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A technical report on the outer boundaries of South Australia's marine parks network.

Government of South Australia

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Abbreviations

AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment Conservation Council
AUSREP	Australian Ship Reporting System
CAMBA	Chinese – Australia Migratory Bird Agreement
CLUZ	Conservation Land-Use Zoning Software
CMCB	Coastal and Marine Conservation Branch
COSEMA	Conservation Status of Endangered Marine Algae
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department for Environment and Heritage
DEWR	Department of the Environment and Water Resources
DTEI	Department for Transport, Energy and Infrastructure
DWLBC	Department of Water, Land and Biodiversity Conservation
EPBC	Environment Protection and Biodiversity Conservation
ERIN	Environmental Resources Information Network
GIS	Geographic Information System
GPS	Global Positioning System
GSV	Gulf St Vincent
ILUA	Indigenous Land Use Agreement
IMCRA	Interim Marine and Coastal Regionalisation for Australia
IUCN – WCPA	International Union for the Conservation of Nature – World Commission on Protected Areas
JAMBA	Japanese – Australia Migratory Bird Agreement
MAC	Marine Advisory Committee
MHW	Mean High Water
MPA	Marine Protected Area
MPSC	Marine Parks Steering Committee
NGO	Non Government Organisation
NPW	National Parks and Wildlife
NRM	Natural Resources Management
NRSMPA	National Representative System of Marine Protected Areas
PIRSA	Department of Primary Industries and Resources South Australia
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
SAG	Scientific Advisory Group
SARDI	South Australian Research and Development Institute
SARSMPA	South Australian Representative System of Marine Protected Areas
SWG	Scientific Working Group
TFMPA	Task Force on Marine Protected Areas
UN	United Nations

1 Preface

In keeping with international and national commitments, the South Australian Government is in the process of establishing a carefully designed network of marine protected areas through the development of 19 new multiple-use marine parks by 2010. A key milestone in the process is the proclamation of the outer boundaries for South Australia's marine parks network. The outer boundaries have been developed by the South Australian Government with assistance and advice from a range of State Government agencies, ministerial advisory groups and scientific experts. The boundaries have been selected through a rigorous process of technical assessment and have been refined through consultation across Government. The boundaries represent the outcome of applying the Design Principles to build a robust network that meets the objects of the *Marine Parks Act 2007* and reflect world's best practice in marine parks design.

1.1 South Australia's marine parks network

South Australia's State waters cover an area of 60,282 km^2 and comprise waters out to three nautical miles from the coastline and include the gulfs and a number of offshore islands. South Australia's network of marine parks comprises 19 marine parks located across State waters from the Western Australian to the Victorian border (Figure 1). The network of marine parks includes representative areas of each of the eight marine bioregions that overlap with the State's marine jurisdiction. The boundaries for the marine parks network cover a total area of 27,526 km^2, approximately 46% of South Australia's waters (Table 1), and include the already established Great Australian Bight (GAB) Marine Park.

The length of South Australia's coastline is measured at mean high water (MHW) and extends over a distance of around 5716 kilometres. The marine parks network includes 3,948 km or approximately 69% of the total length of the South Australia's coastline.

Table 1: Area and percent of the State's waters per bioregion and within the marine parks network

Bioregion	**Bioregion extent**		**Area included within network**	
	km^2	**% of State waters**	**km^2**	**% of Bioregion**
Eucla	1863	3.1	1863	100
Murat	6482	10.8	4114	63
Eyre	18610	30.9	8541	46
Spencer Gulf	11539	19.1	2829	25
North Spencer Gulf	5235	8.7	1934	37
Gulf St Vincent	13184	21.9	5770	44
Coorong	2048	3.4	1587	77
Otway	1320	2.2	888	67
TOTAL	**60282**	**100**	**27526**	**46**

(Please note: all numbers are rounded to the nearest km)

The physical and biological features within the marine parks network include areas of differing depths, sea surface temperatures, shoreline types, shoreline exposures and benthic habitats. Figure 2 shows the variety of benthic habitats included in the network, displayed as a percentage of the total area of the habitats which occur in State waters. Of those habitats which have been mapped and are recorded at a scale of 1:100,000, the network includes 43% of the area of seagrass habitats, 53% of all sandy seafloor habitats and 59% of all reef habitats. About two thirds of the State's marine environment remains unmapped, and the network includes 43% of the unmapped areas.

The coastal habitats included within the network are displayed in Figure 3 and are expressed as a percentage of the total length of each habitat occurring across South Australia's shoreline. South Australia's shoreline, based on South Australia's topographic coastline of 5716 km, is approximately 6,190 km in length and in addition to the coastline includes the perimeter boundaries of the saltmarsh and mangrove habitats and coastal shoal systems found across the State.

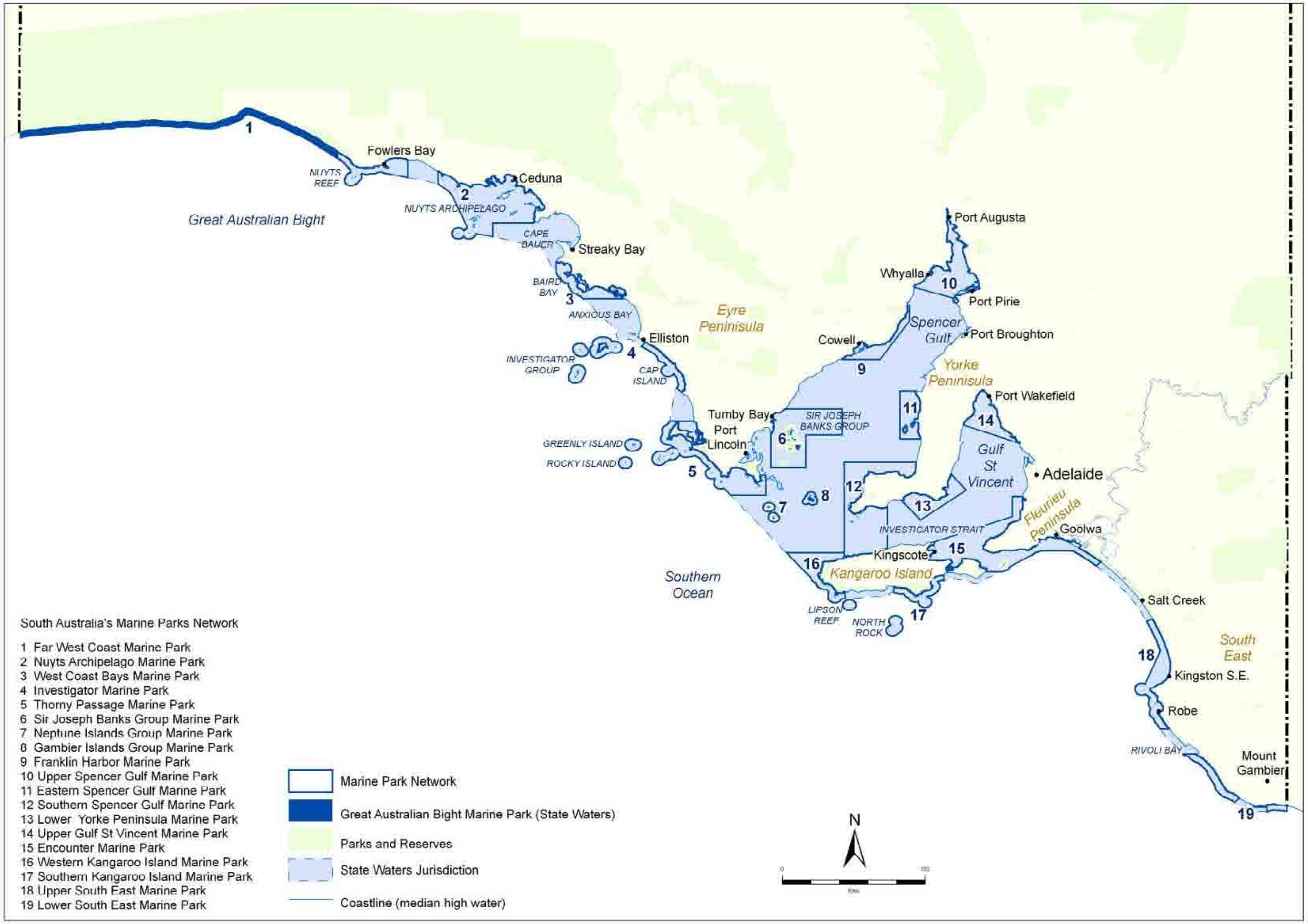

Figure 1: The outer boundaries for South Australia's marine parks network

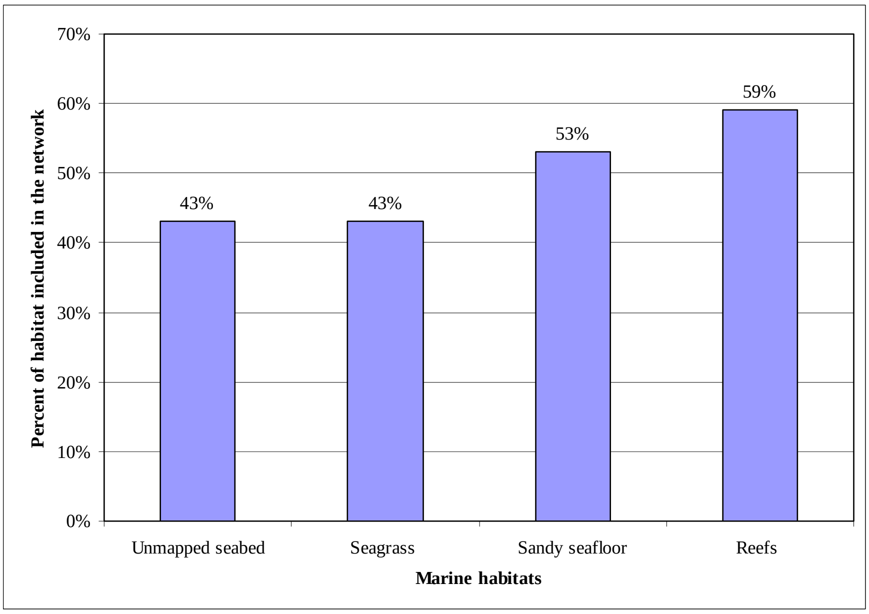

Figure 2: Percent of the area of the State's subtidal benthic habitats included within the marine parks network

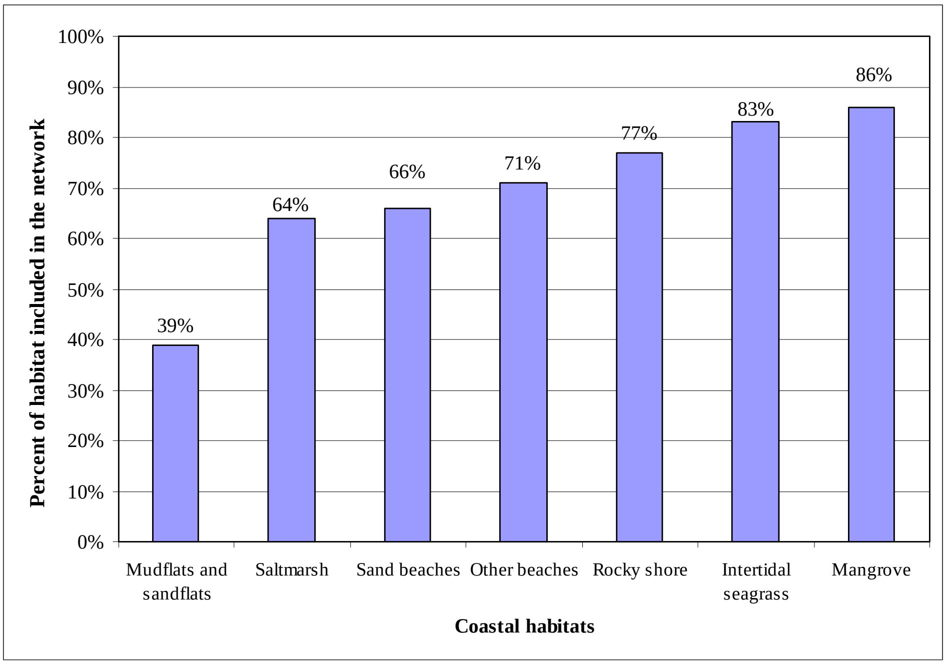

Figure 3: Percent of the length of the coastal habitats along the State's shoreline included within the marine parks network

South Australia's marine parks will offer a spectrum of management strategies ranging from full protection to areas of general use. The network of marine parks will become the State's cornerstone strategy for marine biodiversity protection and will help ensure that future generations can continue to enjoy and benefit from healthy, intact and resilient marine ecosystems.

The purpose of this technical report is to assess the effectiveness of the network in conserving South Australia's marine biodiversity. The report also provides an introduction to South Australia's marine environment, an in depth description of the scientific methodology used, and an assessment of how well the design of the outer boundaries meets the expectations of the Design Principles (DEH, 2008).

2 Introduction

2.1 The importance of caring for the marine environment

Oceans cover more than 71% of the earth's surface and the marine environment is home to an estimated 97% of all life on the planet (UN, 2002). Regardless of where we live, all of us depend on healthy marine ecosystems. For some, that dependence is directly related to lifestyle or livelihood. For others, it is not because of a direct use of the marine environment but simply because oceans shape and regulate the climate and weather that, together with nutrient cycling, help to maintain the conditions necessary for life on earth (Millennium Ecosystem Assessment, 2003; Beeton *et al*., 2006; IUCN-WCPA, 2008). For many developing coastal nations, marine ecosystems are critical to economic growth. For developed countries, marine resources often make strong contributions to established economies through fisheries, petroleum production, tourism and mining. The oceans are also culturally, spiritually and recreationally important to human communities across the world.

In South Australia, the majority of the population lives near the coast and gains enjoyment from the sea in many different ways. South Australia's marine environments are unique and precious resources, containing some of the most biologically diverse waters in the world. For many generations, our marine ecosystems have provided food and other resources and these ecosystems retain a strong cultural significance today. The coast also represents a major lifestyle destination attracting South Australians of all ages, with the populations of many coastal communities such as Victor Harbor, Whyalla and Port Lincoln expected to continue to grow.

South Australia's marine environment is important for South Australia's economy, supporting a wide array of activities from mining and shipping to fishing, aquaculture and tourism. Effective management is needed to protect this environment and its plants and animals from the impacts of increasing human pressures, and to ensure that opportunities for ecologically sustainable growth, use and enjoyment are retained.

2.2 The global need for Australian marine protected areas

Generally speaking, marine protected areas (MPAs) are areas that provide some level of special protection to parts of the ocean for conservation purposes. MPAs exist in multiple forms with diverse definitions and objectives ranging from biodiversity conservation, fisheries management and protection of social and cultural values (IUCN-WCPA, 2008). MPAs may range from village-level community managed areas to multi-million hectare national parks and have various names including marine reserve, marine park, fishery reserve, closed area, no-take area or zone, sanctuary park, wilderness area and locally managed area, among others (IUCN-WCPA, 2008). They may vary in operation from seasonal closures to protect breeding and spawning sites to areas that are permanently closed to resource extractive activities. They include marine parks that provide for multiple uses through the implementation of zones that cater for a range of different activities and uses.

Healthy marine resources depend on healthy, intact and resilient ecosystems. Coastal and marine ecosystems are in decline worldwide due to increased population pressures, extractive activities, pollution and/or the increasing impacts of climate change (Sobel and Dahlgren, 2004; Ward and Butler, 2006; IUCN-WCPA, 2008). Technological advances have greatly increased the ability to harvest living and non-living resources, but our progress in conserving examples of our marine ecosystems in a natural state has been slow compared to our progress on land. The integrity of marine ecosystems needs to be maintained for the dual purpose of conserving marine biological diversity for the benefit of future generations and promoting on-going sustainable development and use today.

The need for healthy marine ecosystems and the need to embrace sustainable growth led the nations of the world to agree to a series of high level political commitments for marine conservation. Acting now to conserve biodiversity is particularly important as there is still limited knowledge of ocean systems, or of the magnitude of how current activities may be affecting them locally, regionally and globally.

Effective site-based protection, through the development of MPAs, can help to maintain ecosystem health and productivity and to safeguard future opportunities for social and economic growth. Marine protected areas can provide a key contribution to the conservation of biodiversity in our oceans provided that they are designed to represent the environments that they are conserving and that they are adequate in size and connectivity. However, MPAs are not the only solution to the diversity of challenges facing marine ecosystem managers. MPAs are only one component of a broader integrated management strategy to ensure the long-term security of marine environments.

The World Summit on Sustainable Development, the 5th World Parks Congress, the Convention on Biological Diversity and the G8 Group of Nations have all called for the establishment of a global network of MPAs by 2012 (IUCN-WCPA, 2008). In 1992, the Australian, State and Territory Governments made a commitment through the *Intergovernmental Agreement on the Environment* to develop a National Representative System of MPAs (NRSMPA) (DEWR, 1992). Through that agreement, the Government of South Australia is committed to contributing to the NRSMPA by establishing South Australia's Representative System of MPAs (SARSMPA).

The challenge, however, is in turning these commitments into practical and effective reality. Currently, over 5,000 MPAs have been established throughout the world's oceans (http://www.mpaglobal.org). Despite global targets to establish MPA networks by 2012, approximately only 0.65% of the world's oceans are protected and, of that, only around 0.20% of the world's oceans have a level of protection that excludes extractive use (Wood *et al*., 2008). Heightening the urgency with which improved protection must develop, nearly 70% of the area of the world's MPAs are concentrated in 10 large MPAs, meaning that the vast remainder of MPAs make up 30% of the area protected (Wood *et al*., 2008).

The majority of global marine protected areas (65% of the total area and 43% of the protected areas by number) occur in the tropics. Most of the remaining MPA areas (including 5 of the 10 large MPAs mentioned) occur towards the poles (in latitudes greater than 50^{o}), and two thirds of those are in the northern hemisphere (Wood *et al*., 2008). The intermediate latitudes that constitute the temperate waters of the globe, particularly the southern temperate oceans of the world, are the least protected of all (Wood *et al*., 2008). This fact highlights the need for southern Australian States and the Australian Government to create marine protected areas within the oceans under their care and control. Importantly, Figure 4 illustrates that the southern temperate area is predominantly ocean and that Australia has the southern hemispheres longest east-west aligned coastline, and yet protection afforded to the southern temperate zone is the amongst the least protected by MPAs in the world.

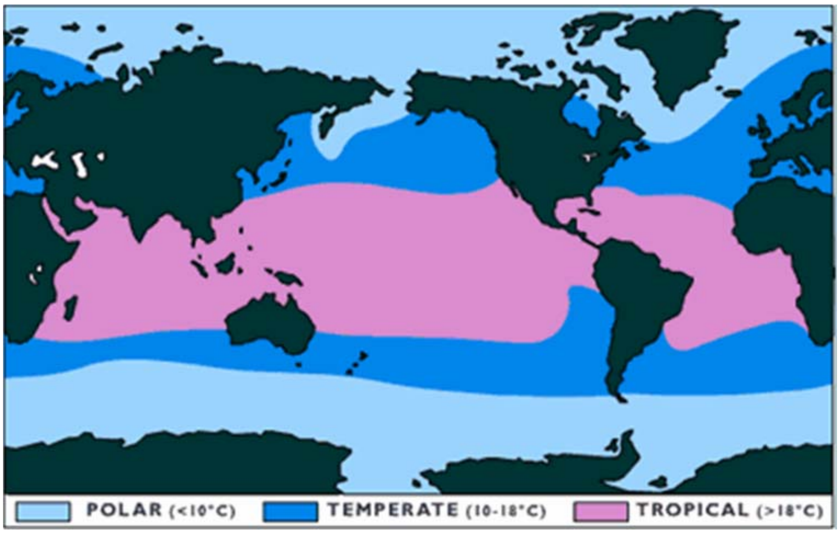

Figure 4: The climatic zones of the globe showing the temperate areas of the world (in blue) (Source: http://www.gma.org/herring/biology/distribution/comparing_oceans.asp).

2.3 The benefits of marine protected areas

Through careful planning, and in conjunction with effective fisheries management and more general spatial planning and management, well connected networks of MPAs can achieve the following outcomes (Day, 2006; Halpern, 2003; IUCN-WCPA, 2008):

- maintaining or restoring ecosystems by protecting physical habitats from damage;
- protecting ecological processes by maintaining abundances of keystone species, maintaining resilience by removing stresses, preventing unforseen thresholds being reached and maintaining food webs;
- protecting biodiversity by preventing loss of vulnerable species, protecting spawner biomass, restoring population sizes and diverse age structures, and restoring community composition;
- protecting genetic diversity that is important to evolution and the maintenance of resilient ecosystems that can absorb the shock of, and/or adapt to, change;
- maintaining high quality feeding areas;
- catering for nature-based recreation and tourism;
- providing undisturbed control or reference sites that serve as baselines for scientific research and for evaluating the health of other areas; and
- promoting a holistic approach to ecosystem management.

Scientists have studied no-take marine protected areas in at least 124 places around the world (PISCO, 2007). Usually when marine protected areas are established, the scientific interest is to determine whether the abundance and/or diversity of marine life within highly protected areas changes. From the published literature, in places that are protected from extractive uses, the biomass of plants and animals within no-take areas typically increases by almost 450% globally, and by over 550% in temperate areas (PISCO, 2007). The density of plants and animals also increases by an average of 166% (and as much as 230% in temperate waters) while the average body size of animals in protected places is 28% greater on average than in unprotected waters. Overall, the average number of species in protected areas is 21% greater than in waters not protected.

Although the trend is for large increases in biomass, density, body size and diversity, the response is variable from species to species. Some species may become more plentiful, while others may decline or not change at all (Buxton *et al.*, 2006; IUCN-WCPA, 2008; PISCO, 2007). Worldwide analyses on no-take marine protected areas suggest that approximately 61% of fish species studied respond positively to protection, and that 39% of the species studied also became more abundant outside of protected places (PISCO, 2007). Some fish and invertebrate species may become less abundant in an area, with declines generally a reflection of increased natural ecological interactions between species. For example, predator populations may recover following protection from fishing, and then eat more prey, thus causing prey populations to decline (PISCO, 2007). In Tasmania, research has shown that while lobsters have increased in biomass, urchin and abalone biomass has declined within MPAs (possibly due to predation by lobsters) (Buxton *et al.*, 2006; Edgar and Barrett, 1999). In New Zealand, the size and number of lobster and snapper inside MPAs increased and these species target sea urchins as prey. The subsequent decrease in urchin numbers resulted in the return of kelp forests that had been stripped bare by urchin grazing (Shears and Babcock, 2003).

Although marine protected areas may lead to increased population sizes for some species of fish and invertebrates, it is important to note that they cannot replace fisheries management as a sole mechanism for managing fish stocks. In fact, MPAs are likely to be more effective in achieving their overall biodiversity conservation objectives if they work in conjunction with effective fisheries management. Buxton *et al.* (2006), state that implementing MPAs alone for fisheries management may actually lead to negative impacts on fish stocks. While MPAs may provide some benefit for fisheries in terms of protecting mature biomass, spawners and egg production; their greatest service is likely to be through increased knowledge (Buxton *et al*., 2006). Studying protected areas increases our understanding of the ecological effects of fishing and ecosystem based fisheries management.

Whilst there are well documented benefits of MPAs for some marine species (Day, 2006; PISCO, 2007, IUCN-WCPA, 2008), the rate of change in MPAs depends very much on the species being investigated. Some species grow and reproduce quickly, while others take many years to do so. Responses by plants and animals to MPAs may depend on the following factors (PISCO, 2007):

- the availability of breeding adults;
- how fast plants and animals grow and how quickly they reach maturity;
- the number and timing of young produced by each female;
- how far young are dispersed and the overall connectivity of the network to ensure some young can stay within marine protected areas;
- ecological interactions between species;
- the intensity of impacts to populations prior to protection;
- ongoing impact from outside protected areas;
- the availability of adequate areas of habitat within protected areas to support viable populations; and
- the level of compliance within the protected areas.

2.4 The importance of building networks

The inclusion of examples of all types of habitats and ecosystems occurring within biogeographically different places is a prerequisite for effective biodiversity conservation because assemblages of species will be distinct in each (Hockey and Branch, 1994; Ballantine, 1997; Day and Roff, 2000; Roberts *et al.*, 2003). Effective biodiversity conservation can therefore be facilitated by building networks of marine parks across the regions in the sea that are physically and/or biologically different.

To be successful, networks of MPAs also need to be of sufficient size to protect large enough populations of plants and animals to allow them to persist locally. When used in isolation though, MPAs can generally only provide protection to plants and animals that live their lives within the protected area. The young of many marine species move from place to place by drifting with water currents, while adults of the same species may be sessile, sedentary or may migrate seasonally from feeding to breeding grounds (Gillanders *et al*., 2003, Kinlan and Gaines, 2003, Palumbi, 2004, IUCN-WCPA, 2008). In the case of pelagic fish such as tuna, the adults may be mobile their entire lives. MPAs therefore need to have good ecological connections so that populations of species that disperse over any distance can be sustained throughout their life cycles.

Kinlan and Gaines (2003) investigated the dispersal capability of the larvae of relatively sedentary species of macroalgae, invertebrates and fish and their findings suggest that three modes exist: species that disperse over distances less than one kilometre; species that disperse over distances from kilometres to tens of kilometres; and species that are able to disperse over distances from tens to hundreds of kilometres. To be successful, protected area networks need to cater for each of these broad ranges of dispersal ability.

MPA networks that include examples of all types of marine habitats and ecosystems, as well as providing the important spatial links needed to maintain ecosystem processes will be a major step in restoring and sustaining the health of the world's oceans (IUCN-WCPA, 2008). In addition, networks of MPAs will provide resilience to marine ecosystems by spreading the risk in case of localised disasters, climate change and other hazards, and therefore will help to ensure the long term survival of populations of marine species better than single sites (NRC, 2000).

2.5 South Australia's commitment

The South Australian Government's commitment to develop the SARSMPA is outlined in its policy documents: *South Australia's Strategic Plan 2007*, the *Living Coast Strategy for South Australia* and the *Blueprint for the South Australian Representative System of Marine Protected Areas*. Although there are a range of marine protected areas in South Australia in the form of fisheries aquatic reserves, rock lobster sanctuaries, shipwreck reserves and terrestrial parks with a marine extent, few of the existing MPAs have been established with the aim of maintaining marine biological diversity and none have been designed with a mandate to contribute to a state-wide system. Therefore, as a key contribution to the SARSMPA, the Government has set a target to develop a network of 19 new marine protected areas, in the form of multiple-use marine parks, by 2010. The establishment of 19 marine parks is Target 3.4 of South Australia's Strategic Plan under the attaining sustainability objective. The intent is for marine parks to work in conjunction with a broad range of existing management strategies including fisheries management, coast protection, natural resources management and environmental protection to deliver sustainable use and management of the marine environment.

2.6 The aims and objectives of the *Marine Parks Act 2007*

A further commitment to developing marine parks in South Australia is legislated in the *Marine Parks Act 2007.* Section 8(1) of the *Marine Parks Act 2007* requires the delivery of a network of marine parks that:

- Protects and conserves marine biological diversity and marine habitats by declaring and providing for the management of a comprehensive, adequate and representative system of marine parks; and by doing so helps with:
  - the maintenance of ecological processes in the marine environment;
  - adaptation to the impacts of climate change in the marine environment;
  - the protection and conservation of features of natural and cultural heritage significance;
  - ongoing ecologically sustainable development and use of marine environments; and
  - providing opportunities for public appreciation, education, understanding and enjoyment of marine environments.

2.7 Community engagement and participation

The success of the marine parks network ultimately depends upon the ownership of the network by the community. Therefore, an essential part of marine park design is community engagement and a commitment to design that balances conservation and use. The South Australian Government's commitment to community involvement is mandated by the *Marine Parks Act 2007*, requiring formal community consultation throughout the marine parks development process. In addition, the Marine Parks Council of South Australia has been established to provide independent advice to the Minister for Environment and Conservation throughout this process. Local advisory groups will also be established for each marine park to further facilitate community engagement and participation in the management planning process.

2.8 The recent history of marine parks development in South Australia

In addition to the national commitment to a NRSMPA made by South Australia in 1992, a key catalyst for marine parks development in South Australia was the endorsement of the national Interim Marine and Coastal Regionalisation for Australia (IMCRA) by the Australian and New Zealand Environment and Conservation Council (ANZECC) in 1998. The IMCRA was developed through the collaborative efforts of Commonwealth, State and Northern Territory marine conservation and research agencies and classified Australia’s coast and marine environment into 60 distinct marine biogeographical regions (IMCRA, 1998). Each marine biogeographical region, or bioregion contains biological and physical characteristics distinct from those elsewhere in Australia (ANZECC, 1999). In order to maximise the conservation outcomes of the NRSMPA, the national guidelines recommend that one or more examples of ecosystems within each bioregion in Australia should be represented in a marine protected area (ANZECC, 1999). Based on the national IMCRA marine bioregions developed in 1998, eight marine bioregions have been recognised by the South Australian Government for the State’s marine waters (Figure 5). The South Australian Government has determined that the State’s network of marine parks will be developed within that marine bioregional framework, designed to encompass the major ecosystems and habitat types within and between each bioregion.

In the early 1990’s, a 36-member Marine Protected Areas Working Group was established by the South Australian Government to assess nominations for marine protected areas, based on high conservation areas identified through scientific research. Some of the earlier work in this area culminated in a two part report (Edyvane, 1999 Parts 1 and 2). The report identified areas of high conservation value across South Australia’s marine environment within South Australia’s marine bioregions. From that work, a preliminary list of 96 potential MPAs (referred to in this document as hotspots) were identified based on recommendations by the Marine Protected Areas Working Group (Figure 5).[1]

A Scientific Advisory Group (SAG) was established in 2000 to assist with the process for further refining the potential areas for the network. The SAG consisted of representatives from the South Australian Research and Development Institute (SARDI), Primary Industries and Resources South Australia (PIRSA), the Department for Environment and Heritage (DEH), the University of Adelaide, Flinders University, and the South Australian Museum. Collectively, this group had expertise in the fields of marine ecology and biology, marine geology, and commercial and recreational fisheries research.

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[1] For more information on the history of the MPA process in South Australia, please refer to Baker, 2000

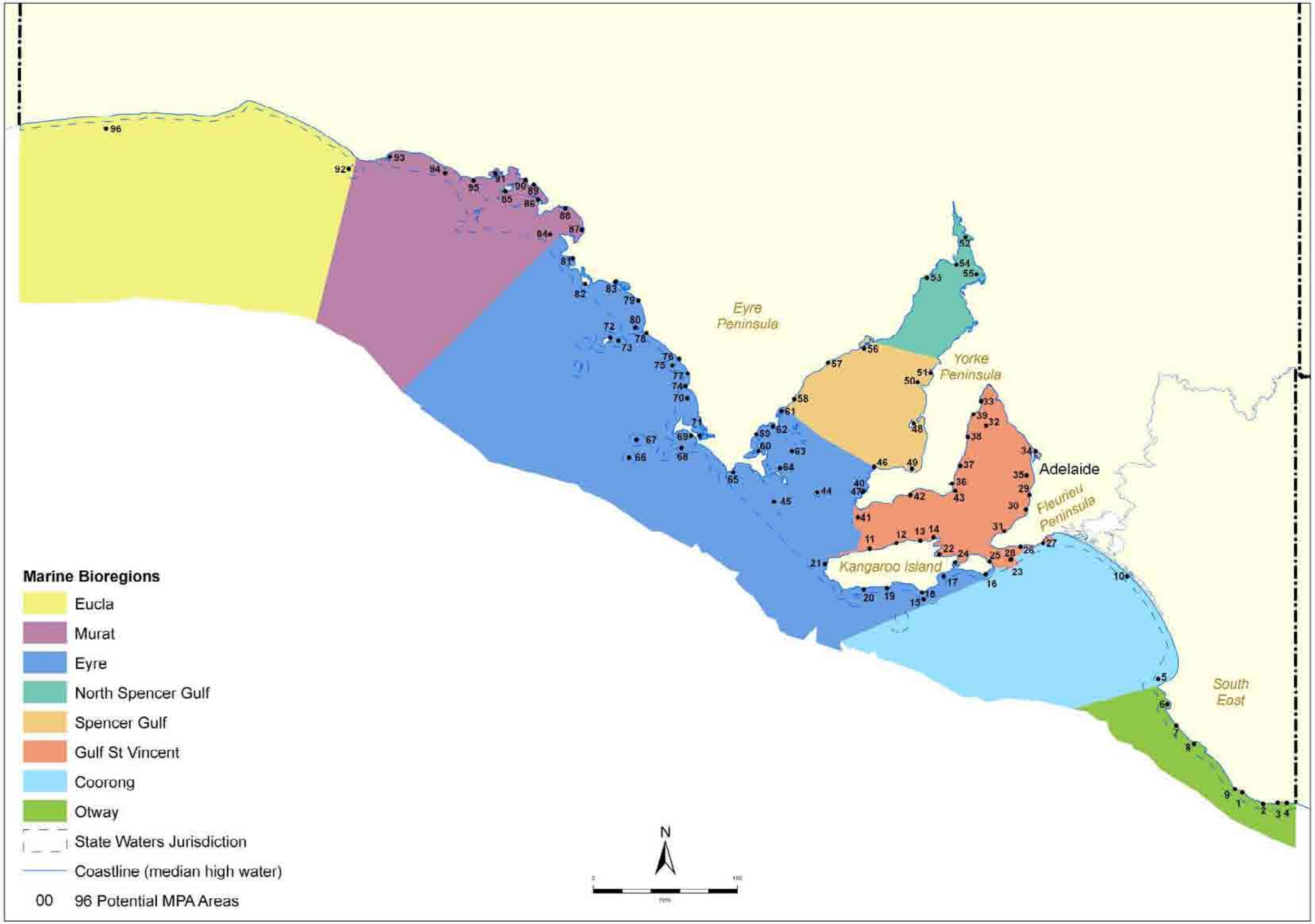

Figure 5: The 96 hotspots for biodiversity conservation identified in Edyvane (1999, Part 2)

In providing advice on the design of potential MPAs, this group endorsed the model that an MPA would be a large multiple use area, as multiple-use MPAs provide an effective means of creating resilience through the buffering of core protection areas from outside influences. This is because the highly protected places can be buffered by areas of moderate protection, distancing the most significant external risks from the core protection areas. Through the assessment of the National design principles and the ecological, cultural and socio-economic criteria advocated by Kelleher and Kenchington (1992), a number of potential marine park focus locations were identified for South Australia. Further work identified the 19 focus locations adopted by the Government to underpin the development of the network.

In 2004, DEH released a technical report (Baker, 2004) describing the scientific process that underpinned the identification of the 19 focus locations for South Australia's marine parks network. Table 2 and Figure 6 display the 19 focus locations identified within and across each marine bioregion. The focus locations identified represent general areas for potential marine park locations rather than specific sites.

Table 2: South Australia's focus locations in each marine bioregion

Bioregion	**Focus location no.**
Eucla	No focus location because the Great Australian Bight Marine Park was already established.
Murat	1
Eyre	2, 3, 4, 14, 5, 6, 7, 8, 12, 13
Spencer Gulf	6, 9, 11
North Spencer Gulf	9, 10
Gulf St Vincent	12, 15, 16, 17
Coorong	17, 18
Otway	18, 19

In 2005, a Scientific Working Group (SWG) was established to provide independent advice to the Minister for Environment and Conservation on technical and scientific matters relating to the marine environment, including marine parks design. Although the SWG superseded the previously established SAG, some of the original SAG members have continued their involvement as members of the SWG. In 2006, a Marine Advisory Committee (MAC) was also formed to provide the Minister with advice on social, cultural and economic aspects relating to the development of policy and management frameworks for conservation of the marine environment. A key role of both the SWG and the MAC was to provide advice on the development of South Australia's Design Principles which have guided the development of the marine park boundaries.

The systematic development of a representative network of marine parks is an iterative process that involves many rounds of improvement to discover the best solutions. It requires evaluation of conservation needs at appropriate scales, descriptions of key environmental, biological and ecological features of the area of interest (Baker, 2004), and the identification of sites that provide the best potential to achieve all the program's objectives (environmental and societal). To this end, world's best practice (IUCN-WPCA, 2008) involves the application of expert knowledge to develop opinions that can guide decision making and this approach is often called the Delphic approach. The Delphic approach commonly involves identifying and using a series of design principles or selection criteria to guide decision making.

In 2008, based on the advice from the SWG and the MAC, a set of Design Principles (DEH, 2008) were finalised to assist with the formulation of South Australia's marine park boundaries (Figure 7 and Table 13).

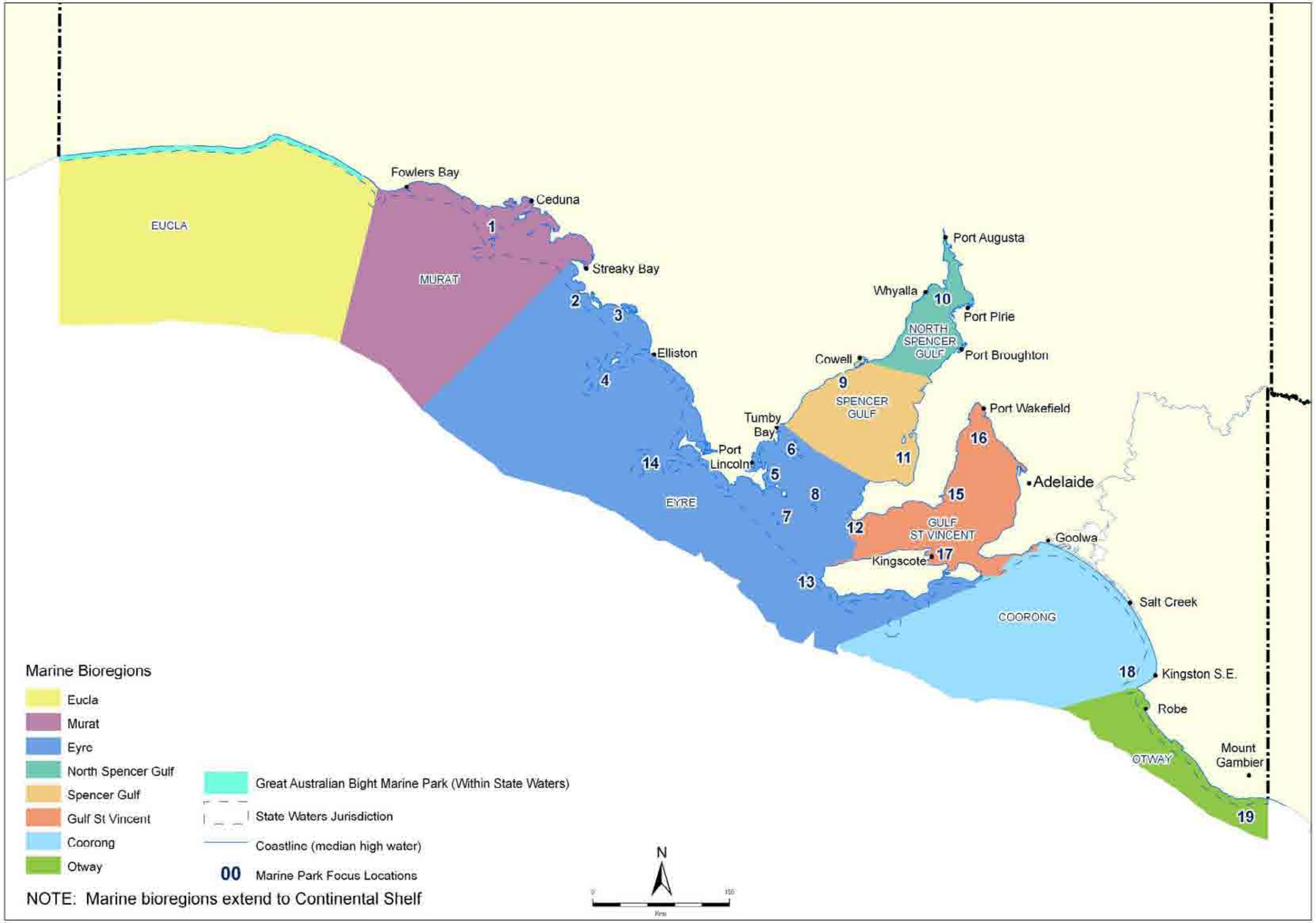

Figure 6: Marine Park focus locations in each marine bioregion

The Design Principles draw from international and national experience and, given that the South Australian network will be part of the national MPA network, the South Australian Principles reflect those endorsed nationally (ANZECC, 1998 and 1999), with some additions to cater for local needs. The Scientific Working Group (SWG) provided advice on the biophysical Design Principles which were used to help identify areas for potential marine parks, and the Marine Advisory Committee (MAC), provided advice on the community Design Principles, which were used to select candidate marine parks from those areas identified[1]

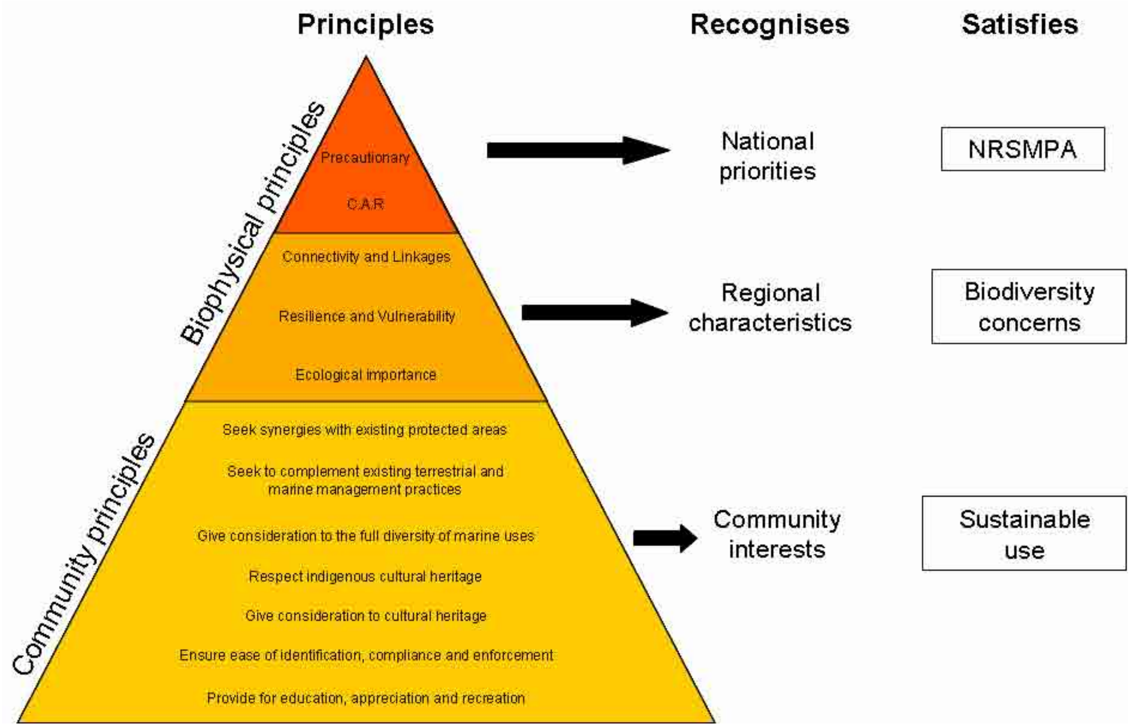

Figure 7: Pyramid of the design principles showing their relationship to the reserve selection process and the objectives of the *Marine Parks Act 2007*. "CAR" refers to the Comprehensive-Adequate-Representative triad

Between 2005 and 2009, the SWG provided additional technical advice on the development of South Australia's marine park outer boundaries, informed by the earlier work identifying the 19 focus locations. Once a draft network of marine park boundaries was identified, the next step in the process was to refine the network using the expertise and local knowledge across State Government. The cross-Government consultation (in particular with PIRSA Fisheries and Aquaculture) on the draft network of marine park boundaries allowed refinements to be made which achieved the same biodiversity conservation outcomes, but increased the success in meeting the community design principles, in particular, considering the full diversity of marine users. The Marine Parks Council of South Australia, formed in 2008 under the *Marine Parks Act 2007* also supported the process by providing advice on the rigour of the design process and the proposed mechanisms to communicate the network to the community. The network of marine park boundaries was proclaimed by His Excellency the Governor of South Australia, on the recommendation of the Minister for Environment and Conservation, on 29 January 2009.

Following public comment, the outer boundaries may be refined where submissions with technical merit demonstrate an opportunity to improve the representative system. The final outer boundaries will then be reviewed and proclaimed again under the *Marine Parks Act 2007*.

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[1] Further information about the development of the Principles and a full explanation of each is included in *Design Principles: Guiding the Development of South Australia's Marine Park Boundaries*, DEH (2008).

3 South Australia’s marine environment

3.1 Physical diversity

Southern Australia constitutes the longest stretch of south-facing coastline in the southern hemisphere (Figure 4). The continental shelf along southern Australia is relatively broad, and the coastal waters are subject to relatively low volumes of natural runoff from land, creating marine ecosystems adapted to nutrient poor conditions. South Australia’s coastline spans large east-west and north-south ranges, totals more than 5,716 km in length and abuts around 30% of the southern extent of the continental shelf of Australia. Twelve broad types of shoreline have been identified along the State’s waters ranging from steep cliffs to mudflats (see Table 31 in Appendix 1) (Short, 2001). South Australia is also the custodian of significant coastal habitats such as the Coorong Beach, which represents the largest dissipative, gently sloping surf beach in the temperate southern hemisphere.

An understanding of how currents, waves and tides influence our marine biodiversity is important to inform the development of a connected network of marine parks. Oceanographically, South Australian waters are diverse, with varying patterns of water depth (Figure 8), movement, chemistry and temperature. Current patterns along the southern Australian coastline are generally influenced by weather systems. In summer, slow moving high pressure systems dominate the atmosphere south of the Australian mainland and generate winds over South Australia’s coastal waters that typically blow from the south east. In winter, the high pressure systems move up over the continent and low pressure systems dominate the atmosphere over our southern oceans, creating westerly winds (Fowler *et al.*, 2007).

While the movement of waters against our coastline are mostly affected by winds and waves, several other important features influence the ecology of our region. The first is the Flinders Current that flows along the edge of the continental shelf westward from Tasmania to Cape Leeuwin in Western Australia (Middleton and Bye, 2007). The Flinders Current is linked to the cold water upwelling events that occur in South Australia during summer. The nutrient rich waters of these upwellings lead to the formation of surface swarms of coastal krill (*Nyctiphanes australis*), which provide important food for a range of species from plankton through to blue whales (Womersley, 1984; Gill, 2002; Middleton and Bye, 2007; Suthers and Wait, 2007). Figure 11 displays a schematic from Middleton and Bye (2007), which shows some of the key circulation features for winter, including the Leeuwin Current, Leeuwin Undercurrent, Flinders Current and shelf-edge South Australian Current (SA Current). During winter, water is downwelled throughout and as a dense salty outflow from the Gulfs (Middleton and Bye, 2007). Figure 12 displays the summertime circulation and upwelling which occurs off Kangaroo Island and the Bonney Coast. During summer, shelf-edge downwelling may occur in the western Bight (Middleton and Bye, 2007).

In winter, the Leeuwin Current is dominant and the influence of the Flinders Current diminishes. The Leeuwin Current brings warm tropical waters south along the Western Australian coast, then east along the shelf break to the Great Australian Bight (Middleton and Bye, 2007; Suthers and Waite, 2007). The Leeuwin flows regularly as far east as Kangaroo Island, sometimes reaching Tasmania, thus forming one of the longest currents in the world (Middleton and Bye, 2007; Suthers and Waite, 2007).

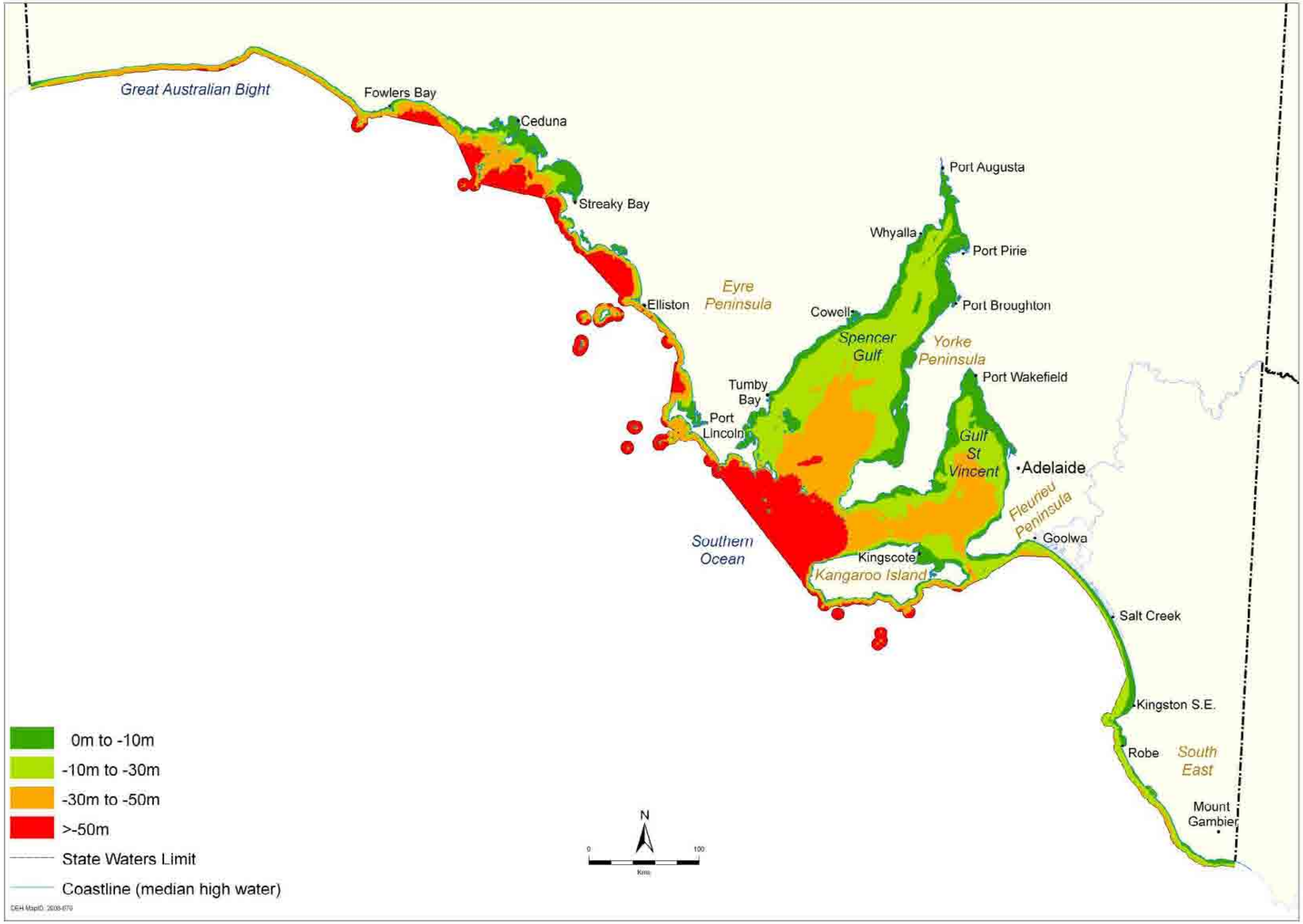

Figure 8: Water depths in South Australia's State waters

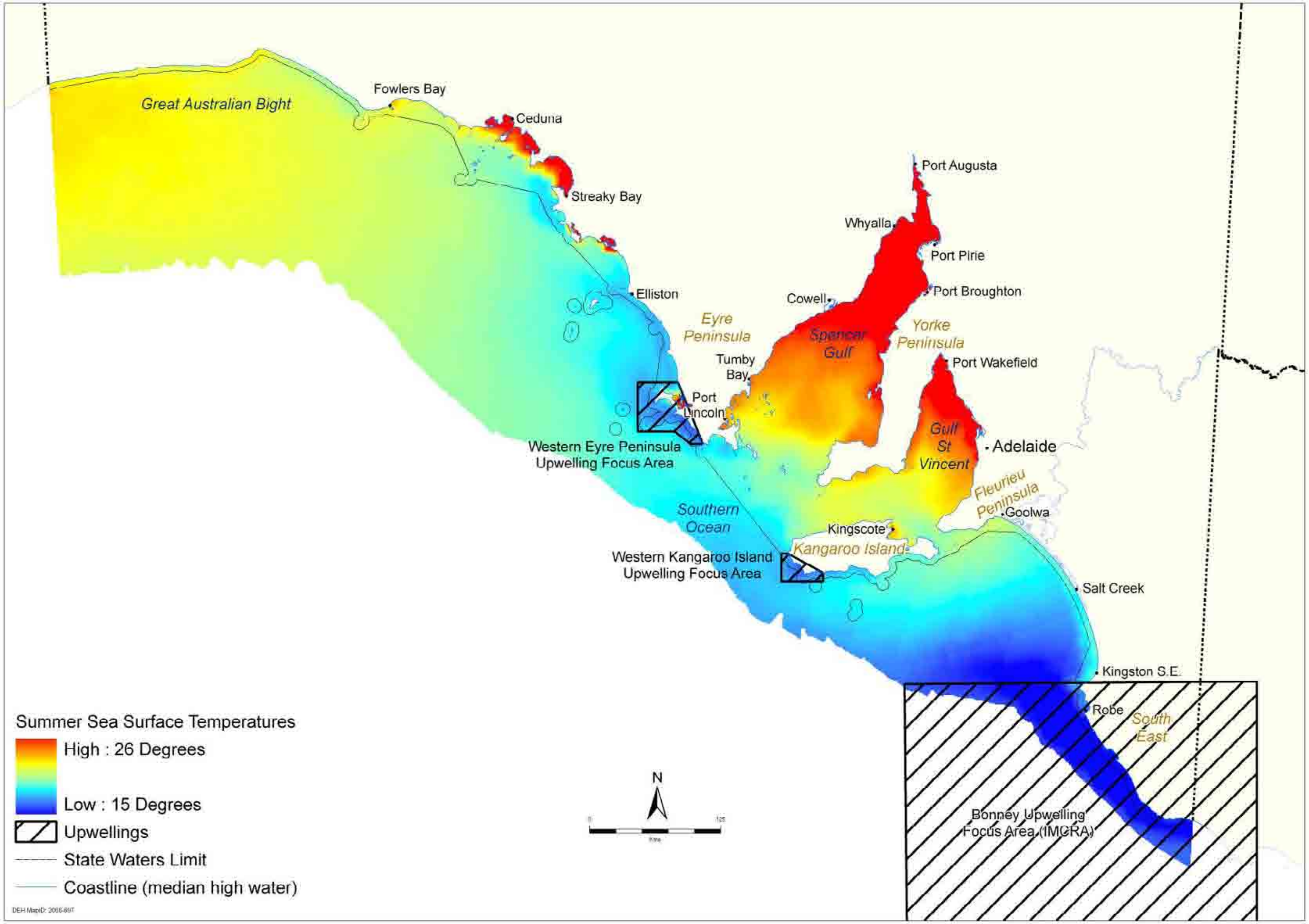

Figure 9: Summer sea surface temperature and upwelling areas in South Australia

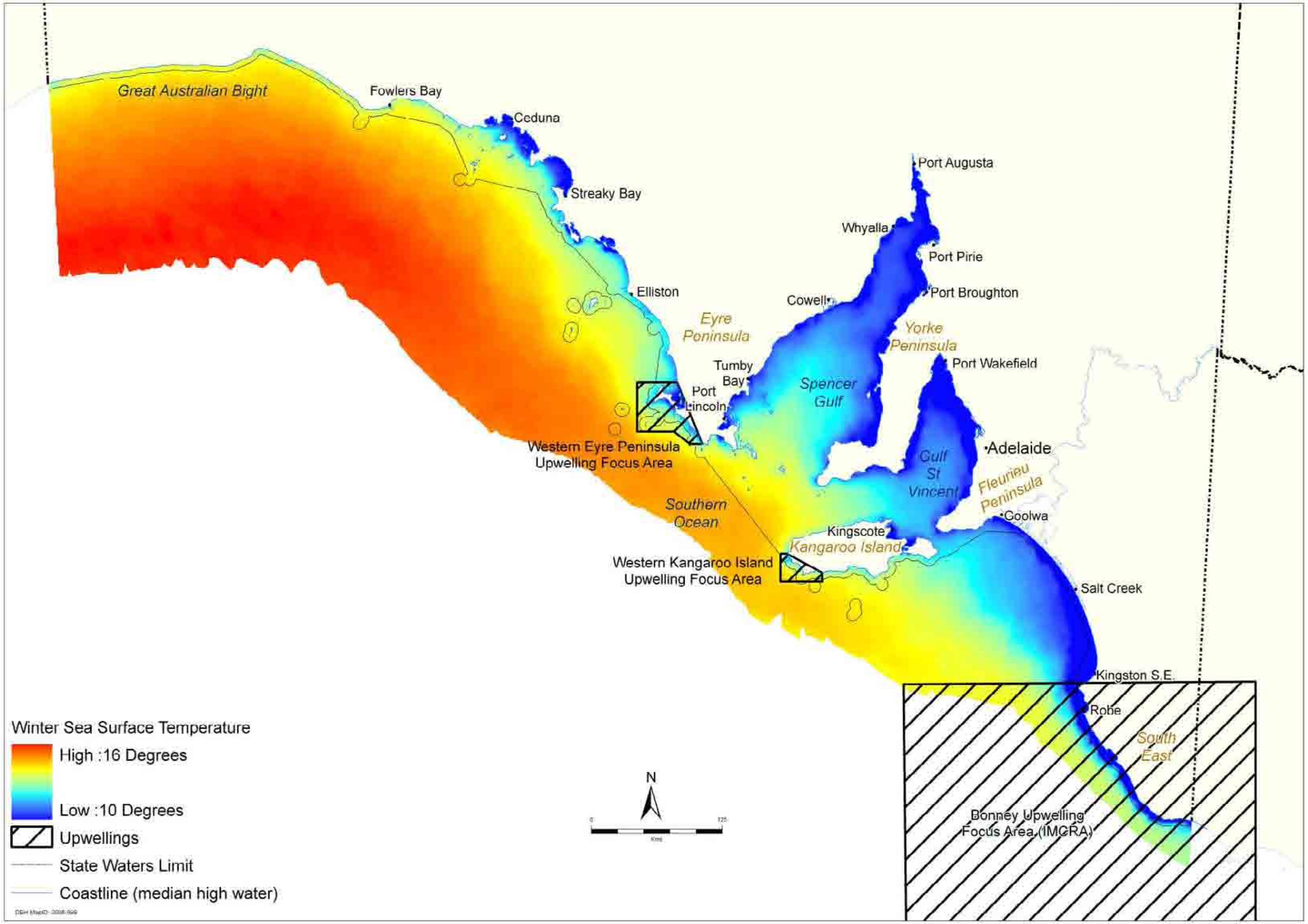

Figure 10: Winter sea surface temperature and upwelling areas

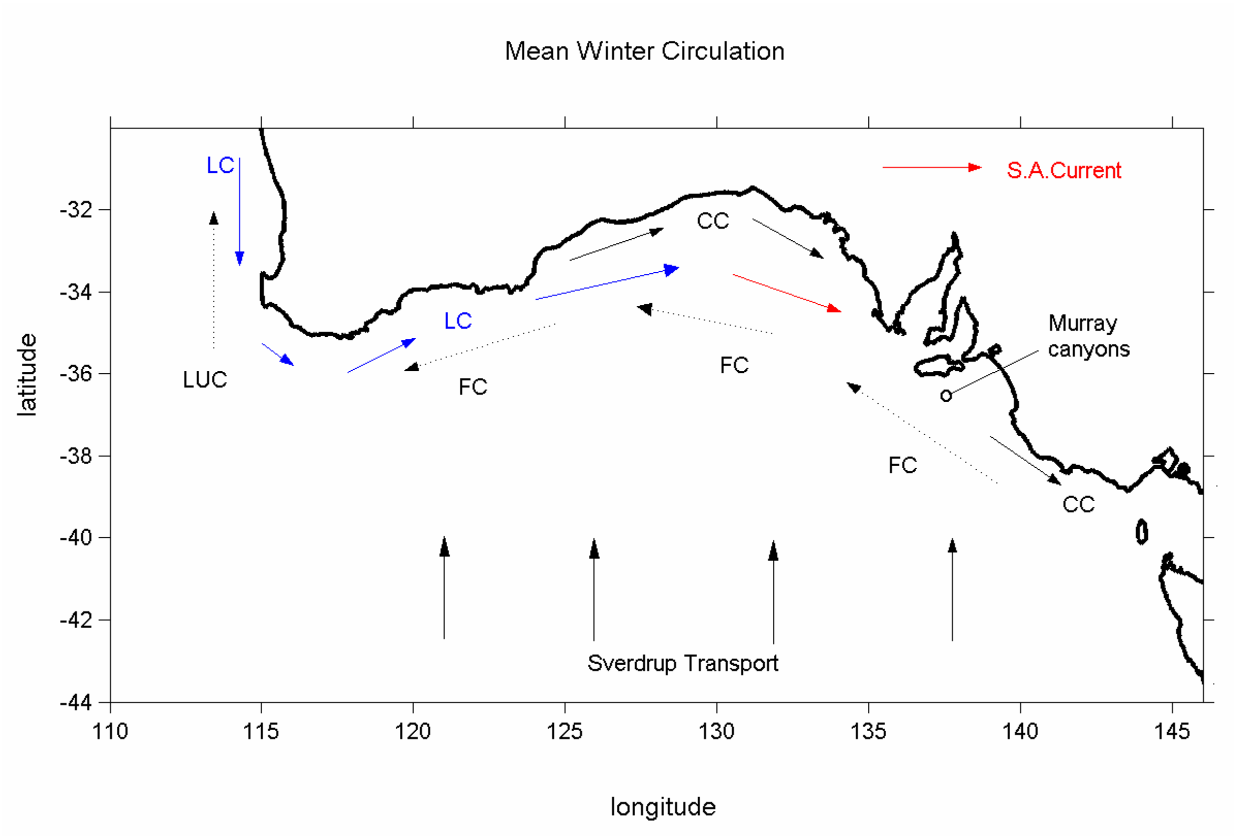

Figure 11: A schematic of some key circulation features for winter (source: Middleton and Bye, 2007) (Leeuwin Current (LC), Leeuwin Undercurrent (LUC), Flinders Current (FC) and shelf-edge South Australian Current (SA Current)

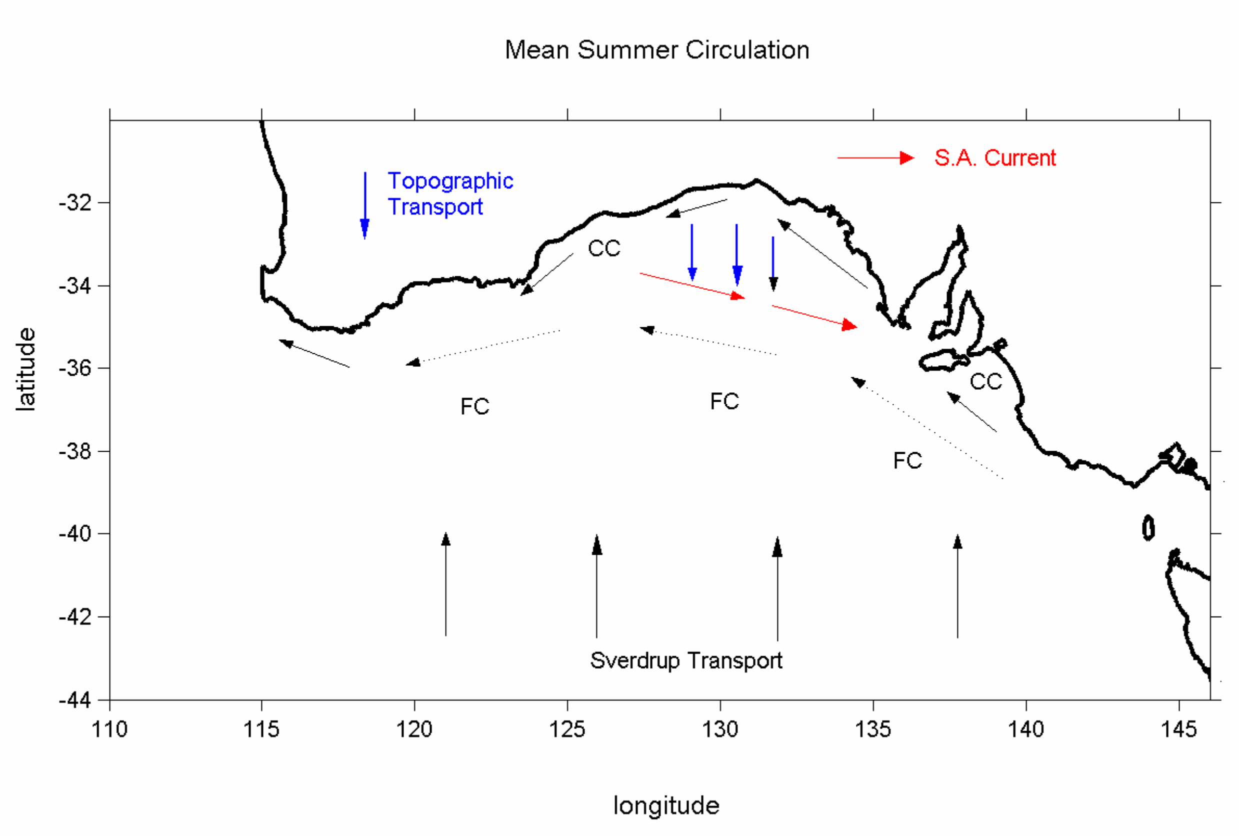

Figure 12: Summertime circulation and upwelling (Source: Middleton and Bye, 2007) (Leeuwin Current (LC), Leeuwin Undercurrent (LUC), Flinders Current (FC) and shelf-edge South Australian Current (SA Current)

The gulf systems are also important oceanographically. In Spencer Gulf, water enters on the western side of the gulf and leaves on the eastern side, with movement basically clockwise in direction (Nunes and Lennon, 1986). In Gulf St Vincent, water also flows in from the west through Investigator Strait but flows out through Backstairs Passage and the central part of the gulf, with an anti-clockwise area of circulation adjacent to the Fleurieu Peninsula (Nunes and Lennon, 1986). During summer, temperature and salinity fronts form at the mouths of the gulfs, restricting water exchange with waters offshore. Little freshwater runs into our gulfs from land and high levels of evaporation during summer cause salt concentrations in the northern gulfs to elevate. As a result the waters of the gulfs become denser than those on the shelf and, during winter, a plume of salty water flows out of the eastern part of the mouth of Spencer Gulf. The salty outflow moves along the seabed, and continues in a southeasterly direction past Kangaroo Island, influencing both ocean circulation and marine ecology in the region (Middleton and Bye, 2007).

3.2 Biological diversity and endemism.

Biological diversity, or biodiversity, is the term used to describe the variety of ecosystems, habitats and species (including genetic variability) found in an area, together with their ecological functions. At the finest biological scale, biodiversity is also about genetic diversity and the importance of recognising and catering for the sustenance of populations and communities in the areas within which they persist (Secretariat of the Convention on Biological Diversity, 2006). An important concept relating to biodiversity is that of endemism, which is the term used to describe species restricted to a specific region.

Overall, the marine waters of southern Australia have remarkably high levels of endemism, with approximately 85–90% of all of the marine plants and animals found in the region not recorded anywhere else in the world. In contrast, only 10–15% of the marine life that lives in Australia’s tropical seas is unique to Australia. Southern Australia’s waters are also very diverse, being home to 1,200+ species of red, brown and green algae. More than 700 species of fish visit or live in southern Australia’s marine environment (Scott *et al*., 1974), along with crustaceans (such as blue swimmer crabs), seabirds, marine mammals and hundreds of invertebrate species, e.g. bryozoans (lacy corals) and nudibranchs (sea slugs) (Baker, 2004).

Within the context of southern Australia, South Australia’s marine waters are regarded as being both diverse and distinct, a result of our long coastline, our varying oceanographic conditions and the wide variety of coastal and marine environments that characterise the area. Globally, some of the largest areas of temperate saltmarsh (Morrisey, 1995; Connolly *et al*., 1997; Connolly, 1999), mangroves (Chapman, 1976; Galloway, 1982) and seagrasses (Shepherd and Robertson, 1989) occur in South Australia. Several of the species found in South Australia’s waters are unique relics of tropical and sub-tropical communities, occurring in the warmer parts of Spencer Gulf in particular (Shepherd, 1983; Womersley, 1987; Womersley 1990). South Australia has three times more algal species than are found in the tropics of Australia, among the highest number of seagrass species, the greatest diversity of ascidians (sea squirts) (over 200 known species) and some of the highest levels of diversity of bryozoans (lace corals) (over 500 recorded species) (information sourced from: http://www.sardi.sa.gov.au/).

Other habitats, ecosystems and/or biotic communities that characterise South Australian marine waters include islands, intertidal and subtidal reefs, soft sediment seabed environments, estuaries and coastal lagoons. The water column itself is a significant, but often overlooked, source of biological diversity, providing habitat for life at all levels of the food chain and especially for dispersing the eggs, spores and/or larvae of many species. Water column habitats are typically defined by depth, especially based on the extent to which light penetrates through the water (Kingsford, 1995).

3.3 South Australia’s marine bioregions

As introduced in Section 2.8, the South Australian Government has designed a network of marine parks for the State using the eight bioregions to encompass the major ecosystems and habitat types within and between each of South Australia’s bioregions. Table 3 display the eight marine bioregions and the extent of their coverage in the State’s waters.

Some of the most obvious differences between these bioregions occur in the south east, west coast and upper gulfs where the existence of three areas of very different oceanographic, geographic and climatic conditions has led to the development of different biological assemblages. In the following section each of South Australia’s bioregions is described in a brief overview to present their unique and interrelated characteristics which are an important consideration in the development of South Australia’s marine parks network[1].

Table 3: Area of each marine bioregion and percent of the State's waters

Bioregion	**Bioregion extent**	
	km^2	**% of State waters**
Eucla	1863	3.1
Murat	6482	10.8
Eyre	18610	30.9
Spencer Gulf	11539	19.1
North Spencer Gulf	5235	8.7
Gulf St Vincent	13184	21.9
Coorong	2048	3.4
Otway	1320	2.2
TOTAL	**60282**	**100**

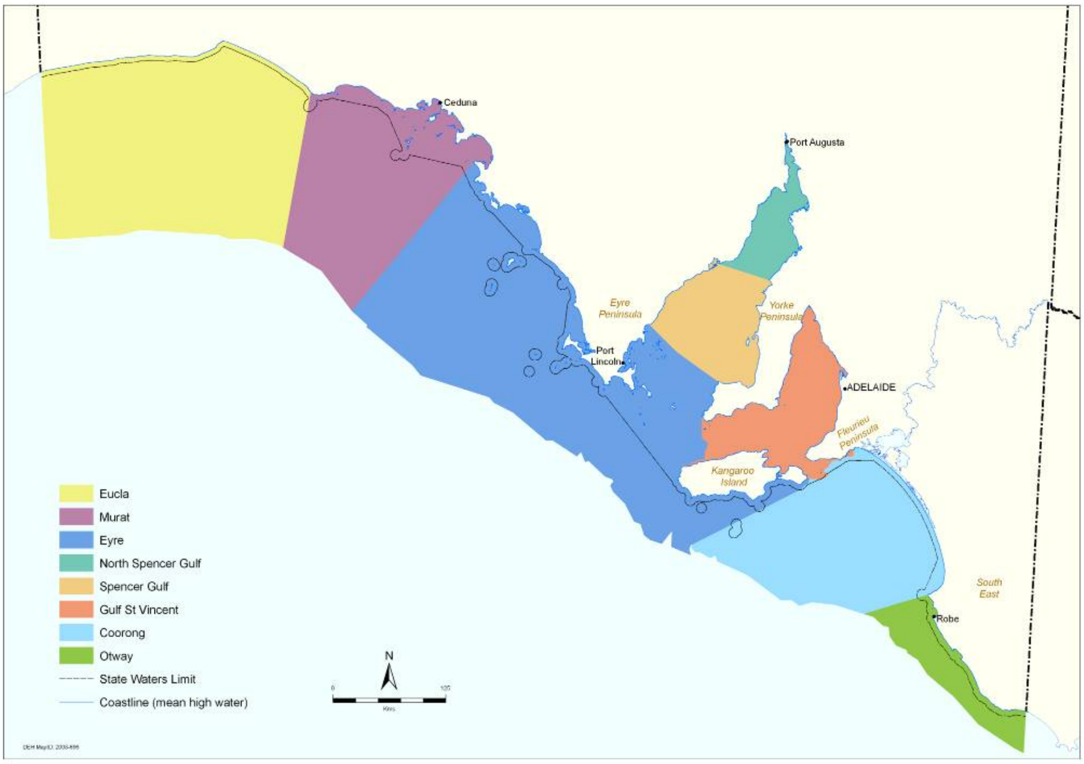

Figure 13: South Australia's marine bioregions

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[1] For a comprehensive review of South Australia’s marine bioregions, please refer to Lewis *et al.* (1998), Edyvane (1999 Parts 1 and 2) and Baker, 2004.

3.3.1.1 Eucla Bioregion

The Eucla Bioregion extends from the spectacular ninety metre high limestone cliffs at the Western Australian border to Cape Adieu, near Fowlers Bay (Figure 14). Exposed to the strong force of the southwesterly swells, the coastline experiences some of the highest wave energies in the State. More than 93% of the coastline is classified as exposed to the full force of ocean swells, which is more than any other bioregion in South Australia.

Head of the Bight (Photo: Robyn Morcom)

The area is characterised by deep water (30–50 metres), with the average yearly temperature maxima between 13.5–22 °C (taken over a ten year period) (Table 4). Most of the mapped subtidal habitats are bare sand stretches along the coast with patches of reefs. There is a relatively low diversity of algal species, and only a few seagrass communities are found in the region (Baker, 2004). The Leeuwin Current, brings a distinct tropical element to the marine plants and animals in this bioregion (Edyvane, 1999).

Southern Right Whale (Photo: Aude Loisier)

The South Australian State waters component of the Great Australian Bight Marine Park, covering the majority of the Eucla Bioregion, was established to protect benthic habitats and significant breeding habitat of the southern right whale (*Eubalaena australis*) and colonies of Australian sea lions (*Neophoca cinerea*), one of only five species of sea lion in the world (DEH, 2005). Both species are listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), the former as an endangered species and the latter as vulnerable. Both species are also regarded as vulnerable under the South Australian *National Parks and Wildlife Act 1972 (*NPW Act).

Table 4: Key characteristics of the Eucla Bioregion

Characteristics	**Eucla Bioregion**
Depth class	59% deep water (30–50m), 24% intermediate (10–30m), 12% shallow (0–10m) and 5% very deep (>50m).
Sea surface temperature	100% of the waters during summer are generally between 19–22 °C. For winter, 60% of the waters are between 13.5–15.5 °C and 40% >15.5 °C.
Subtidal benthic habitats	76% unmapped, 21% bare sand, 2% low profile platform reef and less than 1% heavy limestone or calcarenite reef.
Shoreline classification	65% cliffs, 30% fine-medium sand beaches, 5 % coarse sand beaches.
Key aspect	South facing, uniform.
Currents and exposure	Significantly influenced by the Leeuwin Current, little effect of Flinders Current towards east but coastal counter current to west; offshore transport to south, exposed to weather from the Southern Ocean. The shoreline is classified as 93% exposed, 7% moderate and less than 1% sheltered.
Notable biota	Southern right whale (*Eubalaena australis*), Australian sea lion (*Neophoca cinerea*), Great white shark (*Carcharodon carcharias*) and large red algal species such as *Amansia pinnatifida* and *Dictymenia* spp.

Figure 14: Eucla Bioregion

3.3.1.2 Murat Bioregion

The Murat Bioregion extends from Cape Adieu to the west of Fowlers Bay and eastward to Cape Bauer near Streaky Bay (Figure 15). The Bioregion is characterised by deep and very deep waters, with over 50% being over 30 metres in depth. The coastline features a series of sheltered bays bound by capes, points and headlands. Offshore, the area includes many islands comprising the Nuyts Archipelago.

Deep oceanic water
(Photo: Marinethemes.com/Kelvin Aitken)

Biologically, the marine communities are typically dominated by species adapted to warm temperate conditions (Edyvane, 1999; Baker, 2004) (Table 5). The sheltered bays of the area contain extensive seagrass meadows, while grey mangrove (*Avicennia marina*) forests occur in a number of areas including Tourville Bay and Acraman Creek. *A. marina* is the only species of mangrove growing in South Australia.

The area is strongly influenced by seasonal incursions of the Leeuwin Current and less so by the Flinders Current. As a result, the flora and fauna include species with tropical ranges, such as a subset of fish species found more frequently in Western Australia than in most parts of South Australia, e.g. the western footballer *Neatypus obliquus*, western wirrah *Acanthistius serratus*, blue-tailed leatherjacket *Eubalichthys cyanoura* and red-lipped morwong *Cheilodactylus rubrolabiatus* (Baker, 2004). The occasional presence of tropical whale species is also attributed to the Leeuwin Current (Kemper and Ling, 1991).

Table 5: Key characteristics of the Murat Bioregion

Characteristics	**Murat Bioregion**
Depth class	Waters distributed among depth classes: 30% deep (30−50m), 29% very deep (>50m), 26% shallow (0−10m) and 15% intermediate (10−30m).
Sea surface temperature	For summer more than half (55%) of the waters are between 19−22 °C, 33% between 17.5−19 °C, 12% over 22 °C. For winter 13% of the waters are between 12−13.5 °C, 58% between 13.5−15.5 °C and 28% more than 15.5 °C.
Benthic habitats	78% unmapped, 14% seagrass, 4% bare sand, 2% each heavy limestone or calcarenite reef and low profile platform reef.
Shoreline classification	Mangrove 28%, coarse sand beaches 26%, cliffs 17%, fine-medium sand beaches 14%, saltmarsh 8%, bedrock platform 6%, sand dunes 1%.
Key aspect	South-south-west facing, uniform.
Currents and exposure	Some effects of South Australian current to east and coastal counter current to west; offshore transport to south; exposed to weather from Southern Ocean. The shoreline exposure is classified as 64% sheltered, 6% moderate and 30% exposed.
Notable biota	Fish species: western footballer (*Neatypus obliquus*), western wirrah (*Acanthistius serratus*), blue-tailed leatherjacket (*Eubalichthys cyanoura*) and red-lipped morwong (*Cheiloodactylus rubrolabiatus*). The smallest starfish in the world *Parvulastra parvivipara*, the grey mangrove *Avicennia marina* and seagrass meadows including *Zostera muelleri*, *Heterozostera tasmanica* and subtidal species of *Amphibolis sp.* and *Posidonia sp.* (such as *P. australis*).

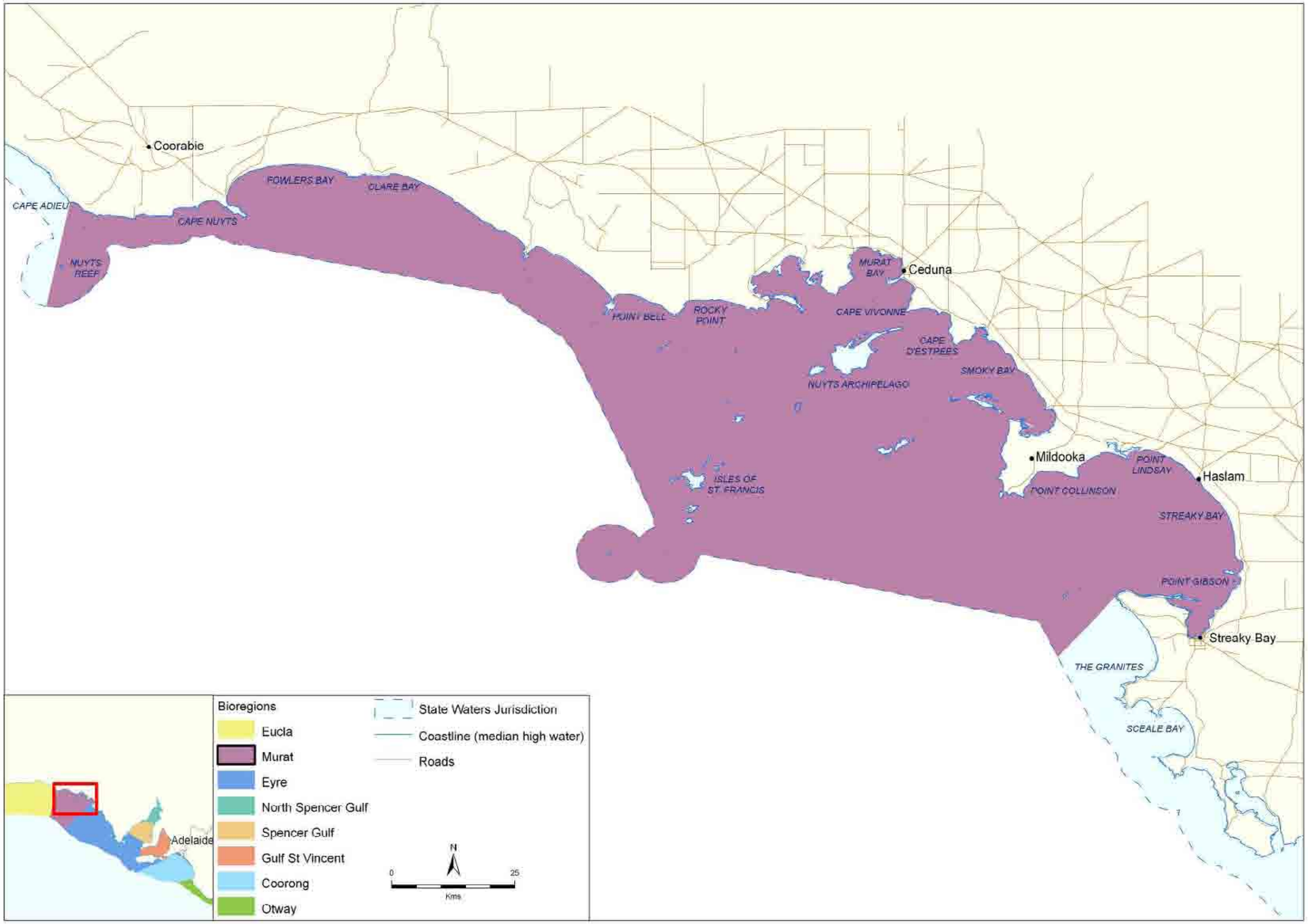

Figure 15: Murat Bioregion

3.3.1.3 Eyre Bioregion

The Eyre Bioregion is the largest bioregion in South Australia, comprising around 31% of the State's waters (Table 3). It extends from Cape Bauer to Tumby Bay, then eastward across Spencer Gulf to include waters from Corny Point to West Cape, and then across to Kangaroo Island to Cape Borda and around the southern side to Cape Willoughby (Figure 16). The coastline is highly variable, with many changes in orientation and thus degrees of protection from the strong wave attack from the Southern Ocean. It is also the region where some of the deepest waters in South Australia's seas are found (Table 4 and Figure 8).

Australian sea lion
(Photo: Marinethemes.com/Clay Bryce)

The Eyre Bioregion is bounded by the warm waters of the Murat Bioregion and the gulf waters. The Eyre Bioregion runs across the two gulf systems, making it complex and biologically very diverse. During the late summer months, this Bioregion is subject to cold, nutrient rich upwellings associated with the western end of Kangaroo Island and the lower Eyre Peninsula.

The Eyre Bioregion, particularly the offshore islands, contains significant breeding colonies of New Zealand fur seals (*Arctocephalus forsteri*) and Australian sea lions, the only endemic and least abundant seal species in Australia (Goldsworthy *et al*., 2007). These waters are also well known for the presence of the great white shark (*Carcharodon carcharias*). The pygmy right whale (*Caperea marginata*) is a rarely seen baleen whale that also frequents the region (Kemper *et al*., 1997).

Table 6: Key characteristics of the Eyre Bioregion

Characteristics	**Eyre Bioregion**
Depth class	Almost half (47%) very deep (>50m), 29% deep (30–50m), 15% intermediate (10–30m), 9% shallow (0–10m).
Sea surface temperature	Over summer, 61% of the waters are between 17.5–19 °C, 34% between 19–22 °C, 4% less than 17.5 °C and 1% greater than 22 °C. For Winter, 1% of the waters are less than 12 °C, 5% between 12–13.5 °C, 74% between 13.5–15.5 °C and 20% more than 15.5 °C.
Benthic habitats	81% unmapped, 10% bare sand, 4% seagrass, 3% low profile platform reef, 1% each heavy limestone or calcarenite reef and granite reef.
Shoreline classification	30% cliffs, 25% bedrock platform, 21% coarse sand beaches, 16% fine-medium sand beaches, 5% saltmarsh, around 2% of mangroves and 1% of mixed sediment beaches.
Key aspect	Variable, from south-west facing to south facing to south-east facing, plus western and southern end of Kangaroo Island and Yorke Peninsula.
Currents and exposure	Clockwise gulf circulation on eastern side; some influence of Flinders Current during summer, causing weak and intermittent upwelling at western end of Kangaroo Island and off Point Avoid (probably linked to passage of high pressure systems). Mostly exposed to weather from Southern Ocean, especially southern part of Eyre Peninsula and most offshore islands. The shoreline exposure is classified as 52% exposed, 40% sheltered and 8% moderate exposure.
Notable biota	Australian sea lions *Neophoca cinerea*, New Zealand fur seals *Arctocephalus forsteri*, the great white shark *Carcharodon carcharias*, western blue groper *Achoerodus gouldii*, the smallest starfish in the world *Parvulastra parvivipara* and brown macroalgae *Corynophlaea cristata*.

Figure 16: Eyre Bioregion

3.3.1.4 North Spencer Gulf Bioregion

The North Spencer Gulf Bioregion includes all waters north of the line between Point Riley and Shoalwater Point (Figure 17). Spencer Gulf is classified as an inverse estuary and the North Spencer Bioregion is an area that experiences seasonal extremes in temperature (Table 7). In addition, due to a lack of freshwater input, high evaporation and relatively poor mixing, northern Spencer Gulf seawater tends to be unusually salty, with ranges between 42−48 parts per thousand (ppt.) salinity compared to the normal seawater range of around 35 ppt.


Giant Cuttlefish (Photo: Deb Allen)

It is clear that the habitats in the North Spencer Gulf Bioregion are quite different in species composition from those in the Spencer Gulf Bioregion. While North Spencer Gulf appears to be low in overall species richness, it is relatively rich in species that are endemic, with a benthic flora and fauna characterised by a distinctive tropical assemblage. The North Spencer Gulf shallow ecosystems form important breeding and nursery areas for several marine species including blue swimmer crabs, prawns and cuttlefish. The intertidal forests of the grey mangrove (*Avicennia marina*) and associated biologically rich mud flats, saltmarshes and seagrasses of the North Spencer Gulf Bioregion are the most extensive in South Australia, with over 49% of the mangrove shorelines for the State and 59% of the seagrasses.

Some algal species typically tropical in distribution, e.g. the brown algae *Sargassum decurrens* and *Hormophysa cuneiformis* (Edgar, 2000; Baker, 2004), are not found anywhere else in South Australia but exist only in the warm waters of North Spencer Gulf Bioregion. Giant cuttlefish (*Sepia apama*)[1] migrate to the rocky reefs around Whyalla each winter forming the largest known mating aggregation for this species in the world. North Spencer Gulf is also a major contributor to South Australia's fisheries, including extensive western king prawn (*Melicertus latisulcatus*), blue swimmer crab (*Portunus pelagicus*) and snapper (*Pagrus auratus*) fisheries.

Table 7: Key characteristics of the North Spencer Gulf Bioregion

Characteristics	**North Spencer Gulf Bioregion**
Depth class	Approximately half and half shallow (0−10m) and intermediate (10−30m) waters with less than 1% deep water (30−50m).
Sea surface temperature	The summer mean temperature is of all warm waters, more than 22 °C. For winter the waters are 1% less than 12 °C, 89% between 12−13.5 °C, 8% between 13.5−15.5 °C, 3% no data.
Benthic habitats	Over half (53%) of the seafloor is covered in seagrass with another 39% bare sand. The remainder is low profile platform reef (7%) and unmapped seafloor (1%).
Shoreline classification	53% mangrove, 20% coarse sand beach, 15% mixed sediment beach, 8% saltmarsh, 3% bedrock platform and 1% mudflats.
Key aspect	East and west facing shorelines, narrowing to headwaters
Currents and exposure	Clockwise gulf circulation; quite protected. Shoreline exposure classified as 88% sheltered, and 12% moderate.
Notable species	Grey mangrove *Avicennia marina*, giant cuttlefish *Sepia apama*, greenlip abalone *Haliotis laevigata*, stony coral *Plesiastrea versipora*, stromatolites, like mounds of the blue-green algae *Oscillatoria* sp. and the bottle nose dolphin *Tursiops truncatus*.

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[1] Note: likely genetic differentiation between *S. apama* in northern Spencer Gulf and the rest of southern Australia (pers. comm, Professor Steve Donnellan, South Australian Museum and Associate Professor Bronwyn Gillanders, University of Adelaide)

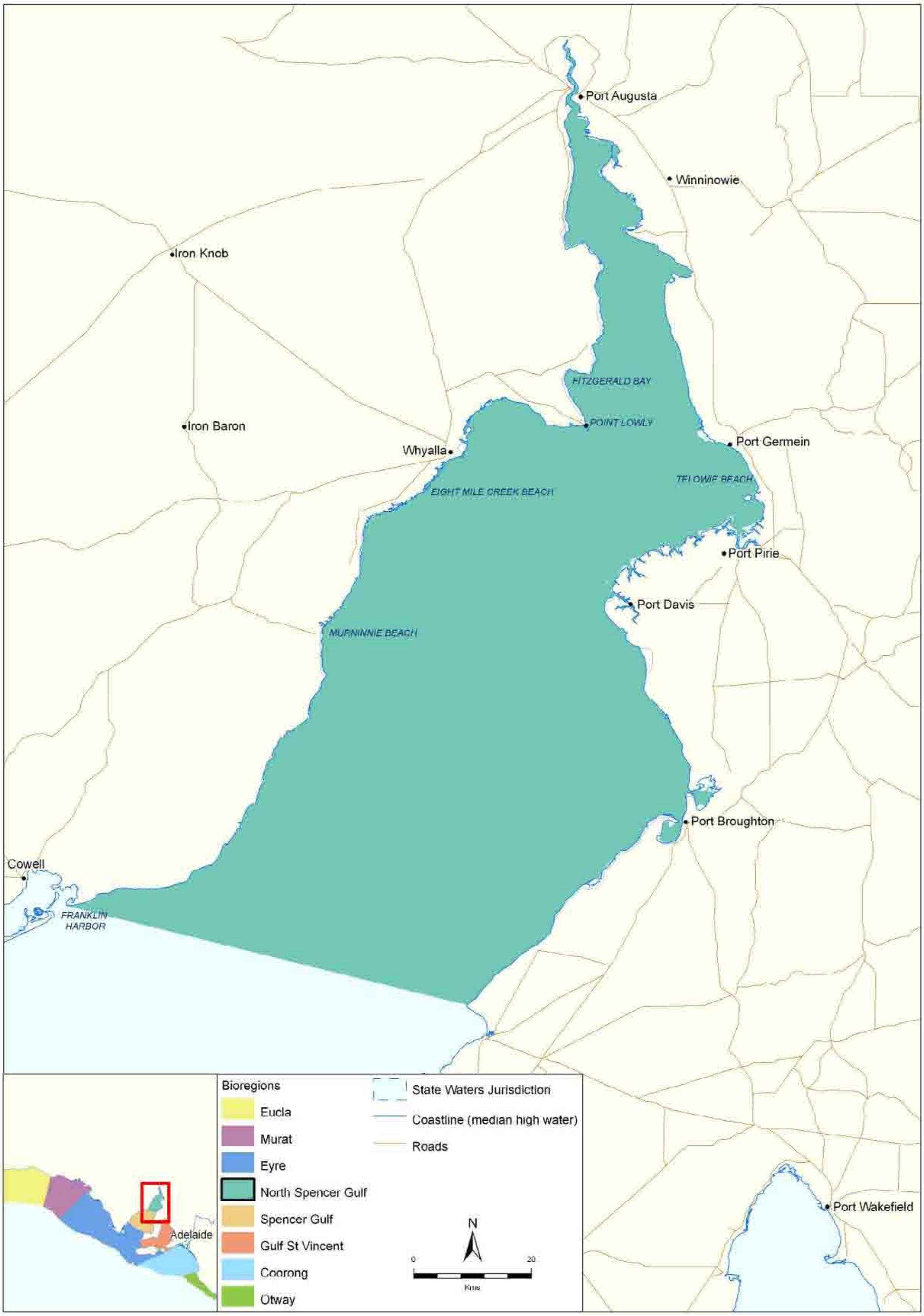
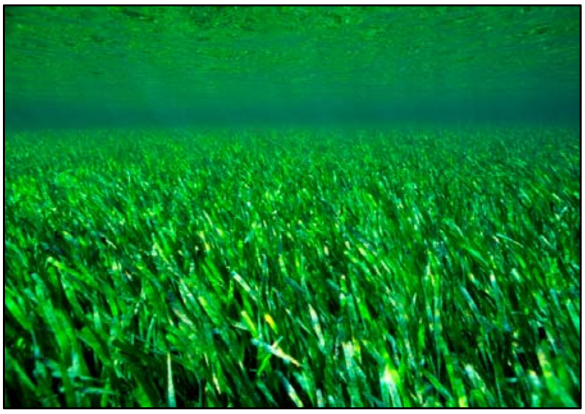


Figure 17: North Spencer Gulf Bioregion

3.3.1.5 Spencer Gulf Bioregion

The Spencer Gulf Bioregion contains the central portion of the gulf proper, extending from Corny Point across to Tumby Bay and Point Riley across to Shoalwater Point (Figure 18). Spencer Gulf is a semi-sheltered system, with warm temperate waters from North Spencer Gulf mixing with the warm to cool seawater influx from the Southern Ocean (Table 8).



Seagrass bed
(Source: Marinethemes.com/Clay Bryce)

Over 60% of the seafloor within the Spencer Gulf Bioregion remains unmapped but the mapped area of the bioregion changes from mangrove lined flats and soft-bottom sedimentary ecosystems of the sheltered waters of the northern parts of the gulf to rocky shorelines and reef structures in the more exposed waters, accommodating diverse habitats and biota that share them (Baker, 2004).

Sandy seafloor habitat
(Source: Marinethemes.com/Mary Molloy)

The waters of the Spencer Gulf Bioregion are among some of the most productive and diverse in South Australia, supporting important recreational and commercial fisheries for a variety of marine species such as the King George whiting (*Sillaginodes punctata*). Tiparra Reef off Moonta Bay is a seagrass and reef habitat renowned for diverse marine life and is a major commercial fishing ground for greenlip abalone (*Haliotis laevigata*) in South Australia.

Table 8: Key characteristics of the Spencer Gulf Bioregion

Characteristics	**Spencer Gulf Bioregion**
Depth class	58% intermediate waters (10–30m), 25% deep (30–50m) and 17% shallow (0–10m).
Sea surface temperature	Summer water averages 85% between 19–22 ° C, 15% greater than 22 ° C. For winter, 29% is between 12–13.5 ° C, 68% between 13.5–15.5 ° C, for 3% of the area there is no data.
Benthic habitats	Unmapped (66%), 15% bare sand, 12 % seagrass, 6 % low profile platform reef and 1% heavy limestone or calcarenite reef.
Shoreline classification	Dominated (59%) by coarse sand beaches, with lesser amounts of bedrock platform (15%) and mangroves (14%). Saltmarsh (5%), fine-medium sand beaches (3%), mixed sediment beaches (2%) and cliffs and boulder beaches (1%).
Key aspect	East and west facing shorelines, uniform but opposing.
Currents and exposure	Clockwise gulf circulation; relatively protected. Shoreline exposure classified as 70% sheltered, 29% moderate and 2% exposed.
Notable biota	Grey mangrove *Avicennia marina*, western king prawn *Melicertus latisulcatus*, seagrass species such as *Zostera muelleri and Heterozostera tasmanica*, *Posidonia australis* and other *Posidonia* species (e.g. *P. sinuosa*), *Amphibolis antarctica*, and *Halophila ovalisi.* Sub-tropical organisms include solitary ascidian assemblages such as *Polycarpa viridis* and *Halocynthia dumosa*, the soft corals *Carijoa multiflora*, *Euplexaura* and *Echinogorgia* spp. (sea fans).

Figure 18: Spencer Gulf Bioregion

3.3.1.6 Gulf St Vincent Bioregion

The Gulf St Vincent Bioregion is the second largest bioregion in South Australia. It extends from West Cape to Cape Borda and Cape Willoughby to Port Elliot (Figure 19). Gulf St Vincent is also a confined, inverse estuary with seasonal surface water temperatures varying from 11ºC in winter to 26ºC in summer and salinities ranging from 35 to 42 ppt. (Edyvane, 1999).

The tidally dominated, low wave energy coasts provide an ideal habitat for extensive mangrove forests, together with associated tidal mudflats and saltmarsh communities (Table 9). These habitats are ecologically important, acting as nursery, juvenile and feeding grounds for diverse marine fauna. Other significant habitats include seagrass beds, algal dominated reefs, sponge gardens and the deepwater environments of Backstairs Passage.

Mangrove
(Photo: Deb Allen)

The seagrass *Posidonia coriacea* found near Aldinga is a less common species for this State, along with a few other seagrasses found in Marion Bay, Yorke Peninsula and Emu Bay, Kangaroo Island. The leafy sea dragon (*Phycodurus equus*), a species protected in South Australia under fisheries legislation, occurs in seagrass and macroalgal habitats around the Fleurieu Peninsula. Fast flowing tidal currents in some areas of the Bioregion provide optimal conditions for filter feeding organisms, particularly sponges and bryozoans that out compete plant communities for space, and hence dominate in these areas.

Leafy sea dragon
(Photo: Deb Allen)

Table 9: Key characteristics of the Gulf St Vincent Bioregion

Characteristics	**Gulf St Vincent Bioregion**
Depth class	40% deep water (30–50m), 36% intermediate (10–30m) and 23% shallow (0–10m) with 1% very deep water (>50m).
Sea surface temperature	Summer temperatures dominated by 84 % of waters between 19–22 ° C, 12% greater than 22 ° C, with 4% between 17.5–19 ° C. For winter the waters are 5% less than 12 ° C, 25% between 12–13.5 ° C, 69% between 13.5–15.5 ° C, 1% no data.
Benthic habitats	71% unmapped seafloor, 18% seagrass, 7% bare sand, 4% low profile platform reef.
Shoreline classification	Varied shoreline with similar percentages of bedrock platform (17%), coarse sand beaches (18%) and mangroves (18%). Smaller stretches of mixed sediment beaches (14%), cliffs (13%) and fine-medium sand beaches (11%). Small sections of intertidal seagrass (4%), boulder beaches (3%), mudflats and sand (1%), saltmarsh (1%) and pebble and cobble beaches (less than 1%).
Key aspect	Variable, from north facing Kangaroo Island to opposing east and west shorelines of the gulf and south facing heel of Yorke Peninsula.
Currents and exposure	Clockwise gulf circulation at a slow rate; shore-parallel tidal oscillations off Adelaide dominate water movements. Shoreline exposure classified as 56% sheltered, 37% moderate and 7% exposed.
Notable species	14 species of seagrass including *Posidonia australis, P. coriacea, P. kirkmanii, Zostera muelleri, Heterozostera tasmanica* and *Amphibolus antarctica*. The grey mangrove *Avicennia marina,* beaded samphire *Tecticornia flabelliformis* leafy sea dragon (*Phycodurus equus*) and Verco's pipefish *Vanacampus vercoi.*

Figure 19: Gulf St Vincent Bioregion

3.3.1.7 Coorong Bioregion

Stretching eastward from Port Elliot to Cape Jaffa, the Coorong Bioregion is dominated by a large beach-dune barrier coast that forms the extensive Coorong lagoon complex and the beach-ridge plains of Lacepede Bay (Figure 20). The gently curving sandy coastline is exposed to high energy wave action near the mouth of the Murray River and lower wave energy near Cape Jaffa.

The Coorong (Photo: Coast Protection Board)

The Coorong is a shallow, very salty, coastal lagoon system more than 100 kilometres in length. The Younghusband and Sir Richard Peninsulas separate the Coorong from the ocean with the only connection being a narrow channel at the Murray Mouth. The lagoonal waters support a diverse range of aquatic plants and animals, and the lengthy ocean beach is an important feeding, breeding and nursery area for many marine species, including the Goolwa cockle (*Donax deltoides*). The large sand barrier coast of these two peninsulas varies from a steep depth gradient, shaped by the high wave energies near the Murray River mouth, to a flat depth gradient, shaped by the lower wave energy in the more sheltered waters near Cape Jaffa. Extending offshore from the mouth of the Murray River and western Kangaroo Island are the sub-marine Murray Canyons, an ancient river mouth system formed when sea levels were much lower. Offshore, these canyons are within a Commonwealth marine protected area.

The Coorong supports one of the largest concentrations of waterbirds in Australia. A total of 90 species have been recorded, with many species gathering in this area to breed. West of Cape Jaffa, Margaret Brock Reef is the most westerly extent of some cold water plants such as the giant kelp (*Macrocystis angustifolia*) and bull kelp (*Durvillaea potatorum*) that typically dominate the high energy reefs eastward of this point. Seagrass beds are scarce along most of the coast due to high wave energy and active sand movement (Table 10). Even so, *Posidonia australis*, *P. angustifolia*, *Amphibolis antarctica* and *Zostera tasmanica* are present near Cape Jaffa. A dense and extensive seagrass meadow is located in the near shore region of Lacepede Bay, which is the eastern extent of the seagrass species *Posidonia sinuosa.*

Table 10: Key characteristics of the Coorong Bioregion

Characteristics	**Coorong Bioregion**
Depth class	50% intermediate waters (10–30m) and 30% shallow waters (0–10m) with 10% each of deep (30–50m) and very deep waters (>50m).
Sea surface temperature	Predominantly (73%) waters between 7.5–19°C, 22% between 19–22°C, with 5% less than 17.5°C. For winter 27% less than 12°C, 39% between 12–13.5°C, 21% between 13.5–15.5°C, 12% greater than 15.5°C, 1% no data.
Benthic habitats	42% unmapped and 30% bare sand. Low profile platform reef (15%) and seagrass (12%) make up most of remaining area with less than 1% each of heavy limestone or calcarenite reef and granite reef.
Shoreline classification	87% fine-medium sand beach, 12 % coarse sand beach and less than 1% bedrock platform.
Key aspect	Varies from south-south-east-facing through south facing to west facing.
Currents and exposure	Some residual effects of Flinders Current in summer plus coastal counter currents. Shoreline exposure is 12% sheltered, 9% moderate and 79% exposed.
Notable biota	Goolwa cockles *Donax deltoids*, hammerhead shark *Sphyrna zygaena*, mulloway *Argyrosomus japonicus* and Australian pelicans *Pelicanus conspicillatus*.

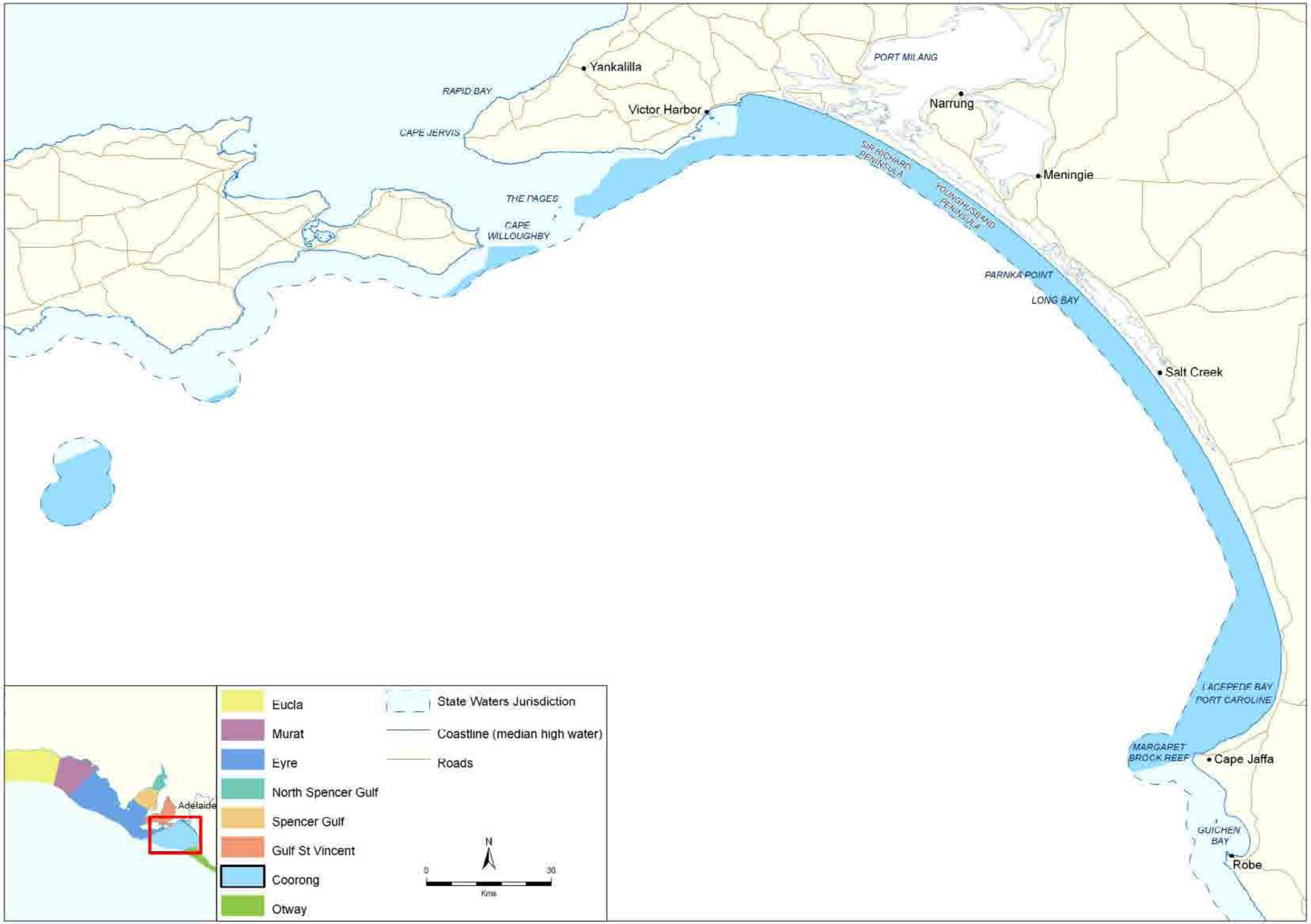


Figure 20: Coorong Bioregion

3.3.1.8 Otway Bioregion

The Otway Bioregion extends eastwards from Cape Jaffa to the Victorian border (Figure 21). Although it is the smallest of South Australia's bioregions, the Otway Bioregion supports some of the most diverse and productive waters in South Australia.

The Otway Bioregion is characterised by summer upwelling plumes known as the Bonney Coast upwelling. Due to the high energy coastline, soft sediment habitats colonised by seagrass communities occur less frequently in the Otway Bioregion than they do elsewhere in the State (Table 11). Even so, they are present in some sheltered embayments due to the blocking of waves by offshore reefs.

View from Cape Northumberland, Lower South East
(Photo: Sarah Bignell)

Southern rock lobster
(Source: Marinethemes.com/Kelvin Aitken)

Unlike the rest of the State, the fauna and flora east of Robe are typical of colder water areas and are similar to the marine plants and animals of Victoria and Tasmania. The Bioregion is highly productive as a result of the upwelling, supporting rich communities of plants and filter feeding animals such as sponges, bryozoans and corals. It is also a productive fishing ground, particularly for the southern rock lobster (*Jasus edwardsii*). Groups of the blue whale (*Balaenoptera musculus*) (listed as an endangered species under both the EPBC Act and the NPW Act) are also known to aggregate in the Bonney Coast upwelling area to feed on the abundant krill (Gill, 2002).

Table 11: Key characteristics of the Otway Bioregion

Characteristics	**Otway Bioregion**
Depth class	Dominated (58%) by intermediate waters (10–30m), with 28% shallow (0–10m) and 14% deep (30–50m). No very deep (>50m) in this bioregion.
Sea surface temperature	Summer temperatures over 99% are less than 17.5 degrees. For winter 20% less than 12 ° C, 66% between 12–13.5 ° C, 12% between 13.5–15.5 ° C, 2% no data.
Benthic habitats	48% unmapped, 38% low profile platform reef with the remainder divided between heavy limestone or calcarenite reef and bare sand.
Shoreline classification	Dominated (62%) by fine-medium sand beaches and coarse sand beaches (20%), interspersed with cliffs (13%), pebble and cobble (3%), and mixed sediment beach types (2%).
Key aspect	Relatively uniform, south-west facing to south facing.
Currents and exposure	Bonney upwelling occurs from November to May, but generally around December/January and February/March. Strongly influenced by Flinders Current during summer. During winter an eastward counter current predominates. Shoreline classified as 38% sheltered 16% moderate exposure and 46% exposed.
Notable biota	Blue whales *Balaenoptera musculus*, giant kelp *Macrocystis angustifolia*, bull kelp *Durvillaea potatorum*. uncommon species of brown algae *Myriodesma leptophyllum, Claviclonium ovatum and Cliftonaea semipennata*.

Figure 21: Otway Bioregion

4 Building a marine parks network for South Australia

The following section outlines the scientific methodology employed by the South Australian Government, with support from the SWG, in the process to develop the outer boundaries for South Australia's marine parks network.

4.1 Using the Design Principles

In developing South Australia's marine parks network, technically there are likely to be a number of equally relevant marine park design solutions that exist. Ultimately the design that is chosen needs to be one that meets the technical objectives of the marine parks network and also provides an optimal solution socially and economically. The purpose of the Design Principles is to support achievement of these outcomes. The first four biophysical Design Principles are the Principles underpinning our global and national commitments. The last three biophysical Design Principles focus the design of marine parks on key elements of marine systems so that the network includes unique and important places, provides protection to vulnerable systems and connects places physically and/or ecologically. The biophysical Principles identify sites for biodiversity conservation purposes and the community Principles guide the selection of areas through the consideration of economic, social and cultural uses. To allow the Principles to make a strong contribution to the decision making process, the following guidelines were used (adapted from Brody 1998):

1. *Clearly identify the goals, objectives and expectations of the program* - The identification and application of the Design Principles is intricately linked to the program goals and objectives. It was critical to clearly define the goals as they determined how decision rules were applied in the design process. For example, the goal to establish a system of marine parks to conserve biodiversity in South Australia emphasised the biophysical Design Principles which were tempered by societal expectations rather than the other way around.

2. *Obtain relevant information* – Marine park design relied on accurate and current data and information that related to the Design Principles. For example, up-to-date information on protected species and the places/habitats on which they depend was important to identify ecologically important places.

3. *Use Design Principles as a general guide to the planning process* - Because the process was a qualitative one, the Principles were used to guide and focus decision makers throughout the planning process. They were meant to help humans make decisions, not take humans out of the decision making process.

4. *Maintain flexibility* - Every region and area of interest has different environmental and societal values. The key is to maintain flexibility throughout the selection process.

4.2 Surrogacy

Along with recognition of the bioregions and application of the Design Principles, a key scientific concept used in planning the marine parks network was surrogacy, where relatively easily measured characteristics are used to stand in for other variables that are intrinsically harder to measure (e.g. cryptic or little known taxa, or for aspects of biodiversity at the other levels, see review by Rodrigues and Brooks, 2007 for many examples). The most straightforward of these surrogates was adopted in the DEH habitat mapping, where habitats (however defined) were used hopefully to represent species diversity (especially in terms of habitat heterogeneity capturing most of the diversity) and other aspects of biodiversity.

A focus upon biodiversity *per se* is relevant to conservation and seems to be a reasonably customary use now, but it is ultimately limited because we know very little about the full range of taxa (e.g. across all taxonomic groups of organisms), genomes, or ecosystem level processes that we are seeking to protect. It is probably impractical to ever expect to that we can get a complete enumeration of all taxa of biota in any marine habitat. Instead of such direct measures, we tend to use one form or other of surrogacy (Rodrigues and Brooks, 2007) to guide our decisions. Essentially we seek to make choices that maximise the diversity protected within well known or easily studied habitats or subsets of taxa and assume that the full range of taxonomic groups and ecological processes will also be included. Biodiversity itself is mostly not known but it is rarely ever justified to try to measure everything in terms of the biota on a routine basis, hence the need for judicious use of surrogates.

A subset of this approach was to emphasise physical surrogates, where we ask whether aspects of the non-living environment can be used to represent biodiversity (for example, can rock type/aspect/ geomorphology/depth/wave exposure/particle grain size/water quality be used to predict or reflect key variations in biodiversity?). Generally these data sources are indicative only, in that only some aspects of coarse-scale variation in biodiversity can be represented by physical variables.

The main set of surrogates used in determining a set of outer boundaries has been the replacement of direct measures of biodiversity with planning based on a set of recognisable subtidal or intertidal habitats and some environmental features based on mainly physical measures such as water depth, temperature, exposure, seafloor substrate, aspect and the like. Because these potential surrogates are mapped across the State at a 1:100,000 scale, it is easy to substitute them in the planning and modelling for the diversity measures of genetics, taxa and ecosystemic processes that we generally lack.

In addition, areas of subtidal benthic and shoreline habitats which are yet to be mapped across the State were also included within the network to satisfy the Principle of the precautionary approach. Eventually, as our habitat mapping and other field programs become more complete, we would be able to assess the relative success of our precautionary inclusion of unmapped habitat areas within the network and zones but this would be best done if we made explicit predictions beforehand of what habitats we expect to see in the presently unmapped areas. These predictions could be based on a suite of environmental parameters such as depth, aspect, wave exposure, sea surface temperature, distance from the shoreline and bottom slope that exist as data layers for all the State waters. Such a test would also serve to assess our use of surrogacy. The key data sets used as surrogates are listed in Table 12.

Table 12: Physical and oceanographic factors influencing the design of marine parks
(modified from Nowlis and Friedlander, 2004).

Physical characteristic	Influence on marine ecosystems
Distinct geomorphic features	Topography (e.g. bay shape, inselbergs, beach shoreline types) provides a range of local conditions.
Benthic (seabed) structure	Whether hard solid rock or unconsolidated sediments (e.g. sand, mud) seabed structure affects the biota living near or on it, i.e. the types of biotic habitats present in a place.
Oceanographic characteristic	**Influence on marine ecosystems**
Water depth	Marine communities change with different depth profiles (e.g. due to light penetration).
Wave exposure	Wave energy of the seawater environment affects life forms that can live in any given location and hence community structure.
Ocean upwelling (cold nutrient rich waters)	Areas of upwelling are generally highly productive regions which influence pelagic fish (e.g. tuna), seals and birds via their migratory and feeding patterns.
Seawater properties	Sea surface temperature, salinity or water quality can be major physical engineers of biodiversity by limiting or promoting which species can live in a location.

4.3 Information used to develop marine parks

A large volume of data and information exists for the South Australian marine environment and these data were used during the marine park design process. Reference materials specific to marine conservation in South Australia (Edyvane, 1999 Parts 1 and 2; Baker, 2000; Baker 2004) were also used to support the marine park design. Consideration of the conservation features included within the marine parks network, however, were also based on quantitative data such as the extent of particular habitats or the length of shoreline features. Of the available data layers held by the DEH, a subset was selected for repeated use, constrained by the following requirements:

- widespread coverage of all or most of the State, including at least some of all eight bioregions;
- mapping at an appropriate scale (e.g. 1:100000);
- definitions of the categories or feature classes that were explicit and ideally corresponded to nationally agreed usage; and
- availability for use with geographical information systems (GIS) and park selection software as at 1 September 2008.

Following that assessment, a subset of environmental and socio-economic data layers were selected for regular use because they related to one or more of the Design Principles (refer to Table 13 and Table 14 for the data layers relating to each of the Design Principles and Table 32 in Appendix 2 for the full list of GIS data layers). Where any ambiguity arose during use of such data, the database was interrogated to examine exactly where a feature was mapped and then compared with independent ground-truthed data or local scientific expertise. If any uncertainty remained after that cross checking, certain classes were lumped across the whole database to arrive at broader classes that engendered more confidence. Thus the quantitative analyses for the network were constrained by the data layer resolution.

4.4 Identifying network options

The design of any marine protected area network needs to be grounded in science. The evaluation and selection of marine parks needs to occur in a way that results in a functional, interconnected network that meets multiple objectives (Roberts *et al*., 2003). There is a logical sequence in which the Design Principles were applied, with the first four biophysical Principles being the primary consideration in designing the network, followed by the remaining biophysical and the community principles.

The fundamental objective of the program is to conserve and protect the ecosystems, habitats, species and populations that are represented in our marine environment – and to do so in a way that is adequate enough to allow the protected places and species to be sustainable into the future. Table 13 and Table 14 provide a detailed description of how each of the Design Principles was applied, however a general overview of the process is described below.

The foundation of the marine parks network design was South Australia's eight bioregions. These bioregions formed the building blocks for the development of the network. For each of the eight marine bioregions, a comprehensive list of habitats and ecosystems was generated using information drawn from established databases. The objective was to protect a comprehensive set of the biological features that characterise each bioregion. In doing so it was assumed that if the network included examples of the characteristics of each bioregion, then by default, it must include examples of the characteristics representative of marine systems across the whole State.

Having compiled a list of habitats that occur within the bioregion, and recognising the focus locations already identified, candidate areas were compared for inclusion as parts of the marine park network. Some general rules were applied at this stage (adapted from Roberts *et al.*, 2003 and the Scientific Peer Review Panel for the National Representative System of Marine Protected Areas, 2006):

1. examples of all habitats identified in the bioregion, including unmapped areas, were included within the boundaries of marine parks;
2. examples of all habitats identified in the bioregion were also included at the different depth and sea surface temperature ranges and relative exposure in which they occur;
3. where a physical feature is incorporated into a marine park, where practicable, the whole feature was included, for example, seamounts, canyons and persistent upwellings;
4. each habitat type was protected in more than one area and in appropriate locations to ensure connectivity and linkages between parks;
5. the network includes a number of large parks rather than a greater number of small marine parks to minimise edge effects, the influence of off-reserve impacts and to guard against local catastrophes;
6. the total area set aside for protection approximately reflects its relative prevalence in the region (e.g. if seagrass constitutes 40% of the bioregion, it should constitute approximately 40% of the parks network for that bioregion); and
7. special care was taken to include biophysically unique sites as well as ecologically important habitats that are more vulnerable and/or less resilient. This is in keeping with the biophysical Principles that are meant to ensure that regionally specific characteristics are captured. An example of this is the inclusion of sites of importance to threatened, endangered or protected species such as the Australian sea lion.

Once ecosystems that contribute to the marine parks network were identified, it was also important to consider what these ecosystems need to persist through time. Central to this are the concepts of adequacy and connectivity. The marine parks network must facilitate the opportunity to manage the environment in a way that is adequate. The sizes of marine parks, and how well they provide connection between species and surrogates, are important. Sustenance depends on the inclusion of populations large enough to reproduce and to absorb sudden (e.g. oil spills or viruses) or more subtle (e.g. recruitment variability) shocks. It also depends on the protection of connected pathways, often conceptualised by considering source and sink areas for dispersing propagules (such as larvae). Finally, the persistence of populations will depend on the availability of resources, including viable habitat suitable for all life cycle stages and access to food that is either produced locally or arrives from other places.

As briefly discussed in section 2.4, all of these features operate at a number of spatial scales. For example, a typical marine life cycle involves potentially wide dispersal in the plankton as larvae, followed by more sedentary juvenile and adult stages. However, this is not always the case, as other species live out their entire life cycles in a very local area with individuals never leaving the bay or habitat in which they were conceived (Kinlan and Gaines, 2003). Other species have enormous dispersal capacity throughout their lives (e.g. southern right whales and a range of pelagic predators such as tuna and sharks), although often, even those species will return repeatedly to localised places for particular biological events, such as breeding. Because of this complexity, there is no certainty about how large marine parks should be or how they should be placed to be well connected. There is general consensus in the scientific literature that marine parks are a biodiversity conservation tool that becomes more effective with increasing size as larger parks cater for a wide range of dispersal capabilities (Claudet *et al*., 2008, IUCN-WCPA, 2008).

The next stage in network development was to modify the final design by carefully reviewing available information that relates to the full set of community Principles. At this stage, the identified boundary options were overlaid with a range of point source and area data relating to the Design Principles (Table 14). Some of the community Design Principles, such as those relating to protecting indigenous sites and cultural heritage, or seeking synergies with other protected areas, identified areas for inclusion in the network. Other Principles such as those relating to considering the full diversity of marine uses, specifically in relation to commercial fishing and aquaculture, identified areas where overlap could be minimised (without jeopardising the biodiversity conservation objectives). Other community Design Principles such as providing for education and appreciation and ensuring ease of identification, were considered in the process, but are more applicable for zoning and management plan development and implementation. Once the assessment of the modifying data layers had been completed, a draft network of marine park boundaries was selected. As mentioned in section 2.8, cross-Government consultation on the draft network also helped to further refine the boundaries in meeting the objectives of the community Design Principles.

4.4.1 Developing landward boundaries

In identifying the draft network of marine park boundaries, the default landward extent of each marine park boundary was the median high water mark[1]. An important piece of advice provided by the SWG was that marine parks should be extended inland where the linkages between nearshore waters and coastal habitats play an important role in determining and maintaining marine ecosystem function. For example, on sandy coasts, seagrass wrack and dunes above the high tide mark are important habitats for birds and insects, and in turn play an important role in cycling nutrients back into the marine environment. Extending marine park boundaries inland also plays an important role in providing resilience to impacts of climate change, particularly sea level rise.

The *Marine Parks Act 2007* states that an area proclaimed as a marine park must be within the limit of the State's marine waters, and may also include land or waters held by, or on behalf of, the Crown within or adjacent to the specified part of the sea. This means that coastal Crown land may be incorporated within a marine park boundary. The landward extent of the boundaries for each marine park was determined by assessing the available Crown land parcels adjacent to each marine park, paying particular attention to the concepts of connectivity and linkages, resilience and vulnerability, and ecological importance of the interface between the coast and marine environments. Importantly, the creation of inland boundaries allowed whole ecosystems or habitats to be incorporated within marine parks.

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[1] Please note that the default inland extent of marine parks is median high water. For the purposes of this report, the mapped coastline of Australia at mean high water has been used as an approximation of median high water.

Table 13: Biophysical Design Principles: key concepts and methodology for their application.

No	Design Principle	Relevant concepts and application
1	Precautionary approach	Key concepts: If there are threats of serious or irreversible harm to the marine environment, lack of full scientific certainty should not be used as a reason for postponing measures to prevent harm (*Marine Parks Act, 2007*). The Scientific Peer Review Panel for the NRSMPA (2006) recommended that when biodiversity data availability is low, the principle of precaution should be applied. This is to establish a relatively larger MPA with an appropriately higher level of protection that will provide the best opportunity for the network to capture the expected biotic diversity within the region. Method for applying the Design Principle: To apply the Precautionary Principle, unmapped areas of benthic and shoreline habitats were included as a class of habitat within marine parks. The area of unmapped habitats varies from bioregion to bioregion. For benthic subtidal habitats, two thirds of the State is unmapped. By including unmapped areas of habitat at different depth ranges, protection is provided for whatever habitats exist in those areas. The precautionary approach is also applied by developing large marine parks. Key data and information applied: *Key GIS layers:* ▪ Benthic subtidal habitats ▪ Depth class (bathymetric data grid)
2	Comprehensiveness	Key concepts: Protect examples of all the features identifiable within the environment. Method for applying the Design Principle: To achieve comprehensiveness, the full range of ecosystems and habitats occurring within and between each bioregion were incorporated within marine parks. Ecosystems and habitats were primarily identified using benthic habitats and shoreline classification data. For landward boundaries, coastal habitats such as sand dunes, saltmarsh and mangroves are considered part of the marine environment. To be comprehensive, these habitats were included. Key data and information applied: *Key GIS layers:* *Habitat layers:* ▪ Subtidal benthic habitats ▪ Shoreline classification (substrate type) ▪ Terrestrial water courses including coastal wetlands of national importance ▪ Estuaries of South Australia ▪ Saltmarsh and mangrove habitats in South Australia ▪ Islands and emergent rocks ▪ Sand dune coastal hazard mapping
3	Adequacy	Key concepts: The network should provide for the maintenance of ecological viability and integrity of populations, species and communities. The Scientific Peer Review Panel for the NRSMPA (2006) states that no precise basis exists for determining criteria to address adequacy. However, the probability of long term survival increases with increased proportions of populations or ecosystems reserved and appropriately managed. The recommendation is for several larger marine parks rather than a greater number of smaller marine parks. This is to increase the level of protection, reduce the exposure to risk, minimise edge effects and the influence of off park

		impacts. Important considerations are the size and shape of marine parks, building redundancy by replicating protection for habitats within and between marine parks, the degree of protection given to ecosystems and habitats through appropriate zoning, the connectivity of the network of marine parks and the complementary management of threats within and outside of the network (The Scientific Peer Review Panel for NRSMPA, 2006). For landward boundaries, incorporating the whole of an ecosystem or habitat within a marine park creates the opportunity to maintain ecosystem integrity and thus progress towards achieving adequacy. Method for applying the Design Principle: There are no specific indicators that can be applied to adequacy at the start of the marine park design process, because success will depend to a large extent on the zoning and management plans for each marine park. At this stage, consideration was given to the size of each park. A visual assessment was also made of some threats to each marine park, for example the location of point source pollution via stormwater drains. Through the landward boundary assessments, where possible, the marine park was extended inland to enable the whole of an ecosystem or habitat to be incorporated. Key data and information applied: ▪ State waters boundary ▪ 19 focus locations ▪ Stormwater drains and point source visual assessment
4	Representativeness	Key concepts: The network will reflect the biodiversity and variability naturally present in the marine environment. Representativeness is distinguished from comprehensiveness by focussing on overall levels of biodiversity protected by the system as opposed to habitat level alone. As little information is available about the levels of biodiversity within South Australia's marine habitats, physical or ecological aspects of the environment were used as a surrogate for biodiversity. Geomorphic, oceanographic and biological information can provide information about large scale patterns of biodiversity to guide marine park selection (The Scientific Peer Review Panel for the NRSMPA, 2006). The Scientific Peer Review Panel recommends that known conservation features and habitats should be represented within a marine park network at approximately similar levels as they are represented within biogeographical areas such as a bioregion or province. The features were incorporated in similar proportions as they occurred within each bioregion. Method for applying the Design Principle: For South Australia's marine park design, habitats and recognisable features such as depth and water temperature were used as surrogates for biodiversity within the marine parks network. Key data and information applied: *Key GIS layers:* *Oceanographic layers:* ▪ Depth class (bathymetric data grid) ▪ Sea surface temperature and upwellings *Habitat layers:* ▪ Subtidal benthic habitats ▪ Shoreline classification (type) – using three substrate types ▪ Shoreline exposure ▪ Estuaries of South Australia ▪ Saltmarsh and mangrove habitats in South Australia ▪ Coastal wetlands of national importance

		▪ Sand dune coastal hazard mapping ▪ Fish habitats (Bryars, 2003) ▪ Offshore islands
5	Connectivity and linkages	Key concepts: The concepts of connectivity and linkages refer to the process of sharing plants and animals (connectivity) between sites and water borne transport of materials (linkages). The ways tides, currents and the behaviour of plants and animals combine to connect neighbouring and more widely separated ecosystems in the marine environment are complicated. The inclusion of habitats within marine parks across local, bioregional and provincial scales can be used as surrogates to achieve measurable connectivity and linkages between and within marine parks. The Principle of connectivity doesn't have specific metrics apart from the physical distance separating any pair of sites. The Principle can be informed by physical oceanography, such as current patterns, and the properties and quality of seawater for larval transport. Propagule (larvae, spores) dispersal ranges for marine organisms, and foraging areas for pinnipeds and migratory pathways for seabirds and cetaceans, are also a consideration. Method for applying the Design Principle: The Principle of connectivity and linkages was applied by developing a network of marine parks within and between each of the eight bioregions across the State. Consideration was given to the distances between marine parks and the habitats or other features, such as migratory pathways for whales, or the propagule dispersal ranges for sessile or sedentary marine species within them (identified in Kinlan and Gaines, 2003) as a surrogate for connectivity. When considering the landward extent of the marine park boundaries, consideration was given to the inclusion of coastal habitats such as estuaries and coastal vegetation communities such as *Melaleuca halmaturorum* swamp lands which have linkages with the marine environment through their role in either filtering, processing and/or exporting organic nutrients and sediments to/from adjacent marine habitats (DEH, 2007; Fairweather and Quinn, 1992; Turner *et al.*, 2004) Key data and information applied: ▪ Published dispersal ranges for marine organisms identified in Gillanders *et al.* (2003); Kinlan and Gaines (2003) and Palumbi (2004). *Key GIS layers:* ▪ Foraging areas for the Australian sea lion, based on Goldsworthy et al. (2007) suggesting that breeding sea lions forage in an 80 kilometre mean range from their colonies ▪ Known migration pathways of significance and feeding grounds (where they intersect state waters) for the blue whale in Australian waters (Environmental Resources Information Network (ERIN)) ▪ Known significant aggregation areas, migratory pathways and calving areas for the southern right whale in Australian coastal waters (ERIN). ▪ Estuaries that are known to be important nurseries and where adult habitat links occur ▪ Coastal wetlands
6	Resilience and vulnerability	Key concepts: Marine parks should be designed to maintain the natural state of ecosystems and absorb shocks, particularly in the face of large scale and long term impacts such as climate change. Key concepts include incorporating natural (minimally disturbed) areas into marine parks design, incorporating areas or habitats that are resilient and providing for areas or species that are vulnerable. Method for applying the Design Principle: The concept of resilience (ability to recover from impact) was applied in the design of South Australia's marine parks by carefully considering habitats that are resilient as well as those that are slow to recover from impacts and by deliberately incorporating some redundancy through the inclusion of replicated examples of ecosystems within the network. The concept of naturalness was applied by incorporating areas that are less subjected to levels of human induced changes. The concept of vulnerability was applied by incorporating habitats and ecosystems that are vulnerable to impacts, i.e. they are easily disturbed or transformed by human action (Roberts *et al*., 2003). Examples of vulnerable habitats included in South Australia's marine parks were saltmarshes, mangroves and seagrass beds. Mangrove and saltmarsh habitats were an important consideration in the landward boundaries assessments. Almost three quarters of the State's mangrove and saltmarsh

		habitat are above MHW. Estuaries were also a consideration in developing the landward extent of marine park boundaries as they are considered vulnerable because they are naturally fragmented and their substrata are strongly influenced by biological processes that are easily disrupted (Hockey and Branch, 1994). In addition to the inclusion of vulnerable habitats, species with vulnerable life stages, for example critical nursery areas, spawning and nesting grounds were also incorporated into the marine parks. Key data and information applied: *Key GIS layers:* *Habitat layers:* ▪ Benthic habitats: subset – dense seagrass habitats ▪ Saltmarsh and mangrove habitats in South Australia ▪ Sand dunes ▪ Estuaries *Species of conservation concern* ▪ Flora and fauna of conservation significance listed under the NPW Act and the EPBC Act ▪ South Australian marine species of conservation concern (Bryars, 2003 and Baker, 2008) ▪ Point locations of the known distributions of vulnerable Australian macroalgae in South Australian waters (Conservation Status of Endangered Marine Algae - COSEMA) ▪ Beaded samphire (*Halosarcia flabelliformis*) sites (listed as vulnerable under the NPW Act)
7	Ecological importance	Key concepts: Areas of particular ecological importance to South Australia's marine environment. Method for applying the Design Principle: The Principle of ecological importance was applied by incorporating areas in marine parks which have high biological productivity, where particular interactions sustain communities, where unique or unusual communities or aggregations occur, with rare or endangered species, which are nursery grounds or are resting areas for migratory birds. Some coastal cliff tops in South Australia provide important breeding and foraging habitats for raptors such as the endangered white-bellied sea-eagle (*Haliaeetus leucogaster*), the endangered osprey (*Pandion haliaetus*) and the rare peregrine falcon (*Falco peregrinus*) (NPW Act). Sandy beaches and dune ecosystems in South Australia are ecologically important for a number of species including shorebirds such as the vulnerable hooded plover (*Thinornis rubricollis)* (population less than 540 birds) along with endangered fairy terns (*Sterna nereis),* vulnerable banded stilts (*Cladorhynchus leucocephalus)* and eastern curlews (*Numenius madagascariensis)* (NPW Act). Hooded plovers and fairy terns breed on open sandy surf beaches and are particularly sensitive to disturbance (DEH, 2007). Estuaries have high environmental, social and economic significance. Several South Australian estuaries, especially the Coorong, Lower Lakes and Murray Mouth are important regions for migratory shorebirds (Turner *et al.*, 2004). Many estuaries are breeding and nursery habitats for commercially and ecologically important species of fish and other organisms. Some of South Australia's prime fisheries stocks such as whiting, bream, molluscs, baitworms and prawns are found in estuarine regions at different stages of their life cycles. Islands are important ecologically because they provide breeding and nesting sites for many seabirds and shorebirds and provide breeding and haul-out sites for the Australian sea lion, listed as vulnerable under the EPBC Act and NPW Act 1972; New Zealand fur seal (*Arctocephalus forsteri*) and rare Australian fur seal (*Arctocephalus pusillus*) (NPW Act). Key data and information applied: *Key GIS layers:* *Species of conservation concern:* ▪ Australian sea lion and New Zealand fur seal locations within South Australian waters (breeding and haul-out sites)

		▪ The bycatch risk assessment on the Australian sea lion conducted by Goldwsorthy *et al*. (2007) ▪ Australian fur seal haul-out locations within South Australian waters ▪ Point locations of the known distributions of species of macroalgae thought to be potentially endangered in South Australian waters (COSEMA) ▪ Known significant aggregation and calving areas and migratory pathways for the southern right whale ▪ Known migration pathways of significance and feeding grounds for the endangered blue whale in Australian waters (ERIN); ▪ Flora and fauna of conservation significance listed under the NPW Act and the EPBC Act. ▪ South Australian marine species of conservation concern (Bryars, 2003; Baker, 2008) ▪ Beaded samphire sites ▪ Dragon search *Habitat layers:* ▪ Coastal wetlands of national importance ▪ Conservation hotspots for South Australia (Edyvane, 1999) ▪ Saltmarsh and mangrove habitats in South Australia ▪ Ramsar reserves *Biodiversity layers:* ▪ Bird species of Western Cove and Bay of Shoals – (Kangaroo Island only) ▪ Seabird nesting locations within South Australia including mainland and offshore island sites (population and breeding seasons) (Biological Survey Team, DEH) ▪ Marine and coast bird sites ▪ Hooded plover survey sites (Coorong and Kangaroo Island) ▪ Locations of significant wader bird sites along the South Australia coastline (Wilson, 2000) ▪ Western blue groper survey sites ▪ Fish habitats (Bryars, 2003)

Table 14: Community Design Principles: key concepts and methodology for their application

8	Seek synergies with existing protected areas	<u>Key concepts:</u> Complement and augment South Australia's existing protected areas where possible. This avoids unnecessary duplication of protected areas and minimises additional restrictions placed on the community. Synergies with existing protected areas provide buffering from land based impacts and ecosystem linkages between the land and sea. <u>Method for applying the Design Principle:</u> Align marine parks with existing protected areas, for example, terrestrial parks and reserves, aquatic reserves, rock lobster sanctuaries, netting closures, defence area boundaries and shipwreck zones. In applying this Principle, existing protected areas were identified both above and below MHW. Where possible the marine park overlayed the existing protected area. For the landward boundaries assessments, terrestrial protected areas were particularly considered, and where appropriate the landward boundary was extended to ensure seamless protection across the coast and marine interface. <u>Key data and information applied:</u> *Key GIS layers:* ▪ Great Australian Bight Marine Park ▪ Reserves dedicated under the NPW Act, *Wilderness Protection Act 1992* (WP Act) and reserves for conservation purposes under the *Crown Lands Act 1929* ▪ Aquatic reserves under the *Fisheries Management Act 2007* ▪ Shipwreck aquatic reserves (Adelaide and Yorke Peninsula) – declared as protected under *Historic Shipwrecks Act 1981* and the *Fisheries Management Act 2007*. ▪ Rock lobster sanctuary boundaries under *Fisheries Management Act 2007* - Fisheries (General) Regulations 2000

		▪ Defence area boundaries in South Australia[6] (Australian Defence Force) ▪ Netting closure locations and extent of waters in which the use of fishnets are prohibited *Fisheries Management Act 2007* - Fisheries (General) Regulations 2000 ▪ Aquatic reserve under the *Fisheries Management Act 2007*.
9	Seek to complement existing terrestrial and marine management practices and conservation agreements	Key concepts: Complement existing terrestrial and marine management practices and conservation agreements where possible. Method for applying the Design Principle: The Principle was applied by considering areas, or areas associated with, species listed under international and national conservation agreements (JAMBA, CAMBA, Ramsar), such as saltmarsh, mangroves and estuarine environments. Existing management boundaries or practices by Natural Resources Management Boards, Local Government and PIRSA Fisheries and Aquaculture were considered. When developing landward boundaries, the management of Crown land parcels under care and/control of Local Government was taken into particular consideration. Key data and information applied: *Key GIS layers:* *Existing management data:* ▪ Reserves dedicated under the NPW Act, WP Act, and reserves for conservation purposes under the *Crown Lands Act 1929* ▪ Crown lands - leasehold, unallotted, reserves, annual licences ▪ Local Government areas ▪ NRM regional boundaries ▪ Aquaculture management zones and fisheries closures (i.e. western blue groper closures) ▪ Navigation channels and markers ▪ *Fisheries data layers:* ▪ Coastal wetlands of national importance *Cultural use data and information* ▪ Register for the National Estate sites *Habitat layers* ▪ Directory of important wetlands in Australia and Ramsar listings (Commonwealth) ▪ Sand dune coastal hazard mapping
10	Give consideration to the full diversity of marine uses	Key concepts: Take into consideration the full diversity of uses of the marine environment. Method for applying the design principle: Existing uses of the marine environment such as resource extraction (e.g. commercial and recreational fishing and mining), recreational activities (e.g. diving, swimming and boating) and ecosystem services were taken into account during marine parks design. Wherever possible the marine parks program sought to achieve its objectives by selecting areas that are of less importance to the commercial fisheries sectors. Existing large scale aquaculture leases were also avoided where possible. However, as marine parks will be zoned for multiple uses, most of the existing activities and uses of the marine environment will be catered for in multiple use marine parks zoning design. When assessing Crown land parcels for inclusion into the marine parks network, the ecological benefits were weighed against the likely resultant management implications. There is no ecological or biodiversity conservation benefit from picking up modified areas already established as

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[6] While these areas are intended for the use of the Australian Defence Force, many of the ecosystems and habitats within them have been conserved and protected until such time as the ADF requires them for other purposes.

		recreational areas such as open space reserves containing infrastructure (playgrounds, parks, coastal shacks) as these areas are unlikely to be targeted for rehabilitation or natural succession. Key data and information applied: *GIS layers:* *Infrastructure:* ▪ Existing port and harbour limits, marina locations, boat ramps, lighthouses, moorings ▪ Shoreline construction ▪ Navigation markers – to identify shipping and transport routes, ferry routes ▪ Shack sites ▪ Marine underwater infrastructure/submarine cables ▪ Major and minor towns *Socio-economic data:* ▪ Mining tenements, leases, licences and applications ▪ Crown lands - leasehold, unallotted, reserves, annual licences *Fisheries and aquaculture* ▪ Boundaries of marine scalefish, rock lobster, prawn, abalone and crab fishing blocks ▪ Aquaculture lease and licence boundaries, management boundaries and exclusion zones ▪ Popular recreational fishing site locations ▪ National recreational and indigenous fishing survey *Recreation* ▪ Popular recreational scuba diving sites - complete for the Spencer Gulf, Gulf St Vincent and Kangaroo Island, correspondence with local dive clubs ▪ Published tourism information
11	Respect indigenous interests and culture	Key concepts: Consider traditional use and heritage. Method for applying the Design Principle: Traditional usage, indigenous cultural heritage, Indigenous Protected Areas, Indigenous Land Use Agreements, Native Title claims and Aboriginal Heritage sites were considered during the design of the marine parks network. Indigenous traditional fishing and hunting within marine parks will be facilitated in marine park zoning and management plans. Landward boundaries include many coastal habitats such as sand dunes and contain sites which are important to indigenous cultural heritage such as middens or indigenous fish traps. Key data and information applied: ▪ ILUA – registered national region ▪ Boundary and attribute information for Aboriginal, natural or historic heritage sites (Australian Heritage Commission Statutory Register of the National Estate) ▪ Aboriginal Heritage site buffers ▪ South Australian Native Title applications and determination areas (National Native Title Tribunal) ▪ National recreational and indigenous fishing survey
12	Give consideration to cultural heritage	Key concepts: Complement or seek to include sites of natural, cultural or maritime heritage. Method for applying the Design Principle: To apply the Principle of considering cultural heritage, sites listed on World and Commonwealth Heritage lists, shipwreck zones, the South Australian Heritage

		Register, History Trust and National Trust were assessed and where appropriate included in the marine parks network. The Heritage database lists 28 sites of significance to European culture and history including lighthouses, shipwrecks and monuments. Many coastal land parcels contain areas which are important to cultural heritage. Key data and information applied: ▪ Boundary and attribute information for Aboriginal, natural or historic heritage sites (Australian Heritage Commission Statutory Register of the National Estate) *Key GIS layers:* ▪ All known shipwrecks (declared and undeclared) located in South Australian and Australian waters adjacent to South Australia (South Australian Shipwrecks database) ▪ The State Heritage Register layer which includes geological monuments, shipwreck reserves (Adelaide and Yorke Peninsula), European heritage sites, registered piers and jetties and registered lighthouses.
13	Ensure ease of identification, compliance and enforcement	Key concepts: The marine park boundaries and their zones are easy for marine park users to identify. Methods for applying Design Principle: To apply this Principle, consideration was given to the shape of marine parks and using straight lines instead of curves. Where possible, marine park boundaries were also aligned with prominent coastal features or a well known locality. When developing landward boundaries, it was considered important from a management perspective to create boundaries which would be easily identified by local communities. Other methods for applying this Design Principle will be implemented during the implementation phase of the marine parks program. Key data and information applied: *Key GIS layers:* ▪ Coastal place names ▪ Major towns and minor towns ▪ Roads ▪ Topography - coastline
14	Provide for education, appreciation and recreation	Key concepts: Provide community education, appreciation and recreation in the marine environment. Methods for applying Design Principle: To provide for education, appreciation and recreation, consideration was given to existing university, school and community education and monitoring activities such as university field sites, school marine programs, Reef Watch (intertidal and sub-tidal) and Coastcare. Consideration was also given to known recreational areas such as beaches and estuaries which have aesthetic appeal and offer recreational opportunities for human populations (Levin *et al.*, 2001). Other opportunities to provide for education, appreciation and recreation will be considered during the management planning and implementation phase of the marine parks program. Key data and information applied: ▪ Existing education initiatives ▪ Proximity to towns ▪ University study centres/field stations ▪ Natural areas for appreciation ▪ Reef Watch ▪ Ecotourism interests

5 Auditing the boundaries – Analysis of the boundary network

The final stage in the process was to undertake quantitative and qualitative assessments of how well the marine parks network delivers the objectives of the program. In keeping with the development process, the assessment focused on how well the network design delivers against the Design Principles. Some Design Principles, for example adequacy, ensuring ease of identification, compliance and enforcement and providing for education, appreciation and recreation were either difficult to quantify, or make more sense to quantify once zoning arrangements have been made. Of the Design Principles which could be quantified (at least partially) at this stage in the process (12 of the 14 Principles), appropriate data layers that could be used to measure performance against the Design Principles, were selected for further statistical analyses (refer to Table 13 and Table 14).

GIS processing formed the basis of the assessments. Procedures such as intersections or unions of GIS layers, and frequency analysis, as well as manual measurements and layer attribute queries were used to extract raw data from the various layers. The raw data were either in the form of counts (e.g. number of Australian sea lion breeding sites) or area and lengths of feature classes (such as benthic habitats and shoreline substrate type). The data were used in a number of ways to explore the performance of the network in light of varying expectations for the different features (Table 15). Comprehensiveness was first assessed by using a presence/absence matrix to determine whether all of the benthic habitats and shoreline substrate types existing in each bioregion had been incorporated within the marine parks network.

Benthic habitats and shoreline classifications at varying summer and winter sea surface temperature classes, and depth and shoreline exposure classes were also used as a surrogate for biodiversity to achieve representativeness. The data was visually explored in SYSTAT v.12 using dual (mirror) bar charts and pie charts to see if the patterns of occurrence across features within a bioregion were captured within the park boundary (comprehensiveness), and to see if the proportions of different features within the network were comparable to those available in each bioregion (representativeness).

For site-specific features such as Australian sea lion breeding and haul-out sites which had frequency or count data, the results were analysed in SYSTAT v.12 using a Chi-square goodness-of-fit test. A Chi-square goodness-of-fit test is a type of statistical analysis used when frequency data are available and when the data fall into several categories (e.g. inside versus outside of marine parks) and we have a quantitative expectation of how many instances of a given feature should be included within the network. Essentially, the Chi-square goodness-of-fit test can be used to see whether the degree of inclusion of some feature that can be counted is what would be expected by chance alone if marine parks were randomly located. In this case, by including 46% of the State’s waters within the marine parks network, it would be expected by chance that around 46% of any particular feature occurring across State waters to also be included within the network if their design was random. The Chi-square goodness-of-fit test calculates the difference between the frequency of what would be expected by chance (the expected value corresponding to 46%) and the actual frequency found (the observed value). A statistically-significant result means that either significantly more, or significantly less, than 46% of the feature was included within the marine parks network. The critical value of such a Chi-square test for two categories is 3.84, so any value returned above that is considered significant. Inspection of the observed value then tells you if you have more or less than expected. For conservation features that we are deliberately trying to protect within the network, containing significantly more than 46% would then represent a positive result. A similar method was applied to human-use related data where the desired outcome was to include only the expected value of 46% of that use within boundaries, or if the opportunity existed, to include significantly less than would have occurred by chance.

Table 15: Analyses performed on the proposed boundary network

Design Principle Number	Design Principle	Features explored	Analytical method
1	Precautionary Approach	Unmapped benthic areas calculated as a total for each bioregion and the amount included within marine parks in each bioregion.	GIS processing – layer intersection and frequency analysis.
		The unmapped benthic areas in four depth classes for each bioregion and included within the marine parks in each bioregion.	GIS processing – layer intersection and frequency analysis.
2 and 4	Comprehensiveness and representativeness	Habitats represented within marine park boundaries for each bioregion. Shows benthic habitats (8), shoreline classes (12), sand dunes.	GIS processing – layer intersection and frequency analysis.
		Comparisons of shoreline class type to exposure or benthic habitats to depth, summer sea surface temperatures and winter sea surface temperatures.	GIS processing – layer intersections and frequency analysis.
		Areas or distances of environmental features from seven key data layers included in the network compared to what is available in each bioregion and across all State waters. Layers for benthic habitats, depth classes, summer sea surface temperature classes, winter sea surface temperature classes, shoreline classification type, shoreline exposure, and mangrove and saltmarshes were selected because they encompass all or most of the State waters and describe either important habitats or physical features that can act as surrogates for biota. Shoreline classification type was summarised from 21 categories into 12 for the purposes of statistical analyses and then further grouped into three categories of substrate type (rock, sand and mud) to display graphically (see Table 31 in Appendix 1 for the details).	GIS processing – layer intersections and frequency analysis. Graphical display – dual (mirror) bar charts and pie charts. Ranking of graphs pairs for matches/mismatches.
3	Adequacy	Total network area as a percent of State waters and the size ranges of the parks.	GIS processing - layer intersections and frequency analysis.
5	Connectivity and linkages	Distances between parks (centroid to centroid) were calculated to determine the connectivity or possible dispersal distances for marine organisms between parks. Distances between the centre points and closest outer boundaries within each park were also calculated to determine the shortest possible dispersal distances for organisms within parks. The calculated distances between and within marine parks were then compared to the propagule dispersal ranges for sessile or sedentary marine organisms identified in Kinlan and Gaines (2003) and movement ranges for adult and larval stages of marine organisms identified in Palumbi (2004) and Gillanders *et al*. (2003) to assess whether the connectivity ranges identified for the marine organisms fall within and between parks in the network.	GIS processing – manual measurements between parks.
		Australian sea lion foraging areas - to identify potential foraging areas in South Australian State waters. Known breeding colonies buffered by 80 kilometres, based on findings suggesting female breeding sea lions forage in an 80 kilometre range of their colonies on average (Goldsworthy *et al.*, 2007).	GIS processing – buffered distances of 80 kilometres.
		Crown land and estuarine areas in the landward boundaries were visually assessed to determine potential connectivity and linkages between the land and sea.	Basic calculations of numbers of estuaries included using the GIS layer of the network.
6	Resilience and vulnerability	Replication and redundancy - replication of habitat types within the network and number of patches of each habitat per bioregion.	GIS processing – layer intersections and frequency analysis.
		Area covered for vulnerable habitats - saltmarsh, mangrove, dense subtidal seagrass and estuaries.	Assessment of number of polygons of each habitat per bioregion (should be greater than 1).
	Ecological importance	Islands occurring in South Australia were assessed for their inclusion within and outside of the network	GIS processing – layer intersection and percent calculation plus frequency analysis.
		Seal/sea lion breeding and haul-out sites within and outside the network and number protected in each bioregion.	Basic calculations using a reference

7		Sites assessed for risk of likely by-catch interactions between the Australian sea lion and the commercial fishing industry were assessed for their inclusion within and outside of the marine parks network for each bioregion (Goldsworthy *et al.*, 2007). Southern right whale aggregation areas were assessed for number of areas within and outside of the marine parks network.	(Goldsworthy *et al*., 2007) and GIS network layer. Also frequency analysis.
		The number of sites of Conservation Status of Endangered Marine Algae (COSEMA) was calculated within parks compared to outside, displayed for network and for each bioregion.	GIS processing – layer intersection and percent calculation plus frequency analysis.
		Whilst the 96 conservation hotspots identified through in Edyvane (1999) were subsequently short listed to 19 focus locations, the biodiversity hotspots were chosen as a measure of achieving ecological importance within the network. The 96 biodiversity hotspots were assessed as a number and percent of the hotspots within parks for each bioregion and across the State. An assessment was also made regarding the number of hotspots listed as important in Edyvane (1999), due to the presence of saltmarsh /samphire, mangroves, estuaries or sand dunes. A word search was conducted in Excel for 'mangrove', saltmarsh', 'samphire', 'estuary', 'estuaries' and 'dune'. Any hotspots identified were then assessed using Edyvane (1999) and the GIS mapping of the boundaries for their inclusion within the marine parks network.	Basic calculations from the Edyvane reference and related GIS layer. Plus frequency analysis.
8	Seek synergies with existing protected areas	NPW Act reserves, aquatic reserves, shipwreck reserves, netting closures, rock lobster sanctuaries and defence areas compiled and expressed as number, area (total and length of coastline) and percent within and adjacent to marine parks for each bioregion and the network as a whole.	GIS processing – layer intersection and percent calculation for frequency.
9	Seek to complement existing terrestrial and marine management practices and conservation agreements	Ramsar reserves - expressed as number, area, and percent within and adjacent to marine parks for each bioregion and the network as a whole.	Frequency analysis.
10	Consider the full diversity of marine users	Statistics for commercial fishing blocks for each fishery. Calculated number of blocks in marine parks (or part blocks) and extrapolate percent of total catch in marine parks for each bioregion and network.	GIS processing – layer intersection and percent calculation.
		Aquaculture zones - percent of area within parks for each bioregion and network as a whole.	
		Recreational fishing sites.	
		Dive sites.	
11	Respect indigenous interests and culture	Aboriginal Heritage sites.	GIS processing – layer intersection and percent calculation. Plus frequency analysis
12	Give consideration to cultural heritage	The State Heritage Register GIS data layer included shipwreck reserves, lighthouses, piers and jetties, coastal cliffs, geological monuments and European heritage. In addition, the shipwreck sites layer incorporating the Register of Historic Shipwrecks and the Register of Historic Relics under the (Commonwealth) *Historic Shipwrecks Act 1976* and the (South Australian) *Historic Shipwrecks Act 1981*. The database also includes shipwrecks not declared under either Act.	GIS processing – layer intersection and percent calculation. Plus frequency analysis.
13	Ensure ease of identification, compliance and enforcement	No statistical analysis was performed for this Design Principle.	
14	Provide for education, appreciation and recreation	No statistical analysis was performed for this Design Principle.	

NB: The data layers listed above represent spatial layers used in analyses, it is not a comprehensive list of all layers used.

5.1 Meeting the Design Principles

The design of South Australia's marine parks network was guided by the application of the biophysical and community Design Principles listed in Table 13 and Table 14. The marine parks network was reviewed both qualitatively and quantitatively against these Principles to determine whether the design objectives had been met. Wherever possible, quantitative key performance indicators were developed (with the assistance of the Scientific Working Group; refer methods section 3.2.3) to make these assessments. Chi-square goodness-of-fit tests were also conducted for a range of frequency data relating to a subset of the biophysical and community Design Principles. The results of the chi-square tests are referenced in the text under each relevant biophysical or community Design Principle. The Chi-square tests are then summarised in Table 25 (biophysical data) at the end of the biophysical Design Principles and Table 28 (socio-economic data) at the end of the community Design Principles.

5.2 The biophysical Design Principles

5.2.1 The precautionary approach

5.2.1.1 Benthic habitats

To satisfy the Principle of the precautionary approach, unmapped areas of subtidal benthic and shoreline habitats were included within marine parks. Two thirds of the seafloor within State waters remains unmapped, and 43% of this unmapped area has been included within the marine parks network (Table 16). The bioregion with the least amount of unmapped area included within the marine parks network is the Spencer Gulf Bioregion, while the Eucla Bioregion has all of its unmapped area included within the network (Table 16). The area of unmapped benthos within each bioregion was also examined across different depth classes. In all bioregions, the unmapped areas increased with water depth, with the exception of the North Spencer Gulf Bioregion, where nearly all of the seafloor has been mapped.

Table 16: Unmapped benthic areas in each bioregion and within boundaries in each bioregion

Bioregion	**Area unmapped (km^2)**	**% of bioregion unmapped**	**% of unmapped area within the network**
Eucla	1,413	76	100
Murat	5,088	78	65
Eyre	14,973	80	42
Spencer Gulf	7,669	66	19
North Spencer Gulf	72	1	79
Gulf St Vincent	9,362	71	40
Coorong	869	42	85
Otway	630	48	67
State network	**40,076**	**66**	**43**

5.2.1.2 Shoreline classifications

The only unmapped lengths of shoreline in South Australia are on offshore islands, totalling 484 km (approximately 8% of the State's shoreline of 6,190 km). About 74% of this 484 km is included within the network and some 83% of the 420 islands are included within the boundaries.

The inclusion of unmapped subtidal benthic areas as an additional "habitat" is an effective step to act in a more precautionary manner. Hence, an additional benthic habitat type called 'unmapped' is reported on below in relation to all relevant Design Principles. The use of this 'unmapped' surrogate recognises that such areas may also be important irrespective of whether the unknown portion may be unique or just a more typical or familiar habitat in a novel location.

5.2.2 Comprehensiveness and representativeness

The initial presence/absence assessment of comprehensiveness (Table 17) determined that all benthic habitats and shoreline classes occurring in each bioregion are included within the marine parks network, with one exception. There is a one kilometre section of boulder beach in the Murat Bioregion just north of Streaky Bay, the only case of that shoreline habitat within this bioregion; this was not included within the network. However, boulder beaches were represented in the other bioregions in which they occurred, with 22 out of 37 kilometres in total protected (59%) in the network.

For further analysis of the physical and biological features included within the network, the shoreline classes were consolidated from 12 classes into three substrate types: mud, sand and rock (see Table 31 in Appendix 1 for the summaries). All physical and biological variables were displayed graphically in both pie and bar graphs. The bar graphs in Figure 22 to Figure 28 display the total area of each physical variable (i.e. benthic habitat or shoreline class) included within the marine parks network (red bars), compared to the total area found in the State (blue bars). Appendix 5 displays the individual bioregional graphs for each variable. To meet the Principle of comprehensiveness, there should be a red bar above every blue bar in all bar graphs. Visual analysis of the bar graphs reveals that at the network level, every type of marine habitat or physical variable present across the State is included in the marine parks network, thus meeting the Principle of comprehensiveness. When assessing the bioregional bar graphs, all habitats and physical variables are present, with the exception of saltmarsh and other soft sediment habitats in the Otway Bioregion, which will be discussed in further detail under the Principle of resilience and vulnerability.

To assess whether the Principle of representativeness had been met, the pattern of the red and blue bars in each graph was analysed. As the bar graphs show absolute values, the red bars depicting the area within the network are expected to be on average shorter than the blue bars below, which depict the amount that is available in the State. However, if the network is representative of the features shown in a given dual bar chart, then the pattern of the blue bars in each graph is expected to be mirrored by the red bars above. This shows that the relative amounts of habitat features that exist in State waters are also reflected within the network. Each bar graph for the network and for each of the bioregions was visually assessed and ranked between 1 and 4, based on how closely the red and blue bars mirrored each other. The results of the visual assessment and rankings are in Table 18. The red and blue bars in each dual bar graph were generally a mirror image for the different variables at the network level (except for mangrove and saltmarsh for the Otway Bioregion), so representativeness can be demonstrated at the network level, and for most but not all of the bioregions.

Table 17: Habitats and other features within the marine parks network (based on IMCRA bioregions)

Benthic (subtidal) habitats	**Otway**	**Coorong**	**GSV**	**Nth Spencer**	**Spencer**	**Eyre**	**Murat**	**Eucla**	**Whole Network**
Sparse seagrass	▨	▨	◆	▨	◆	◆	◆	▨	◆
Medium seagrass	▨	▨	◆	◆	◆	◆	◆	▨	◆
Dense seagrass	◆	◆	◆	◆	◆	◆	◆	▨	◆
Dense seagrass patches	▨	▨	◆	◆	▨	◆	◆	▨	◆
Granite reef	▨	◆	◆	▨	▨	◆	◆	▨	◆
Heavy limestone or calcarenite reef	◆	◆	◆	▨	◆	◆	◆	◆	◆
Low profile platform reef	◆	◆	◆	◆	◆	◆	◆	◆	◆
Bare sand	◆	◆	◆	◆	◆	◆	◆	◆	◆
Shoreline classes									
Saltmarsh	▨	▨	◆	◆	◆	◆	◆	▨	◆
Mangrove	▨	▨	◆	◆	◆	◆	◆	▨	◆
Mudflats & sand	▨	▨	◆	◆	▨	◆	▨	▨	◆
Intertidal seagrass - shallow / emergent	▨	▨	◆	▨	▨	◆	▨	▨	◆
Fine/medium sand beach	◆	◆	◆	▨	◆	◆	◆	◆	◆
Coarse sand beach	◆	◆	◆	◆	◆	◆	◆	◆	◆
Cobble / pebble Beach	◆	▨	◆	◆	▨	▨	▨	▨	◆
Mixed beach	◆	▨	◆	◆	◆	◆	▨	▨	◆
Bedrock platform	▨	◆	◆	◆	◆	◆	◆	▨	◆
Cliff	◆	▨	◆	▨	◆	◆	◆	◆	◆
Boulder beach	▨	▨	◆	▨	◆	◆	O	▨	◆
Sand dunes	◆	◆	◆	◆	◆	◆	◆	◆	◆
▨ doesn't occur in bioregion									
◆Occurs in bioregion and represented in network									
O Occurs in bioregion but not represented									

NB: This table presents information based on an assessment of habitats within State waters (below MHW). Coastal habitats above MHW are examined later to further assess any gaps.

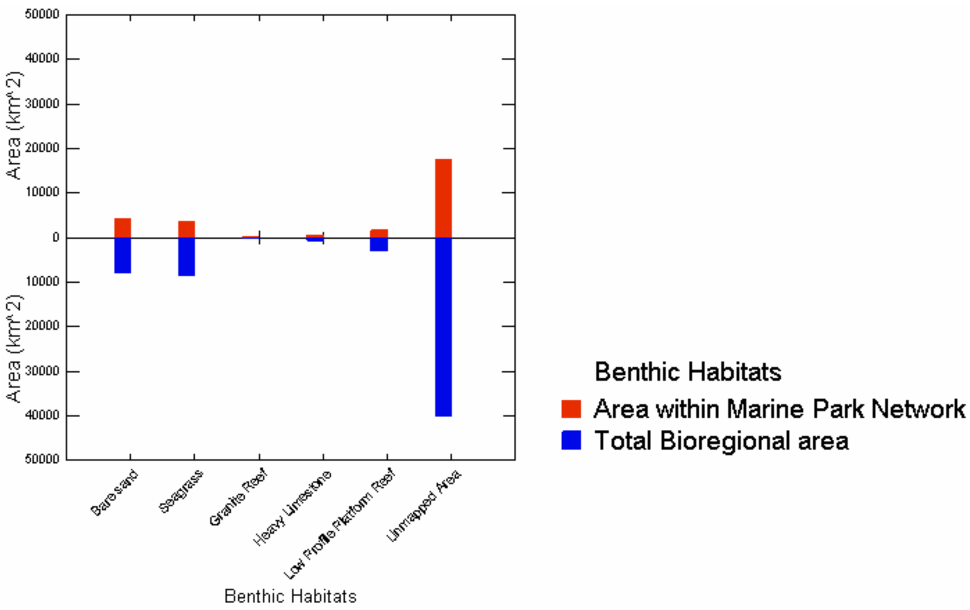

Figure 22: Area of benthic habitats within the marine parks network compared to the State
(Ranking = 1)

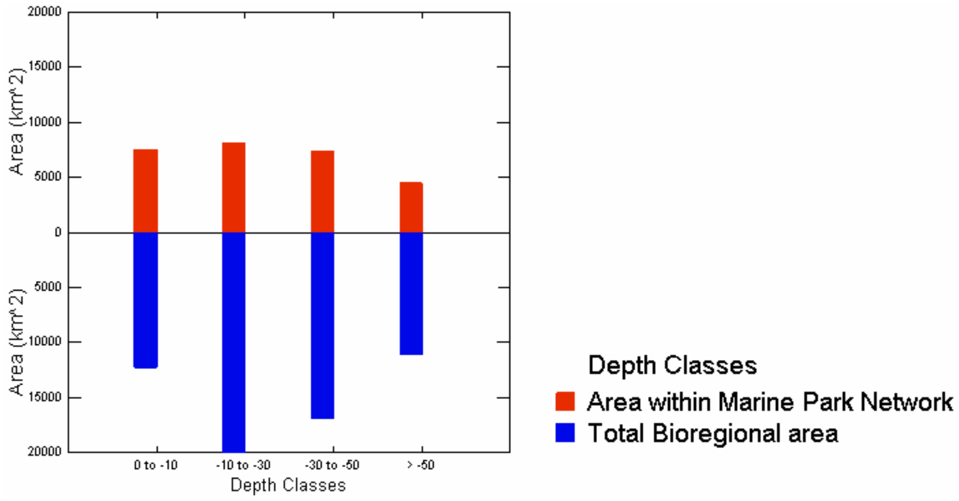

Figure 23: Area of water depth classes within the marine parks network compared to the State
(Ranking = 2)

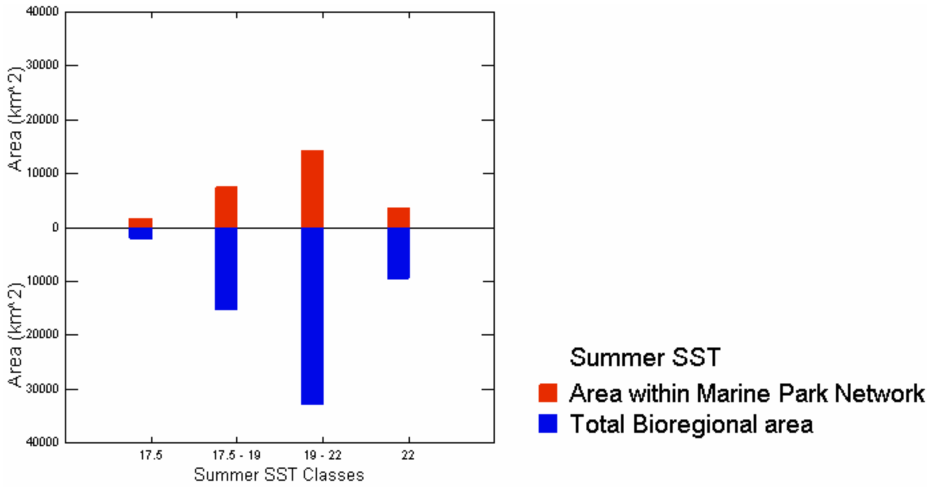

Figure 24: Area of summer sea surface temperature classes within the marine parks network compared to the State
(Ranking = 1)

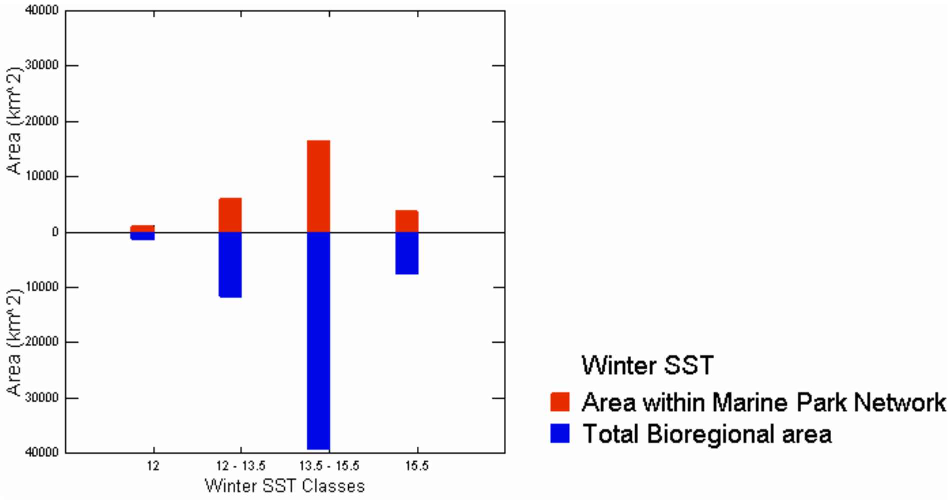

Figure 25: Area of winter sea surface temperature classes within the marine parks network compared to the State
(Ranking = 1)

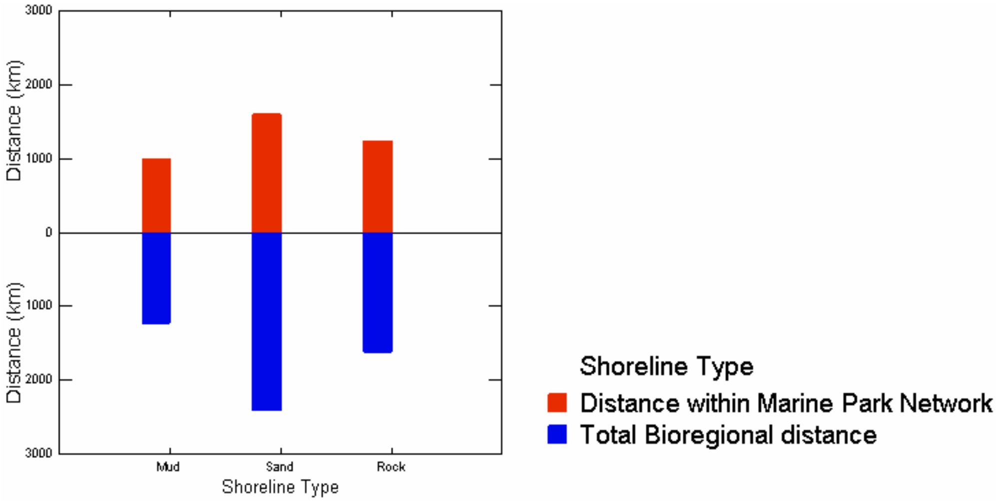

Figure 26: Area of shoreline type within the marine parks network compared to the State
(Ranking = 1)

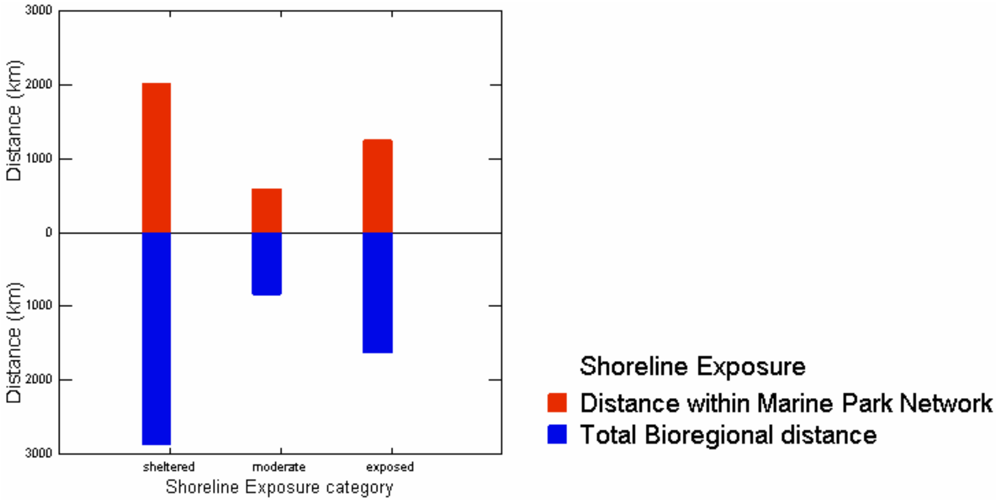

Figure 27: Area of shoreline exposure within the marine parks network compared to the State
(Ranking = 1)

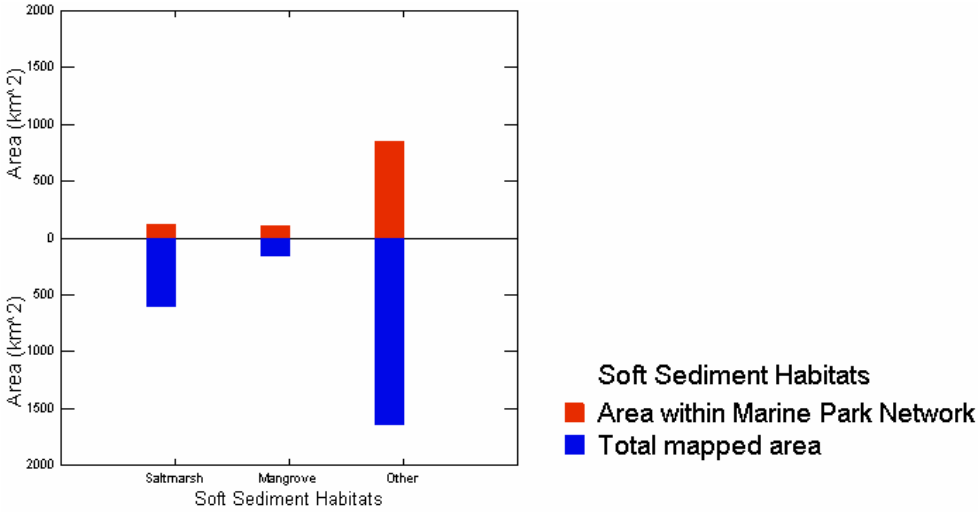

Figure 28: Area of saltmarsh, mangrove and other soft sediment habitats within the marine parks network compared to the State.
(Ranking = 2)

The pie charts (Figure 29 to Figure 35) compare the relative proportions of physical and biological variables within the marine parks network compared to within the State. For the pie charts for each of the bioregions, please refer to Figure 55 to Figure 59 in Appendix 5. To achieve comprehensiveness, the pairs of pies should resemble each other in terms of their colours and number of slices (features included). To achieve representativeness, the size of the slices (proportions of each feature) should be similar when comparing the network (park) compared to the State pie charts. The pie charts were also visually assessed and ranked between 1 and 4 as was done with the bar charts. The results of these assessments indicate that the network achieves the objectives of these Principles, with the benthic habitats appearing to be the best represented (but others were very similar).

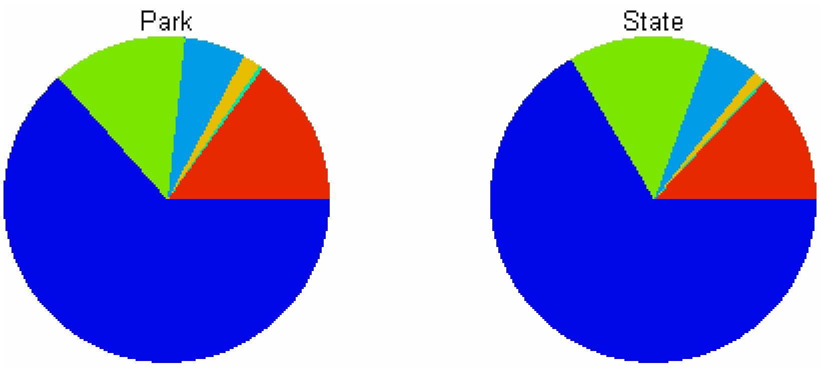

Figure 29: Proportion of subtidal benthic habitat areas included within the marine parks network compared to State waters
(Habitats: Red = Bare sand; Cyan = Granite reef; Orange = Heavy limestone or calcarenite reef;
Light blue = Low profile platform reef; Green = Seagrass; Dark blue = Unmapped area)
Ranking for this pair = 1 (on a scale of 1 to 4 for decreasing matches, see Table 18)

The pair of pie charts for the mangrove and saltmarsh habitats performed worst in terms of meeting the Principle of representativeness. This is likely due to the fact that the GIS data layer for these habitats was designed to cover vegetated intertidal and supratidal habitats within the State and therefore extends further inland than the marine bioregions (which end at mean high water). In particular, saltmarshes were somewhat under represented in the State wide network graphs, as well as those for the Murat, Spencer Gulf, Gulf St Vincent and Otway Bioregions (see Appendix 5 for bioregional graphs). The relativity between these habitat types may also be distorted by the inclusion of portions of other unvegetated habitats (such as supratidal saline bare patches) located within the near vicinity of the saltmarsh and mangrove habitats. This does not include any of the ‘Other’ habitat that might exist elsewhere, and are included in the saltmarsh and mangrove GIS layer, but are not associated with either saltmarsh or mangrove (for example intertidal *Melaluca* or shingle ridges). Given that the linear coastline extent of many of these habitats is also considered in the Shoreline Classification data layer (which performed better overall), there is confidence that these vegetated habitats have been included within the parks network.

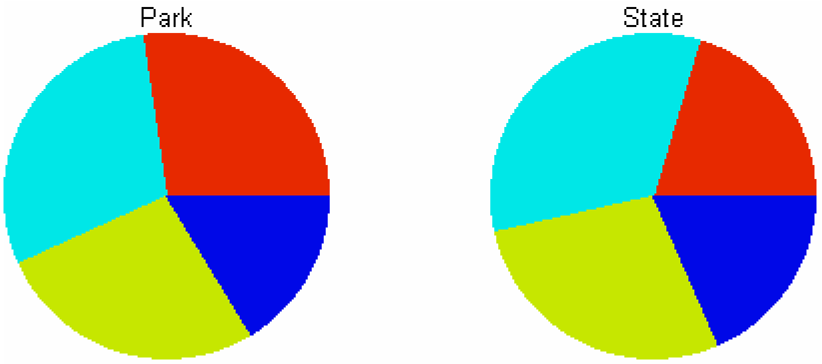

Figure 30: Proportion of water depth class areas included within the marine parks network compared to State waters

(Depth classes (m): Red = 0–10; Light blue = 10—30; Green = 30—50; Dark blue = >50) Ranking = 1

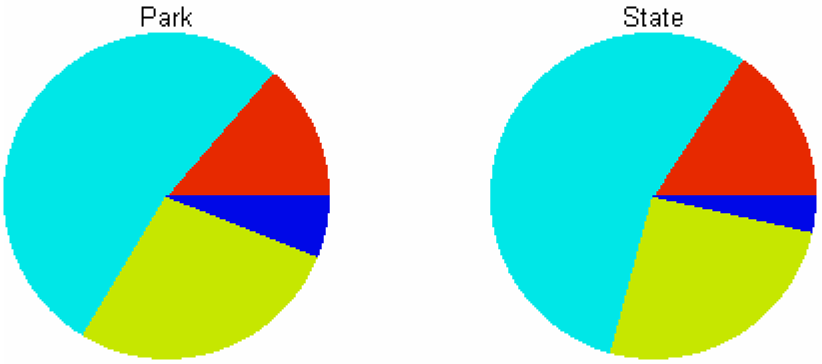

Figure 31: Proportion of summertime sea surface temperature class areas within the marine parks network compared to State waters

(Summer temperature classes (°C): Red = >22; Light blue = 19–22; Green = 17.5–19; Dark blue = < 17.5) Ranking = 1

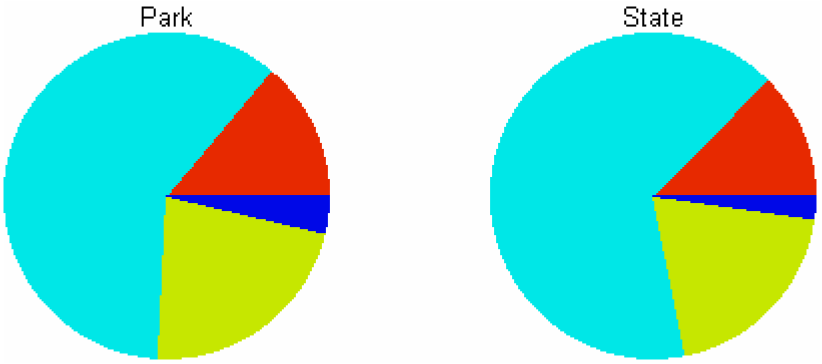

Figure 32: Proportion of wintertime sea surface temperature classes included within the marine parks network compared to State waters

(Winter temperature classes (°C): Red = 15.5; Light blue = 13.5 – 15.5; Green = 12 – 13.5; Dark blue = < 12) Ranking = 1

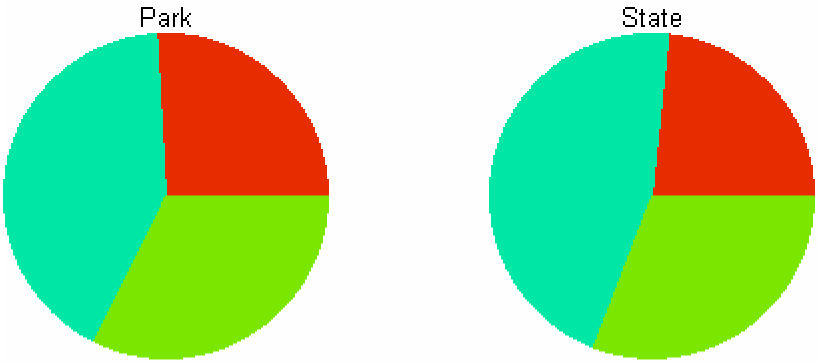

Figure 33: Proportion of shoreline substrate class lengths included in the marine parks network compared to State waters

(Shoreline substrates: Red = Mud; Cyan = Sand, Green = Rock) Ranking = 1

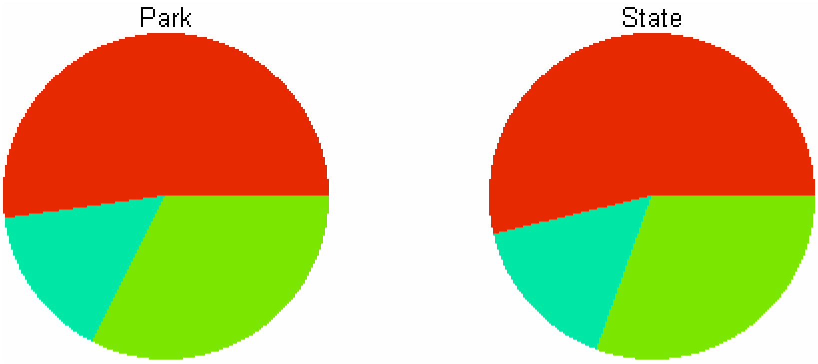

Figure 34: Proportion of shoreline exposure class areas included in the marine parks network compared to State waters

(Shoreline exposures: Red = Sheltered; Cyan = Moderate; Green = Exposed) Ranking = 1

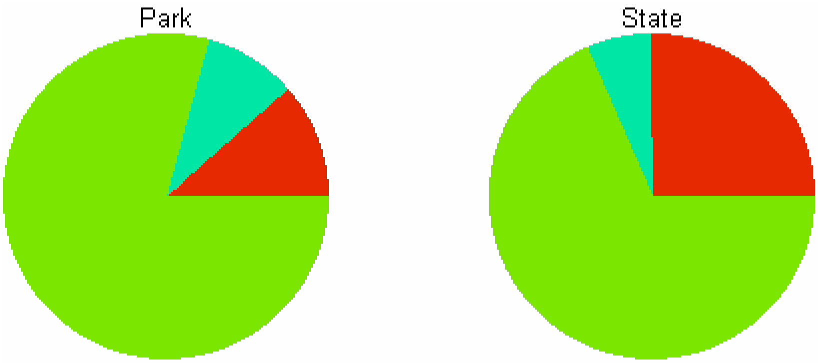

Figure 35: Proportion of saltmarsh, mangrove and other intertidal and supratidal soft sediment areas included in the marine parks network compared to the State

(Intertidal and supratidal areas: Red = Saltmarsh; Cyan = Mangrove, Green = Other) Ranking = 2

As mentioned above, all bar and pie graphs for the network and each bioregion for each of the different biological and physical characteristics were visually assessed and ranked between 1 and 4, based on how closely the pattern of red and blue bars mirrored each other. Table 18 displays the results of the visual assessment and rankings of all bar and pie charts including those that are presented above for the overall network, and the individual charts for each bioregion. Table 18 shows a total of nine rankings for each bar and pie chart under each of the biological or physical characteristics. The column on the left side shows the rankings between one and four, and the columns under each of the physical characteristics show how many of the nine charts are ranked between one and four. For the mangrove and saltmarsh column there are only eight rankings, as there are no saltmarsh and mangrove habitats found in the Eucla Bioregion. The rankings show that in almost all cases comprehensiveness and representativeness were achieved. The only exception was for the saltmarsh and mangrove charts for the Otway Bioregion which was the only ranking of four (saltmarsh and mangrove habitats were examined above MHW). The low score for the mangrove and saltmarsh graphs for the Otway Bioregion was not surprising as the saltmarsh habitat in this bioregion occurs well above mean high water (in many cases in private land on the landward side of the main coastal road) and therefore could not be included within the marine parks network. Although there are some small patches of saltmarsh included within the marine parks in the Otway Bioregion (for example on the beach at Stony Point), they are too small to show up in the current mapping resolution.

Table 18: Rankings of all bar and pie charts for the network and each bioregion for comprehensiveness and representativeness

Outcome (rank)	Benthic habitats	Depth classes	Summer SST	Winter SST	Shoreline class	Shoreline exposure	Mangrove & saltmarsh
Bar charts							
1	7	3	9	7	7	9	3
2	2	6	0	2	2	0	4
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	1
Pie charts							
1	7	5	9	5	8	6	2
2	2	4	0	4	1	3	4
3	0	0	0	0	0	0	1
4	0	0	0	0	0	0	1

5.2.3 Adequacy

To achieve adequacy in marine parks design, a successful network must provide for the long-term protection of fully functioning ecosystems, communities, populations and species. It is therefore difficult to apply any specific indicators or performance metrics for this Principle without having implemented effective management plans (Halpern, 2003; Byers and Noonburg, 2007; Claudet *et al.*, 2008). However, initial assessments of adequacy of the marine parks network were conducted by assessing the size of each marine park (after Halpern, 2003; Claudet *et al.*, 2008).

Table 19 reveals the smallest park is the Neptune Islands Group, consisting of marine park parcels of only 71 and 72 km^2 water area. The largest single park is the Nuyts Archipelago with an area of 3496 km^2, larger than 5% of State waters. Some eight of the 19 parks have a combined water area of more than 1000 km^2 and another seven have more than 500 km^2. Thus there is a wide range of sizes with at least some being quite large.

Another consideration of adequacy was the incorporation of coastal land above mean high water within the landward boundaries of the marine parks network. Table 19 shows the total area of the network (which includes the land on islands and landward boundaries) and the State waters component, which reveals that around 270 km^2 of the network is made of coastal land and islands[7]. The inclusion of coastal land allowed whole ecosystems or habitats to be incorporated within marine parks. Some examples include saltmarsh and mangrove communities in the Gulfs (e.g. around Port Gawler and Middle Beach in Gulf St Vincent and near Port Pirie in Spencer Gulf) or sandy beaches and adjacent dune systems at Browns Bay (Lower South East) and at South Port Noarlunga (Adelaide). The inclusion of whole ecosystems or habitats within marine parks creates the

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[7] Please note, all numbers are rounded to the nearest kilometre squared.

opportunity to maintain ecosystem integrity and thus enhanced progress towards achieving adequacy within the marine parks network. The incorporation of coastal land within marine parks is also linked to the Principle of connectivity and linkages, which is examined below in section 5.2.4

Table 19: Area of each marine park in the network

Park Name	Park Parcel No.	Area of State waters (km^2)	Total park area (km^2)
Far West Coast	1	2496	2496
Nuyts Archipelago	2	3493	3560
West Coast Bays	3	780	789
Investigator	4A	208	211
Investigator	4B	143	143
Investigator	4C	385	385
Investigator	4D	445	445
Thorny Passage	5A	110	110
Thorny Passage	5B	140	142
Thorny Passage	5C	2212	2221
Sir Joseph Banks Group	6	2617	2627
Neptune Islands Group	7A	72	74
Neptune Islands Group	7B	71	72
Gambier Islands Group	8	114	120
Franklin Harbor	9	623	636
Upper Spencer Gulf	10	1626	1707
Eastern Spencer Gulf	11	784	784
Southern Spencer Gulf	12	2971	2972
Lower Yorke Peninsula	13	874	874
Upper Gulf St Vincent	14	955	971
Encounter	15	3070	3119
Western Kangaroo Island	16A	921	921
Western Kangaroo Island	16B	99	99
Southern Kangaroo Island	17A	453	453
Southern Kangaroo Island	17B	219	219
Upper South East	18	1114	1114
Lower South East	19A	410	411
Lower South East	19B	121	122
Total	▨	**27526**	**27797**

NB: The total park area includes islands and the coastal land above MHW

An additional consideration of adequacy for marine parks design is to build redundancy into the network by replicating the protection for habitats within and between marine parks. As this is also linked to the Principle of resilience and vulnerability, the analysis is picked up under that Principle in Section 5.2.5.

5.2.4 Connectivity and linkages

Several different metrics were calculated to provide a variety of techniques for assessing the Principle of connectivity and linkages. The first, already established in Section 1, is that the network of marine parks is comprised of 19 marine parks located within and between each of South Australia's marine bioregions. The network therefore provides protection across the full range of ecosystems and habitats in the State, creating the opportunity to maintain ecological connections for populations of species that disperse over a range of distances between different habitats. The assessment of this metric was to calculate the actual distances between and within each marine park in the network, which can be used as a surrogate for achieving connectivity and linkages between and within marine parks.

5.2.4.1 Distances between parks

An assessment of the ranges of straight line distances between the centre of marine parks (or parcels of marine parks in the cases where there are more than one isolated parcel for a particular marine park) was conducted. The assessment revealed that the distances between marine parks/park parcels range from 10 km, between the two parcels of the Neptune Islands Group Marine Park to 1,150 km between the Lower South East Marine Park (the parcel abutting the Victorian border) and the Far West Coast Marine Park. Figure 36 displays the ranges of distances between each of the possible pairs of connections between marine parks or park parcels. The most common distances between individual marine parks (or parcels) were 0 to 200 kilometres (29%) and 200 to 400 km (36%).

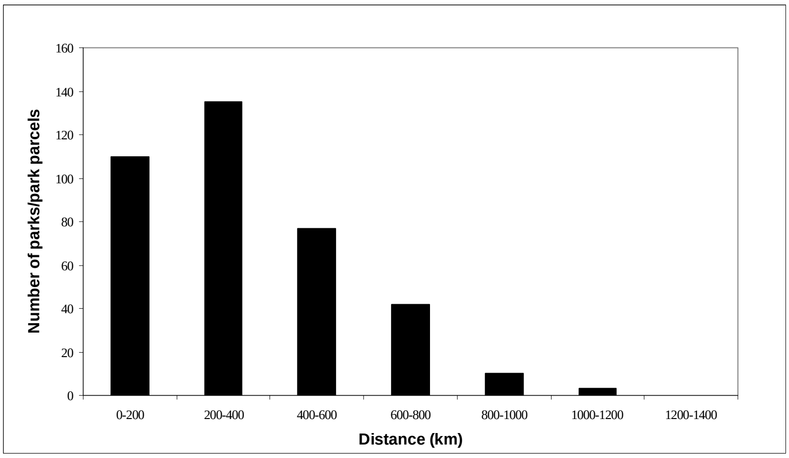

Figure 36: Distances between marine parks of park parcels, from centroid to centroid (kilometres)

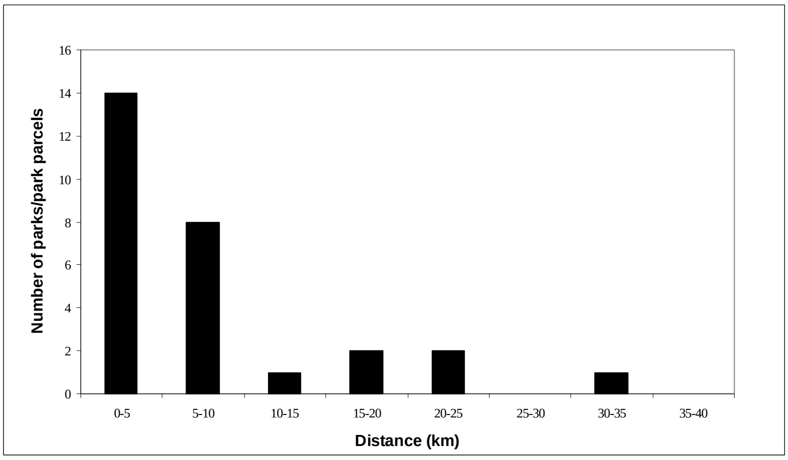

Figure 37: Shortest distances from centroid to boundary within parks (kilometres)

5.2.4.2 Distances within parks

An assessment of the shortest internal distances within marine parks (Figure 37) (measured from centroid to closest boundary within a marine park or park parcel) reveals that the shortest distance from the centroid to the edge of a marine park was 1.65 km in the Gambier Islands Group Marine Park.

The shortest distances within parks were predominantly less than five kilometres (50%), with 29% between five and 10 km. Only one of the shortest distances from centroid to closest outer boundary was more than 30 kilometres, measuring 33 km. The analysis of the distances within and between marine parks revealed that the network has provided the potential for connectivity and linkages over a range of distances across the entire State waters.

5.2.4.3 Comparison of distances within and between marine parks with published dispersal ranges for marine organisms.

The second metric was a more direct method for assessing connectivity as the distances between and within marine parks or park parcels were compared with published dispersal ranges and marine neighbourhoods for a variety of marine organisms. Palumbi (2004) defined a marine neighbourhood as an, "area centered on a set of adult parents that is large enough to retain most of the offspring of those parents". Palumbi (2004) goes on to explain that neighbourhoods may be large if the adult parents move over large distances, or if the adults are sedentary or sessile but have offspring (larvae) that move over large distances. Alternatively, if the adult parents are sedentary or sessile and their offspring also have small dispersal ranges then the neighbourhoods would be defined as small (Palumbi, 2004). Kinlan and Gaines (2003) identified that sessile or sedentary marine taxa, including macroalgae, invertebrates and fish that disperse throughout the marine environment via their propagules (e.g. larvae, spores.) fall within distinct dispersal ranges. Kinlan and Gaines (2003) also revealed that the dispersal scales of marine organisms vary over five orders of magnitude, show distinct patterns for particular taxa and appear to cluster around specific distances (Figure 38). Palumbi (2004) also identifies approximate movement ranges for a range of adult and larval stages of nektonic and other marine organisms (Table 20). The movement ranges identified in Kinlan and Gaines (2003) and Palumbi (2004) are also consistent with the findings of Gillanders *et al.* (2003) in their literature review of studies of juvenile to adult habitat migration ranges. Gillanders *et al.* (2003) found that in the 110 studies they reviewed (mostly dealing with commercially important fish and crustaceans), the scale of movements of organisms transitioning from juvenile to adult habitats ranged from movements over metres to thousands of kilometres, with the majority of fish and crustaceans moving distances of kilometres to hundreds of kilometres. In order to compare the connections within and between marine parks or park parcels with dispersal ranges from the published literature, the data was graphed using a log scale as was used in Kinlan and Gaines (2003). Figure 39 shows the distances between marine parks (for all possible connections) and Figure 40 displays the ranges of shortest distances (from centroid to boundary) within marine parks. Figure 40 shows that in all instances the park parcels have at least a distance of 1km from their centre to their outer boundary. A subset of them have a distance from centre to boundary of at least 10km while none of them are singularly large enough to have an internal distance from centre to boundary of 100km or more (the greatest being 33km).

The analysis of the distances between marine parks or park segments showed that there are connections between parks ranging from 10 to 1,150 km. The analysis of shortest distances within parks revealed that the shortest distances range from 1.65 to 33 km. Comparisons with the propagule dispersal ranges identified in Kinlan and Gaines (2003) show that all dispersal ranges identified for species of macroalgae, invertebrates and fish fall into the range of distances either within or between marine parks. When comparing Figure 40 with Figure 38 visually, it appears that the marine parks network has not performed as well for the dispersal ranges above 10 km and up to 100 km. However, when assessing the results for connections between parks, it should be noted that there are 47 possible connections between marine parks where propagules can disperse between 10 and 100 km. Although Figure 40 shows only six parks for which propagules can disperse more than 10 km within parks, it should be noted that these are minimum dispersal ranges between centroid and outer boundary (presenting a worst case scenario) and the actual areas within parks to disperse are therefore much greater.

Kinlan and Gaines (2003) state that their dispersal estimates may or may not directly reflect patterns of propagule dispersal, because their studies were limited to organisms which had successfully dispersed, established and reproduced. However, their studies do identify orders of magnitude differences in dispersal ranges for different organisms and at the very least reflect patterns of dispersal for the successful individuals within a given population.

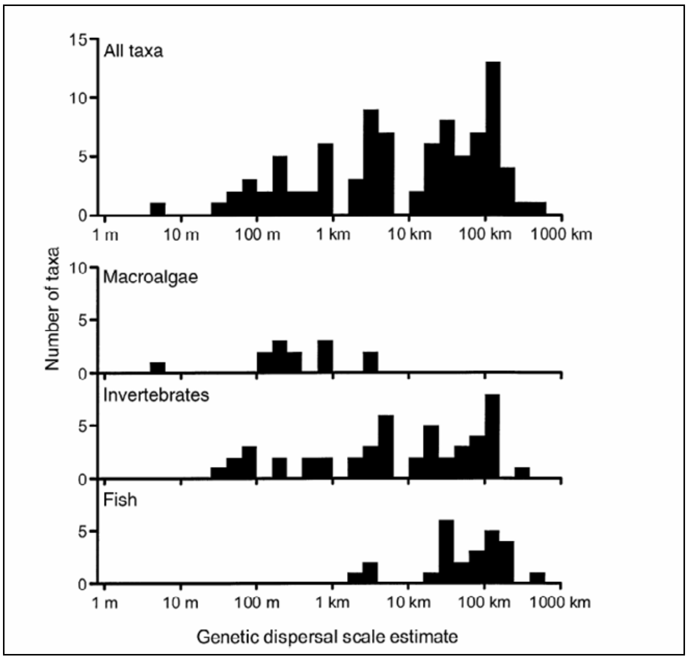

Figure 38: Identified propagule dispersal ranges for marine taxa
(source: Kinlan and Gaines, 2003)

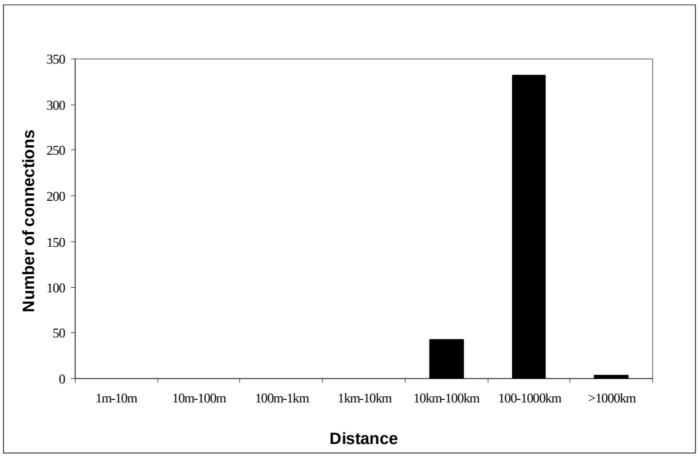

Figure 39: Measured distances between marine parks or park parcels from centroid to centroid (kilometres)

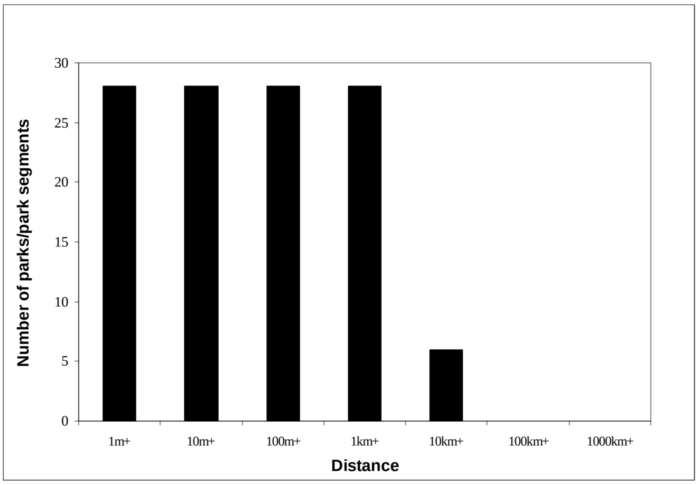

Figure 40: Shortest distances from centroid to boundary within parks

Because Kinlan and Gaines (2003) excluded pelagic species, species with high rates of adult migration and species with asexual reproduction in their studies, assumptions about the connectivity within the South Australian marine parks network based on their research can only be made for similarly sedentary species of macroalgae, invertebrates and fish that use propagules as their primary dispersal mechanism. However, when comparing the connectivity and linkages within and between marine parks in South Australia's network to the findings by Gillanders *et al.* (2003) and Palumbi (2004) on the dispersal ranges of juvenile, adult and larval migration on a wide range of species, the marine parks network provides for all of the published dispersal ranges. It is therefore concluded that the marine parks network provides for connectivity for a wide range of marine organisms.

Table 20: Approximate adult and larval movement ranges (source: Palumbi, 2004)

Movement range (km)	**Adult stage**	**Larval stage**
>1000 km	Large migratory species	Many species
100 – 1000 km	Large pelagic fish (eg blue-fin tuna)	Some fish
10 – 100 km	Most benthic fish and smaller pelagic fish (eg mackerel, kingfish)	Most fish, most invertebrates
1 – 10 km	Small benthic fish (leafy sea-dragons, snapper); many benthic invertebrates	Algae; planktonic direct developers, few fish
<1 km	Sessile species; species with highly specialised habitat needs	Benthic direct developers

5.2.4.4 Australian sea lion foraging areas

To further test the connections between and within marine parks, potential foraging areas for the Australian sea lion were assessed against the marine parks network. Goldsworthy *et al.* (2007) suggested that female breeding Australian sea lions forage in an average range of 80 km from their colony. To identify potential foraging areas in South Australian State waters, all known breeding colonies of the Australian sea lion were buffered by 80 km. The analysis resulted in almost 70% of South Australia's state waters being potential foraging areas for breeding Australian sea lions. Of the identified potential foraging area, 50% is within the marine park boundaries. Although this result is slightly higher than the 46% of the State waters included within the network, it is not an optimal result in terms of providing connectivity for Australian sea lion breeding colonies. Locations identified as potential foraging areas outside of the marine parks network include Anxious Bay, south-western Eyre Peninsula (north of Thorny Passage Marine Park), Arno Bay, the Neptune and Gambier Islands groups and the central area of Gulf St Vincent between the Fleurieu, the heel of Yorke Peninsula and north-eastern Kangaroo Island. Of these areas, Arno Bay, central Gulf St Vincent and south-western Eyre Peninsula were outside of the focus locations for the network. The Neptune and Gambier Islands groups which were focus locations and have been included in the network are between 72 and 120 km^2 in size, which is relatively small compared with some of the other parks in the network. Therefore, improvements could be made to the overall size of the Neptune and Gambier Islands Marine Parks in order to provide better connectivity for Australian sea lion foraging areas.

The IUCN–WCPA (2008) states that to date there has been little consideration given in the design of marine park networks to protect marine megafauna whose survival requires access to large oceanic pelagic areas. The design of MPAs or marine park networks that protect highly migratory species such as marine mammals, turtles and tuna should take into consideration permanent protection of the spaces in the pelagic zone related to some key life history patterns, including breeding, feeding and nursery areas, as well as migratory routes (IUCN-WCPA, 2008). When comparing the results for the Australian sea lion foraging areas to the assessments made on Australian sea lion sites for the protection of ecologically important species (see section 5.2.6.2), it should also be noted that 91% of all the breeding colonies of the Australian sea lion are located within the network, which also includes 100% of the very high risk and 91% of the high risk colonies identified by Goldsworthy *et al.* (2007). In addition to the protection of important Australian sea lion breeding sites, the marine parks network also provides protection for all five of the identified important aggregation and calving sites for the southern right whale (see section 5.2.6.3 for more details). The marine parks network therefore performs very well in terms of protecting key life history patterns for marine mammals which are migratory species or have relatively large foraging ranges.

5.2.4.5 Estuaries

No direct quantitative assessments were performed on known linkages within the marine parks network. However, as estuaries are known to provide important connections and linkages between the coast and marine environments an assessment was performed on the number of estuaries included within the marine parks network. Of the 111 estuaries identified in the State, 80 or 72% of the estuary mouths are located within the marine parks network, yielding a statistically significant result with the Chi-square goodness-of-fit test. As described in Section 5, a statistically significant result means that significantly more than 46% (what would be expected by chance) of the State’s estuaries were included within the network. Of the 80 estuary mouths included, a number of estuaries are also protected further upstream, due to the incorporation of coastal land within the landward boundaries of the marine parks. Examples of estuaries protected upstream include the Cygnet River on Kangaroo Island, the Onkaparinga Estuary and the Hindmarsh River on the Fleurieu Peninsula. The inclusion of coastal land upstream surrounding the Hindmarsh River also provides protection for the *Melaleuca halmaturorum* swamp lands which are also known to provide important linkages with the marine environment.

5.2.5 Resilience and vulnerability

To meet the Principle of resilience and vulnerability, marine parks are designed to maintain the natural state of ecosystems and absorb shocks, particularly in the face of large-scale and long-term impacts such as climate change.

5.2.5.1 Resilience

One of the key methods of designing resilient marine parks is to deliberately incorporate some redundancy (i.e. multiple protected areas) into the network. Redundancy is desirable in protected areas because including more than one example of a particular habitat type provides some insurance against threatening processes and catastrophic events. For example, if shallow seagrass was only protected in one bay and the bay experienced unnaturally high nutrient levels that had a severe impact on the health of the seagrass leading to seagrass dieback, that habitat type would no longer be represented in the network, and the network could not be considered to be resilient. In a network that is resilient, one would expect to find two or more examples of each ecosystem or habitat type in each park, including having replicate examples across the full range of conditions in which they occur, i.e. at different depths. The amount of replication of habitats within the proposed network was therefore used to assess its ability to absorb shocks, and was measured by calculating the number of discrete patches of benthic habitats and shoreline classifications at varying depth classes and shoreline exposures from the relevant GIS data layers.

The results show that multiple examples of each benthic habitat type occur at all depth classes within the proposed network. Table 21 shows that, with the exception of seagrass beds, which have a physical distribution limited by depth, there are at least two examples (19 parks by 2 = 38 replicates) of each benthic habitat type in the two shallower depth classes (columns labelled 0-10 m and 10-30 m). In deeper waters the network has limited replication of habitat types with most habitats having less than one patch per park on average (columns labelled 30-50m and >50m). Unmapped areas of the seafloor within each depth class are not considered habitat types *per se* but are important to include in the analysis as they are likely to contain further replicate examples of habitats naturally occurring at those depths. Of the two deeper depth classes, only 7% and 2%, respectively, have been mapped leaving very large unmapped patches (far right column in the table).

It is therefore possible that habitats appearing to lack replication now will be revealed to be better replicated once further habitat mapping has occurred.

Analysis of the number of shoreline segments included within the marine parks network revealed that there are also multiple examples of each shoreline type for each exposure rating within the network (Table 22). The only exception to this is for exposed mud which does not occur anywhere along the coastline in the data layer. All other combinations of shoreline types and exposure categories have two or more replicate examples per park, except for moderately exposed mud which occurs relatively infrequently (only 15 replicates) across the whole coastline. In terms of shoreline type therefore, the network achieves replication which contributes to its overall resilience to catastrophic events. The second part of resilience, the ability of the full range of ecosystem and habitat types to recover from deleterious events, however, is much less known, and is not able to be measured at this part of the network development process.

Table 21: Number of discrete habitat patches and their average size per depth class for benthic habitats within the network

Number of patches per depth class						
Habitat Type	**0 to 10 (m)** **(83% mapped)**	**10 to 30 (m)** **(40% mapped)**	**30 to 50 (m)** **(7% mapped)**	**>50 (m)** **(2% mapped)**	**Total no. patches per benthic habitat**	**Average size of patches (km^2)**
Bare sand	741	176	15	5	937	4
Seagrass	287	74	1	0	362	10
Granite reef	68	45	7	3	123	1
Heavy limestone or calcarenite reef	244	138	35	5	422	1
Low profile platform reef	129	53	14	9	205	8
Unmapped area	8	7	7	5	27	646
Total no. patches per depth class	1477	493	79	27	**2076**	

Table 22: Number and length of shoreline segments (rounded to nearest whole number) within each exposure category within the network

Number of segments per relative exposure category					**Average length of segments (km)**
Shoreline type	**Sheltered**	**Moderate**	**Exposed**	**Total no. segments**	
Mud	189	11	**NA**	200	5
Sand	435	132	215	782	2
Rock	180	115	192	487	3
Total	804	258	407	**1469**	

5.2.5.2 Vulnerable habitats

The types of vulnerable benthic and coastal habitats assessed in relation to the Principle of resilience and vulnerability were saltmarshes, mangroves, seagrass beds and estuaries. All of these habitats were included within the network. In terms of areas occupied, 20% of saltmarshes and 66% of mangroves are included within the boundaries. The majority of saltmarshes (89%) are located above

MHW and 17% of those are included within the network. Of the limited area of saltmarsh located below MHW, 49% is included within the network. Figure 41 displays a pie chart for saltmarsh and mangrove habitats for the whole marine parks network compared with the State, but only for the proportion of those habitats occurring below MHW (and therefore more likely to be included within a marine park). As can be seen from the charts, the proportions comparing the network to the State are much more similar than what was found for the comparison of the pie charts in Figure 35, which showed the proportions for the entire area of the habitats.

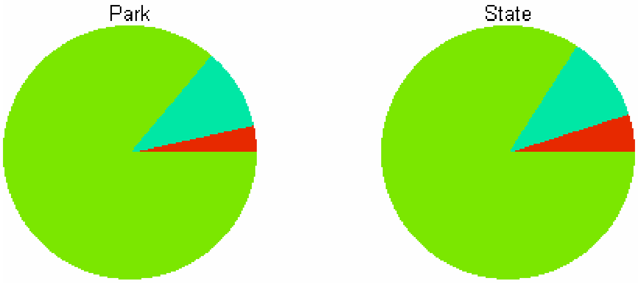

Figure 41: Proportion of saltmarsh, mangrove and other intertidal and supratidal soft sediment areas included in the marine parks network compared to the State for habitats existing below MHW
(Intertidal and supratidal areas: Red = Saltmarsh; Cyan = Mangrove, Green = Other) Ranking = 1

The low figure of 20% for the total inclusion of saltmarsh is not surprising given that the majority is above MHW, quite frequently in private land and therefore not available to include within the marine parks network. Of the 604 km^2 of coastal saltmarsh habitat mapped within the state, approx 120 km^2 or 20% is also within a NPW Act reserve. A further 123 km^2 (or 20%) is included within the marine parks network (with 23 km^2 coming under both forms of protection).

Very little mangrove forest (less than 2%) extends above MHW but 44% of that is included within the network along with 66% of the more extensive stands below MHW. For seagrass beds, approx. 8,500 km^2 has been mapped state-wide and approximately 3,680 km^2 is included within the network, approximately 43% overall. As detailed in Table 25, 72% of estuary mouths are also included within the network.

5.2.6 Ecological importance

The incorporation of ecologically important species and areas in marine parks design was assessed by analysing a variety of GIS data sets including those for islands, marine mammals, endangered marine macroalgae and conservation hotspots.

5.2.6.1 Islands

Islands are important ecologically because they provide breeding and nesting sites for seabirds and shorebirds and breeding and haul-out sites for pinnipeds (listed below in 5.2.6.2). The Chi-square goodness-of-fit test shows statistically significant results for the inclusion of islands within the marine parks network. Of the 111 islands located in State waters, 80, or 72%, were located within the network.

5.2.6.2 Australian sea lion, New Zealand fur seal and Australian fur seal sites

The Chi-square goodness-of-fit test shows statistically significant results for the inclusion of Australian sea lion (breeding and haul-out), New Zealand fur seal (breeding and haul-out) and Australian fur seal (haul-out) sites within the marine parks network. Figure 42 displays the location for each of the breeding and haul-out sites within and outside of the marine parks network. Table 25, the summary table of the Chi-squared tests for the biophysical Design Principles shows that between 84 and 92% of all the ecologically important pinniped (seals and sea lions) sites are included within marine parks.

An analysis of sites identified in the Australian sea lion fisheries by-catch risk assessment study by Goldsworthy *et al.* (2007) is displayed in Table 23. The results when assessed for each bioregion show that between 84 and 100% of the sites in the study are included within each of the bioregions, totalling 89% inclusion across the State. Within the marine parks network 100% of the very high risk (4 out of 4), 91% of the high risk (21 out of 23), 80% of the medium risk (8 out of 10) and 100% of the low risk (only 1 site) breeding sites have been included within the marine parks network.

The Australian sea lion is listed as vulnerable under the EPBC Act and the NPW Act. Goldsworthy *et al* (2007), states that a number of sea lion sub-populations are at risk of going locally extinct (the number of adult females is too low to ensure population persistence) and that several more are also at risk if current small levels (1−2 females per year) of fishery bycatch interactions are continued. Goldsworthy *et al.* (2007) also identifies just six sites, where the majority of pup production (67%) occurs (where more than 100 pups are produced each breeding cycle). The six sites are Dangerous Reef in Southern Spencer Gulf (585 pups), The Pages in Backstairs Passage (577 pups), Seal Bay on Kangaroo Island (214 pups), West Waldegrave (157 pups) and Olive Islands (131 pups) off Eyre Peninsula, and Purdie Island in the Nuyts Archipelago (132 pups) (Goldsworthy *et al.* 2007). Of these six, four sites are included within the marine parks network, with West Waldegrave and Olive Islands being the exceptions. Therefore, the marine parks network performs very well in terms of protecting the ecologically important pinniped sites occurring in South Australia. For further information, Table 34 in the Appendix 6 displays the name and bioregional location of each of the Australian sea lion breeding sites assessed in the Goldsworthy *et al.* (2007) risk assessment.

Table 23: Summary of the risk assessment of Australian sea lion breeding sites across South Australia and their marine park conservation status

Bioregions	Number included within the marine parks network	Number outside of the marine parks network	Percent inclusion within the network
Eucla	1 very high risk; 6 high risk	0	100%
Murat	1 very high risk; 5 high risk; 4 medium risk	1 medium risk	91%
Eyre	2 very high risk; 10 high risk; 3 medium risk; 1 low risk	2 high risk; 1 medium risk	84%
Gulf St Vincent	1 medium risk	0	100%
Total	4 very high risk; 21 high risk; 8 medium risk; 1 low risk	2 high risk; 2 medium risk	89%

5.2.6.3 Southern right whale and blue whale aggregation areas

There are five southern right whale (*Eubalaena australis*) aggregation areas identified within South Australian State waters (Table 24). All five of these locations are included within the marine parks network. Blue whale and southern right whale migratory pathways were also visually examined and compared to the marine parks network.

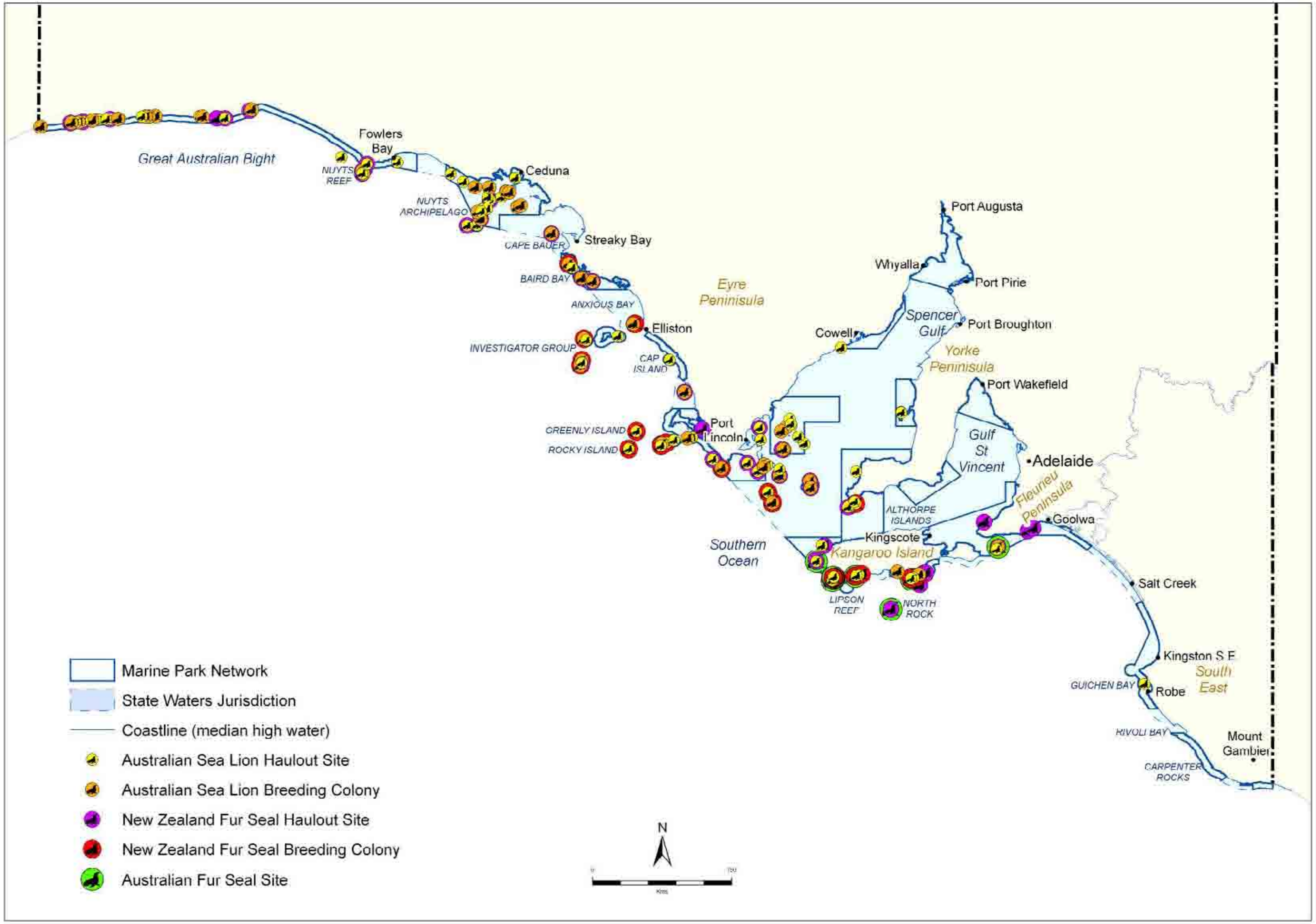

Figure 42: South Australia's marine parks network with Australian sea lion, New Zealand fur seal and Australian fur seal sites

Table 24: Southern right whale aggregation areas (from GIS dataset)

Location	Bioregion	Site type	Within network?
Encounter Bay	Gulf St Vincent/Coorong	Calving	Yes
Sleaford Bay	Eyre	Calving	Yes
Fowlers Bay	Murat	Calving	Yes
Head of the Bight	Eucla	Significant aggregation	Yes
Merdeyarrah Sandpatch	Eucla	Calving	Yes

Visual examination of the blue whale migratory pathways revealed a pathway along the Bonney Coast within State waters, travelling offshore into Commonwealth waters and then coming back into State waters on the western end of Kangaroo Island. The sections of the pathway that occur in State waters are included within marine parks in the lower and upper South-East and the western end of Kangaroo Island.

5.2.6.4 Conservation status of endangered marine algae (COSEMA) sites.

The data set for the COSEMA sites was generated in June 2003 based on an extensive literature search of field studies on vulnerable Australian macroalgae. The dataset identifies 161 important sites for endangered macroalgae across South Australia. Of the 161 sites, 114 or around 71% are included within the marine parks network. The Chi-square goodness-of-fit test concluded that this was a statistically significant result for the inclusion of COSEMA sites within the marine parks network. Although the inclusion of COSEMA sites within the marine parks network is statistically significant, the assessment can only be made for known sites which have been recorded through field studies. It is therefore highly likely that there are other sites which contain vulnerable macroalgae which are in the marine parks network; however, because they are yet to be identified, they have not been included in this assessment. Although the marine parks network has performed well in terms of including vulnerable macroalgae sites, future research into additional sites around South Australia will provide more information by which to assess the success of the marine parks network.

5.2.6.5 The ninety-six conservation hotspots

Of the 96 conservation hotspots identified in the Ocean's 52 program (Edyvane, 1999), 66 (69%) of these sites are included within the marine parks network. The Chi-square goodness-of-fit test shows that this inclusion of the conservation hotspots within the network is statistically significant. Figure 43 displays the marine park boundaries and the 96 conservation hotspots within the marine parks network. Of the 96 hotspots, 35 were listed as important due to the presence of saltmarsh communities, mangrove forests, estuaries or sand dunes. Twenty-six (or 74%) of these 35 hotspots are included within the marine parks network. The Chi-square test yielded a statistically significant result for the inclusion of hotspots important for saltmarsh, mangroves, estuaries or sand dunes within the marine parks network. Of the 30 hotspots that are not included within the marine parks network, 11 of these are included within other protected areas (i.e. the Adelaide Dolphin Sanctuary, NPW Act reserves, rock lobster sanctuaries, shipwreck reserves and netting closures). Therefore, in total 77 of the 96 (80%) conservation hotspots lie within some form of protected area in the State.

As mentioned above, all of the Chi-square tests reveal a statistically significant result for the inclusion of ecologically important sites within the marine parks network, indicating that the ecological importance Design Principle has been very effectively met within the marine parks network.

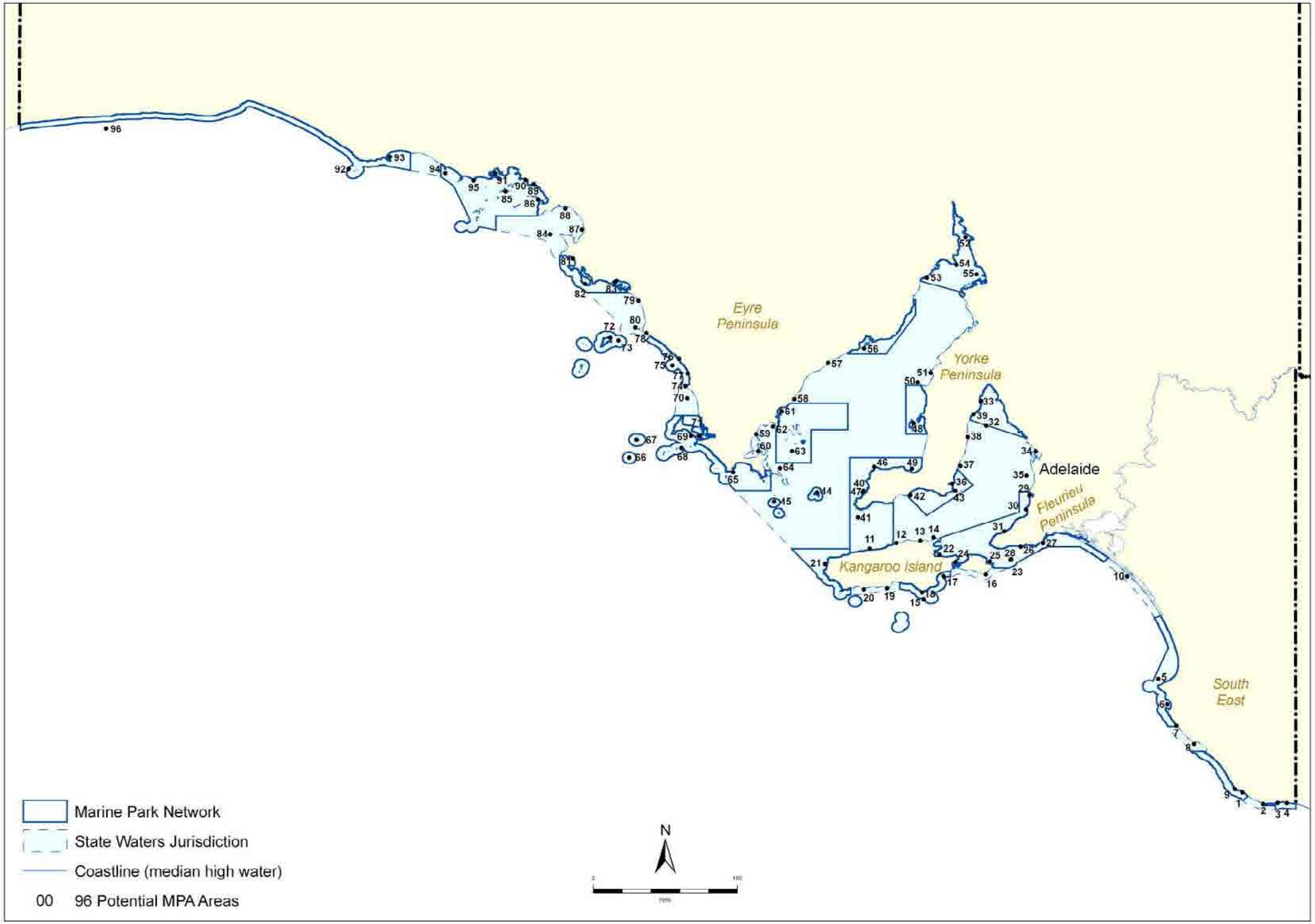

Figure 43: Conservation hotspots within the marine parks network

5.2.7 Summary of Chi-square goodness-of-fit tests for the biophysical Design Principles

As described in Section 5, the Chi-square goodness-of-fit test was used to see whether the degree of inclusion of different features in the marine parks network is what we would expect by chance alone if we were to randomly locate marine parks. By including 46% of State waters within the marine parks network, we would expect by chance that around 46% of any particular feature occurring across State waters to also be included within the network. A statistically significant result means that significantly more, or significantly less, than 46% of the feature was included within the marine parks network.

The results for the analyses of conservation features (linked to the biophysical Principles above) show that in all cases there were significantly more than 46% of all features included in the network. For each significant result, it was determined whether the excess count was in the correct direction, meaning was the inclusion of the sites within the network significantly more, or significantly less than 46% and if so, was this the desired result? In the results displayed in Table 25 all of the counts are significantly more than 46%, which was the desired result.

Table 25: Chi-square goodness-of-fit test results for conservation features

Attribute	**No. available in State waters**	**Included within network**	**% included in network (approx)**	**Chi-square value for df = 1**	**Significant?**	**Excess of count in correct direction?**
ASL breeding sites	46	42	91	38.0	Y	Y
ASL haul-out sites	136	116	85	84.1	Y	Y
NZFS breeding sites	35	30	86	22.2	Y	Y
NZFS haul-out sites	83	70	84	49.1	Y	Y
AFS haul-out sites	12	11	92	10.1	Y	Y
COSEMA species	161	114	98	39.9	Y	Y
Conservation hotspots	96	66	69	20.0	Y	Y
Conservation hotspots with saltmarsh, mangrove, dunes or estuaries	35	26	74	11.28	Y	Y
Islands	420	345	82	220.9	Y	Y
Estuary mouths	111	80	72	30.4	Y	Y

NB: The critical value of Chi-square test is 3.84, so any value returned above that is significant.

5.3 The community Design Principles

5.3.1 Seek synergies with existing protected areas

Seeking synergies with protected areas in marine parks design helps to buffer the marine environment from land based impacts, as terrestrial protected areas should have less impact on the marine environment than other more heavily utilised areas. Aligning marine parks with existing protected areas also helps to provide ecosystem linkages between the land and sea and avoid unnecessary duplication of protected areas, which minimises the additional restrictions placed on the community to use and enjoy the marine environment. The assessment of protected areas revealed that there are 158 protected areas in State waters, with 127 or 80% included within the marine parks network (Table 26 and Figure 44). The total area that protected areas cover in State waters is 15,650 km^2 with 9,826 km^2 or 63% of the area included within the marine parks network. When assessing the terrestrial protected areas along the coastline of South Australia, the results show that there are 1962 linear kilometres of protected areas along the coast, with 86% (1,633 km) of this included within or adjacent to the marine parks network.

Table 26: Protected areas in State waters included in the marine parks network

Type of protected area	% of the total number of protected areas existing in State waters included in the network	% of the total area of protected areas existing in State waters included in the network	% of the total length of terrestrial parks adjacent to the coastline included in the network
Conservation Parks	75	98	86
Conservation Reserves	100	100	71
National Parks	100	99	82
Recreational Park	100	100	100
Wilderness Protection Areas	83	64	77
Aquatic Reserves	87	75	N/A
Shipwreck Reserves (buffered)	50	74	N/A
Adelaide Dolphin Sanctuary	0	0	N/A
Defence Area Boundaries	100	100	N/A
Rock Lobster Sanctuaries	75	98	N/A
Netting Closures	78	57	N/A
Total	**79**	**63**	**83**

The Chi-square test indicated that the inclusion of protected areas within the marine parks network was statistically significant, and therefore above the 46% that would have been included by chance given that 46% of the State's waters are within the marine parks network. Many of the protected areas found in State waters are on islands, and given that 82% of all islands are included in the network, it is not surprising that such a high proportion of the number of protected areas in the State are included within the network. Locations where protected areas were not included are the St Kilda-Chapman Creek Aquatic Reserve, and the Barker Inlet Aquatic Reserve, both of which are in the Adelaide Dolphin Sanctuary (which is also not included). The Wilderness Protection Area (WPA) not included in the marine parks network is the Cape Bouguer WPA on Kangaroo Island. The shipwreck reserve not included was the *Zanoni*, which is located just outside the boundary of the Upper Gulf St Vincent Marine Park. The shipwreck reserve which was included in the network, is the *HMAS Hobart* within the Encounter Marine Park. Only one of the four Rock Lobster Sanctuaries is not included in the network, the Penguin Island Rock Lobster Sanctuary, which is located at Rivoli Bay near Beachport in the lower south east of South Australia. Areas where netting closures are not included are the lower south east (Rivoli Bay and Robe Lakes – which are more than 3 km inland), the metropolitan area of Adelaide (Outer Harbor to Aldinga and Port Adelaide), Yorke Peninsula (which has a large netting closure, with three marine parks within the closure), Port

Broughton, and the Eyre Peninsula (Port Neill and Port Lincoln which are on either side of the Sir Joseph Banks Group Marine Park, and the West Coast Bays Marine Park). Overall, the marine parks network has performed well in meeting the Design Principle of seeking synergies with protected areas.

5.3.2 Seek to complement existing terrestrial and marine management practices and conservation agreements

Complementing existing terrestrial and marine management practices in marine parks design helps to ensure greater understanding of on water or on park management arrangements by Government, industry and the community. Complementing existing conservation agreements such as those for migratory birds or important wetlands (i.e. JAMBA or Ramsar respectively) honours Australia’s commitments to international and national agreements as well as to protect ecologically important habitat areas.

As management practices for marine parks are not being determined at this stage in the development process, the evaluation of the success in meeting this Design Principle is more applicable to the zoning and management plan implementation phase of the program. However, one quantitative analysis was conducted at this stage, for Ramsar reserves.

There are five Ramsar reserves within South Australia; of these only one is adjacent to the coast, the Coorong and Lakes Alexandrina and Albert Ramsar Reserve. The Coorong runs approximately 142 km along the coastline. Of the 142 km, approximately 66 km or 46% is adjacent to the marine parks network.

No statistical analysis was performed on the number of species listed under conservation agreements (such as JAMBA and CAMBA) within marine parks as this information is not currently available within GIS data layers.

5.3.3 Give consideration to the full diversity of marine uses

Marine usage analyses for the purposes of assessing the achievement of this Design Principle include commercial and recreational fishing, aquaculture and recreational diving.

5.3.3.1 Commercial fishing effort

The total number of commercial fishing blocks, as well as the blocks which included 95% of the total commercial catch were analysed for inclusion within the marine parks network. The numbers of blocks in total and the blocks including 95% of the total catch, as well as the percentage degree of overlap of the network with that high value subset varied across fisheries (Table 27). Some fisheries had most value concentrated in few blocks (e.g. sardines, prawns) whereas others had value over many blocks (e.g. abalone). The degree of overlap varied from less than 2% (prawns in Gulf St Vincent) to 67% (prawns on the west coast).

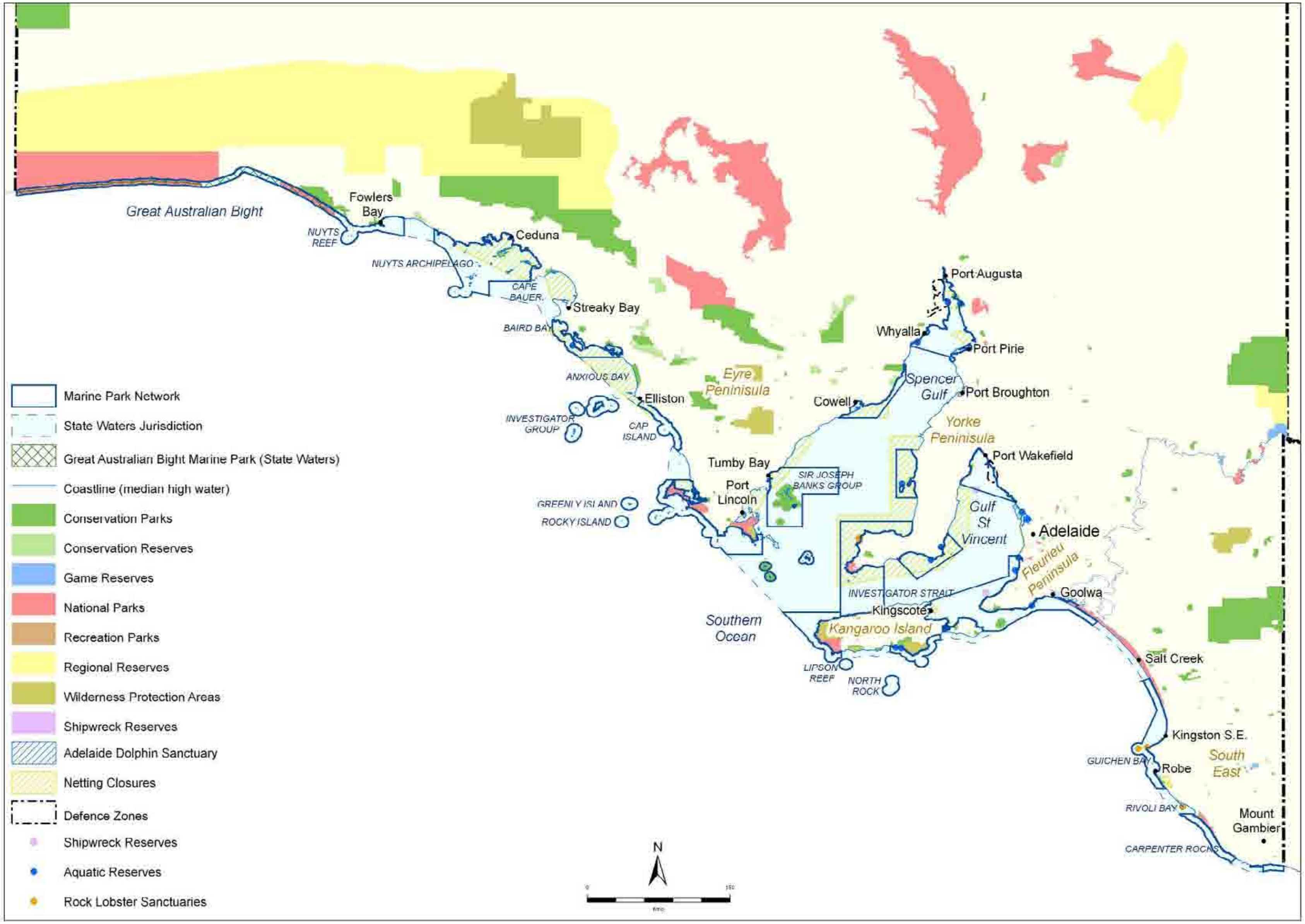

Figure 44: South Australia's marine parks network with other terrestrial and marine protected areas

Table 27: Fishery-specific statistics for total blocks, blocks yielding 95% of the catch during 2002−7, and the % overlap of that subset with the parks network.

Fishery	Total number of blocks	Number of blocks to 95% value	% area of overlap with network
Marine scalefish	46	24	39
Sardines	43	6	38
Rock lobster Northern Zone	38	12	53
Rock Lobster Southern Zone	5	3	67
Charter Boats	43	20	42
Prawn West Coast	94	12	67
Prawn Spencer Gulf	123	35	15
Prawn GSV	121	38	2
Abalone West	107	59	65
Abalone Central	45	23	50
Abalone South	35	19	57

5.3.3.2 Aquaculture leases

There are currently 415 active aquaculture leases within State waters, of these, 235 or just under 57% are included within the network. These 415 active aquaculture leases cover an area of 46 km^2; of this area, 15 km^2 or just under 33% were included within the marine parks network.

The total number of leases yielded a significant Chi-square result for the inclusion of aquaculture leases within marine parks, which was not the desired result. Overlap with activities such as fishing and aquaculture should where possible be minimised within marine parks, and where overlap is unavoidable, will be catered for in appropriate zoning design.

5.3.3.3 Recreational fishing sites

Of the 669 recreational fishing sites identified by Pescatore and Ellis (1998) and other sources, 284 or 42% of the sites are within the marine parks network. The Chi-square goodness-of-fit test (Table 12) shows that this result is not significant, meaning that there are no more recreational fishing site than that included by chance within the marine parks network.

The non-significant result is what would be expected as recreational fishing sites were neither targeted for inclusion or exclusion in the marine parks design. Whilst recreational fishing sites were considered when developing the marine parks network, it was determined that recreational fishing would be catered for more appropriately in zoning design, specifically in regards to the location of sanctuary zones within the network. At this boundary development stage, including recreational fishing sites considers the full diversity of marine users and provides for recreation, appreciation and education within marine parks.

5.3.3.4 Recreational dive sites

Of the 87 published dive sites in South Australia (see Appendix 2), 54, or 62% were included within the marine parks network. The Chi-square goodness-of-fit test (Table 12) shows that the inclusion of recreational dive sites within the marine parks network is statistically significant, with more than expected by chance.

The dataset used to analyse the information for recreational dive sites is currently only complete for Spencer Gulf, Gulf St Vincent and Kangaroo Island. There are some sites recorded in the South-East and around Port Lincoln, however the data set is not complete for these areas. The information for this dataset comes from various dive clubs and federations and from descriptions taken from the brochure “Dive Secrets of Fleurieu Peninsula & Kangaroo Island” produced by Onkaparinga & Kangaroo Island Councils. Whilst recreational dive sites have been successfully included within the marine parks network, it will make sense to perform the analysis of recreational dive sites within marine parks again, once more information is collected about popular dive sites from local communities around the State, during the management plan development phase of the program.

5.3.4 Respect indigenous interests and culture

The Indigenous Heritage Database (from the Department of the Premier and Cabinet, Aboriginal Affairs and Reconciliation Division) lists many indigenous sites around South Australia. These include midden sites, campsites, fish traps, dreaming sites and sites with archaeological deposits. The number of sites was determined by assessing the total number of Aboriginal heritage sites within State waters. Of the sites listed within the GIS layer (which are buffered to hide the exact location of the site), 26% are included within the marine parks network. When assessing those sites that occur just within the States waters, 69% of a total of 327 sites within the State waters are included in the marine parks network.

5.3.5 Give consideration to natural and cultural heritage

Statistical analyses of the number and percent of the coast and marine related State Heritage sites within the marine parks network are detailed below.

5.3.5.1 Shipwrecks

There are two shipwreck reserves listed on the State Heritage register, the *Zanoni* in upper Gulf St Vincent and the *HMAS Hobart* off the Fleurieu Peninsula. As mentioned in section 5.3.1, the HMAS *Hobart* is included in the Encounter Marine Park, whereas the *Zanoni* is located just outside the boundary of the Upper Gulf St Vincent Marine Park.

In addition to the State Heritage list, there are 747 shipwrecks within South Australia listed in the South Australian shipwrecks database. Of these, 392 are protected under legislation, with 147 protected under the Commonwealth *Historic Shipwrecks Act 1976* and 245 protected under the South Australian *Historic Shipwrecks Act 1981*. Of those 392 protected shipwrecks, 190 (48%) are located within the marine parks network.

The Chi-square test for this inclusion yielded a non-significant result indicating that no more shipwreck sites had been included within the network than would have been by chance (given the 46% inclusion of State waters). Within the shipwrecks dataset, there are actually 59 shipwrecks that are more than 5 km inland, all of which are adjacent to the River Murray, with the exception of the '*Tom Brennan'*, which is located at Cooper Creek in the north-east of South Australia. Therefore, although 48% of shipwreck sites were included within the marine parks network, it was extremely unlikely that the 59 shipwrecks more than 5 km inland would been included within the network. Historic shipwrecks under both Commonwealth and State legislation are protected for their heritage values and maintained for recreational, scientific and educational purposes. Divers can use wreck sites for recreational diving but relics must not be removed from the wreck site. Recreational fishing is also permitted; however, it is illegal to anchor directly onto an historic shipwreck. The two historic shipwreck reserves (the *Zanoni* and the *HMAS Hobart*) listed on the State Heritage list in South Australia are also protected under the State historic shipwreck legislation, but have an additional protected zone (aquatic reserves established under the fisheries legislation) surrounding them which excludes all activities, even boating in the zone, unless a permit is issued. The *HMAS Hobart* and the *Zanoni*, are buffered at a distance of 926 m (0.5 nautical miles) and 550 m, respectively. Whilst the protected shipwrecks included within the marine parks contribute to meeting this Design Principle by incorporating cultural heritage sites within the parks, the protected shipwreck reserve surrounding the *HMAS Hobart* provides additional biodiversity conservation benefits as it is an established no-take marine protected area within the marine parks network.

5.3.5.2 Lighthouses

Of the 12 lighthouses registered as State Heritage, three, or 25% are found within the marine parks network. There are also an additional six lighthouses which are adjacent to the network but not included within the parks. The three lighthouses included within the marine park boundaries are on Neptune Island, in the Neptune Islands Group Marine Park, on Althorpe Island in the Southern Spencer Gulf Marine Park and at Cape Banks in the Lower South East Marine Park.

The three State Heritage listed lighthouses protected was a non-significant result in the Chi-square tests. Two of the three lighthouses incorporated within the network were on islands, and were therefore overlayed entirely by the marine parks network. Therefore, the low number of lighthouses within the network is likely due to the majority of lighthouses being on the mainland of South Australia on the coast where Crown land parcels were not available for incorporation into the network.

5.3.5.3 Piers and jetties

There are 26 piers and jetties registered as State Heritage and 12, or 46% are included within the marine parks network. As expected the 12 were included by chance alone, and therefore a non-significant result in the Chi-square tests. This result was expected as piers and jetties were not targeted for either exclusion or inclusion within the marine parks network. It is intended that any piers and jetties (whether cultural heritage listed or not) within the marine parks network will be zoned appropriately within a marine parks management plan to allow for ongoing use of the areas.

5.3.5.4 European heritage

There are 17 European Heritage sites listed on the State Heritage Register. Of these sites, three are included within the marine parks network. The three included are the St Peter Island whaling site and the Point Collinson whaling station site in the Nuyts Archipelago and the Whale Bone Area and Point Fowler Structure in Fowler Bay. Of the 14 sites not included in the park, only one is identifiable as being coast and marine related (the Thistle Island sealing site), with others found inland, including missions and churches, hospitals, wineries and a range of other buildings and infrastructure. The low numbers of European heritage sites included within the network is due to most of the sites occurring inland and therefore unavailable for inclusion within the marine parks network.

5.3.5.5 Geological monuments

There are five State recognised geological monuments within the marine and coastal environs of South Australia, and all five are adjacent and partially included within the marine parks network. The geological monuments are the Second Valley Coastal Cliffs geological site, the Cape Jervis geological site, Normanville Coastal Dunes, Maslin Bay to Aldinga coastal cliff, and the Red Cliff Point geological site. The reason for this 100% inclusion was due to all of the sites occurring along the coast adjacent to focus areas for the marine parks network.

Overall, the inclusion of cultural heritage sites within the marine parks network was no more or less than what would have been expected given that 46% of the State's waters are included within the marine parks network. In most cases this was due to the sites being located on the coast in areas where no Crown land was available for inclusion within the network.

5.3.6 Ensure ease of identification, compliance and enforcement

No quantitative assessments were performed for this Design Principle. However, the marine parks network was designed to ensure ease of compliance, identification and enforcement where possible using straight lines (north-south and east-west) instead of curves. Where possible, marine park boundaries were also aligned with prominent coastal features (i.e. a headland) or a well known locality (such as the main road used to drive onto the beach). Visual assessments of the boundary network (Figure 1) show that 10 of the 19 marine parks have straight lines running either north-south or east-west. Of the nine which do not, four have boundaries which follow the State waters jurisdiction of approximately 3 nautical miles.

Whilst the boundaries have been designed at this stage in the process to, as far as practicable (whilst meeting all other Design Principles) ensure ease of identification, compliance and enforcement, the real test of this Design Principle is more applicable to the zoning and management plan implementation phase of the program. It is envisaged that in addition to boundary design, this principle will be further met by providing GPS points to the community for each marine park, using on-water marker buoys at select locations and having marine park rangers available to educate the community.

5.3.7 Provide for education, appreciation and recreation

There was no quantitative assessment conducted for the principle of providing for education, appreciation and recreation. However many of the marine parks contain known field sites used in community monitoring, such as Coastcare and Reef Watch (intertidal and subtidal monitoring). There are also a number of field sites used by schools with established marine programs included within the network. Some of these include Kingscote Area School on Kangaroo Island, Victor Harbor Primary School on the Fleurieu Peninsula, and Cowell Area School on the Eyre Peninsula. Opportunities have also been provided for recreational fishing and diving by including popular locations within marine parks that will ultimately be zoned appropriately within multiple use management plans.

Providing for education, appreciation and recreation within marine parks design, is another community Design Principle that is more applicable to management plan implementation than boundary design. Additional opportunities for education, appreciation and recreation in the implementation phase of the program will likely include educational and interpretive information and signage at marine park locations, additional field sites established for community monitoring programs (such as Reef Watch) within marine parks, and opportunities to join other community volunteer programs such as Friends of Parks.

5.3.8 Summary of the Chi-square goodness-of-fit tests for the community Principles

The results for the analyses of Chi-square goodness-of-fit tests were mixed (Table 28). Sites for recreational fishing, shipwreck sites and piers and jetties were non-significant. More sites than expected by chance alone were included for dive sites, indigenous sites, protected and marine management areas, and the subset that are Aquatic Reserves under the *Fisheries Management Act 2007*. As mentioned in section 5, each significant result was assessed to determine whether the inclusion for each attribute was significantly more or less than 46% and whether it was the desired result. The only significant result for an attribute that was included within the network when the desired result was to exclude the attribute was for aquaculture leases, which is explained in section 5.3.3.2 above.

Table 28: Chi-square goodness-of-fit tests for socio-economic data

Attribute	No. available in State waters	Included within boundaries	% included in network (approx)	Chi-square value for df = 1	Significant?	Excess of count in correct direction?
All protected areas with marine interests	158	125	80	69.7	Y	Y
Aquaculture leases	415	235	57	18.9	Y	N
Recreational fishing sites	669	284	42	3.39	N	na
Popular dive sites	87	54	62	9.0	Y	Y
Indigenous sites in State Waters	327	227	70	63.1	Y	Y
Shipwreck sites	392	190	48	0.96	N	na
Lighthouses	12	3	25	2.13	N	na
Piers/jetties	26	12	46	0.0002	N	na

NB: The critical value of Chi-square test is 3.84, so any value returned above that is significant.

5.4 Assessing the boundary design with conservation planning software

One of the tools used to support the Delphic approach for the design of South Australia's marine parks network was the application of conservation planning software. The implementation of systematic conservation planning depends on an ability to use large volumes of relevant environmental, social and economic data and information (Margules and Pressey, 2000; Pressey and Cowling, 2001; Ardron *et al.*, 2008). As a result, a range of conservation planning software has been developed to support the design of protected areas on land and in the sea to provide a way to analyse and inspect complex data more simply and objectively (Margules and Nicholls, 1988; Pressey and Nicholls, 1989; Freitag *et al.*, 1997; Pressey and Cowling, 2001; Stewart and Possingham, 2002; Beger *et al.*, 2003; Day *et al.*, 2003).

The strength of the tools is that they lend flexibility to the process. They can process large amounts of data and display a range of scenarios, each showing potentially valuable areas to consider during the design phase. By running the software programs a number of times, the tools can quickly show how solutions might change if different data or different target levels (e.g. 10, 20, 30 and 50% of habitats included) are used. The programs also provide a measure of how important individual sites are to a network. If a certain site is selected every time a model is run, then it may be irreplaceable to the system.

5.4.1 Using Marxan to audit South Australia's marine parks network

Marxan, the most commonly used conservation planning software worldwide (refer Table 33 in Appendix 3) was used to audit the final series of boundary proposals, testing for gaps in the system not identified through the Delphic approach.

The software was run for all of South Australia's waters on grid cells 1 km^2 in size, to match the resolution of data being used and to balance between detail and the computational time taken to run individual models. The environmental data available for analysis at a state-wide scale included habitat information, bathymetry, seasonal sea surface temperatures, shoreline exposure and shoreline type. Key point specific data layers were also used to capture ecologically important features such as seal/sea lion breeding and haul-out sites and whale aggregation areas. For site specific features targeted as particularly important, such as Australian sea lion breeding colonies, the target was always set at 100%. To examine the final set of boundaries, which cover 46% of South Australia's State waters, the final step was to run the model for each bioregion asking the computer to identify networks that equal 46% of the State waters. The results were used to check for places not included in the system that the model always included (which indicates potential importance of that site to conservation).

As part of the process, weights were determined and applied to the data to encourage the software to preferentially select particular planning units in close proximity to existing terrestrial and/or marine protected areas such as coastal conservation parks, lobster sanctuaries, netting closure and Aquatic Reserves. Doing this addressed the community Design Principles that calls for marine parks to complement existing management and align with existing protected areas.

A number of data layers relevant to human activities were included in the final round of software to identify sites that were subject to a high density of use and/or high economic value. Data used included high value commercial fishing areas, aquaculture leases, recreational fishing and diving sites, marinas, harbour limits, jetties, wharves and boat ramps. The human use modelling outcomes and the conservation outcomes were then overlaid in a geographical information system (GIS) and potential areas of both separation and overlap were identified to further inform the design process.

5.4.2 Modelling outputs

After assessing South Australia's proposed network of 19 marine parks against the Design Principles, the final step in the process was to test the network using mathematical modelling. As described above, a range of GIS data layers were applied to the modelling program Marxan in order to identify key areas in each marine bioregion that are irreplaceable from a conservation perspective. Figure 45 displays the outputs of the modelling program across the State, with the red areas highlighting cells that were chosen by the modelling program every time it was run (and are hence irreplaceable) (see Appendix 7 for individual bioregional maps). Table 29 shows the number of discrete irreplaceable (in red) areas included within marine parks for each bioregion.

Table 29: Number of Marxan derived areas of irreplaceability within the marine parks network

Bioregion	No. of irreplaceable areas within parks	No. of irreplaceable areas outside of parks	Total no. in bioregion	Percent
Eucla	1	0	1	100
Murat	13	3	16	81
Eyre	27	5	32	84
Spencer Gulf	11	1	12	91
North Spencer Gulf	4	0	4	100
Gulf St Vincent	15	1	16	94
Coorong	3.5	0.5	4	88
Otway	4	2	6	67
Total	**77.5**	**12.5**	**90**	**86**

Approximately 86% of the areas of irreplaceability identified by Marxan are included within the marine parks network, a statistically significant result indicated by the Chi-square goodness-of-fit test. It is intended that further statistical analysis will be conducted on the number of highly irreplaceable cells included within and outside of the network, however at this stage, visual analysis of the Marxan outputs shows that the best performing bioregions were the Eucla and North Spencer Gulf Bioregions with all the identified areas of irreplaceability included within the network. The worst performing bioregion was the Otway Bioregion, with 67% of identified areas of irreplaceability included within the network. Visual analysis of the areas of irreplaceability also identified eight areas with multiple red irreplaceable cells which were not included within the network, these are presented in Table 30.

Table 30: Marxan derived areas of irreplaceability, not included within the marine parks network

No.	**Bioregion**	**Location**	**Current protection**
1	Murat	Acraman Creek	Adjacent to Acraman Conservation Park which has a seaward limit of MHW.
2	Eyre	Waldegrave Islands	Adjacent to Waldegrave Islands Conservation park, which has a seaward limit of MHW.
3	Eyre	Rocky Island	Adjacent Rocky Island North Conservation Park, which has a seaward extent of approximately 75 m below MHW.
4	Eyre	Cape Bouger	Adjacent to Bouguer Conservation Park, Kangaroo Island, which has a minor seaward extent of approximately 75m below MHW.
5	Spencer	Bird Island and Moonta Bay area	Adjacent to Bird Island Conservation Park, which has a varied seaward limit, with the maximum marine extent of up to 2km below MHW. However the hotspot covers an area up to 4km seaward.
6	Gulf St Vincent	Barker Inlet and Port Estuary area	Within the Adelaide Dolphin Sanctuary (~118km^2), which covers majority of hotspot, except for part of one cell (less than 1km^2).
7	Otway	Cape Martin and Penguin Island near Beachport	Adjacent to Penguin Island Conservation park which has a seaward limit of MHW.
8	Otway	Cape Douglas	Adjacent to Douglas Point Conservation Park, extends seaward approximately 75m below MHW.

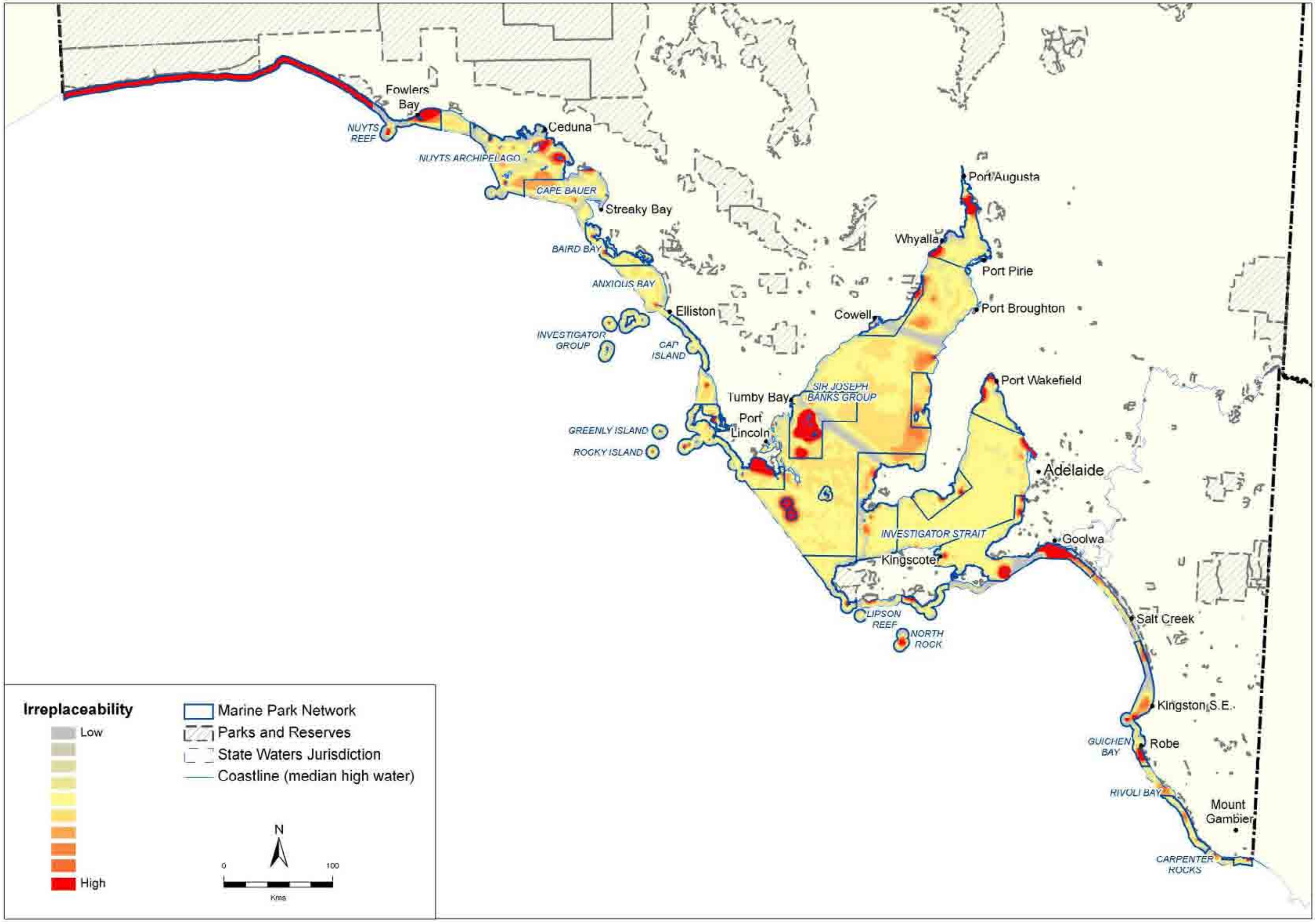

Figure 45: Marine parks network displaying Marxan derived areas of irreplaceability

Of the areas of irreplaceability not included within the marine parks network, the only irreplaceable area which currently has most of the area protected is at the Barker Inlet and Port Estuary in the Adelaide Dolphin Sanctuary. The remainder of the irreplaceable areas either have minor protection, i.e. the Bird Island and Moonta Bay area in the Bird Island Conservation Park or no marine protection, i.e. at Acraman Creek in the Murat Bioregion which is a conservation park with no protection seaward of MHW.

Overall, the comparison between the Marxan outputs and the marine parks network indicate that the network has performed well in terms of incorporating key conservation areas, but some improvements could be made in certain areas. Whilst Marxan and other site selection software can provide a systematic approach to marine park design, they do not attempt to replace the human decision making process. Moreover, the power and efficiency of these tools depends on the quality of the data used in the modelling system, and on the recognition that the tools are designed to support decision making not to replace it. Modelling was used as a way to audit the final proposal, but has primarily relied on expert knowledge and the use of a much broader range of data and information to assess the validity of model outputs and to build the network.

6 Discussion of the boundary options

6.1 Assessment of the network as a whole

The systematic development of protected areas is an important and valuable biodiversity conservation strategy. South Australia is the custodian of a diverse and unique marine environment and we have an obligation to ensure that future generations of South Australians can draw enjoyment and prosperity from our marine environments. The decline in health of the Murray River and Coorong Lagoon systems can be used as an example of why it is better to act early to conserve environments while they are still in good health, as apart from the ecological losses that are being suffered, the impact also has a significant social and economic component.

While South Australia has a successful track record in fisheries management and our marine resources are generally in good condition, the State is one of the last jurisdictions in Australia to establish a systematically planned network of marine parks for biodiversity conservation purposes. The outer boundaries of the marine parks network proclaimed by the Government of South Australia include 46% of State waters, and represent a significant step in the delivery of a comprehensive, adequate and representative system of MPAs for the State.

Establishing a network of marine parks in South Australia’s seas fulfils our obligations at a national level and helps Australia to honour commitments to global treaties to establish a worldwide network by 2012. In delivering their networks of MPAs, several countries and some Australian States, have committed to protecting a minimum percentage of their waters. South Australia has chosen not to target a particular percent because it is not possible to identify a single percent that will apply well to all of our habitats in all of the bioregions. Instead, the outer boundaries were built using the Design Principles and applying the decision making rules discussed earlier to ensure that the system is comprehensive and representative within and across the eight known bioregions covering State waters.

The resulting size of the network was dependent on the inclusion of all the necessary components in a way that is expected to create a functioning and inter-connected network of protected areas (relates to adequacy). The network of marine parks will enable flexibility in developing multiple-use zoning and management plans, meeting our objectives of biodiversity conservation and ongoing sustainable use.

The best represented bioregion in relation to percent of area covered within the network is the Eucla Bioregion, with 100% of the Bioregion’s waters included in the marine parks network. Historically, there was no focus location identified for the Eucla Bioregion, because the Great Australian Bight (GAB) Marine Park already existed in both State and Commonwealth waters. However, when assessing the focus locations and designing the boundaries, key biodiversity hotspots at Nuyts Reef and in Fowlers Bay were recognised, and reinforced by the modelling which always selected both sites as areas of high irreplaceability.

The Nuyts Reef is the single largest area of limestone reef in the Murat Bioregion and is also home to a colony of Australian sea lions. Fowlers Bay is a southern right whale aggregation area, contains seagrasses at the westerly limit of their distribution in South Australia and also contains examples of coral communities not common elsewhere in the State. The need to include those areas in a way that connects them well into the network determined the decision to merge the area with the GAB Marine Park rather than either isolating them as a very small marine park or extending the already very large Nuyts Archipelago Marine Park west to include them.

The Bioregion with the least area covered by marine parks is the Spencer Gulf Bioregion, with only 25% included in the network. The performance indicators show, however, that all of the known features of the region are included within the network. Some features, and particularly deep water environments are relatively less well represented in the Bioregion.

6.2 Meeting the conservation objectives of the program

6.2.1 The precautionary approach

The *Marine Parks Act 2007* states that “if there are threats of serious or irreversible harm to the marine environment, then lack of full scientific certainty should not be used as a reason for postponing measures to prevent harm” (Section 8 (3)(b)). So, to act in a precautionary manner is to safeguard against any irreversible consequences of even possibly mild actions, by preventing them from happening. This approach acts to protect an environment even before all relevant data have been collected, especially so that some future options that later generations might want to explore are not cut off by actions now (Fairweather, 1993).

The precautionary Principle as a theme has influenced many parts of the design of the marine parks network; for example, it is why we need to protect much of our coastline whilst it is still in relatively good condition and it also is why aspects like replication feature in the network design. In terms of key performance indicators of the network, we have successfully incorporated large park areas into the network (46% of State waters), increasing the likelihood that more and larger habitats, more species and a greater number of individuals of each species are included within the boundaries (The Scientific Peer Review Panel for the NRSMPA, 2006). The Scientific Peer Review Panel for the NRSMPA (2006) state that developing larger marine parks minimises the risk of leaving out unknown aspects of biodiversity (thus being precautionary), and that by protecting more of the local ecosystem, larger marine parks are less prone to the risks of failing to meet biodiversity objectives.

The key performance indicator using the area or shore length of unmapped habitats as a measure of being precautionary has also successfully been met, but the application of the precautionary Principle goes further than that. It is a fundamental concept that applies throughout the planning for outer boundaries and will continue to do so for zoning and management planning. An extension of the usage of this Principle for the future will be in creating an impetus for other managers with responsibilities in the marine environment to also be precautionary to reduce their likelihood of impacting upon marine parks. The *Marine Parks Act 2007* mandates such a role by amending other Acts to include the requirement to seek to further the objects of the Marine Parks Act.

6.2.2 Comprehensiveness, adequacy and representativeness (CARs)

South Australia’s network of multiple-use marine parks has been designed using the eight recognised bioregions of the State’s seas as a foundation. To be comprehensive, the network needed to include appropriate examples of each of the habitats and features that are known to occur in each of the bioregions. The network achieves that goal for all habitats that dominate each bioregion, and for almost all habitats that occur in relatively small amounts. In only 2 instances spatial information suggests that inclusion is not completely comprehensive. In the Murat Bioregion the network does not include boulder beach habitat. In the Otway Bioregion, the boundaries do not include saltmarsh habitat. In the case of the boulder beach habitat, it is present in a single instance in the Bioregion and that is less than 1 km long. In the case of saltmarshes in the South East, that habitat is largely located above MHW but almost entirely excluded from availability because the small parcels that exist occur on privately held or licensed lands and are beyond the scope of the *Marine Parks Act* 2007.

Superficially, representativeness has similar meaning to comprehensiveness (i.e. representing all of the habitats that occur in a region of interest). To be truly representative, however, the network needs to cater for the variety of life that occurs within each bioregion and it operates at a much finer level of resolution than comprehensiveness does.

Using habitats as the surrogate for biodiversity, representativeness introduces the nuance of how communities differ because of the relative importance or dominance of that habitat within a region and through the influence of different physical environments.

One of the key elements of representativeness at a bioregional level, is that of proportionality, which implies that the total area set aside for protection should approximately reflect its relative prevalence in the region (if seagrass constitutes 40% of the bioregion, it should constitute approximately 40% of the designed network for that bioregion). General percent targets are often promoted as important for marine park design but the South Australian approach has been to target proportionality within marine parks for the following reason (first introduced in section 4.4), if a target to protect 20% of the marine environment was adopted, then 20% of each habitat type would be included for a bioregion. If a habitat actually constitutes 50% of a bioregion, then the network in that case would include only one fifth of that habitat, which would under-weigh its local ecological significance (example taken from Roberts *et al.*, 2003). Based on an assessment of proportionality using dual bar graphs and pie charts, the proclaimed network of marine parks delivers successfully against representativeness in this case.

Ecologically, there is no question that the biotic assemblages associated with habitats in sheltered and exposed places, or deep and shallow water, differ noticeably. How representative the network is, depends on how well each habitat is represented across the diversity of physical environments within which it occurs. The network was designed to include habitats across the spectrum of depths and wave exposures within which they are known to occur in South Australia. From the results, the network successfully represents habitats across those gradients in almost all instances. Where the network does not include particular habitats at a certain depth (e.g. some deepwater instances of seagrass in some bioregions), the presence of that habitat is in very small amounts and the inclusion of significant areas of unmapped habitat creates the possibility that it is, in fact, included if it is a proportionally more prevalent feature than is currently known.

Adequacy addresses the difficult question of extent and degree of protection that will ensure viability of populations, species and communities (Scientific Peer Review Panel for the NRSMPA, 2006). No precise basis exists for determining criteria that provide for adequacy before zoning and management plans are in place or, ideally, protection has been applied for some time. However, a number of factors are predicted to contribute to adequacy in marine parks including the size, shape, replication, connectivity, and the degree of management of threats within and outside a network of marine parks (The Scientific Peer Review Panel for the NRSMPA, 2006). Given only the outer boundaries of the marine parks have been proclaimed, it is impossible to assess how adequate the protection afforded by those boundaries really is. For the moment, some gross correlates of marine park success like the size can be discussed but these will essentially remain predictions to be assessed after the network is established and management plans are in place and have been given time to function.

The published literature on MPA design suggests that networks should include at least several large marine parks rather than just a greater number of small marine parks to maximise biodiversity conservation success (e.g. The Scientific Peer Review Panel for the NRSMPA, 2006; PISCO, 2007). Large parks are important to provide protected habitat large enough for populations to persist. Generally, the marine parks that make up South Australia’s network meet that design criterion. The largest of the proclaimed parks is nearly 3,500 km^2 and, together, the whole network establishes the opportunity to manage over 27,000 km^2 of South Australia’s waters to achieve the objects of the *Marine Parks Act 2007*. The smallest parks are around the Neptune and Gambier Islands and in each instance these parks are designed to incorporate the whole island environment and to include the deepest waters around them. Comparing the achievements to other parts of Australia, including 46% of State waters aligns South Australia with Queensland and creates the opportunity for the state to become a leader in marine biodiversity conservation nationally and internationally (see Wood *et al.*, 2008).

Another factor contributing to adequacy was the incorporation of coastal land in the landward boundaries of the marine parks. As described in Section 5.2.3, the inclusion of coastal land allowed whole ecosystems or habitats to be incorporated within the network, maintaining ecosystem integrity and thus increasing the potential of achieving adequacy. Other likely predictors of adequacy (like redundancy and connectedness) are also picked up under the biophysical Design Principles ‘Connectivity and linkages’, ‘Resilience and vulnerability’, and ‘Ecological importance’. Adequacy can most directly be achieved in the long term through effective implementation of marine parks zoning and management plans and through the mitigation of external risks and threats, such as land-based pollution and catchment runoff.

6.2.3 Connectivity and linkages, ecological importance, resilience and vulnerability

6.2.3.1 Connectivity and linkages

The IUCN-WPCA (2008) states that well planned networks of marine parks provide important spatial links needed to maintain ecosystem processes as well as improve resilience by spreading risk in the event of localised disasters, climate change and other hazards. Marine organisms have varied abilities to move from one place to another either as larvae being transported by water movement or as adults, with some species dependent on the same reef or bay from birth to death, and others moving over thousands of kilometres. Given the variety of connectivity ranges that need to be catered for, marine parks need to be placed at varying distances away from each other and be large enough to cater for different dispersal ranges within and between marine parks in the network. The 19 marine parks form an effective network, with 28 individual areas (of different size ranges), located within and between each marine bioregion across the State (from the Western Australian to the Victorian Border).

The Principle of connectivity and linkages has been met for organisms with both long and short dispersal ranges relative to the extent of State waters. The network designed for South Australia facilitates connectivity from 0 km to more than 1,000 km, catering for connectivity at the ocean scales identified above and also for connectivity across the distribution ranges identified by Gillanders *et al.* (2003), Kinlan and Gaines (2003) and Palumbi (2004), who estimate dispersal capability in marine life to predominantly range from 0 to 100 km in the majority of instances.

In addition, the marine parks network provides for connectivity and linkages between the land and sea through the inclusion of coastal ecosystems and habitats in the landward boundaries of the marine parks. For example, estuaries and coastal wetlands, both vegetated (mangroves, salt marshes, and seagrass beds) and unvegetated (mudflats and sandy beaches), form critical linkages between land, freshwater habitats and the sea. As well as providing for the movement of different marine organisms, these environments, in particular estuaries, are also well known for filtering, processing and/or exporting organic nutrients and sediments to and from adjacent marine habitats (DEH, 2007; Fairweather and Quinn, 1992; Turner *et al.*, 2004). According to Roberts *et al.* (2003), ecosystem linkages between the land and sea, to date, have not had extensive investigation or use in the decision making process of designing and setting up marine parks and reserves. Including landward areas in marine parks provides for important buffers and linkages over mean high water with dynamic estuarine, beach, bay and ocean areas. Roberts *et al.* (2003) state that “areas that link with and support other systems have a greater value than those that do not; similarly, sites that depend on links with other systems are vulnerable unless these places are also protected”.

Another key influence on connectivity and linkages in the marine environment is the physical oceanographic processes that occur such as the major current systems, waves and tides. The IUCN-WCPA (2008) state that water currents that transport organisms from one location to another help facilitate connections between populations (although most species do not ride the currents passively). Roberts *et al.* (2001) recommend that to compensate for constantly changing ocean conditions, MPAs should be located in a wide variety of places in relation to the prevailing currents. The marine parks network caters for the connectivity and linkages between and along the major current systems in South Australia (as identified earlier from Middleton and Bye, 2007) by including marine parks from border to border across the entire State. Further research into the influence of the South Australian current systems on the transportation of organisms and other materials in the marine environment will help gain further knowledge about the connectivity and linkages within the marine parks network. Further exploration of the connectivity and linkages within the marine parks network is also planned through the utilisation of oceanographic modelling software such as AusConnie, which has been developed by the CSIRO.

Fairweather and Quinn (1992) state that organisms, organic matter, nutrients and energy can be transferred within the marine environment through a variety of ways including between nearshore coastal and oceanic pelagic waters; the surface of the ocean and the sea floor, from fresh waters to the sea via estuaries; onshore and offshore habitats via recruitment and to and from a variety of benthic habitats. The marine parks network successfully caters for all of these connections and linkages across the State’s marine environment.

6.2.3.2 Resilience and vulnerability

Resilience is regarded as a critical concept in MPA development today (IUCN-WCPA, 2008). Places and habitats that are resilient to, and/or resistant to change are important to include in MPAs given they are more able to endure and adapt to new circumstances. It is also important to provide protection for habitats and species that are less resilient or more vulnerable to impacts. How resilient communities can be depends on intrinsic factors (such as biological traits that create resilience) and extrinsic factors (such as the physical place they occur) and both need to be considered (IUCN-WCPA, 2008).

By including the full range of habitats that occur in each bioregion, the network of marine parks creates the opportunity to protect the health of examples of each of them and the expectation is that healthy systems will be more resilient to change. At the same time it is important to include multiple examples of each habitat so that the network is buffered against network level extinction of any feature if a significant impact was to remove a whole habitat. The network proclaimed for South Australia includes multiple examples of each benthic habitat type, including those identified as vulnerable (saltmarshes, mangroves, seagrass beds and estuaries), within each bioregion and across the physical gradients in which they occur.

Although replicate examples of each habitat type have been included across the network, further research is needed to determine whether they are truly independent replicates (and therefore create resilience). Further research and analysis is required to determine how far away each of the replicate habitat patches are from each other, as any catastrophic impacts might affect more than one patch if they are in close proximity. It also needs to be determined whether the habitat patches separated at larger spatial scales can truly be viewed as replicates. Further research will help to determine if patches of the same type of habitat found in similar environmental and physical gradients (e.g. depth, water temperature) are similar in terms of their biological characteristics (e.g. species diversity). Another determinant is whether a discrete patch of habitat actually represents a viable habitat in terms of its ecosystem functioning, as the average size of the habitat patches ranged from 1 km^2 in the case of granite and limestone reefs, to 10 km^2 for seagrass habitats. In the case of the seagrass habitat patches, although there were fewer replicates than for some of the other habitat types, as the average size of the patches were relatively large, it could be argued that whilst it is yet to be determined whether they provide redundancy, they provide resilience through buffering from edge effects, the influence of off-reserve impacts and to guard against local catastrophes.

The reason the South Australian Government has chosen to create large multiple-use marine parks is also linked to the concept of resilience. If the objective of biodiversity conservation is to protect proportions of the sea in an undamaged state, it is necessary to account for the fact that some places will be recovering from disturbance at any given time. It follows, then, that the proportion of a region protected should be greater than the fraction of the sea to be retained as undamaged, and that the undamaged sites are buffered as well as possible from outside influence (Roberts and Hawkins, 2000). Multiple-use marine parks provide the most effective means of creating that buffering effect because the highly protected places can be buffered by areas of moderate protection, distancing the most significant external risks from the core protection areas.

In addition, the inclusion of coastal land in the landward boundaries of marine parks also plays a role in providing resilience to the impacts of climate change, particularly sea level rise. For example, as areas of coastal saltmarsh (as well as land behind saltmarsh) have been included within the network, the network should provide for the inland migration of those habitats with increasing sea levels and therefore increase their resilience to climate change.

6.2.3.3 Ecological importance

The concepts of building a comprehensive, adequate and representative system of MPAs are founded on including examples of all of the habitats and ecosystems in similar proportion to that existing in the region of interest. For certain features, however, marine parks should seek to include them in disproportionate abundance because they are particularly important to biodiversity conservation. Obvious examples of those features include rare or endangered plants and animals.

Failing to include ecologically important places in a network of MPAs would mean that the network is probably not catering for the species most in need of protection or the places most likely to ensure the viability of the protected area network over the long term, such as key spawning or nursery environments or feeding places for different species (IUCN-WCPA, 2008).

South Australia’s network of marine parks is designed in a way that includes the majority of places known to be important ecologically. For example, 82% of islands, 100% of known southern right whale aggregation areas, 98% of COSEMA sites and 69% of identified conservation hotspots are included within the network. In addition, 86% of the Australian sea lion, New Zealand fur seal and Australian fur seal sites known to occur in South Australia are included within the network, together with some of their important foraging places (e.g. Denial Bay near Ceduna). Apart from species specific features, the network performs well as a conservation initiative that includes ecologically important habitats such as estuaries and known nursery areas (e.g. Franklin Harbor, Venus Bay and Tourville Bay).

Conservation planning software was used to audit how well the network includes ecologically important places. For each bioregion, the software was asked to generate 1000 alternative solutions that would achieve the same level of protection as the boundaries do (i.e. 46% of State waters). Marxan derived areas of irreplaceability were identified from the process as sites that contained at least one 1 km^2 cell that was selected every time by the program, as a measure of those sites that are irreplaceable. Across the bioregions, 90 areas of irreplaceability were identified by the software and 86% of those were located within the proclaimed network. Several of the Marxan derived areas of irreplaceability outside the network benefit from other protection strategies such as the Barker Inlet Aquatic Reserve and Adelaide Dolphin Sanctuary.

6.3 Meeting community expectations

Apart from the need to give careful consideration to sustainable growth, upon which South Australia depends, the marine parks program has an intergenerational obligation to recognise the needs of future generations. The ecosystem services provided by healthy marine environments are paramount to sustainability and conservation has an important role to play if ecosystem health is to be well understood and therefore well protected into the future.

6.3.1 Seek synergies with existing protected areas and complementing existing management

Seeking synergies with protected areas in marine parks design helps to buffer the marine environment from land based impacts, as terrestrial protected areas should have less impact on the marine environment than other more heavily used areas. Marine parks with existing protected areas also help to provide ecosystem linkages from the land and sea and avoid unnecessary duplication of protected areas, which minimises the additional restrictions placed on the community to use and enjoy the marine environment. The proclaimed network successfully aligns marine parks with terrestrial parks and other forms of marine protected areas.

The success of MPAs depends on their integration with broader and complementary management strategies. The protected area is, by definition, bound to a place within a fluid and dynamic system and all that happens on land and outside the maritime boundaries of an MPA can impact on the health of the MPA. To make sure that our network of marine parks is successful, and that it does not introduce new risk to other resource management, the network must be imbedded in an integrated framework of management that shares responsibility with Natural Resource Management Boards, Local Governments and targeted primary industry sectors such as fisheries, aquaculture and mining. How marine parks management plans are developed and regulated will play a pivotal role in achieving the integration necessary for success.

6.3.2 Give consideration to the full diversity of marine uses

The desire to minimise inconvenience or displacement extends to all uses and activities. Whilst the full diversity of marine users was a consideration in the development of the outer boundaries of the marine parks network, the achievement of this Design Principle for many uses (such as recreational fishing and diving) is more applicable to zoning development than to boundary design. However, particular consideration was given to a number of key marine uses including commercial fishing and aquaculture.

South Australia’s wild-catch fisheries and aquaculture sectors are a valuable component of the State’s economy and maintaining ongoing opportunity for them to sustain and grow is important. Our aquaculture industry has been responsible for significant growth in the seafood sector over the past decade and is an important producer of some species at an international scale (e.g. southern bluefin tuna). Our wild-catch seafood sector includes fisheries targeting western king prawns, giant crabs, abalone, a variety of scalefish species, blue swimmer crabs, rock lobster and sardines, the latter being the largest fishery by volume in the country.

The establishment of the outer boundaries of South Australia’s marine park network does not impact either seafood sector. All activities and uses will continue to occur as they have done in the interim period between the proclamation of boundaries and the establishment of management plans for each park. While the outer boundaries do not displace any effort, and although the Government has committed in law to compensating displaced effort, it is important to provide as much certainty as possible to industries during each step of the program. Accordingly, overlap with valuable fishing areas has been minimised where doing so has not created significant impediment to the conservation objective of the program. In particular, for fisheries with the greatest level of uncertainty about how much access may be granted to multiple-use areas, the network overlays relatively small proportions of their most important catch areas. For example the fishing blocks from the Spencer Gulf Prawn Fishery which make up 95% of the total average catch over the last five years, have only 15% of those blocks included in the marine parks network. The Gulf St Vincent prawn fishery only has 2% of its high value blocks included in the network.

In other fisheries, more significant overlay occurs. For example the western zone abalone fishery has 65% of its valuable area overlain and the southern zone rock lobster fishery has 67% overlain. Significant overlap with fisheries does not necessarily signify areas of significant or likely displaced effort (especially as the fishing blocks data layer is a simple overlay indicating areas of high use, rather than specific fishing sites), and only helps to identify that a collaborative approach to marine park management planning will be necessary to ensure that displaced effort can be avoided or kept to a minimum through effective zoning.

6.3.2.1 Recognising existing uses

At this early stage in the marine park development process, the South Australian Government has made a range of policy commitments to both industry and recreational sectors. The Government has made formal commitments relating to recreational and commercial fishing, aquaculture, development, infrastructure, shipping and mining, which will be honoured during the zoning and management planning phases of the program.

Recreational fishing will be provided for in all marine parks, with the exception of some zones or periods of time where fishing will not be permitted. The Government has made a commitment that recreational fishing upon, or access to, any jetties, breakwaters or boat ramps will not be affected by the creation of marine parks. Recreational fishing opportunities at iconic locations such as Greenly Island, Browns Beach (Yorke Peninsula), Waitpinga Beach and the Murray Mouth will be accommodated, and important events like the Whyalla Snapper Competition and Kingston Surf Fishing Competition will also continue to be enjoyed.

As reflected in the figures mentioned above, the Government has made a commitment that a portion of each commercial fishery will be located outside the network and that marine parks zoning will aim to minimise displacement of commercial fishing. In the cases where displacement is unavoidable, compensation for displaced commercial fishing effort will be paid after management plans with zoning arrangements are finalised.

The Government will accommodate fishing in specific locations including: identified high use prawn trawling blocks seaward of St Peters Island, the mouth of Coffin Bay, the south east corner of Sir Joseph Banks Group and seaward of western Yorke Peninsula; identified high use rock lobster blocks west of Kangaroo Island, around the toe of Yorke Peninsula and between Coffin Bay and Thorny Passage on the lower Eyre Peninsula; haul netting in shallow waters (less than 5 m) of the Upper Spencer Gulf Marine Park, Upper Gulf St Vincent Marine Park and the Franklin Harbor Marine Park; Goolwa cockle fishing in the Coorong beach area and mud cockle fishing in the Coffin Bay and Venus Bay quota zones.

The policy commitments to the commercial fishing industry relate to the outer boundaries and are a first step in addressing industry issues. These commitments are not an exhaustive list of the arrangements that will be finalised through consultation. Other issues may be raised and discussed throughout the marine parks development process.

For aquaculture, the Government has made a commitment that no existing aquaculture activities will be displaced as a result of a marine park proclamation or future marine park zoning arrangements. There will be no additional approval processes or permits for existing leases and zones, and pilot leases will be accommodated where they are consistent with the marine park management plan. Where they are not consistent, a special permit may be available. Minor movement of existing aquaculture sites within marine parks for normal farming needs or environmental changes will also be accommodated.

The Government will accommodate aquaculture in proposed aquaculture zones: in identified waters offshore from Boston and Tumby Bays (but not within buffers around sea lion colonies in the Sir

Joseph Banks group of islands); near the mouth of Franklin Harbor; adjacent to Fitzgerald Bay; and offshore from Point Turton in Hardwicke Bay. Aquaculture will also be accommodated in proposed zones in deeper waters east and west of St Peters Island near Ceduna and at the mouth of Coffin Bay. Aquaculture will also be accommodated for in proposed zones in waters yet to be identified between Point Pearce and Wardang Island for the interests of the Narungga community and in waters offshore from Corny Point.

For development, shipping and infrastructure, existing and future development and infrastructure needs will be accommodated. Approved coastal developments, including associated activities such as dredging and installation of infrastructure can be provided for within marine parks through suitable zoning arrangements or other concessions. All shipping and harbour activities will also be accommodated within marine parks by appropriate zoning arrangements.

In relation to mining, petroleum and geothermal resource industries in marine parks, all existing licences and leases will be accommodated by zoning or special purpose areas, with no changes to existing conditions. For applications for new (or the renewal of existing) licenses, leases and permits, the Minister for Environment and Conservation must agree to the approval of the application. In the cases where the application is consistent with zoning regulations, no further approvals or permits will be required.

6.3.3 Catering for cultural expectations and needs

The marine park network includes a range of sites of cultural significance within its boundaries, providing extra opportunity for protection. Sites occurring within the boundaries include Aboriginal heritage sites, shipwrecks, lighthouses and other cultural monuments.

In addition to incorporating Aboriginal heritage sites within marine parks, the South Australian Government is committed to providing for indigenous interests (such as traditional fishing) within the marine parks network. This commitment was incorporated within the *Marine Parks Act 2007*, where the Government must (when developing a management or zoning plan) seek the views of a representative of all signatories to any indigenous land use agreement (ILUA) that is in force in any area within a marine park. The Government must also seek the views of a representative of any native title holders or claimants that have a native title determination or registered native title claim. Any prohibitions or restrictions applying within a marine park are also subject to native title and native title rights and interests. One of the principles for achieving ecologically sustainable development within the *Marine Parks Act 2007* is to consider Aboriginal heritage and the interests of the traditional owners of any land or other natural resources. It is also a requirement in the marine parks legislation that one of the members of the Marine Parks Council of South Australia (established under the Act) must be a person with extensive knowledge of indigenous culture in relation to the marine environment.

Discussions and negotiations between Government and Aboriginal communities in relation to fishing ILUAs has been the catalyst for the interpretation of section 211 of the *Native Title Act 1993* (which describes the preservation of native title rights and interests) in relation to South Australia’s marine parks. In order to cater for Aboriginal Traditional Fishing Rights in marine parks, the South Australian Government will provide for the exercise of traditional fishing rights in any marine park zone, with the exception of ‘Restricted Access’ zones (as defined in the *Marine Parks Act 2007*). Restricted access zones will only be established for the explicit purposes of research, environmental protection, public health or public safety.

6.3.4 Catering for compliance and enforcement, education and appreciation

Whilst the boundaries have been designed at this stage in the process to, as far as practicable (whilst meeting all other Design Principles) ensure ease of identification, compliance and enforcement, the real test of this Design Principle is more applicable to the zoning and management plan implementation phase of the program. It is envisaged that in addition to the boundary design described in section 5.3.6, this Principle will be further met by providing GPS points to the community for each marine park, using on-water marker buoys at select locations and having marine park rangers available to educate the community.

Additional opportunities for education, appreciation and recreation in the implementation phase of the program will likely include educational and interpretive information and signage at marine park locations; increased opportunities for tourism, particularly ecotourism; additional field sites established for community monitoring programs (such as Reef Watch) within marine parks; and opportunities to join other community volunteer programs such as Friends of Parks.

7 Conclusion

The establishment of representative systems of MPAs is regarded, both nationally and internationally, as one of the most efficient mechanisms for protecting marine biodiversity and ensuring the integrity of natural systems is sustained. By proclaiming the outer boundaries of South Australia’s marine parks network, the South Australian Government has taken a significant and important step towards a comprehensive, adequate and representative system of MPAs for the State and the proclamation represents a major advance in biodiversity conservation management. The network has not been proclaimed in response to threats but rather in response to the need to act now to be sure that the healthy marine systems we enjoy and benefit from today provide the same prosperity for future generations.

The establishment of practical and effective management plans for each of the 19 marine parks will determine the true success of the network as a biodiversity conservation measure. The outer boundaries successfully represent a comprehensive set of examples of the environments of each of our bioregions and create the opportunity for those management plans to succeed. If successful, South Australia can expect the network to:

- conserve our biodiversity and ecosystems;
- help maintain the genetic diversity of our marine plants and animals;
- protect rare and threatened species and communities;
- make significant contributions to scientific knowledge;
- create tourism and other business opportunities; and
- provide an important tool to improve how we integrate the use and management of our marine environments and the resources they provide.

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9 Appendices

9.1 Appendix 1 – Shoreline classifications, grouping by class

Table 31 displays the shoreline classifications contained in the shoreline classification GIS dataset. The shoreline classifications were grouped from 21 classes into 12 for running statistical analyses and then further grouped into three classes for graphical display purposes.

Table 31: Shoreline classification type, grouping by category

Shoreline Classification (OSRASHORE)	**Broad Shoreline Class (Grouped)**	**Shoreline Class (3 groups)**
Artificial	**Not used**	**Not used**
Bedrock platform	bedrock platform	**Rock**
Boulder beach	boulder beach	
Cliff high	cliffs	
Cliff low		
Cliff medium		
Coarse sand beach	coarse sand beach	**Sand**
Cobble beach	pebble & cobble beach	
Pebble beach		
Fine-medium sand beach	fine-medium sand beach	
Mixed sand-cobble / pebble beach	mixed beach	
Mixed sand-shellgrit beach		
Mixed sand-shellgrit beach		
Sand dunes stable	sand dunes	
Sand dunes unstable		
Mudflats (LITZ) consolidated (firm)	mudflats and sandflats	**Mud**
Mudflats (LITZ) unconsolidated (loose)		
Sandflats (LITZ)		
Saltmarsh	saltmarsh	
Mangrove	mangrove	
Seagrass intertidal/shallow emergent	intertidal seagrass	

9.2 Appendix 2 – List of GIS data layers used in boundary development

Table 32 displays the list of GIS data layers considered during the marine parks network design process.

Table 32: List of GIS data layers used in the marine parks network design process.

Category	Dataset title	Description and source (scale and accuracy)	Last updated	Data custodian
Habitat layers	Marine Benthic Habitats	Marine Habitats mapped as part of a National seagrass marine habitat mapping program undertaken by CSIRO.	25 March 2004	DEH
	Coastal Shoreline Classification	Classification of the South Australian shoreline based on substrate, form, exposure and biological character.	7 March 2007	DEH
	Coastal Hazard Areas	Geomorphic assessment of the coastal landscape. Contains coastal areas that have been assessed as being at risk of flooding or erosion.	3 July 2007	DEH
	Ramsar Wetland Areas	All wetlands within these areas are of international importance protected by the Ramsar Convention.	5 November 2005	DEH
	Estuaries of South Australia	This dataset contains Estuaries of South Australia identified in the draft Estuaries Policy and/or estuaries identified for the National Land and Water Audit.	8 June 2007	DEH
	Coastal Saltmarsh and Mangrove Mapping	Mapping of individual coastal saltmarsh and mangrove habitats throughout Sout Australia, providing landform, lifeform and condition categories.	12 November 2007	DEH
Habitat layers	Islands of South Australia	This data set contains islands of South Australia identified in South Australia's Offshore Islands, Commonwealth of Australia, DENR 1996.	1 September 2008	DEH
	SA Wetlands of National Importance	Identifies the location of South Australian wetlands cited in "A Directory of Important Wetlands in Australia" Third Edition (EA, 2001), plus additions for wetlands listed after 2001.	18 September 2006	DEH
	Topography - Intertidal Flats	Data layer consists of a broad indication of the intertidal zone. It includes sand or mud flats which are predominantly devoid of seagrass.	27 September 2006	DEH
	Fish Habitat	Displays data collected for Bryars (2003) .		PIRSA
Oceanographic layers	Topography - Bathymetry - Navigation Chart	Bathymetry contours digitised from the Australian Navigation charts for South Australian State Waters (i.e. out to the three nautical mile limit).	1 December 2003	DEH
Geographic layers	Australian Maritime Boundaries	This data set defines the limit of Australia's maritime zones as constructed and maintained by the Maritime Boundaries Program within Geoscience Australia (GA).		
	SARSMPA Identifying Proposed Locations	Areas surrounding these point locations are to be investigated as potential sites for the establishment of the South Australian Representative System of Marine Protected Areas. Descriptions taken from Baker (2004).	1 April 2005	DEH
Administration Boundaries	Admin - Statewide Crown Land	Parcels held by Department for Environment and Heritage for the Crown, parcels in the care, control and management of the Department for Environment and Heritage (includes NPW Act parks and reserves), reserves dedicated in the care, control and management of other government agencies, Local Government or other authorities and land parcels held under Crown lease e.g. perpetual lease, miscellaneous lease and agreements.	24 October 2008	DEH

	Admin - Crownland Annual Licences	The licensed information relates to approvals given to users of recognised Crown land within South Australia for both private and public use.	12 August 2008	DEH
	Natural Resources Management Regions	The Natural Resources Management Boundaries define the area of responsibility for each of the State's eight NRM Boards.	24 November 2006	DWLBC
	DCDB - Local Government Areas	This dataset records the location and extent of the Local Government areas within South Australia and their relationship to the Cadastre.	23 October 2007	DTEI
	National Marine Parks	The spatial and textual information about the Marine Protected Areas (MPA's) under the jurisdiction of the Commonwealth Government's EPBC Act, which are managed by the Australian Government, Department of the Environment and Water Resources.	22 September 2008	C'wealth DEH-ERIN Unit
	Aquatic Reserves	Extent of all Aquatic Reserves in South Australia that have been proclaimed under the *Fisheries Management Act 2007*.	7 April 08	PIRSA
	Rock Lobster Sanctuaries	This dataset delineates the spatial boundaries of Rock Lobster Sanctuaries in State waters.	6 June 2005	DEH
	Topography - SouthAust	Data layers include polygons and lines that represent the State mainland, islands and adjacent ocean. The River Murray and Lower Lakes are included.	7 March 2008	DEH
Biodiversity layers	Seabird Colonies	Seabird locations within South Australia, describing population and breeding seasons, including mainland and offshore islands.	25 March 2004	DEH
	Western Blue Groper Survey Sites	Spatial location for Western blue groper survey sites conducted around coastal waters in four regions.	6 May 2005	DEH
	Coastal Wader Bird Sites	Location of significant wader bird sites along the South Australia coastline, derived from the South Australia Wader Surveys, January and February, Wilson (2000).	16 September 2006	DEH
	New Zealand fur seal colonies	New Zealand fur seal locations within South Australian waters, describing population, breeding season and breeding and haul-out sites for both mainland and island locations. Data was provided by Drs Anthony Robinson, Peter Shaughnessy, Jane McKenzie and Simon Goldsworthy.	6 May 2008	DEH
	Supertable – Fauna	This dataset depicts the spatial locations (points) of all recorded fauna species from the DEH Biological Databases of SA (BDBSA) databases.	19 February 2007	DEH
Species of conservation concern	Australian sea lion Colonies	Sea lion locations within South Australian waters, describing population, breeding season and breeding and haulout sites for both the mainland and island locations.	6 May 2008	DEH
	Australian fur seal Haulout	Australian fur seal haulout locations within South Australian waters. Australian Fur Seal data was supplied to the National Seal Strategies Group by Shaughnessy & Dennis (1994,1998,1999,2003,2004,2006,2007) - DEH Report.	5 May 2008	DEH
	Blue Whale Aggregation Areas	Represents known migration pathways, and aggregation areas of significance for three species of whale includes blue, fin and sei whales in Australian coastal waters. Data capture scale: 1:100,000. Accuracy indicative only.	17 October 2005	C'wealth DEH
	Southern Right Whale Aggregation Areas and Pathways	Known significant aggregation areas and migratory pathways for the southern right whale in Australian coastal waters.	17 October 2005	C'wealth DEH
	Conservation Status of Endangered Marine Algae (COSEMA)	Shows point location of the known distributions of vulnerable Australian macroalgae based on an extensive literature search of previously conducted work. Point locations were obtained with permission from Reef Watch from the COSEMA online database.	1 December 2002	DEH

	Rated Species - Flora / Fauna (Buffered)	These datasets depicts the point location of all recorded species, flora or fauna respectively, from the DEH ORACLE biological database that have a conservation rating as defined by the EPBC Act or the NPW Act.	16 July 2008	DEH
Infrastructure	Stormwater	Contains the location of the stormwater network for Metropolitan Adelaide	1 January 2002	DEH-EPA Head Office DWLBC
	Marine Pointsource Pollution Sites (incomplete)	This dataset contains locations of industrial point source pollution sites which have an EPA licence that states that they can discharge to the marine environment.	Incomplete	DEH
	Topography – Navigation	Data layer includes major features related to marine or freshwater navigation, including lighthouses, marine lights and major beacons.	6 February 2007	DEH
	Topography - Navigation Markers and Channels	Navigation markers and channels from the Transport SA Navigation Marks database - May 2004 extract.	3 May 2004	DTEI
	Topography - Boat Ramp Locations - South Australian Coast	Used as an indicator for the location of boat launching facilities.	1 April 2004	DEH
	Topography - Marina Locations - South Australia Coast	Location of marinas around the South Australian coastline and parts of Lake Alexandrina.	31 January 2007	DEH
	Topography - Mooring Locations - South Australia Coast	Location of mooring areas along the South Australian coastline.	31 January 2007	DEH
	GeoData 250k Topographic Data	Includes the following themes: hydrography, infrastructure, utilities, vegetation and reserved areas.	16 November 2007	Geoscience Australia
	Admin - Port and Harbour Limits	Identifies port and harbor limits along the South Australian coastline.	25 November 2004	DEH
	Topography - Shoreline Constructions	Data layer includes infrastructure features located in the marine or freshwater shoreline zones. Included features: jetty, wharf, breakwater, sea wall, slipway, boat ramp, mooring.	23 May 2007	DEH
	Ferry Route (no metadata)	Ferry route between Cape Jervis and Penneshaw.	Incomplete	DEH
	Marine Underwater Infrastructure/Submarine Cables (no metadata)	Generally identifies locations of pipelines in State waters; i.e. it identifies the locations of North Spencer Gulf. Gas pipeline Morgan to Whyalla and the Electrical cable from Deep Creek to Kangaroo Island.	Incomplete	DEH
	Topography - Roads	The dataset has been compiled from a combination of DCDB road centreline data and topographic road data.	14 August 2008	DEH
	Coastal Shack Sites	This dataset contains point locations of identified shacks along the South Australian coastline.	22 December 2006	DEH
Industry	Netting Closures - South Australian Coastal Waters	Defines the location and extent of waters in which the use of fish nets are prohibited pursuant to *Fisheriens Management Act 2007*	12 October 2005	PIRSA
	Aquaculture Zones	This dataset contains all current aquaculture zones and aquaculture exclusion zones in South Australia which are declared under the *Aquaculture Act 2001*.	8 November 2007	DEH
	Admin - Australian Sea lion	This dataset identifies Aquaculture Exclusion Zones and Risk Assessment Zones put in	8 June 2007	DEH

	Colonies 5 and 15km Aquaculture Exclusion and Risk Assessment buffers	place to guide the location of future finfish aquaculture, within the vicinity of significant sea lion colony sites.		
	Aquaculture Licence and Lease Boundaries	The location and extent of aquaculture licence and lease boundaries as administered under the *Fisheries Management Act 2007*.	24 September 2008	PIRSA
	Fishing Blocks – Abalone	This data set shows the spatial boundaries of abalone fish blocks used for recording 'catch and effort' data by the abalone fishing industry.	Date acquired 22 March 2002	SARDI - Aquatic Sciences Centre
	Fishing Blocks – Crab	This data set shows the spatial boundaries of crab blocks for the recording of 'catch and effort' data by the crab fishing industry.	Date acquired 22 March 2002	SARDI - Aquatic Sciences Centre
	Fishing Blocks - Marine Scale and Lobster	This data set shows the spatial boundaries of marine scale fish blocks and lobster blocks.	Date acquired 22 March 2002	SARDI - Aquatic Sciences Centre
	Fishing Blocks – Prawn	This data set shows the spatial boundaries of prawn blocks for the recording of 'catch and effort' data by the prawn fishing industry.	Date acquired 22 March 2002	SARDI - Aquatic Sciences Centre
	Australian Maritime Safety Authority (AMSA) - shipping data 2000, 2001 and 2003	Point locations of major ships when they report into AMSA for the Australian Ship Reporting System (AUSREP) which has been designed to contribute to safety of life at sea.	11 April 2005	AMSA
	Exploration Licence Applications for Minerals and/or Opals	Location of all current mineral and/or opal Exploration Licence (applications) issued under the *Mining Act, 1971*.	24 September 2008	PIRSA
	Exploration Licences for Minerals	Exploration Licences provide exclusive tenure rights to explore for mineral and/or opal resources for up to a maximum of 5 years.	24 September 2008	PIRSA
	Mining Production Tenements	Location of all current mining production tenements issued under the *Mining Act 1971* including claims, leases, licences and private mines.	24 September 2008	PIRSA
	Petroleum Exploration Licences/Permits	Location of all current Exploration licences/permits issued under the *Petroleum Act, 2000, Petroleum (Submerged Lands) Act, 1982*, for the regulated resource or commodity of petroleum.	24 September 2008	PIRSA
	Petroleum Production Licences	Location of all current Production Licences issued under the *Petroleum Act, 2000, Petroleum (Submerged Lands) Act, 1982*, or *Petroleum (Submerged Lands) Act, 1967* for the regulated resource or commodity of petroleum.	24 September 2008	PIRSA
	Geothermal Exploration Licences	Location of all current Exploration Licences issued under the *Petroleum Act, 2000* for the regulated resource or commodity of geothermal.	24 September 2008	PIRSA
Cultural	Shipwreck Aquatic Reserves	Boundaries of two aquatic reserves enclosing historic shipwrecks, which have been declared as protected areas under the *Historic Shipwrecks Act 1981* and the *Fisheries Management Act 2007*.	10 August 2005	DEH
	Shipwrecks	This data set is an extract from the South Australian Shipwrecks Database.	28 November 2007	DEH
	National Estate Register	These data provide locational and attribute information for places on the Register of the National Estate (RNE) as determined by the Australian Government Department of the Environment and Water Resources, Heritage Division.	8 May 2008	C'wealth DEH - Australian Heritage Commission
	Heritage Development Plan	Heritage contains all recognised heritage sites within South Australia.	24 September	DEH, PIRSA

	(State Heritage Sites)		2008	
	Geological Monuments	Location of Geological Monuments registered with the Geological Society of Australia.	18 May 2007	Geological Society of Australia Incorporated
	Admin - ILUA (Indigenous Land Use Agreement)	This dataset reflects the boundaries of those Indigenous Land Use Agreements (ILUAs) that have been registered and placed on the Register of Indigenous Land Use Agreements (s199A, *Native Title Act,1993*; Commonwealth).	20 October 2008	DEH
	Indigenous Protected Areas – SA	This dataset details the declared Indigenous Protected Areas across South Australia through the implementation of the Indigenous Protected Areas Programme.	7 September 2006	C'wealth DEH, ERIN unit.
	Native Title Claims Boundaries	This dataset depicts the spatial definition of active claimant and non-claimant native title determination applications and compensation applications.	20 October 2008	National Native Title Tribunal
Recreation	Recreational Fishing Spots	This dataset contains points of popular recreational fishing spots obtained from Pescatore and Ellis, (1998) and the Tourism Eyre Peninsula (2008).	2 May 2006	DEH
	National Recreational and Indigenous Fishing Survey - Fishing Results	The National Recreational and Indigenous Fishing Survey conducted from 2000 to 2001.	16 February 2007	DEH
	Recreational Scuba Diving Sites	Popular recreational scuba diving sites within South Australian State waters. Currently only complete for the Spencer Gulf, Gulf St Vincent and Kangaroo Island.	16 April 2004	DEH

9.3 Appendix 3 – Use of Marxan in conservation planning

Table 33 displays the use of the modelling software Marxan in conservation planning. The table has been adapted from Leslie *et al*., (2003) and other recent literature.

Table 33: The use of Marxan in conservation planning

Location and reference	Approach	Reference or contact
Australia – Great Barrier Reef Marine Park (GBRMP)	Re-zoning of the Great Barrier Reef Marine Park.	Day J., Fernandes L., Lewis A., and Innes J. 2003. Representative Areas Program (RAP) – An ecosystem level approach to biodiversity protection planning. *Paper for items: Manilla, Philippines, March 2003.*
Galapagos Islands (Ecuador)	To further the implementation of the Galapagos Marine Reserve and the associated zoning initiative, and to monitor its performance.	Bustamante, R., Collins K.J, and Bensted-Smith, R. 2000. *Biodiversity conservation in the Galapagos Marine Reserve*. Proceedings of the symposium 'Science for Conservation in Galapagos'. April 15, 1998.
Northwest Atlantic (USA/Canada)	Collaboration between WWF Canada and The Conservation Law Foundation (Boston, MA, USA) to design areas of high conservation value in the Gulf of Maine/Bay of Fundy/Scotian Shelf/Georges Bank/Offshore waters.	Hussein Alidina, Sr. Manager GIS/ Conservation Planning, Marine Program, WWF Canada, Suite 1202 – 5251 Duke Street, Duke Tower, Halifax, Nova Scotia B3J 1P3 Canada. Email: halidina@wwfcanada.org
South Australia	Identification of marine reserve systems to compare solutions that retain existing marine reserve and solutions that can either include or ignore existing reserve	Stewart R.R., Noyce T., and Possingham H.P. 2003. Opportunity cost of ad hoc marine reserve design decisions: an example from South Australia. *Marine Ecology Progress Series* **253**, 25-38.
British Columbia	Exploring the possible configurations of a system of marine protected areas, including fully protected marine reserves, for the British Columbia Central Coast.	Ardron, J., Lash, J. and Haggarty, D. *Modelling a network of marine protected areas for the central coast of British Columbia*. Ver. 3.1. Living Oceans Society. Sointula, British Columbia, Canada. 2002.
Connecticut/New York	MPA designs for Estuary of Long Island Sound.	Amanda E. Wheeler, University of New Haven. 2005.
Florida (USA)	Framework for site prioritization.	Geselbracht L., Torres R., Cumming, G.S., Dorfman D. and Beck M. 2005. *Marine/Estuarine Site Assessment of Florida: A Framework for Site Prioritization.* Final report for Florida's Wildlife Legacy Initiative, a program of the Florida Fish and Wildlife Conservation Commission.
Marine Protected Areas along California's Central Coast: A multicriteria analysis of network design (USA)	Evaluation of the compliance criteria of California's network of MPAs.	Carissa Klein, Allison Chan, Amanda Cundiff, Nadia Gardner, Yvana Hrovat, Lindsay Kircher. 2006.The Bren School of environmental science and management, University of California, Santa Barbara.
The Pacific Northwest Coast Eco-region of USA	Integration of conservation planning for terrestrial and marine systems. Use of a novel threats assessment that included 5 cross-system	Tallis H., Ferdana Z. and Gray E. 2008. Linking terrestrial and marine conservation planning and threats analysis. *Conservation Biology*. 22(1), 120-130.

	threats in a site-prioritisation exercise for the pacific Northwest coast ecoregion.	The Nature Conservancy's eco-regional planning process. In marine Geography: GIS for the Oceans and Seas. J. Breman, ed. Pp. 151-158. Redlands, WA:ERSI.
Papua New Guinea **Kimbe Bay, Papua New Guinea.**	To establish a resilient network of MPAs for Kimbe Bay in Papua New Guinea	Green A., Lokani P., Sheppard S., Almany J., Keu S., Aitsi J., Karvon J.W., Hamilton R. and Lipset-Moore G. 2007. *Scientific design of a resilient network of marine protected areas. Kimbe Bay, West New Britain, Papua New Guinea.* The Nature Conservancy. Pacific Island Countries. Report No 2/07.
Chile	Identification of priority areas for conservation of coastal marine vertebrates in Chile.	Tognelli M.F., Silva-Garcia C., Labra F.A. and Marquet P.A. 2005. Priority areas for the conservation of coastal marine vertebrates in Chile. *Biological Conservation* **126(3)**, 420-428.
North Sea and Irish Sea	Design of MPA networks in the North Sea and Irish Sea.	Roberts CM, Mason L: Design of marine protected area networks in the North Sea and Irish Sea. Unpublished. Available at http://www.rcep.org.uk/fisheries/ReporttoRCEP.pdf.
Continental Caribbean Coast of Columbia	Identifying potential conservation areas in the continental Caribbean coast of Columbia.	Martha Patricia Vides Casado. 2008. *Thesis. Colombian Caribbean marine biodiversity mapping for conservation planning.* International institute for geo-information science and earth observation, Enschede, The Netherlands.
Cuba	Use of a national scale analysis to identify potential areas desirable for a system of MPAs, and to assess the coverage of the existing MPA sites on the shelf of Cuba.	Alidina H.M., Gerhartz, J.L., Areces A. and Regla D. 2005. *Using systematic planning to assess the existing coverage MPAs on the insular Shelf of Cuba.* Presented at the inaugural International Marine Protected Areas Congress (IMPAC 1), Geelong, Australia, October 23-30th 2005.

9.4 Appendix 5 – Comprehensiveness and representativeness graphs for each bioregion

Figure 46 to Figure 59 display the bar and pie graphs for each bioregion for benthic habitats, shoreline class, shoreline exposure, depth class, summer and winter sea surface temperature, and saltmarsh and mangrove habitats.

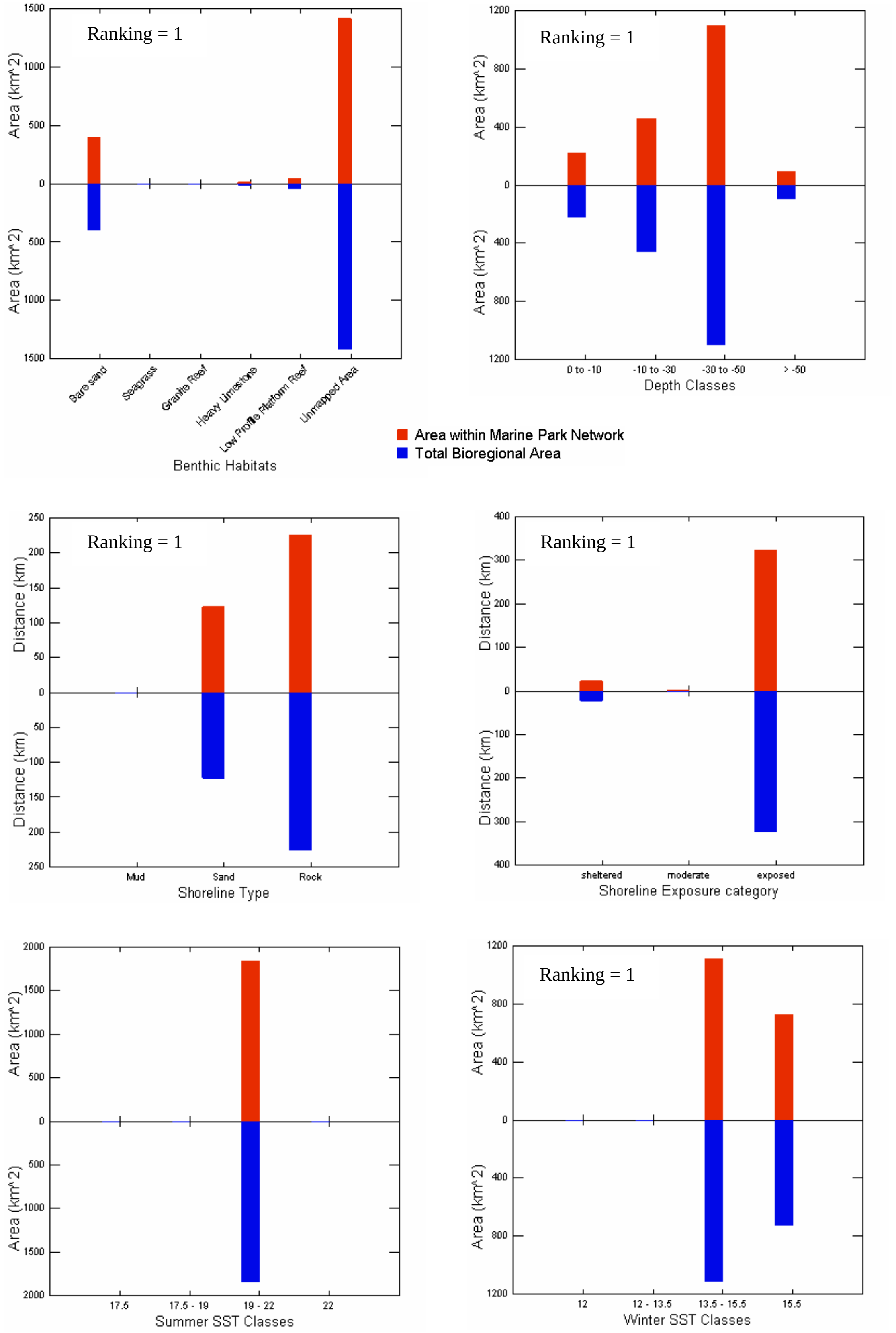


Figure 46: Bar graphs for Eucla Bioregion SST.

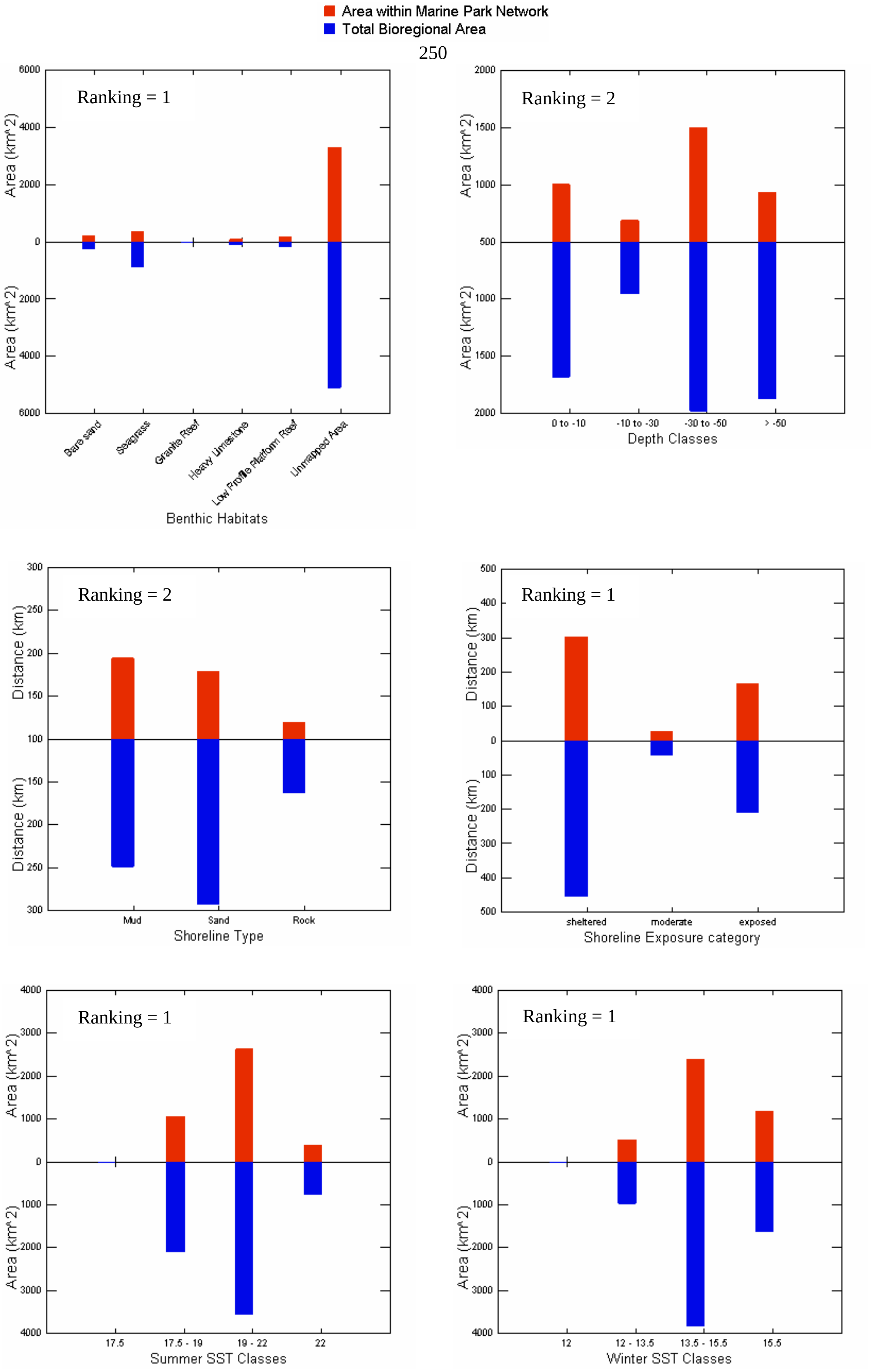


Figure 47: Bar graphs for Murat Bioregion

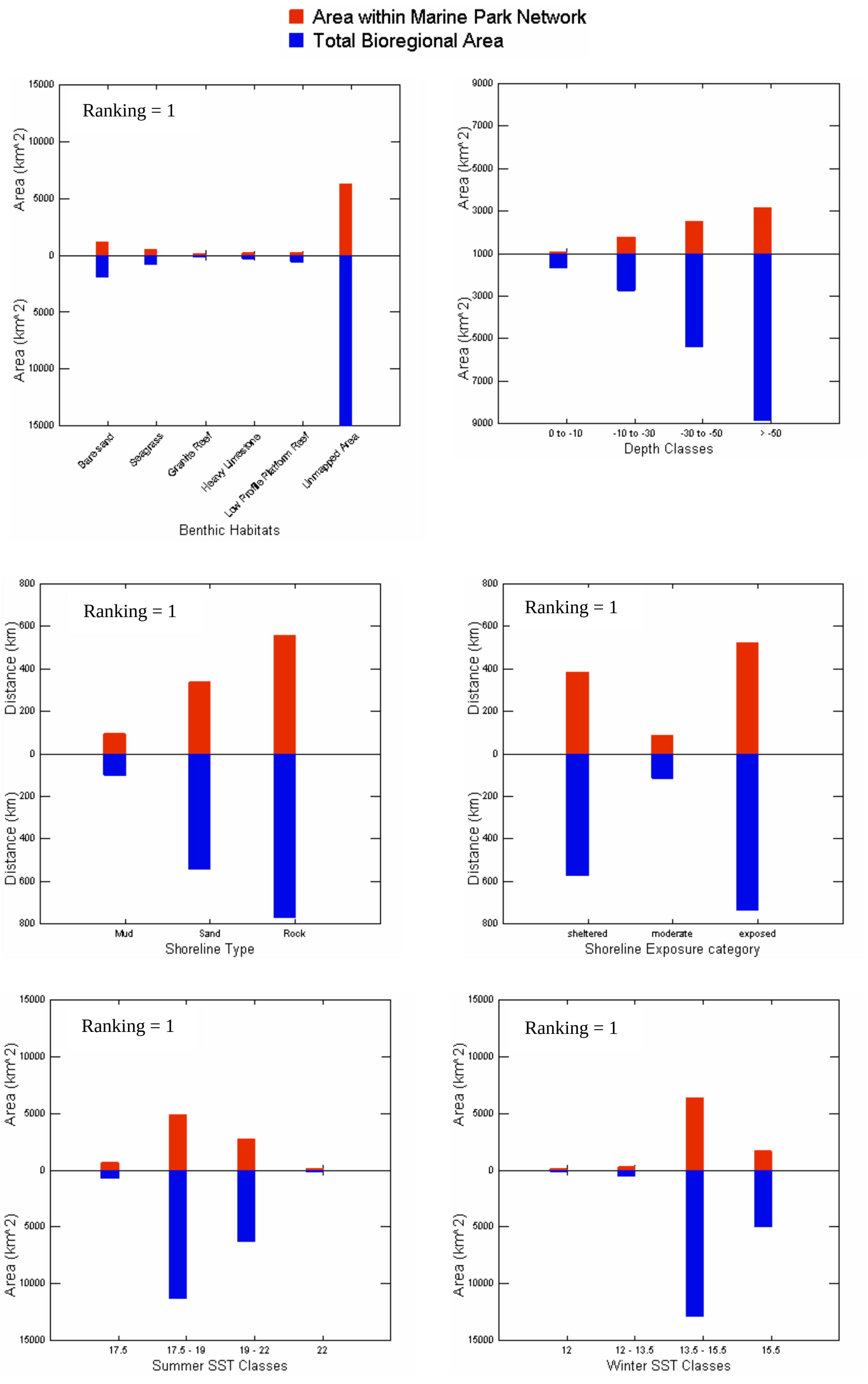


Figure 48: Bar graphs for Eyre Bioregion

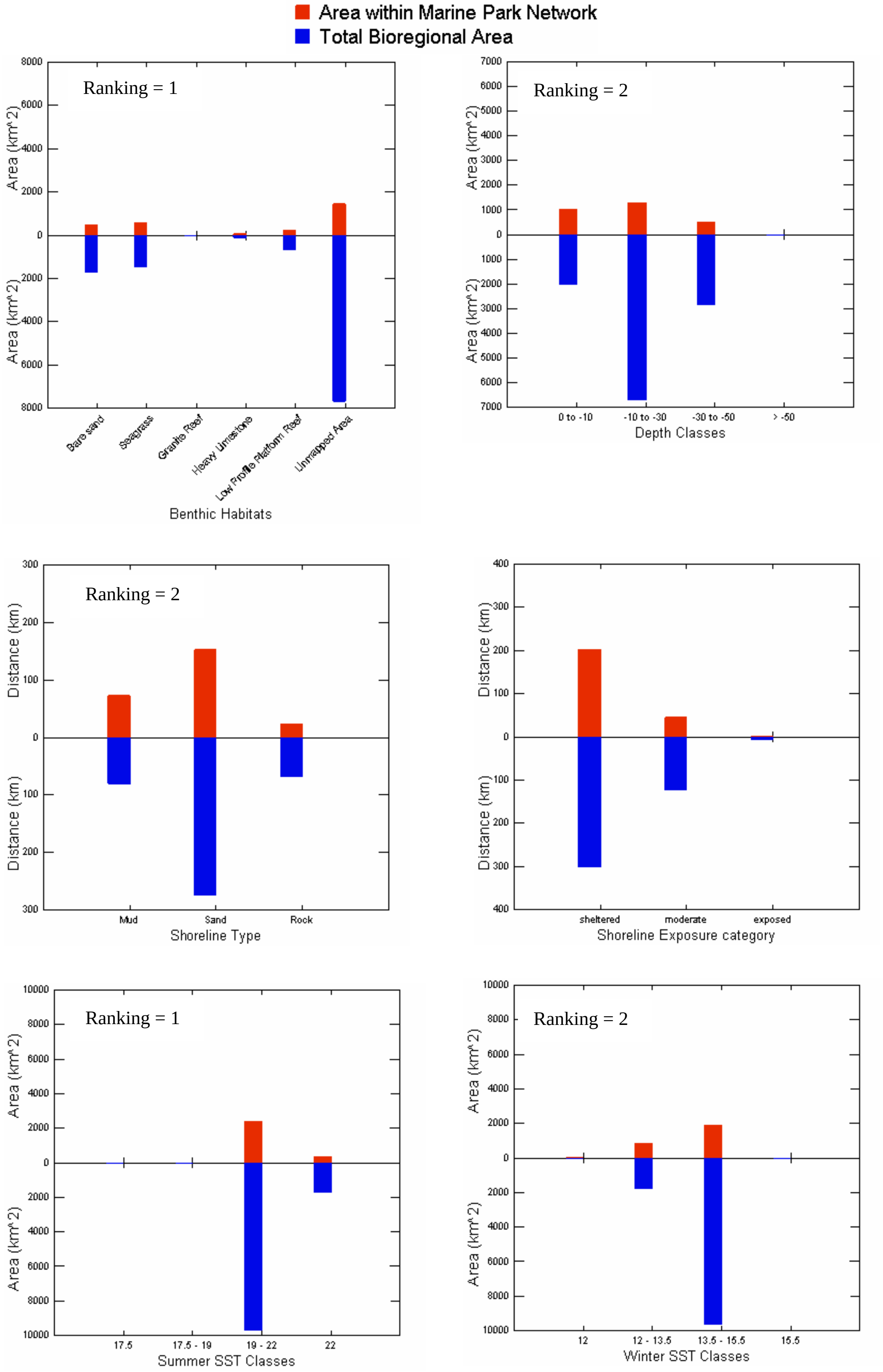


Figure 49: Bar graphs for Spencer Gulf Bioregion

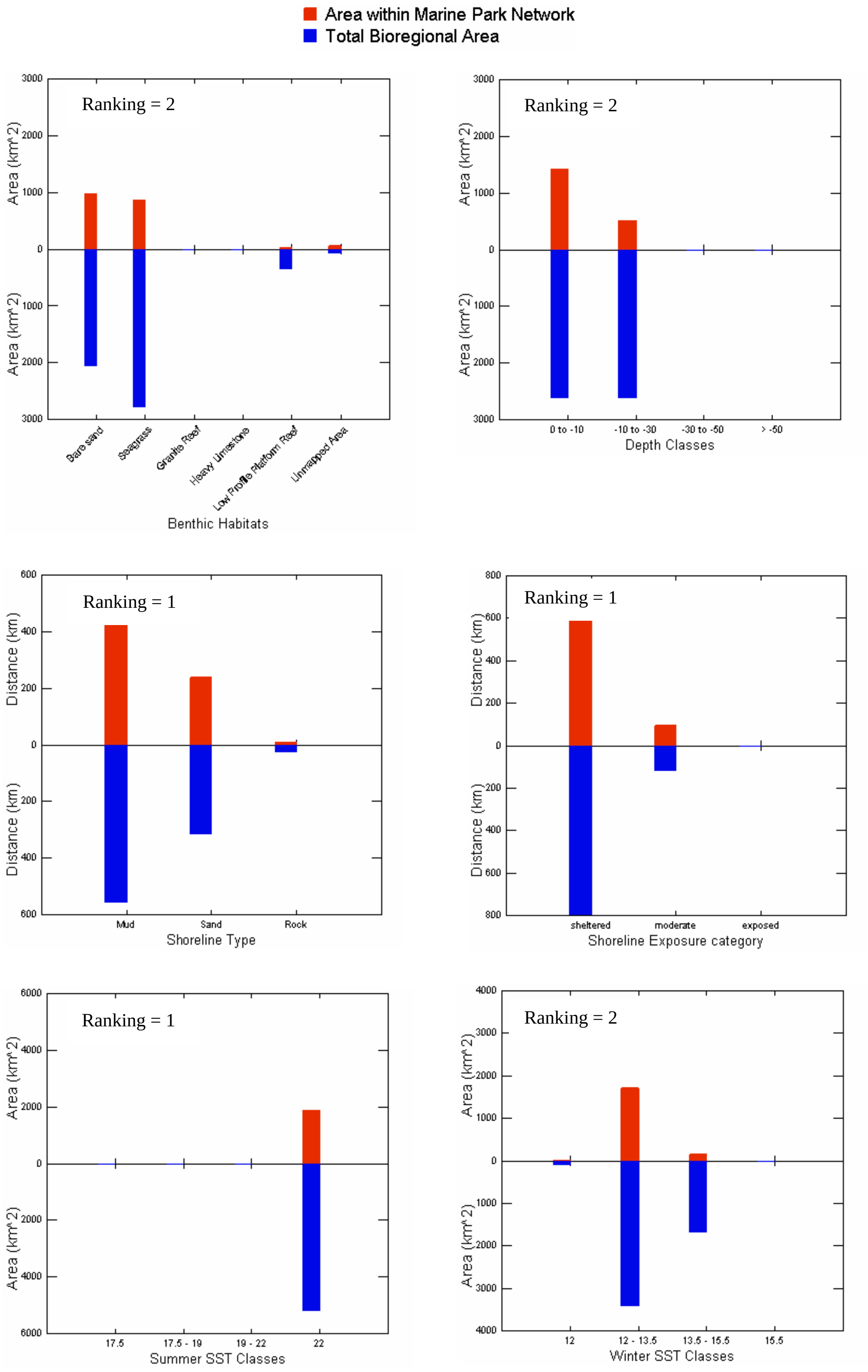


Figure 50: Bar graphs for North Spencer Gulf Bioregion

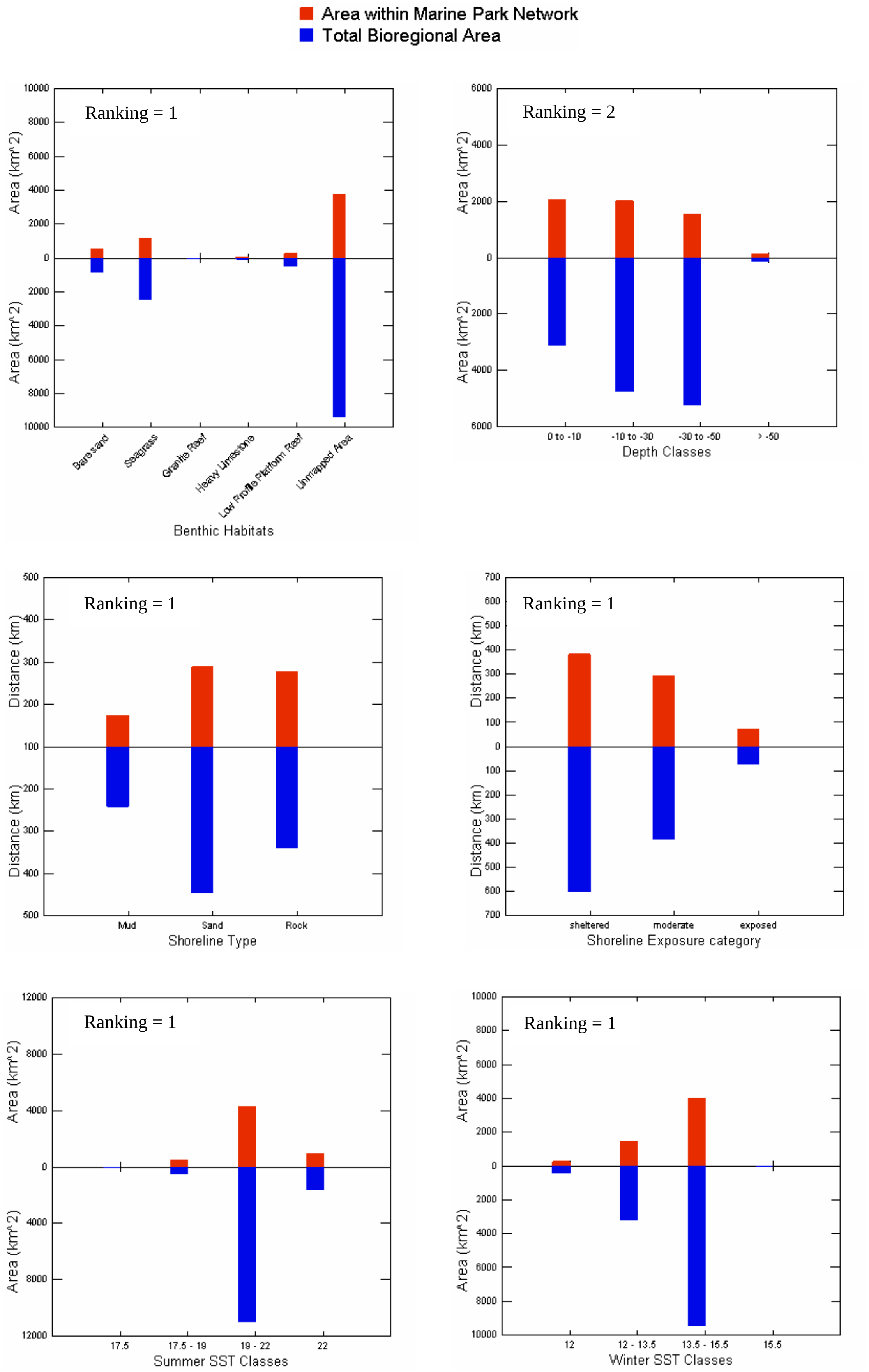


Figure 51: Bar graphs for Gulf St Vincent Bioregion

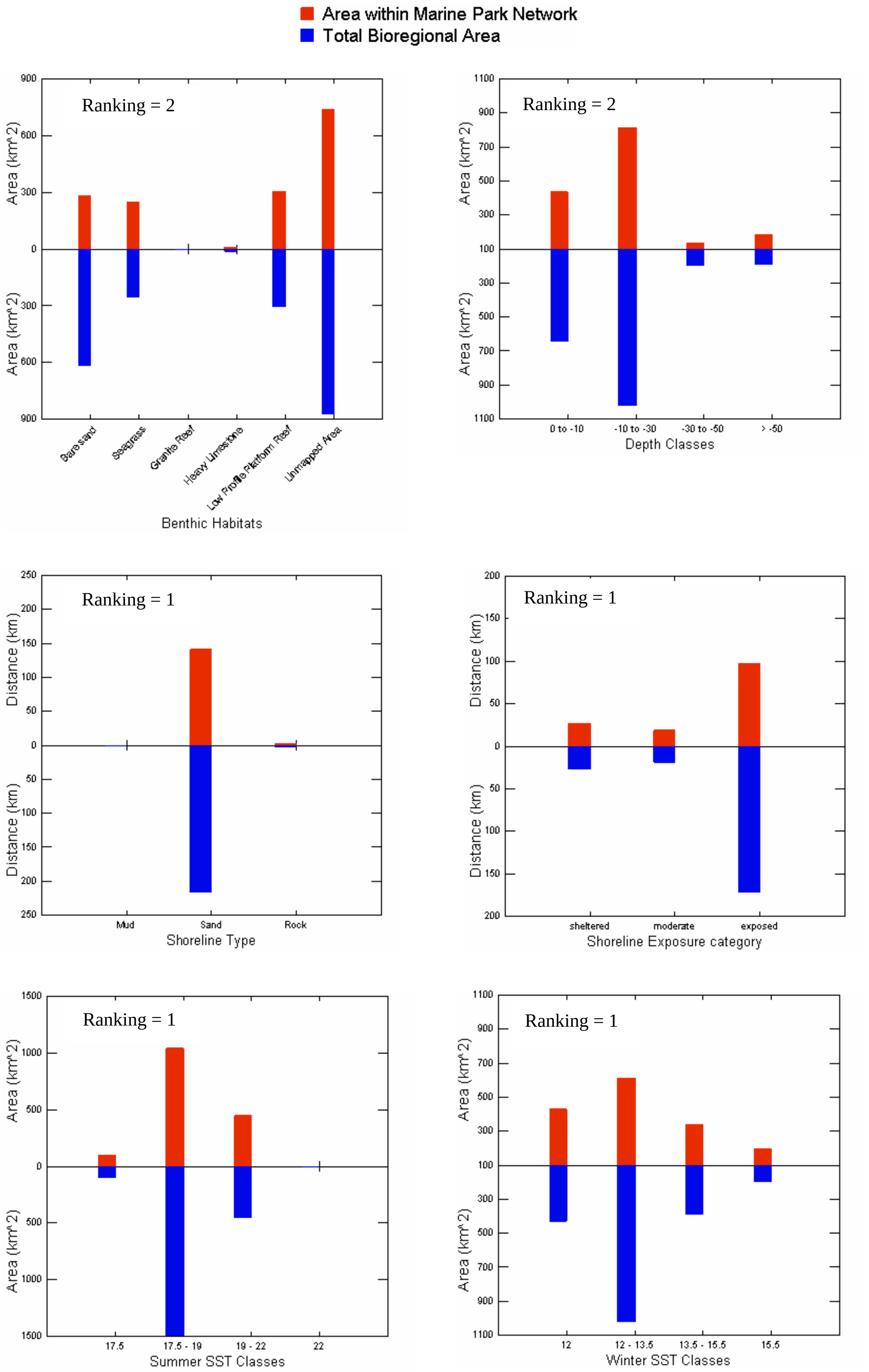


Figure 52: Bar graphs for Coorong Bioregion

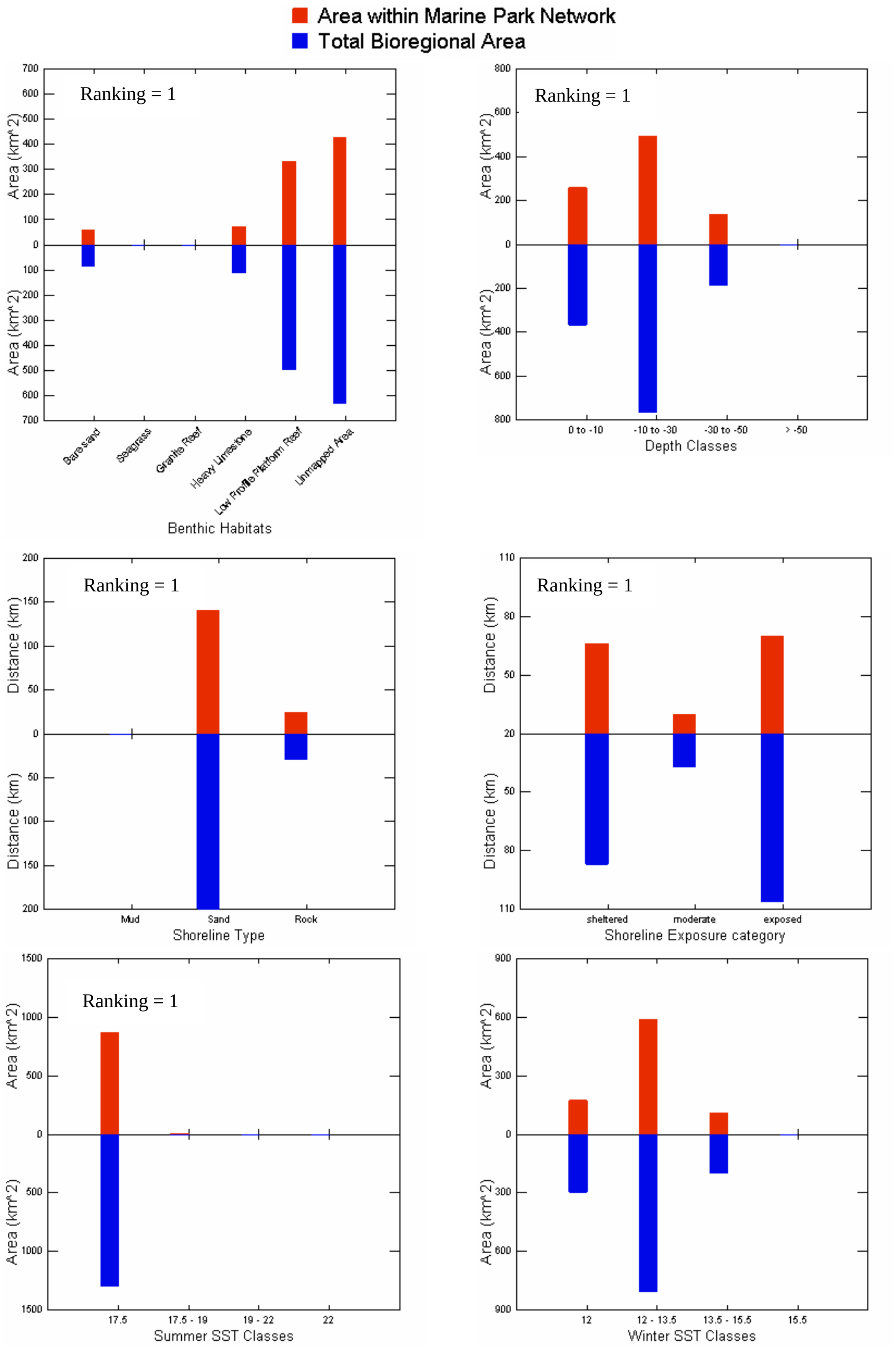


Figure 53: Bar graphs for Otway Bioregion.

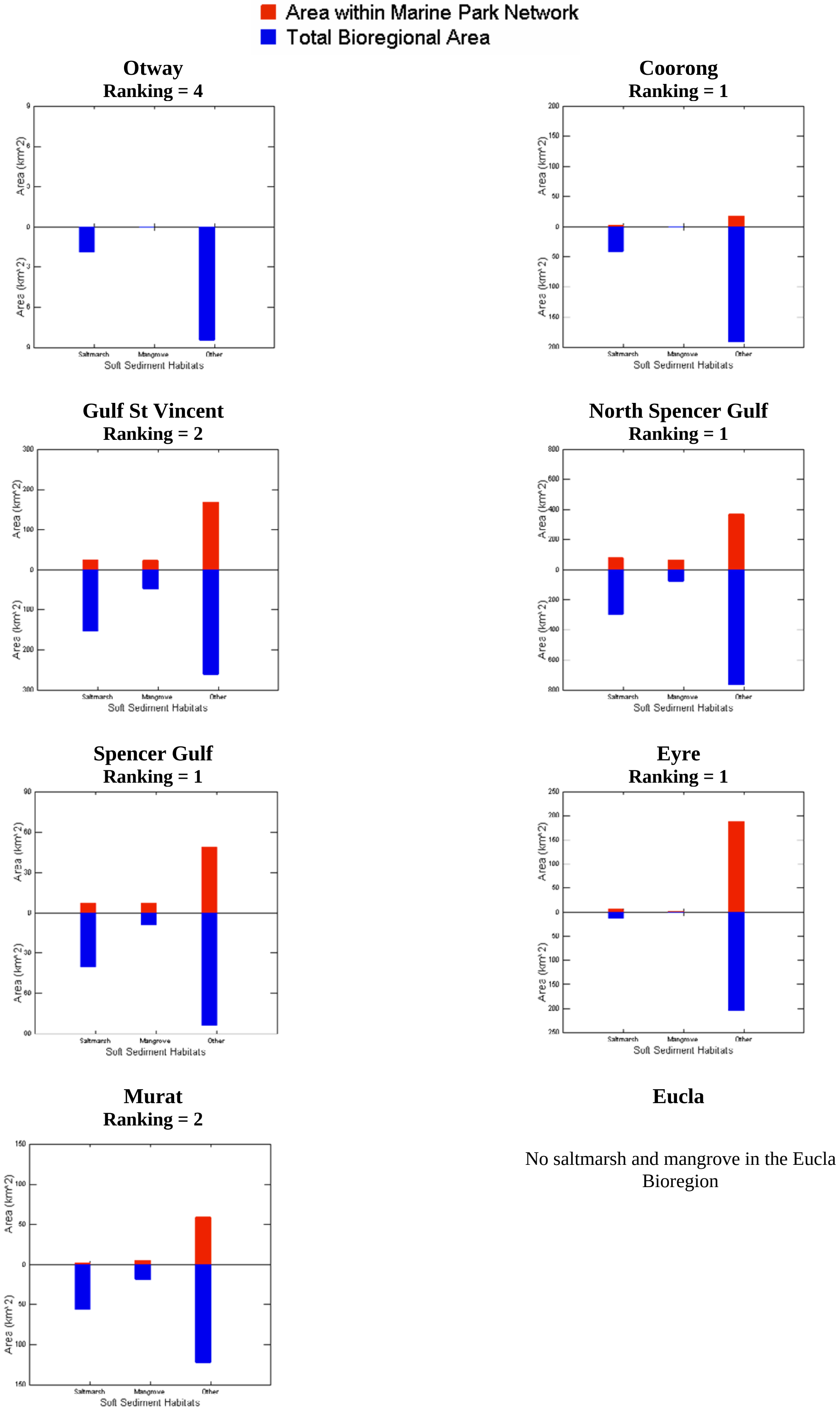
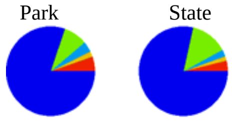


Figure 54: Bar graphs for all bioregions for saltmarsh and mangrove habitats

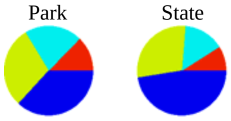
Murat

Benthic Habitats
Ranking = 1



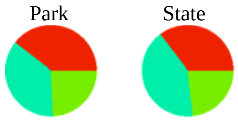
Red = Bare sand; Cyan = Granite reef; Orange = Heavy limestone reef; Light Blue = Low profile platform reef; Green = Seagrass; Dark Blue = Unmapped area

Depth (-m)
Ranking = 1



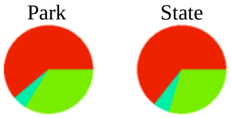
Red = 0-10m; Cyan = 10-30; Green = 30−50; Blue = >50

Shoreline Classification
Ranking = 1



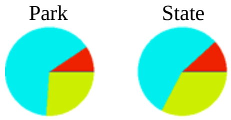
Red = Mud; Green = Rock; Cyan = Sand

Shoreline Exposure
Ranking = 1



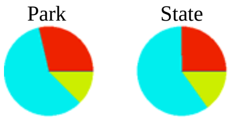
Red = Sheltered; Cyan = Moderate; Green = Exposed

Summer SST (°C)
Ranking = 1



Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22

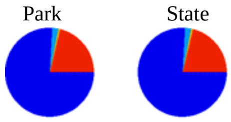
Winter SST (°C)
Ranking = 1



Red = <12; Light Blue= 12 – 13.5; Green = 13.5–15.5; Dark Blue = >15.5

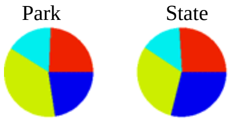
Eucla

Benthic Habitats
Ranking = 1



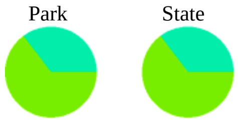
Red = Bare Sand habitats; Light Blue = Granite Reef; Gold = Heavy Limestone or Calcarenite Reef; Mid Blue = Low Profile Platform Reef; Green = Seagrass; Dark Blue = Unmapped Area

Depth (-m)
Ranking = 1



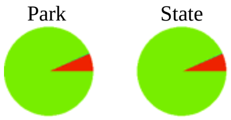
Red = 0−10m; Cyan = 10−30; Green = 30−50; Blue = >50

Shoreline Classification
Ranking = 1



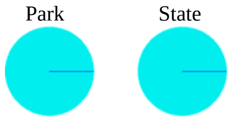
Red = Mud; Green = Rock; Cyan = Sand

Shoreline Exposure
Ranking = 1



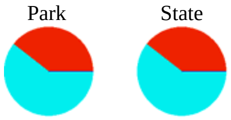
Red = Sheltered; Cyan = Moderate; Green = Exposed

Summer SST (°C)
Ranking = 1



Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22

Winter SST (°C)
Ranking = 1



Red = <12 Light Blue = 12 – 13.5; Green = 13.5 – 15.5; Dark Blue = >15.5

Figure 55: Pie charts for Murat and Eucla Bioregions for benthic habitats, depth, shoreline classification, shoreline exposure, summer Sea Surface Temperature (SST) and winter SST

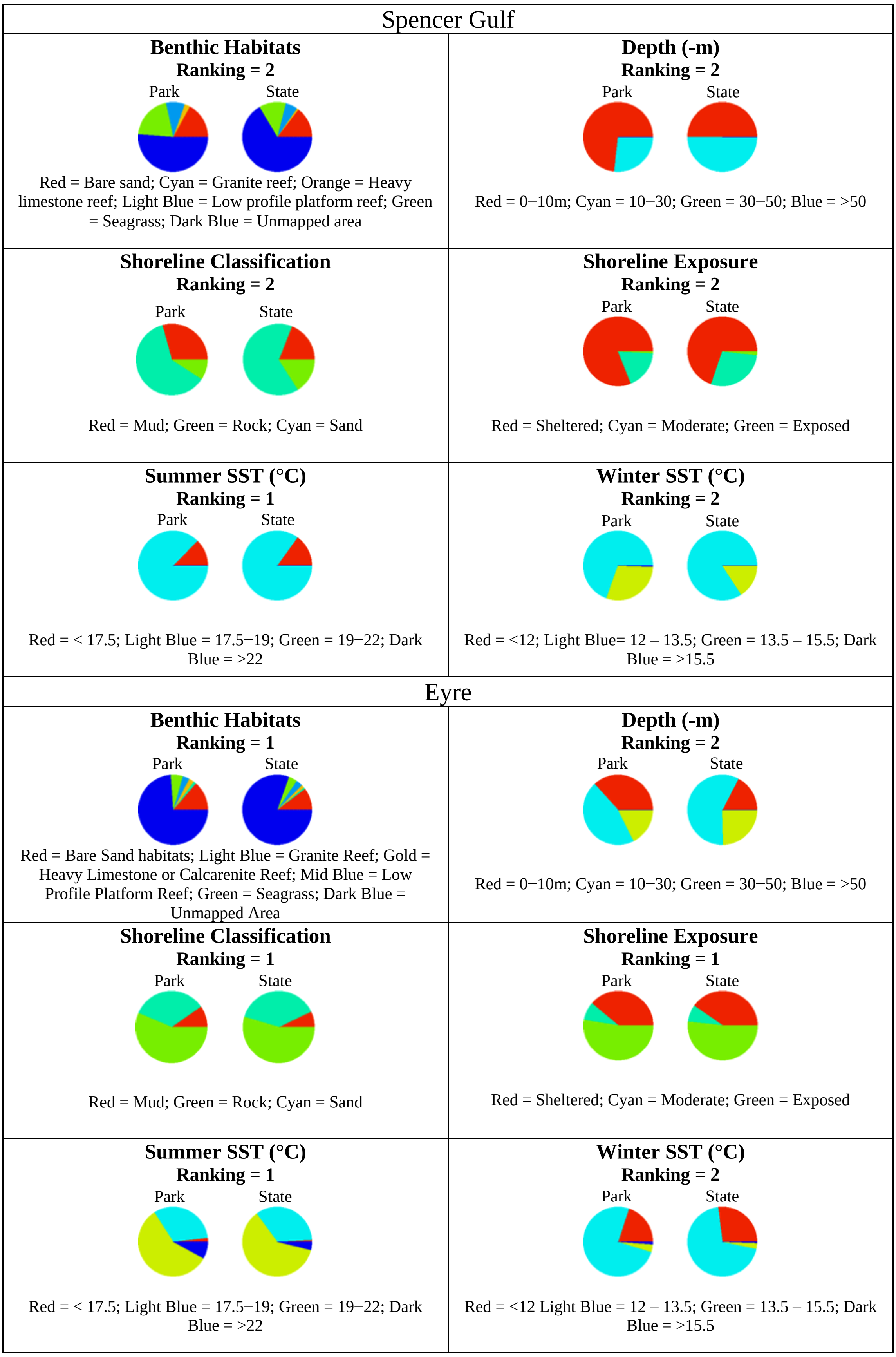
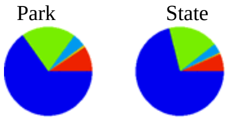


Figure 56: Pie charts for Spencer Gulf and Eyre Bioregions for benthic habitats, depth, shoreline classification, shoreline exposure, summer Sea Surface Temperature (SST) and winter SST

Gulf St Vincent

Benthic Habitats

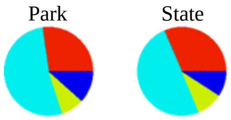
Ranking = 1



Red = Bare sand; Cyan = Granite reef; Orange = Heavy limestone reef; Light Blue = Low profile platform reef; Green = Seagrass; Dark Blue = Unmapped area

Depth (-m)

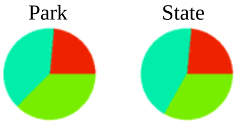
Ranking = 2



Red = 0−10m; Cyan = 10−30; Green = 30−50; Blue = >50

Shoreline Classification

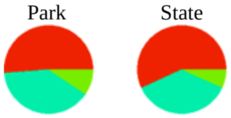
Ranking = 1



Red = Mud; Green = Rock; Cyan = Sand

Shoreline Exposure

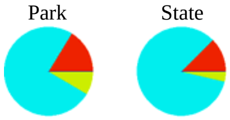
Ranking = 2



Red = Sheltered; Cyan = Moderate; Green = Exposed

Summer SST (°C)

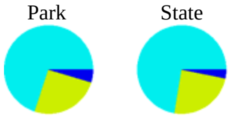
Ranking = 1



Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22

Winter SST (°C)

Ranking = 1

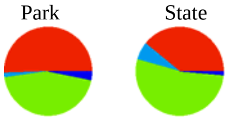


Red = <12; Light Blue= 12 – 13.5; Green = 13.5 – 15.5; Dark Blue = >15.5

North Spencer Gulf

Benthic Habitats

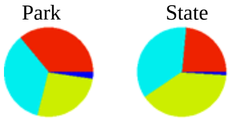
Ranking = 1



Red = Bare Sand habitats; Light Blue = Granite Reef; Gold = Heavy Limestone or Calcarenite Reef; Mid Blue = Low Profile Platform Reef; Green = Seagrass; Dark Blue = Unmapped Area

Depth (-m)

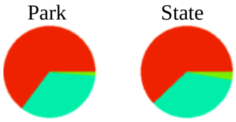
Ranking = 2



Red = 0−10m; Cyan = 10−30; Green = 30−50; Blue = >50

Shoreline Classification

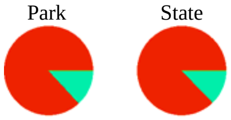
Ranking = 1



Red = Mud; Green = Rock; Cyan = Sand

Shoreline Exposure

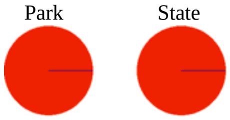
Ranking = 1



Red = Sheltered; Cyan = Moderate; Green = Exposed

Summer SST (°C)

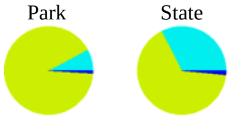
Ranking = 1



Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22

Winter SST (°C)

Ranking = 2



Red = <12 Light Blue = 12 – 13.5; Green = 13.5 – 15.5; Dark Blue = >15.5

Figure 57: Pie charts for Gulf St Vincent and North Spencer Gulf for benthic habitats, depth, shoreline classification, shoreline exposure, summer Sea Surface Temperature (SST) and winter SST

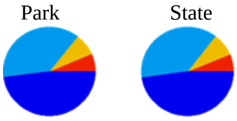
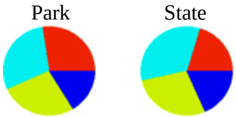
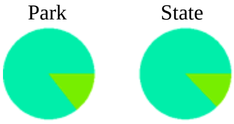
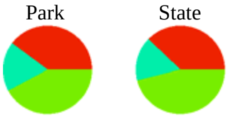
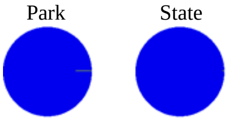
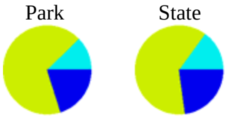
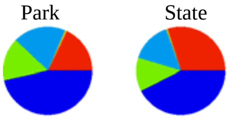
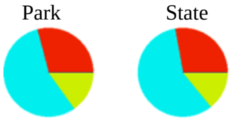
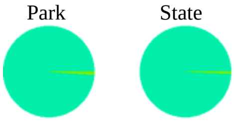
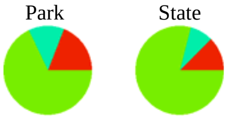
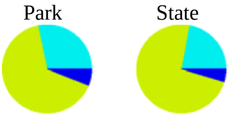
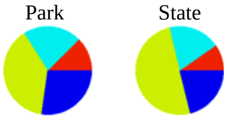
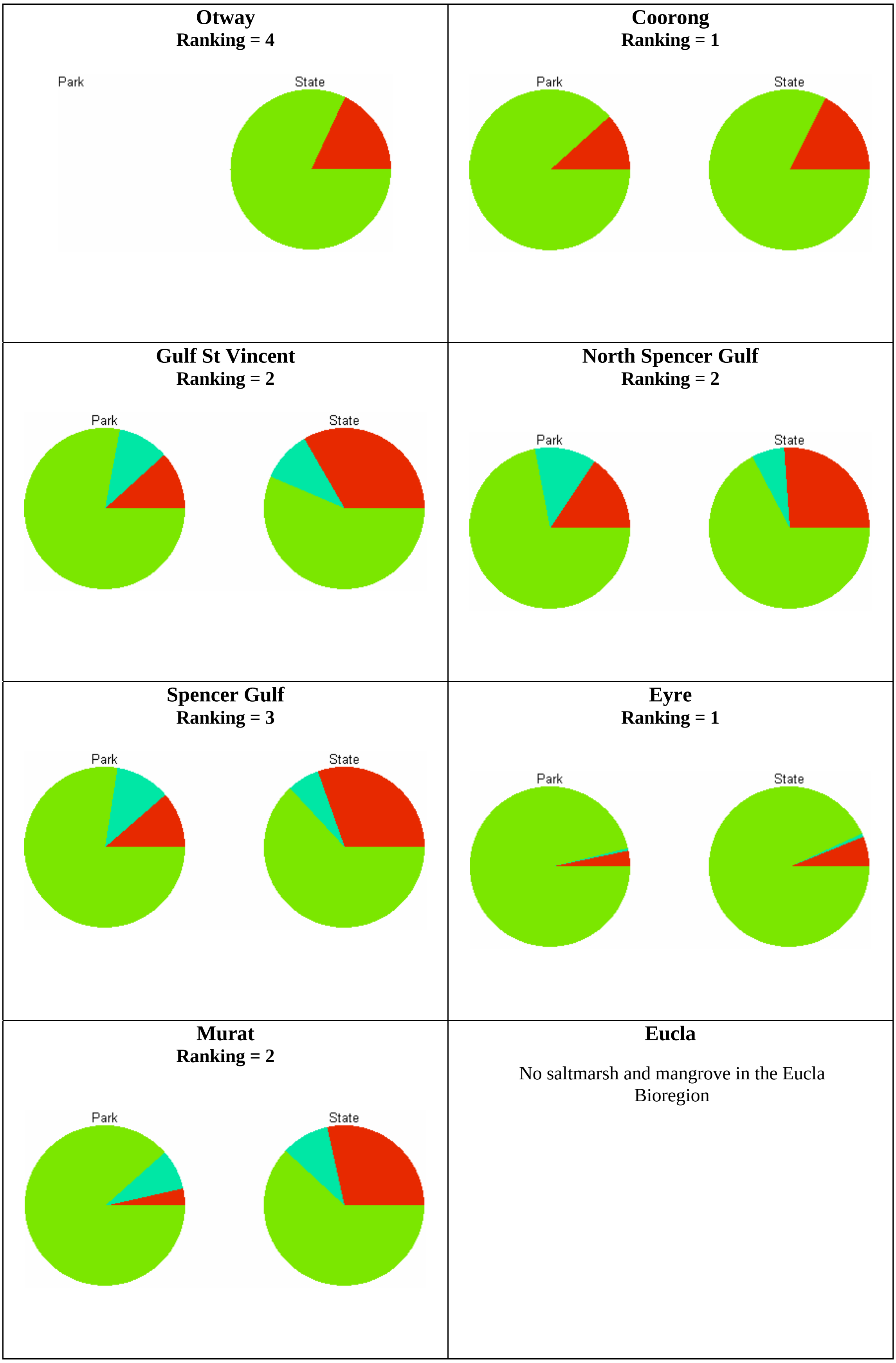
Otway Bioregion	
Benthic Habitats **Ranking = 1**  Red = Bare sand; Cyan = Granite reef; Orange = Heavy limestone reef; Light Blue = Low profile platform reef; Green = Seagrass; Dark Blue = Unmapped area	**Depth (-m)** **Ranking = 1**  Red = 0−10m; Cyan = 10−30; Green = 30−50; Blue = >50
Shoreline Classification **Ranking = 1**  Red = Mud; Green = Rock; Cyan = Sand	**Shoreline Exposure** **Ranking = 1**  Red = Sheltered; Cyan = Moderate; Green = Exposed
Summer SST (°C) **Ranking = 1**  Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22	**Winter SST (°C)** **Ranking = 1**  Red = <12; Light Blue= 12 – 13.5; Green = 13.5 – 15.5; Dark Blue = >15.5
Coorong Bioregion	
Benthic Habitats **Ranking = 2**  Red = Bare Sand habitats; Light Blue = Granite Reef; Gold = Heavy Limestone or Calcarenite Reef; Mid Blue = Low Profile Platform Reef; Green = Seagrass; Dark Blue = Unmapped Area	**Depth (-m)** **Ranking = 1**  Red = 0−10m; Cyan = 10−30; Green = 30−50; Blue = >50
Shoreline Classification **Ranking = 1**  Red = Mud; Green = Rock; Cyan = Sand	**Shoreline Exposure** **Ranking = 2**  Red = Sheltered; Cyan = Moderate; Green = Exposed
Summer SST (°C) **Ranking = 1**  Red = < 17.5; Light Blue = 17.5−19; Green = 19−22; Dark Blue = >22	**Winter SST (°C)** **Ranking = 2**  Red = <12 Light Blue = 12 – 13.5; Green = 13.5 – 15.5; Dark Blue = >15.5

Figure 58: Pie charts for Otway and Coorong Bioregions for benthic habitats, depth, shoreline classification, shoreline exposure, summer Sea Surface Temperature (SST) and winter SST



Otway
Ranking = 4

Coorong
Ranking = 1

Gulf St Vincent
Ranking = 2

North Spencer Gulf
Ranking = 2

Spencer Gulf
Ranking = 3

Eyre
Ranking = 1

Murat
Ranking = 2

Eucla

No saltmarsh and mangrove in the Eucla Bioregion

Figure 59: Pie charts for all South Australian Bioregions for saltmarsh and mangrove
Red =Saltmarsh; Cyan = Mangrove; Green = Other

Appendix 6 - Australian sea lion breeding site risk assessment

Table 34 displays the risk assessment conducted by Goldsworthy *et al.* (2007) on breeding sites of of the Australian sea lion.

Table 34: Risk assessment of Australian sea lion breeding sites across South Australia and their marine park conservation status

🟥 Very high risk 🟧 High risk 🟨 Moderate risk 🟩 Low risk

Bioregions	Breeding site name	In a marine park	Not in a marine park
Eucla	🟥 GAB B2	√	
	🟧 GAB B6	√	
	🟧 GAB B9	√	
	🟧 GAB B1	√	
	🟧 GAB B3	√	
	🟧 GAB B8	√	
	🟧 GAB B5	√	
	SubTotal	**7**	**0**
Murat	🟥 Gliddon Reef	√	
	🟧 Masilon Island	√	
	🟧 Western Nuyts Reef	√	
	🟧 Breakwater Reef	√	
	🟧 Lounds Island	√	
	🟧 Fenelon Island	√	
	🟨 West Island	√	
	🟨 East Franklin Reef	√	
	🟨 Olive Island		√
	🟨 Purdie Island	√	
	🟨 West Franklin Reef	√	
	SubTotal	**9**	**1**
Eyre	🟥 South Neptune Island	√	
	🟥 Ward Island	√	
	🟧 Albatross Island		√
	🟧 Little and Four Hummock Island	√	
	🟧 Seal Slide	√	
	🟧 Rocky North Island		√
	🟧 North Neptune Island	√	
	🟧 Jones Island	√	
	🟧 Peaked Rocks	√	
	🟧 Price Island	√	
	🟧 North Island	√	
	🟧 English Island	√	
	🟧 Pearson Island	√	
	🟧 Linguanea Island	√	
	🟨 Nicholas Baudin Island	√	
	🟨 Seal Bay	√	
	🟨 Lewis Island	√	
	🟨 West Waldegrave Island		√
	🟩 Dangerous Reef	√	
	SubTotal	**17**	**3**
Gulf St Vincent	🟨 The Pages	√	
	SubTotal	**1**	**0**
	Total	**34**	**4**

9.5 Appendix 7 – Marxan derived areas of irreplaceability for each bioregion

Figure 60 to Figure 67 display the Marxan derived areas of irreplaceability for each marine bioregion.

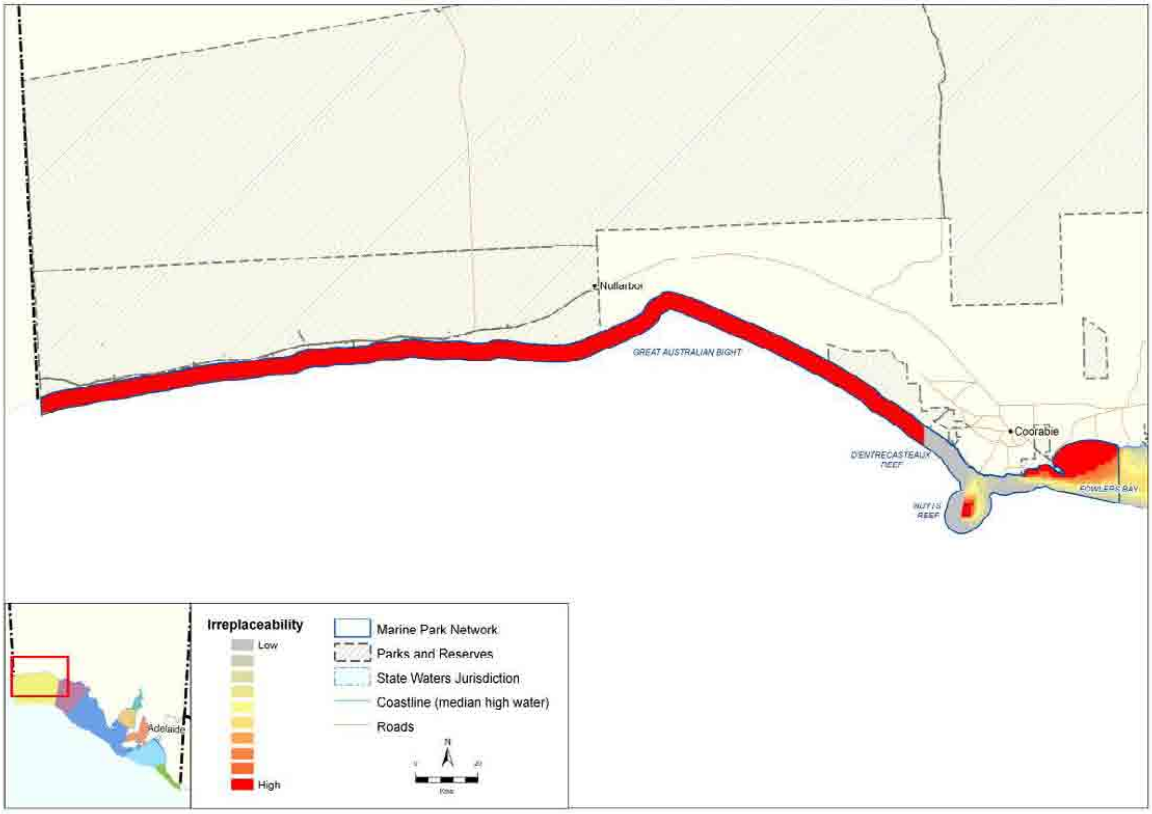


Figure 60: Marxan derived areas of irreplaceability for the Eucla Bioregion

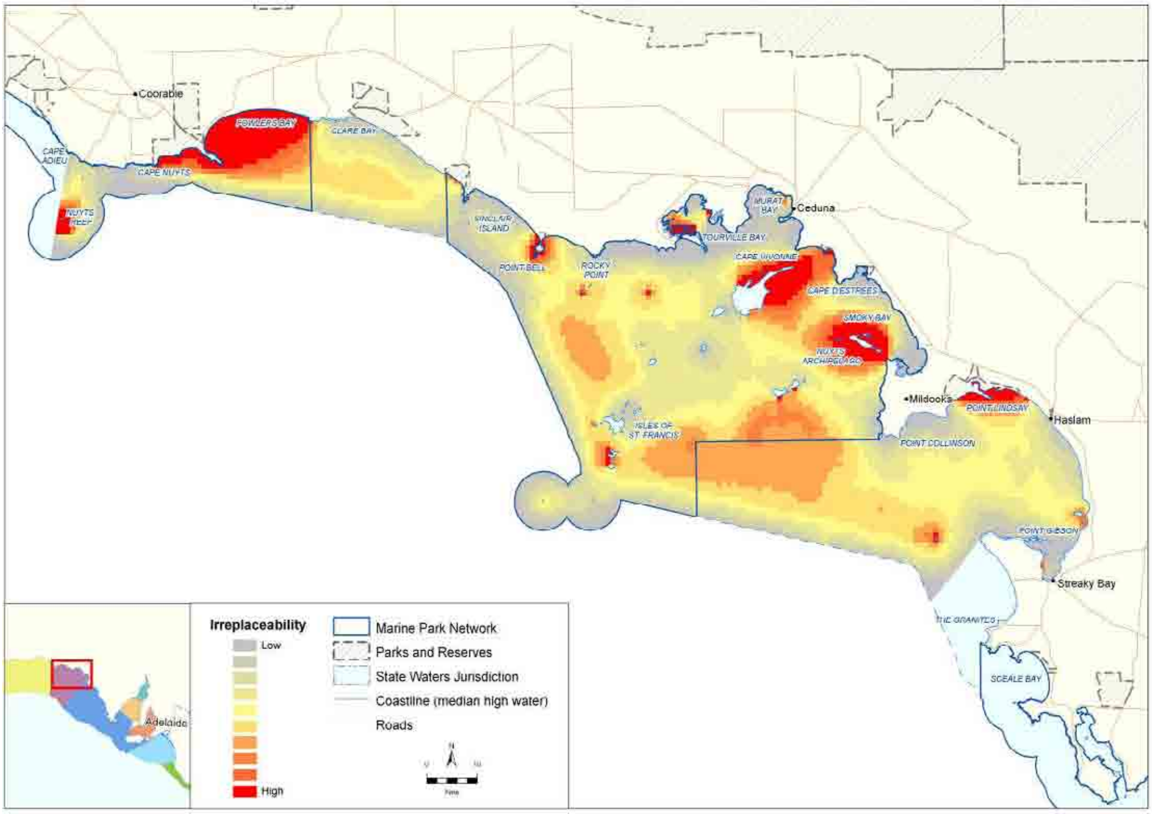


Figure 61: Marxan derived areas of irreplaceability for the Murat Bioregion

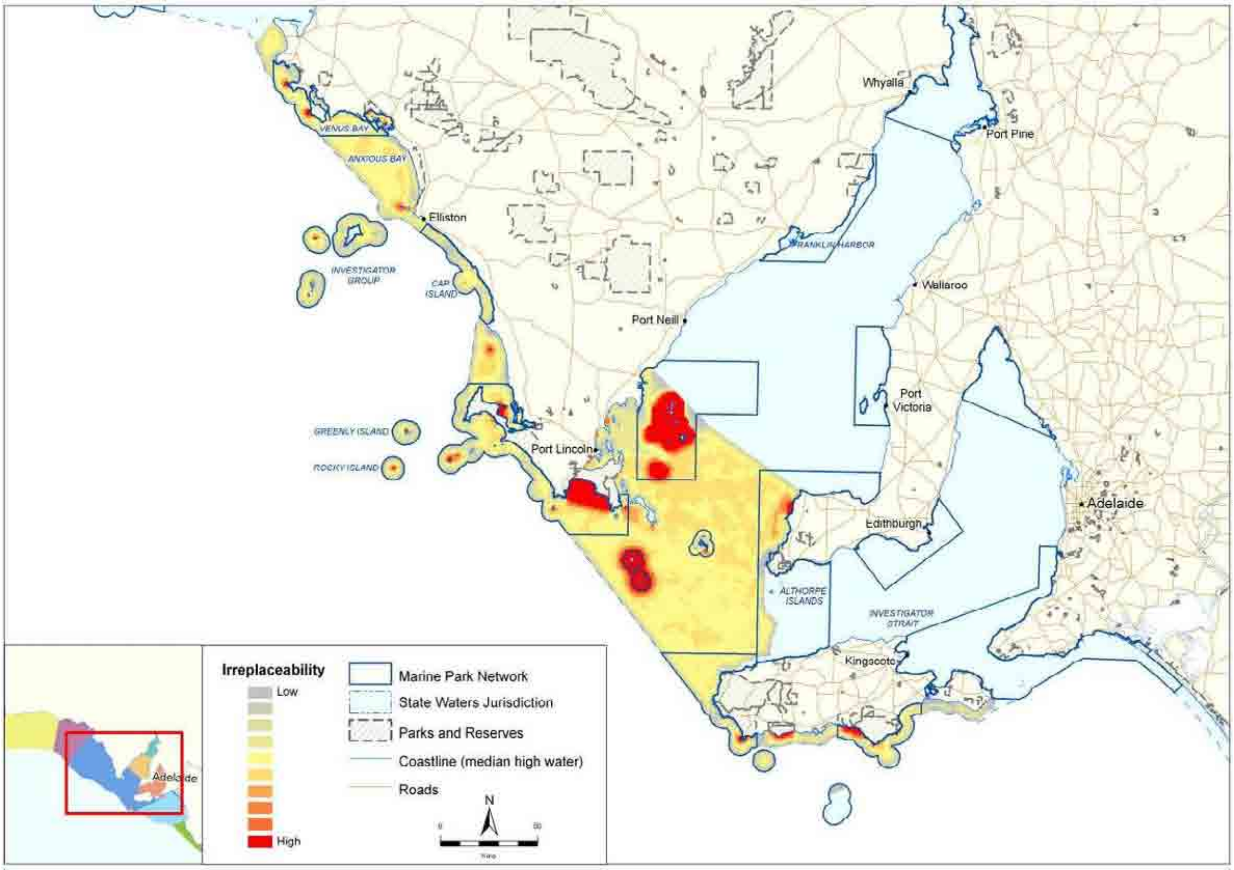


Figure 62: Marxan derived areas of irreplaceability for the Eyre Bioregion

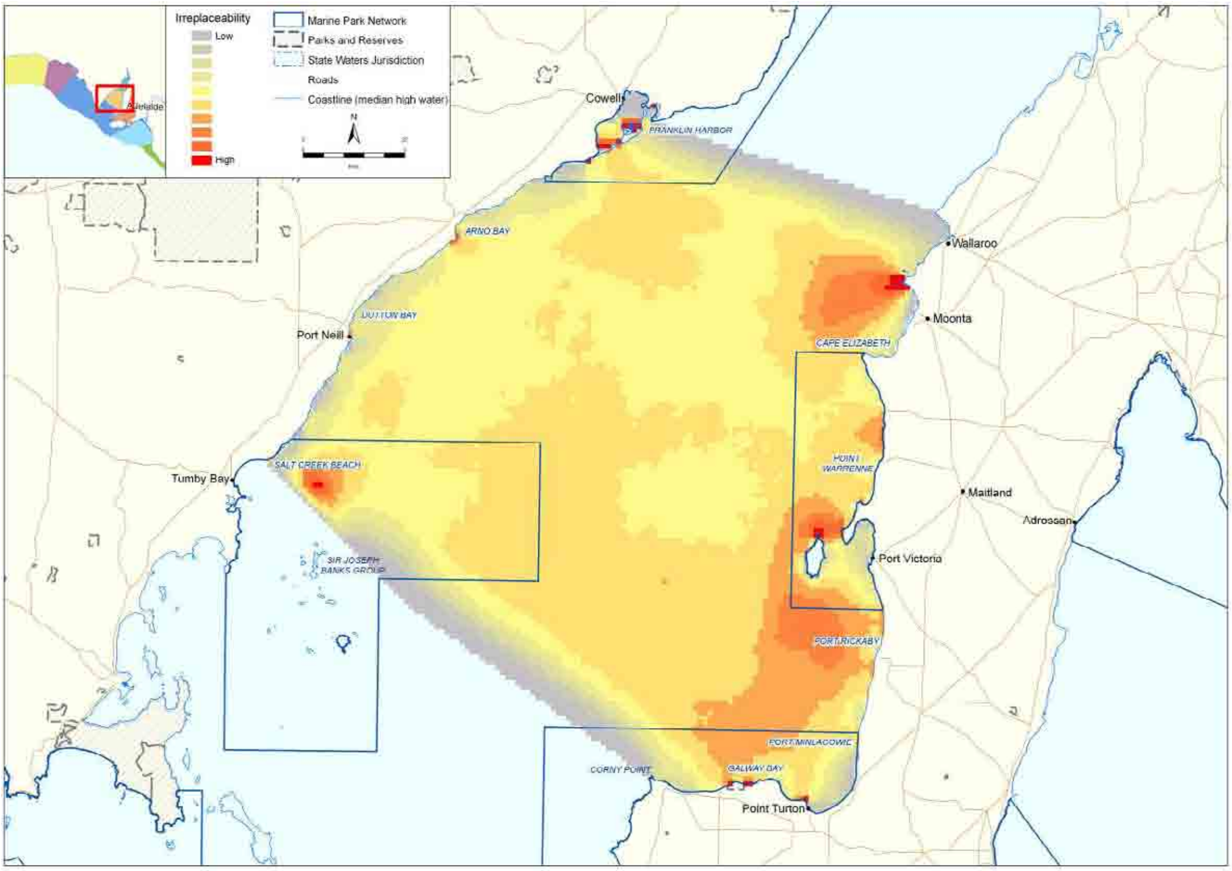


Figure 63: Marxan derived areas of irreplaceability for the Spencer Gulf Bioregion

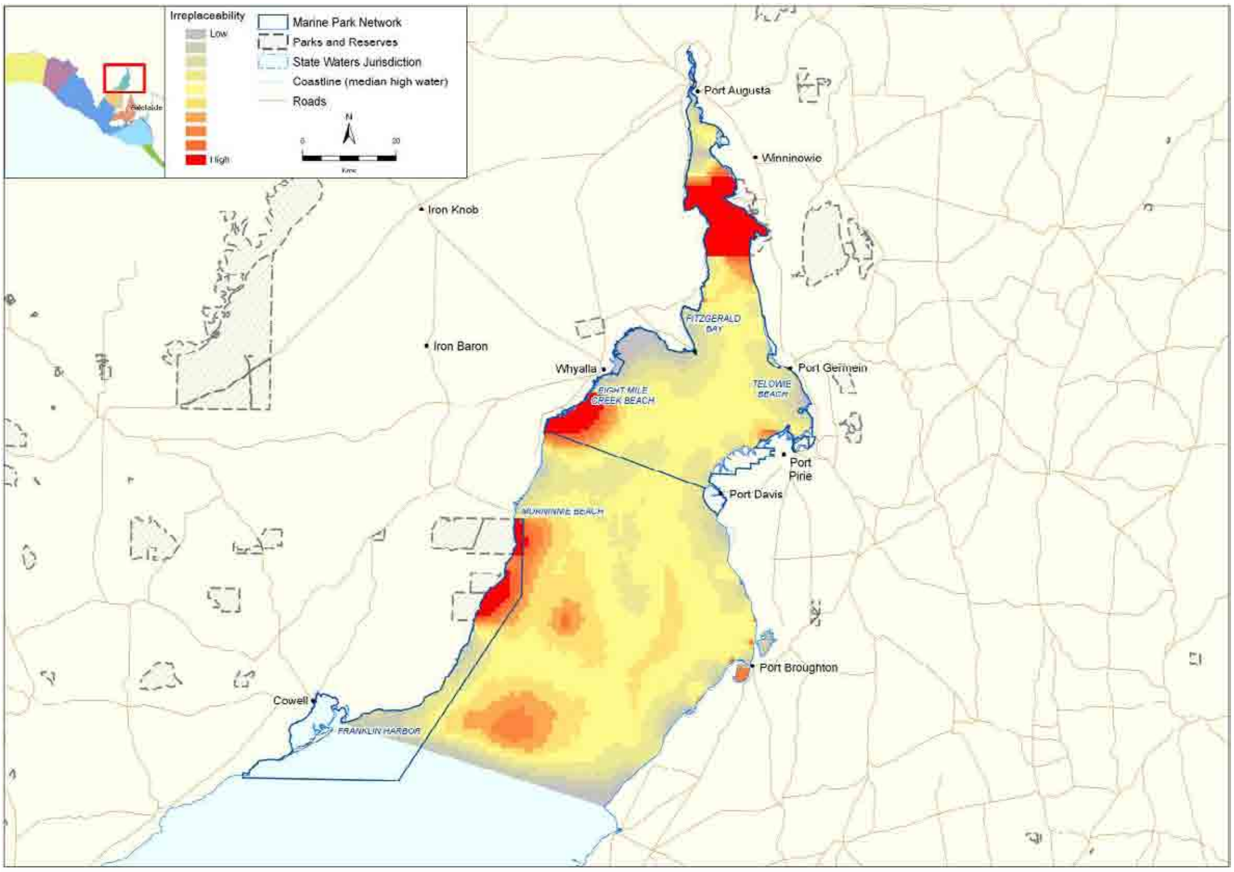


Figure 64: Marxan derived areas of irreplaceability for the North Spencer Gulf Bioregion

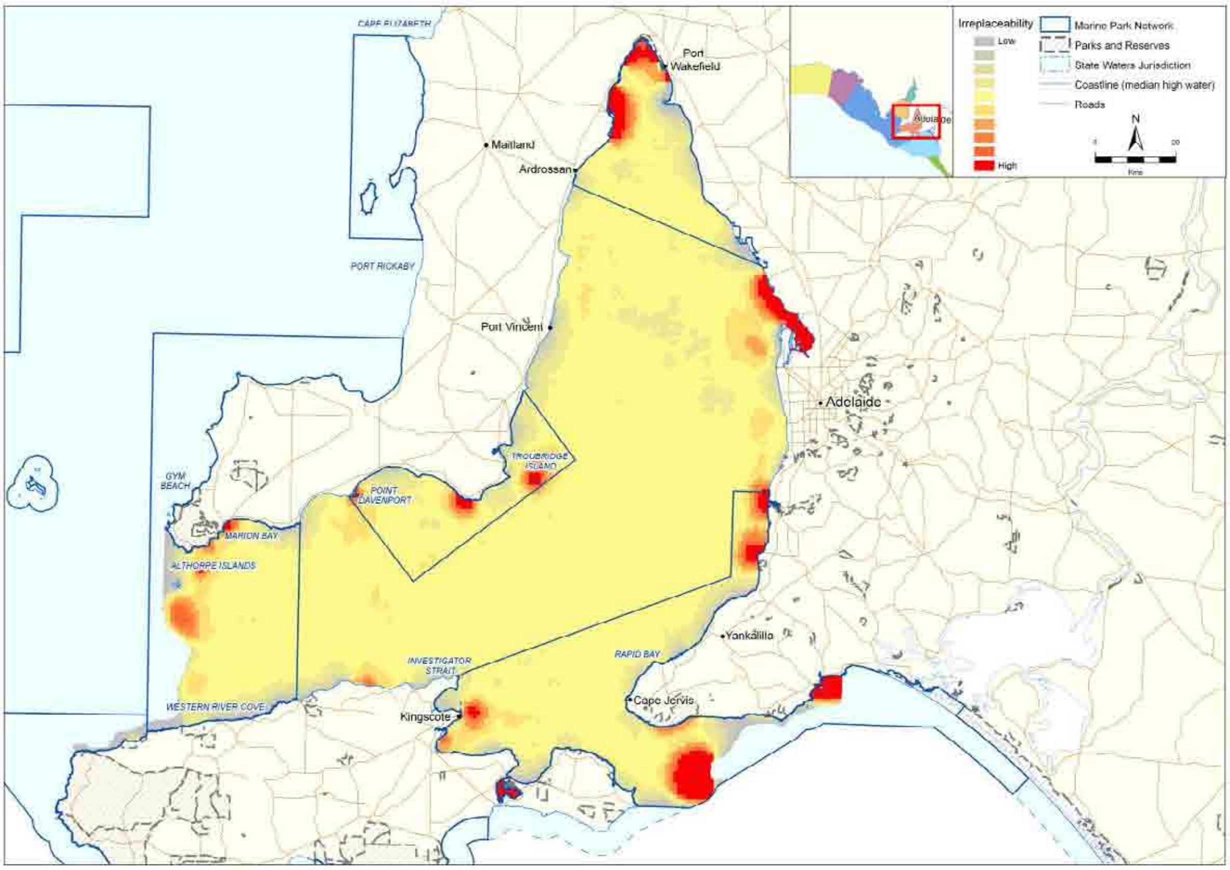


Figure 65: Marxan derived areas of irreplaceability for the Gulf St Vincent Bioregion

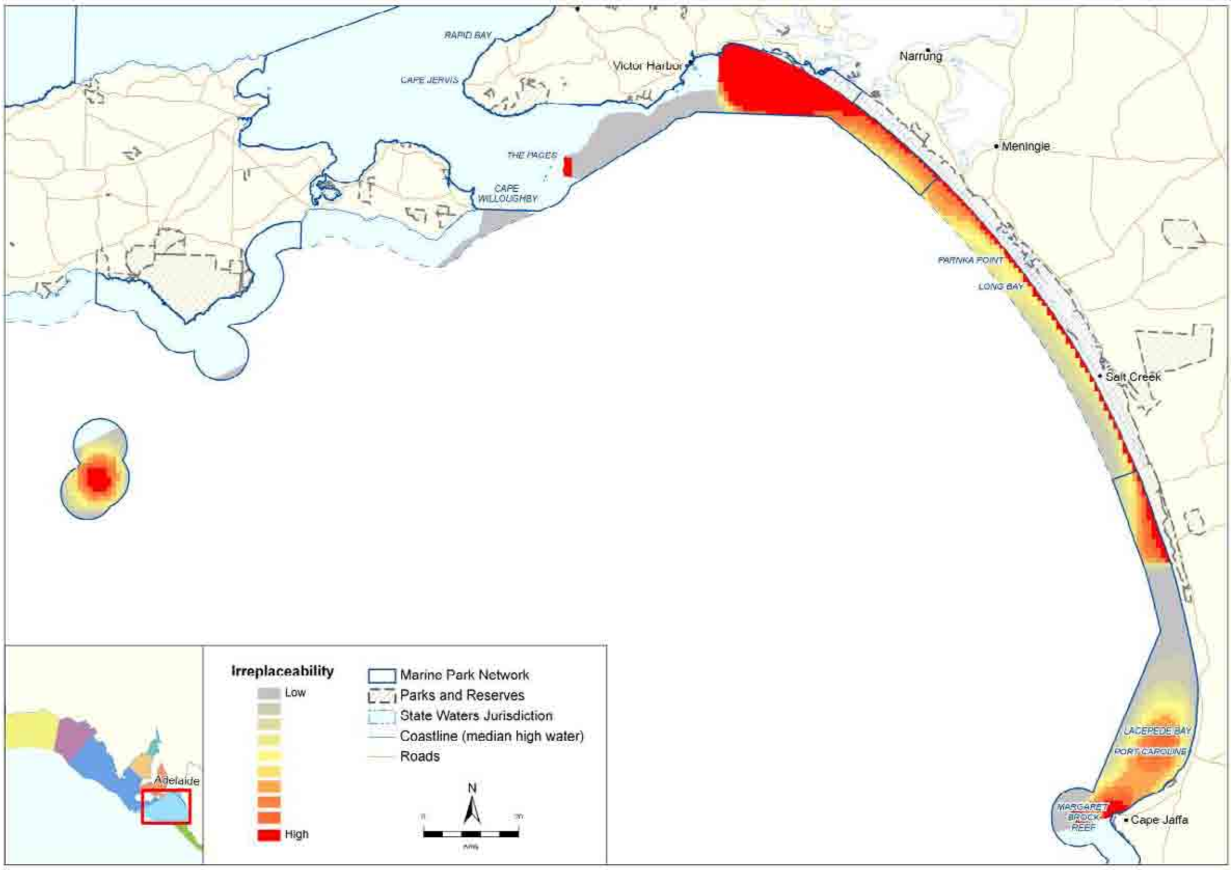


Figure 66: Marxan derived areas of irreplaceability for the Coorong Bioregion

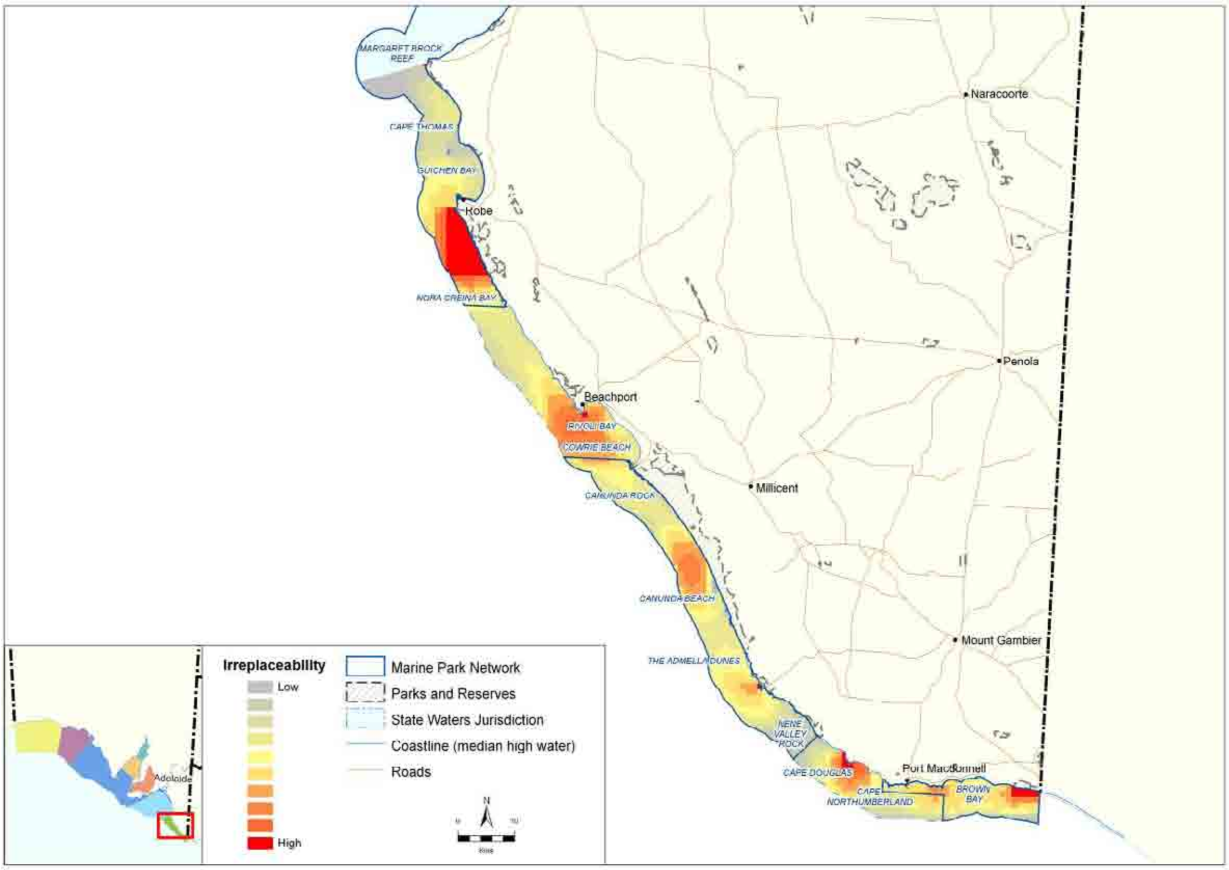


Figure 67: Marxan derived areas of irreplaceability for the Otway Bioregion