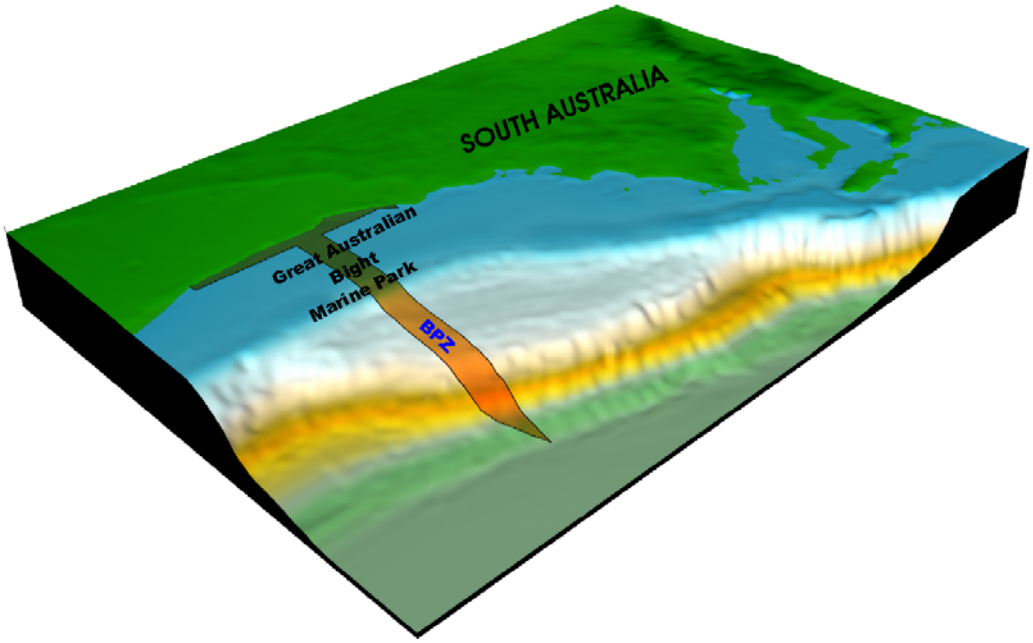
BENTHIC PROTECTION ZONE OF THE GREAT AUSTRALIAN BIGHT MARINE PARK: 1. LITERATURE REVIEW



L.J. McLeay, S.J. Sorokin, P.J. Rogers and T.M. Ward

December 2003

South Australian Research and Development Institute (Aquatic Sciences)
PO Box 120, Henley Beach,
South Australia 5022

Final Report to
National Parks and Wildlife South Australia and the
Commonwealth Department of the Environment and Heritage

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

Government of South Australia

DEPARTMENT FOR environment and heritage

ISBN 0 7308 5305 5

Benthic Protection Zone of the Great Australian Bight Marine Park: 1 Literature Review

Report to Department of Environment and Heritage

Authors: McLeay, L.J., Sorokin, S.J., Rogers, P.J. and Ward, T.M.

South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8200 2400
Facsimile: (08) 8200 2406
http://www.sardi.sa.gov.au

Printed in Adelaide December 2003.

Authors:	McLeay, L.J., Sorokin, S.J., Rogers, P.J. and Ward, T.M.
Reviewers:	Dr Scoresby Shepherd and Dr Keith Jones
Approved by:	Professor Anthony Cheshire

Signed:

Date:	December 2003
Distribution:	South Australian Department of Environment and Heritage, Commonwealth Department of Environment and Heritage, Consultative Committee of the GABMP, SARDI Aquatic Sciences Library
Circulation:	Public Domain
ISBN:	7308 5305 5

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The National Heritage Trust, National Parks and Wildlife South Australia and the Commonwealth Department of Environment and Heritage provided funding to support this project. SARDI Aquatic Sciences provided significant additional funding and substantial in-kind support.

We thank the numerous people that assisted us to collect the information for this review. Ms Suzanne Bennett (SARDI Aquatic Sciences) helped us to obtain many resources. Mr Paul Van Ruth (SARDI Aquatic Sciences and Adelaide University) provided information on oceanographic processes and primary productivity. Dr Keith Jones (SARDI Aquatic Sciences) provided sea-surface temperature maps of southern Australia. Mr Trevor Gilbert from the Australian Maritime Safety Authority provided an image of the shipping routes of southern Australia. Ms Evelina Paraschivoiu (Petroleum and Energy, Primary Industries and Resources of South Australia) supplied information on mineral exploration activities in the GAB. Ms Suyin Deakin (SARDI Aquatic Sciences) obtained numerous documents and assisted with the development of the reference database and the bibliography.

Mr Peter Graham (Commonwealth Department of Environment and Heritage) and Mr Simon Clark (South Australian Department of Environment and Heritage) commented on drafts of the report. The review was formally reviewed by Dr Scoresby Shepherd and Dr Keith Jones (SARDI Aquatic Sciences) and approved for release by Professor Anthony Cheshire (Chief Scientist, SARDI Aquatic Sciences).

EXECUTIVE SUMMARY

1. This literature review was conducted to assist the development of a performance assessment system for the Benthic Protection Zone (BPZ) of the Great Australian Bight Marine Park (GABMP). It summarises past and current research in the Great Australian Bight (GAB) and synthesises oceanographic, physiochemical, biological and ecological information for the region. It also identifies additional data that are required to assess the status of benthic communities within the GABMP.

2. The Great Australian Bight (GAB) extends from Cape Pasley in Western Australia to Cape Catastrophe, Eyre Peninsula in South Australia. It is unique, having the world's longest southern-facing coastline, being adjacent to the only circumpolar ocean and including a continental shelf that is up to 260 km wide.

3. Meteorological and oceanographic processes in the GAB are complex: the Flinders Current travels northwest along the continental slope throughout the year and the Leeuwin Current intrudes into surface waters of the western and central Bight during early winter. An anti-clockwise surface gyre develops over the shelf during summer and autumn, whereas shelf currents flow towards the southeast during winter. Southeasterly winds during summer and autumn favour upwelling and assist the movement of water from the Flinders Current onto and across the shelf. Westerly winds during winter favour downwelling. During this period shelf waters are well mixed and comprised of warm saline water that develops in the western GAB during summer and autumn and intrudes from the west as the Leeuwin Current during early winter.

4. Upwelling events during summer and autumn produce cool patches of surface water along the coast of the southern Eyre Peninsula. These patches contain elevated nutrient concentrations and support enhanced levels of primary productivity. High densities of zooplankton to the northwest of the patches indicate that the prevailing southeasterly winds transport the products of this enhanced biological production into the central GAB. These plankton communities support the highest densities of small planktivorous fishes, including sardine and anchovy, in Australian waters. Juvenile southern bluefin tuna (SBT) migrate into the GAB annually to feed on these rich pelagic resources.

5. Limestone cliffs dominate the western coastline and the eastern GAB is characterised by an array of cliffs, scattered islands, headlands and large embayments. The continental shelf is an almost featureless plain that slopes out to the shelf break, which occurs at a depth of 125-165 m. Sediments are comprised mainly of relict calcareous Pleistocene sands and

modern biofragments. The inner shelf is located in depths of up to ~50 m and comprises modern biofragments, rhodolith gravel and quartz sand. The middle shelf is located between 50 and 120 m and consists of intraclasts, mollusc shells and bryozoan skeletons. The outer shelf and upper slope are comprised of bryozoan sediments. Below 300 m spiculitic mud is dominant. Shelf sediments of the central and eastern GAB have been divided into eight facies.

6. The "Interim Marine and Coastal Regionalisation of Australia (IMCRA)" suggests the GAB includes one pelagic and three demersal provinces. The Southern Pelagic Province is comprised mainly of temperate species, although its western edge is the southern limit of some tropical pelagic taxa. The western GAB forms part of the South Western Province, which includes warm temperate species, widely distributed species that extend eastward into Bass Strait and eurythermal species that occur as far north as central Western Australia. The GAB demersal biotone is dominated by species from the South Western Province and the Gulfs Province. This biotone also includes a group of wide-ranging western, warm temperate species that extend eastward to the coast of Victoria and ubiquitous temperate Australian species. The western margin of the Gulfs Province comprises almost one third of the eastern GAB and includes small quantities of endemic and subtropical relict species and cool temperate species that have distributions that extend into southern Victoria and Tasmania.

7. The IMCRA classification suggests that high biodiversity in the GAB may be explained by the presence of temperate species with eastern and western affinities, as well as "tropical stragglers" from northern regions. However, patterns of diversity vary between taxa. Mangroves are poorly represented due to the lack of estuaries. Seagrasses are confined mainly to sheltered bays and the lees of reefs and islands due to the frequent disturbance of inshore habitats by large swells. In contrast, the macroalgal assemblage of the GAB is one of the world's most diverse and includes >1200 species. Over 90% of species in most invertebrate groups are endemic to southern Australia, but the proportion that is confined to the GAB is unknown. Some data are available on the species composition of inter-tidal and sub-tidal invertebrate assemblages of the GAB, but there have been few studies of the invertebrates of the shelf. For example, taxonomic experts consulted during this study suggest that hundreds of undescribed species of macroinvertebrates occur in the GAB.

8. The fish fauna of the GAB is better known than the invertebrate assemblage. Approximately 370 of the 600 fish species that occur in southern Australia have been recorded in SA. Several species, including the coastal stingaree (*Urolophus orarius*) and

crested threefin (*Norfolkia cristata*), are restricted to South Australia and occur in the GAB. The patterns of distribution and abundance of fishes in the GAB are poorly understood.

9. The GAB provides critical habitat for two species of marine mammals that are recognised internationally as being priorities for conservation. The southern right whale (*Eubalaena australis*), which is listed as 'endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, breeds at the Head of Bight during winter. The Australian sea lion (*Neophoca cinerea*), which is endemic to Australia and is currently listed as "near threatened", breeds in small colonies along the cliffs of the GAB.

10. Approximately 1.4-1.6 million pairs of seabirds belonging to at least 16 species breed in South Australia. Greater than 75% of these occur in the eastern GAB, including ~1.3 million pairs of short-tailed shearwaters (*Puffinus tenuirostris*) and white-faced storm petrels (*Pelagodroma marina*). Other important species include the little penguin (*Eudyptula minor*), which is endemic to southern Australia and New Zealand, and the osprey (*Pandion haliaetus*), which nests on the GAB cliffs.

11. The Great Australian Bight (GAB) supports five Commonwealth fisheries and six major (and several minor) South Australian fisheries. The main Commonwealth fisheries that operate near the GABMP are the GAB Trawl Fishery, SBT Fishery and the Gillnet Hook and Trap Fishery (formerly the Southern Shark Fishery). The main South Australian fisheries that operate near the GABMP are the Northern Zone Rock Lobster Fishery, Western Zone Rock Abalone Fishery and Marine Scalefish Fishery.

12. Relatively few other human activities occur in the central GAB. Few commercial ships pass through the GABMP. Exploratory drilling for petroleum commenced in the GAB in 2003 and may increase in the future. The main marine-based tourist activities in the central GAB are recreational beach fishing and observing southern right whales within the GABMP from the Nullarbor Cliffs.

13. The aim of the BPZ is to preserve a representative sample of the sediments and benthic biota of the GAB. However, virtually no information is available to assess the effectiveness of the BPZ in either representing or preserving the benthic communities of the GAB. Quantitative data on the species composition of benthic communities in the GAB and effective monitoring of anthropogenic activities undertaken in and around the GABMP are prerequisites for the development of systems for assessing the performance of the BPZ.

GLOSSARY

BPZ	Benthic Protection Zone
CARS	CSIRO Atlas of Regional Seas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPBCA	Environmental Protection and Biodiversity Conservation Act 1999
EPP	Exploration Petroleum Permits
EUC	Eucla Region
EYR	Eyre Region
GAB	Great Australian Bight
GABB	Great Australian Bight Biotone
GABMP	Great Australian Bight Marine Park
GABTF	Great Australian Bight Trawl Fishery
GHTF	Gillnet Hook and Trap Fishery
GULF P	Gulfs Province
ITQ	Individual Transferable Quota
MAFRI	Marine and Freshwater Resources Institute
MMPZ	Marine Mammal Protection Zone
MSF	Marine Scalefish Fishery
MUR	Murat Region
NZRLF	Northern Zone Rock Lobster Fishery
PAS	Performance Assessment System
PSLA	Petroleum (Submerged Lands) Act 1967
SA	South Australia
SARDI	South Australian Research and Development Institute
SBTF	Southern Bluefin Tuna Fishery
SPP	Southern Pelagic Province
SST	Sea surface temperature
SWB	South West Biotone
SWP	South Western Province
TAC	Total Allowable Catch
VMS	Vessel monitoring systems
WA	Western Australia
WSC	Western Australia South Coast Region

1. INTRODUCTION

1.1 General Background

This literature review is the first in a series of three reports by SARDI Aquatic Sciences on the Benthic Protection Zone (BPZ) of the Great Australian Bight Marine Park (GABMP). It synthesises background information for the Great Australian Bight (GAB) to assist the development of a Performance Assessment System for the BPZ.

The GAB extends from Cape Pasley in Western Australia to Cape Catastrophe on Eyre Peninsula in South Australia (Fig. 1). The GAB is unique, having the world's longest southern-facing coastline, being adjacent to the only circumpolar ocean and including a continental shelf that is up to 260 km wide.

The GAB has international significance for ecologists and conservationists, as it supports high levels of biodiversity, numerous species that are endemic to southern Australia and several threatened and endangered species. The high level of biodiversity in the GAB may be explained by the presence of both western, warm temperate species and cool temperate species common to southern Victoria and Tasmania. A suite of ubiquitous temperate Australian species and a small number of locally endemic and subtropical relict species also occur in the GAB. As the GAB is linked to the tropics via the Leeuwin Current, which intrudes from the west during winter, numerous "tropical stragglers" also periodically visit South Australian waters (Shepherd 1991).

The GAB includes critical habitats for several species of marine mammals and seabirds with international conservation significance, including breeding grounds of the southern right whale (*Eubalaena australis*) and Australian sea lion (*Neophoca cinerea*).

The GAB region supports several economically valuable commercial fisheries, including the Commonwealth GAB Trawl, Gillnet Hook and Trap (formerly Southern Shark) and Southern Bluefin Tuna Fisheries and the South Australian Northern Zone Rock Lobster, Western Zone Abalone, Marine Scalefish and Sardine Fisheries, which had a combined value of over A$400M in 2001/02. The Commonwealth fishery for southern bluefin tuna (SBT) also supports the South Australian tuna mariculture industry that was valued at over A$260M in 2002.

There is significant potential for petroleum production in the GAB, and the region has the potential to support other mineral exploration activities (Edyvane 1998). Exploratory drilling for petroleum commenced in the GAB Basin in deep-water 320 km southwest of Ceduna in 2003. The major marine based tourist activities in the GAB are recreational fishing along the region's beaches and observing southern right whales from the Nullarbor cliffs.

1.2 Great Australian Bight Marine Park

The Great Australian Bight Marine Park (GABMP) was established through a series of proclamations under State and Commonwealth legislation in recognition of the region's global conservation significance. The GABMP Whale Sanctuary was established in 1995 under the South Australian *Fisheries Act 1982*. In 1996 the GAB Marine National Park (State Waters) was proclaimed under the South Australian *National Parks and Wildlife Act 1972*, followed in 1998 by the proclamation of the GABMP (Commonwealth Waters) under the Commonwealth *National Parks and Wildlife Conservation Act 1975* (Repealed).

The GABMP aims to protect and maintain current levels of biodiversity while providing for ecologically sustainable use of marine resources. The GABMP is divided into four management zones that offer different levels of protection at different times of the year. The 'Sanctuary Zone' (State Waters), 'Conservation Zone' (State Waters) and 'Marine Mammal Protection Zone' (Commonwealth Waters) primarily protect the breeding grounds of the southern right whale (*E. australis*) and Australian sea lion (*N. cinerea*) (Fig. 2).

The Benthic Protection Zone (BPZ, Commonwealth Waters) encloses a 20 nautical mile wide strip of ocean, orientated North-South, which extends three nautical miles from the coast to the edge of the Australian Exclusive Economic Zone, approximately 200 nautical miles offshore (Fig. 2, Table 1). The objectives of the BPZ are twofold: (1) to protect the ecological integrity of a large, representative sample of the GAB's unique and diverse benthic flora and fauna and (2) to provide an undisturbed "sample" of the GAB's benthic habitat that can be used as a reference area for comparison with neighbouring zones that may have been disturbed by trawling or mineral exploration. Demersal trawling is prohibited within the BPZ due to the potential impacts on benthic communities. Applications to conduct mineral exploration in the BPZ are considered by the Commonwealth Government in consultation with the manager of the Marine Park on a case-by-case basis (Table 1).

Scientific information is a prerequisite for the establishment of a multiple use framework for the BPZ that balances economic and social uses with ecological objectives. The GABMP Plan, Part B (Edyvane 1998), provides a review of the Park's resources and information to support the establishment of the Marine Mammal Protection Zone, but not the establishment of the BPZ. Although the report discusses the regional setting, physical features (climate, bathymetry, oceanography, geology and geomorphology), and biological values of flora and fauna (particularly marine mammals), and outlines commercial (fisheries, shipping and mineral and petroleum exploration), recreational (whale watching, recreational fishing) and cultural values, few references are made to benthic communities within the Park.

1.3 Aim and objectives

The aim of this literature review is to provide background information to assist the development of a Performance Assessment System (PAS) for the BPZ of the GABMP. Where relevant, parts of Edyvane (1998) are, for the purpose of completeness, summarised within this review. The objectives of the review are:

1. To collate and synthesise oceanographic, physiochemical, biological and ecological information for the GABMP and surrounding areas.
2. To summarise past and current research in the GABMP and surrounding areas, including unpublished data and reports.
3. To identify additional data that are required to comprehensively describe and assess the status of benthic communities within the GABMP.

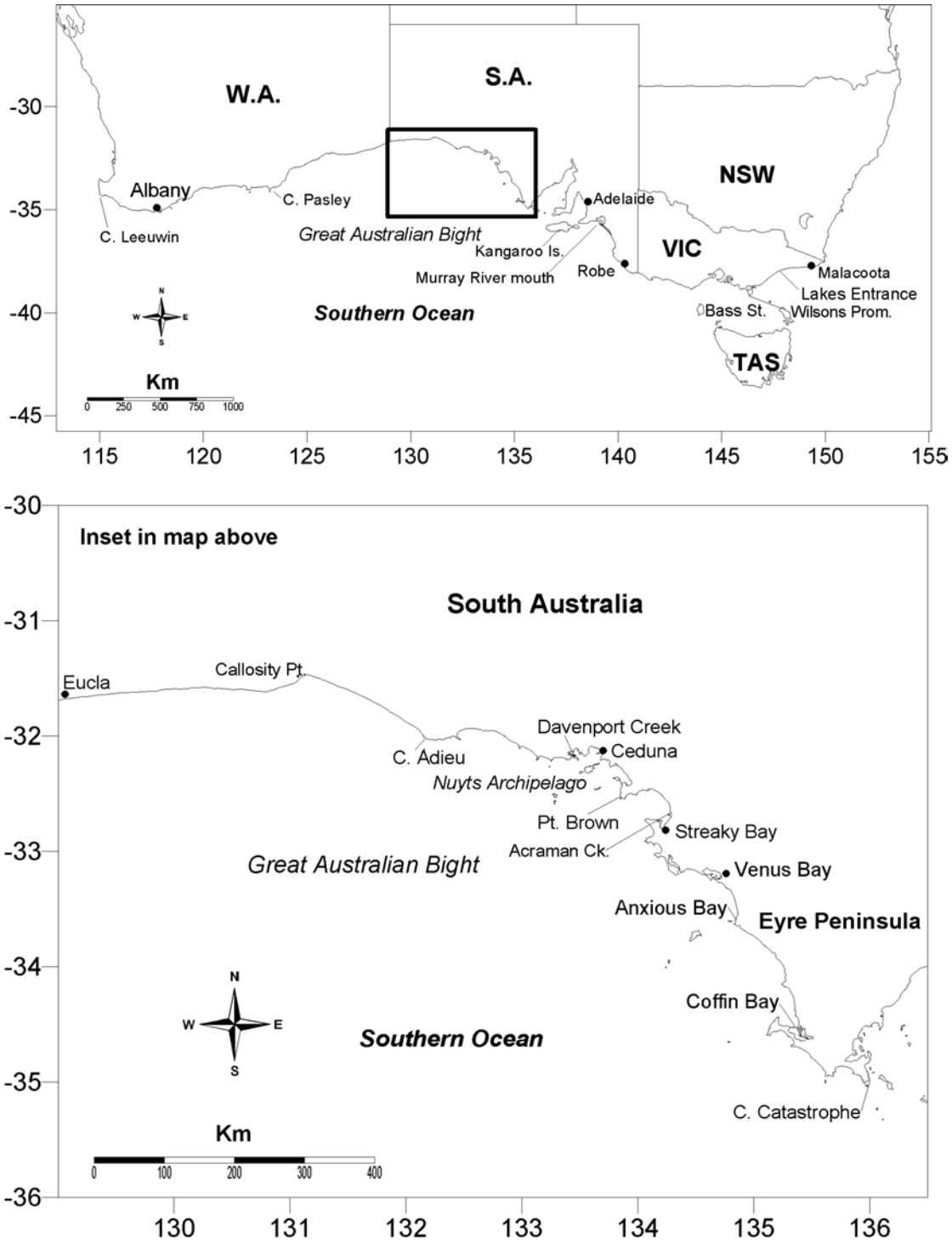


Figure 1. Locations in southern Australia and the GAB referred to in this review.

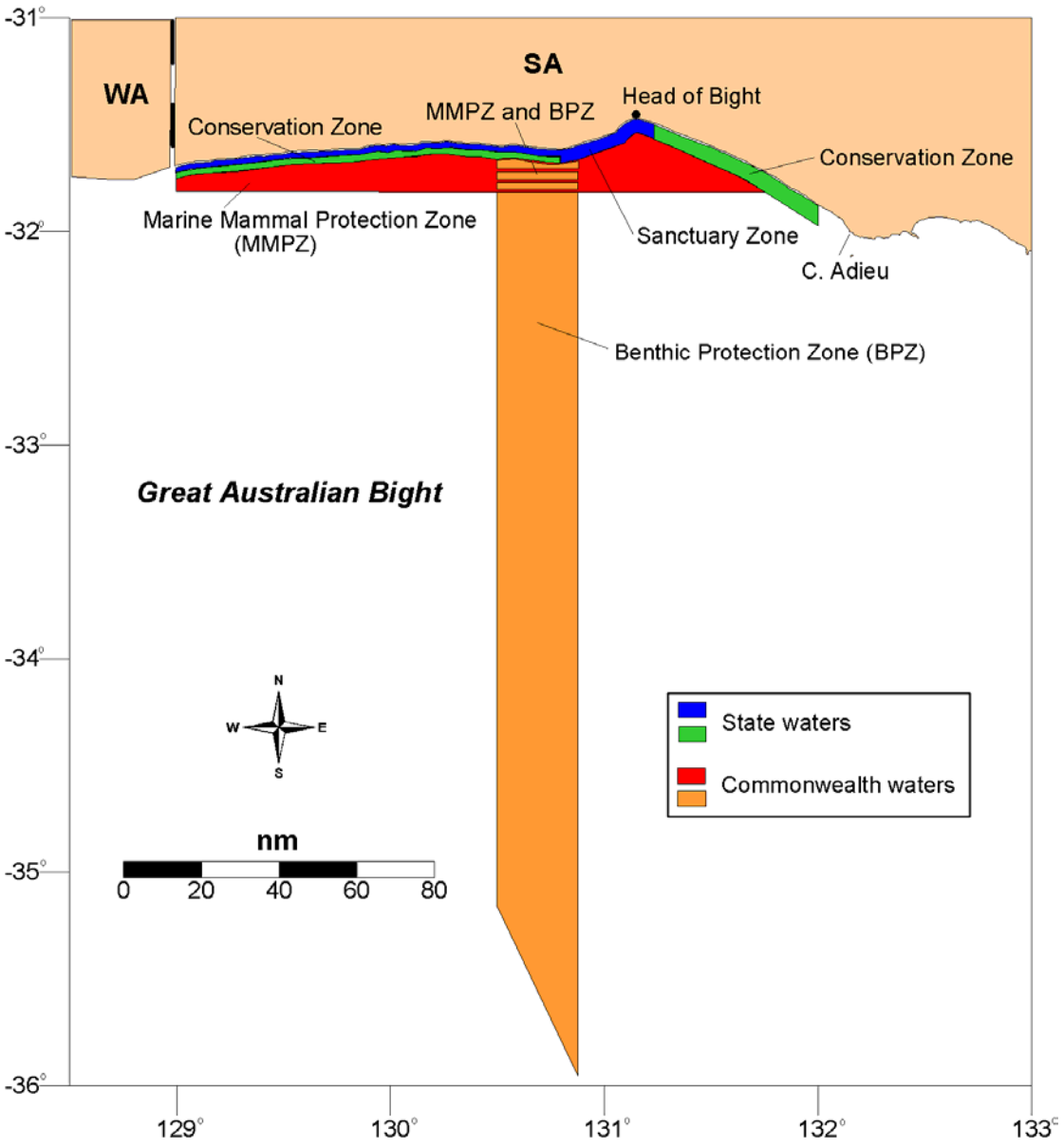


Figure 2. Location of the Great Australian Bight Marine Park and the Benthic Protection Zone.

Table 1. Main regulation of key uses in each zone of the Great Australian Bight Marine Park (colours of text match those for zones in Fig. 2). Additional Commonwealth and State regulations apply to the various types of activities that could occur in the GABMP (DEH website 2003a).

	Sanctuary Zone (whales and sea lions)	Conservation Zones East and West	Marine Mammal Protection Zone	Benthic Protection Zone
Access to Vessels	Not permitted	Prohibited from May 1 to October 31	Prohibited from May 1 to October 31	Permitted except for overlapped area with MMPZ which is closed from May 1 to October 31
Mining and Exploration	Not permitted	Prohibited from May 1 to October 31	Not permitted	Approval granted by the Governor General on a case by case basis
Cetaceans	Aircraft must fly >1000 ft from May 1 to October 31	Vessel/aircraft speed and proximity regulations apply	Vessel/aircraft speed and proximity regulations apply	Vessel/aircraft speed and proximity regulations apply
Demersal trawling	Not permitted	Prohibited from May 1 to October 31	Not permitted	Not permitted
Commercial fishing (other)	Not permitted	Prohibited from May 1 to October 31	Prohibited from May 1 to October 31	Permitted except for overlapped area with MMPZ which is closed from May 1 to October 31
Recreational fishing	Shore based line fishing only	Shore based line fishing only	Subject to management plan	Subject to management plan
Other activities	No facilities or structures available	No facilities or structures available	Interactions with marine mammals must be reported to the Director of National Parks through the Park Manager	Interactions with sea floor or associated benthic plants and animals must be reported to the Director of National Parks through the Park Manager

2. PHYSICAL FEATURES OF THE GREAT AUSTRALIAN BIGHT

2.1 Climate

Information on the climate of the GAB is summarised from Edyvane (1998). The coastal area of the western GAB has a semi-arid climate and rainfall occurs mostly in winter. Occasional heavy rainfall occurs in summer from low-pressure systems or cyclone remnants that originate in northern Australia. Similarly, the eastern GAB is characterised by hot, dry summers and cool winters.

In summer, high pressure systems move slowly across the GAB and generate moderate to fresh south to south-easterly winds and sea-breezes (Fig. 3). In winter, the high pressure systems are pushed north over the continent by constant low pressure cells that form off the Antarctic continent. These systems typically generate strong to gale force north-westerly to south-westerly winds (Fig. 3). Mean monthly air temperatures in Ceduna range from 28°C in January to 17°C in July (Edyvane 1998).

2.2 Oceanography

Oceanographic processes in the GAB are influenced by frequent gales and heavy seas in the Southern Ocean. The coastline is exposed to moderate to high-energy waves, has no true rivers and only a few intermittent streams (Edyvane 1998). Fine-scale measurements of temperature, salinity and oxygen for GAB waters are sparse. Broad-scale measurements are available in hydrographic datasets for southern Australia in the Commonwealth Scientific and Industrial Research Organisation Atlas of Regional Seas (CARS) (CSIRO website 2003). Seasonal sea-surface temperatures (SSTs) in the GAB typically range between 12 and 20˚C (Fig. 4) and salinities are often above 35. Tides are microtidal in range and predominantly semi-diurnal with a mean tidal range between 0.8 and 1.2 m (Edyvane 1998).

The oceanography of the GAB is complex. In winter, the Leeuwin Current carries warm (17-19°C) low salinity water from north-western Australia into the GAB (Rochford 1986; McGowran *et al.* 1997). The Flinders Current runs westward along the continental slope throughout the year and is the world's only northern boundary current (Bye 1972, 1983; Middleton and Cirano 2002). An anti-clockwise surface gyre develops over the shelf during summer and autumn, whereas shelf currents flow towards the southeast during winter (Provis and Lennon 1981; Hahn 1986, Fig. 5). The southeasterly winds that predominate during summer and autumn favour upwelling and assist the movement of slope water onto and across the shelf. Westerly winds during winter favour downwelling, and shelf waters during this period are well mixed and comprised of warm saline water that develops in the western GAB during summer and autumn, as well as warm low salinity water from the Leeuwin Current.

Upwelling during summer and autumn produces patches of cool surface water along the coast of the southern Eyre Peninsula between Cape Catastrophe and Cape Adieu (Middleton 2000; Ward and McLeay 1999; Ward *et al.* 2000, 2001, 2002a; Fig. 5). These patches contain elevated nutrient concentrations and support enhanced levels of primary productivity. High densities of zooplankton to the northwest of the patches indicate that the prevailing southeasterly winds transport the products of this enhanced biological production into the central GAB (Ward and McLeay 1999; Ward *et al.* 2000, 2001, 2002a). The CARS data contains estimates of nitrate, phosphate and silicate levels for southern Australian oceanic waters, however estimates for the GAB are uncertain (CSIRO website 2003).

2.2.1 Oceanographic Sectors

2.2.1.1 Baxter Sector

The Baxter Sector is the western-most part of the GAB (James *et al*. 2001; Fig. 6). Although affected by strong winter storm waves and surges, the shelf is semi-protected from south-westerly swells. In near-shore waters, SSTs reach a maximum of 22°C in spring and summer. This warm saline water extends offshore forming a strong thermocline that characterises the shelf throughout autumn. After autumn, the warm oligotrophic Leeuwin Current intrudes from the west occupying the entire outer shelf throughout winter and inshore waters cool significantly.

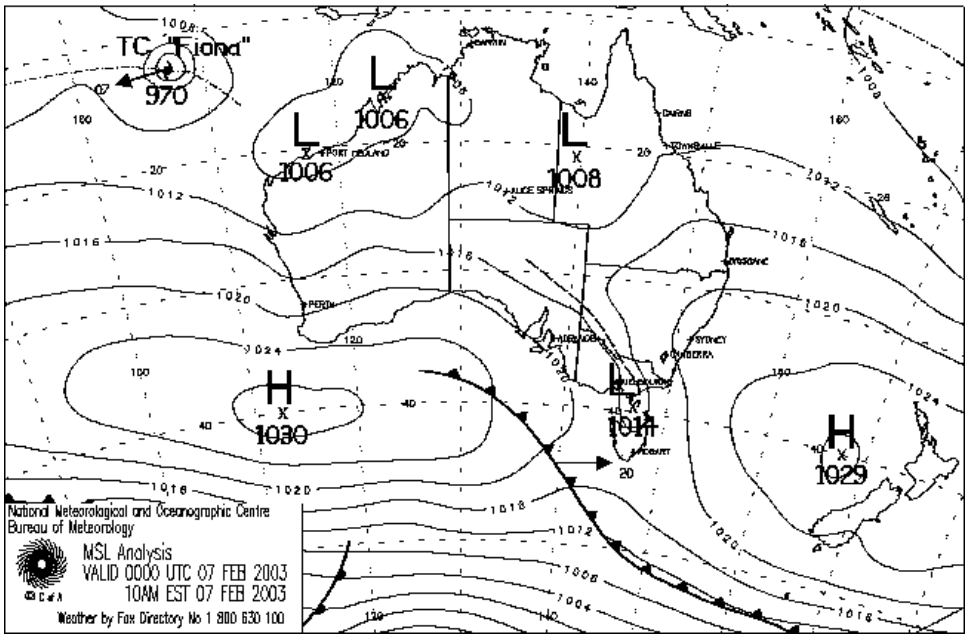
2.2.1.2 Eyre Sector

The Eyre Sector is fully exposed to winter storms and year-round south-westerly swells. Inshore waters warm during summer, with SSTs rising to >23°C (the warmest in the GAB), and salinity increases through evaporation. The water column is stratified in summer. In winter, inshore waters cool and the warm Leeuwin Current enters from the west to join with the GAB plume over the outer shelf and upper slope (James *et al.* 2001).

2.2.1.3 Ceduna Sector

The Ceduna Sector is directly exposed to south-westerly swells. Spring SSTs are similar to other sectors (~17°C). Cool, nutrient rich water intrudes onto the shelf during summer forming a strong thermocline across the shelf and reaching the surface in some coastal areas (Ward *et al.* 2000). Stratification of shelf waters weakens during late autumn and disappears during winter, as saline, nutrient-depleted water from the central GAB moves eastward.

a)



b)

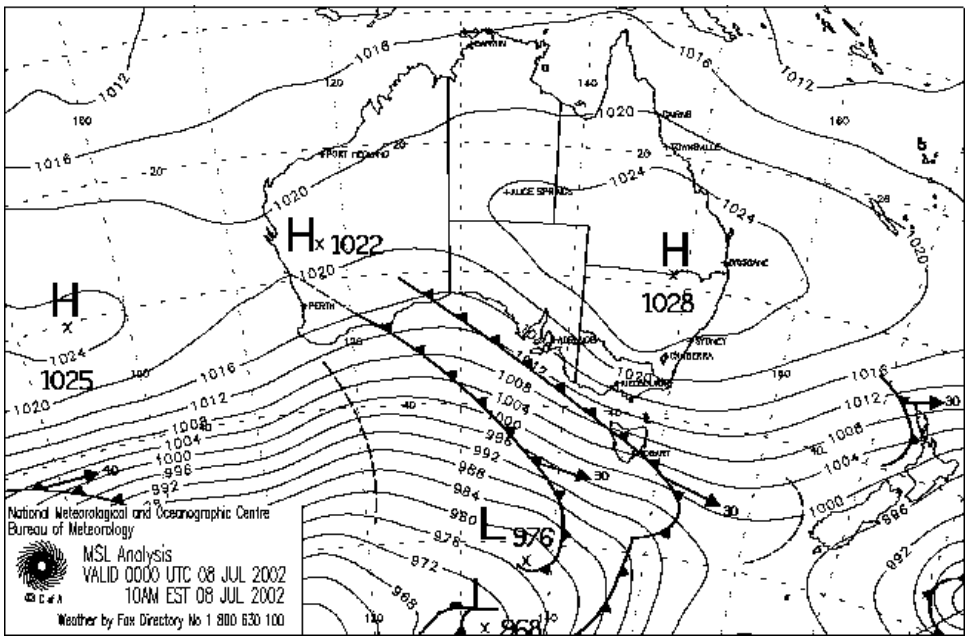
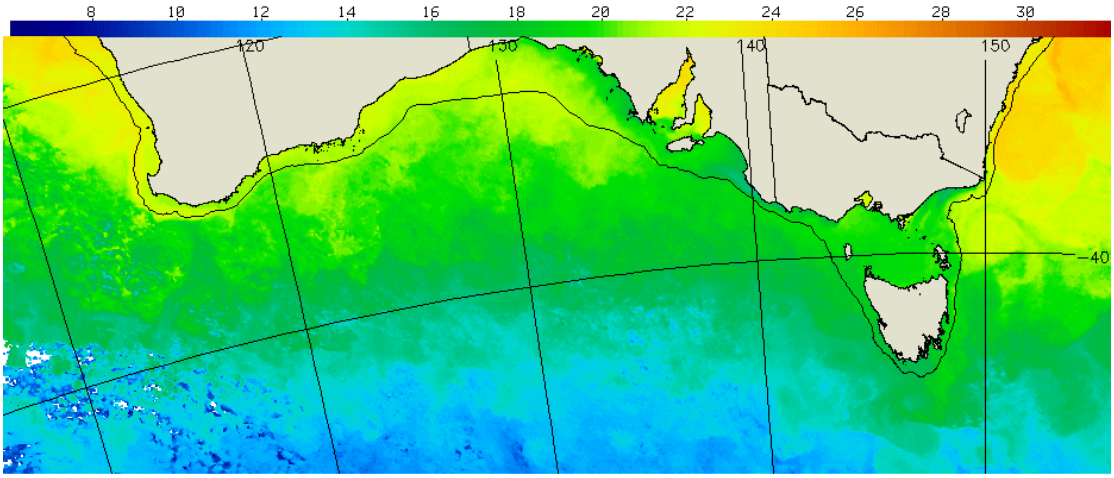


Figure 3. Typical summer (a) and winter (b) synoptic charts for the Great Australian Bight (Source, Bureau of Meteorology Website 2003).



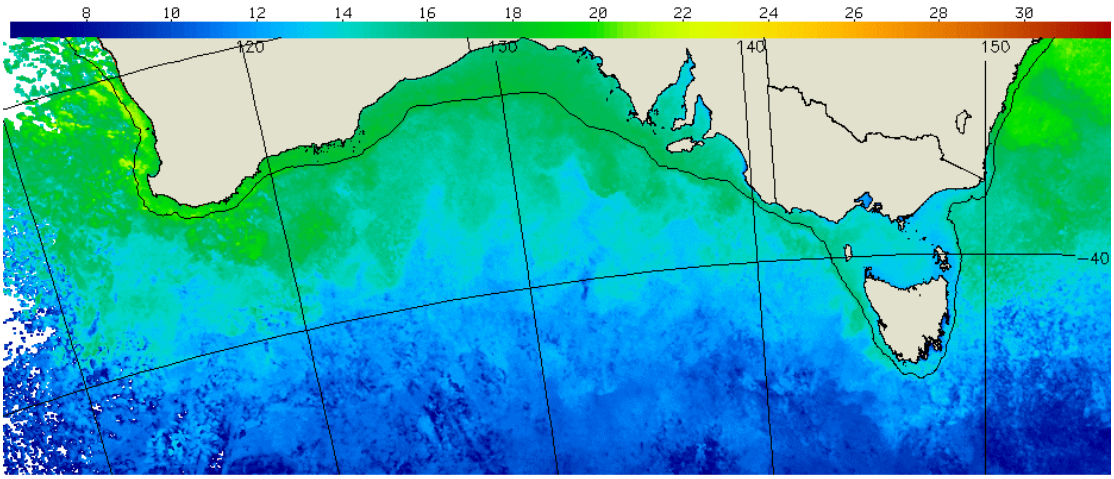


Figure 4. Typical sea-surface temperature charts for summer (above) and winter (below) in southern Australia (Source: CSIRO 2002).

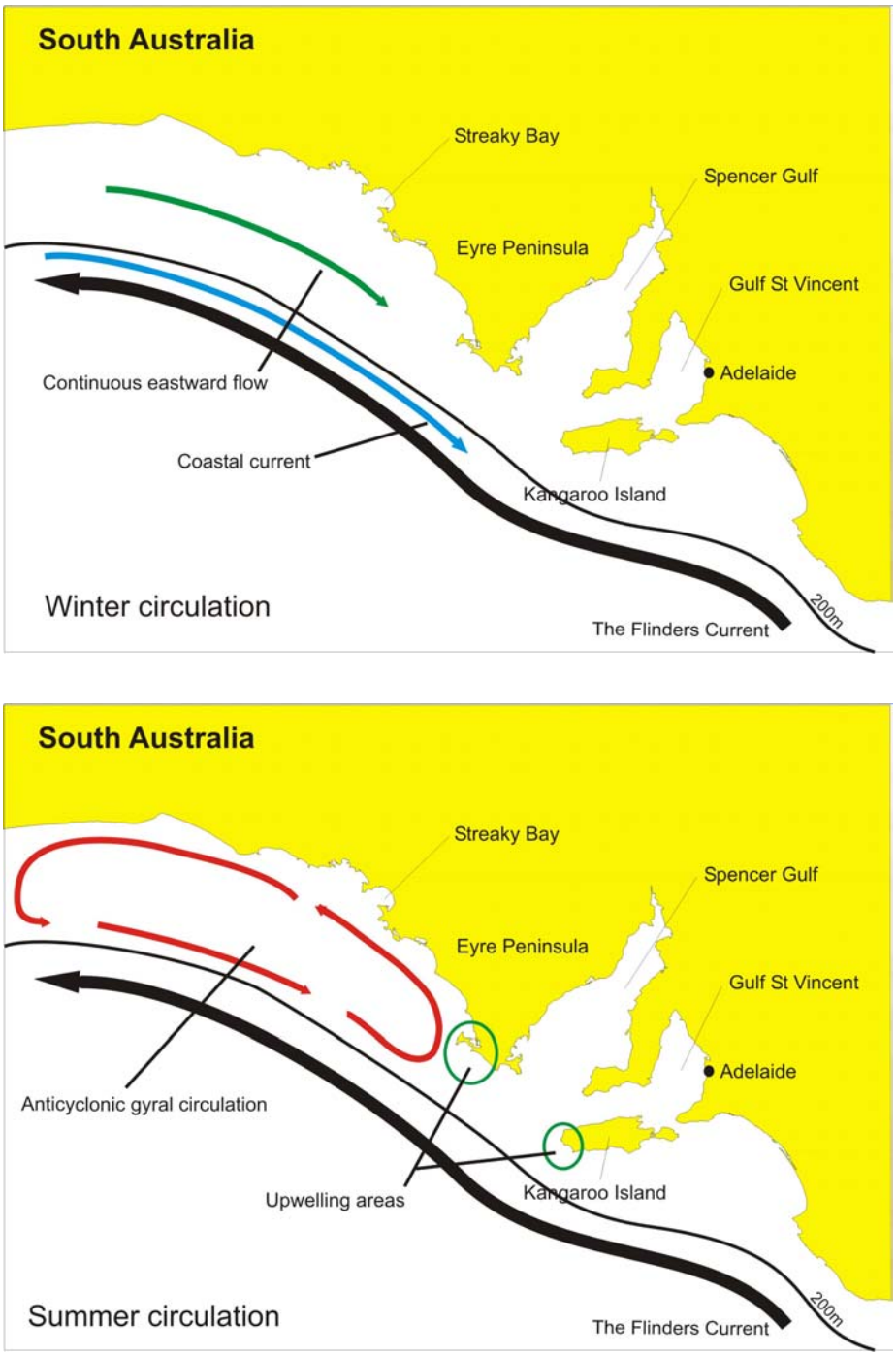


Figure 5. Map showing the direction of surface currents during winter and summer-autumn in the eastern GAB.

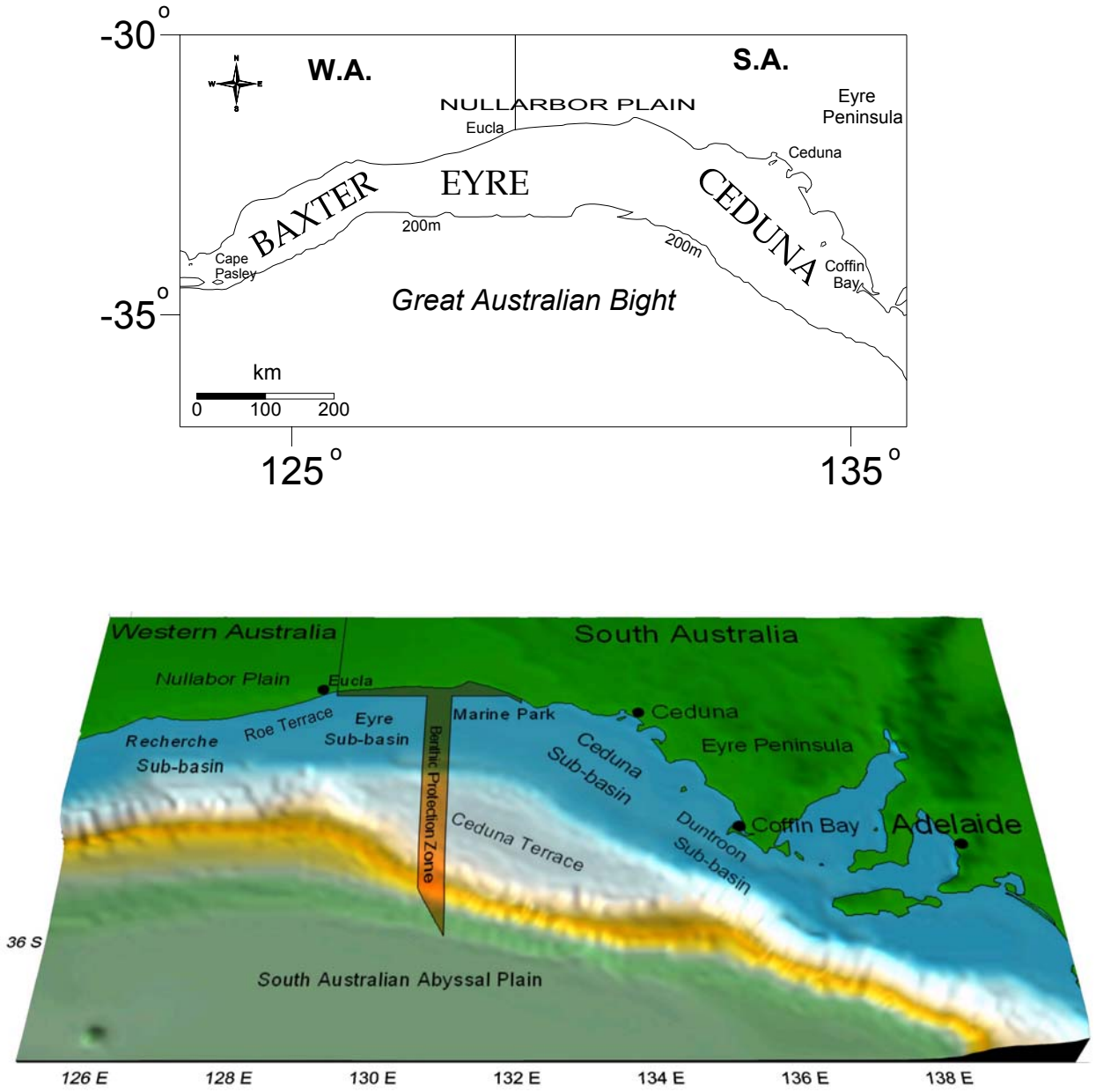


Figure 6. Maps showing oceanographic (above) and geological (below) sectors of the continental shelf within the Great Australian Bight (Hill *et al.* 2001).

2.3 Geology

The GAB is part of a divergent, passive continental margin that was formed during the Cretaceous by the separation of Australia and Antarctica (James *et al.* 2001). Limestone cliffs up to 70 m high dominate the western coastline from Cape Pasley to the Head of Bight. The eastern coastline is more complex, and is characterised by cliffs, scattered islands, headlands and large embayments (James *et al.* 2001). Considerable information on the structural elements and stratigraphy of the GAB has been derived from swathe mapping, seismic surveys and exploratory drilling (Geoscience Australia website 2003a).

The GAB is underlain by the Bight Basin, which is subdivided into the Eyre, Recherche, Ceduna and Duntroon Sub-basins (Hill *et al*. 2001, Fig. 6). The margin of the GABMP is gently sloping down to 2500 m and relatively featureless except for two pinnacles less than 100 m high and 700 m across, near the 1750 m isobath. From 2500 to 5000 m, the margin is steeper, faulted and traversed by canyons, some of which include giant holes up to 5 km wide and 500 m deep (Hill *et al*. 2001).

The continental shelf of the GAB is less than 200 m deep and comprises deep continental margin basins that underlay an approximately 800 m thick Cenozoic carbonate platform (Feary and James 1998; Feary *et al.* 2000). The shelf is an almost featureless plain that slopes gently out to the shelf break, which occurs at a depth of approximately 125-165 m (Edyvane 1998). The shelf is approximately 260 km wide at the Head of Bight and is thus the broadest part of the southern Australian shelf (Willcox *et al.* 1988). To the east and west of the GAB, the shelf is generally narrower and flanked by steep continental slopes that are incised by canyons (Conolly and Von der Borch 1967; Tilbury and Fraser 1981).

Important papers on the bathymetric and geological characteristics of the shelf include Wilson *et al.* (1984), James and Von der Borch (1991), Von der Borch and Hughes-Clarke (1993), James *et al.* (1997), Feary and James (1998), Feary *et al*. (2000), James *et al.* (2001) and Hill et al (2001). James *et al.* (2001) describe three shelf regions. The 'inner shelf' is located in depths of up to ~50 m; the 'middle shelf' lies between 50 and 120 m and the 'outer shelf' extends out to the shelf break. The northern and north-western portion of the shelf is the Roe Terrace, which slopes from the coast to a depth of approximately 30-50 m. In contrast, the seafloor at the Head of Bight and eastern GAB reach depths of greater than 50 m within a few kilometres from shore.

There are anecdotal reports that low salinity artesian water seeps into the GAB through faults in the basement rock (Peter Graham, Environment Australia, personal communication)

however, a CSIRO survey found no evidence of "fresh water seeps" in the GAB (CSIRO, unpublished data).

2.4 Sedimentology

Carbonate sediments on mid-latitude shelves are poorly understood compared to their tropical counterparts. The southern margins of the Australian continent comprise the world's largest cool water carbonate province (James *et al.* 1992; Gostin *et al.* 1988; James and Von der Borch 1991; Wass *et al.* 1970). Due to the lack of rivers, most of the shelf receives minimal inputs of terrigenous sediments. This effect, combined with the upwelling of cold ocean waters, has resulted in the preservation of relict calcareous Pleistocene sands and the growth of sediment-producing bryozoa, coralline algae, sponges, molluscs, asteroids and foraminiferans (Wass *et al.* 1970; James *et al.* 1992).

The first sediment analyses in the GAB were carried out by Conolly and Von der Borch (1967). More recently, details of the subsurface have been revealed by vibracores (James *et al.* 1994, 1997). These studies suggest that sediments in the western GAB are dominated by coralline algae and large foraminiferans, and that bryozoans are rare. However, shelf sediments in the eastern GAB are dominated by bryozoans (James *et al.* 1994). A comprehensive description of the surficial sediments of the GAB is provided by James *et al*. (2001). Slope sediments were drilled recently by Hine *et al.* (1999) and Feary *et al.* (2000).

James *et al.* (2001) divides the sediments of the shelf and upper slope out to 500 m deep into nine facies (Fig. 7). The inner shelf is comprised of modern biofragments, rhodolith gravel and quartz sand. The middle shelf between 50 and 100 m consists of intraclasts, mollusc shells and bryozoan skeletons. The outer shelf and upper slope are comprised of bryozoan-dominated sediments. Below 300 m spiculitic mud is dominant.

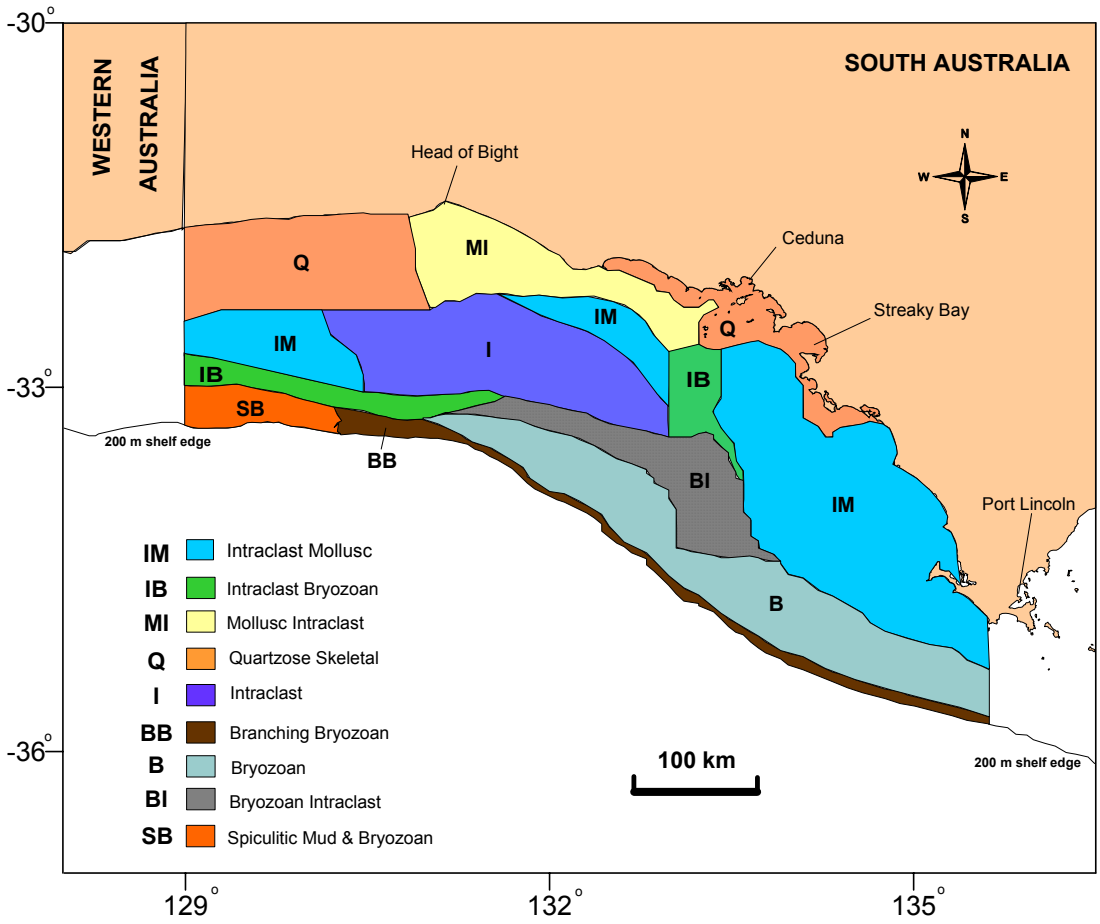


Figure 7. Sediment types on the shelf and upper slope in the eastern Great Australian Bight (adapted from James *et al.* 2001).

2.4.1. Inner shelf

Quartzose Skeletal Sand and Gravel (Q)

Facies Q (Fig. 7) consists of heterogenous sediment of fine to coarse sand and gravel (near islands) with intraclasts, equal proportions of bryozoans and bivalves and 10-30% terrigenous particles (quartz, crystalline rock fragments, feldspar and granite fragments).

Mollusc Intraclast Sand (MI)

Facies MI is composed of 25-50% intraclasts and mollusc fragments over bryozoans in fine to medium well-sorted sand or poorly sorted fine sandy gravel.

Intraclasts are classified as being either '*skeletal intraclasts'* comprised of single skeletons, typically eroded and filled with carbonate silicate iron oxides or '*lithic intraclasts'* comprised of numerous skeletons, fine sediment and cement with a grainstone to wackestone texture (James *et al.* 2001).

2.4.2 Middle shelf plain

Intraclast Sand (I)

Facies I consists of brown coarse to very coarse, well-sorted, round, particulate sand composed of 80-90% intraclasts.

Intraclast - Mollusc Sand and Gravel (IM)

Facies IM is characterised by well-sorted medium sand to coarse gravel composed of 50-75% intraclasts and numerous large molluscs. A sand component composed of up to 40% foraminiferans is also present in some regions.

IB Intraclast - Bryozoan Sand (IB)

Facies IB is essentially a mixture of Facies I and Facies B. It is composed of 50-75% sand-sized intraclasts with bryozoan sands and gravels of Holocene origin. The gravel fraction comprises 25-50% of the sediment and is dominated by bryozoans.

2.4.3 Outer shelf and Upper slope

Bryozoan Sand and Gravel (B)

Facies B is a cream to green coloured sediment with < 25% intraclasts. Sediment ranges from poorly- to well-sorted with very fine sand to cobble-size particles. Sand is moderately sorted and rich in medium-sized sand to gravel-size bryozoan fragments.

Bryozoan–Intraclast Sand (BI)

This sediment is composed of 25-50% intraclasts and abundant bryozoans. It is essentially the same as the bryozoan sand and gravel facies (Facies B) but mixed with a higher proportion of intraclasts, bivalves, coralline algae and abraded particles.

Branching Bryozoan Sand and Gravel (BB)

Facies BB is a mixture of numerous delicate branching bryozoans and mud. Deposits range from well-sorted medium to very coarse sand to a bimodal sediment of bryozoans and very fine sand/silt. Transition from Facies B is gradual and elements of Facies B exist in the shallower parts of the Branching Bryozoan Facies.

Spiculitic, Branching Bryozoan Mud (SB)

This sediment is a mixture of more than 50% fine biofragments and the branching/vagrant bryozoan assemblage common to Facies BB. Relict rhodoliths and coralline rods characterise shallow sites.

2.4.4 Slope

Spiculitic Mud (M)

Facies M occurs at depths of >300 m and is not shown in Fig. 7. Sediment on the slope grades from mud to the upslope Branching Bryozoan Facies (Facies BB) that may contain up to 10% delicate-branching cyclostomes. Mud is a mixture of approximately 66% fine biofragments and 33% fine pelagic components. Sediment is rich in numerous *Dentalium,* pteropods, gastropods, echinoid plates, spherical and vagrant bryozoans, benthic foraminiferans, ostracods, micromolluscs and angular clasts.

3. BIOREGIONS OF THE GREAT AUSTRALIAN BIGHT

Ecosystem-level classification of Australia's coastal and marine environments, known as the "Interim Marine and Coastal Regionalisation of Australia", suggests that the GAB consists of one pelagic province, three demersal provinces and biotones, and four meso-scale regions Information provided in this section was sourced from Interim Marine and Coastal Regionalisation for Australia Technical Group (1998).

3.1 Pelagic Province

3.1.1 Southern Pelagic Province (SPP)

The GAB includes approximately half of the SPP that extends from near Albany, Western Australia to Lakes Entrance, Victoria and encloses Bass Strait and Tasmanian waters (Fig. 8). The SPP largely comprises temperate species, although its western edge is the southern distributional limit of some tropical pelagic species.

3.2 Demersal Provinces and Biotones

3.2.1 South Western Province (SWP)

The GAB encompasses only the western limits of the SWP (Fig. 9). This region is defined by two primary distribution types: western warm temperate species that emerge from the South Western Biotone (SWB) and extend into the Great Australian Bight Biotone (GABB) and Gulfs Provinces (GULF P) and more widely distributed species that extend from the SWB eastward into Bass Strait (Fig. 9). A suite of eurythermal species from this province extend north into Western Australia near Exmouth. Similarly, some species from the coast of central Western Australia extend southward into this province.

3.2.2 Great Australian Bight Biotone (GABB)

The GABB comprises nearly two thirds of the area from Cape Pasley to Cape Catastrophe (Fig. 9). It is dominated by species from the SWP and a few elements of the GULF P. The GABB includes a large suite of wide-ranging western, warm temperate species that extend eastward along southern Australia to the east coast of Victoria, as well as a suite of ubiquitous temperate Australian species.

3.2.3 Gulfs Province (GULF P)

The western margin of the GULF P comprises almost a third of the eastern GAB (Fig. 9). The GULF P is characterised by a small proportion of endemic and subtropical relict species. It supports cool temperate water species common to southern Victorian and Tasmanian waters. The hyper-saline and sub-tropical temperature conditions in the gulfs also provide refuge for warm water species.

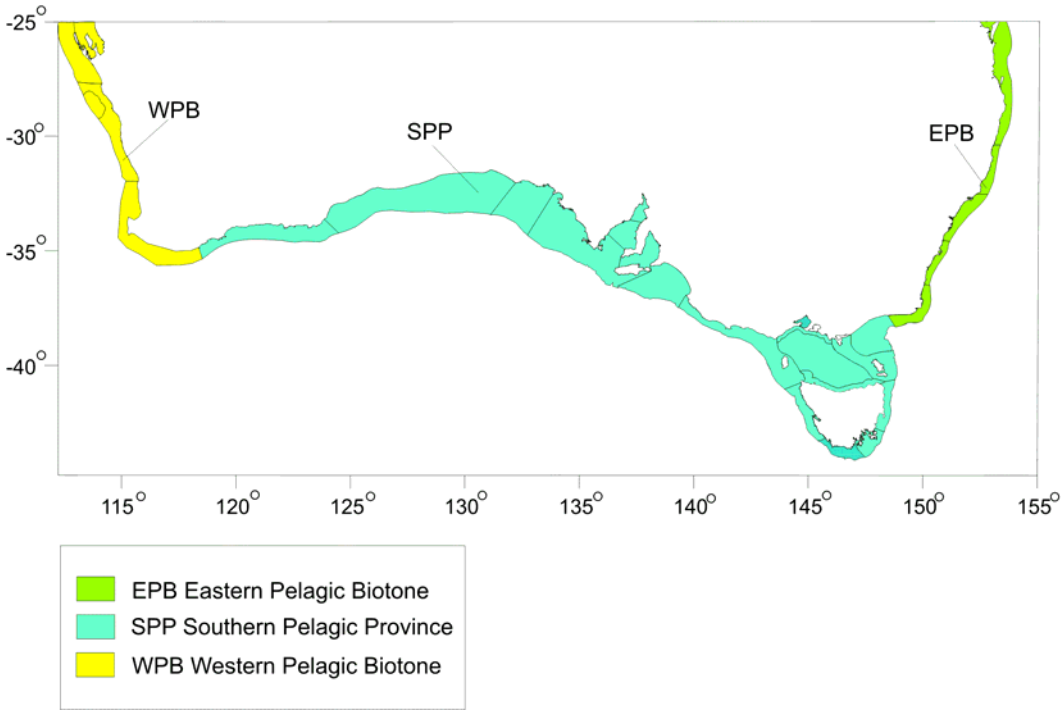
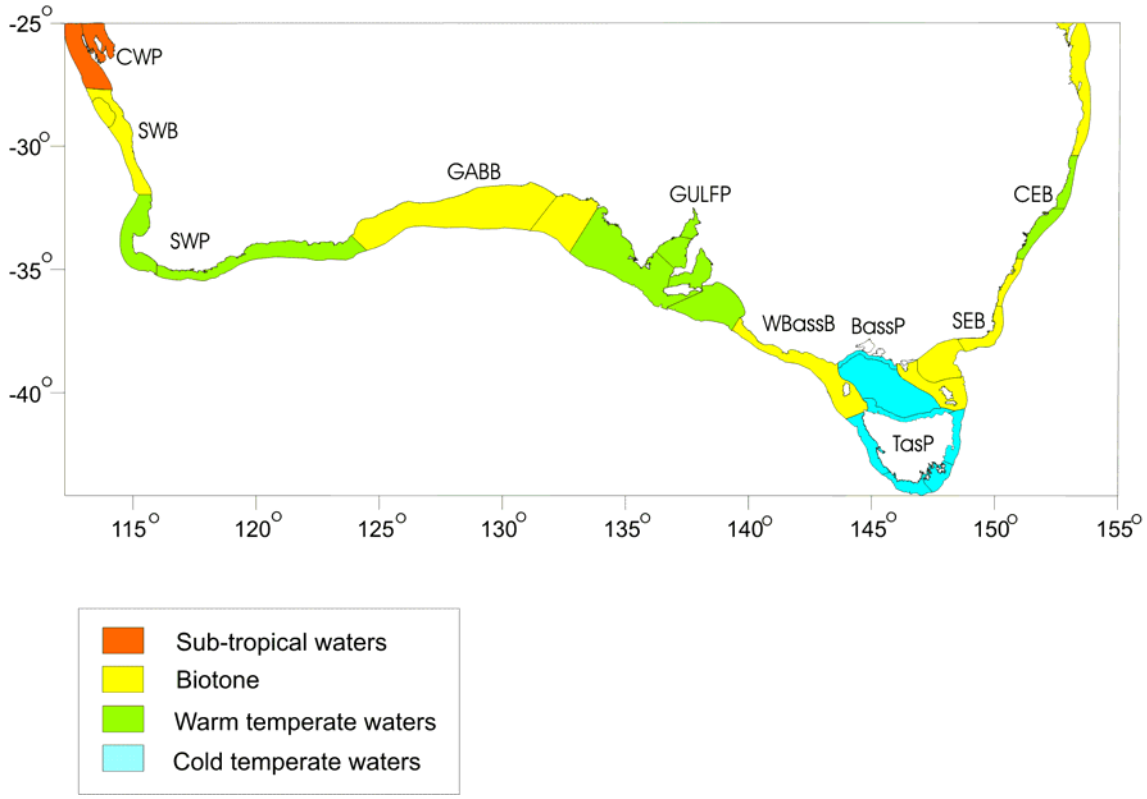


Figure 8. The pelagic provinces of southern Australia. (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998).



Key to Demersal Provinces and Biotones

BassP	Bassian Province
CEB	Central Eastern Biotone
CWP	Central Western Biotone
GABB	Great Australian Bight Biotone
GULF P	Gulfs Province
SEB	South Eastern Biotone
SWB	South Western Biotone
SWP	South Western Province
TasP	Tasmanian Province
WBassB	Western Bassian Biotone

Figure 9. The demersal provinces and biotones in southern Australia. The outer edge of regions represents the edge of the continental shelf (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998)

3.3 Meso-scale Regions

3.3.1 Western Australia South Coast Region (WSC)

The eastern boundary of the WSC and the SWP coincide, and the western GAB only includes the eastern limits of the WSC (Fig. 10). The climate of this region is semi-arid and the water is clear and affected by the West Wind Drift. The WSC is a high-energy wave environment characterised by prominent headlands, limestone cliffs, semi-sheltered bays and beaches backed by dune fields.

The marine and estuarine flora and fauna has strong affinities with the southern Australian region. However, there is a significant local endemic element and a few Indo-West Pacific 'straggler' species. Kelp dominates rocky substrates in the sub-littoral zone and there is a rich rocky shore intertidal fauna. Nearshore islands are used as haul-out and breeding areas for the Australian sea lion (*Neophoca cinerea*) and New Zealand fur seal (*Arctocephalus forsteri*) (Edyvane 1998). The southern right whale (*Eubalaena australis*) utilises sheltered bays.

3.3.2 Eucla Region (EUC)

The EUC comprises over half the total area of the GAB and includes the GABMP. It lies in the western half of the GAB and has a semi-arid climate characterised by hot dry summers and cool winters. Waters are warm to cold (mean SST of 14-19°C) and influenced by the Leeuwin Current in winter. In summer, SSTs reach up to 22°C. The coastline is subject to moderate to high wave energy and high swells (2-4 m). This region features limestone cliffs interspersed by rocky headlands, narrow intertidal rock platforms, reefs and beaches backed by dune barriers. There are no estuaries in the region.

Marine biota is typical of transitional warm to cold temperate waters. Distinct tropical elements reflect the intrusion of warm water from the Leeuwin Current. Plant diversity is moderate to low. Brown algae, such as *Cystophora intermedia* dominate the intertidal and sublittoral fringe. On high-energy reefs, subtidal macro-algal communities are dominated by *Scytothalia dorycarpa* and *Ecklonia radiata*. Few seagrass communities occur along this coast. It is a significant breeding and calving area for the southern right whale and supports breeding colonies of Australian sea lion (*Neophoca cinerea*).

3.3.3 Murat Region (MUR)

The MUR covers almost half of the eastern part of the GAB from Cape Adieu to Point Brown. Like all regions in the GAB, it is characterised by hot, dry summers and cool winters. The waters in the MUR have similar seasonal physical characteristics to the EUC. The

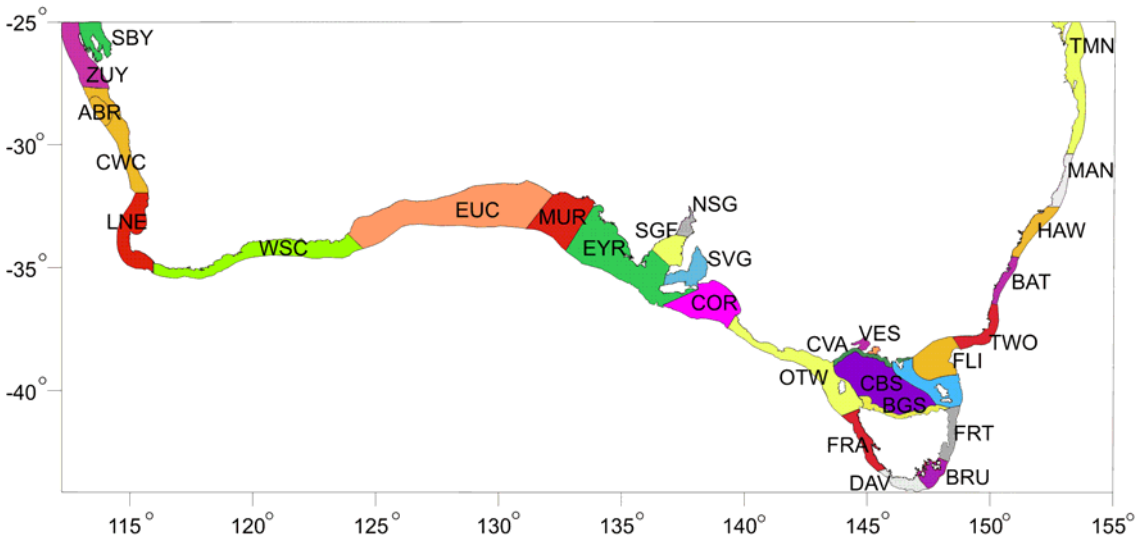
coastline is subject to moderate to low wave action and features rocky cliffs, reefs and headlands, numerous shallow, sheltered embayments interspersed with beaches, dunes and intertidal/supratidal flats. There are numerous offshore islands and seamounts. No true rivers exist; however, there are a few intermittent streams and tidal mangrove creeks (*e.g.* Davenport Creek).

Marine fauna and flora of this region are typical of warm temperate areas. A distinct tropical faunal element exists due to the influence of the Leeuwin Current. Plant species diversity is moderate to low. Extensive seagrass communities dominate shallow embayments and the lee of islands. Intertidal regions are dominated by the grey mangrove (*Avicennia marina*), brown algae (*Hormosira banksii*) and seagrasses *Heterozostera muelleri* and *Zostera tasmanica*. Subtidal areas are dominated by *Amphibolis* species in shallow water and *Posidonia* species in deep water. Rocky exposed limestone shores are dominated by *Ecklonia radiata* and *Scytothalia dorycarpa*. In calmer areas, macro-algal communities are dominated by *Sargassum* and *Osmundaria* species on moderate energy coasts and *Scaberia agardhii* in low wave energy conditions. Granite boulder reefs are dominated by *Cystophora* species.

3.3.4 Eyre Region (EYR)

The EYR covers the eastern GAB, extending east to Kangaroo Island (Fig. 10). The weather and oceanic characteristics in this region are similar to the EUC and MUR. Localised upwelling influences inshore waters. The coastline is subject to moderate to high wave energy and features a rocky coast with numerous headlands, sheltered bays, cliffs, shore platforms, beaches backed by dune barriers, offshore islands, seamounts and lagoon deposits in sheltered areas. There are no true rivers but several intermittent streams (*e.g.* Tod River) and coastal salt lakes (*e.g.* near Baird Bay).

Marine flora and fauna in this region are typical of transitional warm to cold temperate waters. Plant species diversity is high, particularly among red algae. The intertidal and sublittoral fringe on rocky shores is dominated by the brown algae *Cystophora intermedia*, and on limestone shores by red algal assemblages (particularly *Osmundaria* and *Plocamium* species, *Ecklonia radiata)* and *Caulerpa* and *Cystophora* species. Seagrasses are dominated by *Posidonia australis* and *Amphibolis antarctica* in sheltered shallow waters and *P. sinuosa*, *P. angustifolia* and *A. griffithii* in deeper waters. Marine fish fauna is noted for the presence of endemic species such as the crested threefin (*Norfolkia cristata*) and the coastal stingaree (*Urolophus orarius*) (Gomon *et al.* 1994). Significant breeding colonies of the Australian sea lion (*Neophoca cinerea*) and New Zealand fur seal (*Arctocephalus forsteri*) occur in the region, particularly on the offshore islands.



Key to meso-scale regions

ABR	Abrolhos	**HAW**	Hawkesbury Shelf
BAT	Batemans Shelf	**LNE**	Leeuwin-Naturaliste
BGS	Boags	**MUR**	Murat
CBS	Central Bass Strait	**NSG**	Northern Spencer Gulf
COR	Coorong	**OTW**	Otway
CVA	Central Victoria	**SBY**	Shark Bay
CWC	Central West Coast	**SGF**	Spencer Gulf
DAV	Davenport	**SVG**	St Vincent Gulf
EUC	Eucla	**TMN**	Tweed-Moreton
EYR	Eyre	**TWO**	Twofold Shelf
FLI	Flinders	**VES**	Victorian Embayments
FRT	Freycinet	**WSC**	WA South Coast
FRA	Franklin	**ZUY**	Zuytdorp

Figure 10. Meso-scale regionalisation in southern Australia. The outer edge of regions represents the edge of the continental shelf (Interim Marine and Coastal Regionalisation for Australia Technical Group 1998).

4. FLORA AND FAUNA OF THE GREAT AUSTRALIAN BIGHT

4.1 Mangroves

Mangrove forests occur at sheltered sites on the South Australian coast and cover an area of approximately 230 km^2 (EPCSA 1998). Mangroves are poorly represented in the GAB as they show preference for low energy, muddy shorelines, particularly in the tropics. Of the 69 species in the world only one occurs in the eastern part of the GAB, the grey mangrove, *Avicennia marina* (Robertson and Alongi 1995). It forms coastal woodlands up to 5m tall with the most significant stands in the GAB occurring near Ceduna in the east (Lewis *et al.* 1998).

4.2 Seagrasses

The Australian coastline has the highest number of seagrass species of any continent (Zann and Kailola 1995). There are approximately 30 species of seagrasses in Australia belonging to 11 genera (Larkum *et al.* 1989). Approximately one third (18 species) of all species known worldwide are endemic in Australia. Of these, 16 species are restricted to temperate waters.

Southern temperate waters have two endemic genera, *Heterozostera* and *Amphibolis*. Many endemic species belong to the genera *Posidonia*. The distribution and abundance of seagrasses is a function of topography and environment. A distinction exists between sub-tropical and warm temperate types. In southern Australia, species with warm water affinities (*Posidonia*, *Amphibolis*) decline in number from west to east as water temperatures decrease.

In South Australia, seagrasses cover approximately 9620 km^2 and represent one of the largest seagrass ecosystems in the world (Larkum *et al.* 1989). Seagrass distribution in the GAB is patchy and limited by exposure to swell. Most seagrass is found in sheltered bays or in the lee of reefs and islands in the eastern GAB. These areas contain nearly 10% of the seagrass meadows found in South Australia (Edyvane 1999). *Posidonia* species dominate, especially *P. angustifolia, P. coriacea* at the base of cliffs and *P. australis* and *P. angustifolia* in the sheltered lee of fringing reefs. *Amphibolis antarctica* and *Heterozostera tasmanica* are present but less common in sheltered bays of the region (Shepherd and Robertson 1989).

4.3 Macroalgae (Seaweeds)

Seaweed diversity and endemism in temperate waters of Australia is among the highest in the world, perhaps due to the length of the southerly-facing rocky coastline and the long period of geological isolation (Edyvane 1999). The number of species found in southern Australia is 50-80% greater than other temperate regions of the world. A small number of tropical species and isolated species from tropical genera also occur in the GAB (Womersley 1990).

Oceanic waters of South Australia support one of the world's most diverse seaweed assemblages, with >1200 species recorded (Womersley 1981). Many species of macroalgae found in South Australian waters extend into the cool temperate waters of Victoria and Tasmania and warmer waters of Western Australia. However, South Australia has the highest concentration of species. The waters of the GAB are clear and allow chlorophyllus plants to live at depths of up to 70 m (Shepherd 1979).

Among the green algae (Chlorophyta), few microscopic forms have been studied; however, a few southern Australian species are recognised in the genera *Ulva* (2) and *Bryopsis* (6). Coenocytic green algae are well represented, including *Codium* (15 species) and *Caulerpa* (19 species) (Womersley 1981). Brown algae (Phaeophyta) and red algae (Rhodophyta) are particularly diverse. Approximately 43% of the genera (658) and 20% of the species (~4000) of red algae that occur worldwide are found in southern Australia (Womersley 1990). Over 75% of red algae, 57% of brown algae, and 30% of green algae are endemic to southern Australia (Womersley 1990). Womersley (1984, 1987, 1994, 1996, 1998 and 2003) documents the macroalgae of southern Australia. Algal distribution records from periodic collecting in the eastern GAB are held at the SA Biodiversity Centre. A list of surveys is provided in Edyvane (1999).

4.4 Plankton

4.4.1 Phytoplankton Assemblage

The phytoplankton of Australian seas is poorly known but has been described by Hallegraeff (1988) as being similar to that in other parts of the world. Phytoplanktonic algae comprise 13 divisions, including diatoms, dinoflagellates, golden-brown flagellates, green flagellates and coccoid picoplanktonic forms (cyanobacteria, prochlorophytes). Smaller species (2-20μm) are often common to both tropical and temperate Australia, due to transport southwards by the Leeuwin and East Australian Currents. However, tropical and temperate waters tend to support distinct patterns of species composition and abundance (Lewis *et al.* 1998).

Studies on phytoplankton distribution and taxonomy in Australasia have been spasmodic and fragmentary (Jeffrey 1981). No information is available for spatial and temporal distribution patterns of phytoplankton of the GAB, even though the region comprises one of Australia's most significant upwelling systems. Some information exists for estimates of standing stock of phytoplankton via measurements of chlorophyll-*a.* (Motoda *et al*. 1978; Ward *et al*. 2001, 2002a). A current doctoral study by Van Ruth (SARDI Aquatic Sciences) is examining patterns of primary productivity and species composition of phytoplankton in the region.

4.4.2 Zooplankton Assemblage

There are few data on the spatial or seasonal patterns of zooplankton abundance in southern Australia. A study of the western GAB during summer found that zooplankton biomass was only 2% of that in the Gulf of Carpentaria (Motoda *et al.* 1978). Samples collected by SARDI Aquatic Sciences suggest that the zooplankton assemblage in the GAB is dominated numerically by small copepods, meroplanktonic larvae and cladocerans (Godinot and Ward 2000).

4.5 Benthic Invertebrates

Considerable information is available for a few commercially important species of invertebrates in the GAB (Section 5), but few data are available for most other species (Edyvane 1999). Of the 6640 invertebrate species thought to occur in South Australian waters only one third have been collected and described (EPCSA 1998).

Over 90% of the species in almost every group of marine invertebrates in temperate Australia are endemic (Wilson and Allen 1987). The invertebrate fauna of the GAB also displays a high degree of endemism (85-95%, Shepherd 1991). South Australia's benthic invertebrate assemblages also include tropical species. Fossils of benthic foraminiferans, nektonic nautiloids and planktonic protists suggest that tropical species have been transported into South Australia by the Leeuwin Current since the Eocene (McGowran *et al.* 1997).

Early research in the GAB included an expedition on Australia's first fisheries research vessel, the *Southern Endeavour* that reported the presence of hydroids, molluscs and sponges (Dannevig *et al.* 1911). Many of South Australia's invertebrate species are included in the South Australian Handbook Series *Marine Invertebrates of Southern Australia*. Part I, includes the Porifera, Cnidaria, Platyhelminths, Annelida, Sipuncula, Echiura, Bryozoa and Echinodermata (Shepherd and Thomas 1982); Part II deals solely with the Mollusca (Shepherd and Thomas 1989); and Part III includes the Nemertea, Entoprocta, Phoronida, Brachiopoda, Hemichordata, Pycnogonids and Tunicates (Shepherd and Davies 1997). The most notable group not covered by these books is the Crustacea. Edgar (2000) describes 1200 species of invertebrates, fish, algae and sea grasses that occur in the intertidal zone to 30 m depth between Sydney and Perth.

Zoological Catalogues on Australian marine invertebrates are available for Porifera (Hooper and Weidenmayer 1994), Crustacea (Poore 2002, Davie 2002, Stoddart and Lowry 2003), Mollusca (Lamprell *et al.* 2001) and Echinodermata (Rowe and Gates 1995). These catalogues provide species lists, ecological attributes, synonymy, location and status of type

material, summaries of geographical distribution and references important for understanding aspects of the biology of these taxa. Checklists of marine invertebrate species of Australia with their type localities and associated literature can be found online. (Environment Australia website 2003a).

4.5.1 Sponges (Phylum Porifera)

In southern Australia, approximately 1000 species of sponges belonging to 200 genera have been described. However, most descriptions were made in the 1800s and there is a paucity of knowledge of the sponges in this region compared to elsewhere in the world (Bergquist and Skinner 1982). Reiswig (1992) identified hexactinellid (glass) sponges from the continental shelf and slope of southern Australia. Sponges can be identified to genus level using Hooper and Van Soest (2002).

4.5.2 Hydroids (Phylum Cnidaria, Class Hydrozoa, Order Hydroida)

Eleven families composed of approximately 200 species of hydroid have been recorded from southern Australia (Watson 1982). This represents approximately half the known hydroid families, and reflects the lack of knowledge of species composition and distribution in Australia (Watson 1982). Studies in southern temperate waters have shown hydroid species can comprise 20% of the total assemblage of sessile organisms (Watson 1982). However, due to their small size they form only a minor part of the total biomass. Hydroids are the exclusive food source for some species of nudibranchs and pycnogonids.

4.5.3 Corals, soft corals, gorgonians and sea pens (Phylum Cnidaria, Class Anthozoa)

Few species of scleractinian and soft coral (Orders Stolinifera, Telestacea and Alcyonacea) occur in southern Australia. Three reef-building species occur in shallow waters and >50 species of non-reef-building (ahermatypic) species occur in waters up to 900 m deep (Shepherd and Veron 1982). The distribution patterns of corals in the GAB are largely unknown.

A recent revision of the Isididae (Alderslade 1998) includes some South Australian species. Alderslade (2003) notes that records of soft corals are very rare from Albany to the GAB and that there are “no records of shallow-water soft corals from the western and central GAB”. Fabricius and Alderslade (2001) revised the higher classification levels of soft corals and gorgonians in a summary of the tropical fauna. This reference is useful for classification of soft corals and gorgonians from the GAB. Williams (1995) revised the penatulid (sea-pen) genus *Sarcoptilus* and recorded only one species, *Sarcoptilus grandis*, from the GAB.

4.5.4 Polychaetes (Phylum Annelida, Class Polychaeta)

Most polychaete families (67 out of 81) are represented in Australia, with the highest degree of species endemism occurring in southern Australia (Glasby and Alvarez 1999). In 2002, CSIRO and Environment Australia published *Polychaetes and Allies* (Beesley *et al.* 2000) as part of the Fauna of Australia series. The biogeography section discusses southern Australia but no specific mention is made of any studies in the GAB. One hundred polychaetes from southern Australia are described by Hutchings (1982). However, Hutchings described this listing as incomplete and a reflection of the paucity of knowledge of the taxa in Australia. Beesley *et al.* (2000) and Rouse and Plijel (2001) are the most useful reference books for identification of polychaetes.

4.5.5 Crabs, shrimp, lobsters (Phylum Arthropoda, Subphylum Crustacea)

The class Malacostraca contains nearly three quarters of all known species of crustacea and includes all the larger, well-known forms including crabs, lobsters and shrimps. Little is known of most crustaceans in southern Australia, except those taken commercially including southern rock lobster (*Jasus edwardsii*), western king prawn (*Melicertus latisulcatus*) and giant (king) crab (*Pseudocarcinus gigas*). In a checklist of marine decapods of south-western Australia, Morgan and Jones (1991) note that there is a "dearth of specimens" collected from east of Esperance and even less research has been undertaken on non-decapod species in this area. Jones *et al.* (1990) listed 204 species of barnacle from Australia with 11 occurring in the GAB (only three in water deeper than 40 metres). Okuno (1997) described a shrimp, *Rhynchocinetes enigma,* which is only known from the GAB.

4.5.6 Shells, sea slugs, octopus, squid and cuttlefish (Phylum Mollusca)

Southern Australian waters contain many species of mollusc and the level of endemism is approximately 95%, including several endemic genera (Poore 1995). Early research on molluscs of South Australia was conducted by Sir Joseph Verco during several expeditions to the GAB (Verco 1912, 1935). Nudibranchs (Class Gastropoda) are well represented in South Australia with over 500 species recorded (Greenwood and Gum 1986). Volutes, cones and cowries (Class Gastropoda) represent relict tropical fauna with noteworthy species such as the giant baler shell (*Melo miltonis*) and the black cowrie (*Cypraea friendii*) found in the GAB (Edyvane 1999). The distribution and abundance of most molluscs in the GAB is unknown; however, information is available for commercially important abalone (*Haliotis rubra*, *H. laevigata* and *H. roei*), and the southern calamary (*Sepioteuthis australis*) (see Section 5).

4.5.7 Lace corals (Phylum Bryozoa)

Bryozoans contribute up to 80% (average 20-60%) of total sediment production on the shelf of South Australia (Edyvane 1999; Wass *et al.* 1970). Bock (1982) reported that there are over 500 species of bryozoan in southern Australia. However, the number and distribution of species in the GAB is poorly understood. Several recent papers include species from the GAB (Bock and Cook 1993, 1998a, 1998b, 1999, 2001a, 2001b; Cook and Bock 2001; Hayward and Parker 1994; Parker and Cook 1994). There are more than 100 potentially undescribed species of bryozoan from the GAB in the Victorian Museum (Phil Bock, personal communication). The South Australian Museum also has a large collection of unidentified bryozoans from the GAB (Thierry Laparousaz, personal communication).

4.5.8 Sea stars, brittle stars, sea cumbers, urchins, feather stars (Phylum Echinodermata)

There are a few hundred species of echinoderm in Australia. Approximately 34 species of sea star (Class Asteroidea) inhabit southern Australian waters to depths of 30 m (Zeidler and Shepherd 1982). In addition, 17 species of sea star have been recorded from deeper waters of the continental shelf. Seventy-three species of brittle star (Class Ophiuroidea) and 49 species of sea urchin (Class Echinoidea) have been recorded from waters around southern Australia (Baker 1982a, b). Several species of feather star (Class Crinoidea) inhabit southern Australian coasts to depths of 75m. Ninety percent of temperate echinoderm species in southern Australia are endemic. There is also significant endemism at the generic level.
Although many species of echinoderm have been described for southern Australian waters, little is known of their patterns of abundance and distribution in the GAB.

4.5.9 Sea squirts (Phylum Chordata, Class Ascidiacea)

There are 210 species of ascidian recorded from southern Australia. Kott (1972) examined the ranges of 72 species of ascidian in the eastern GAB and Gulf St Vincent and found evidence to support the existence of 'a marine faunal boundary at the eastern end of the Great Australian Bight.' A high degree of endemism is known for the ascidian fauna from the northern GAB (Kott 1975). There are several reviews of the tunicates of the GAB (Kott 1985, 1990a, 1990b, 1992a, 1992b, 2001).

4.6 Fishes

Three quarters of the 3400 marine fish species living in Australian waters occur on the shelf and in nearshore areas (Poore 1995). Approximately 85% of southern Australia's fishes are endemic to the region and 11% are also found in New Zealand waters (Poore 1995). Wilson

and Allen (1987) describe several physical barriers that may inhibit dispersal of temperate fish fauna of southern Australia and account for the high levels of endemism. These are:

1) a sharp temperature gradient near Albany due to cessation of the Leeuwin Current;
2) the absence of shallow reef habitat in the GAB;
3) a reef free "dead zone" of sand-mud substratum at the Murray River outflow between Kangaroo Island and Robe; and
4) a reef free substratum in south-eastern Victoria between Wilson's Promontory and Mallacoota (Wilson and Allen, 1987).

Such barriers may act to maintain allopatric eastern and western species pairs (Poore 1995). Of the 600 species of fish occurring in southern Australia, 370 are recorded from South Australian waters (Scott *et al.* 1980). Species restricted to South Australia that occur in the GAB include the coastal stingaree (*Urolophus orarius*) and the crested threefin (*Norfolkia cristata*) (Edyvane 1998).

In South Australia, 77 species of fish are utilised commercially (Scott *et al.* 1980). The main fishes targeted by commercial fishers in the GAB are southern bluefin tuna (*Thunnus maccoyii*), sardine (*Sardinops sagax*), school shark (*Galeorhinus galeus*), gummy shark (*Mustelus antarcticus*), bronzewhaler shark (*Carcharhinus brachyurus*), snapper (*Pagrus auratus*), King George whiting (*Sillaginodes punctata*) and deepwater species such as deepwater flathead (*Neoplatycephalus conatus*), bight redfish (*Centroberyx gerrardi*), deep sea trevalla (*Hyperoglyphe antarctica*) and orange roughy (*Hoplostethus atlanticus*). Surveys conducted by the CSIRO in the GAB between 1965 and 1989 collected information on species composition, sizes, and distribution patterns of fishes. Surveys were conducted by trolling (1979, 1981) and demersal (1978-81), pelagic (1979) and mid-water trawling (1978, 1980-81). CSIRO also have data from Russian surveys conducted in the GAB in 1965-1974.

Recreational fishers in the GAB target Australian salmon (*Arripis truttacea*), mulloway (*Argyrosomus japonicus*), snapper (*Pagrus auratus*), King George whiting (*Sillaginodes punctata*), Australian herring (*Arripis georgiana*) and yellowtail kingfish (*Seriola lalandi*).

4.7 Reptiles

Three species of tropical and subtropical marine turtles have been recorded in South Australian waters: the loggerhead (*Caretta caretta*), green (*Chelonia mydas*) and leathery (*Dermochelys coriacea*) turtles. All species are mainly found in tropical and subtropical waters and sightings in South Australian waters are rare.

4.8 Mammals

The GAB is increasingly being recognised as an area of global conservation significance for species of rare and endangered marine mammals (Edyvane and Andrews 1995). Two of the three species of pinnipeds that occur in Australia are found in the GAB. The Australian sea lion (*Neophoca cinerea)* and New Zealand fur seal (*Arctocephalus forsteri*) both belong to the Otariidae. The New Zealand fur seal reaches 185 kg and is considerably smaller than the Australian sea lion that may reach 400 kg. Both species breed ashore and exhibit delayed sexual maturity (3-5 years).

The Australian sea lion has a unique life history. It is the only pinniped with a non-annual, aseasonal breeding cycle that is temporally asynchronous across its range (Gales and Costa 1997). This breeding cycle of slightly less than 18 months causes a seasonal drift in the timing of breeding, so that for any site, breeding takes place at all times of the year over a 20 year period (Gales *et al*. 1994). The duration of the breeding season (5 months), and the placental phase of gestation (up to 14 months) are the longest of any seal.

The Australian sea lion is endemic to Australia. It is considered 'rare' and 'a special protected species' by the South Australian and Western Australian Governments, respectively, and listed as endangered by Kennedy (1990). It is currently listed under the *Environment Protection and Biodiversity Conservation Act 1999* as near threatened. The world population is estimated at 10,000-12,000 individuals with approximately 7500 occurring in South Australia and 3100 in Western Australia (Gales 1990, Gales *et al.* 1994). Almost 10% of the South Australian population occurs in the GAB. Of particular significance, are the small breeding colonies along the cliffs of the GAB, which have never been harvested commercially (Dennis and Shaughnessy 1996). Edyvane (1998) lists population surveys undertaken of haul-out sites within the GAB and threats to recovery of Australian sea lion populations.

Most of the world population of New Zealand fur seal occurs in New Zealand, however there are a few colonies totalling approximately 35,000 individuals in Australia with over 80% of these in South Australia (Shaughnessy *et al.* 1994). Most of the Australian population (77%) is located in central South Australia and the islands of the Nuyts Archipelago in the eastern GAB support small colonies. Population studies indicate that the New Zealand fur seal populations are in a major phase of expansion with increases of 15 to 20 % per year (Shaugnessy *et al.* 1996). This species has been protected in Commonwealth waters since it's inclusion in 2000 under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* as a 'listed marine species'.

There is a general lack of knowledge for the order Cetacea. None of the 44 species that occur in Australia are endemic. Sightings and strandings suggest that 28 species from six families occur in South Australia waters, mostly the GAB (Environment Australia website 2003b). Seven of these species belong to the suborder Mysticiti (Baleen whales) and 21 to the suborder Odontoceti (the toothed whales). The Leeuwin Current may help to bring individuals of tropical species such as Bryde's whale (*Balaenoptera edeni*) into southern waters (Kemper & Ling, 1991). All cetaceans are protected in the Australian Whale Sanctuary established by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The most common baleen whale in the GAB is the southern right whale (*Eubalaena australis*), which migrates from summer feeding grounds in the Southern Ocean to the Head of Bight to breed and calve during winter. This species was recognised as both 'endangered' under the Commonwealth *Endangered Species Protection Act 1992* (repealed) and 'vulnerable to extinction' by the World Conservation Union and the International Union for the Conservation of Nature (Edyvane 1998). It continues to be recognised as 'endangered' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.* Population levels are classed as severely reduced, probably increasing but not yet secure. The rate of population increase is slow due to the three-year calving cycle.

The most commonly sighted toothed whales in the GAB are the resident bottlenose dolphin (*Tursiops truncatus*) and common dolphin (*Delphinus delphinus).* These species are common throughout Australian waters.

4.9 Seabirds

The seabird fauna of Australia is probably the best known of all faunal assemblages, yet the abundance and population trends of nearly all species are poorly understood (Van Tets and Fullager 1984). Of the 110 species found in Australia, 72 visit coastal and oceanic waters of South Australia. Approximately 1.4 to 1.6 million pairs of seabirds belonging to at least 16 species breed in South Australia, but only 10 species breed each year in significant numbers (Copley 1995). Approximately 75% of the breeding seabirds in South Australia are found in the eastern GAB. This is mainly due to the large annual migration of approximately 1.3 million pairs of short-tailed shearwaters or muttonbirds, (*Puffinus tenuirostris*) and white-faced storm petrels (*Pelagodroma marina*) to islands in the region (DEH website 2003b). Few data relating to feeding and nesting aggregations in the GAB are available. A survey of the GAB during 2000/2001 (Burton *et al.* 2001) recorded over 5000 seabirds belonging to 17 species. Petrels, shearwaters and albatross were the species most commonly sighted. The great winged petrel (*Pterodroma macroptera*) comprised 76% of all sightings.

Other species commonly observed in the GAB include the shy albatross (*Thalassarche cauta*), wandering albatross (*Diomedea exulans*), royal albatross (*Diomedea epomophora*), fleshy-footed shearwater (*Puffinus carneipes*), crested tern (*Sterna bergii*), fairy tern (*Sterna nereis*), Caspian tern (*Sterna caspia*), Australasian gannet (*Morus serrator*), silver gull (*Larus novaehollandiae*), Pacific gull (*Larus pacificus*), pied cormorant (*Phalacrocorax varius*), black-faced cormorant (*Phalocrocorax fuscescens*), white-bellied sea-eagle (*Haliaeetus leucogaster*) and osprey (*Pandion haliaetus*) (Simpson and Day 1999).

The little penguin (*Eudyptula minor*) is the world's smallest penguin species and is endemic to southern Australia and New Zealand. GAB populations are globally significant, and several breeding sites are in the GABMP (Reilly 1974). The GAB supports significant numbers of breeding osprey, which favour rock-stacks and cliffs as nest sites (Edyvane 1998). Fairy terns, Caspian terns and Pacific gulls occur in a small number of colonies in the GAB and may be vulnerable to disturbance.

Threats listed for seabirds include anthropogenic disturbance of nesting sites, habitat degradation, pollution, fisheries entanglement and predation by feral animals (DEH website 2003b; Edyvane 1998). Many seabirds that occur in the GAB are protected as 'listed marine species' and 'listed migratory species' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

5. GREAT AUSTRALIAN BIGHT FISHERIES

This section provides an overview of the main commercial Commonwealth and State fisheries within the GAB. A more detailed description of spatial and temporal patterns of fishing activity in the GAB is provided by Ward *et al.* (2003a).

5.1 Great Australian Bight Trawl

Numerous trawl surveys have been conducted in the GAB (Houston 1954, Kesteven and Stark 1967, Collins and Baron 1981, Maxwell and Garrey 1981; Newton and Klaer 1991; Burnell and Newton 1989; Walker and Clarke 1990; Walker *et al*. 1982; Walker *et al.* 1989). However, prior to the 1980s, commercial trawling was limited by the lack of suitable vessels and refrigeration (Maxwell and Garrey 1981). A detailed history of the Great Australian Bight Trawl Fishery (GABTF) is provided in Caton (2003).

Today's GABTF is comprised of a maximum of 10 vessels that operate from the western end of Kangaroo Island to Cape Leeuwin and out to the edge of the Australian Fishing Zone (AFZ, 200 nautical miles offshore), an area of approximately 812,000 km^2 (Caton and McLoughlin 1999; Caton 2002). Trawling is demersal and occurs on the continental shelf or shelf slope in waters less than 1000 m in depth. The GABTF is managed under the Commonwealth *Fisheries Management Act 1991* using limited entry input controls and restrictions on vessel size of 40 m.

Species caught vary according to the depth and area being fished. In a trawl survey carried out in 1988, 166 fish species from 125 genera and 71 families were taken (Newton and Klaer 1991). At depths less than 200 m catches are composed mostly of deepwater flathead (*Neoplatycephalus conatus*) and Bight redfish (*Centroberyx gerrardi*), while on the continental slope (depths greater than 200m) orange roughy (*Hoplostethus atlanticus*) and oreo dories (family Oreosomatidae) are the main species. In 2000, total landings were over 2000 tonnes, with a value of over A$3.5 million. Bight redfish and deepwater flathead comprised 64% of the total catch weight (Caton 2002).

There is a small bycatch of undersized target species. An onboard observer program indicated 'significant discarding' of non-commercial fishes (Caton 2002). Whilst most trawls are carried out on substrates with minimal sessile epifauna, some exploratory shots contain significant amounts of benthos (Caton 2002). There are no data for the species composition or quantities of sessile fauna taken as bycatch in the GABTF. Logbook data suggest that demersal trawling continued to occur in the BPZ up to at least 2000 (Caton 2002).

5.2 Shark Fishery

The Southern Shark Fishery was incorporated into the Gillnet, Hook and Trap Fishery (GHTF) in 2003. The shark fishery has operated for more than 70 years and targets demersal shark in waters of the AFZ of Victoria, Tasmania and South Australia. In 2001 the fishery expanded to include State waters (out to 3 nautical miles). The fishery is managed by the Australian Fisheries Management Authority (AFMA). The primary management tools for the fishery are limited entry, gear restrictions, minimum legal lengths and total allowable catches (TACs). Individual transferable quotas (ITQs) were introduced in 2001 for school (*Galeorhinus galeus*) and gummy shark (*Mustelus antarcticus*).

Shark fishers initially used longlines to target school shark but by the 1970s gillnetting was the main fishing method used and gummy shark became the principal species in the catch (Caton 2002). These two species now make up to 88% of the catch. Other species include bronze whaler shark (*Carcharhinus brachyurus*), whiskery shark (*Furgaleus macki*), saw shark (*Pristiophorus nudipinnis, P. cirratus*), elephant fish (*Callorhinchus millii*) and dogfish species (family Squalidae). In 2000, the total shark catch was 2395 tonnes with a value of A$13.8 million. School shark and gummy shark comprised 253 and 1651 tonnes of the catch, respectively. Since the 1980s, the proportion of school shark in the catch has decreased dramatically. An assessment in 1991 indicated severe overfishing of school shark with the total biomass reduced to 10-25% of the initial level (Caton 2002). Gummy shark catches are currently considered to be sustainable (Caton 2002).

Records of catch in the shark fishery are available since the 1920s, and can be obtained from the Marine and Freshwater Resources Institute (MAFRI) of Victoria and AFMA. The ongoing Southern Shark Monitoring Project provides data for stock assessments of school and gummy shark. Recent research has focussed on developing population models and used tagging and genetic studies to investigate the spatial structure of populations (Caton 2002). Additional research is needed on species taken as bycatch, including other sharks, seals and dolphins.

5.3 Southern Bluefin Tuna

The southern bluefin tuna (*Thunnus maccoyii*) fishery (SBTF) is an international fishery, and has been managed by the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) since 1994. The CCSBT receives advice from a scientific committee of member-country scientists and independent international scientists (Caton 2002). In Australia, the fishery is managed using ITQs.

In South Australia, most SBT are taken from the central part of the GAB. In recent years, the South Australian fishery has moved away from longlining and poling to purse-seine operations that supply the tuna mariculture industry in Port Lincoln. In 1999-2000, over 5000 tonnes were transferred to farms in Port Lincoln, and the total value of exports was A$280 M (Caton 2002). A more detailed history of the SBTF is provided in Caton (2003).

Excessive catches of SBT over many years has reduced the size of the spawning stock to an unsafe level. This problem has been exacerbated through fishing by countries outside the international convention (Caton 2002). There has been extensive data collected for landings of SBT in Australia. Research has included stock assessments, tagging, age estimation, nutrition studies for farmed SBT and analysing the impact of tuna fishing on seabirds (Caton 2002).

5.4 South Australian Sardine Fishery

Historically, sardine or pilchard (*Sardinops sagax*) have been taken by marine-scalefish fishers for recreational fishing bait and human consumption. SBT pole-and-line fishers also used sardine as live-bait. In 1991, a dedicated purse-seine fishery for sardine was established to supply fodder for the tuna mariculture industry in Port Lincoln. The purse-seine fishery for sardine is managed under a regime of input and output controls that involve entry limitations, gear restrictions an annual TAC and ITQs. The current fishery is comprised of 14 licence holders using nets not exceeding 1000m in length, depths of 200 m and mesh size restrictions of 14-22 mm.

The TAC for the South Australian purse-seine fishery was set at 1200 t in 1991/1992 and increased to 3500 t per annum between 1993 and 1996 (Mackie 1995). Since 1999 the TAC has been established on the basis of annual estimates of spawning biomass provided by SARDI Aquatic Sciences. The fishery is now South Australia's largest by weight. The TAC increased from 17,700 tonnes in 2002 to 36,000 tonnes in 2003 (Ward *et al*. 2001, Ward *et al.* 2002a). Currently, most fishing occurs in southern Spencer Gulf, however there is significant potential for the fishery to move westward in the eastern GAB (Ward *et al*. 2001, 2002a).

5.5 South Australian Marine Scalefish Fishery

The Marine Scalefish Fishery (MSF) in the GAB is managed by the South Australian Government under provisions of the *Fisheries Act 1982*. Fishers in inshore waters target gummy (*Mustellus antarcticus*) and bronze whaler (*Carcharhinus brachyurus*) sharks, sweep (*Scorpis aequipinnis*), King George whiting (*Sillaginodes punctata*), snapper (*Pagrus auratus*), mulloway (*Argyrosomus japonicus*) and Australian salmon (*Arripis truttacea*).

Offshore waters are fished for school shark (*Galeorhinus galeus*), oceanjackets (*Nelusetta ayraudi*) and deep sea trevalla (*Hyperoglyphe antarctica*) (Jones 1991). The fishery is managed by input controls including limited entry and gear restrictions. Research is limited mainly to analysis of catch and effort data and population modelling of size and age data for major species, including King George whiting and snapper (McGarvey *et al* 2003).

The main species targeted by recreational fishers in the GAB are Australian salmon, mulloway, snapper, King George whiting, Australian herring (*Arripis georgianus*), garfish (*Hyporhamphus melanochir*), mullet (*Aldrichetta forsteri*) and blue swimmer crab (*Portunus pelagicus*). The recreational fishery is managed through bag and boat limits and size restrictions. A considerable amount of information on the amount and type of species taken by recreational fishers within the GAB is available in the recently published National Recreational and Indigenous Fishing Survey (Henry and Lyle 2003).

5.6 Northern Zone Rock Lobster

The commercial rock lobster fishery in the GAB is a single species (*Jasus edwardsii*) fishery managed under regulations of the Northern Zone Rock Lobster Fishery (NZRLF). The fishery developed in the late 1940s and early 1950s when overseas markets for frozen tails were established (Copes 1978; Lewis 1981). Currently, over 90% of the commercial catch is exported live to overseas markets, mainly China (Ward *et al.* 2002b).

Operations are restricted mainly to the eastern GAB, where islands and offshore reefs provide suitable habitat for rock lobster. Up until 2003, the fishery was managed through input controls that restrict the number of pots and days fished (Zacharin 1997). Minimum size limits, restrictions in boat size/engine capacity and a prohibition on the taking of berried females are also enforced. A quota system will be in place from 2003 onwards. Commercial licence holders are permitted to take other species including giant (king) crab (*Pseudocarcinus gigas*), Australian salmon, mulloway, octopus (*Octopus* species) and snapper. Recent research has focussed on the analysis of catch and effort data, establishing a pot sampling program, monitoring puerulus settlement and by-catch levels, and developing a new stock assessment model (Ward *et al.* 2002b).

There is an important recreational fishery for lobster in the eastern GAB, especially around Port Lincoln, Coffin Bay, Elliston, Venus Bay, Streaky Bay and Ceduna. Venema *et al*. (2003) estimated that a total recreational catch of 23 tonnes was taken from the NZRLF in 2001/2002. Recreational fishers are permitted to take rock lobster during the same season as the commercial fishery. Recreational fishers have access to all harvesting methods, including

diving, drop nets, hoop nets, and pots (same dimensions as commercial sector). A maximum of 4 lobsters per person or 8 lobsters per boat may be taken each day. A recreational possession limit of 15 lobsters per person is in place. All rock lobster pots must be registered with PIRSA Fisheries, at which time a coloured tag is provided which must be attached to the float at all times. A maximum of two rock lobster pots may be registered by any person over the age of 15 years.

All rock lobster caught by recreational fishers must have the centre tail fan clipped to a recognisable straight line before landing, to allow compliance officers to identify recreational catches. The same size limit applies as for the commercial fishery. Retention of egg-bearing females is prohibited at all times.

5.7 West Coast Prawn Fishery

Commercial prawn fishing in the eastern GAB is limited to three licence holders that catch western king prawn (*Melicertus latisulcatus)* by otter trawling in waters deeper than 10 m. Trawling is concentrated in three areas: Nuyts Archipelago, Anxious Bay and Coffin Bay. The fishing season runs from the last quarter of the moon through to the first quarter during all months except January, May and October (MacDonald 1998; Svane 2003). Catches vary markedly between years due to variation in the supply of recruits to nursery areas (Carrick 1996). The total reported catch for the 2000/01 fishing season was 106.2 tonnes from 78 fishing nights. As in most trawl fisheries, there is a significant by-catch of non-target species. Licence holders are also permitted to retain slipper lobster (*Ibacus* species), octopus (*Octopus* species), scallop (family Pectinidae), southern calamary (*Sepioteuthis australis*) and arrow squid (*Notodarus gouldii*). Recent research by SARDI Aquatic Sciences has involved commercial analysis of catch and effort data, catch sampling and tagging.

5.8 Western Zone Abalone

The commercial abalone fishery of South Australia focuses on greenlip (*Haliotis laevigata*) and blacklip (*Haliotis rubra*) abalone. Transferable licences are issued to persons, partnerships or companies. Each licence holder is allocated an annual ITQ that is an equal share of the TAC. A total of 23 licence holders operate in the eastern GAB (Mayfield *et al.* 2002).

The Western Zone is split into two regions for management purposes. In region A (Arno Bay to Point Brown) the commercial catch quota for 2002 was 293 tonnes and 207 tonnes (whole weight) for blacklip and greenlip, respectively. In Region B (north and west of Point Brown) each of the 23 fishers may harvest 1.8 tonnes (whole weight) of either greenlip or blacklip

abalone (Mayfield *et al.* 2002). Research needs are defined by the Abalone Fisheries Management Committee and include improving stock assessment techniques, developing a stock assessment model, evaluating reference points and assessing the impact of marine reserves on productivity (Mayfield *et al.* 2002).

A small recreational fishery (mostly snorkelling or diving) also exists for greenlip and blacklip abalone. Bag-limits apply (5 per person per day or 10 per boat per day). Minimum size limits are 14.5 cm for greenlip and 13 cm for blacklip abalone.

5.9 Ocean Jacket

Commercial fishing operations for ocean jacket (*Nelusetta ayraudi*) in the eastern GAB include licence holders from MSF, NZRLF and GABTF sectors (Grove-Jones and Burnell 1991). Operations involve setting traps in deep waters (>60m) of the eastern GAB. Management arrangements for this fishery include limits on the number of fishers, number of traps and length of the fishing season. Grove-Jones and Burnell (1991) assessed catch information and described the age, growth and reproduction patterns of this species.

6. OTHER ACTIVITIES

6.1 Tourism and recreational fishing

Recreational fishing in the eastern GAB includes charter fishing operations out of Port Lincoln, Ceduna and Coffin Bay, and beach fishing by members of fishing clubs, fishing safaris and four wheel drive fishing enthusiasts (Jones 1991). There are no facilities for launching boats along the entire coast of the GABMP (Edyvane 1998). Target species from beach fishing include Australian salmon and mulloway. Charter vessels visit Flinders Reef and Nuyts Archipelago as well as fishing offshore for southern bluefin tuna, snapper, nannygai (*Centroberyx affinis*), blue morwong (*Nemadactylus valenciennesi*), samson fish (*Seriola hippos*), yellowtail kingfish (*Seriola lalandi*), trevally (*Pseudocaranx dentex*), sweep (*Scorpis aequipinnis*) and salmon (*Arripis truttacea*). Tourists travel to the Nuyts Archipelago to see dolphins and sea lions.

Coastal waters near the Head of Bight are renowned as critical breeding and calving areas for the southern right whale (*Eubalaena australis*). The cliffs at Callosity Point provide a spectacular vantage point and attract thousands of visitors each year. The area is partly managed by the Yalata aboriginal community and permits must be obtained to access the area and view whales.

6.2 Petroleum exploration

The Geoscience Australia website (2003b) maps explorations in the GAB by Shell (1972/73), AGSO (1965, 1986, 1997) and other exploration companies (1990, 1999). Five Exploration Petroleum Permits (EPP) were granted in the GAB in 2000, including EPPs 28, 29, 30 and 31 to *Woodside Energy* (operator) and its Canadian (*Encana*) and US (*Anadarko*) partners, and EPP32 to Santos. Two of the licences (EPP28 and EPP29) include portions of the Commonwealth's declared GABMP (BPZ). *Woodside Energy* drilled a wildcat exploratory well (Gnarlyknots 1) in over 1300 m of water in the Bight Basin in EPP 29 in April-May 2003. The well lies 325 km southwest of Ceduna and 425 km west of Port Lincoln and is located approximately 50 km east of the BPZ. Drilling operations under EPP 29 have been subject to a rigorous environmental review under the *Petroleum (Submerged Lands) Act 1967* (PSLA) and the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBCA) (Commonwealth). Special effort was invested to ensure that environmental impact of exploration activities was minimized, due to the proximity of the well to the GABMP. *Woodside Energy* prepared an Environment Plan pursuant to the requirements of *Petroleum (Submerged Lands, Management of Environment) Regulations 1999* under the PSLA. The Environment Plan assessed the specific environmental risks of the Gnarlyknots 1 and set clear

management measures to address those risks. A copy of the accepted Environment Plan is available from the PIRSA Petroleum Group environmental register (PIRSA website 2003).

Further exploration activity is anticipated in the GAB over the next 5 years. All measures are in place to ensure compliance with the PSLA and EPBCA. The level of activity in the near future is uncertain and another well may not be drilled before 2006.

6.3 Commercial Shipping

Information provided by the Australian Marine Safety Authority shows that very few commercial ships pass through the GAB or BPZ. Most ships travel south of the Bight in a line from the corner of southwest Australia to Melbourne. Ships travelling between Perth and Adelaide enter the southern limits of the BPZ (Fig. 11).

6.4 Biotechnology and drug discovery from marine invertebrates

Many animals and plants produce chemicals with antimicrobial, antiviral and anti-tumour properties (Lowenstein 1989). Like many other diverse regions, the GAB supports marine organisms that produce secondary metabolites that could be synthesised into pharmaceutical products. Dr Robert Capon and his team from the University of Melbourne have isolated several chemicals from sponges found in the GAB. These include; new stesterterpenes from *Spongia hispida* (Davies and Capon 1993); antimicrobial sesquiterpenes; quinones from a *Spongia* species (Capon *et al.* 1993); antimicrobial acetylenic acids from *Phakellia carduus* (Barrow and Capon 1994) and a new antimicrobial alkaloid from a *Clathria* species. A previously undescribed functional group of novel metabolites ‘aplidites’ has been isolated from a tunicate (*Aplidium* species) found in the GAB (Murray *et al.* 1995).

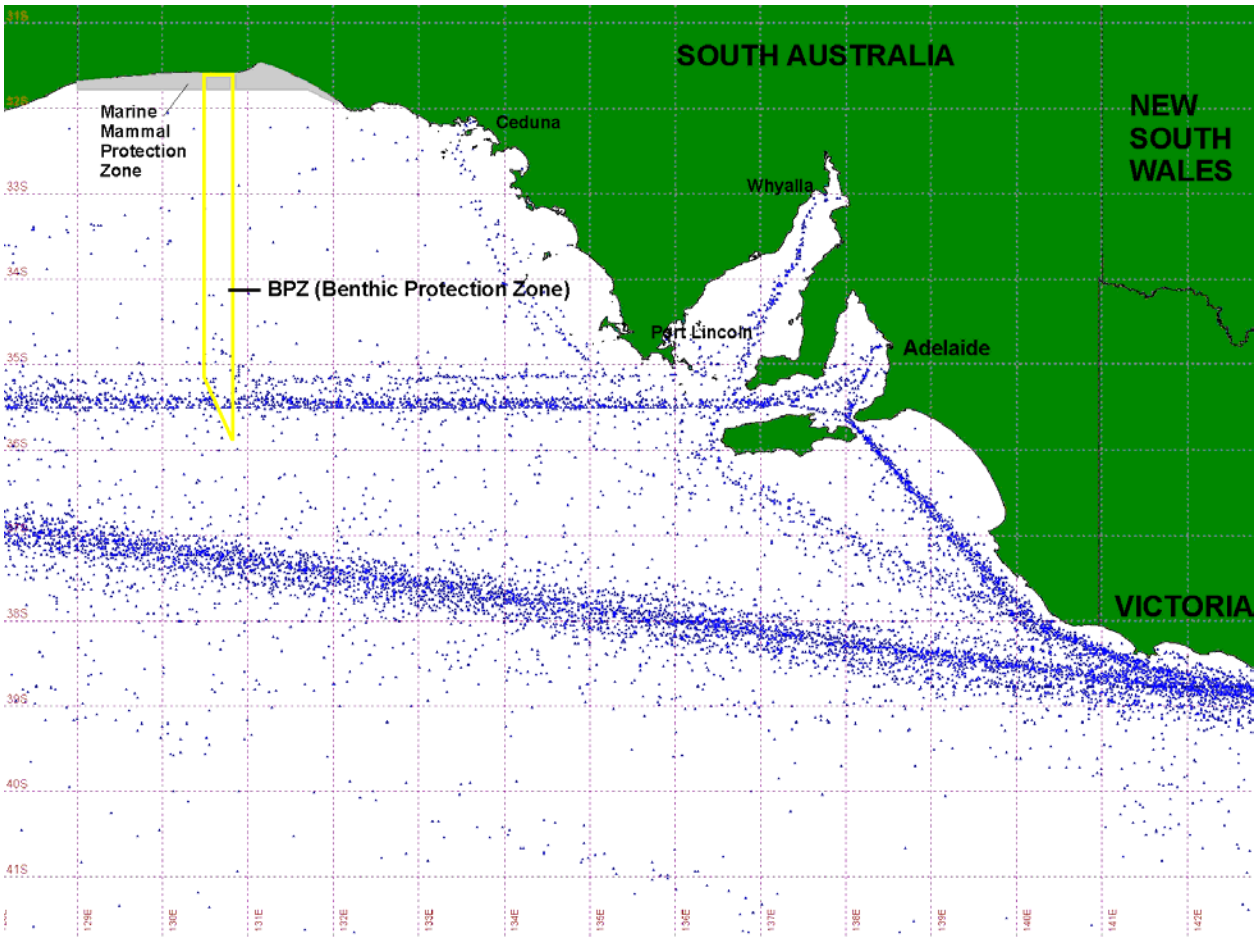


Figure 11. Main shipping routes off South Australia (Map provided by Australian Maritime Safety Authority).

7. GENERAL DISCUSSION

Relatively few data are available on the biology of non-commercial species in the GAB and there have been few studies of either the pelagic or benthic ecology of the region. Broad-scale oceanographic processes have been investigated using numerical models, but there is minimal information on fine-scale physical processes and relatively few *in situ* oceanographic data have been collected. To address these information needs, SARDI Aquatic Sciences established a large-scale, multidisciplinary investigation of the pelagic productivity and trophodynamics of the GAB in 2003 (FRDC Project 2003/072). This study will compliment ongoing investigations of the GAB's pelagic fishes being undertaken by SARDI Aquatic Sciences and CSIRO, as well as a doctoral study by Mr Paul Van Ruth (SARDI Aquatic Sciences, Adelaide University) of primary productivity, phytoplankton community structure and zooplankton grazing patterns in the region. Hence, the need for information on the pelagic ecology of the GAB is being addressed.

The lack of information on the benthic communities of the GAB prevented the BPZ being established on the basis of quantitative ecological data. This lack of information is the major impediment to assessing the effectiveness of the BPZ in achieving its main aim, which is to "preserve a representative sample of benthic flora and fauna and sediments" of the GAB (Department of Environment Heritage and Aboriginal Affairs 1998a).

The aim of the BPZ has two critical elements. The first is to "represent" the GAB's benthic biota within the BPZ. The second is to "preserve" the ecological integrity of this biota by protecting the communities from potentially destructive anthropogenic activities, such as demersal trawling.

To assess the degree to which the BPZ represents the benthic communities of the GAB, information is needed on the structure and species composition of benthic communities inside and outside the Marine Park. This review clearly shows that this information is not currently available: no quantitative surveys of the benthic communities of the GAB have been conducted; there is no detailed inventory of benthic species of the region; and it is likely that the benthic communities of the GAB include hundreds of undescribed species of macro-invertebrates, including sponges, bryozoans and cnidarins.

Currently, the most useful indicator of the degree to which the BPZ represents the benthic communities of the GAB is the information on the sedimentary facies provided by James *et al.* (2001). This information suggests that: (i) the sedimentary facies in the GAB may reflect the spatial distribution of benthic communities; and (ii) the BPZ may represent the benthic

communities of the GAB relatively effectively because four of the eight facies that occur on the shelf are included in the BPZ. However, the hypothesis that the sedimentary facies of the GAB reflect the spatial distribution of benthic communities has not been tested empirically. If the structure and species composition of the benthic communities of the GAB are not correlated with sedimentary facies, then using these data to assess the effectiveness of the BPZ in representing the benthic communities of the GAB may not be justified. Addressing this issue is a priority for managers of the GABMP, because establishing expensive performance assessment systems may not be appropriate if the benthic communities of the BPZ are not particularly diverse or do not include a significant proportion of the species that occur in the GAB, and hence do not represent the regions benthic communities effectively.

The lack of information on the structure and species composition of the GAB's benthic communities also prevents assessment of the effectiveness of the BPZ in protecting the ecological integrity of the communities of the BPZ. Baseline data on the species composition of the benthic communities of the BPZ and the environmental factors that affect patterns of distribution and abundance are needed to provide a basis for assessing future changes in community structure. To provide a context for assessing the potential causes of future changes in community structure, detailed information is also required on the nature and extent of anthropogenic activities in and around the GABMP, including sustainable extractive uses. For example, detailed information on the levels of effort and catch in fisheries that operate in and near the GABMP is needed to quantify the potential impacts of these operations.

The second report in this series by SARDI Aquatic Sciences synthesises information available on fishing activities in the GAB, especially those that operate in and near the BPZ, and identifies options for monitoring future sustainable-use of the GABMP and surrounding areas (Ward *et al.* 2003a). The third report describes a benthic survey of the GAB that was conducted to provide a basis for assessing the effectiveness of the BPZ for representing and preserving the sediments and benthic biota of the GAB (Ward *et al.* 2003b).

REFERENCES

Alderslade, P. (1998). Revisionary systematics in the gorgonian family Isididae, with descriptions of numerous new taxa (Coelenterata: Octocorallia). *Records of the Western Australian Museum.* **55**: 1-359.

Alderslade, P. (2003). A new genus and new species of soft coral (Octocorallia: Alcyonacea: Alcyoniidae). *Zootaxa.* **175**: 1-10.

Baker, A.N. (1982a). Sea-urchins. In: S.A.Shepherd and I.M.Thomas (Ed.) Marine Invertebrates of Southern Australia, 437-453. Govt. Printer, South Australia.

Baker, A.N. (1982b). Brittlestars. In: Shepherd S.A. and Thomas I.M. (Ed.) Marine Invertebrates of Southern Australia, 418-436. Govt. Printer, South Australia.

Barrow, R.A. and Capon R.J. (1994). Carduusynes (-E): Acetylenic acids from a Great Australian Bight marine sponge *Phakellia carduus*. *Australian Journal of Chemistry.* **47**(10): 1901-1918.

Beesley, P.L., Ross, G.J.B. and Glasby, C.J. (2000). Polychaetes and allies: The southern synthesis. CSIRO Publishing, Melbourne. 465p.

Bergquist, P.R. and Skinner, I.G. (1982). Sponges (Phylum Porifera). In: Shepherd S.A. and Thomas I.M. (Eds.) Marine Invertebrates of Southern Australia, 38-72. D.J. Woolman Printer, South Australia.

Bock, P.E. (1982). Bryozoans. In: Shepherd S.A. and Thomas I.M. (Eds.) Marine Invertebrates of Southern Australia, 319-394. D.J. Woolman Printer, South Australia.

Bock, P.E. and Cook, P.L. (1993). *Quadriscutella gen. nov.* (Bryozoa, Cheilostomata) from the tertiary and recent of Victoria and South Australia. *Alcheringa.* **17**: 159-171.

Bock, P.E. and Cook, P.L. (1998a). Otionellidae, a new family including five genera of free-living lunulitiform Bryozoa (Cheilostomatida). *Memorie de Scienze Geologiche.* **50**: 195-211.

Bock, P.E. and Cook, P.L. (1998b). A new species of multiphased *Corbulipora* MacGillivray, 1895 (Bryozoa: Cribriomorpha) from southwestern Australia. *Records of the South Australian Museum.* **30**: 63-68.

Bock, P.E. and Cook, P.L. (1999). Notes on tertiary and recent 'Lunulite' Bryozoa from Australia. *Memorie de Scienze Geologiche.* **51**: 415-430.

Bock, P.E. and Cook, P.L. (2001a). The genus *Macrocamera* Gordon and d'Hondt (Bryozoa, Cheilostomata) from Australia. *Memorie de Scienze Geologiche.* **53**: 139-151.

Bock, P.E. and Cook, P.L. (2001b). A review of Australian *Siphonicytara* Busk (Bryozoa: Cheilostomatida). *Records of the Western Australian Museum.* **20**: 307-322.

Burnell, S. and Newton, G. (1989). Commercial stocks in the GAB. *Australian Fisheries.* **48**(4): 20-24.

Bureau of Meteorology website (2003), <www.bom.gov.au/products/>

Burton, C.J., Coleman, C., Serginson, C. and Green, C. (2001). Dedicated Marine Fauna Monitoring Program During the Flinders Deepwater 2D Seismic Survey in the Great Australian Bight: December 2000 - May 2001. Woodside Energy, Anadarko and Pan Canadian Perth, Western Australia. Unpublished report.

Bye, J.A.T. (1972). Oceanographic circulation south of South Australia. Antarctic Oceanography II. *The Australian-New Zealand Sector. Antarctic Research Series. American Geophysics Union.* **19**: 95-100.

Bye, J.T. (1983). The general circulation in a dissipative basin with longshore wind stresses. *Journal of Physical Oceanography.* **13**: 1553-1563.

Capon, R.J., Groves, D.R., Urban, S. and Watson, R.G. (1993). Spongiaquinone revisited: structural and stereochemical studies on marine sesquiterpene/quinones from a southern Australian marine sponge, *Spongia* sp. *Australian Journal of Chemistry.* **46**: 1245-1253.

Carrick, N. (1996). Key factors which affect prawn recruitment and implications to harvesting prawn stocks. Final Report to FRDC. FRDC 91/3. 82p.

Caton, A. and McLoughlin, K. (1999). Great Australian Bight trawl fishery. Fishery Status Report. 1-250. Bureau of Rural Resources. Agriculture, Fisheries and Forestry of Australia. 250p.

Caton, A. (2002). Fishery status reports 2000-2001 - resource assessments of Australian Commonwealth fisheries. Bureau of Rural Sciences - Agriculture, Fisheries and Forestry, Australia, Victoria. 252p.

Collins, S.P. and Baron, M.P. (1981). Demersal and pelagic trawling survey of the MT Denebola in Southern Australian waters, 1979-89 summer. *Tasmanian Fisheries Research* **24**: 1-48.

Commonwealth Scientific and Industrial Research Organisation (CSIRO) website (2003) <www.marine.csiro.au/~dunn/eez_data/atlas>.

Conolly, J.R. and Von der Borch, C.C. (1967). Sedimentation and physiography of the sea floor south of Australia. *Sedimentary Geology.* **1**: 181-220.

Cook, P.L. and Bock, P.E. (2001). Calescharidae, a new family for the tertiary to recent genera *Caleschara* MacGillivray and *Tretosina* Canu and Bassler (Bryozoa: Cheilostomata). *Invertebrate Taxonomy.* **15**: 527-550.

Copes, P. (1978). Resource management for the rock lobster fisheries of South Australia. A report commissioned by the steering committee for the review of fisheries of the South Australian Government.

Copley, P. (1995). Status of South Australian seabirds. Unpublished report. Department of Environment and Natural Resources.

Dannevig, H.C., McCulloch, A., Hedley, C., Hallaman, E.F. and Raff, J. (1911). Zoological results of the fishing experiments carried out by FIS Endeavour 1909-10 under H.C. Dannevig, Commonwealth director of fisheries. Department of Trade and Customs, Australia.

Davie, P.J.F. (2002). Zoological catalogue of Australia Crustacea:Malacostraca:Eucarida (Part 2): Decapoda - Anomura, Bravura. 656p.

Davies, R. and Capon, R.J. (1993). Two new sclarane sesterterpenes: Isoscalarafuran-A and B, Epimeric alcohols from a southern Australian marine sponge, *Spongia hispida*. *Australian Journal of Chemistry.* **46**: 1295-1299.

Dennis, T.E. and Shaugnessy, P.D. (1996). Status of the Australian Sea Lion *Neophoca cinera*, in the Great Australian Bight. *Wildlife Research.* **23**: 741-754.

Department of Environment Heritage and Aboriginal Affairs (1998a). Great Australian Bight Marine Park. Part A. Management Prescriptions. Government of South Australia. 26 p.

Department for Environment and Heritage website (2003a). Great Australian Bight Marine Park, <http://www.environment.sa.gov.au/coasts/pdfs/gab_mp.pdf>

Department for Environment and Heritage website (2003b). Conservation status of South Australia's breeding seabirds, <www.environment.sa.gov.au/biodiversity/seabirds>

Edgar, G.J. (2000). Australian marine life. Reed New Holland, Australia. 544p.

Edyvane, K.S. and Andrews, G.A. (1995). Draft management plan for the Great Australian Bight Marine Park. Prepared for Primary Industries South Australia. SARDI (South Australian Research and Development Institute). West Beach, South Australia.

Edyvane, K.S. (1998). Great Australian Bight Marine Park Management Plan, Part B, resource information. Department of Environment, Heritage and Aboriginal Affairs. South Australia.

Edyvane, K.S. (1999). Conserving marine biodiversity in South Australia, Part 1 - Background, status, and review of approach to marine biodiversity in South Australia. SARDI report. SARDI (South Australian Research and Development Institute). South Australia.

Environment Australia (Department of the Environment and Heritage) website (2003a). Australian Faunal directory <www.ea.gov.au/biodiversity/abrs/online-resources/abif/fauna/afd/frames/groups.html>.

Environment Australia website (2003b). Cetaceans, <www.ea.gov.au/coasts/species/cetaceans.>

EPCSA (Environmental Council of South Australia) (1998). The state of the environment report for South Australia. Department of Environment and Planning. Adelaide. 44p.

Fabricius, K. and Alderslade, P. (2001). Soft corals and Sea fans - A comprehensive guide to the tropical shallow-water genera of the central-west Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Queensland. 264p.

Feary, D.A. and James, N.P. (1998). Seismic stratigraphy and geological evolution of the Cenozoic, cool-water Eucla platform, Great Australian Bight. *American Association of Petroleum Geologists Bulletin.* **82**: 792-816.

Feary, D.A., Hine, A.C., and Malone, M.J. (2000). Great Australian Bight: Cenozoic cool-water carbonates. *Proceedings of the Ocean Drilling Program, Initial Reports.* **182**: 1-5.

Gales, N.J. (1990). Abundance of Australian Sea lions (*Neophoca cinerea*) along the southern Australian coast and related research. Report to the Western Australian Department of Conservation and Land Management, South Australian National Parks and Wildlife Service and the South Australian Wildlife Conservation Fund.

Gales N.J and Costa DP. (1997). The Australian sea lion: a review of an unusual life-history. p 78-87. In: Hindell M and Kemper, C (Eds), Marine Mammal Research in the southern hemisphere (Volume 1): Status, Ecology and Medicine.

Gales, N.J., Shaugnessy, P.D., and Dennis, T.E. (1994). Distribution, abundance and breeding cycle of the Australian Sea Lion *Neophoca cinerea* (Mammalia: Pinnipedia). *Journal of Zoology, London.* **234**: 353-370.

Geoscience Australia website (2003a). Oil and Gas project index. <www.ga.gov.au/oceans/projects>.

Geoscience Australia website (2003b). Great Australian Bight- petroleum exploration. <www.agso.gov.au/oceans/projects/20011009_8.jsp>.

Glasby, C.J. and Alvarez, B. (1999). Distribution patterns and biogeographical analysis of Australian Polychaeta (Annelida). *Journal of Biogeography.* **16**: 507-533.

Godinot, O. and Ward, T.M. (2000). Abundance variation of zooplankton in shelf waters of central and western South Australia. SARDI Aquatic Sciences. West Beach , Adelaide. 37p.

Gomon, M.F., Glover, J.C.M. and Kuiter R.H. (1994). The Fishes of Australia's south coast. State Print, Adelaide. 992p.

Gostin, V.A., Belperio, A.P. and Cann, J.H. (1988). The Holocene non-tropical coastal and shelf carbonate province of southern Australia. *Sedimentary Geology.* **60**: 51-70.

Greenwood, G. and Gum, E. (1986). The state of biological resources in South Australia. Department of Environment and Planning. Adelaide.

Grove-Jones, R. and Burnell, A.F. (1991). Fisheries biology of the ocean jacket (Monocanthidae: *Nelusetta ayraudi*) in the eastern waters of the Great Australian

Bight. Final Report to the Fishing Industry Research and Development Council (Grant No. DFS01z). 107p.

Hahn, S.D. (1986). Physical structure of the waters of the South Australian continental shelf. Technical Report 45. Flinders Institute for Atmosphere and Marine Sciences, Flinders University of South Australia. Australia. 284p.

Hallegraeff, G.M. (1988). Plankton: a microscopic world. Robert Brown and associates. CSIRO. 112p.

Hayward, P.J. and Parker, S.A. (1994). Notes on some species of *Parasmittina* Osburn, 1952 (Bryozoa: Cheilostomatida). *Zoological Journal of the Linnean Society.* **110**: 53-75.

Henry, G.W. and Lyle, J.M. (2003). The national recreational and indigenous fishing survey. FRDC Project No. 99/158. FRDC. Canberra. 200p.

Hill, P., Rollet, N. and Symonds, P. (2001). Seafloor mapping of the South-east marine region and adjacent waters-AUSTREA final report: Lord Howe Island, south-east Australian margin (includes Tasmania and South Tasman Rise) and central Great Australian Bight. Canberra: Australian Geological Survey Organisation, Record 2001/08.

Hine, A.C., Feary, D.A. and Malone, M.J. (1999). Research in Great Australian Bight yields exciting early results. *EOS.* **80**: 521-526.

Hooper J.N.A. and Wiedenmayer, F. (1994). Porifera. CSIRO/ABRS, Melbourne.

Hooper, J.N.A. and Van Soest, R.W.M. (2002). Systema Porifera. A guide to the classification of sponges. Kluwer Academic/Plenum Publishers, New York. 1101p.

Houstan, T.W. (1954). Commercial trawling tests in the Great Australian Bight, 1949-1952. *CSIRO Australian Division of Fisheries and Oceanography (Technical Paper).* **2**.

Hutchings, P. (1982). Bristleworms (Phylum Annelida). In: S.A.Shepherd and I.M.Thomas (Ed.) Marine Invertebrates of Southern Australia Part I. Pp. 228-298. Govt. Printer, South Australia.

Interim Marine and Coastal Regionalisation for Australia Technical Group (1998). Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments. Version 3.3. Environment Australia, Commonwealth Department of the Environment. Canberra. 104p.

James, N.P. and Von der Borch, C.C. (1991). Carbonate shelf edge off southern Australia: a prograding open platform margin. *Geology.* **19**: 1005-1008.

James, N.P., Bone, Y., Von der Borch, C.C. and Gostin, V.A. (1992). Modern carbonate and terrigenous clastic sediments on a cool water, high energy, mid-latitude shelf: Lacepede, southern Australia. *Sedimentology.* **39:** 877-903.

James, N.P., Boreen, T.D., Bone, Y. and Feary, D.A. (1994). Holocene carbonate sedimentation on the west Eucla shelf, Great Australian Bight: a shaved shelf. *Sedimentary Geology.* **90**: 161-178.

James, N.P., Bone, Y., Hageman, S., Gostin, V.A. and Feary, D.A. (1997). Cool-water carbonate sedimentation during the terminal quaternary, high-amplitude, sea-level cycle: Lincoln Shelf, southern Australia. In: N.P. James and J.A.D. Clarke (Ed.) Cool-water carbonates. 53-76.

James, N.P., Bone, Y., Collins, L.B. and Kyser, T.K. (2001). Surficial sediments of the Great Australian Bight: Facies dynamics and oceanography on a vast cool-water carbonate shelf. *Journal of Sedimentary Research.* **71**(4): 549-567.

Jeffery, S.W. (1981). Phytoplankton ecology - with particular reference to the Australasian region. In: N. Clayton and R.J. King (Ed.) Marine Botany, an Australian perspective 242-291. Longman and Cheshire Pty, Ltd., Melbourne.

Jones, D.S., Anderson.J.T. and Anderson, D.T. (1990). A checklist of the Australian Cirripedia (Thoracica, Acrothoracica). *Technical Reports of the Australian Museum.* **3**: 1-38.

Jones, G.K. (1991). Fin fishery considerations in the management of the proposed Great Australian Bight Marine Park. *SAFISH.* **15**(4): 11.

Kemper, C.M. and Ling, J.K. (1991). Possible influences of oceanic features of the GAB on cetaceans. In: Collection of abstracts: The Great Australian Bight - a regional perspective, Adelaide 2 May 1991, South Australian Department of Fisheries, Australian National Parks and Wildlife Service and the Australian Marine Science Association.

Kennedy, M. (1990). Australia's endangered species: the extinction dilemma. Simon Schuster, Brookvale, NSW.

Kesteven, G.L. and Stark, A.E. (1967). Demersal fish stocks of the Great Australian Bight as estimated from the results of operations of FV Southern Endeavour. *CSIRO Australian Division of Fisheries and Oceanography (Technical Paper)*. **24**: 1-62.

Kott, P. (1972). The ascidians of South Australia II. Eastern sector of the Great Australian Bight and Investigator Strait. *Transactions of the Royal Society of South Australia.* **96**(4): 165-196.

Kott, P. (1975). The ascidians of South Australia III. Northern sector of the Great Australian Bight and additional records. *Transactions of the Royal Society of South Australia.* **99**(1): 1-20.

Kott, P. (1985). The Australian Ascidiacea Pt 1, Phlebobranchia and Stolidobranchia. *Memoirs of the Queensland Museum.* **23**: 1-440.

Kott, P. (1990a). The Australian Ascidiacea Pt 2, Aplousobranchia (1). *Memoirs of the Queensland Museum.* **29**: 1-266.

Kott, P. (1990b). The Australian Ascidiacea, Phlebobranchia and Stolidobranchia, supplement. *Memoirs of the Queensland Museum.* **29**(1): 267-298.

Kott, P. (1992a). The Australian Ascidiacea, Pt 3 Aplousobranchia (2). *Memoirs of the Queensland Museum.* **32**(2): 377-620.

Kott, P. (1992b). The Australian Ascidiacea, Supplement 2. *Memoirs of the Queensland Museum.* **32**(2): 621-655.

Kott, P. (2001). The Australian Ascidiacea. *Memoirs of the Queensland Museum.* **47**(1): 1-410.

Lamprell, K.L., Scheltema, A.M., Healy, J.M., Gowlett-Holmes, K.L. and Lu, C.C. (2001). Zoological catalogue of Australia Mollusca: Aplacophora, Polyplacophora, Scaphopoda, Cephalopoda. **17**(2): 1-368.

Larkum, A.W.D., McComb, A.J., and Shepherd S.A. (Eds) (1989). Biology of seagrasses. A treatise on the biology of seagrasses with special reference to the Australian region. Elsevier press, Amsterdam, Oxford, New York, Tokyo. 841p.

Lewis, R.K. (1981). Southern rock lobster *Jasus novaehollandiae.* Zone N review. Department of Fisheries. Internal Report No 88.

Lewis, R.K., Edyvane, K.S., and Newland, N. (Eds). (1998). The state of our seas and coasts-description, uses and impacts on South Australia's marine and estuarine environment. A technical reference document for the Government of South Australia. Adelaide. 142p.

Lowenstein, J.M. (1989). Medicines from the sea. *Oceans.* **22**(1): 72.

MacDonald, N. (1998). Management plan for the Spencer Gulf and West Coast prawn fisheries. South Australian Fisheries Management Series No. 34.

Mackie, D.W. (1995). A management plan for the experimental sardine fishery. *South Australian Fisheries Management Series* **13**: 1-19.

McGarvey, R. Fowler, A.J. Feenstra, J.E. Fleer, D.A. and Jones, G.K. (2003). King George whiting (*Sillaginodes punctata*) Fishery. Fishery Assessment Report to PIRSA for the Marine Scalefish Fishery Management Committee.

Maxwell, J. and Garrey, H. (1981). The fishing ventures of the Great Australian Bight: with a resume of known potential resources and review of trawling surveys on the south-western continental shelf. CSIRO. 58p.

Mayfield, S., Rodda, K.R. and Ward, T.M. (2002). Abalone (western zone) - fishery assessment report to PIRSA fisheries policy group. South Australian Fisheries Assessment Series 2000/02c. South Australian Research and Development Institute (SARDI) - Aquatic Sciences. Adelaide. 112p.

McGowran, B., Li, Q., Cann, J., Padley, D., McKirdy, D.M. and Shafik, S. (1997). Biogeographic impact of the Leeuwin Current in southern Australia since the late middle Eocene. *Palaeoecology.* **136**: 19-40.

Middleton, J.F. (2000). Wind-forced upwelling: the role of the surface mixed layer. *Journal of Physical Oceanography.* **30**: 745-763.

Middleton, J.F. and Cirano, M. (2002). A northern boundary current along Australia's southern shelves: The Flinders Current. *Journal of Geophysical Research-Oceans*. **107**(C9): 3129-3143.

Morgan, G.J. and Jones, D.S. (1991). Checklist of the marine decapod Crustacea of southern Western Australia. In: F.E. Wells, D.I. Walker, H. Kirkman, and R. Lethbridge (Eds.) Proceedings of the Third International Marine Biological Workshop: The Marine

Flora and Fauna of Albany, Western Australia. Pp. 483-497. Western Australian Museum, Perth.

Motoda, S., Kawamusra, T. and Taniguchi, A. (1978). Differences in productivities between the Great Australian Bight and the Gulf of Carpentaria, Australia, in summer. *Marine Biology*. **46**: 93-99.

Murray, L., Lim, T.K., Currie, G. and Capon, R.J. (1995). Aplidites (A-G): Macrocyclic Orthonitrates from an Australian tunicate, *Aplidium* sp. *Australian Journal of Chemistry*. **48**: 1253-1266.

Newton, G. and Klaer, N. (1991). Deep-sea demersal fisheries resources of the Great Australian Bight: a mutivessel trawl survey. Australian Government Publishing Service, Canberra.

Okuno, J. (1997). A new shrimp of the genus *Rhynchocinetes* from the Great Australian Bight (Crustacea: Decapoda: Rhynchocinetidae). *Records of the South Australian Museum.* **30**(1): 13-18.

Parker, S.A. and Cook, P.L. (1994). Records of the Bryozoan family Selenariidae from Western Australia and South Australia, with the descriptions of new species of *Selenaria*. *Records of the South Australian Museum.* **27**: 1-11.

Primary Industries and Resources of South Australia (PIRSA) website (2003). <http://intranet.pirsa.sa.gov.au/>.

Poore, G.C. B. (1995). Biogeography and diversity of Australia's marine biota. In: L.P. Zann and P. Kailola (Ed.) The State of the Marine Environment Report for Australia. Technical Annex:1. The Marine Environment. Pp. 75-84. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Poore, G.C.B. (2002). Zoological Catalogue of Australia Crustacea: Malacostraca:Syncarida, Peracarida, Isopoda, Tanaidacea, Mictacea, Thermosbaenacea, Spelaeogriphacea. (19.2A): CSIRO Publishing: Collingwood, Vic. 448p.

Provis, D.G. and Lennon, G.W. (1981). Eddy viscosity and tidal cycles in a shallow sea. *Estuarine, Coastal and Shelf Science.* **16**: 351-361.

Reilly, P.N. (1974). Breeding of little penguins along the Great Australian Bight. *Emu.* **74**: 198-200.

Reiswig, H.M. (1992). First Hexactinellida (Porifera) (glass sponges) from the Great Australian Bight. *Records of the South Australian Museum.* **26**(1): 25-36.

Robertson, A.I. and Alongi, D.M. (1995). Mangrove ecosystems in Australia: structure, function and status. In: L.P. Zann and P. Kailola (Ed.) The State of the Marine Environment Report for Australia. Technical Annex:1. The Marine Environment. 119-134. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Rochford, D.J. (1986). Seasonal changes in the distribution of Leeuwin Current waters off southern Australia. *Australian Journal of Marine and Freshwater Research.* **37**: 1-10.

Rouse, G.W. and Pleijel, F. (2001). Polychaetes. Oxford University Press, London. 362p.

Rowe, F.W.E. and Gates, J. (1995). Zoological catalogue of Australia Echinodermata. CSIRO Publishing: Collingwood, Vic. 510p.

Scott, T.P., Glover, C.J.M., and Southcott, R.V. (1980). The marine and freshwater fishes of South Australia. Government Printer, Adelaide. 392p.

Shaughnessy, P.D., Gales, N.J., Dennis, T.E., and Goldsworthy, S.D. (1994). Distribution and abundance of New Zealand fur seals, *Arctocephalus forsteri*, in South Australia and Western Australia. *Wildlife Research.* **21**(6): 667-695.

Shaughnessy, P.D., Stirling, I., and Dennis, T.E. (1996). Changes in the abundance of New Zealand fur seals, *Arctocephalus forsteri*, on Neptune Islands, South Australia. *Wildlife Research.* **21**: 667-695.

Shepherd, S.A. (1979). The ecology of a deep-water red algal community off Cape Northumberland, South Australia. Department of Fisheries Series Report No.4. 255p.

Shepherd, S.A. (1991). Biogeography of the GAB region (Abstract). In: Collection of Abstracts: The Great Australian Bight: A regional perspective, Adelaide, 2 May, 1991. South Australian Department of Fisheries, Australian National Parks and Wildlife Service and the Australian Marine Science Association.

Shepherd, S.A. and Davies, M. (Ed). (1997). Marine invertebrates of southern Australia Part III. South Australian Research and Development Institute (Aquatic Sciences) in conjunction with the Flora and Fauna of South Australia Handbooks Committee, Adelaide. 363p.

Shepherd, S.A. and Robertson, E.L. (1989). Regional studies - Seagrasses of South Australia, Western Victoria and Bass Strait. In: A.W.D. Larkum, A.J. McComb, and Shepherd S.A. (Eds.) Biology of seagrasses. A treatise on the biology of seagrasses with special reference to the Australian region. **7**: 211-229. Elsevier press, Amsterdam, Oxford, New York, Tokyo.

Shepherd, S.A. and Thomas I.M. (Eds.) (1982). Marine invertebrates of southern Australia Part I. D.J. Woolman, Government Printer, South Australia. 491p.

Shepherd, S.A. and Thomas I.M. (Eds.) (1989). Marine invertebrates of southern Australia Part II. D.J. Woolman, Government Printer, South Australia.

Shepherd, S.A. and Veron, J.E.N. (1982). Stony corals (Order Scleractinia or Madreporaria). In: Shepherd S.A. and Thomas I.M. (Eds.) Marine Invertebrates of Southern Australia Part I. Pp. 169-178. Woolman Government Printer, South Australia.

Simpson, K. and Day, N. (1999). Field guide to the birds of Australia. Penguin Books Australia Ltd., Victoria. 440p.

Stoddart, H.E. and Lowry, J.K. (2003). Zoological Catalogue of Australian Crustacea: Malacostraca: Peracarida: Amphipoda, Cumacea, Mysidacea. (19.2B) CSIRO Publishing: Collingwood, Vic.

Svane, I. (2003). West coast prawn fishery (*Melicertus latisulcatus*). Fishery Assessment Report to PIRSA for the Prawn Fishery Management Committee. South Australian Research and Development Institute (SARDI) Aquatic Sciences. Adelaide. 23p.

Tilbury, L.A. and Fraser, A.R. (1981). Submarine valleys on the Ceduna Terrace off South Australia. *BMR Journal of Australian Geology and Geophysics.* **6**: 259-264.

Van Tets, G.F. and Fullager, P.F. (1984). Status of seabirds breeding in Australia. In: J.P. Croxall, P.G.H. Evans, and R.W. Schreiber (Ed.) Status and Conservation of the World's Seabirds. 559-571. International Council for Bird Preservation, Cambridge.

Venema, S., Boxall, V., and Ward, T.M. (2003). Survey of Recreational Rock Lobster Fishing in South Australia. Final Report to the PIRSA Fisheries Policy Group. 42 pp.

Verco, J.C. (1912). Shells from the Great Australian Bight. *Transactions Royal Society of South Australia.* **36**: 206-232.

Verco, J. (1935). Combing the southern seas. The Mail, Adelaide. 174p.

Von der Borch, C.C. and Hughes-Clarke, J.E. (1993). Slope morphology adjacent to the cool-water carbonate shelf of South Australia. *Australian Journal of Earth Sciences.* **40**: 57-64.

Walker, M.H., Blight, S.J. and Cliff, G.M. (1982). Feasibility trawling activities in the Great Australian Bight by the Korean trawlers Dong Bang 91 and Dong Won 509 during the period 15.11.79 to 12.1.80. Western Australia Department of Fisheries and Wildlife Report. Perth. 59p.

Walker, M.H., Blight, S.J. and Clarke, D.P. (1989). A description of the British United trawlers/southern ocean trawlers operation in the Great Australian Bight during the period 19.11.77 to 28.5.79. 85ii. Western Australia Fisheries Department. 28p.

Walker, M.H. and Clarke, D.P. (1990). The demersal trawl resource of the Great Australian Bight as indicated by the fishing operations of the stern trawlers Othello, Orsino and Cassio in the period 19.11.77 to 28.5.79. 86v. Western Australia Fisheries Department. 65p.

Ward, T.M. and McLeay, L.J. (1999). Spawning biomass of pilchards (*Sardinops sagax*) in shelf waters of central and western South Australia in 1999. Report to the Pilchard Working Group. 1-38. SARDI Aquatic Sciences. West Beach, Adelaide. 38p.

Ward, T.M., Dimmlich, W.F., McLeay, L.J. and Rogers, P.J. (2000). Spawning biomass of pilchard (*Sardinops sagax*) in shelf waters of central and western South Australia in 2000. Report to PIRSA Fisheries. 1-32. SARDI Aquatic Sciences. West Beach , Adelaide. 32p.

Ward, T.M., McLeay, L.J., Rogers, P.J. and Dimmlich, W.F. (2001). Spawning biomass of pilchard (*Sardinops sagax*) in South Australia in 2001. SARDI Aquatic Sciences. 31p.

Ward, T.M., McLeay, L.J., Rogers, P.J., Dimmlich, W.F., Schmarr, D. and Deakin, S. (2002a). Spawning biomass of pilchard (*Sardinops sagax*) in South Australia in 2002. SARDI Aquatic Sciences. 33p.

Ward, T.M., McGarvey, R., Xiao, Y., and Brock, D.J. (2002b). Northern Zone Rock Lobster (*Jasus edwardsii*) Fishery. Fisheries Assessment Series 2002/04b. South Australian Research and Development Institute (SARDI). Aquatic Sciences. 109p.

Ward, T., Rogers, P.J., and McLeay, L.J. (2003a). Development of a Benthic Protection Performance System for the Great Australian Bight Marine Park. Review of Fisheries in the Great Australian Bight. Report to National Parks and Wildlife South Australia and Department of Environment and Heritage. 83p.

Ward, T.M., Sorokin, S.J., Rogers, P.J., McLeay, L.J. and Turner, D. (2003b). Development of a Benthic Protection Performance Assessment System for the Great Australian Bight Marine Park. Evaluating procedures and designing an ongoing monitoring program. Report to National Parks and Wildlife South Australia and Department of Environment and Heritage. 92p.

Wass, R.E., Conolly, J.R., and MacIntyre, R.J. (1970). Bryozoan carbonate sand continuous along southern Australia. *Marine Geology.* **9**: 63-73.

Watson, J.E. (1982). Hydroids. In: Shepherd S.A. and Thomas I.M. (Eds.) Marine Invertebrates of South Australia 77-114. D.J. Woolman, Government Printer, South Australia.

Willcox, J.B., Stagg, H.M.J. and Davies, H.L. (1988). Rig Seismic research cruises 10 and 11: structure, stratigraphy and tectonic development of the Great Australian Bight region-preliminary report. Bureau of Mineral Resources, Australia: Report No. 88/13.

Williams, G.C. (1995). Revision of the pennatulacean genus *Sarcoptilus* (Coelenterata: Octocorallia), with descriptions of three new species from southern Australia. *Records of the South Australian Museum.* **28**(1): 13-32.

Wilson, B.R. and Allen, G.R. (1987). Major components and distribution of marine fauna. In: G.W. Dyne (Ed.) Fauna of Australia. 43-68. Australian Government Publishing Service, Canberra. 275p.

Wilson, M.A., Evans, K.R. and Cameron, M.R. (1984). A ground survey of the upper and mid-continental slope of southern Australia. 1-275. Tasmanian Fisheries Development Authority. Hobart.

Womersley, H.B.S. (1981). Biogeography of marine macroalgae. In: M.N. Clayton and R.J. King (Eds.) Marine Botany. An Australasian perspective. 211-240. Longman Cheshire, Melbourne. 329p.

Womersley, H.B.S. (1984). The marine benthic flora of southern Australia - Part I Chlorophyta and Charophyta. Flora and Fauna Handbooks Committee, Adelaide.

Womersley, H.B.S. (1987). The marine benthic flora of southern Australia - Part II Phaeophyta and Chrysophyta. Flora and Fauna Handbooks Committee, Adelaide.

Womersley, H.B.S. (1990). Biogeography of Australasian marine macroalgae. In: M.N. Clayton and R.J. King (Eds.) Biology of Marine Plants. 266-295. Longman Cheshire, Melbourne.

Womersley, H.B.S. (1994). The marine benthic flora of southern Australia Rhodophyta - Part IIIA. Australian Biological Resources Study, Canberra. 508p.

Womersley, H.B.S. (1996). The marine benthic flora of southern Australia Rhodophyta - Part IIIB. Australian Biological Resources Study, Canberra. 392p.

Womersley, H.B.S. (1998). The marine benthic flora of southern Australia Rhodophyta - Part IIIC. State Herbarium of South Australia. Adelaide. 533p.

Womersley, H.B.S. (2003). The marine benthic flora of southern Australia Rhodophyta - Part IIID. Australian Biological Resources Study and the State Herbarium of South Australia, Canberra, Adelaide. 531p.

Zacharin, W. (1997). Management plan for the South Australian northern zone rock lobster fishery. South Australian Fisheries Management Series. Paper No. 28.

Zann, L.P. and Kailola, P. (Eds). (1995). The marine environment - The State of the Marine Environment Report for Australia. Technical Annex 1. Great Barrier Reef Marine Park Authority. Townsville, Queensland. 193p.

Zeidler, W. and Shepherd S.A. (1982). Sea-stars. In: Shepherd S.A. and Thomas I.M. (Eds.) In: Marine Invertebrates of Southern Australia. Pp. 400-417. D.J. Woolman Printer, South Australia.