusta site of Georgiana Park – site of Molloys' first house in 1830
- The Adelphi house site of 1831 near Alexandra Bridge
- Chapman Hill camp site of the pioneer travellers
- Busselton Jetty and beach where settlement was established in 1834

Over the years, wide-scale clearing, broad-acre cropping, fertilising, draining, filling wetlands and irrigation placed huge demands on the environment. Expectations of the land were high and sometimes two or more crops were expected per year. Town settlement cleared more of the land as did railways, roads, bridges, mining, dams and weirs. Land degradation is evidence of past, and continuing practices.

11.7 Outline the historical commercial activities (eg whaling, sealing, pearling)

- Within the Region, and specifically within Geographe Bay, the inshore and estuarine fisheries industry was one of the first industries to become established.
- Intensive whaling activity occurred in Geographe Bay. Foreign whalers started to arrive along the coast and initiate pelagic whaling in the early 1830s, initially frequenting the north west coast, and then frequenting southern waters around Augusta. Western Australians did not enter the deepsea whaling industry, lacking the experience, capital and equipment to compete with the Americans. In 1834, American Whalers began to frequent the waters off Augusta. Between 1840 and 1870 the Hobart whaling fleet operated on the south coast between Cape Leeuwin and the Australian Bight. Pelagic whaling saw peaks in activity in the early 1840s and the early 1870s. By the 1880s whaling had all but ceased in the Geographe Bay area and the only remains are the whaling lookout point at Castle Rock and factory ruins in Castle Bay. In 1888, the last American pelagic whalers left WA. In 1912 a Norwegian whaling company operated between Cape Leeuwin and the Recherche Archipelago. At this time a Fremantle Company operated between Cape Leeuwin and Steep Point (Adam Wolfe, WA Maritime Museum, *pers.comm.*)

11.8 Are there any sites gazetted by the WA Maritime Museum in the study area (eg shipwrecks/historical remains), governed by the *Heritage of Western Australia Act 1990* or on the register of the National Trust?

There are nine shipwrecks listed on the Western Australian Historic Shipwreck Database (Custodian - WA Maritime Museum, Department of Maritime Archaeology). Details on this database include historical background material, location, information on the site and the vessel history.

Table 26: Details of the shipwrecks of the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Name	Where lost	When lost	Protected	Country built
Chaudiere	Hamelin Bay	1883	Federal	UK
Cumberland	Augusta	1830	Federal	India
Georgette SS	Calgardup Bay	1876	Federal	Scotland
Katinka	Hamelin Bay	1900	Federal	Scotland
Mary	Lockeville	1879	Federal	WA
Mayflower	Augusta, Deere Reef	1880	State	UK
Pericles SS	Off Cape Leeuwin	1910	Federal	Northern Ireland
Unidentified	Ringbolt Bay	1880	Federal	Australia
Agincourt	Hamelin Bay	1882	Federal	UK

(Western Australian Historic Shipwreck Database, WA Maritime Museum, Department of Maritime Archaeology).

Listings on the Register of Heritage Places, governed by *The Heritage of Western Australia Act*,1990 include:

- Cape Naturaliste Lighthouse and Quarters

- Sandilands
- Wonnerup Precinct
- Ellensbrook Farmhouse, dam and waterfall
- Cape Leeuwin Lightstation and cottages

Listings can be found at *www.heritage.wa.gov.au*

Listings on the Register of the National Trust which are in or adjacent to the study area (coastal zone) are:

- Flinders Bay settlement
- Cape Leeuwin Lighthouse and Lighthouse Cottages
- Ellensbrook (owned by the National Trust)
- Sandiland's Homestead
- Busselton Jetty
- Lockeville
- Wonnerup Complex (owned by the National Trust)
- Cape Naturaliste Lighthouse
- Waterwheel, Leeuwin

(Robert Mitchell, National Trust of Australia (WA), *pers. comm.*, as listed on the cdrom "Traces on the Past – the National Trust Register of the Built Heritage of Western Australia (1997)")

Military

11.9 Outline the history of any significant military activities relevant to the study area

Negligible significant military activity occurred in the study area. The military activities which occurred were:

- Busselton Air Field – advanced operational base WWII
- Air to Ground firing and bombing range Vasse-Wonnerup Estuary WWII
- Cape Naturaliste – early warning radar station WWII
- Barracks Pt, Flinders Bay 43rd Regiment (British)
- Cape Leeuwin Lighthouse WWII – voluntary observer corps site
- Flinders Bay WWII – Internees Camp
- Cape Mentelle and Cow Rock – air to ground bombing range
- Busselton was an advanced operational air base (fuel and ammunition)
- POW control centre in Margaret River
  (Paul Bridges, Army Museum, *pers.comm.*)

11.10 Is there any evidence/remains of historical military activities?

No

11.11 Have any sites of historic military significance been declared?

No

12 Tenure

AWAITING GIS DATASETS

CONTACTS
DAVID THOMLINSON (SHIRE OF BUSSELTON)
KIM DAVIES (MANAGER REGIONAL FACILITIES, DPI)
MICHAEL BETTISON, PROJECT OFFICER COASTAL FACILITIES, DPI)

12.1 Which shires/local government authorities are responsible for the administration of the area? What are the major townsites of each shire?

Shires/local government authorities:

- Shire of Busselton - major townsites are Busselton; Dunsborough; Yallingup; Jarrahwood; Vasse; and Carbunup. Total shire area is 145,966 ha (Weaving, 1998)
- Shire of Augusta-Margaret River - major townsites are Augusta; Margaret River; Cowaramup; Gracetown; Prevelly Park; Witchcliffe; Karridale; and Rosa Brook. Total shire area is 222,718 ha (Weaving, 1998)

12.2 What is the population and growth rate of each shire?

Shire of Busselton

- Population 14,592 in 1990-91, and has increased to 21,568 in 1998-99 (ABS, 2000)
- The Shire of Busselton is recorded as one of the fastest growing LGA outside the Perth metropolitan area, with a growth rate of approximately 5.9%. This growth rate has been consistent over the past eight years (Ministry for Planning, 2000b)
- In Busselton it is commonly believed that the Shire's population possibly doubles over the December-January holiday period (Coastwise, 2000)

Shire of Augusta-Margaret River

- In June 1991, the Shire of Augusta-Margaret River's estimated resident population was 6218 persons, with an average annual population growth of 5.5%, measured from 1991 to 1999. In 1999, the estimated resident population had increased to 9564 persons (62% Margaret River zone, 38% Augusta zone), an average increase of 372 persons (ABS, 2000; Ministry for Planning, 2000a)

12.3 Outline any illegal or formalised squatter development in the area

None (Shire planners of Shire of Busselton and Augusta/Margaret River (David Thomlinson), *pers.comm.*)

12.4 What are the details of any existing leases held by squatters?

N/A

12.5 Do the shire/s have a squatter removal program (provide details)?

N/A

12.6 What is the past, present and predicted future land development in the study area (eg proposed town sites, resort developments)?

Digital dataset available – refer to MCB GIS section or Map 3A & 3B Leeuwin-Naturaliste Ridge Statement of Planning Policy Areas and Local Town Planning Schemes *In* Augusta-Margaret River Land Release Plan 2000-01 to 2004-05 (Ministry for Planning, 2000)

Shire of Busselton

In recent years, the development of tourism and residential facilities throughout the Shire and within the townsites has been significant. In addition to the rapid expansion of the urban areas of Busselton and Dunsborough, rural land has been under increased pressure for subdivision for rural and residential purposes. This trend has been attributed to a lifestyle choice and has resulted in a change in social characteristics, transport and economic patters, and community facilities within these areas.

The townsites of Busselton and Dunsborough contain substantial stacks of vacant, zoned and serviced land. There is no immediate prospect of a shortage of rural, commercial or industrial land. In view of the significant demographic growth and change experienced within the Shire over the past 20 years the shire has identified the need to review the provision of human services infrastructure (Ministry for Planning, 2000b).

Land development pressure on the environment is likely to increase in the longer term as the supply of suitable land close to the sea and estuary diminishes.
The Leeuwin-Naturaliste Ridge Policy (WAPC, 1996), the new Shire District Town Planning Scheme (The Shire of Busselton, 1999), the Busselton Urban Growth Strategy (Shire of Busselton, 1998) and the Shire of Busselton Rural Strategy (Shire of Busselton 1983) constitute an important regulatory framework

For further information with respect to land development, refer to Ministry for Planning (2000b)

Shire of Augusta-Margaret River

Land use within the Shire is characterised by an expanding horticultural industry, mainly vineyards and market gardens, and there is increased pressure for the subdivision of rural land into Rural Residential and Special Rural zones. Authorities are becoming increasingly concerned that these pressures, and the associated changes in land use and land cover, any have a negative impact oh the environment (EPA, 1999), resulting in the loss of productive prime agricultural land to non-agricultural purposes, or environmental degradation due to inappropriate use or management. As a response to development pressures, the Rural Strategy (Shire of Augusta-Margaret River, 1992) and the Leeuwin-Naturaliste Ridge Statement of Planning Policy (Western Australian Planning Commission, 1998) provide a strategic planning framework (Ministry for Planning, 2000a).

With the exception of Special Residential zoned lots, all other residential zones in the Margaret River zone have a considerable surplus. There is no apparent shortage of commercial or industrial lots within the Margaret River zone. Dwelling land supply within the Augusta zone is oversupplied between 70% and 90%, although there is a relative shortage of existing and potential lots zoned Special Residential and special Rural. There is no apparent shortage of commercial lots within the Augusta Zone. There is a need for a detailed investigation of the status of industrial zoned land within the Shire (Ministry for Planning, 2000a)

Refer to Koltasz, Smith & Partners (2000a) - Gracetown Development Investigation Report, a study by MoP, DOLA and the Department to determine the parameters, principles and guidelines for the further investigation of any expansion of the Gracetown townsite. The report nominates a preferred Development Investigation Node, a preferred servicing strategy, being the provision of a reticulated sewerage and water supply, ungrading of the power supply and onsite drainage.

The rapid growth in population and development requires an ongoing review of the services and facilities within the Shire by the Service providers (Ministry for Planning, 2000a). For further information with respect to land development, refer to Ministry for Planning (2000a).

12.7 Is there any current use of the area for military purposes?

No – (Shire of Busselton, *pers.comm.*; David Thomlinson, Shire of Augusta-Margaret River planner, *pers.comm.*)

12.8 Any there any other existing leases on land, seabed or waters of the study area? Do these leases permit input into the administration of the area?

Awaiting GIS datasets

No fishing exclusion zones: Yallingup, Cowaramup, HMAS Swan Wreck site.

12.9 How is the territorial sea baseline determined in the identification of the seaward limit of state territorial seas?

Essentially, the Territorial Sea Baseline (TSB) is the line of Lowest Astronomical Tide (LAT), although the TSB may jump across bays (bay closing lines), rivers (river closing lines) and between islands and heavily indented areas of coastline (straight baselines) under certain circumstances. Such is the case for Geographe Bay-Capes-Hardy Inlet, as the baseline varies in relation to different geographical features such as bays, offshore islands e.t.c. As such, the limit of State territorial seas is more than three nautical miles from the mainland coast in some places (AMBIS dataset).

The TSB was originally determined in the early 1970s by AUSLIG's predecessor (Natmap). The Maritime Boundaries Program is now carefully attributing the data quality, including lineage (history) to form part of AMBIS (Australia's Maritime Boundaries Information System)(www.auslig.gov.au). Note a more current TSB is being developed by AMBIS, and is due for completion soon (Mark Sheridan, *pers comm.*).

13 Infrastructure and facilities

CONTACTS
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JOHN BARRETT (BUNBURY PORT AUTHORITY)
KIM DAVIES (DPI, MANAGER REGIONAL SERVICES)
MIKE PETTERSON (DPI)
NEVILLE ROGERSON (WC)
GUY WATSON (DEP)
ROBYN PAICE (WRC)

Coastal access

13.1 Do roads/tracks provide access to all sections of the coast?

The Bussell Highway and Caves Road are the major sealed roads of the area. The Bussell Highway connects Busselton to Augusta, as does Caves Road, although the latter is closer to the coast. Refer to the GIS datasets of the Digital Acquisition Program, the Department, for datasets of roads and tracks.

In general, there is a high level of coastal access around the more developed towns such as Busselton, Dunsborough, Yallingup, Gracetown, Prevelly and Augusta. The close proximity and alignment of Bussell Hwy and Caves rd to the coast, including the road pattern and level of residential development along the coast between Busselton and Dunsborough, provides high levels of pedestrian access to the coast of Geographe Bay. From Cape Naturaliste to Yallingup vehicular tracks provide access to most areas of the coast, with Sugarloaf rd (sealed) and Yallingup Beach rd (sealed) the primary roads. There is intermittent coastal access provided mainly by sealed roads and vehicular tracks between Yallingup and Cape Clairault. Sealed roads are Yallingup Beach rd, Smiths Beach rd, Canal Rock rd, Wyadup rd and Cape Clairault rd. Between Cape Clairault and Gracetown, vehicular tracks provide access to much of the coast, although the are still some isolated pockets. Important roads are Cowaramup Bay rd (sealed) and Moses rock rd (unsealed). The coastal access between Gracetown and Cape Mentelle is provided for by tracks and is high, with the exception immediately north of Cape Mentelle. Ellenbrook rd (unsealed) is an important road. There are large pockets between Cape Mentelle and Cape Hamelin where there is no coastal access. Major roads are Gnarabup rd (sealed), Walcliffe rd (sealed), Rivermouth rd (sealed), Redgate rd, Conto rd (unsealed) and Hamelin Bay rd (sealed). Tracks provide intermittent access. From Cape Hamelin to the study area boundary there is an intermediate level of coastal access, again provided for mainly by tracks. Major roads are Skippy Rock rd (unsealed) and Leeuwin rd (sealed). (Digital Acquisition Program, the Department).

An aerial study of the parking and beach access arrangements along the study area on Australia Day 2000 revealed that the parking facilities in the main settlements of Busselton and Dunsborough have sufficient capacity to accommodate beach vehicles during peak times (Coastwise, 2000). However, further residential development in both Busselton and Dunsborough could place pressure on the existing facilities and may require provision of additional parking facilities in sensitive locations.

13.2 What is the nature of the authorisation of the airports/landing strips?

Shire of Busselton: Busselton airport is under the control of the Shire of Busselton and is licensed by the Civil Aviation Authority. There are four other major private landing strips in the area (Peter Hails, Shire of Busselton, *pers.comm.*).

Shire of Augusta-Margaret River: there are two commercial light aircraft landing strips, located in the Augusta and Margaret River townsites. These are both on Shire reserves and under the control of the Shire.

13.3 Are there any plans to develop additional infrastructure and/or expand existing infrastructure?

The following is taken primarily from the Leeuwin-Naturaliste Ridge Statement of Planning Policy Report (Ministry for Planning *et al.*, 1997):

Leeuwin-Naturaliste Ridge

Settlement Pattern
The settlement pattern will be based on

- Major urban growth within the Principal Centres
- Other urban growth focused on inland centres
- Designated Coastal and Tourism Nodes
- Clustered rural settlement in Enclaves
- Limiting Rural Residential living to existing designated areas

Settlement Servicing (Infrastructure)
The designated settlement hierarchy and form will be facilitated by an appropriate level and timing of infrastructure provision by:

- Promoting the primary settlement function of Principal Centres, the expansion of nominated inland settlements, and the efficient and innovative servicing of identified rural settlement nodes
- Providing required infrastructure in a timely manner that has regard for development needs of the settlements
- Maintaining and upgrading the existing road network

Busselton, Dunsborough, Margaret River (including Prevelly/Gnarabup, Gracetown), Flinders Bay and Augusta will continue to be the Principal Centres in the settlement hierarchy and cater for the majority of residential, large-scale commercial and other urban development (Ministry for Planning *et al.*, 1997; Shire of Augusta-Margaret River Coastal Management Policy). Busselton is expected to accommodate substantial urban growth. Other residential development will focus on the inland settlements of Vasse, Carbanup River, Cowaramup, Witchcliffe, Karridale and Kudardup Coastal nodes are identified as Eagle Bay, Yallingup, Gracetown, Prevelly an Gnarabup. Tourist Nodes are identified at Bunker Bay, Caves House, Smiths Beach and Hamelin Bay.

Proposals/policies:

- A new Strategic Road is proposed at Ridgelands in the north (from Vidler Road near Yallingup to Cape Naturaliste Road near Eagle Bay/Bunker Bay) which will provide a direct link from Caves Road to Cape Naturaliste.
- The proposed road link between Vasse and Dunsborough/Yallingup will be planned in consultation with relevant government authorities and the community and include consideration of landscape and social impacts
- A Margaret River bypass, east of Darch Road, will be planned in consultation with local government, MRWA, the Department and the community. The bypass will form the eastern boundary of the townsite.
- There will be provision for the progressive extension and development of a Dunsborough to Cape Naturaliste Lighthouse walk/cycleway -

- Provision for cyclists will be encouraged in the development of district and local level roads

13.4 Have there been any past/current/potential environmental impacts of infrastructure in the study area? Provide details of the relevant research/monitoring programs.

Refer to section 2.6 – pressures on the geomorphology of the study area – for a discussion regarding the impacts of car parks, groynes etc

13.5 What strategies are the relevant management authorities and/or involved companies utilising/proposing to minimise the environmental impact of infrastructure on the marine and coastal environment?

- In 1997 the Western Australian Planning Commission published the Leeuwin Naturaliste Ridge Statement of Planning Policy. The policy area covers the near-shore waters of Cape Naturaliste to Cape Leeuwin and inland area, which covers much of the town sites adjacent to Bussell Highway. It addresses issues including nature conservation, tourism, cultural heritage and resources (Ministry for Planning *et al.* 1997)
- Leeuwin-Naturlaiste Ridge Planning Review (WA Planning Commission and Shires)
- State of the Environment in Australia's South West (South West (WA) Local Government Association)
- South West Environmental Strategy (South West (WA) Local Government Association)
- South West Region Priority Project Register (South West Development Commission)
- South West Strategy (South West Development Commission)
- The State Planning Strategy provides a strategic guide for land use planning in Western Australia to the year 2029. The strategy is aimed to develop a land use planning system to help the State fulfil a number of goals, including:
    - To focus on environmental and economic management
    - To provide a range of residential lifestyles, tourist experiences and economic opportunities
    - To protect coastal, riparian, heritage and natural environment (Coastwise, 2000)
- In 1986 a Country Coastal Planning Policy, WAPC No DC 6.1 was developed in WA incorporating coastal planning and management principals.
- Western Australian Planning Commission published Coastal Planning and Development in Western Australia: Towards a Policy Framework in 1996. This policy deals with a wide range of coastal planning and development issues in an integrated manner but has yet to be finalised.
- Gutteridge Haskins & Davey consultants prepared the Busselton Foreshore Development Study in 1989. The report provided a detailed assessment of the study area with regard to development/management of the urban beachfront of Busselton. This report was prepared for the Shire of Busselton, the South West Development Authority and the Western Australian Tourism Commission.
- Town Planning Schemes. For Example: Shire of Busselton Town Planning Scheme No. 20 identifies Coastal Management Areas along the coast, to ensure that development does not impact on the dunes or the beach. The Scheme provision (Section 28) requires that applications received for development within the Coastal Management Areas may be referred to the Department of Transport the Water & Rivers Commission and the Ministry for Planning for comment
- Geographe Bay: Recommendations for Coastal Reserves, Building Setbacks and Development Controls, published in 1992, examined the coast in detail and proposed a setback line for permanent development. It was never adopted by the Shire of Busselton,

and was virtually superseded by 'Busselton Foreshore Environs Management of Residential Development (Department of Transport, 1995).

Shipping and boating

13.6 What are the management authorities of the ports in the study area?

There are no ports in the study area. The nearest port is the Bunbury port, managed by the Bunbury Port Authority.

13.7 What is the number of vessels calling at each port each year, and where are the majority from?

Total ship visits to the port of Bunbury in the year ending 30th June 2000 was 288. Imports are predominantly from Japan, USA and Canada. (http://byport.com.au).

13.8 What is the type and quantity of cargo exported/imported? Identify the importance of each port in relation to cargo exported and imported on a local scale and a state-wide scale

Bunbury port for the year ending 30th June 2000:

Total imports – 816, 420 tonnes
Major imports – Caustic soda, methanol, vegetable oils, and phosphate rock/potash

Total exports – 8,407,959 tonnes
Major exports – alumina, mineral sands, woodchips and silica sand
(http://byport.com.au)

WA ports in total (and numerous other maritime facilities) encounter more than 4000 international trading vessels, and account for approximately 200 million tonnes of cargo. Total exports in WA in 1998-99 were valued at more than A$24.6 billion (www.dot.wa.gov.au). If necessary, contact the Port of Bunbury for more information regarding the significance of this port.

13.9 What is the total value of trade through the port?

Bunbury port: Approximately $2 billion for the year ending 30th June 2000 (John Barrett, Bunbury Port Authority, *pers.comm.*)

13.10 What are the trade forecasts for the port?

Bunbury port: A predicted 10% increase in both imports and exports in the 2001 financial year (John Barrett, Bunbury Port Authority, *pers.comm.*)

13.11 Provide the details of any shipping/boating channels. Who is responsible for maintaining the channels , and provide details of the associated dredging programs (eg where is the spoil dumped and how often)?

- Port of Bunbury

Depth in approaches:	13.4m
Depth in seaward channel:	12.8m
Depth in inner channel:	12.2m
Outer harbour approach:	9.6m
Channel width to inner harbour:	135m

(http://byport.com.au)

The Port of Bunbury is located north-east of Geographe Bay. It undergoes periodic dredging as part of its maintenance program, with the sediment spoils being discharged at sea approximately 2 km offshore in depths of 11m (State of the Environment Report). This site was determined by environmental survey and the Port operates under a Dumping permit granted by Environment Australia. The discharge site is located to the north of Geographe Bay and there is a general northerly littoral current, so that it is assumed that there is minimal impact on the study area. The Bunbury Port Authority undertakes monitoring as part of their Dumping Permit requirements (State of the Environment Report).

Hardy Inlet boating channel (note that this is not a declared shipping channel, Davies, DPI, *pers.comm.*):

- navigable channel through the Hardy Inlet linking August to the Blackwood River.
- DPI file number 425/97
- Constructed 1956
- 20 m wide
- hydrographic survey of channel every 3 years
- frequency of dredging: infrequent. Previous dredging took place in 1973, 1977 and 1998, 1993 (two shallow areas)
- best time for dredging: May to September (being outside the tourist season) (Maintenance dredging program report; the Department of Conservation and Land Managment, 1994)

There are clearly defined channels of the Hardy Inlet, 2-8m deep. The main channel extends into Molloy Basin, around the west side of Molloy Island and up the riverine part of the estuary as far as Warner Glen Bridge. That portion of it within the inlet was dredged in 1956 and again in 1973 (The Department of Conservation and Land Management, 1994). Dimensions in 1973 – 12.1m wide and 1.5 m deep below chart datum. A survey in 1992 found its limiting depth to be 0.67m, which is inadequate for the local tourist ferry at all stages of tides. Some minor work carried out in 1993 provided short term alleviation of the problem (DPI, 1994).

Note that the Port Geographe development has a requirement to undertake sand-bypassing operations at the entrance to their development (Michael Bettison, Project Officer, DPI Coastal Facilities, *pers.comm.* Contact Martin Baird for more information).

13.12 Provide the details of any public and private wharfs (eg maximum draughts)

Geographe Bay is well supplied with boat launching facilities, especially given the nature of the coastal processes that occur along Geographe Bay. In total there are 36 boat launching facilities located along the coast within Geographe Bay.

NB: Think there is conflict with the definition of ‘wharf’

Awaiting DPI correspondence

13.13 Provide details of moorings and management of the harbours of the study area

Port Geographe, as currently proposed, has the potential to satisfy the requirements of a significant number of boaters in the region in terms of protected deep water in which to launch and retrieve vessels and for fuel and sullage facilities. The Port Geographe Boat Harbour will serve as a refuge during times of inclement weather in Geographe Bay (Department of Transport, 1995).

Awaiting DPI correspondence

13.14 Provide details of the holding capacity and management of the marina facilities in the study area

Awaiting DPI correspondence

13.15 Are there any plans to develop additional shipping/boating infrastructure and/or expand existing infrastructure?

Key documents:

- Hardy Inlet boating channel – Maintenance Dredging Program Report
- Preliminary site investigation for the proposed Augusta boat Harbour (Department of Transport, 1995)
- Boating facilities study for the Shire of Busselton (Department of Transport, 1995)
- Boating Facilities study for the Shire of Augusta-Margaret River (Department of Transport, 1996)

Due to the increase in the population within the south west it is likely that there will be an increase in the demand for a number of the proposed developments in the above publications to be constructed. Transport therefore needs to ensure that it is fully involved in the planning of this marine conservation reserve to ensure the protection of the environment can be incorporated into the operational requirements of Transport (Michael Bettison, Project Officer, DPI Coastal Facilities, *pers.comm.*)

- An alternative site for the Gnarabup Beach ramp is currently being investigated; future extension of the Flinders Bay boat ramps would be desirable; Swing mooring at Turner Street are not satisfying current demand (Ministry for Planning, 2000).
- Port Geographe, as currently proposed, has the potential to satisfy the requirements of a significant number of boaters in the region in terms of protected deep water in which to launch and retrieve vessels and for fuel and sullage facilities. The Port Geographe Boat Harbour will also serve as a refuge during times of inclement weather in Geographe Bay (Department of Transport, 1995)
- Until Port Geographe is developed, the Shire should improve facilities at Quindalup. Once Port Geographe Boat Harbour has been constructed, the Shire should examine the use of boat ramps at Wonnerup, Georgette Street and Elmore Street with a view to closing them down. Current levels of maintenance at Scout Road, Dolphin Street, Newtown Beach and Dunsborough boat ramps should be continued and, if possible, improved, depending on demand. Maintenance at Quindalup ramp should be increased immediately, and investigation into the feasibility of establishing a boat harbour at or near Quindalup should be commenced immediately. The maintenance o f facilities at Canal Rocks should also be improved in the short term and the number of ramps at that location increased from one to two. A central finger jetty should also be provided. Limited private access to the ocean off Eagle Bay should be encouraged. Improved wave protection for the Canal Rocks boat ramps should be planned for the medium term and achieved by extending the existing natural rock groyne west of the boat ramp in a north-easterly direction (Department of Transport, 1995)
- On the sandy shore east of Dunsborough the coast of mechanically bypassing the longshore littoral drift ahs been a major impediment to development and it is unlikely that a harbour of any type at any site in this general location will be built until a management scheme to overcome that problem has been accepted and adopted by its beneficiaries (Department of Transport, 1994)
- Existing boating activities within the Shire of Augusta-Margaret River are assisted by way of eight public boat ramps. The current levels of use do not justify major upgrading

at the majority of these ramps at this time. However, the existing boat ramp at Gnarabup Beach should be upgraded by constructing a finger jetty at the ramp. The preferred location for a boat harbour within the Shire of Augusta- Margaret River is in the Southern Ocean at Flat Rock near Augusta. An opportunity exists for a combined power/sail boating facility to be developed in the Blackwood River adjacent to West bay Creek (Department of Transport, 1995a)

- Draft Strategic Plan for Maritime facilities. Department of Transport, November 1994:
  - The few existing boat launching ramps on the Leeuwin-Naturaliste shore are not ideal but suitably serve the local population along this section of the coastline. There are no current plans for further facilities along this section of the coastline, although in time the growing population will justify a small harbour at one of the major towns
  - Nornalup Inlet to Cape Leeuwin. The lcoal commercial fishermen are seeking a boat maintenance facility (slip or ramp) and an ocean anchorage for use when the bar is dangerous. Maintenance facility concepts have been examined, and an anchorage proposal at Dead Finish Bay has been investigated but without a feasible development being apparent. Construction of a jetty at East Augusta is planned.

13.16 Have there been any past/current/potential environmental impacts of shipping/boating in the study area? Provide details of the relevant research/monitoring programs

- 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.*).

13.17 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of shipping/boating?

- The Bunbury Port Authority undertakes monitoring as part of their Dumping Permit requirements, and has drawn up an oil spill contingency plan (State of the Environment Report).
- Development of the Coastal Resource Atlas (Marine Geographic Information Sevices, DPI) to provide a resource and analysis tool to help respond to emergencies such as oil spills.
- Refer to Boating Facilities study for the Shire of Busselton (Department of Transport, 1995) – detailed list of previous studies/publications undertaken by Public Works Dept, consultants, Shire of Busselton, Geological Survey of WA, State Planning Commission, DPI, Fisheries Dept etc relating to shoreline dynamics, boating facilities investigations e.t.c. Excellent reference
- Refer to Boating Facilities Study for the Shire of Augusta-Margaret River (Department of Transport, 1995a). Detailed list of previous research
- In 1994, the Department of Transport prepared the Strategic Plan for Maritime Facilities for Western Australia (Department Of Transport, 1995). The maritime facilities omitted from the report are ports for commercial shipping and groynes.
- The Discharge of Sewage From Vessels into the Marine Environment: a Draft Discussion Paper (Department of Transport, 1999)

<u>Sewage</u>

13.18 Provide details of any wastewater treatment plants located in the study area, including the type of treatment, location, details of outfall pipes and the maximum volume of sewage that each is licensed to treat per day

Capel

- not in the study area, but potentially could impact on Geographe Bay
- Secondary treatment
- Effluent to land infiltration
- Licensed inflow 130m^3/day
- Inflow of 33,042m^3 for 1999/2000
- Design work currently in progress to replace this plant
- (Neville Rogerson, Water Corporation, pers.comm.)

Busselton

- Advanced secondary treatment
- Effluent to drain via reed bed system - sewage collected is currently treated in an existing lagoon system and released into a former sumpland, which is now a permanent wetland. Treated wastewater flows from the wetland into a drain which in turn flows into the Vasse Diversion Drain before ultimately discharging to Geographe Bay (Kinhill, 1998).
- Licensed inflow 4500m^3/day (Neville Rogerson, Water Corporation, *Pers.comm.*)
- Inflow of 833,870m^3 for 1999/2000
- Currently, only a small proportion of Busselton is provided with reticulated sewerage, and septic tank systems are common.

The plant is now producing an annual average of 1800m3/d of wastewater, with a winter peak of 2600m3/d and a summer holiday peak of 1700m3/d (Kinhill, 1998).
In order to treat the increasing quantity of wastewater anticipated, the Water Corporation proposed to construct an advanced wastewater treatment plant and upgrade the existing wetland to further treat the treated wastewater before discharge to the nearby drain. Discharge from the Vasse Diversion Drain is highly seasonal. During winter steady flows are typical. Dispersal of the discharge is expected to be strongly influenced y the prevailing wind conditions (Kinhill, 1998).

Currently, the Busselton WWTP contributes approximately 2% of the total nitrogen and 4% of the total phosphorous to southern Geographe Bay, and thus its total contribution to the total quantity of nutrients entering Geographe Bay is low. In contrast, the unsewered areas of Busselton are estimated to presently contribute 4% of the total nitrogen and 10% of the total phosphorous load. This will gradually reduce as the Infill Sewerage Program is progressively implemented (Kinhill, 1998).

The Water Corporation is in the process of upgrading and developing a reticulated sewage system for Busselton. This is considered the best form of urban waste management and the only feasible option for large-scale developments. Where houses cannot be connected to a reticulated sewage system a number of alternative disposal systems are commercially available which have been approved by the Health Department of WA (Ecoscape, 1999).

Dunsborough

- Advanced secondary treatment
- Effluent to woodlot and some discharge to drain during four months of winter
- Licensed inflow 2000m^3/day
- Inflow of 294,762m^3 for 1999/2000
- New plant – therefore no data available on outputs into marine environment

(Neville Rogerson, Water Corporation, *Pers. comm.*)

Only about half of the townsite lots are sewered. A new sewerage treatment plant has been operational since February 2000 when all flows from the old plant were diverted to this new plant (Ministry for Planning, 2000a)

Gnarabup Beach (Prevelly)

- Secondary treatment
- Effluent to land discharge
- Licensed inflow 365 m^3/day
- Inflow of 31,274m^3 for 1999/2000

(Neville Rogerson, Water Corporation, *Pers. comm.*)

Margaret River

- Secondary treatment
- Discharge to brook (dries in summer), and into Margaret river and finally to the ocean in winter. Discharge into the Margaret River will soon change when the plant becomes fully contained (Guy Watson, DEP, *pers.comm.*).
- Licensed inflow 270m^3/day
- Inflow of 206,945m^3 for 1999/2000 (NB: this exceeds the license limit)

(Neville Rogerson, Water Corporation, *Pers.comm.*; Guy Watson, DEP, *pers.comm*).

The majority of the existing urban area is serviced by this plant. There are no plans to construct a sewer service to the rural residential areas located to the east of the townsite as these areas are currently being serviced by on-site effluent disposal.
The plant has reached its optimum economic life and is to be replaced by a new plant, which will have an ultimate capacity of 2,8349m^3/day. An irrigation system involving the construction of a dam is to be undertaken to store and dispose of treated effluent on an adjacent woodlot (Ministry for Planning, 2000).

Cowaramup Village is serviced with a reticulated sewerage system, which flows to a wastewater pump station, from where it is removed and transported by trucks to the Margaret River Wastewater Treatment Plant. There are no plans to increase the current reticulated sewerage scheme to those areas which are presently not serviced (Ministry for Planning, 2000).

The township of Margaret River has been targeted for the Infill Sewerage Program; in 2000-01 approximately 66 lots in the township will be connected to the system. No other centres within the Shire are planned to be included within the Infill Program.

Augusta

- Secondary treatment
- overland infiltration channels, with discharge to brook and ocean in winter
- Licensed inflow 180m^3/day
- Inflow of 40,624m^3 for 1999/2000

(Neville Rogerson, Water Corporation, *Pers.comm.*; Guy Watson, DEP, *pers.comm*).

While the majority of the Augusta townsite is currently connected to the wastewater treatment plant there are still a number of properties that are not connected.
However, there are no plans, under the current Government Infill Sewerage Program, to provide a sewerage service to these areas (Ministry for Planning, 2000)

NB: The Bunbury WWTP is located approximately 7km south of Bunbury and discharges into effluent ponds located behind the coastal dunes. The effluent seeps into the porous

sands and some (estimate 50%) is then carried west by the prevailing groundwater flow to the ocean (Lord and Associates, 1995)

13.19 Is the study area serviced by deep sewage?

Capel, Busselton, Dunsborough, Gnarabup and Augusta are serviced by deep sewerage (Neville Rogerson, Water Corporation, *pers.comm.*).

13.20 Are there any plans to develop additional sewage facilities and/or expand existing facilities?

- Busselton and Dunsborough are 'new' plants (within approximately the last six months)
- Gnarabup has just been upgraded
- Investigation for new Capel plant is currently in progress
- Under the Government Sewerage Policy, most new developments must be deep sewered but most of the older, established housing uses septic tanks. The State Government has commenced a 10 year backlog (infill) sewerage program, with Busselton a high priority. Work commenced in 1995.
- The Water Corporation, as part of its Infill Sewerage Program, has commenced the installation of reticulated sewerage services to many unsewered areas. Construction of the reticulated sewerage system and the expected growth in population of Busselton will increase the capacity required at the WWTP from the current 1,700m3/d to 4500m3/d by the year 2005 and a flow of some 9000m3/d is expected by the year 2035 (Kinhill, 1998).

Contact Water Corporation Infill Branch for further details (Neville Rogerson, Water Corporation, *Pers.comm,.*)

13.21 What are the controls on the discharge of sewage by boats in the study area?

The Discharge of Sewage From Vessels into the Marine Environment: a Draft Discussion Paper (Department of Transport, 1999)

13.22 Have there been any past/current/potential environmental impacts of sewage treatment and disposal in the study area? Provide details of the relevant research/monitoring programs

- No past/current environmental impact of sewage treatment and disposal in the study area (Neville, Rogerson, Water Corp. *pers.comm.*)
- In contrast: the treatment and disposal of waste is a known problem in the Geographe Bay catchment. Waste disposal is a known contributor to pollution, particularly nutrient enrichment of groundwater, rivers, wetlands, drains and ultimately Geographe Bay. Evidence of this is elevated nutrient levels in rivers and wetlands and the occurrence of algal blooms (Ecoscape, 1999; Robyn Paice, Water & Rivers Commission/Geocatch, *pers. comm.*). Public health is threatened by sewage disposal into waterways or where treatment plants or sites are inadequately contained. Both rural sources (particularly dairy waste) and urban sewage are identified as sources in the Geographe Catchment Management Strategy (Ecoscape, 1999)
- Tertiary effluent from the recently upgraded Busselton Wastewater Treatment Plant is released into an on-site wetland, which flows into the Vasse Diversion Drain before discharging into Geographe Bay. Bacterial concentrations have been tested on Busselton Beach at sites adjacent to the Vasse Diversion Drain. Concentrations were higher during winter than the guidelines for primary contact recreation, but within the guidelines for secondary contact recreation. Sampling during summer, the period of

most intensive recreational use, has to date found not evidence of the presence of thermo-tolerant coliform bacteria (Water Corporation, 1998).

13.23 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of sewage treatment and disposal?

- The Water Corporation is in the process of upgrading and developing a reticulated sewerage system for Busselton. This is considered the best form of urban waste management and the only feasible option for large-scale developments. Where houses cannot be connected to a reticulated sewage system a number of alternative disposal systems are commercially available which have been approved by the Health Department of WA. Engineering and environmental considerations may determine the effectiveness of these systems (Geographe Catchment Management Strategy)
- Contact the Water Corporation for more information

14 Water quality

Awaiting correspondence from Richard Murton; need to complete Bob Humphries follow-up (Try Ben O'Grady re GIS MapInfo of Busselton Environmental Improvement Initiative spatial rep of water qual data, Water Corp Planning Support Group – Sue Taylor 94203606 or Bob Bowers 94202892; and Robin Paice @WRC Bunbury).
**Considering the difficulty in obtaining some of the information for this section, it will be more appropriate to complete this section later in the planning process

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14.1 How does flushing/exchange influence the water quality of the study area?

Geographe Bay
Geographe Bay is generally well flushed by longshore currents and wind action. However, the southern part of Geographe Bay is not well flushed as a result of the prevailing southerly and easterly winds during the summer (WA, 1995).

The rate and direction of dispersion of water leaving nutrient point sources, eg Vasse Diversion Drain, is dependent on the prevailing hydrodynamic conditions. 1997 monitoring data presented in Kinhill (1998) indicate that nutrient and phytoplankton levels in Geographe Bay, within 500m of the Busselton drains, including the Vasse Diversion Drain, are currently elevated. Excess nutrients result in extensive outbreaks of algal blooms, bad odours and perceived health risks occurring in the summer months. Accelerated weed growth and damage to the seagrass beds also take place.

Naturaliste-Leeuwin
There is a possibility of restricted flushing due to the shape of the shoreline and interference to exchange by alongshore reef lines, islands, promontories, headlands and bottom undulations. Fine scale oceanographic processes have not been studied in detail for this section of the coastline (D'Adamo & Mamaev, 1999).

Hardy Inlet
With the arrival of winter rains, runoff and strong river discharges to the estuary, the system is purged of its saline water. This process begins about May, with flushing complete (all the way to the entrance channel) typically by mid-winter. Freshwater discharge causes outflow

speeds up to about 1m/s through the basin, inlet and channel as freshwater escapes to the ocean (D'Adamo & Mamaev, 1999)

14.2 What are the natural turbidity levels of the study area? Include rates of deposition and the effects of local conditions (eg wind, swell, riverine input)

Secchi disc readings in the Blackwood river ranged from 0.1m to 0.3m in July 1974, during high river discharge, and 1.0m under the lower flow conditions of July 1975. In summer the readings were 2 to 3m and considerably greater in the marine water of the inlet channel. Scott River water is a dark peaty colour in contrast to the brown muddy water of the Blackwood River (Hodgkin, 1976).

Natural turbidity levels of Geographe Bay and the Leeuwin-Naturaliste coast are not known (Nick D'Adamo, *pers.comm.*).

Wind, waves, currents and tides can be effective mixing agents. Refer to section 5 for a review of the relative importance of each in determining the hydrology of the study area.

14.3 What are the sediment re-suspension patterns in the study area? Include rates and the effects of local conditions (eg wind, swell)

Sediment re-suspension patterns of the study area have not been studied in detail.

Wind, waves, currents and tides can be effective mixing agents. Refer to section 5 for a review of the relative importance of each in determining the hydrology of the study area.

14.4 What are the natural nutrient levels of the study area?

There has been insufficient studies to draw any conclusions about seasonal variabioity of chlorophyll in Geographe Bay. The indicative background conditions of the Southern Metropolitan Coastal Waters Study (1991-1994) (DEP, 1996) for the nearshore and offshore coastal waters of southern Perth are supported by water quality data collected in Geographe Bay (Walker *et al.*, 1994). The background conditions shown in the table below indicate that the southern coastal waters off Perth are oligotrophic by world standards. Inorganic N:P ratios (mass) are generally much less than 7, suggesting that nutrient limitation of primary productivity is determined by the availability of total inorganic nitrogen. Chlorophyll *a* concentrations and light attenuation of the water column are also low by world standards (Pearce, 1991) and decrease in an offshore direction.

Table 27: Median and 90th percentile (in parentheses) background levels for selected water quality parameters for the 'nearshore' and 'offshore' south Western Australian coastal waters in summer and winter.

	Nearshore coastal waters		Offshore coastal waters	
	Summer	Winter	Summer	Winter
Total inorganic nitrogen (μg l^{-1})	<6(9)	<4(8)	<6(9)	<5(8)
Total inorganic phosphorous (μg l^{-1})	<5(6)	<4(6)	<4(4)	<4(6)
Chlorophyll a (μg l^{-1})	<0.5(0.8)	-	<0.2(0.4)	-
Light attenuation coefficient (m^{-1})	<0.08(0.09)	-	<0.04(0.05)	-

(DEP, 1996)

14.5 Have there been any past/current/potential uses and/or pressures (ie nutrient/toxic/pathogenic contaminant inputs) on the water quality of the study area. Provide details of these inputs (source, type and level)

The wastewater treatment plants of the study area are not licensed to discharge directly into the ocean. Busselton, Dunsborough, Margaret River and occasionally the Augusta plants have discharges which enter drains/creeks which then discharge into the ocean. However, wastewater treatment plants are considered to contribute relatively minor nutrient loads to the study area (Guy Watson, DEP, *pers.comm.*).

In contrast, agricultural activities discharge relatively high nutrient loads into the study area (eg dairies). Greater than 90% of nutrient loading into Geographe Bay can be contributed to rural sources (Bob Humphries, Water Corporation, *pers.comm.*).

Geographe Bay

- The waterways of Geographe Bay have been subjected to extensive engineering in an effort to control the level of water in the inland waterways. In the early nineteen hundreds, tidal gates were constructed at the outlets of the Vasse and Wonnerup Estuaries (to limit the inundation of pasturs and to control the level of fresh water behind the gates) and the Vasse Diversion Drain was built to avoid the flooding of Busselton Town by the Vasse River. The construction of these structures has resulted in a reduction in the flow of water and the accumulation of sediment and nutrients. The waterways of Geographe Bay, particularly in the lower catchment, are now considered to be severely degraded (WRC, 1997)
- Wastewater disposal in the Geographe Bay are occurs directly by release of primary treated wastewater into local drains which discharge into the Bay and indirectly via septic tank seepage to groundwater. Nutrient inputs into Geographe Bay occur mainly in winter, in surface drainage: Surface flows from river sand drains currently contribute about 87% and 79% of the total nitrogen and phosphorus respectively (Lord et al, 1995). The majority of other nutrients are delivered from groundwater flows, which are more uniform over the year (Kinhill, 1998). Nutrients and other contaminants discharged into Geographe Bay from industrial processes are not considered to be important since the major components in these discharges include the natural constituents of sea water. 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).
- Refer to table 28
- Refer to figure in Geography Bay Study/WAWA Wastewater 2040 (Lord and Associates, 1995). There is a poster of this figure in MCB's map cabinet, and a photocopy in the Capes Management Planning Official file.
- Refer to figure of existing and potential pollution sites in WAWA (1995): Busselton-Capel Groundwater Area Management Plan (copy available in Capes Management Planning official file)
- 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 decreasing order of magnitude, this total was comprised of:
    1. surface flows from rivers and drains (92% of all N and 87% of all P during winter, and 47% N and 33% of all P discharges during summer)
    2. groundwater discharges (deliver a relatively small proportion of the total nutrient discharges during winter, and 22% of all N and 8% of total P during summer), and

3. discharges from coastal wastewater treatment plants and unsewered areas adjacent to the coast.

Table 28: Major nutrient sources to the southern part of Geographe Bay

	Total Nitrogen						**Total Phosphorous**					
	Summer		*Winter*		*Total*		*Summer*		*Winter*		*Total*	
Vasse Diversion Drain (1996)[1]	1.4	3	198	42	199	38	1	11	15	28	16	25
Vasse-Wonnerup Estuary (1993)[2]	19	44	185	39	204	39	2	27	25	45	27	43
Carbanup/Buayanup Drain (1993)[2]	8	18	78	16	86	17	1	11	10	19	11	18
Busselton unsewered areas (1993)[2]	12	27	10	2	22	4	4	37	3	6	7	10
Wastewater Treatment Plant (1997)[1]	3.4	8	5.6	1	8.9	2	1.3	14	1.0	2	2.3	4
Total	**43**	**100**	**478**	**100**	**520**	**100**	**9**	**100**	**54**	**100**	**63**	**100**

Sources: 1: Kinhill (1998); 2:Holmes (1994)
Note: Vasse Diversion Drain includes estimated inputs from Vasse Sub-A Drain (based on catchment area of approximately 7% of the Vasse Diversion Drain/and excludes inputs from the WWTP.
Note: Summer=November-April, Winter=May-October

- According to Lord & Associates (1995) estimates, the nutrient load entering Geographe Bay from Dunsborough to Capel for 1992-93 was 499 tonnes of nitrogen and 63 tonnes of phosphorous. Most of this input occurs in winter when the rainfall flushes nutrients into the Bay. The order of magnitude of inputs was consistent with Holmes (1994).
- Note that more recent monitoring indicates that past calculations of the nutrient loads to Geographe Bay may have been underestimated, with the Vasse Diversion Drain, for example, contributing 300 tonnes of phosphorus in 1996, more than the previous total estimate for all nutrient sources to the Bay (Geographe Catchment Management Strategy)
- See Kinhill (1998) for figures of predicted total nitrogen and phosphorous loading to southern Geographe Bay by source to 2035
- Refer to Busselton Environmental Improvement Initiative: detection of nutrient hotspots. This water quality snapshot project is focussed on spatial representation of water quality data collected during winter and spring baseflows in 2000 and 2001. Currently draft winter 2000 results have been plotted using MapInfo GIS (Ben O'Grady, Water Corporation, *pers. comm.*). The results will indicate which catchments, sub-catchments and minor tributaries are contributing the most significant quantities of nutrients into the nearshore marine environment of Southern Geographe Bay.
- Busselton is considered to be at high risk of nutrient pollution of its groundwater. Several potential pollution sites in the catchment have been identified, including sand mines, landfill sites, sewage treatment facilities and holiday resorts (Water Authority, 1995).
- Of interest: Bunbury treatment plant is proposing to have an ocean outfall into Geographe Bay (Guy Watson, DEP, *pers.comm.*)
- Refer to Kinhill (1998) - table 4.6 and Holmes (1994) table 3.1
- Refer to figure: WAWA Wastewater 2040: Australian Research Centre For Water In Society (1995).

<u>Naturaliste-Leeuwin</u>

- Total nutrient input figures are not available for this coastline. Cape Rock (an initiative of the Shires of Busselton and Augusta-Margaret River) has identified this as an issue of

concern, and believe a catchment group should be established, as does the South West Catchment Council (Kirrily White, Shire of Busselton, *pers.comm.*).

- Potential sources include:
  - surface flows from rivers and drains (eg Margaret River, Willyabrup Brook and Yallingup Brook (which has septic leachate))
  - groundwater discharges, and
  - discharges from coastal wastewater treatment plants and unsewered areas adjacent to the coast (eg the Gnarabup wastewater treatment plant)

Hardy Inlet

- There are a number of sources of nutrients into the Hardy Inlet:
  - the townsite of Augusta,
  - the Scott River,
  - the Blackwood River and
  - Molloy Island
- Total N load 29.49g/m^2 (highest of all of the southwest estuaries investigated) and total P load 1.18 g/m^2. The large catchments and runoff from the Blackwood river cause the Hardy Inlet to have high winter water loadings because of the sheer volume of runoff through relatively small estuaries. However, summer flushing is low (Deeley, 1999)
- Monitoring has provided comparison of inputs from the two main tributaries but has not conclusively identified the proportion and origin of nutrient inputs (Scott Coastal Plain Steering Committee, 1999)

Potential pressures (in general):

- Nutrient inputs (especially nitrogen, phosphorus, organic matter) from:
  - Sewage discharge from vessels
  - Septic tanks via groundwater flows
  - Agricultural catchments
  - Urban stormwater runoff
  - leachates from rubbish tips
- Toxin inputs from (pesticides, petroleum, heavy metals, acids, solvents, oil and detergent):
  - Accidental spillages of fuel and oils from boating activity
  - Hull antifouling of commercial and recreational boats
  - Agricultural catchments
  - Urban stormwater runoff
  - Oil spills from passing ships
- Pathogen inputs from (bacteria and viruses)
  - Sewage discharge from vessels
  - Urban stormwater runoff
  - Septic tank via groundwater flows
- Litter from:
  - Commercial and recreational boating/fishing activities
  - Urban stormwater runoff

14.6 Is there any evidence of environmental impact (eg the occurrence of algal blooms; enhanced epiphyte growth)? Provide the details of the relevant research/monitoring programs

Geographe Bay

- The waterways of Geographe Bay have been subjected to extensive engineering in an effort to control the level of water in the inland waterways. In the early nineteen hundreds, tidal gates were constructed at the outlets of the Vasse and Wonnerup

Estuaries (to limit the inundation of pasturs and to control the level of fresh water behind the gates) and the Vasse Diversion Drain was built to avoid the flooding of Busselton Town by the Vasse River. The construction of these structures has resulted in a reduction in the flow of water and the accumulation of sediment and nutrients. The waterways of Geographe Bay, particularly in the lower catchment, are now considered to be severely degraded (WRC, 1997)

- The Geographe Bay study found that all nutrient concentrations were low in Geographe bay in summer, while conditions were far more variable in winter, with some extremely high nutrient concentrations found close to drains entering the sea. During July and September when the drains were flowing, water column nutrient concentrations were significantly elevated out to 50-100m from shore. Light attenuation is substantial in winter at a distance of 500m from shore (although note that the discoloured water does not contain elevated nutrient levels). Inputs are rapidly mixed and dispersed within 500m of the shore (Lord and Associates, 1995; McMahon,1994; and McMahon & Walker, 1998).
- 1997 monitoring data presented in Kinhill (1998) indicate that nutrient and phytoplankton levels in Geographe Bay, within 500m of the Busselton drains, including the Vasse Diversion Drain, are currently elevated. This is a cause for concern, because unlike an ocean outfall, a drain exit is not designed to ensure efficient dilution around the point of release. It was clear that the rate and direction of dispersion of water leaving the Vasse Diversion Drain is dependent on the prevailing hydrodynamic conditions.
- Excess nutrients result in extensive outbreaks of algal blooms, bad odours and perceived health risks occurring in the summer months. Accelerated weed growth, fish deaths (regularly reported behind the flood gates in late summer) and damage to the seagrass beds also take place. The elevated nutrient load is considered to be the result of unfavourable drain management as well as unsuitable agricultural management practices, groundwater leachate from unsewered areas and grass and weed infestations (WRC, 1997) Mc Alpine *et al.* (1989) indicate that the Vasse-Wonnerup Estuaries are the most heavily nutrient-loaded systems in WA.
- Over the past few years blooms in the Vasse River and the Vasse Diversion Drain have been investigated closely by WRC staff. Potentially toxic blue-green algae are of particular concern, and have led to the erection of permanent warning signs n the lower reach of the Vasse River. Also of concern are certain species of dinoflagellates, which can be toxic when ingested. Blooms of green algae (Chlorophyta and Prasinophyta) have also occurred in the Vasse River. While not toxic, green algae blooms are usually precursors to large midge population increases, and can cause offensive odours (State of the Environment Report). However, note that green epiphytic algae such as *Cladophora* spp., commonly considered indicative of eutrophication, are uncommon in Geographe Bay, and when present, appear associated with nutrient point sources such as groundwater intrusions (Walker et al., 1994).

Tertiary effluent from the recently upgraded Busselton Wastewater Treatment Plant is released into an on-site wetland, which flows into the Vasse Diversion Drain before discharging into Geographe Bay. Bacterial concentrations have been tested on Busselton Beach at sites adjacent to the Vasse Diversion Drain. Concentrations were higher during winter than the guidelines for primary contact recreation, but within the guidelines for secondary contact recreation. Sampling during summer, the period of most intensive recreational use, has to date found not evidence of the presence of thermo-tolerant coliform bacteria (Water Corporation, 1998).

There have been sudden, mass fish deaths in the Vasse-Wonnerup Estuary System. Many fish were reported dead in February 1905. Further kills occurred between then and 1960. Since 1960, mass deaths have occurred in 1966, 1988, 1989 and 1997. All kills have been in the lower reaches of the system, either in the Vasse Estuary exit channel or in Wonnerup Inlet, or, on one occasion, in the Deadwater. Most have

occurred during summer, usually in February and often following hot weather. The principal cause of summer deaths is believed to be temporary declines in dissolved oxygen concentrations to critical levels, thought due to night-time respiration by algal blooms, algal bloom decay and high water temperatures. Toxic products of algal blooms and (Wonnerup Inlet only) decaying seaweed might also be involved (Lane *et al.*, 1997).

Table 29: Cyanobacteria recorded in Vasse-Wonnerup estuaries, 1996-1997

Oscillatoria	Up to 35 730 cells/ml	
Anabaenopsis	Up to 216 140 cells/ml	
Anabaena	Up to 25 600 cells/ml	Gazetted toxic species
Microcystis	Up to 6500 cells/ml	Gazetted toxic species
Merispodemia	Up to 1200 cells/ml	

(Lane *et al.*, 1997).

- The potentially toxic blue green *Nodularia* has been found in the Vasse-Wonnerup river (Water and Rivers Commission, 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). Dense growths of epiphytic algae were found in the summer of 1993/94, especially between Dunsborough to the Vasse Estuary. Overall, epiphyte loads were low and comparable to healthy meadows elsewhere in local coastal waters (Lord and Associates, 1995)

  The seagrasses, algae and water quality of Geographe Bay were investigated by McMahon (1994), Walker *et al.* (1994, 1995a, 1995b, 1995c, 1995d, 1995e), McMahon *et al.* (1997) and McMahon & Walker (1998). The presence of blue-green algal and diatom aggregations did not appear to be an indication of nutrient enrichment. As summer progresses, the epiphytic algae did not increase significantly in either cover or biomass. Nitrogen appeared to be the limiting nutrient for growth of primary producers. It was suggested that the accumulation of diatomaceous mucopolysaccharide slimes and blue-green algal aggregations on the seagrasses, particularly at Buayanup and Busselton, are of some concern and require further investigation. Note, however, that mucopolysaccharrides have also been reported form the Mediterranean and the Baltic Sea, where they occur when nutrients are depleted, as a shunt for carbon from photosynthesis, when no nutrients are available for growth. These blooms dissipated when water movement increased.

  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. Geographe Bay has a high seasonal input in July to September when drains from agricultural catchments flow into the bay. During winter, nearshore nutrient concentrations adjacent to the drains increased ten-fold compared to the reference site, however greater than 100m 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.

  McMahon (1994) suggested that the nutrient input form the Vasse Diversion Drain is having a low impact on near-shore nutrient concentrations in the vicinity of the drain; chlorophyll-*a* levels, total phosphorus and nitrate/nitrite and ammonia levels were within

National Guidelines. It appeared that the discharge was dissipated, so that levels returned to background levels within 1 km of the mouth of the drain.

- In response to an EPA enquiry, the water and soil testing project of the Sussex Land Conservation District Committee aimed to test the main waterways draining the Sussex hinterland into Geographe Bay 1992-1996. This was a national landcare funded project. Sites included Carbanup River, Broadwater and Toby Inlet. It was concluded that the nutrient levels of drainage lines in Sussex Land Conservation District Committee area is consistently well above the standard of total phosphorus and total nitrogen set by the Department of Environment Protection. While the Bay itself did not seem to be under immediate threat, the restricted waterways and wetlands like Toby Inlet, Capel River and Vasse River were identified as serious potential trouble spots with the current nutrient concentrations flowing into them. Farmland was predicted to be the source of the nutrients. Problems with the accuracy and use of the data gained in these surveys were identified (Sussex Land Conservation District Committee, 1996).

- 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. Claplin, CSIRO Division of Marine Research, *pers.comm.* In Elscot and Bancroft, 1998).

- <u>In summary, symptoms of eutrophication in Geographe Bay?</u>
  Physical – No
  - Dissolved oxygen concentration always saturated
  - High attenuation coefficients in winter due to runoff, but very low in summer

  Biological – No
  - Low Chlorophyll A concentration at all times of year
  - Very low epiphyte load
  - Biomass of seagrass indicative of a healthy meadow
  - Blooms of diatoms and/or cyanobacteria do occur, but at times of nutrient minima in summer (dilution and dispersion of nutrients when they come into the system in winter occurs)

  Note, however, that the system is at risk – if high nutrient input continues, the frequency and spatial extent of blooms may increase; a cyclonic rain event in summer could cause massive algal blooms and either of these two events would place the health of the seagrass at risk.

<u>Naturaliste-Leeuwin</u>

- No significant evidence of environmental impact on the water quality
- It can be expected that the nutrient loads in the numerous small freshwater steams and seeps will increase as urbanisation of the areas grows. These may have some impact on the intertidal areas in protected areas such as Cowaramup Bay, and Prevelly and Kilcarnup. However in many areas the high water movement experienced on this exposed coast will disperse nutrients (Kendrick et al., 1999).
- Current Coasts and Clean Seas NHT-funded monitoring of the lower Margaret River and adjacent Grunters Beach – contact Robin Juniper (Covenor Cape to Cape Cleanwaters Project – info in Capes official management planning file)

<u>Hardy Inlet/Blackwood</u>

- The Hardy Inlet is generally in reasonable health (after comparing it to other rivers and estuaries and National Standards (Scott Coastal Plain Steering Committee, 1999).

However, the limited data that is available does indicate that nutrient concentrations may be of concern. Elevated total nitrogen concentrations were recorded in August 1995 and in both June and July during 1999. Oxidised nitrogen concentrations were elevated in August 1995 and between June and September 1999. Filterable reactive phosphorous was slightly elevated at some sites within the Inlet during June 1999. In addition, elevated ammonia concentrations have been recorded on the majority of sampling occurrences throughout the estuary (Scott Coastal Plain Steering Committee, 1999).

14.7 According to water and sediment quality survey data and to the occurrence of historical and current input of nutrient, toxic and pathogenic contaminants, what is the current water and sediment quality of the study area (high, medium or low)?

- Water quality of the study area is very high (Bob Humphries, Water Corporation, *pers.comm.*)

- The main conclusions drawn by the Water Authority for the Geographe Bay Study are that the Bay is generally in a healthy environmental condition: the coastal marine water quality is very high. There has been some loss f seagrasses as a result of nutrient enrichment in southern parts of Geographe Bay. However, the overall areas of seagrass have remained constant over the past 20 years (WA, 1995). It was concluded that dissolved concentrations of dissolved nutrients in Geographe Bay are consistently low, and current nutrient levels are within national guidelines for the protection of estuaries and embayments (Walker 1994a; McMahon 1994; and D.A. Lord and Associates, 1995). Even though high concentrations of nutrients enter the Bay, elevated nutrient concentrations in the water column are not detectable more than 100 m from the shore (McMahon and Walker, 1998).

  Mean chorophyll-*a* levels in Geographe Bay in 1994 were approximately 0.15mg/m3 (range 0.05-0.23 mg/m3), classifying this embayment as oligotrophic according to national criteria (ANZECC, 1992). Draft chlorophyll-*a* criteria for the maintenance of ecosystem integrity (Environmental Quality Objective 2, Class II – Multiple Use Zone) are 0.8 (1.1) mg/m3 chlorophyll-*a* during non-winter periods (DEP, 1996).

  Note that an area of nutrient-enriched waters exists around the discharge point of most drains which discharge into Geographe Bay. At the Vasse Diversion drain, this water has nutrient levels in excess of the guidelines for protection of marine ecosystems, and periodically has bacterial levels in excess of the National Guideline for primary contact recreation (eg swimming) (Kinhill, 1998).

- Geographe Bay itself does not appear to be degraded by nutrient enrichment, although the waterways and wetlands of the catchment are some of the most heavily nutrient-loaded systems in Western Australia (McAlpine *et al.,* 1989; Sussex Land Conservation District Committee, 1996). Vasse Wonnerup and Toby's Inlet are estuaries adjacent to the study area which are highly enriched with nutrients, mainly of agricultural origin. This results in the frequent development of algal blooms during the summer and autumn (Lane et al., 1997).
- Generally a high water quality in the exposed areas of the study area, however there is a lack of research in much of the study area. Margaret River is considered to be the site of significant discharge of nutrients. Studies have shown the Gnarabup treatment plant to have negligible impact on the nearshore environment. Geographe Bay , being sheltered and having a long flushing time (appr. 40 days?) has lower water quality, especially in winter(Guy Watson, DEP Bunbury Regional Manger, *pers.comm)*

- As part of the National Waterwatch Program, the rivers of the Geographe Catchment were sampled in October 1999 to gain a 'snapshot' of the health of our waterways. This involved nine sites across the catchment and one site on the Yallingup Brook. Total levels at all sites were below recommended ANZECC guidelines, except in the Sabina and Vasse rivers. In contrast, Total Nitrogen concentrations were relatively high across the catchment, with seven of the ten sites, including the Vasse River, being above ANZECC guidelines (Scott *et al.*, 2000). As part of the 'Snapshot 97' program with Ribbons of Blue, three local schools sampled the macroinvertebrates at sites along the Carbanup River, and showed the water quality of Carbanup River is fair to good (Andrew, 1997)

14.8 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact on the water quality of the study area?

- Wastewater 2040 Strategy for the South-West deals with the Water Authority's review of the wastewater treatment and effluent disposal strategy for major urban coastal centres in the South-West. It is based on the results of four major studies undertaken by the Water Authority: the Geographe Bay Study; Perth Coastal Waters Study; Study of Alternative Effluent Disposal Options; Wastewater 2040 Community Involvement Programme.
- Southern Metropolitan Coastal Water Study (DEP)
- Management plans and strategies for the study area eg Geographe Bay Integrated Catchment Management Strategy (1995) (GBAC, WRC); a Management Plan for the Vasse River and Estuary (Martinick & Associates, 1995); Geographe Waterways Management (Shire of Busselton and Shire of Capel, 1995); Geographe Bay: Integrated Catchment Management Strategy (West Australian Planning Commission, 1995); Future Management of Geographe Bay Catchment and Marine Environment: The Proposal (WRC, 1996) The Geographe Catchment Management Strategy, which identifies several steps in the process of addressing nutrient enrichment of waterways etc; the Toby Inlet Ocean Entrance Management Study (Rogers, M.P. & Associates, 2000) details the inlet's form; hydrodynamics; ecology and management options; the Scott Coastal Plain – A Strategy for a Sustainable Future *draft* (Scott Coastal Plain Steering Committee, 1999) contains a water management strategies for the Hardy Inlet and Scott River
- Water quality monitoring programs as stated above and stream and bore monitoring (eg Sussex LCDC; WRC; AgWA; the Department)
- Revegetation and restoration projects - there are several NHT projects which are occurring on a catchment scale
- Formation of Geographe Bay Advisory Committee (GBAC) in 1992– formed to provide independent advice to the Shires of Busselton and Capel on environmental issues. Formation of the Geographe Bay Steering Committee in 1996 by the Water and Rivers Commission to consider the need for and means by which the Geographe Bay waterways might be managed. Geocatch was established in 1997 as a coordinating body operating under the delegated power of the Water And River Commission to work in partnership with the WRC, other State, local and Commonwealth agencies, the community and industry
- Actions to reduce nutrient export eg reduction of dairy effluent runoff and experimental biofilters and the mapping of nutrient management units – Vasse-Wonnerup LCDC
- Catchment Management – appointment of catchment officer (GBAC and LCDCs), Land and Sea Conference (GBAC) and the establishment of an environmental centre at Busselton (Busselton Naturalists Club and Busselton Peace and Environment Centre)
- The Environmental Condition of the Vasse Wonnerup Wetland System and a Discussion of Management Options (EPA, 1989)

- General water quality standards such as ANZECC National Water Quality Guidelines
- *The Environmental Protection Act 1986*
- Monitoring by the Bunbury Port Authority to detect introduced species; ballast water from international shipping is controlled by the ports under the AQIS; surveys by CSIRO and the Australian Quarantine Inspection Service (AQIS) are currently underway to establish the number of introduced species and their distribution in WA; in WA a Memorandum of Understanding has been developed between Fisheries WA and DEP on the translocation of live aquatic non-endemic species into or within WA; Water Corp Australian Ballast Water Advisory Council was established in 1995.
- Water & Rivers Commission has developed "Draft Policy and Principles. Protection of Waters from Pollution in Western Australia" Water Resource Protection Series No 27. The Water and Rivers Commission implements its water allocation decision and regulates the use of water through the powers assigned to it under the *Rights in Water and Irrigation Act (1914).*
- Monitoring programs, including:
    - The Water and Rivers Commission (Bunbury) drafted a pilot monitoring program for the Hardy Inlet and the estuarine sections of the Blackwood and Scott Rivers. This program was the first examination of the water quality of the estuary that has been proposed since the Blackwood River Estuary Environmental Study, and formed part of a proposed larger monitoring program that will encompass flora and faunal surveys, sediment studies and habitat mapping. The program has run in the pilot form for about twelve months, and is currently in the process of review. A report is soon to be released regarding the first twelve months data (Hardcastle, WRC Bunbury, *pers.comm.*). In the meantime, it has been strongly advised that nutrient input into the Blackwood and Scott rivers should not be increased (Scott Coastal Plain Steering Committee.
    - Busselton Environmental Improvement Initiative: detection of nutrient hotspots. This monitoring project will produce essential data for use in the implementation of two integrated community projects know as the Busselton Environmental Improvement Initiative and the Geographe Catchment Management Program (Draft). This water quality snapshot project is focussed on spatial representation of water quality data collected during winter and spring baseflows in 2000 and 2001. Currently draft winter 2000 results have been plotted using MapInfo GIS .(Ben O'Grady, Water Corporation, *pers. comm.*). The results will indicate which catchments, sub-catchments and minor tributaries are contributing the most significant quantities of nutrients into the nearshore marine environment of Southern Geographe Bay. Once the most significant catchments have been identified by this project, $200,000 over five years will be made available by the Water Corporation to assist landholders implement on-ground works focussed on nutrient reduction through the Busselton EII project. This money is being made available under state environmental approvals attached to a tertiary upgrade of the Busselton Wastewater Treatment Plant. In addition, implementation of the Geographe Catchment Management Program (coordinated by Geocatch) will focus on catchments that are identified through this project as being significant nutrient exporters. Funded by the Coast and Clean Seas Monitoring Program
    - Sotico Waterwatch (formerly the Bunnings Watercare Program) has been performing water quality monitoring with schools and community groups in the Blackwood and Margaret River Catchments since 1991. The Program is linked with the State-wide Ribbons of Blue/Waterwatch WA Program and is partly funded by the Natural Heritage Trust. The Program has a database containing water quality data from hundreds of sites located throughout the Catchments. Since 1996, the Waterwatch Program has coordinated the Annual Blackwood Snapshot Event, which involves community and schools collecting water samples form over 200 sites across the Blackwood Catchment on one particular day in August. Data is also available

from sample sites located in the Hardy Inlet, Molloy Island and at the Margaret River mouth. The 1999 Snapshot results indicate that salinity ranges from relatively fresh near Augusta, to highly saline in the up[per and middle regions of the Catchment. Phosphorus levels throughout the Catchment were generally low, while nitrogen tended to increase from the lower to upper Catchment (Melissa Campbell, Sotico's Watercare Program Coordinator, *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. In Elscot and Bancroft, 1998)

- The Cowaramup Bay Chapter of the Surfrider Foundation and the Cowaramup Bay Progress Association, 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 bores of the bay townsite, Gracetown, 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. Stage 2 will produce a species inventory and ecological map of the Bay. Funding by the Natural Heritage Trust's Coast and Clean Seas Monitoring Program is currently under negotiation. A report is expected to be completed in 2001 (Hardcastle, WRC, *pers. comm.*).
- The Estuarine Health Indicators Project included five sites in Hardy Inlet (Deeley et al., 1999). The project collected data on the benthic macroinvertebrates, phytoplankton, zooplankton, and water and sediment characteristics and nutrients. 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 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 Connelley). The project is to monitor ocean and river water at six sampling sites over three summers, seeking to understand the cumulative impact on the water and marine biota of intense tourism; residential occupancies of two housing developments near the outfall of the Margaret River, the riverside town of Margaret River, and agricultural properties further inland. 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. Funding by the Natural Heritage Trust's Coast and Clean Seas Monitoring Program is currently under negotiation. A report is expected to be completed in 2001 (Hardcastle, WRC, *pers. comm.*).

- Measures taken to prevent sudden mass fish deaths in the Vasse-Wonnerup Estuary system as recommended in Lane *et al.*(1997) include artificial openings of the sand bar during the onset of summer (if required), guidelines for operation of the floodgates, planting of native vegetation on the north shore of the Vasse exit channel (also planned to occur on the south shore); and implementation of a fish and water quality monitoring program in the lower reaches of the Vasse-Wonnerup system(Lane *et al.*, 1997). This monitoring project is ongoing: data will be entered into the Water and Rivers Commission EDICT database and will be available via a formal data request. Additional measure have also been implemented including allowing professional fishermen to net in the estuary basins in late spring/early summer to reduce standing crop, and fish releases through the floodgates when they exhibit stressed behaviour (Kathryn Hardcastle, WRC, *pers comm.*)
- Water Corporation monitoring:

- Periphyton monitoring project associated with the Busselton Wastewater Treatment Plant in front of the Vasse Diversion Drain (Busselton). This is an annual summer Ministerial condition attached to EPA Bulletin 945. There is currently a Coast & Clean Seas project submission to extend current periphyton monitoring project to other catchment outlets in Geographe Bay – Vasse Wonnerup outlet, Buayanup Main Drain and another 'baseline' comparison site. A report will be available in the Water Corporation's next annual report (Ms Roni Oma, Water Corporation, *pers. comm.*).
- As part of EPA licensing requirements, Water Corporation water quality monitoring programs are ongoing for drainage networks downstream of the Busselton Wastewater Treatment Plant and the Dunsborough Wastewater Treatment Plant. Water quality is said to be variable according to the time of year and flow rates. Contact: Mr Richard Murton or Mr Mick Adams for data (Water Corporation, Bunbury).
- Water Corporation is also undergoing twice yearly monitoring of the marine environment 500m across and 200m out to sea from the Vasse Diversion Drain.

15 Commercial fishing

AWAITING CORRESPONDENCE FROM Department of Fisheries (DoF)

CONTACTS
PETER ROGERS (EXECUTIVE DIRECTOR), DoF

15.1 Identify the major commercial fisheries that operate in the study area. For each industry, identify:
- **(a) Number of licensed and actual operators in the study area**
- **(b) Species targeted as per season**
- **(c) Predominant techniques**
- **(d) Tonnes of product per annum and significance**
- **(e) Economic value and significance**
- **(f) Markets**
- **(g) Past trend, current status and predicted future trend; and**
- **(h) Past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs**

a) Awaiting correspondence from DoF
b) The major species taken commercially in order of weight are whitebait, herring, trevally, blue sprats, sea mullet, blue swimmer crabs, western sand whiting, pilchards, yellow eye mullet and garfish (Rogers, DoF, *pers.comm.*).
c) Commercial fishing methods permitted in the proposed study area include beach seining, gill netting, drop lining, drop netting, hand lining, haul netting, long lining, potting, purse seining, jigging and trapping (Rogers, DoF, *pers.comm.*).
d) Awaiting correspondence from DoF
e) Awaiting correspondence from DoF
f) Awaiting correspondence from DoF
g) Awaiting correspondence from DoF
h) The DoF State of the Fisheries' Report will contain this information, and is due to be released in early 2002.

15.2 Provide details of any processing facilities, including location, products processed, quantity of product, markets and economic value

Not available from DoF

15.3 What are the requirements of commercial fishing in the study area?

Awaiting correspondence from DoF

15.4 What strategies are FWA utilising/proposing to minimise the environmental impact of commercial fishing?

Awaiting correspondence from DoF

No fishing exclusion zones: Yallingup, Cowaramup, HMAS Swan Dive Wreck site

16 Aquaculture and pearling

CONTACTS
PETER ROGERS (EXECUTIVE DIRECTOR), DoF

16.1 Identify the major aquaculture and pearling industries that operate in the study area. For each industry, identify:

(a) number of current licenses/leases and details (eg duration) and number of applications for licenses;
(b) species targeted;
(c) mode of operation (eg with respect to season, physical requirements, source of juveniles);
(d) tonnes of product per annum and significance;
(e) economic value and significance;
(f) markets;
(g) past trend, current status and predicted future trend; and
(h) past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.

There are no existing or proposed aquaculture ventures within the proposed study area (Rogers, DoF, *pers.comm.*).

However, note that the future potential for aquaculture ventures within the proposed study area should be taken into account. The development of new technology could overcome the constraints relating to the lack of shelter along this section of the WA coastline. Contact Ms Tina Thorne (Senior Policy Officer Aquaculture) on 9482 7361 for further information regarding aquaculture proposals.

16.2 What are the requirements of aquaculture/pearling industries in the study area (eg high water quality)?

N/A

16.3 What strategies is FWA utilising/proposing to minimise the environmental impact of aquaculture (eg size limits, quota system, minimum distance between farms)?

N/A

17 Tourism

CONTACTS
MARK EXETER (WA TOURISM COMMISSION, SOUTH-WEST REGIONAL MANAGER)
PHIL READHEAD (DoF)
HAYLEY SORTRAS (AUGUSTA TOURIST BUREAU)

17.1 Identify the major tourism industries that operate in the study area. Identify:

(a) Number of tourism-based charter boat companies
(b) Mode of operation (eg with respect to season, constraints)
(c) Number of participants and significance
(d) Economic value and significance
(e) Market (domestic and/or overseas)
(f) Past trend, current status and predicted future trend; and
(g) **Past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs**

a) The major tourism industries that operate in the study area are diving, fishing, and wildlife observation (whales).

There are no more than 9 charter operators in the study area. Two of the three applicants from the Augusta area are low profile operators who operate in the rivers and estuaries. The others all do a bit of fishing and diving (Phil Readhead – Fisheries WA, *pers comm.*)

However, consider:

- Cape Dive – 9756 8778
- Diving Ventures/Bay Dive and Adventures – 97568846
- Naturaliste Charters/tours – whale watching; fishing; diving - 97523456/9755 3268
- Rojay Fishing Charters – 9752 2544/015 389 317
- Pearl Bay Lugger/Willie Pearl Lugger Cruises/Willie Yacht Charters – whale watching; Swan dive; sunset cruises-0418919781
- Geographe Cruises – 97542788 (dolphin cruises, charter vessel eg fishing)
- Augusta Ferry Service – river cruise on the Blackwood River – 9758 1944
- Leeuwin Marine Charter and Dive – Augusta – 9758 1770 (Phil Readhead, *pers.comm.*)
- The Dive Shed – Busselton – 97541615 (Phil Readhead, *pers.comm.*)
- Scaley Mates – Busselton-9755 4257 (Phil Readhead, *pers.comm.*)
- Rex (?) land-based fishing safaris – Busselton-Augusta – 9755 0131 (Phil Readhead, *pers.comm.*)
- South-west fly-fishing adventures – Blackwood River, including the entrance to the ocean
- MSV Big Day Out Southern Ocean Charters (Whale watching)– Ian Tarbotton, Dunsbroough - 0409107180

b) The tourism season is concentrated in the Christmas to Easter period when existing accommodation in the area is close to its capacity.

The summer months are the most popular for guest arrivals at Busselton with 30.5% of the guests in 1998 attracted over this time. Approximately 45,000 (44.5%) of the year's guests stayed during the annual school holiday periods (WA Tourism Commission, 1998c).

Since 1993, a slight swing away from January towards October being the peak month for guest arrivals (total number of guests counted on their first night of stay) to hotels/motels/guesthouse type accommodation has occurred in the Augusta-Margaret River area (WA Tourism Commision, 1998b)

Domestic visitors to the South West region in 1998 were more likely to travel to the region in the first quarter of the year (January to March). During this quarter in 1998, the summer school holidays, Australia Day long weekend and the Labour Day long weekend fell. Easter in 1998 occurred in April (Western Australian Tourism Commission, 1998e)

c) In, 1995-96 there were 965,390 coastal and marine tourism visits in the lower south west, which constituted 2.8% of the total coastal and marine visits to Australia and 23.2% of the total coastal and marine visits to Western Australia (Australian Economic Consultants, 1998). In 1995-96 there were 2,896,000 coastal and marine tourism visit nights in the lower south west, representing 2.3% of the total Australian value and 21.4% of the total coastal and marine visitor nights to Western Australia (Australian Economic Consultants, 1998).

The Western Australian Tourism Commission estimated that the South-West Region had approximately 1.3 million overnight domestic visitors over the calender year of 1998, 70% of whom originated from Perth. On average, overnight domestic visitors stayed 3.2 nights and spent a combined total of app. $343 million. It was estimated that 91% of visitors arrived by private vehicles. 54% of total visitor nights spent in the region in 1998 were in commercial accommodation, versus 46% in non-commercial accommodation (WATC, 1998a).

d) Travel and tourism generated over $4.4 billion of tourism expenditure in 1998-99 and attracted over 7.2 million visitors to WA (including intrastate and US Navy). The industry contributed 3.9% to WA's Gross State Product in 1996-97. Employment estimates in WA are in the range of 72,000 – 76,000 (8 –8.5%) of the workforce as at May 1999 (WA Tourism Commission, date unknown3). Approximately two thirds of the estimated total expenditure in the Southwest was from visitors who were on a 'Pleasure/holiday' trip (Western Australian Tourism Commission, date unknown).

Table 30: South West Region's Tourism Industry: Domestic Visitor Profile

Total Economic Impact	$627 million
Total Direct Expenditure	$392 million
Number of Visitors	$1.43 million
Average daily spending (per person)	%85.00

Table 31: South West Region's Tourism Industry: All Visitors

Domestic Visitors	1.43 million
International Visitors	50,000
Number of nights stayed	5.02 million
Average length of stay	3.4 nights

(WA Tourism Commission, date unknown3).

From a national perspective, when both the direct expenditure and flow on effects are combined, the effects of tourism on the Australian economy are substantial. Expenditure on coastal and marine tourism was estimated to be $22,892 million in 1995-96, which represents 2.9% of all Australian expenditure on goods and services. This represents:

- A total expenditure on goods and services of $35,984 million, representing 4.6% of the Australian total
- $10,558 million in wages and salaries, or 5.2% of all Australian wages and salaries
- full time jobs numbering 347,461, 5% of the Australian full-time equivalent workforce
- $20,904 million o f gross domestic product, or 4.7% of Australaia's gross domestic product
- (Australian Economic Consultants, 1998).

From an international perspective, the World Travel and Tourism Council estimates that the travel and tourism industry contributed 10.7% to the world's Gross Domestic Product, or US$3.8 trillion, in 1997. It is expected that by the year 2007 travel and tourism will contribute 10.9% of GDP (US$7.1 trillion) to the world economy (http://www.tourism.gov.au/publications).

e) In 1996, intrastate visitors to the southwest accounted for 86%, interstate for 9% and international for 5% (Western Australian Tourism Commission, date unknown).

The composition of Australia's inbound tourism markets has changed dramatically over the past ten years, with Asian visitors accounting for almost half of all visitor arrivals in 1997. Japan remained Australia's largest inbound market, with 19 per cent of the inbound market share. New Zealand was the second largest market, accounting for 16% of all visitor arrivals, and visitors from Europe represented 20% (http://www.tourism.gov.au/publications/tourismtrends.html)

f) The national average annual growth rate for 1999-2004 predicted for visitor nights is 1.6%. The average annual growth rate for the number of visitors from Japan/Asia is 9.8% and 7.3% for all markets to Australia (WA Tourism Commission, date unknown3).

There has been a 32% growth in visitors to the south west using hotel, motel and guesthouse category accommodation over the 10 year period 1986/87 – 1996/97, which averages to be 2.8% growth rate per annum (WA Tourism Commission, 1998d).

% increase of visitor arrivals to south west tourist bureaus in 1998/99:
Busselton –1.37%
Dunsborough 4.39%
Margaret River 2.58%
(WA Tourism Commission, date unknown2)

The lower southwest had 736,000 non-business coastal and marine tourism domestic visits in 1991-92 growing through to 896,000 visits in 1995-96. The lower southwest had 2,421,000 non-business coastal and marine tourism domestic visit nights in 1991-92 growing to

2,774,000 in 1995-96. The lower southwest had 40,785 non-business coastal and marine tourism international visits in 1992 growing through to 69,390 visits in 1995. The lower southwest had 201,000 non-business coastal and marine tourism international visit nights in 1992 growing to 219,000 in 1995 (Australian Economic Consultants, 1998).

Annual growth in international visits in coastal and marine tourism in the southwest:
- -4.945, 1993
- 62.33%, 1994
- 10.26%, 1995

(Australian Economic Consultants, 1998)

Annual growth in international visitor nights in coastal and marine tourism in the southwest:
- -54.23%, 1993
- 125.00%, 1994
- 5.80%, 1995

(Australian Economic Consultants, 1998)

Annual growth in non-business coastal and marine tourism domestic visits to the southwest:
- 13.59% 1992-93
- -16.63% 1993-94
- 32.14% 1994-95
- -2.71% 1995-96

(Australian Economic Consultants, 1998)

Annual growth in coastal and marine tourism domestic visitor nights to the southwest:
- 11.318% 1992-93
- -1.633% 1993-94
- 14.674% 1994-95
- -8.750% 1995-96

(Australian Economic Consultants, 1998)

Coastal and marine tourism is an important sector of Australia's tourism market and is likely to increase in both volume and value in the long-term. The forecasted annual growth rate of total Australian domestic tourism is 1.1%. A sluggish growth rate of 0.6% for non-business tourism is predicted. Predictions for International visitor growth in not particularly favourable, due primarily to the Asian Crisis, causing potential tourists from spending income on overseas holidays. However, the recent depreciation of the Australian dollar has made Australia a particularly attractive tourist destination for non-Asian countries. The overall effect is predicted slow growth (Australian Economic Consultants, 1998).

There has been a noticeable increase in the number of visitors to the study area from interstate and overseas during the past decade. It is anticipated that this trend will continue as a result of the completion of the Busselton airport and continued promotion of the area as a recreational and holiday destination (Coastwise, 2000). For example, the sinking of HMAS Swan to the north-east of Point Picquet in 1997 has led to the expansion of the local diving tour operations in the Busselton area, and there is still considerable potential for development of commercial dive tours in the study area, especially in the clear and sheltered waters of Geographe Bay.

- See Tourism Development Register, June 2000 for projects currently under construction, and those at the planning stage. Of particular interest:
    - A constraint for the development of tourism is the lack of adequate jetty facilities suitable for commercial vessels (eg at Dunsborough). The only adequate

commercial jetty in the study area is at Busselton. This inadequacy limits the development of the whale watching industry and the diving industry (eg diving vessels visiting the Swan wreck site off Dunsborough have to leave from the Busselton jetty). The jetty at Augusta is DOT funded and Council-owned, and does not meet the shore, so that there is a safety issue.

- There has been a DoT jetty feasibility study for Geographe Bay – contact Steve Flottman for more information
- Locals have requested a groyne at Hamelin Bay. There has been a DoT study into this matter, although at this stage nothing definitive has been proposed. The South West Tourism Commission does not think the numbers would justify this development, and also believe that the Port Geographe marina will alleviate some of the pressure (Mark Exeter, Pers.comm.).
- The Capes Lighthouses will be transferred to the Department estate within the next few years
- The Tourism Commision would like to see Cape Leeuwin developed – contact Mark Pittavino, the Department, for more information
- An underwater observatory to be located at Busselton jetty is currently at the design stage. Tenders will be called before Christmas, and it is proposed to be open by December 2002. The South west Tourism Commission will be requesting that this portion of the jetty be made a Fishing exclusion zone (Mark Exeter, pers.comm.).

g) There has been no scientific research into the effects of marine and coastal tourism in the study area.

Potential environmental impacts:

- disease
- disturbance to wildlife
- As expansion of Augusta and tourism activities continues, the natural environment, especially the estuary, will come under increasing pressure (The Department of Conservation and Land Management, 1994).

17.2 What are the major tourist attractions of the study area?

Geographe Bay

- Busselton was judged Western Australia's Top Tourism Town in 1995 and 1996 and is the premier seaside resort town in the Sate. The location of Busselton on the sheltered waters of Geographe Bay make it a popular place for fishers, water skiers, snorkellers, scuba divers, windsurfers and sailors.
- The Busselton Jetty is the longest wooden jetty in the Southern Hemisphere and was built over a 95 year period commencing in 1865. It stretches two kilometers into Geographe Bay. There have recently been plans to develop an underwater viewing area as an extension to the Busselton Jetty. These plans have been temporarily put on hold as a result of a fire on the jetty towards the end of 1999
- Busselton Beach Promenade
- Dunsborough is an ideal family holiday retreat because of its quiet coves, sandy beaches and surrounding National Park, nature reserves and numerous scenic walk trails. Whale watching, the HMAS Swan wreck and the artifical reef are popular tourist attractions
- Cape Naturaliste Lighthouse

(as identified by Coastwise, 2000)

Capes-Hardy Inlet

- Leeuwin-Naturaliste National Park is the most visited national park in the State with in excess of one million visits over the past year. The number of visits is anticipated to

increase at a rate of 8% paer annum, over the next three to five years (Ministry for Planning, 1997).

- Cape Leeuwin Lighthouses. Cape Leeuwin lighthouse marks the extreme South West corner of Australia where the Indian and southern Ocean meet
- Sugarloaf rock – an example of striking coastal scenery
- Yallingup – Yallingup beach is one of the State's most popular and accessible surf beaches; Canal Rocks – an unusual marine rock formation
- Margaret River mouth
- Numerous well-known surf spots such as Prevelly Park
- Calgardup Beach, Redgate – where Grace Bussell and Sam Isaacs rode on horseback into the surf to rescue survivors of the wrecked ship Georgette in 1876 (see Cultural history section for details)
- Hamelin Bay – sheltered swimming and diving around interesting limestone formations and the wreck trail
- Augusta – whale watching. Note that the best vantage points to see humpback whales are Cape Leeuwin, Cape Naturaliste, Gracetown, Cowaramup and Sugarloaf carpark, or by boat.
- Hardy Inlet - fishing

17.3 What are the requirements of tourism industries in the study area?

The main motivations for visitors to participate in nature-based activities is to:

- see the natural beauty of the sites
- experience something new
- see wildlife in detail
- be close to nature
- have an educational experience (69% of interviewees) (http://www.tourism.gov.au).

Subsequently, the following will be requirements for the proposed marine conservation reserve:

- Clean beaches
- High water quality
- Healthy benthic communities
- High aesthetic quality of the marine environment
- Provision of 'undisturbed' areas for nature appreciation
- Equitable access to the natural values of the park
  (The Department of Conservation and Land Management, 2000, marine nature-based tourism section)
- Generally uninterrupted coastal vistas
- Sensitively designed and located offshore and coastal infrastructure
  (Jurien Bay Indicative Management Plan, seascapes section)

17.4 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of tourism (eg codes of conduct)?

- Environmental education (eg LCDCs, Busselton Naturalists Club, Busselton-Dunsborough Environment Centre, DPI)
- The Department's Recreation and Tourism Strategy 1996-2000: "People in CALM places"

- The Nature Based Tourism Strategy for Western Australia, 1997, is the result of a joint effort by the tourism industry, the Western Australian Tourism Commission (WATC) and the Department. It forms part of a broader statewide strategy to manage tourism in Western Australia, and complements the National Ecotourism Strategy released in 1994. It provides the framework to ensure that nature based tourism in WA grows in a way that is sustainable as well as economically and socially beneficial.
- Departmental policy: eg Recreation, Tourism and Visitor Services Policy
- Licensing - wildlife interaction (Department license); fishing activity (Fisheries License). A license is required for tourist operations in calm-managed waters (obtained from the Department)
- The South-West Regional Tourism Strategy (1995)
- The WA Tourism Commission is assisting Tourism Council Australia in implementing a quality assurance programme for the tourism industry that will encompass environmental guidelines

18 Mining and petroleum

CONTACTS
Bill Carr (DMPR)

18.1 Identify the major mining and petroleum industries (exploration and production) that currently operate in the study area. For each industry, identify:

(a) details of leases (eg size and duration);
(b) processes involved;
(c) tonnes of product per annum (including waste product and pollutants) and significance;
(d) economic value and significance;
(e) markets;
(f) uses of the products;
(g) past trend, current status and predicted future trend (ie identify any potential deposits, any expansions, new proposals or new interests); and
(h) past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.

There are no petroleum or mining titles which occur within the study area. However, EP 408 and EP 381 held by Amity Oil NL extend from Busselton to Augusta, ending at the baseline between Dunsborough and Bunbury in the north and eastwards away from the eastern limit of the proposed study area in the south. A major gas resource within Perth Basin sediments is being researched by Amity in the Whicher Range. The offshore areas east of Dunsborough and Augusta are prospective for petroleum and further information will be provided regarding the level of this prospectivity (Bill Carr, DMPR, *pers.comm*).

Titanium mineral sands are known to occur in Geographe Bay, with the previously mined Mininup Deposit gaining further resources from offshore through sediment transport. There has been minimal exploration offshore but the resources may become a target for exploration in the future, particularly north east of the mouth to the Vasse Estuary (Bill Carr, DMPR, *pers.comm*).

Potential environmental impacts of sand mining:

- loss of flora and fauna eg removal of seagrass;
- decrease in light reaching the seagrass communities due to increased turbidity associated with dredging. This will affect photosynthesis and hence leaf production, diminishing the baffling capacity of the meadow and making it more vulnerable to erosion and soil damage;
- increased sediment resuspension, which has the potential to smother benthic organisms (Walker et al., 1987)
- pollution eg noise, soil and water contamination, groundwater contamination, oil spills
- introduction of pests and diseases

18.2 Outline the history of exploration and mining in the study area.

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 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 1974-1975, was a major collaborative project that was collectively known as "The Environmental Study of the

Blackwood River Estuary". Following the preparation of this document, the Estuarine Marine Advisory Committee published a report on the anticipated effects of dredging the estuary that subsequently resulted in the refusal of the mining applications (EMAC, 1978).

18.3 Are there any operations in the study area which are covered by State Agreement Acts?

Not applicable

18.4 Are there any operations in the study area which are required to have an Environmental Management Plan? If so, what are the obligations with respect to operations and lease duration?

Not applicable

18.5 What are the requirements of mining and petroleum industries in the study area?

Not applicable

18.6 What strategies are the relevant management authorities and/or involved companies utilising/proposing to minimise the environmental impact of mining and petroleum (eg waste disposal guidelines, oil spill management plans, exploration permits, production and pipeline licences).

- Proposed marine conservation reserve
- Under current legislation, in the absence of a marine reserve, the grant of any offshore Mining Act titles would require the advice of the Minister for the Environment and any exploration of development proposals involving disturbance of the sea bed would be referred to the EPA (Environmental Impact Assessment). Any petroleum activities within State waters out to 3nm would be referred to EPA for assessment.
- The CALM Act and Mining Act provide further constraint, prohibiting any sea floor disturbing activities and drilling within marine nature reserves and the sanctuary, recreation and certain special purpose zones of marine parks.
- Environmental reporting, auditing and monitoring of operations – the Mining Act 1978 (WA), the Petroleum Act 1967 (WA), Petroleum Pipelines Act 1969 (WA), Petroleum (Submerged Lands) Act 1982 (WA) and the Environmental Protection Act 1986 (WA)
- Flora and fauna surveys of areas where mining or petroleum operations are proposed; policy and guidelines have been developed to assist mining and petroleum companies to develop mineral and petroleum resources in an environmentally acceptable manner
- Oil spill contingency planning
- Reviews of industry performance
- A number of industry associations have developed environmental codes of practice;
- Petroleum companies must have insurance funds to clean up the environment should they be unable to meet their environmental commitments in the event of an environmental accident.

19 Recreation fishing

AWAITING DoF CORRESPONDENCE
Potential sources: Sumner and Williamson (date unknown) A 12-monbth survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-1997 – MCB library
A Quality future for recreational fishing on the west coast – fisheries Management Paper no 139 – Kylie's office

CONTACTS
PETER ROGERS (EXECUTIVE DIRECTOR), DoF
TERRY CONNELL, DoT

19.1 Summarise Department of Fisheries (DoF) recreational fishing survey information if available.

Recreational fishing surveys are carried out at regular intervals (every 5-6) years in the various bioregions of the State. Refer to the latest report for more information.

In addition, the DoF has recently undertaken a statewide telephone survey as part of a National Recreational Fishing Survey which will be analysed and written up over 2002.

19.2 How many participants are involved in recreational fishing as per season and/or on an annual basis, and what is the recreational fishing effort? What is the significance of these values in an international/national/regional/local context?

Recreational fishing effort is recorded in 5 X 5 nautical mile wide blocks. Neil Sumner (DoF) will provide this information in due course.

19.3 What is the origin of the recreational fishers (eg Perth metropolitan area, local coastal communities etc)?

Neil Sumner (DoF) will provide this information in due course.

19.4 What are the predominant fishing techniques used (eg shore or boat angling, net fishing, spearfishing, pots)?

The main recreational fishing methos are hand line, rod fishing, diving and drop netting (Rogers, DoF, *pers.comm*).

19.5 What is the level of boat ownership of the study area?

Neil Sumner (DoF) will provide this information in due course.

19.6 What is the total catch by species?

Historical surveys indicate that the main shore line species taken were herring, garfish, squid, yellowtail, blue swimmer crabs and boat-fished species were blue swimmer drabs, King George whiting, other whiting species, trevally and herring (Rogers, DoF, *pers.comm.*). For total catch information, Neil Sumner (DoF) will provide in due course.

19.7 What is the economic significance of recreational fishing in an international/national/regional/local context?

Neil Sumner (DoF) will provide this information in due course.

19.8 What has been the past trend, and what is the current status and predicted future trend for recreational fishing in the study area?

Fishers face a certain degree of difficulty when launching and retrieving fishing vessel. Improvements in boating facilities in Geographe Bay are likely to result in an increase in the number of fishers and therefore an increase in the catch levels of the recreational fishing industry (Coastwise, 2000).

Neil Sumner (DoF) will provide further information in due course.

19.9 Have there been any past, and/or are there any current/potential environmental impacts of recreational fishing in the study area (eg threats to the sustainability of local fish stocks)? Provide details of the relevant research/monitoring programs.

Neil Sumner (DoF) will provide this information in due course.

19.10 What factors have been shown or appear to influence patterns of recreational fishing activity throughout the study area (eg geomorphology such as sandy beach, season/holiday periods, presence of marine hazards such as crocodiles)?

The study by Ward (1999, unpublished) showed:

- Geomorphology affected recreation fishing intensity: promontories or headlands with 2WD access had the highest intensity of amateur fishing (eg at areas of Meelup Shire Park, Canal Rocks Sugarloaf Rock and "The Fishing Place", and Wyadup).
- Distance from large population centres such as Busselton, Dunsborough Bunbury or even Perth appeared to influence recreational intensity, for example, in the area between Cape Naturaliste and Cape Leeuwin peaks of use intensity showed a generally declining trend from north to south.
- The areas of highest usage in this study also tended to be areas that had 2WD access to points close to the coast including residential areas.
- Infrastructure also influenced recreational intensity (eg Busselton jetty and numerous launching ramps at Geographe Bay).
- The association of certain areas with the migratory run of the Australian Salmon (*Arripis trutta esper*) which occurs between March and May, is targeted by recreational and commercial fishermen (eg western end of Geographe Bay) (Ward, 1999 unpublished).

Neil Sumner (DoF) may provide further information in due course.

19.11 What are the requirements of recreational fishing in the study area (eg maintenance of target species habitat)?

Neil Sumner (DoF) will provide this information in due course.

19.12 What strategies is DoF utilising to minimise the environmental impact of recreational fishing (eg closed seasons, closed areas, bag and size limits).

Neil Sumner (DoF) will provide this information in due course.

No fishing exclusion zones: Yallingup, Cowaramup, HMAS Swan Dive Wreck site

20 Non-extractive recreational activities

AWAITING FIELD TRIP INFORMATION TO BE PROCESSED

CONTACTS
STEVE WARD (FOREST PRODUCTS COMMISSION)
DAVID O'SIGN (REC AND SPORT INDUSTRTY STATISTICAL GROUP)

20.1 Identify the major non-extractive recreational activities in the study area and state the

- **number of participants per season; and**
- **economic value and significance in an international/national/regional/local context.**

The following information (unless otherwise stated) has been derived from Ward(1999) and Ward(2000) aerial surveys

SHORELINE ACTIVITIES

Table 32: Participants in shoreline activities in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

	Beach use	**Amateur fishing**	**Surfing**	**Surfski**	**Walking /cycling along adjacent path**	**Total individuals**	**Boats**
Geographe Bay	667 (74%)	159 (18%)	3 (0.3%)	3 (0.3%)	64 (7%)	897 (100%)	180
Capes	1369 (62%)	278 (13%)	546 (25%)	4 (0.2%)	0 (0%)	2197 (100%)	88
Hardy Inlet and Flinders Bay	141 (77%)	21 (11%)	15 (8%)	0 (0%)	5 (3%)	183 (100%)	79
Total	2177	458	564	7	69	3277	347

(Ward, 1999)

Take note:

- beach use refers to sunbathing/swimming, snorkelling/walking/jogging
- usage intensity for each sub-sector is available in Ward's(1999) report (although this was not calculated for each activity for sector A)
- Ward completed a survey in 2000, but individual counts were not possible, with the exception of surfers (the digital movie used had poor resolution and picture stability). However, total cars in carparks were counted as a surrogate indicator of intensity.
- 1088 individuals at Busselton jetty were counted using ticket sales in a 12 hour period. No hourly breakdown or type of use (fishing, sightseeing) analysis could be made.

BOATING

Geographe Bay, 1999
A total of 180 boats were counted, which was equated to 1.23 boats per km2:
76% launch/dinghy
18% yacht
2% ski boat

2% jet ski (all 4 jetskis were part of the commercial operation that is limited to a small area on the eastern side of Busselton jetty)
2% scuba charter boat (2 of the 3 charter boats were located over the HMAS Swan dives site)

Geographe Bay, 2000
A total of 159 boats were counted, which equated to 1.1 boats per km2:
87% launch/dinghy
8% yacht
4% jetski (2 of the 7 were part of the commercial operation)
1% Scuba charter boat (the two boats were located over the HMAS Swam dive site)

Cape Naturaliste-Cape Leeuwin, 1999
A total of 88 boats were recorded, which equated to 0.22 boats per km2. The types of boat observed were limited to cabin cruisers, dinghies and yachts, with not ski boats or jetskis recorded.

Cape Naturaliste-Cape Leeuwin, 2000
A total of 75 boats were recorded, which equates to 0.2 boats per km2. The types of boat observed were limited to cabin cruisers, dinghies and yachts, with no ski boats or jetskis recorded.

Hardy Inlet, 1999
A total of 111 boats were recorded, which equated to 3.1 boats per km2, the highest boating use of all sectors:
79% launches/dinghies
21% yachts

Hardy Inlet, 2000
A total of 103 boats were recorded, which equates to 2.9 boats per km2, the highest boating use of all sectors:
78% launches/dinghies
22% yachts

Table 33: Leeuwin-Naturaliste Region: Private Boat Distribution by Postcode

Postcode	<4.99m	5.00-9.99m	10.00-19.99m	Total
6271	122	25	1	148
6275	22	4	-	26
6280	765	182	3	951
6281	128	52	2	182
6282	39	14	2	55
6284	34	16	-	50
6285	100	34	-	134
6286	21	3	-	24
6288	37	3	-	40
6299	206	34	-	240
TOTAL	1474	368	8	1850

(DoT, 1995)

ABS Survey: Runabouts, open boats and half cabin cruisers are the most used type of vessel at Busselton, generally less than 5 metres in length. Existing boat ramps are unsuitable for trailerable craft much beyond six metres in length. About 85% of private vessels in WA are less than six metres in length. Quindalup would appear to be the most popular of all the boat launching ramps. Although boating is a popular pastime at Busselton, it ranks sixth in terms of preferred activity, behind walking, swimming, sunbathing, sightseeing and beach fishing, There is a desire for the DoT to implement a licensed swing mooring system in Geographe bay(DoT, 1995).

There is no information available which states the economic value of the major non-recreational activities in the study area,

20.2 What are the annual recreational events which occur in the study area?

Proposed for 2001:

- Busselton Jetty Swim - 11/2/01
- Bluewater Fishing Classic - 9,10,11 March, 2001-02-19
- National Fishing Competition 18/3/01
- Margaret River Masters Surfing Competition – 30/3 –8/4/01
- Sunsmart Festival of Triathlon (Gnarabup Bch) 5/5-6/5
- Busselton Beach Festival – January, 2002
- Summerfest 2002 – 1-31/1 2002
- Whale watching September – November (Geographe Bay; Augusta-Australia's longest whale watching season, Tourism commission online)

(www.downsouth.com.au)

Additional events which have occurred in the past (and may occur in the future)

- Cape Leeuwin Lighthouse Gala
- Swan Dive Wreck Competition – December 1999
- "Yallingup Classic' Longboard Competition – December 1999

20.3 What has been the past trend, and what is the current status and predicted future trend for non-extractive recreational activities in the study area?

Information taken from Ward (1999; 2000):

- As population increases, so too will the number of participants in non-extractive recreation

- Individual numbers for beach activities in Ward's 2000 survey were not possible except for surfing due to the method of recording. In 2000, 296 surfers were recorded, which was 52% of the numbers recorded in 1999. Similar to the survey in 1999, the 2000 survey found high levels of usage in a number of the sub-sectors between Cape Naturaliste-Cape Leeuwin which included well known breaks eg Yallingup, Cowaramup Bay and Prevelly Park. However, it was noticed that there was a highly noticeable reduction in numbers of people using beaches in 2000, which was probably a result of Easter falling 3 weeks later in the year with milder conditions (Ward, 2000 unpubl.).
- There were less boats counted in 2000 in all areas when compared to 1999 figures, as seen in 19.1
- The number of vehicles at the carparks of Geographe Bay was 315 in 1999, and 190 in 2000. The number of vehicles at the 3 carparks located within Cowaramup Bay increased over the years with 62 in 1988, 96 in 1999 and 107 in 2000, which suggests that there has been an increase in shoreline usage within the survey area over the last 10 years (Ward, 2000 unpubl.). At Sugarloaf Rock, the number of vehicles was 25 in 1988, 40 in 199 and 14 in 2000. At Moses Rock, there were 9 vehicles in 1988, 21 in 1999 and 18 in 2000.
- In both the 2000 survey and the 1999 survey, the use of the coastline varied according to physical characteristics such as sandy beaches, rocky shorelines and surf breaks.
- There is considerable potential for development of recreational diving, especially in the clear and sheltered waters of Geographe Bay.
- In addition, refer to 16.1f – past trend, current status and predicted future trend for tourism in the study area

20.4 Have there been any past/current/potential environmental impacts of non-extractive recreational activities in the study area?

There has been no research to determine whether non-extractive recreational activities have had an environmental impact on the values of the study area.

However, as expansion of the towns and tourism activities continues, the natural environment, for example the Hardy Inlet, will come under increasing pressure (The Department of Conservation and Land Management, 1994).

20.5 What factors have been shown to or appear to influence patterns of recreational activity throughout the study area?

- GEOMORPHOLOGY
  The location of surf breaks influenced surfing intensity, with 97% of surfing occurring at the coastline between Cape Naturaliste and Cape Leeuwin (for example, at Three Bears, Yallingup, Prevelly Park and areas just south of Cowaramup and Prevelly Park). Sandy beaches attracted the highest beach use intensity (eg at Geographe Bay and at the mouth of the Hardy Inlet). Small swell/protected areas attracted the highest intensity of boating (eg at Geographe Bay and Hardy Inlet). Rocky promontories or headlands with 2WD access had the highest intensity of amateur fishing (eg at areas of Meelup Shire Park, Canal Rocks Sugarloaf Rock and "The Fishing Place", and Wyadup). Beach use was concentrated at sandy locations of the study area (eg coastline between Wonnerup and Quindalup). In 2000, the use of the coastline similarly varied according to physical characteristics.
- DISTANCE FROM POPULATION CENTRES
  Distance from large population centres such as Busselton, Dunsborough Bunbury or even Perth appeared to influence recreational intensity in the study by Ward (1999,

unpublished). For example, in the area between Cape Naturaliste and Cape Leeuwin, peaks of use intensity showed a generally declining trend from north to south.

- 2WD ACCESS
  The areas of highest usage in this study also tended to be areas that had 2WD access to points close to the coast including residential areas.
- ACCOMMODATION
  In areas where residential and tourist accommodation is located in close proximity to sandy and accessible beaches, recreational beach usage is very high (eg Meelup, Yallingup, Smiths Beach, Cowaramup, Prevelly Park, Hamelin Bay and Barrack Point).
- INFRASTRUCTURE
  eg Busselton jetty and numerous launching ramps at Geographe Bay
- BIOLOGY
  Fish distribution – eg the association of the migratory run of the Australian Salmon (*Arripis trutta esper*)
  The HMAS Swan Wreck at Dunsborough, coral bommies at Eagle Bay and colourful invertebrate growth on the Busselton jetty pilings are popular dive sites
- WEATHER
  When comparing the results of Ward's 1999 and 2000 aerial surveys, there was a highly noticeable reduction in numbers of people using beaches in 2000. This was predicted to be because Easter was 3 weeks later in the year, and subsequently had milder weather conditions (Ward, 2000 unpubl.).
- SEASON
  In the summer months many more people use the beach for swimming than found in the aerial survey of Easter 1999 (Ward, 1999 unplubl.)

20.6 What are the requirements of the non-extractive recreational activities in the study area?

The main motivations for visitors to participate in nature-based activities is to:

- see the natural beauty of the sites
- experience something new
- see wildlife in detail
- be close to nature
- have an educational experience (69% of interviewees) (http://www.tourism.gov.au).

Subsequently, the following will be requirements for the proposed marine conservation reserve:

- Vehicle access
- Facilities eg roads, toilets and walkways
- Control of beach activities eg recreational vehicle use and dogs
- Clean beaches
  (The Department of Conservation and Land Management, 2000, coastal use section)
- High water quality
- Equity of access to appropriate areas within the proposed park
- Separation of incompatible recreational activities
  (The Department of Conservation and Land Management 2000, Water sports section)

- High water quality
- Healthy benthic communities
- High aesthetic quality of the marine environment
- Provision of 'undisturbed' areas for nature appreciation
- Equitable access to the natural values of the park

(The Department of Conservation and Land Management 2000, marine nature-based tourism section)

20.7 What strategies are the relevant management authorities utilising to minimise the environmental impact of non-extractive recreational activities?

- Shire of Augusta-Margaret River Coastal Management Policy, 1998
  eg "the provision of formalised recreational facilities… shall be restricted to the existing activity nodes of Prevelly/Gnarabup, Gracetown and Flinders Bay" and "the development of additional recreational activity nodes or access routes within coastal reserves shall only be considered after a comprehensive assessment of the likely future impacts of such development, and consultation with affected user groups and the wider community"
- DoT guidelines eg the boating guide for Geographe Bay, which outlines the areas of the coast where skiing is prohibited and indicates the areas where landing and take off are permitted.
- Departmental Recreation Manual guidelines
- Monitoring eg a total of 61 species of fishes have been recorded on the HMAS Swan dive wreck, since its scuttling on the 14th December 1997 (Morrison, *pers comm* In Elscot & Bancroft, 1998). 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 (Elscot & Bancroft, 1998)

21 Education

CONTACTS
NICCI TSERNJAVSKI (THE DEPARTMENT)
JOHN BRAID (DPI)
JOHN DAVIS (DPI)

21.1 What has been the past/current/potential use of the study area for education purposes?

- Easy access and proximity of the study area to Perth and regional centres provides opportunities for community education about the marine environment.
- Over 30 Coastwest/Coastcare projects have been funded in the past five years (see 21.3), eg Coastwest/Coastcare summer activities program (initiated in 2000).
- The study area is currently used by local schools and by Perth-based universities and schools for educational purposes. Many of the local primary schools and high schools have marine education as part of their curriculum eg Margaret River High school, Karridale primary, West Busselton primary school, Dunsborough primary school (eg activities at Yallingup Lagoon), Busselton Senior high school (eg wetlands walktrail and activities at Gracetown and Yallingup, proposed marine monitoring at Cowaramup Bay – to be announced Jan/Feb 2001)
- Busselton Jetty Interpretative Centre, managed by Jetty Conservation and Environment Committee and the Busselton Jetty Management Committee – Proposed to open 9/1/01
- Proposed Marine Education Centre at Dunsborough

21.2 What has been the past/current/potential use of the study area for scientific research purposes?

Despite the wide range of natural features and human uses in an environment that is near pristine and close to many of the academic and educational institutions in Western Australia, the level of knowledge about environmental processes and existing and potential pressures from human usage in the study area is relatively limited. Research programs should, ideally be designed to fill key gaps in existing knowledge. However any increase in knowledge is beneficial, so that all legitimate research projects will be encouraged (The Department of Conservation and Land Management, 2000).

The scientific research undertaken in the study area has been referred to throughout this resource assessment.

21.3 Are there any existing community monitoring programs in the study area?

There have been over 30 Coastwest/Coastcare projects funded in the study area over the past five years. For a list of these projects, refer to Ministry for Planning (2000c): "Coastwest/Coastcare: a report to the community 1995-2000". Those projects which received funding in the 1999/2000 year were:

Table 34: Coastwest/Coastcare projects in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve which received funding in the 1999/2000 year

Ref no.	Project title	Cmty Applicant	Agency Applicant	Approved funding
9945	Rehabilitation of Boodjidup Beach	Leeuwin Conservation Group	The Department	$8,360
9947	Moses Rock Coastal Track Rehabilitation	Friends of Cape to Cape track Inc.	The Department	$14,840
9953	Coastal Rehabilitation of Redgate Beach	Redgate Coastcare	Shire of Augusta-Margaret River	$11,037
9955	Busselton High school Wetland Educational Walktrail	Busselton Senior High school	Busselton Senior High Scholl.	$27,920
9957	Cape Hamelin – Turner Brook Foreshore Rehab Plan Implementation (Stage 2)	Lower Blackwood Land Conservation District	The Department	$15,250
99103	Wonnerup Coastal Dune – Rehabilitation, Fencing and Access Control (Stage 4)	Wonnerup Residents Association	Shire of Busselton	$19,055

Table 35: Coast and Clean Seas projects in the study area for the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve

Ref no.	Title	Lead proponent	Project desciption
WA CCS:9704	Bay Watch	Surfriders Foundation Cowaramup Bay Chapter and The Cowaramup Bay Progress Association	Stage 1 – community water quality monitoring of Cowaramup Bay at 12 sites Stage 2 – species inventory and ecological map
WA CCS:9705	Blue Groper Protection Strategy – Information and Assessment	Surfrider Foundation Margaret River Chapter	Information stands, regional mobile education unit, fish monitoring
WA CCS:9706	Margaret River – Gnarabup Community Water Quality Initiative	Surfriders Foundation Margaret River Chapter	Water quality monitoring at 6 sites over 3 summers
WA CCS:9720	Toby Inlet Ocean Entrance Management Study	Geocatch, Shire of Busselton and Sussex LCDC	Aims to provide technical data as a base for management plans
WA CCS:9803	Munster Hill Drainage and Groundwater Survey	Albany Waterways Management Authority	Monthly monitoring of surface drainage (20 sites) and groundwater (15 sites) over a 12 month period
WA CCS:9818	Leschenault Inlet Pollution Free Project	City of Bunbury	Installation of a new pollutant trapping device
CCS:9944	Busselton Environmental	Water Corporation	Identification of nutrient

	Improvement Initiative - detection of nutrient hotspots		hotspots

(John Braid, Ministry for Planning, *pers.comm*)

Refer to the Department's Marine Conservation Branch Contacts Database for contact details of the community groups involved in marine and coastal monitoring or conservation projects in the study area, or contact Nicci Tsernjavski (South-West Regional Coastcare Facilitator)

21.4 What are the requirements of the education use of the study area?

- Access to sites free of major human influences
- Access to sites covering the range of major human activities in the park
- Equitable access to the park (in appropriate zones) for the full range of educational opportunities
  (The Department of Conservation and Land Management, 2000, Education section)

C RANKING VALUES AND PRIORITIES FOR MANAGEMENT

This section to be completed at a later stage of the planning process

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E APPENDIX 1: MAP PRODUCTS FOR THE GEOGRAPHE BAY-CAPES-HARDY INLET PLANNING AND PUBLIC PARTICIPATION PROCESSES

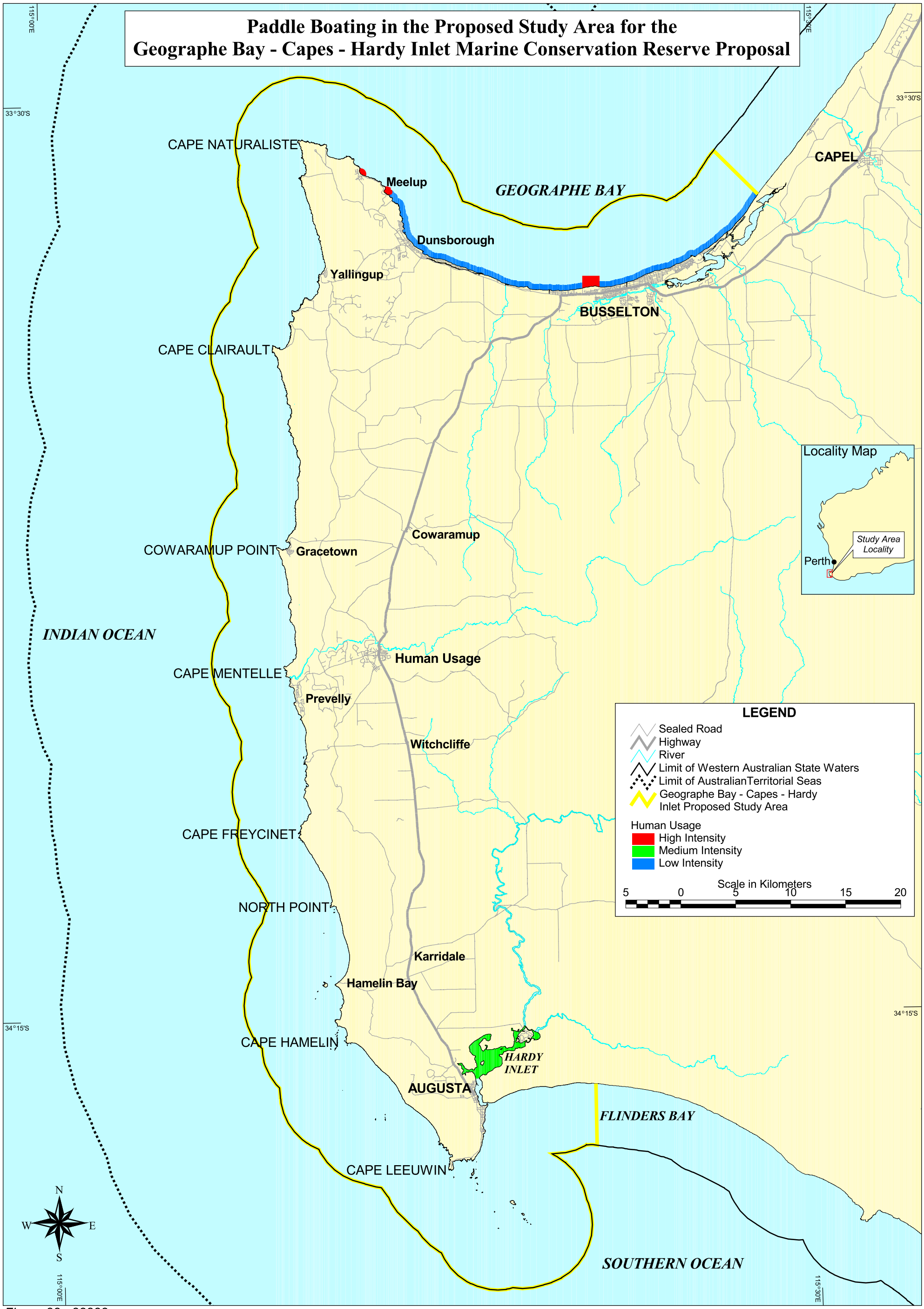

Paddle Boating in the Proposed Study Area for the
Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal
115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
CAPE CLAIRAULT
COWARAMUP POINT
CAPE MENTELLE
CAPE FREYCINET
NORTH POINT
CAPE HAMELIN
CAPE LEEUWIN
INDIAN OCEAN
GEOGRAPHE BAY
FLINDERS BAY
SOUTHERN OCEAN
Meelup
Dunsborough
Yallingup
BUSSELTON
CAPEL
Gracetown
Cowaramup
Human Usage
Prevelly
Witchcliffe
Karridale
Hamelin Bay
HARDY INLET
AUGUSTA
Locality Map
Study Area Locality
Perth
LEGEND
Sealed Road
Highway
River
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Human Usage
High Intensity
Medium Intensity
Low Intensity
Scale in Kilometers
5 0 5 10 15 20
N
W
E
S

Figure ??. ?????

Sailing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

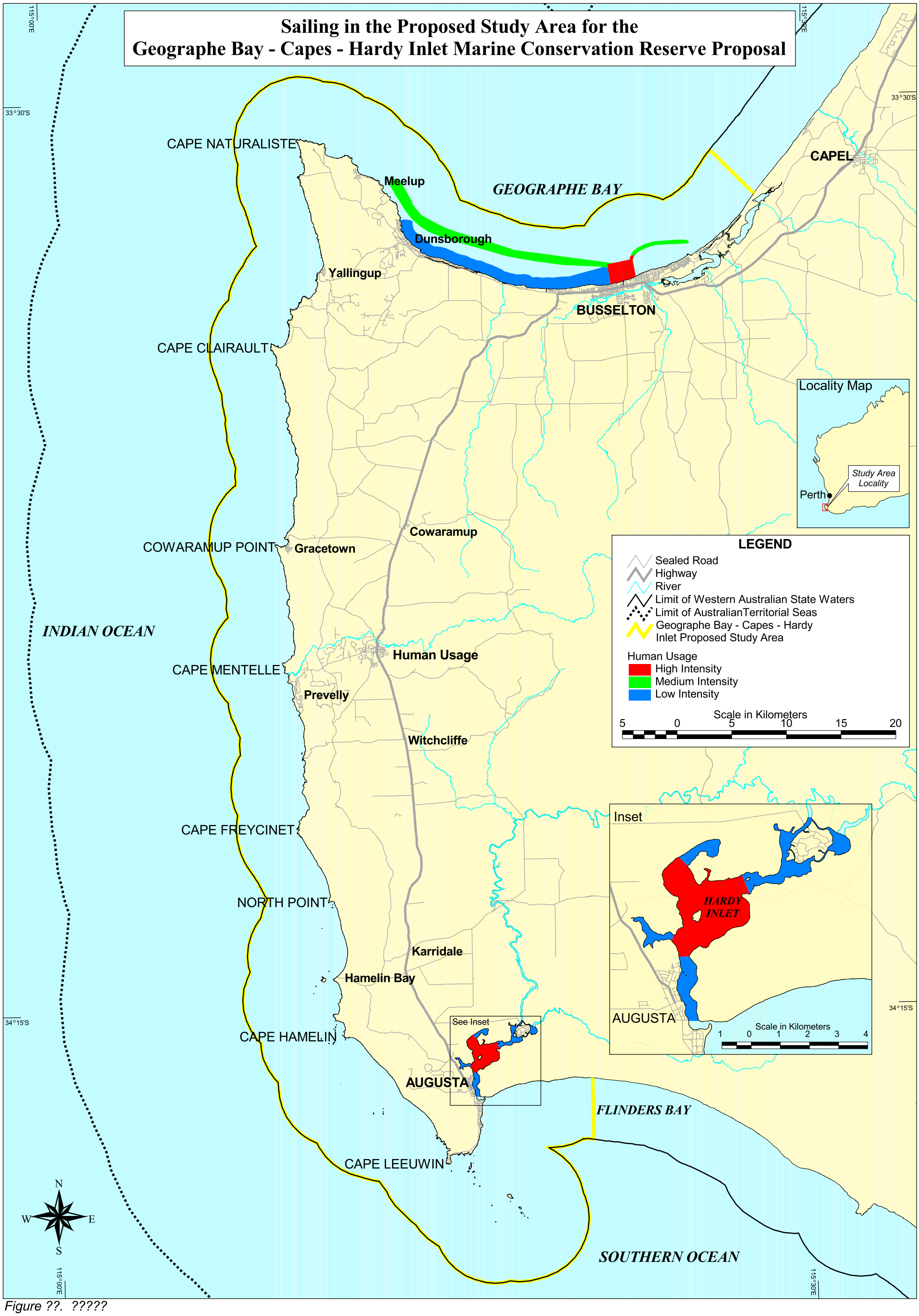


Figure ??. ?????

Diving (Scuba and Snorkelling) in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

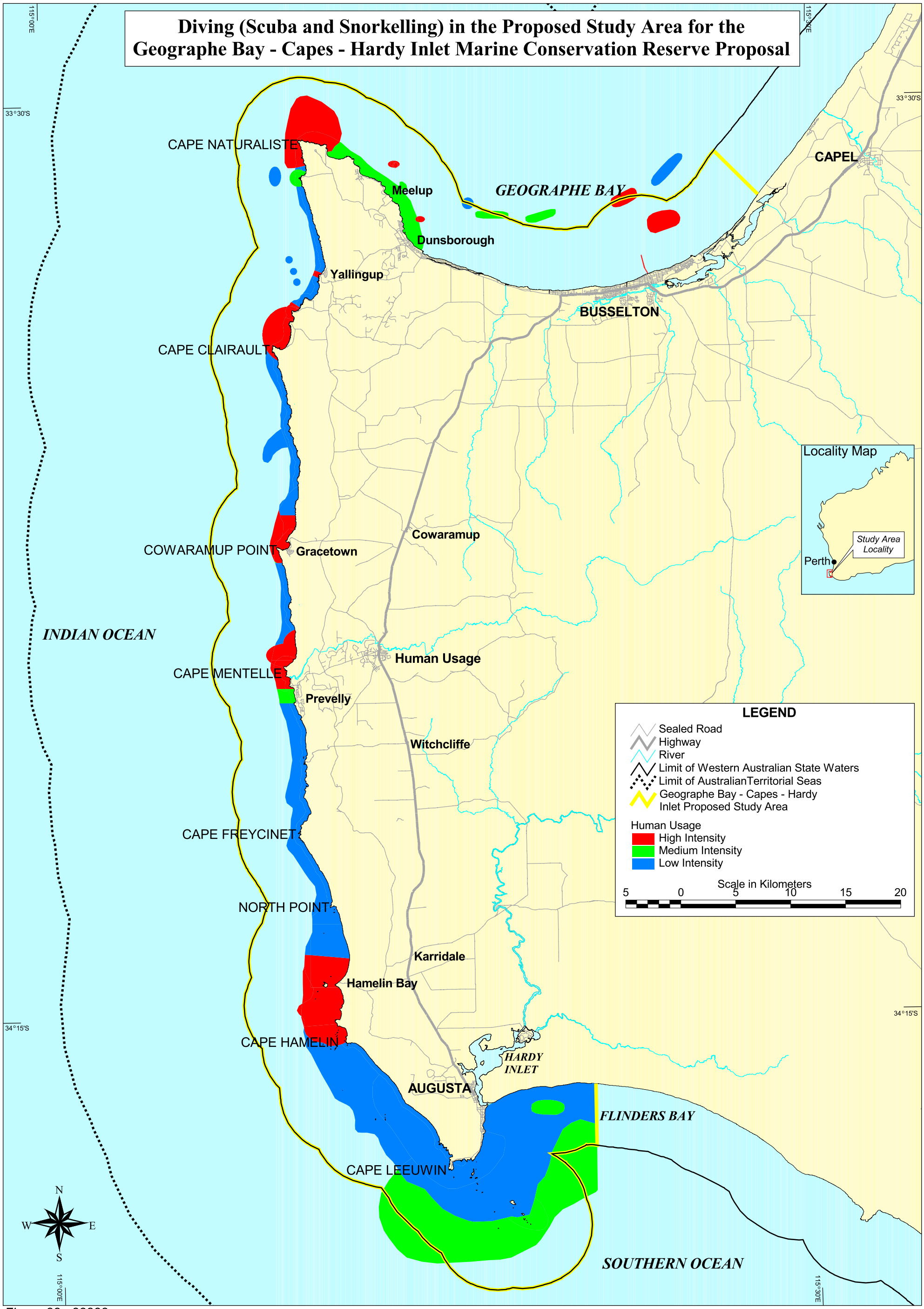


Figure ??. ?????

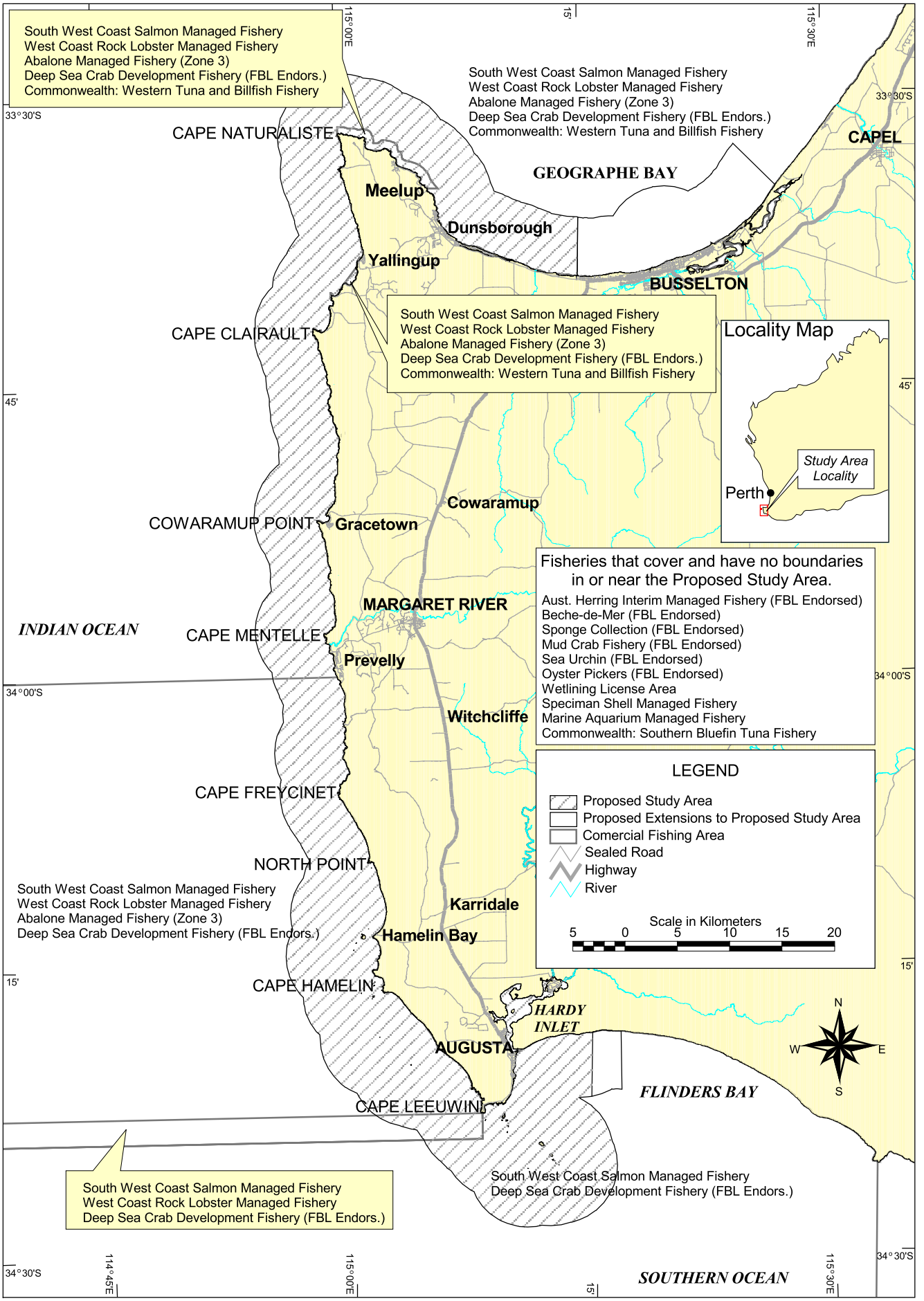

South West Coast Salmon Managed Fishery
West Coast Rock Lobster Managed Fishery
Abalone Managed Fishery (Zone 3)
Deep Sea Crab Development Fishery (FBL Endors.)
Commonwealth: Western Tuna and Billfish Fishery
South West Coast Salmon Managed Fishery
West Coast Rock Lobster Managed Fishery
Abalone Managed Fishery (Zone 3)
Deep Sea Crab Development Fishery (FBL Endors.)
Commonwealth: Western Tuna and Billfish Fishery
GEOGRAPHE BAY
CAPE NATURALISTE
CAPEL
Meelup
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
South West Coast Salmon Managed Fishery
West Coast Rock Lobster Managed Fishery
Abalone Managed Fishery (Zone 3)
Deep Sea Crab Development Fishery (FBL Endors.)
Commonwealth: Western Tuna and Billfish Fishery
Locality Map
Study Area Locality
Perth
Cowaramup
COWARAMUP POINT
Gracetown
MARGARET RIVER
INDIAN OCEAN
CAPE MENTELLE
Prevelly
Witchcliffe
Fisheries that cover and have no boundaries in or near the Proposed Study Area.
Aust. Herring Interim Managed Fishery (FBL Endorsed)
Beche-de-Mer (FBL Endorsed)
Sponge Collection (FBL Endorsed)
Mud Crab Fishery (FBL Endorsed)
Sea Urchin (FBL Endorsed)
Oyster Pickers (FBL Endorsed)
Wetlining License Area
Speciman Shell Managed Fishery
Marine Aquarium Managed Fishery
Commonwealth: Southern Bluefin Tuna Fishery
LEGEND
Proposed Study Area
Proposed Extensions to Proposed Study Area
Comercial Fishing Area
Sealed Road
Highway
River
Scale in Kilometers
5 0 5 10 15 20
CAPE FREYCINET
NORTH POINT
South West Coast Salmon Managed Fishery
West Coast Rock Lobster Managed Fishery
Abalone Managed Fishery (Zone 3)
Deep Sea Crab Development Fishery (FBL Endors.)
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
South West Coast Salmon Managed Fishery
West Coast Rock Lobster Managed Fishery
Deep Sea Crab Development Fishery (FBL Endors.)
South West Coast Salmon Managed Fishery
Deep Sea Crab Development Fishery (FBL Endors.)
SOUTHERN OCEAN
N
W
E
S
33°30'S
34°00'S
34°30'S
45'
15'
115°00'E
115°30'E
114°45'E

Figure ??. ?????

Recreational Abalone Fishing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

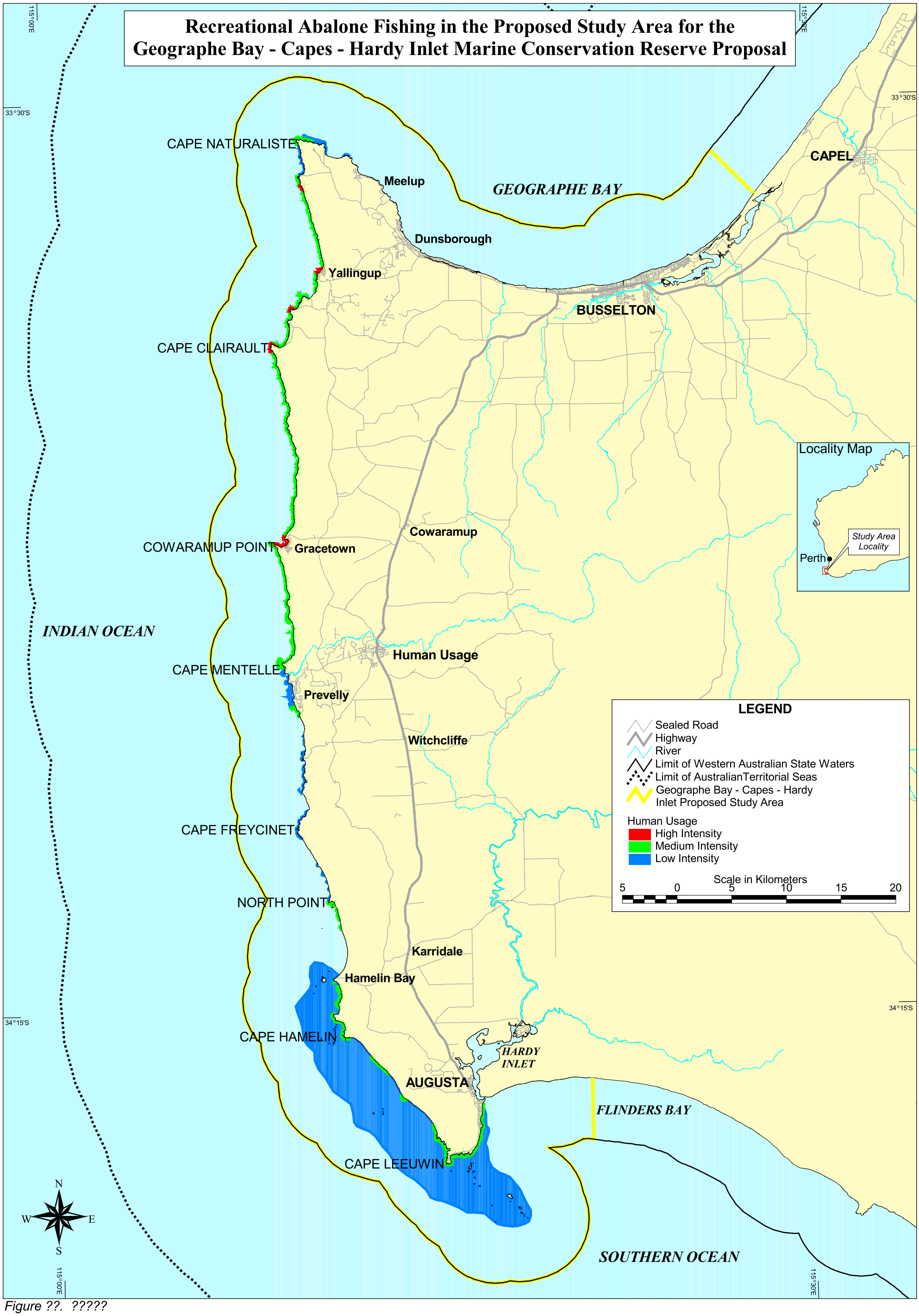


Figure ??. ?????

Recreational Abalone Fishing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

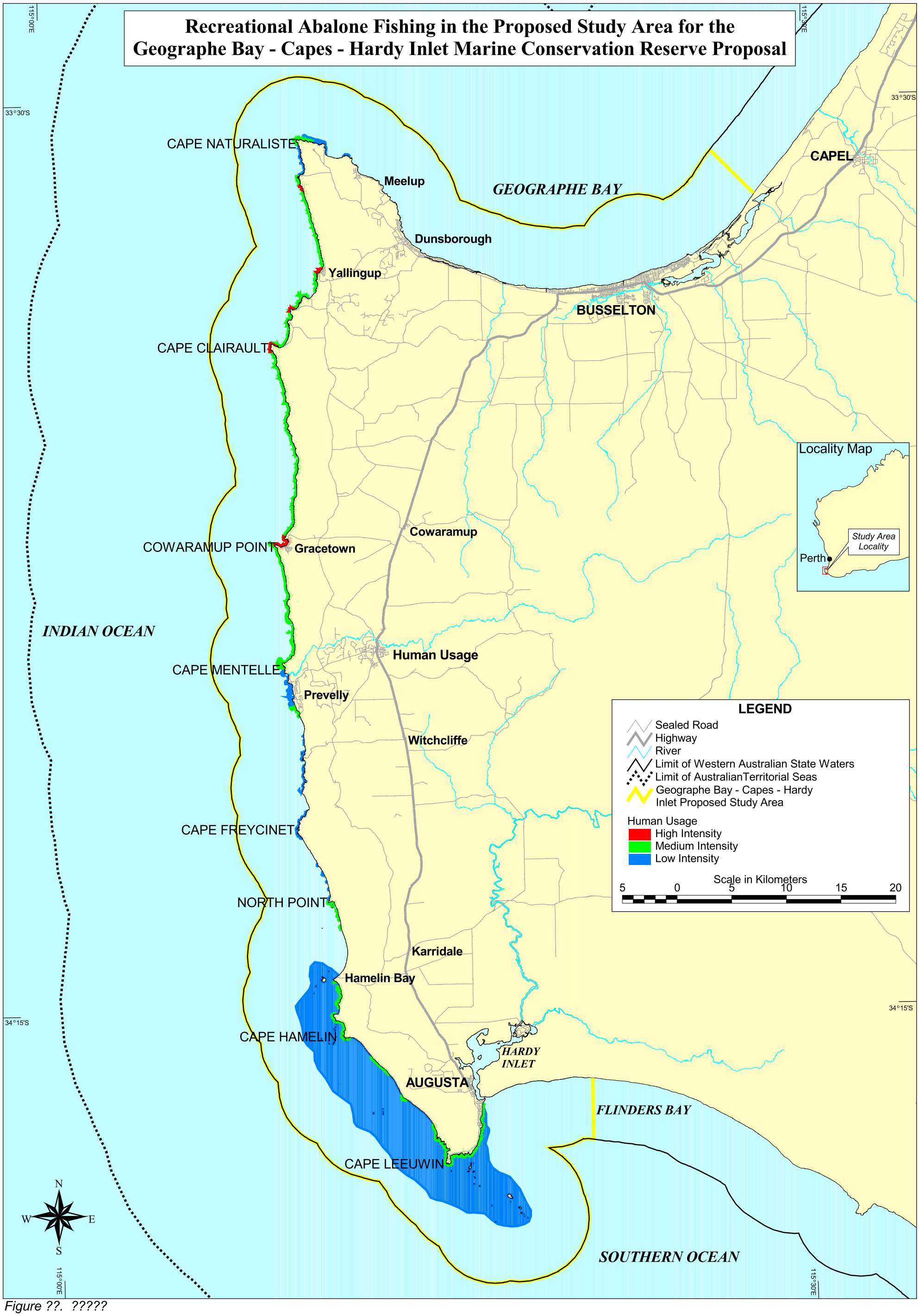


Figure ??. ?????

Recreational Crabbing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

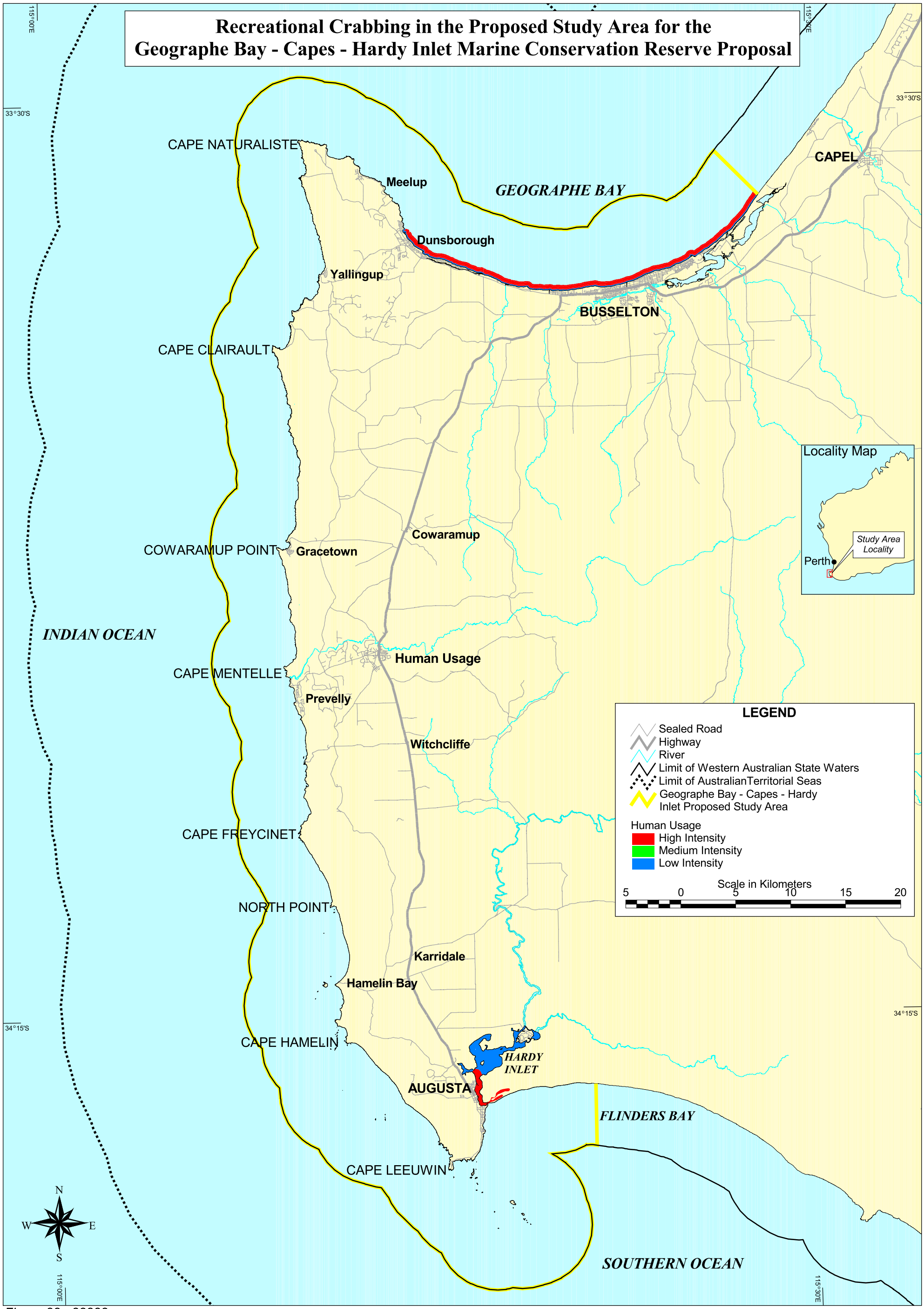


Figure ??. ?????

Recreational Crayfishing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

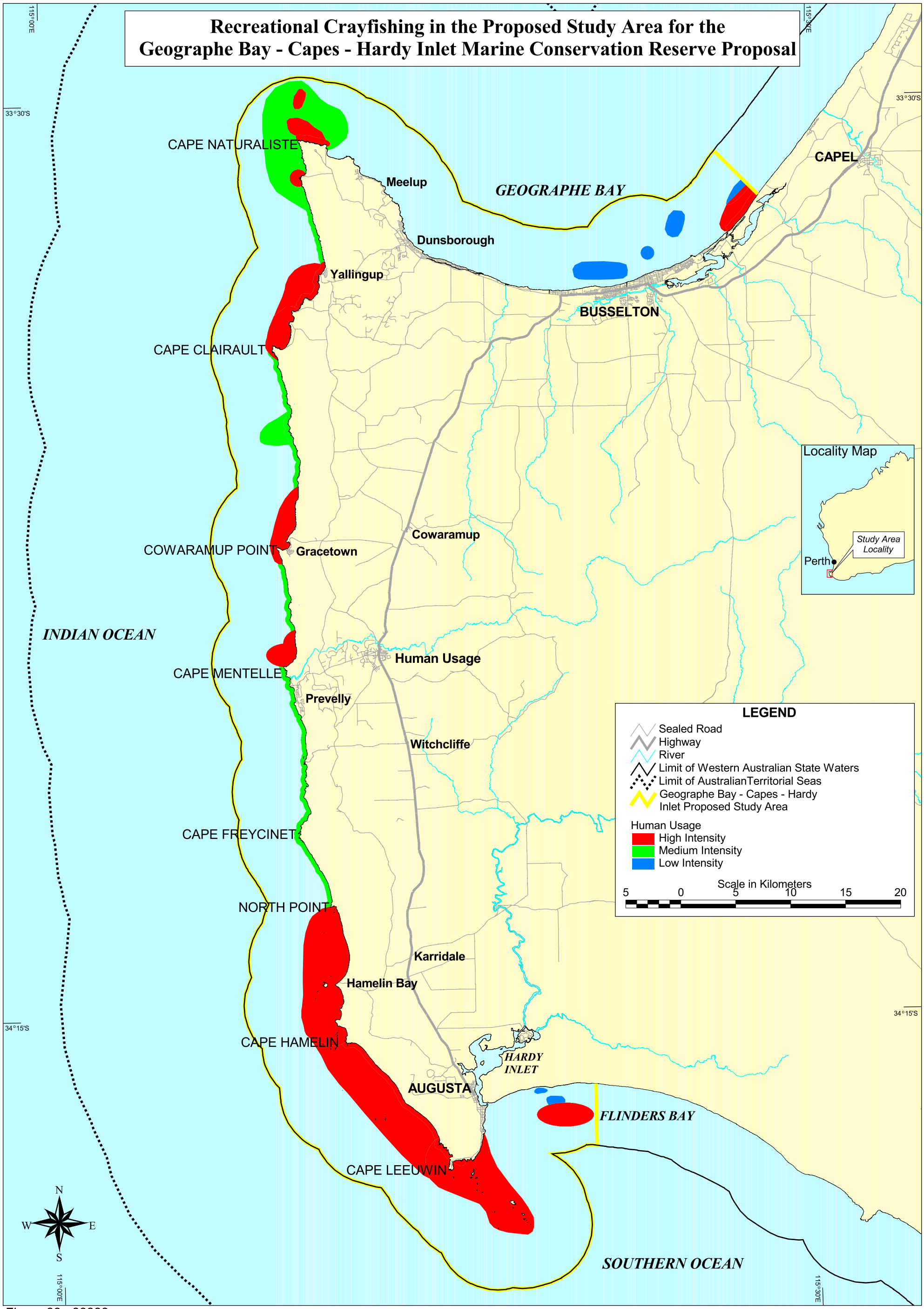


Figure ??. ?????

Recreational Line Fishing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

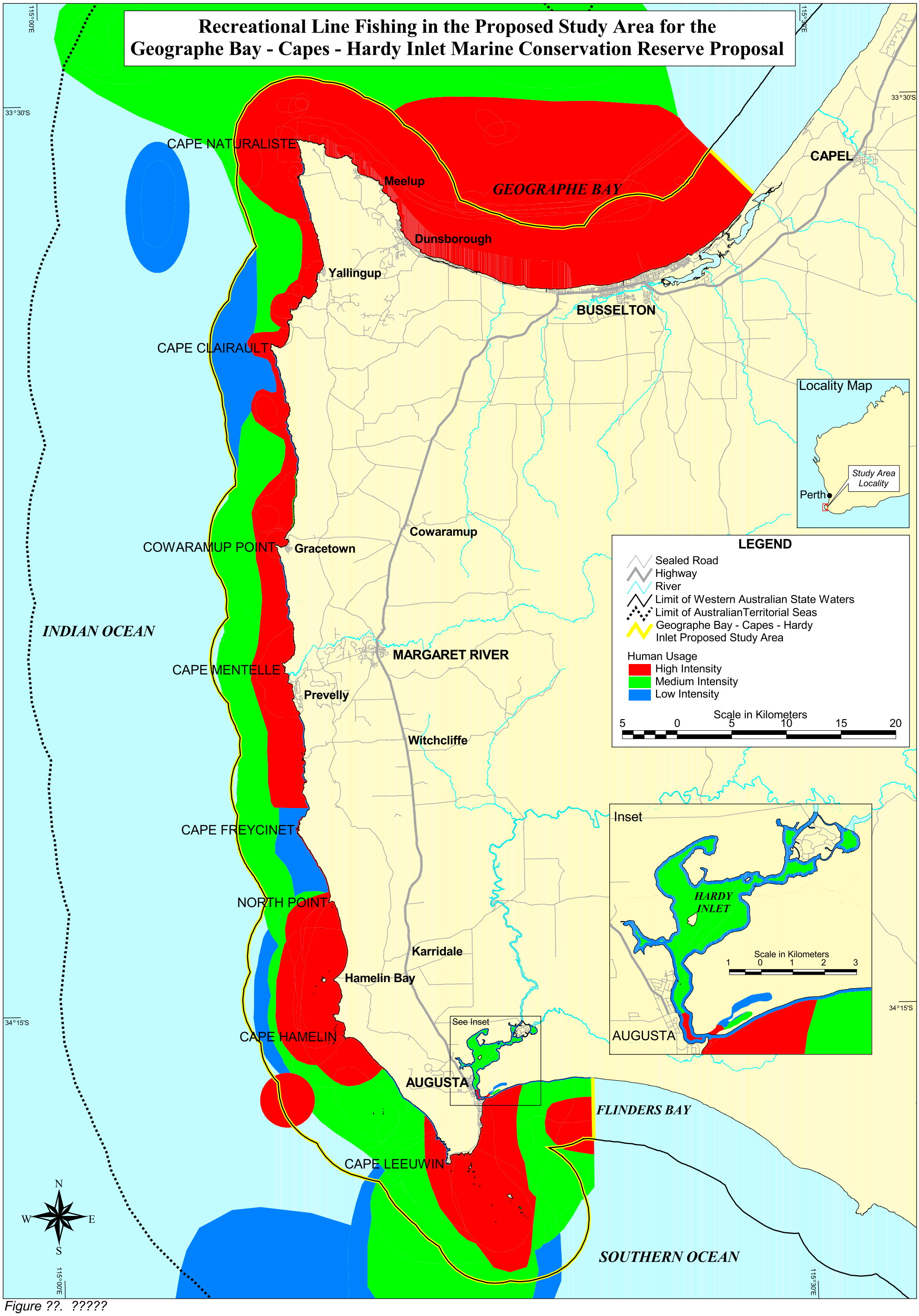


Figure ??. ?????

Recreational Netting in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

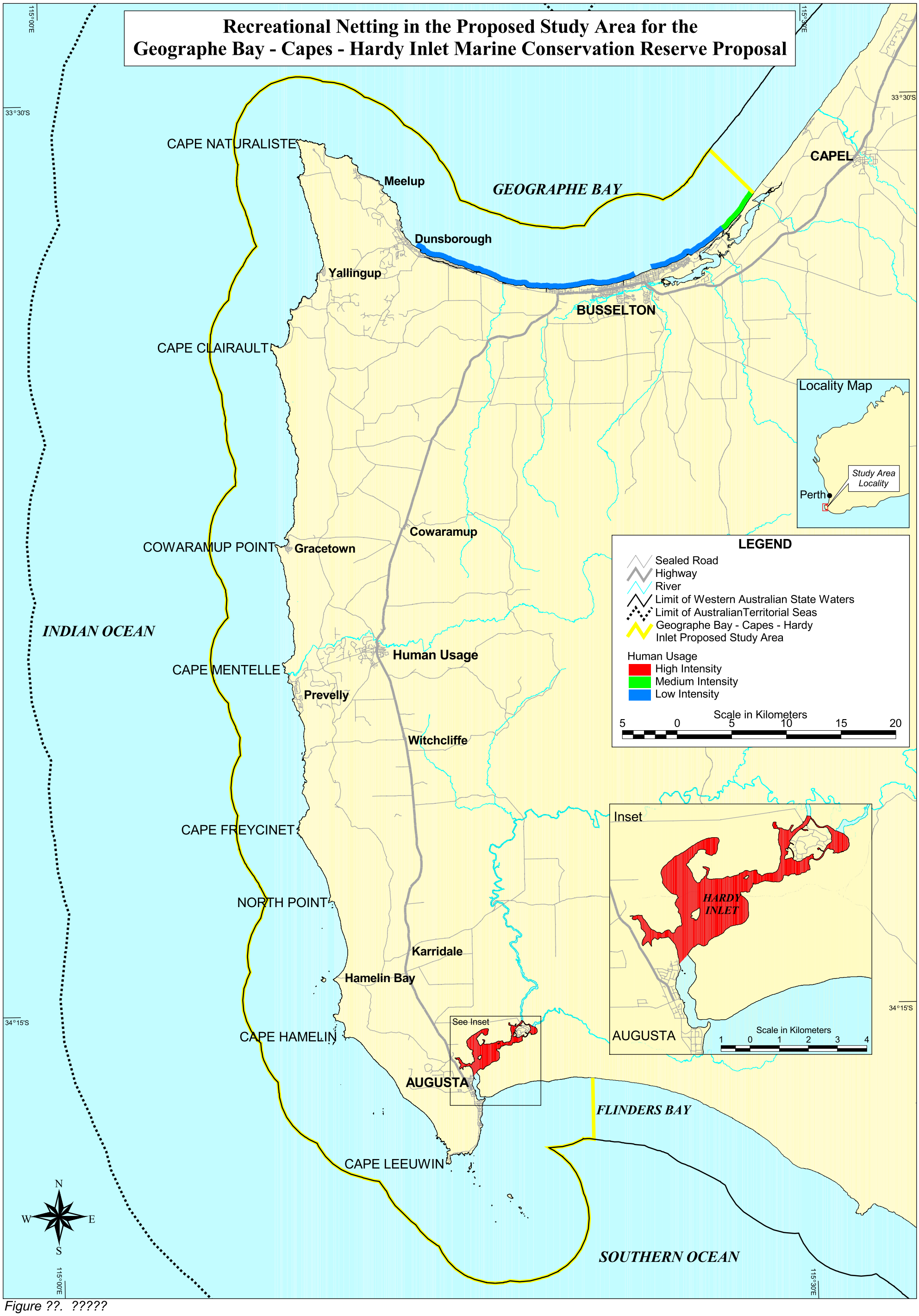


Figure ??. ?????

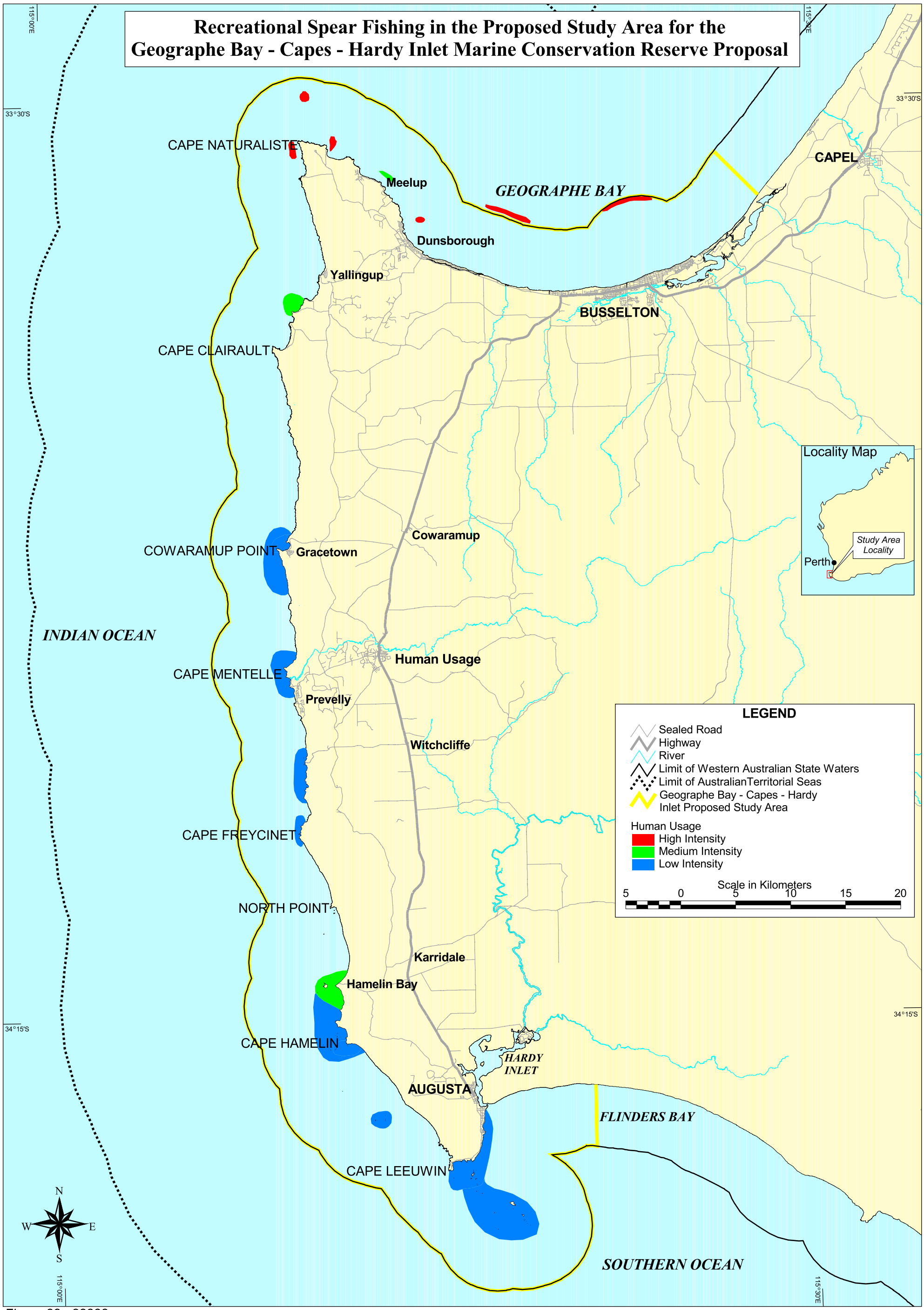

Recreational Spear Fishing in the Proposed Study Area for the
Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal
115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
CAPEL
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
Locality Map
Study Area Locality
Perth
COWARAMUP POINT
Gracetown
Cowaramup
INDIAN OCEAN
Human Usage
CAPE MENTELLE
Prevelly
Witchcliffe
CAPE FREYCINET
NORTH POINT
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
LEGEND
Sealed Road
Highway
River
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Human Usage
High Intensity
Medium Intensity
Low Intensity
Scale in Kilometers
5 0 5 10 15 20
N
W
E
S

Figure ??. ?????

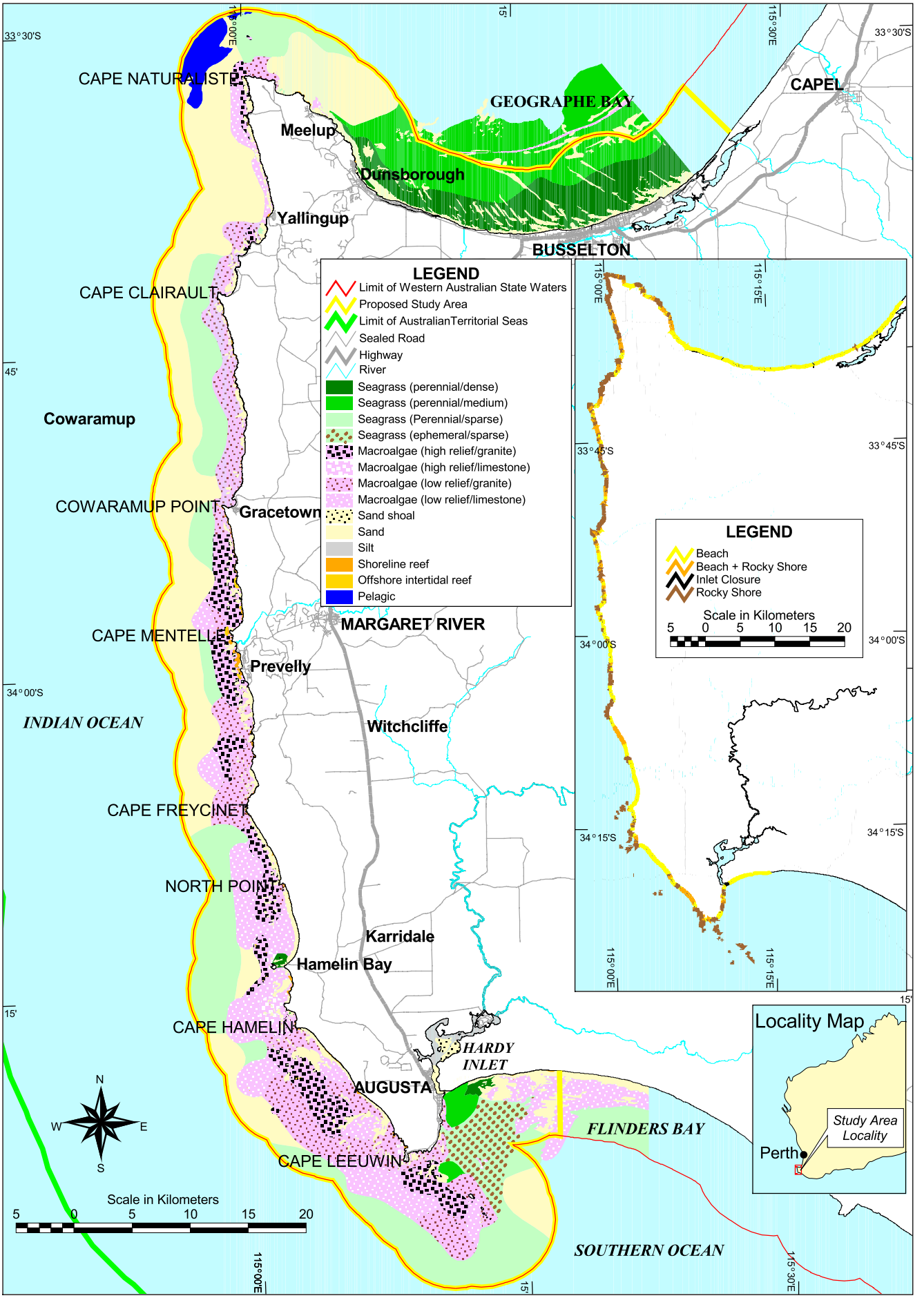

CAPE NATURALISTE
GEOGRAPHE BAY
CAPEL
Meelup
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
Cowaramup
COWARAMUP POINT
Gracetown
MARGARET RIVER
CAPE MENTELLE
Prevelly
INDIAN OCEAN
Witchcliffe
CAPE FREYCINET
NORTH POINT
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
LEGEND
Limit of Western Australian State Waters
Proposed Study Area
Limit of AustralianTerritorial Seas
Sealed Road
Highway
River
Seagrass (perennial/dense)
Seagrass (perennial/medium)
Seagrass (Perennial/sparse)
Seagrass (ephemeral/sparse)
Macroalgae (high relief/granite)
Macroalgae (high relief/limestone)
Macroalgae (low relief/granite)
Macroalgae (low relief/limestone)
Sand shoal
Sand
Silt
Shoreline reef
Offshore intertidal reef
Pelagic
LEGEND
Beach
Beach + Rocky Shore
Inlet Closure
Rocky Shore
Scale in Kilometers
5 0 5 10 15 20
Locality Map
Study Area Locality
Perth
N
W
E
S
Scale in Kilometers
5 0 5 10 15 20
33°30'S
33°45'S
34°00'S
34°15'S
115°00'E
115°15'E
115°30'E
15'
45'

Figure ??. ?????

Wildlife Interaction in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

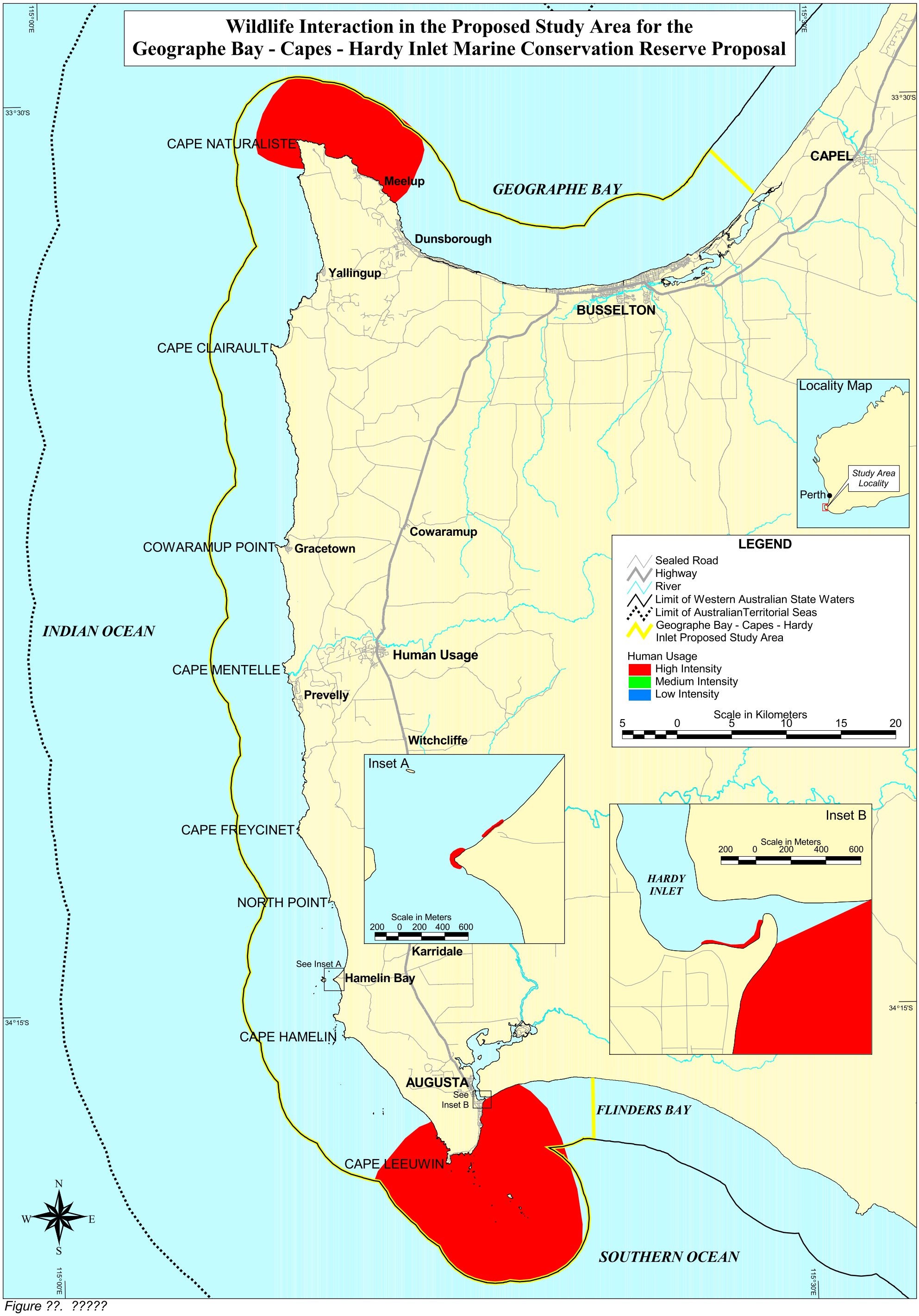


Figure ??. ?????

Jetskiing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

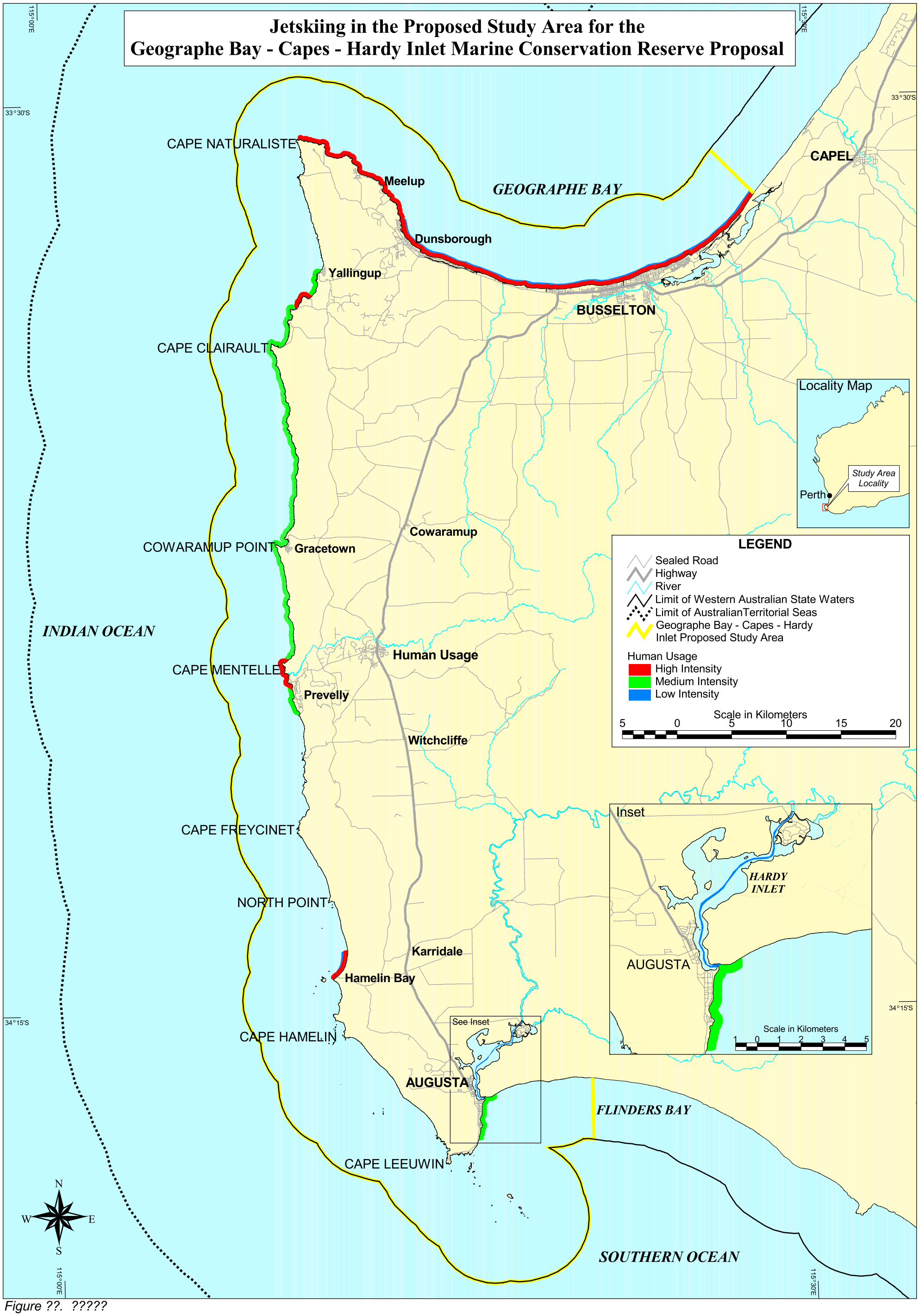


Figure ??. ?????

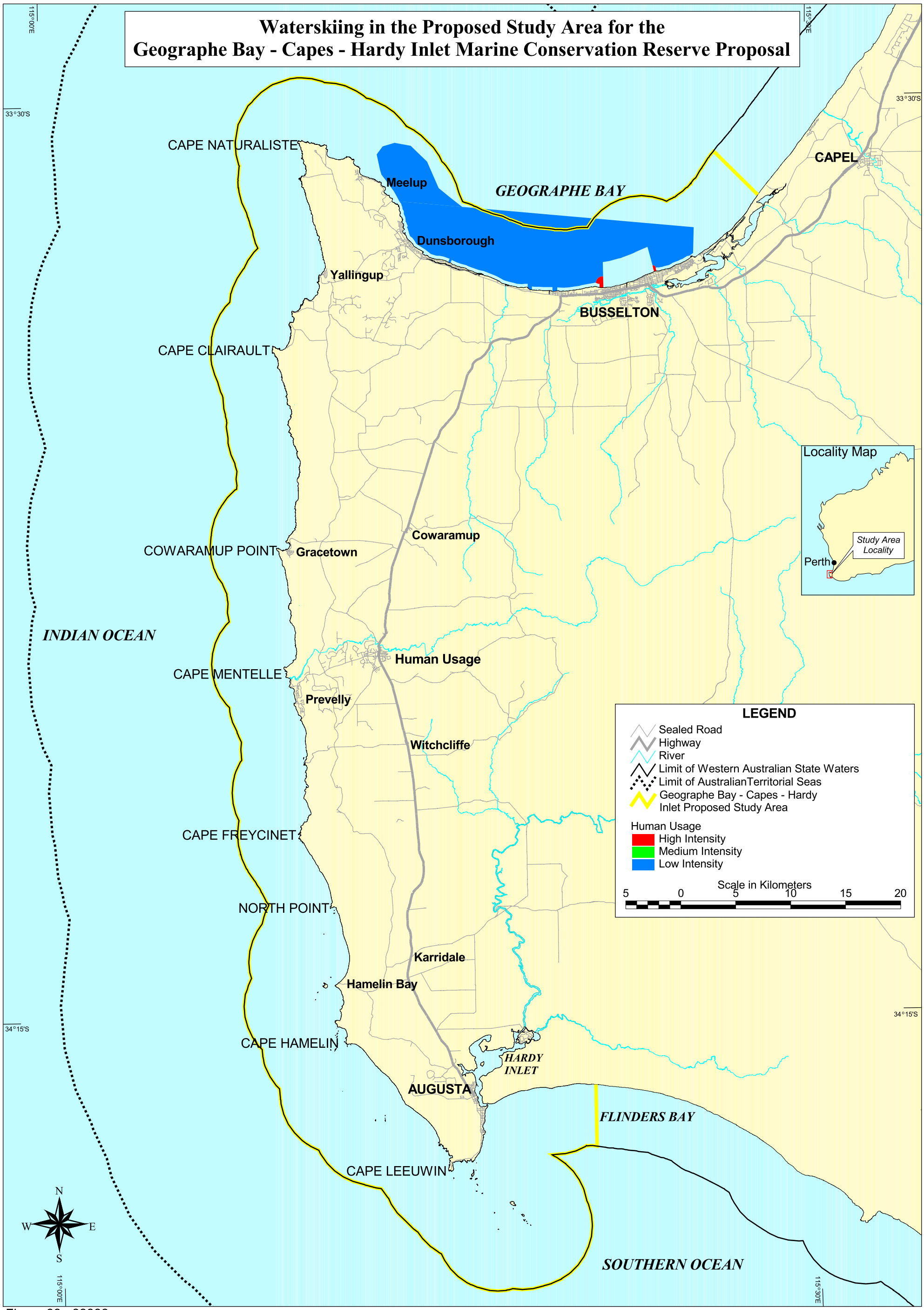
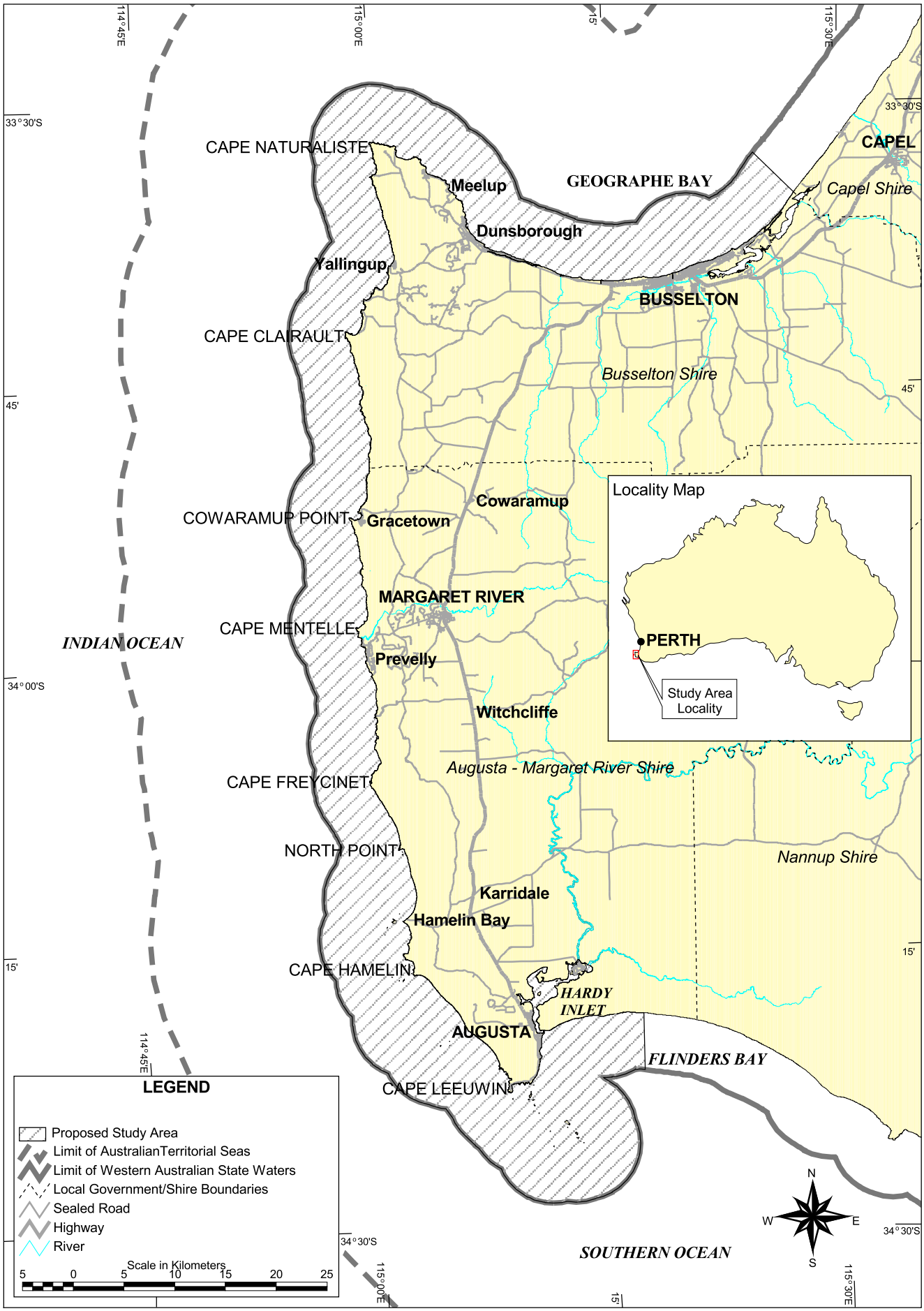

Waterskiing in the Proposed Study Area for the
Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal
115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
CAPE CLAIRAULT
COWARAMUP POINT
CAPE MENTELLE
CAPE FREYCINET
NORTH POINT
CAPE HAMELIN
CAPE LEEUWIN
INDIAN OCEAN
GEOGRAPHE BAY
FLINDERS BAY
SOUTHERN OCEAN
HARDY INLET
Meelup
Dunsborough
Yallingup
BUSSELTON
CAPEL
Cowaramup
Gracetown
Human Usage
Prevelly
Witchcliffe
Karridale
Hamelin Bay
AUGUSTA
Locality Map
Study Area Locality
Perth
LEGEND
Sealed Road
Highway
River
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Human Usage
High Intensity
Medium Intensity
Low Intensity
Scale in Kilometers
5 0 5 10 15 20
N
W
E
S

Figure ??. ?????


CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
CAPEL
Capel Shire
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
Busselton Shire
Cowaramup
COWARAMUP POINT
Gracetown
MARGARET RIVER
CAPE MENTELLE
INDIAN OCEAN
Prevelly
Witchcliffe
Augusta - Margaret River Shire
CAPE FREYCINET
NORTH POINT
Nannup Shire
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
Locality Map
PERTH
Study Area Locality
LEGEND
Proposed Study Area
Limit of AustralianTerritorial Seas
Limit of Western Australian State Waters
Local Government/Shire Boundaries
Sealed Road
Highway
River
Scale in Kilometers
5 0 5 10 15 20 25
N
W
E
S
33°30'S
34°00'S
34°30'S
114°45'E
115°00'E
115°30'E
45'
15'

Surfing in the Proposed Study Area for the Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal

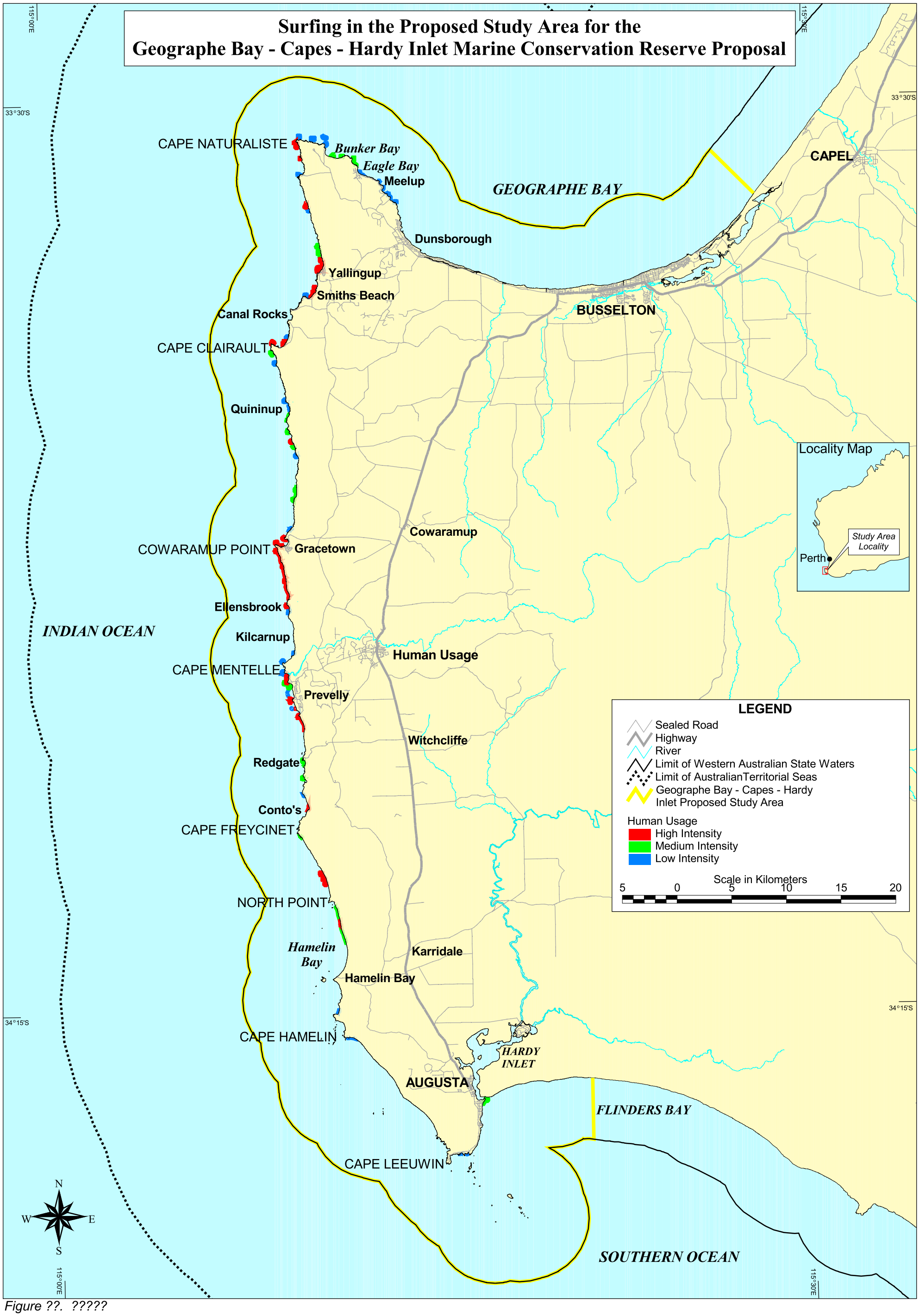


Figure ??. ?????

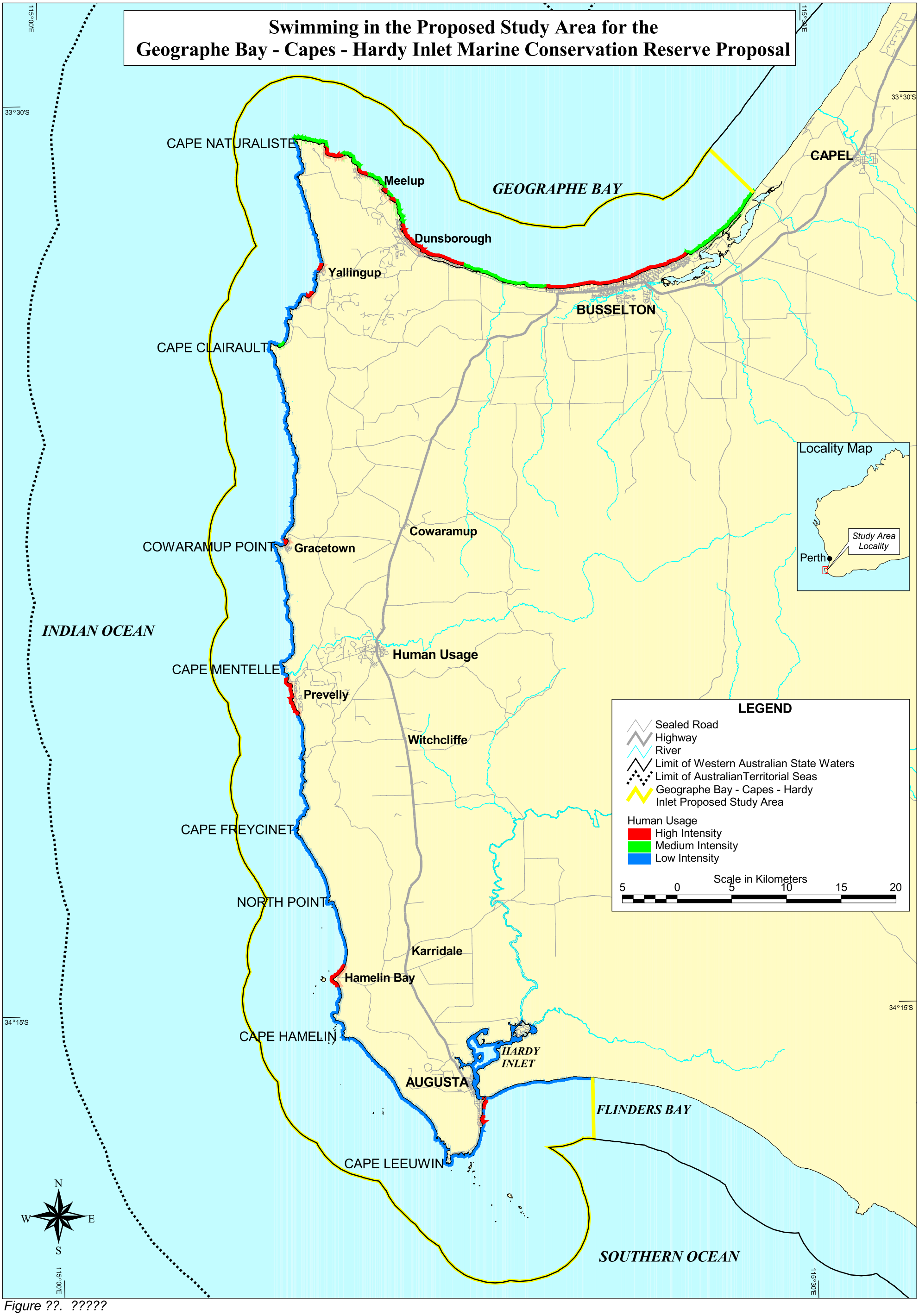

Swimming in the Proposed Study Area for the
Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal
115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
Dunsborough
CAPEL
Yallingup
BUSSELTON
CAPE CLAIRAULT
Cowaramup
COWARAMUP POINT
Gracetown
INDIAN OCEAN
Human Usage
CAPE MENTELLE
Prevelly
Witchcliffe
CAPE FREYCINET
NORTH POINT
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
N
W
E
S
Locality Map
Study Area Locality
Perth
LEGEND
Sealed Road
Highway
River
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Human Usage
High Intensity
Medium Intensity
Low Intensity
Scale in Kilometers
5 0 5 10 15 20

Figure ??. ?????

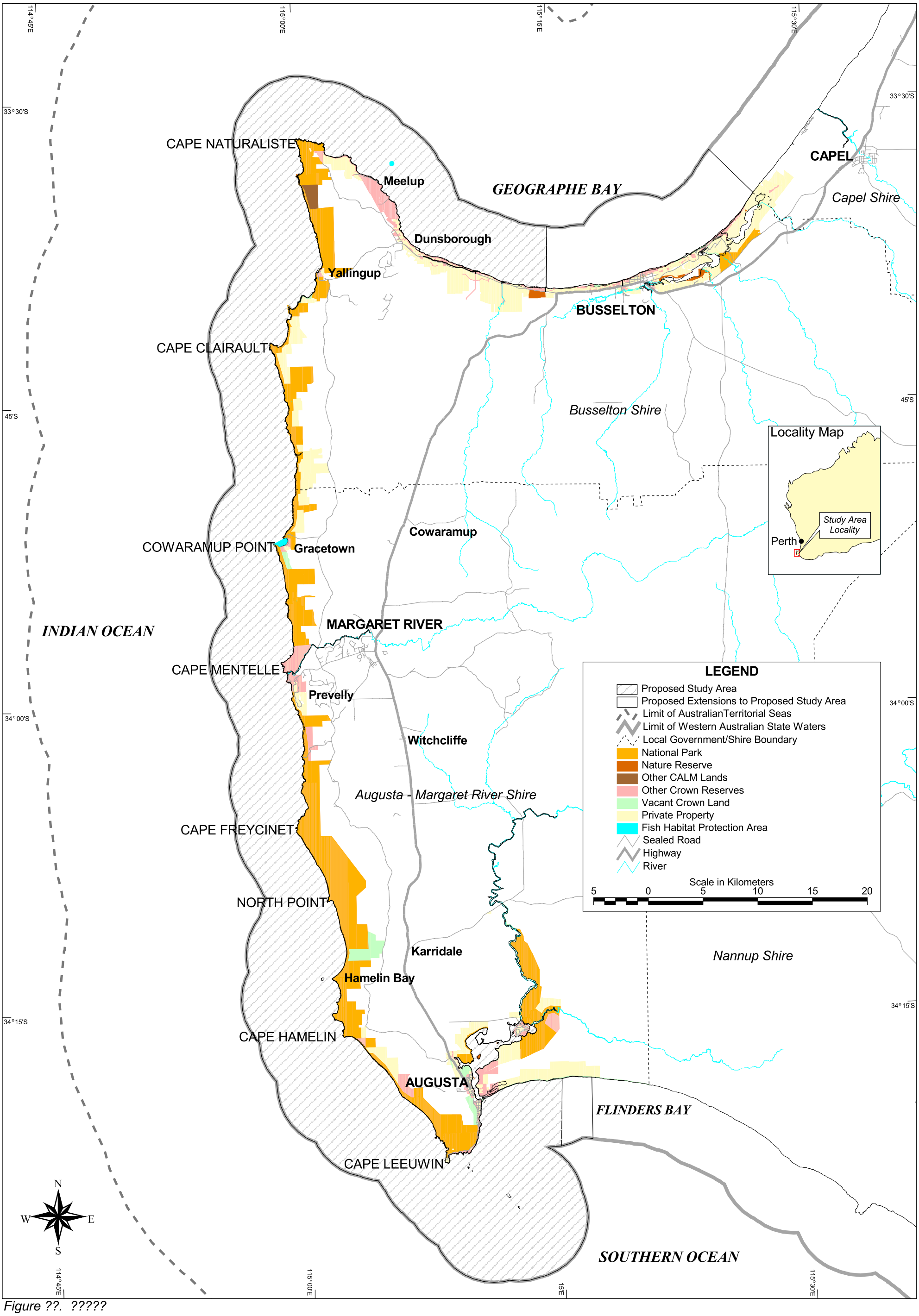

114°45'E
115°00'E
115°15'E
115°30'E
33°30'S
45'S
34°00'S
34°15'S
CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
CAPEL
Capel Shire
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
Busselton Shire
Locality Map
Study Area Locality
Perth
Cowaramup
COWARAMUP POINT
Gracetown
MARGARET RIVER
INDIAN OCEAN
CAPE MENTELLE
Prevelly
Witchcliffe
Augusta - Margaret River Shire
CAPE FREYCINET
NORTH POINT
Karridale
Nannup Shire
Hamelin Bay
CAPE HAMELIN
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
N
W
E
S
LEGEND
Proposed Study Area
Proposed Extensions to Proposed Study Area
Limit of AustralianTerritorial Seas
Limit of Western Australian State Waters
Local Government/Shire Boundary
National Park
Nature Reserve
Other CALM Lands
Other Crown Reserves
Vacant Crown Land
Private Property
Fish Habitat Protection Area
Sealed Road
Highway
River
Scale in Kilometers
5 0 5 10 15 20

Figure ??. ?????

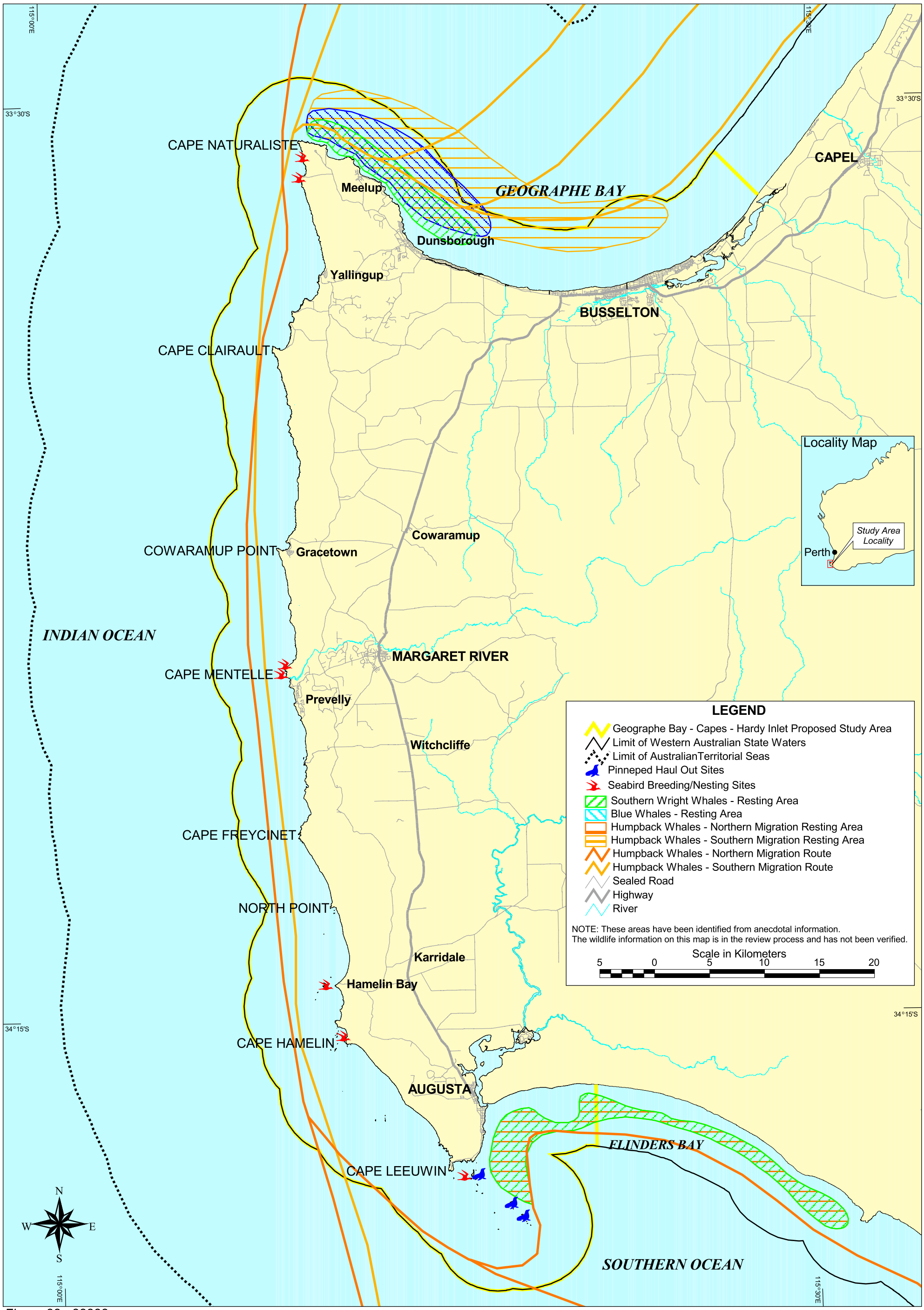

115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
Dunsborough
CAPEL
Yallingup
BUSSELTON
CAPE CLAIRAULT
Cowaramup
COWARAMUP POINT
Gracetown
INDIAN OCEAN
MARGARET RIVER
CAPE MENTELLE
Prevelly
Witchcliffe
CAPE FREYCINET
NORTH POINT
Karridale
Hamelin Bay
CAPE HAMELIN
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
N
W
E
S
Locality Map
Study Area Locality
Perth
LEGEND
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Pinneped Haul Out Sites
Seabird Breeding/Nesting Sites
Southern Wright Whales - Resting Area
Blue Whales - Resting Area
Humpback Whales - Northern Migration Resting Area
Humpback Whales - Southern Migration Resting Area
Humpback Whales - Northern Migration Route
Humpback Whales - Southern Migration Route
Sealed Road
Highway
River
NOTE: These areas have been identified from anecdotal information.
The wildlife information on this map is in the review process and has not been verified.
Scale in Kilometers
5 0 5 10 15 20

Figure ??. ?????

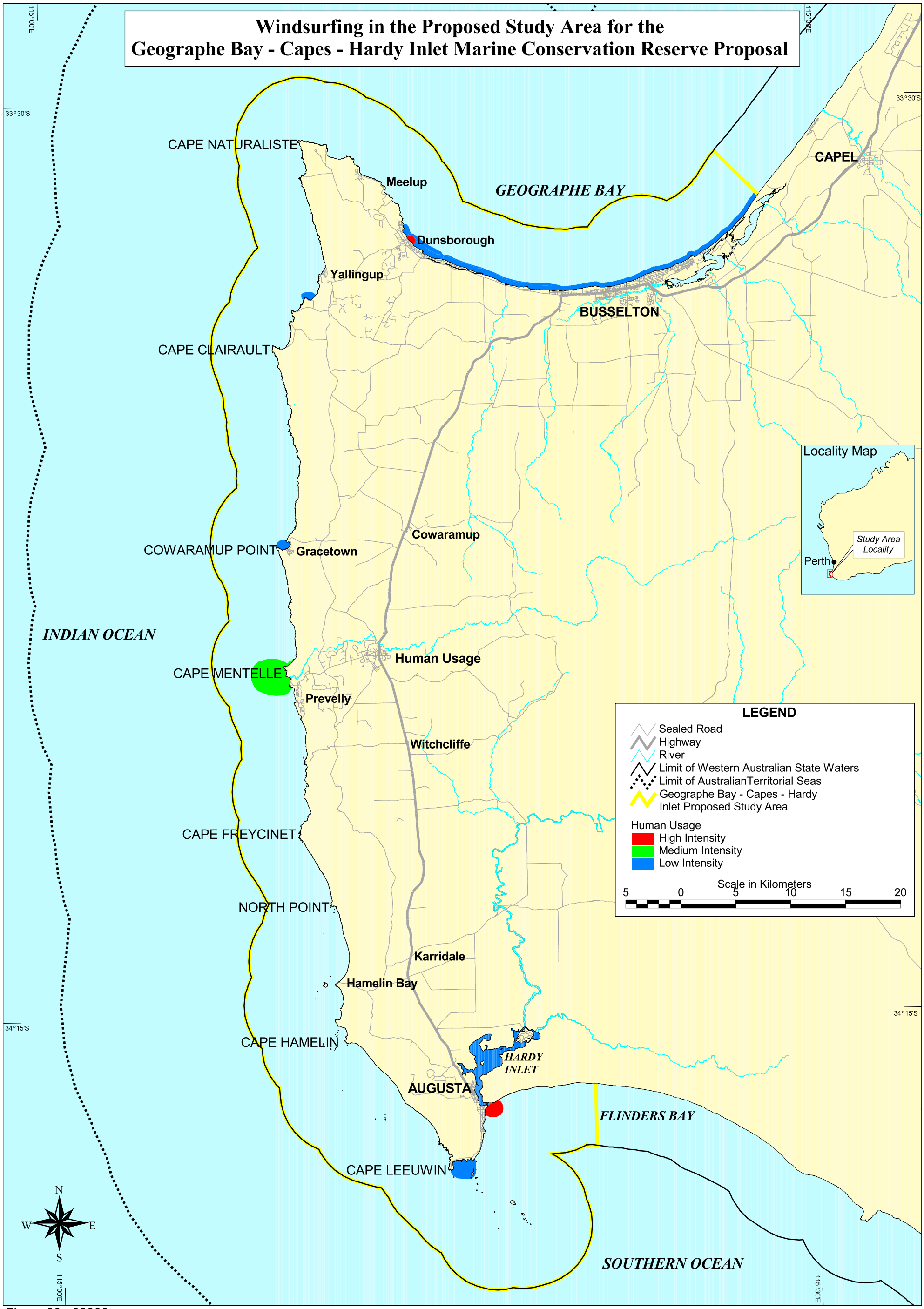

Windsurfing in the Proposed Study Area for the
Geographe Bay - Capes - Hardy Inlet Marine Conservation Reserve Proposal
115°00'E
115°30'E
33°30'S
34°15'S
CAPE NATURALISTE
Meelup
GEOGRAPHE BAY
CAPEL
Dunsborough
Yallingup
BUSSELTON
CAPE CLAIRAULT
Cowaramup
COWARAMUP POINT
Gracetown
INDIAN OCEAN
Human Usage
CAPE MENTELLE
Prevelly
Witchcliffe
CAPE FREYCINET
NORTH POINT
Karridale
Hamelin Bay
CAPE HAMELIN
HARDY INLET
AUGUSTA
FLINDERS BAY
CAPE LEEUWIN
SOUTHERN OCEAN
Locality Map
Study Area Locality
Perth
LEGEND
Sealed Road
Highway
River
Limit of Western Australian State Waters
Limit of AustralianTerritorial Seas
Geographe Bay - Capes - Hardy Inlet Proposed Study Area
Human Usage
High Intensity
Medium Intensity
Low Intensity
Scale in Kilometers
5 0 5 10 15 20
N
W
E
S

Figure ??. ?????