Marine Habitats within bays of the Eyre Peninsula NRM Region

Final Report to the Eyre Peninsula Natural Resources Management Board for the program: Establishing Marine Baselines

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Government of South Australia
Department for Environment and Heritage
Eyre Peninsula Natural Resources Management Board

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Establishing Marine Baselines

December 2009

Coast and Marine Conservation Branch

Department for Environment and Heritage

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1 Executive overview

Under the *Natural Resources Management* (NRM) *Act 2004*, NRM boundaries include all State waters. Therefore, NRM planning and programming must provide for the ecologically sustainable use of marine environments.

Measuring the effects of human activities in marine environments requires the establishment of baseline habitat mapping against which specific threats and condition targets can be measured and assessed. Habitat mapping currently available is at a scale of 1:100,000, which does not provide adequately for the management needs of NRM Boards.

The Eyre Peninsula NRM (EPNRM) Board has commenced a program to address this critical knowledge need by engaging the Department for Environment and Heritage (DEH) in a program of broad scale marine habitat mapping at a resolution that is more suited to local management needs.

The mapping and underlying GIS data outlined in this report form an invaluable resource for managers within the EP NRM region, providing a critical baseline against which future changes can be measured and include recommendations for future monitoring and research.

Detailed spatial mapping of seafloor habitats was conducted across eight large embayments within the EP NRM region. The embayments mapped, each of high economic, social and environmental value to Eyre Peninsula communities, were Denial Bay, Smoky Bay, Streaky Bay, Baird Bay, Venus Bay, Coffin Bay, Franklin Harbor and False Bay.

This summary document forms part of a set of information which also includes:

- a detailed map book;
- an interactive Arc Reader DVD (which will serve as a basis for identifying monitoring and management requirements as well as a driver of basic research and an educational tool); and
- an addendum to the report which includes a summary of baseline biodiversity information for specific habitats within the eight bays.

The total area mapped in this exercise (~ 1200 km^2) is relatively small when compared with the total marine environment encompassed by the EP NRM region (~ 4.15%), but includes high resolution (1:20,000) baseline data on important coast and marine habitats adjacent to areas of population where threats are most likely to arise.

Large areas of seagrass dominate each of the bays considered, although Smoky Bay and False Bay had a high proportion of patchy-sparse seagrass cover, which may indicate systems under stress. While some species of seagrass undergo substantial, natural inter and intra-annual biomass changes, targeted future monitoring of seagrass cover and water quality within these bays will enable the EPNRM Board to determine to what degree the seagrass dynamics in this area are a product of human influences.

Similarly, large continuous seagrass beds dominate Denial Bay, Streaky Bay and Coffin Bay. Ongoing, periodic assessment of the condition of seagrasses in these bays (again in relation to water quality) is recommended, coupled with terrestrial and marine management practices targeted towards the maintenance of seagrass health.

Areas of high habitat diversity were observed within Baird Bay and Coffin Bay. It is recommended that these should be considered in greater detail to determine the nature of this variability and whether these areas are in fact localised biodiversity hotspots which may be of regional importance.

2 Background

It is widely accepted that sustainable management of natural assets should be approached at a holistic systems-level rather than that of individual species. This approach recognises the interconnectivity within and between habitats such that factors which may affect only one species will have flow on effects to the rest of the system (e.g. Fairweather 1999, GESAMP 2001, Allee *et al.* 2000, Flaherty and Sampson 2005). Management at broader ecosystem scales has a number of advantages (Fairweather 1999, GESAMP 2001, Flaherty and Sampson 2005) including (amongst others):

- Recognition that many environmental stress factors are non-specific,
- Broader understanding of the ecosystem effects that may result from exploitation of a resource, with concomitant realignment of what might constitute "sustainability",
- Management and monitoring strategies are more efficient,
- Ecosystems scale data will present the integrated impact of a number of anthropogenic and natural stress factors,
- A greater understanding of the natural dynamics and processes of systems, particularly at larger scales,
- Understanding that environmental threats are now recognised as operating at very large spatial scales including regional (i.e. urbanisation and habitat fragmentation), national (i.e. catchment degradation) and global levels (i.e. climate change),
- Local scale issues (e.g. water pollution, etc) may be placed within a broader biogeographic context (see Connell and Irving 2008), and
- Providing a more effective, cohesive and consistent basis for engagements with all stakeholders that have interests in the system(s) concerned.

Note that a systems level approach to environmental resource management does not preclude or discount the targeted strategies required for rare, threatened and endangered species, or indeed the specific approaches required for high priority pests.

Within the framework of large scale monitoring, there is a concomitant need to increase our understanding of the physical and biological factors that structure ecosystems and to identify areas of high biodiversity. Understanding spatiotemporal variability and biodiversity differences within systems across a range of scales leads to:

- Increased understanding of the ecosystem services provided by the resource, which may lead to improved engagements with stakeholders.
- A capacity to prioritise monitoring and management interventions in areas of high biodiversity.
- More efficient application of conservation/multiple use strategies.
- Identification of specific threats.

- Development of a notion of ecosystem "health" within the context of the broader habitat type (i.e. subtidal reef systems see Turner *et al.* 2007).

Following on from the Australian Government's Natural Heritage Trust (NHT) funded mapping of the upper Gulf St Vincent and Spencer Gulf areas in 2005, and the Adelaide Mount Lofty region between 2006 and 2008, in late 2006 the Eyre Peninsula Natural Resources Management (EP NRM) region (in partnership with the NHT) developed a project with the Department for Environment and Heritage (DEH) to produce a detailed spatial Geographic Information System (GIS) layer of seafloor habitats within six sheltered bays within the EP NRM region. These included Denial, Baird, Venus and Coffin Bays on the west coast and False Bay and Franklin Harbour on the east coast. Together it was envisaged that these bays would provide a representative example of the range of habitats likely to be present in the EP NRM region. In 2008 a further two bays, Streaky and Smoky Bays were included in the survey.

Work associated with this project included an update of previously available broad scale (southern Australia) marine benthic habitat maps produced by CSIRO, covering the inshore waters of the bays at a spatial scale relevant to regional management issues. In addition, the survey protocol and marine habitat definitions were aligned with those being developed elsewhere in Australia with the aim of developing habitat maps that will fit within a broader national framework.

Effective large-scale marine management requires a capacity to obtain data on changes in systems at large spatial scales. Marine benthic habitat mapping offers a cost effective approach to obtaining data on shallow (< 20 m) nearshore systems. Furthermore, the development of a hierarchical approach to habitat differentiation has resulted in a framework for mapping that is readily repeatable, consistent at the national scale and encompasses the capacity to incorporate additional data.

Within the EP NRM region, the need for large scale marine habitat assessment capability is a major motivating factor in the development of Monitoring, Evaluation and Reporting Frameworks (see AMLR NRM 2008). However, while there is a need for large scale baselines, there is also a need to identify, monitor and manage smaller scale biodiversity and conservation "hotspots" as well as understanding spatiotemporal variability and identifying the physical environmental drivers that structure marine systems across a range of spatial and temporal scales. This knowledge allows for ready identification of threats and appropriately targeted management responses. However, the EP NRM region poses a number of challenges to development of finer scale marine mapping, not least of which is the extent of the coastline, which is the longest of any NRM region in South Australia.

The following describes relevant background to the marine habitat mapping process for the Eyre Peninsula (EP) NRM region, including three main aspects:

- Marine management regions, broadscale marine observations and mapping in the EP NRM region, including what is understood with respect to risks to nearshore systems.
- A brief summary of the results of recent marine habitat mapping within eight large embayments within the region.

- Links between results of mapping relative to earlier benthic surveys as well as risks.

This document is analogous to similar reports related to marine habitat mapping developed for the Adelaide and Mount Lofty Ranges NRM Board (DEH 2009a), Northern and Yorke NRM Board (Miller *et al* 2009a) and the South East NRM Board (Miller *et al* 2009b). The structure of these documents and portions of the text related to marine management areas and habitat mapping are therefore similar (if not identical), dealing with the same source material in many instances. While it is certainly feasible to reference this material to the companion documents in such instances, it was felt by the authors that every effort should be undertaken to ensure each report formed a "stand alone" entity.

2.1 Aims

Aims of this study were thus to:

- Establish baselines for coast, marine and estuarine biodiversity that will enable monitoring of change in resource condition within the EP NRM region.
- Develop marine habitat mapping at scales relevant to management for eight large embayments within the EP NRM region.
- Generate map books at a scale of 5 × 5 km and an interactive DVD of benthic habitat maps and other relevant GIS information layers.

This document summarises the management frameworks, approaches and history of habitat mapping for the purposes of natural resource management in the EP NRM region. The summary will cover four areas related to marine environmental management including:

- Current and planned marine management regions within the EP NRM region,
- The history of habitat mapping within the region,
- Large scale habitat characterisation and comparison studies in reef, seagrass and soft bottom systems that might support habitat mapping.
- Risks to coast, estuarine and marine systems within the EP NRM region.

From a mapping perspective this document includes:

- A brief summary of the mapping methodology, including ground truthing approaches.
- Some summary statistics of the results of the mapping, including areas that may be of further interest for marine managers.

In addition, an addendum to this report will outline the methodology and summary results relating to the collection of baseline marine and estuarine biodiversity data that will form part of a monitoring baseline for the detection of change in resource condition within the bays surveyed.

3 Marine habitat mapping and broad scale surveys in the Eyre Peninsula NRM region

Southern Australian nearshore marine systems are widely regarded for their high complexity, diversity and levels of endemism (e.g. Keough and Butler 1995, Edyvane 1999a, Connell 2007). Development of sustainable management strategies for these systems therefore presents a particular challenge (Turner *et al.* 2007), particularly in light of the broad range of potential or actual threats and given (Edyvane 1996, FAO 2003, Baker 2004, Flaherty and Sampson 2005, NY NRM 2008):

- A lack of historical/baseline data on marine systems in most instances,
- A diverse array of stakeholders competing for access to a range of overlapping resources and
- The physical difficulties and logistics of obtaining data in the marine environment at scales relevant to managers across a vast and often isolated coastline.

Broad scale habitat mapping has been a key feature of NRM in terrestrial systems, but has increasingly been applied to coast, estuarine and marine environments - although there is a concomitant need to develop a unified classification system (DEH 2007a, Mount *et al.* 2007). Baker (2004) describes a diverse group of marine benthic habitats from southern Australia:

- Estuaries,
- Freshwater outputs (overlaps with estuaries),
- Tidal flats,
- Beaches,
- Saltmarsh and samphire,
- Mangroves,
- Seagrass meadows,
- Reefs,
- Benthic sand habitats,
- Shallow and deep water sponge "gardens",
- Benthic mud habitats,
- Island habitats and
- Mixed assemblages and gradients between broader habitat groups.

All of the above occur to some extent within the EP NRM region. However, the EP NRM coast and marine systems present a particular challenge to marine managers relative to other South Australian NRM regions. This region has the largest length of coast (~ 1600 km; EP NRM 2008) versus the next highest at around 1380 km for the NY NRM (NY NRM 2008), but it is worth noting that the linear distances between locations on either side of Yorke Peninsula are relatively short. In addition, the EP NRM would appear to have retained a far larger proportion of its original terrestrial habitat relative to other regions (43% of original native vegetation versus 10-20% for other regions; AMLR NRM 2007, EP NRM 2008, NY NRM 2008, SE NRM http://www.senrm.sa.gov.au/Home/tabid/243/Default.aspx, Accessed March 2009). Modification of terrestrial landscapes is a major contributor to water quality decline and habitat degradation within nearshore marine environments (e.g. Bryars 2003, AMLR NRM 2007, Fox *et al.* 2007, Turner *et al.* 2007). Coast, estuarine and marine systems within the EP NRM are thus large, remote and, at this point in time, potentially relatively undisturbed by altered terrigenous inputs. However, this should not be interpreted as suggesting that marine systems within the EP NRM region are not exposed to threats.

The following describes marine management regions, broadscale marine observations and mapping in the EP NRM region, including what is understood with respect to risks to nearshore systems.

3.1 Marine management regions

Marine habitat management regions within the EP NRM region comprise:

- Marine Planning/Ecosystem-based Management Guidelines (based on IMCRA Bioregions),
- Edyvane (1999a, b) Biounits,
- Marine Parks.

It is worth noting that Australian NRM zones are largely based on terrestrial catchments, bioregions or State Government management boundaries (Australian Government, http://www.nrm.gov.au/nrm/region.html, Accessed April 2009, Planning South Australia, http://www.planning.sa.gov.au/go/SAGovernmentRegions, Accessed April 2009). The marine borders for NRM regions have no relationship to IMCRA bioregions and similar. For this reason, bioregions and biounits often overlap NRM marine boundaries.

3.1.1 Bioregions

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA Version 4.0; Commonwealth of Australia 2006) classification places three coastal and two offshore provincial regions that occur to some extent within South Australia, with the EP NRM region including areas from the Spencer Gulf IMCRA Province and the Great Australian Bight IMCRA Transition (Commonwealth of Australia 2006). Mesoscale bioregions (that include the coastal regions defined under IMCRA Version 3.0) include eight coastal areas either wholly or partly within South Australia, five of which occur to some degree within the EP NRM region (Figure 1), including:

- Eucla – transitional warm to cold temperate rocky cliff coast,
- Murat – transitional warm to cold temperate rocky crenulate coast,
- Eyre – transitional warm to cold temperate rocky coast,
- Northern Spencer Gulf – confined inverse estuary on tidal coastal plain and
- Spencer Gulf – semi-confined inverse estuary on tidal coastal plain.

For full descriptions of these areas, including information on climate, oceanography, geology and geomorphology, biota and estuaries, see IMCRA Technical Group (1998).

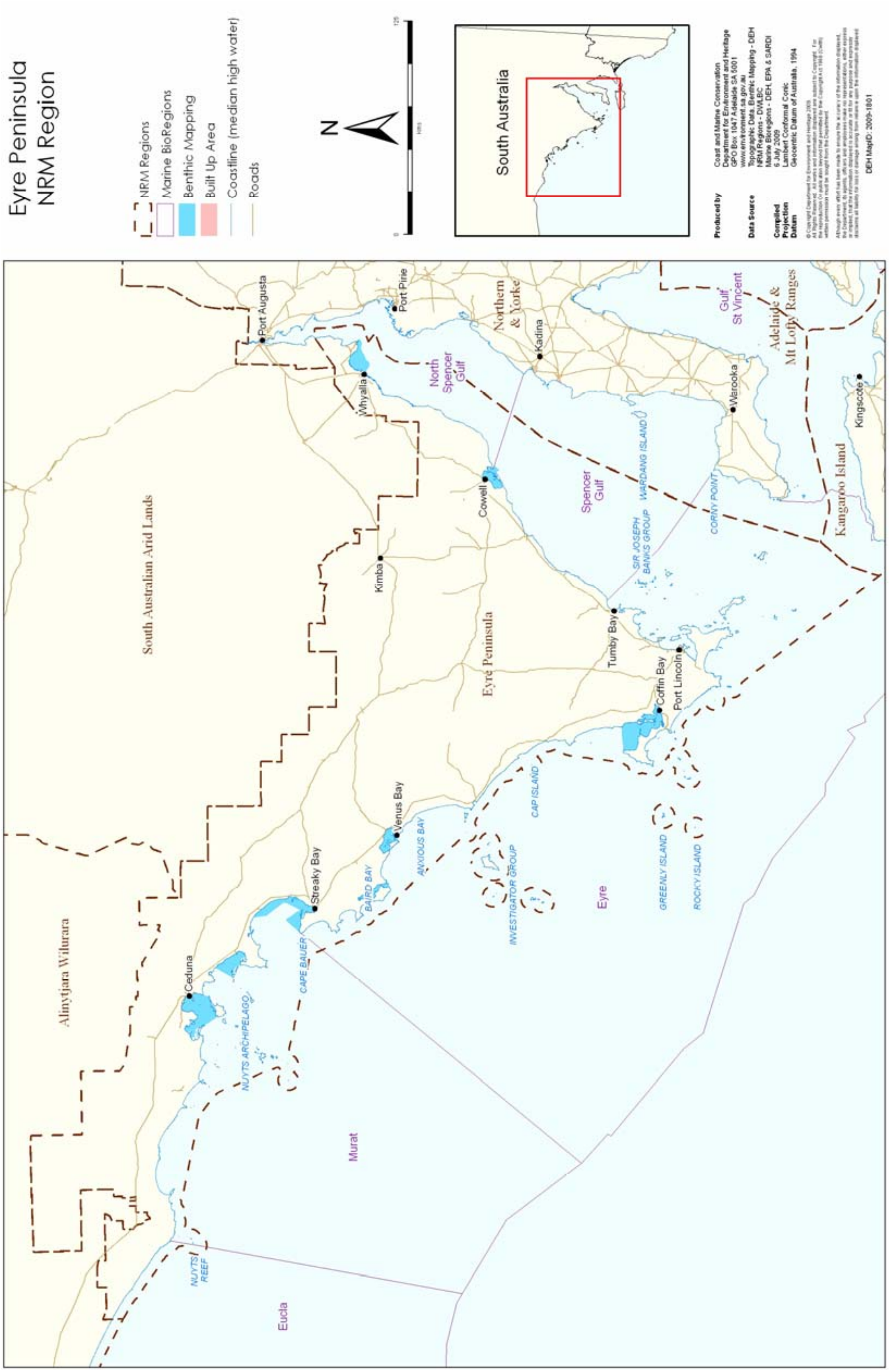

Figure 1 - Map of the EP NRM region showing Bioregions as well as the areas covered in the current benthic habitat mapping.

3.1.2 Biounits

Marine biounits, based on CSIRO habitat mapping (1:100,000 scale) and the work undertaken by Edyvane (1999a, b) comprise 35 areas along the South Australia coast to a depth of around 50 m. There are 15 biounits that occur wholly or partly within the EP NRM region with summary information on each included as part of the draft State of the Region report (EP NRM 2008). For full descriptions of each biounit, see Edyvane (1999b), including information relative to (amongst others): biogeography, conservation values and status, fisheries, recreation and tourism, science, research and education as well as cultural and historical aspects.

IMCRA bioregions and/or Edyvane (1999a, b) biounits may be used to as the first layer in defining areas/natural assets that may be of particular interest as well as the broader targeting of management activity (IMCRA Technical Group 1998, Baker 2004). Indeed, the IMCRA bioregions have played a role in the determination of MPAs (DEH 2009b; see below). Similarly, biounits are employed as descriptive components of State of the Region reporting (AMLR NRM 2007, EP NRM 2008, NY NRM 2008). However, both regional classifications are based on integrated biogeographic data from a range of species groups as well as related geomorphological and physical environmental factors. These regions are therefore difficult to relate to specific areas/habitat types that may require targeted management intervention. Furthermore, most of the stress factors (or threats – see discussion) identified for marine systems relate to habitat destruction and water quality issues that are generally concentrated to the near shore fringe (Bryars 2003, AMLR NRM 2007) at smaller scales than either classification can readily resolve.

3.1.3 Marine parks

Marine Protected Areas (MPAs) are a major marine environmental management and conservation initiative within South Australia. Designation of MPA areas was based on 14 design principles that include biological, social and cultural aspects (DEH 2009b). The system of 19 MPAs spread across the South Australia coast will form a key element for the protection and conservation of marine biodiversity as well as cultural and historical values within a framework that will allow for ecologically sustainable development of marine resources. The associated management and monitoring strategies thus have important implications for NRM throughout the state.

There are 11 proposed MPAs that occur wholly or partly within the EP NRM region including (DEH 2009b):

- Far West Coast Marine Park,
- Nuyts Archipelago Marine Park,
- West Coast Bays Marine Park,
- Investigator Marine Park,
- Thorny Passage Marine Park,
- Sir Joseph Banks Group Marine Park,
- Neptune Islands Group Marine Park,
- Gambier Islands Group Marine Park,
- Franklin Harbour Marine Park,
- Upper Spencer Gulf Marine Park and
- Western Kangaroo Island Marine Park (small portion thereof).

Although MPA boundaries have been defined, each requires further development in terms of internal multiple-use zoning, associated management plans and development of Performance Management Systems that will likely include some level of physical environmental and/or biological monitoring (NY NRM 2008, DEH 2009b). Zoning for Marine Parks in SA will include four types of internal zones plus provision for establishing special purpose areas (Marine Parks Act 2007; http://www.legislation.sa.gov.au/LZ/C/A/MARINE%20PARKS%20ACT%202007/CURRENT/2007.60.UN.PDF). These zones/areas are defined as follows:

- **General managed use zones** - zones established so that an area may be managed to provide protection for habitats and biodiversity within a marine park, while allowing ecologically sustainable development and use.
- **Habitat protection zones** – zones established so that an area may be managed to provide protection for habitats and biodiversity with a marine park, while allowing activities and uses that do not harm habitats or the functioning of ecosystems.
- **Sanctuary zones** - zones established so that an area may be managed to provide protection and conservation for habitats and biodiversity within a marine park, especially by prohibiting the removal or harm of plants, animals or marine products.
- **Restricted access zones** - zones established so that and area may be managed by limiting access to the area.
- **Special purpose areas** - areas within a marine park with boundaries defined by the management plan, in which specified activities, that would otherwise be prohibited or restricted as a consequence of the zoning of the area, will be permitted under the terms of the management plan.

In addition to MPAs, there is a range of existing conservation, recreation parks and reserves within the EP NRM region. See the draft State of the Region report (EP NRM 2008) for a summary.

3.2 Habitat mapping

Relative to elsewhere in the state, the EP NRM region has limited historical data on benthic habitats. As with the rest of the South Australian coast, on the broadest scale, there is the CSIRO 1:100,000 benthic habitat maps that were used by Edyvane (1999a, b) to develop biounit designations. Shepherd and Womersley (1981) used diver and boat observations to map the benthic community within Waterloo Bay using six reef and five seagrass (including bare sand) habitat types. Results of the survey suggest that the arrangement of habitats is spatially and temporally dynamic relative to water movement and depth.

The adjacent NY NRM Board in collaboration with the Department for Environment and Heritage undertook a fine scale habitat (1:10,000) mapping exercise between 2005 and 2007 in the upper reaches of Gulf St Vincent and Spencer Gulf to a depth of 15 m (DEH 2007a, b, c). These areas encompass the largest areas of seagrass in South Australia as well as other unique environmental values (NY NRM 2008, see Winnonowie and Clinton Biounit information Appendix A, Edyvane 1999a, b). A focus on habitat mapping and development of an understanding of both natural changes (see Seddon 2000) and anthropogenic sources of change is critical to appropriate management. As reverse estuaries (e.g. Edyvane 1999a), the biological systems within the upper reaches of both gulfs may be particularly sensitive to factors that may further increase water temperature and salinity such as proposed desalination operations as well as global warming. Within Spencer Gulf, the mapped area encompassed the coast from the Munyaroo Conservation Park on the east coast of Eyre Peninsula to Port Broughton on the west coast of Yorke Peninsula and therefore included a substantial area within the EP NRM region (DEH 2007a, c).

Importantly, these observations were undertaken based on cover assessments of a hierarchy of physical and/or biological characteristics along similar lines to the framework developed by Allee *et al.* (2000) and the Tasmanian Aquaculture and Fisheries Institute (SEAMAP 2008) including:

- Geomorphic type (hard/soft bottom),
- Biogeomorphic type (vegetated or unvegetated),
- Substratum/ecotype (seagrass, algae, sand/silt or reef),
- Structure (habit and density of cover) and
- Cover (extent % of the substratum coverage).

The resultant mapping was verified with extensive video ground truthing (DEH 2007a).

3.2.1 Fisheries habitat areas

An inventory of benthic habitats that are important for fisheries was undertaken by Bryars (2003) through an assessment of coastal near shore assets across South Australia (up to 20 m depth or 3 km offshore – whichever came first). This summary classified benthic communities relative to 13 basic habitat types (that included the associated overlying pelagic component):

- Reef,
- Surf beach,
- Seagrass meadow,
- Unvegetated soft bottom,
- Sheltered beach,
- Tidal flat,
- Tidal creek,
- Estuarine river,
- Coastal lagoon,
- Mangrove forest,
- Saltmarsh,
- Freshwater spring and
- Artificial habitats.

Habitat areas were only included if they were relatively large and/or significant to local fisheries. The depth/distance limit employed in this survey was based on a lack of data on deepwater systems as well as the view that shallow near shore areas were most threatened. The Bryars (2003) inventory was used to define 62 Fisheries Habitat Areas (FHAs) across the South Australian coast, including 30 within the EP NRM region that variously included all of the above habitat types except Coastal Lagoon and Freshwater Spring (Appendix A).

Sustainable management of commercial and recreational fisheries is a critical element of marine NRM. However, the consideration of habitats in terms of their importance to fisheries may discount other values. For example, a large area of reef may support a number of fisheries relative to small, isolated outcrops, but the latter may be critically important in terms of biodiversity/conservation at local scales. In addition, the resolution of habitats within this assessment would appear to be too coarse to determine anything other than major changes through time. This issue may be compounded by the overlapping of some of the habitat types (Appendix A).

3.2.2 Other marine benthic habitat mapping

Alternative sources of information on benthic habitats might be obtained from environmental impact assessments and monitoring associated with current and proposed coastal developments including (amongst others):

- Marinas,
- Jetty and port facilities (e.g. SANTOS Limited 1981),
- Aquaculture zoning,
- Housing developments,
- Stormwater and wastewater outfalls,
- Desalination plants (notably a proposed desalination facility at Point Lowly) and
- Specific "one off" events such as the 1992 *Era* oil spill at Port Bonython (Wardrop *et al.* 1992, Connolly 1994).

There is a diverse array of 'grey' literature associated with the above, the availability of which and relevance in support of benthic habitat mapping is variable. The Draft Environmental Impact Statement for Port and Terminal Facilities at Stony Point, South Australia, describes five distinct intertidal and subtidal habitat types in the vicinity of the (then) proposed development (SANTOS Limited 1981). However, while the habitat types employed in the SANTOS Limited (1981) summary have some resemblance to those identified elsewhere (notably the deeper water group), the potential for alignment with habitat groups at the larger scale is perhaps limited.

3.2.3 Coastal vegetation mapping

The "Biological Survey of South Australia" database (DEH, http://www.environment.sa.gov.au/biodiversity/ecological-communities/biosurveys.html#surveys, Accessed April 2009) provides a nationally consistent approach to vegetation classification called the National Vegetation Information System (NVIS) with more than 9000 distinct habitat types based on the vegetation and physical environmental data (DEH 2006, DEWR 2007). Part of the South Australian biological survey includes a state-wide investigation into coastal, dune and cliff-top vegetation that employed 22 broad vegetation types (Opperman 1999). A similar survey of saltmarsh and mangrove habitats was completed by Canty and Hille (2002) and included 69 habitat codes based on a five-tiered classification system using landform, estuarine influence, degree of inundation, vegetation cover and integrity.

There are 16 recognised estuaries within the EP NRM region, with most being classified as tide-dominated, with the Tod River being the only permanently flowing water course (DEH 2007d). Detailed descriptions of each estuary relative to physical environment (catchment area, flows, etc.), habitats, bird and fish species, protection arrangements, cultural assets, economic importance, activities and pressures are presented in the Estuaries Information Package for the EP NRM region (DEH 2007d).

3.2.4 Satellite imagery

Much of the following is based on a summary developed for Gulf St Vincent (see Petrusevics 2008) but should nonetheless be valid for most, if not all, of the South Australian coast.

Satellite remote sensing provides almost daily data (cloud permitting) on oceanographic, meteorological and hydrodynamic data at a resolution of ~ 1 km^2 since the 1970s (Petrusevics 2008). A range of observational datasets is available from a succession of satellites, with varying degrees of emphasis on either sea surface temperature or visible light imagery including:

- Very High Resolution Radiometer (VHRR, 1972 – 1978),
- Coastal Zone Color Scanner (CZCS, late 1970s),
- Advanced Very High Resolution Radiometer (AVHRR, 1978 – 1984),
- Sea-viewing Wide Field-of-view Sensor (SeaWiFS, 1979 – 2004) and
- Moderate Resolution Imaging Spectrometer (MODIS, *Aqua* and *Terra* – from 2000).

3.2.5 Other potential data sources and GIS layers

Analysis and interpretation of GIS-based habitat mapping would benefit from access to a range of additional information and/or layers related to a range of features including (among others):

- infrastructure (shipping channels, jetties, breakwaters, etc),
- coastal inputs (outfalls, rivers and stream),
- tourist attractions (recreational beaches, boating/fishing or SCUBA diving areas, etc.),
- aquatic and coastal reserves,
- local and State Government planning regions and
- hydrodynamic modelling.

There are a variety of sources available for this type of information, generally at the state level, including (amongst others):

- The extensive list of GIS layers summarised by Caton *et al.* (2007) as part of "Conservation Assessment of the Northern and Yorke Coast", many of which have relevance across the state,
- Atlas of South Australia (http://www.atlas.sa.gov.au/ - Coastal Management Area, accessed May 2008),
- South Australian Waters: an Atlas and Guide (Boating Industry Association of South Australia 2008),
- A number of management strategies developed by the Coastal Protection Board related to acid sulphate soils, coastal weeds, coastal erosion and beach monitoring (see http://www.environment.sa.gov.au/coasts/management.html, accessed March 2009),
- Fisheries stock assessments,
- Aquaculture monitoring (see below) and
- Non-mapping environmental monitoring and research.

3.2.6 Aquaculture monitoring

All marine-based aquaculture in South Australia is required to maintain a level of environmental monitoring as part of licensing (Aquaculture Regulations 2005).

With the expansion of the aquaculture industry in the Eyre Peninsula (notably southern bluefin tuna farming off Pt Lincoln; EP NRM 2008) there has been a growing demand for suitable locations as well as an increased monitoring and research capability at least at the scale of specific operations. Aquaculture operations within the EP NRM region are relatively extensive compared to other regions. The associated water quality and environmental monitoring may thus form a regular input of data that may support the interpretation of habitat mapping.

From 2001, tuna farming operations were monitored under a compliance-based report card approach (called TEMP) that includes annual monitoring of seacages in their present location within lease areas outside Boston Bay (http://www.sardi.sa.gov.au/sbt/environmental_monitoring/introduction_to_southern_bluefin_tuna_environmental_monitoring, Accessed March 2009). These observations are based around video and benthic infauna surveys (macro-invertebrate species living within surface sediments), which in 2007 included 12 compliance (on farm) and 18 control locations (Loo *et al.* 2008). Earlier assessments of tuna farming operations were conducted within Boston Bay in the mid 1990s (prior to all operations being moved offshore) and included observations of the soft bottom benthic community as well as infauna (Cheshire *et al.* 1996a, b).

The South Australia Shellfish Quality Assurance Program (SASQAP) has operated since the early 1990s and ensures that farmed shellfish within 18 regions across the State are fit for consumption through an ongoing program of water quality monitoring (SASQAP 2004). Currently the EP NRM region includes nine SASQAP growing/harvesting areas (http://www.pir.sa.gov.au/aquaculture/monitoring__and__assessment/sasqap, Accessed April 2009). However, it needs to be realised that the primary focus of SASQAP monitoring relates to microbial, phytoplankton and biotoxin monitoring for the purposes of food safety. Nonetheless, information on the pattern of restrictions placed on SASQAP monitoring areas may form a useful indicator for more targeted investigation.

3.2.7 Beach profiling

The Coastal Protection Branch (DEH) has undertaken annual sand profile observations of up to 44 locations along the Eyre Peninsula coast since 1986 (Eaton *et al.* 2001). These observations are targeted to monitoring sand movements (both accumulations and losses) across beaches including dunes and the subtidal nearshore zone. Substantial changes are apparent at most beaches over the sampling period, although most are considered to be of natural origin. However, beaches at North Shields, Lucky Bay, Arno Bay, Smoky Bay and Venus Bay warrant further attention, if not management intervention (Eaton *et al.* 2001).

3.3 Reef systems

The EP NRM coastline has protracted stretches of rocky/cliff coastline and consequently supports large and diverse reef communities (Edyvane 1999b).

Great Australian Bight waters have been reported to support macroalgal communities to a depth of 70 m (Shepherd and Womersley 1971, 1976), which suggests that water clarity within this stretch of coast is very high. However, investigations of reef systems within the EP NRM region are temporally and spatially limited. Notably there have been no reef health surveys along the lines of Turner *et al.* (2007) within the EP NRM region, but in 2007 and 2009 investigations of the lower Eyre and far west coast reef communities were done as part of a collaboration between the University of Tasmania and DEH using the Edgar and Barrett (1997, 1999) methodology (yet to be reported at the time of writing).

Shepherd and Womersley (1971, 1976) describe the composition and structure of macroalgal communities at Pearson Island and St Francis Island respectively. More recent surveys under the general banner of “SA Offshore Island Expeditions” have repeated and expanded on these earlier surveys of offshore islands. These surveys entail a collective effort from a range of organisations (including SARDI, DEH and the Universities) spanning a range of disciplines. The investigations include;

- Isles of St Francis in 2002

  Benthic community investigations were mostly focussed on observations of the reef habitats relative to composition and biogeography (Womersley and Baldock 2003), community composition and productivity (Turner and Cheshire 2003) and zonation (Baker and Edyvane 2003).

- Investigator Group in 2006

  Investigations included (amongst others) surveys of seagrass systems (Bryars and Wear 2008), benthic habitats (Miller and Wright 2008) and the macroalgal community (Baker *et al.* 2008).

Another expedition to the Sir Joseph Banks Group has just been completed (May 2009).

Connell and Irving (2008) undertook an investigation into the composition and structure of reef systems across different spatial scales (1-10 km, > 100 km and >

1000 km) across the whole of southern Australia (Cape Leeuwin in Western Australia to Mooloolaba in southern Queensland),which included observations at Port Lincoln on southern Eyre Peninsula. This study showed that differences between reefs at all scales could largely be explained by biogeography (latitude and longitude of each site).

Observations by the community-based monitoring program "Reef Watch" within the EP NRM region are limited, comprising only "Feral or in Peril" observations (17 spread across six locations) that include sightings of a selection of species that are readily recognised marine pests (Feral) or species that may be of conservation concern/public interest (in Peril). These observations include some information on locations, but no real data of benthic community composition (http://www.reefwatch.asn.au/, Accessed March 2009).

3.4 Seagrasses

Mapping, site comparison or monitoring of seagrasses on the EP NRM coasts are rather limited. Shepherd and Robertson (1989) summarise a number of targeted seagrass investigations/mapping exercises or point observations within the EP NRM region. This summary suggests that seagrasses beds are patchy on the exposed southern Australian coasts such as those within the Great Australian Bight, generally occurring in sheltered areas or at depths where wave energy is reduced but there is still sufficient light. *Posidonia angustifolia* and *Posidonia coriacea* are reported to occur to 25 - 30 m depth at the base of cliffs off western Eyre Peninsula (Shepherd and Robertson 1989).

Shepherd (1975) mapped benthic communities in the vicinity of two outfalls (one for domestic wastewater, one for a fish cannery) at Proper Bay, Port Lincoln. This survey described a number of habitat types relative to each outfall. At Billy Lights Point these community types included:

- Bare sand,
- *Posidonia australis*,
- *Pinna*/holothurian,
- Rubble bottom,
- *Heterozostera tasmanica* and
- Granitic reef.

Within Proper Bay a slightly altered set of community types was considered:

- *Ulva lactuc*a and *Posidonia*,
- *Posidonia australis* (b1),
- *Posidonia australis* (n1),
- Bare sand.

Note that the two forms of *Posidonia australis* (b1 and n1) are probably separate species with n1 being *Posidonia sinuosa* and/or *Posidonia angustifolia*. The Shepherd (1975) survey describes areas of seagrass loss or decline in the vicinity of both outfalls, in particular the Proper Bay site.

Aerial photography has been used to map seagrass distribution and change over a wide variety of coastal environments in South Australia at resolutions superior to Landsat imagery. Within the EP NRM region this includes:

- Boston Bay, Port Lincoln (Hart 1999) and
- False Bay, Whyalla (Cameron 2002).

Hart (1999) considered changes in seagrass cover within the entirety of Proper Bay and strips along the coast of Boston Bay and Boston Island to 10 m depth based on differences between orthorectified aerial images from the mid 1970s and 1996. Although this investigation produced maps of seagrass distribution within the total area considered (~98 km^2), there were no distinctions in terms of seagrass species composition or density (Hart 1999). Rather, a cutoff coverage of 50% was used to differentiate between seagrass cover and bare substrate. Results were thus considered relative to four categories:

- Seagrass no change,
- Substrate no change,
- Seagrass loss and
- Substrate loss.

It is worth noting that the areas of seagrass loss or decline observed by Shepherd (1975) within Proper Bay would appear to be consistent with Hart (1999) observations. From the mid 1970s to 1996 there was a net increase in substrate (or loss of seagrass) of approximately 1.685 km^2 across the entire area considered. However, Hart (1999) stipulates that the aerial images employed were obtained for the purposes of terrestrial applications and are somewhat limited in terms of use in benthic mapping and that differences in seagrass cover (either loss or gain) may be confounded by drifting macroalgae. Nonetheless, results of this mapping can be employed to look for historical changes in seagrass cover within the areas considered, if only in terms of all seagrasses with coverage of 50% or more.

The Cameron (2002) investigation at False Bay, Whyalla is not publically available at the time of writing (D. Hart Pers. Comm. 2009).

3.5 Soft bottom habitats

Soft bottom systems form the largest marine environment within the EP NRM region (EP NRM 2008), although mapping, surveys and research are spatially limited. Most observation has occurred in the Pt Lincoln region in relation to southern bluefin tuna seacage aquaculture with initial surveys and reporting conducted in 1996 when the bulk of farming was conducted inside Boston Bay (Cheshire *et al.* 1996a, b). These surveys included observations (mostly video) at fixed distances from cages as well as controls at least 1 km or more distant. Results of these surveys may serve to ground truth habitat maps, although at more than a decade old, the validity of such a comparison is open to question. There are also the results of seacage monitoring in the current farming locations outside Boston Bay, although the data for mapping may be of limited use owing to the area and depths involved (seacages currently operate in 20 – 24 m). There may also be commercial/confidentiality constraints on data access.

Commercial prawn trawling within Spencer Gulf began in 1967 (PIRSA 2003), but unfortunately there is no analogous investigation of benthic systems along the lines of Shepherd and Sprigg (1976) against which the long term effects of trawling might be measured. Svane *et al.* (2009) undertook a range of benthic observations from five areas within current prawn fishing grounds (21 – 23 m deep) that had a varied, but known, level of accumulated prawn trawling history. The benthic community at these sites was found to be dominated by sandy sediment and some fine gravel in some areas, with varied but overall low macro fauna/flora cover that negatively correlated with the accumulated prawn trawling effort (Svane *et al.* 2009). Less trawled areas were characterised by a mixture of bearded mussel (*Trichomya hirsutus*), southern hammer oyster (*Malleus meridianus*) and razor clam (*Pinna bicolor*) that may be analogous to the *Malleus-Pinna* assemblage identified in Gulf St Vincent by Shepherd and Sprigg (1976). It was concluded that, similar to Gulf St Vincent (see Tanner 2005), prawn trawling was likely to have a strong negative influence on the structure of benthic communities in Spencer Gulf, although there is a north-south environmental gradient that may explain some of the differences between sampling areas (Svane *et al.* 2009). Both Tanner (2005) and Svane *et al.* (2009) noted a lack of eelgrass (*Heterozostera tasmanica*) in their observations, although this species was considered to be abundant over large areas of Gulf St Vincent (Shepherd and Sprigg 1976) and probably within Spencer Gulf to a depth of around 30 m, although in the absence of historical data for the latter this inference cannot be confirmed. It is important to note that, while prawn fishing grounds cover less then 15% of Spencer Gulf waters, they actually include a large proportion of the deeper areas (> 15 m; Svane *et al.* 2009).

3.6 Threats to marine systems in the EP NRM region

There are a diverse range of threats to coast, estuarine and marine systems in South Australia derived from an equally variable array of activities and stakeholders (Edyvane 1996).

In a risk assessment of coast, estuarine and marine assets within the EP NRM region, Cheshire *et al.* (2008) reported a group of 18 assets that were juxtaposed against 23 “issues” (or threats; Table 1). Coastal pest plants and animals, coastal development (both construction and operational phases) and coastal access (off-road vehicles, trail bikes, beach camping, etc) were noted as imposing extreme threats to a range of coastal assets, in particular intertidal and subtidal seagrasses, coastal vegetation, estuarine environments and enclosed soft sediment systems. However, the majority of threats (19 out of 23) imposed at least a high level of risk to some form of asset. Similarly, all assets were associated with some type of high risk (Cheshire *et al.* 2008). An attempt to offer some spatial component to asset-threat combinations across the region was only partially successful owing to a lack of data on the distribution of the asset and/or the associated threat.

Note that although Cheshire *et al.* (2008) acknowledged climate change as a threat to coast, estuarine and marine assets it was considered that this subject required a separate risk assessment. Similarly, invasive marine pests as well as threats with respect to rare, endangered or threatened species were also recommended as subjects for targeted assessments.

The threats identified by Cheshire *et al.* (2008) in the Coast and Marine Prioritisation Workshop for the EP NRM Region broadly align with those described in the State of the Region reporting for the EP NRM region (EP NRM 2008) including:

- Climate change,
- Development – marinas, residential, holiday shacks,
- Flooding and erosion,
- Desalination plants,
- Ferry operations,
- Tourism visitor facilities and coastal infrastructure,
- Aquaculture,
- Commercial fisheries,
- Other industries (e.g. mining),
- Coastal Acid Sulphate Soils (CASS) and
- Visitor use and general human impacts.

Successful management of coast, marine and estuarine assets requires mechanisms to address threats, minimise impacts and ameliorate damage. These approaches include the need for accurate and repeatable benthic habitat mapping at relevant scales.

Table 1 – Assets and issues (threats) identified within the Eyre Peninsula NRM Region.

Assets
Coastal/veg - Dunes/unvegetated
Coastal/veg - Dunes/vegetated
Coastal/veg - Mangroves/intertidal mudflat
Coastal/veg - Rocky Cliff
Coastal/veg - Samphire/gahnia/salt marsh
Estuary - Tidal and river dominated
Saline lakes
Pelagic - Deep Water (> 40 m)
Pelagic - Inshore (< 40 m)
Reef - Intertidal
Reef - Subtidal
Sand/Soft Sediment - Bays/Sandy Beaches (Open coast)
Sand/Soft Sediment - Bays/Sandy Beaches (Enclosed)
Sand/Soft Sediment - Shallow subtidal
Sand/Soft Sediment - Deep water (> 40 m)
Seagrass - Intertidal
Seagrass - Subtidal
Water quality (clarity, nutrient status, etc)
Issues
Point Source - industrial discharge
Point Source - waste water
Point Source - thermal
Point Source - stormwater pipes, drains
Diffuse source - nutrients
Diffuse source - chemical contaminants
Diffuse source - sediment inputs
Marine vessel - leakages, hydrocarbons, antifoulant, airborne pollution

Oil Spills
Desalination plant impacts
Coastal development - operational
Coastal development - construction
Dredging
Acid Sulphate Soils
Domestic animals and livestock - grazing, disturbance
Mining impacts
Marine invasive species
Pest plants and animals (coastal)
Litter, rubbish dumping, marine debris
Water extraction (ground water and loss of surface water flow from catchments)
Access/marine (swimming with sea lions/sharks/tuna, jet skis, etc.)
Access/coastal (off-road vehicles, trail bikes, bush camping, beach combing)
Modification of benthic habitat

4 Remote sensing and marine habitat mapping – development of a standardised approach

A key element to the development and implementation of resource condition targets for Natural Resource Management is to establish accurate baselines from which future changes in ecosystem structure (or health) can be compared. Sustainable management of natural resources and the development of conservation strategies at ecosystems levels require a greater understanding of the distribution and status of the supporting habitats (DEH 2007a, Mount *et al.* 2007). Broad-scale habitat mapping, coupled with geographic information system (GIS) capability is a powerful tool for large-scale environmental management (GESAMP 2001, Flaherty and Sampson 2005, Mount *et al.* 2007). However, this approach is reliant upon a capacity to consistently differentiate and map habitat types and therefore presents a particular challenge when dealing with subtidal marine systems wherein traditional remote sensing techniques may be of restricted value (DEH 2007a, Mount *et al.* 2007). Current marine habitat mapping criteria are targeted at regional scales (Allee *et al.* 2000, Mount *et al.* 2007) and there is thus a need to develop standardised national criteria for marine habitat mapping (Allee *et al.* 2000, DEH 2007a, Mount *et al.* 2007).

National scale habitat mapping definitions have been established for terrestrial systems in Australia (see the National Vegetation Information System (NVIS) DEWR 2007), but marine systems are yet to be comprehensively unified (DEH 2007a, Mount *et al.* 2007). Allee *et al.* (2000) identified several requirements for a national marine habitat classification system including:

- Universal and consistent coverage that is spatiotemporally sensitive,
- An additive structure such that classification can be taken to finer scales that fit within broader classifications as data become available,
- Combines physical, geomorphic and biotic data,
- Compatibility with a GIS framework,
- Amenable to currently available data and technology and
- Provides a basis for identifying functional linkages wherein the observed patterns can be related to ecological processes.

The approach developed by Allee *et al.* (2000) for the USA employs a hierarchical system of 13 levels, most of which relate to broader scale geomorphic features. A hierarchical approach to habitat mapping has the advantage of flexibility in development of summaries as well as improving the resolution within more broadly classified regions as data become available (Allee *et al.* 2000, Mount *et al.* 2007).

Within Australia, one of the best examples of a large-scale marine habitat mapping program is SEAMAP in Tasmania, which has been in operation since around 2001 (Barrett *et al.* 2001). More recently major mapping programs have been undertaken in other states (including those by Marine Parks in NSW, Dept for Primary Industry and Deakin University in Victoria, and the Marine Futures program in WA). In South Australia, there is the recently completed benthic mapping of the upper Spencer Gulf (DEH 2007c) as well as the entire AMLR NRM region (DEH 2009a). The methodologies employed by the SEAMAP and DEH (2007a, c, 2009a) mapping programs are based on that of Allee *et al.* (2000), although the hierarchy includes only four levels; geomorphic type, substratum/ecotype, substrate eco-type and a series of modifiers (see Benthic Mapping and ground truthing methods below).

Aerial and satellite imagery have frequently been employed in understanding shallow marine environments, although most historical aerial/satellite imagery has been obtained with a view to terrestrial objectives (Mount *et al.* 2007) and the analysis of historical images from a marine habitat mapping perspective is frequently restricted (see Hart 1999). The limitations to detecting habitat differences in aquatic systems from aerial images include (Mount 2003, DEH 2007a, Mount *et al.* 2007):

- Water depth,
- Water clarity,
- Sun angle and reflection and
- Water surface state.

In spite of these restrictions, remote sensing has proved to be a useful tool in identifying habitat modification in shallow marine systems (Allee *et al.* 2000, Mount 2003, Mount *et al.* 2007). Even so, acoustic technologies and processing techniques are increasingly capable of covering large areas of substrate with substantial accuracy, largely independently of factors that limit more traditional approaches. However, it is important to realise that habitat mapping is never an exact science with sacrifices being made relative to the competing needs for habitat type resolution versus spatial coverage. Further, it needs to be realised that the boundaries between habitat types are often broad transition zones rather than rigidly constrained and that these zones may shift according to seasonal fluctuations in vegetative cover (DEH 2007a).

Regardless of the approach to broader habitat classification, finer scale investigation requires varying levels of ground truthing, generally in the form of video or SCUBA operations (DEH 2007a, Mount *et al.* 2007).

The following describes a program of marine habitat mapping in the EP NRM region, building on recent developments in subtidal mapping. The aim is to develop a system of reliable, repeatable and relevant habitat mapping capability for near-shore environments that can be employed as a basis for natural resources monitoring and management.

5 Benthic habitat mapping and ground truthing methods within the EP NRM region

5.1 Overview

Mapping of marine habitats included eight large embayments across the EP NRM region from False Bay in upper Spencer Gulf in the east to Denial Bay in the west (Figure 1). Mapping covered the area from median high water out to the sheltered extent of each bay, with the exception of Streaky Bay where mapping was limited by the availability of suitable aerial imagery.

Full coverage mapping of the Eyre Peninsula coastline, while desirable as a long-term goal, was not practical within the constraints of this study. The embayments chosen encompassed the major habitats likely to be impacted by shore-based activities, in particular reef and seagrass systems. Information on the distribution of benthic habitats was collected using a combination of techniques that collected data across increasingly finer scales, including:

- Aerial imagery was used to assess the spatial extent of habitats at the broadest level. Boundaries between habitats such as seagrass, bare substrate and reef are often evident on aerial images and have previously been used to map habitats out to 15 m in South Australia (DEH 2007a provides a simple overview of this process and habitat mapping in general).
- Acoustic data (from a single beam sounder) to further define the extent of habitats in deeper water where light penetration is limited and provide confirmation of habitat extent in areas mapped from imagery.
- Habitat identification and verification carried out using towed underwater video.

All information collected was compiled as spatial layers within a Geographic Information System (GIS) and used to produce hardcopy map books and an interactive ARC reader DVD. The latter enables users to access spatial layers for habitat and video ground truthing as well as underwater images.

The following sections describe this process in detail.

5.2 Digitisation of aerial imagery

Orthorectified aerial imagery used for digitisation of habitat boundaries for the Eyre Peninsula region was collected by DEH in 2004 at a resolution of 1 m per pixel. In 2004, imagery was not available for False Bay and as a result imagery from 2001 collected at a resolution of 2 m was used.

Habitat boundaries were identified on imagery and digitised (digitally traced) based on varying patterns, tones and textures on the orthorectified aerial imagery using GIS (Figure 2).

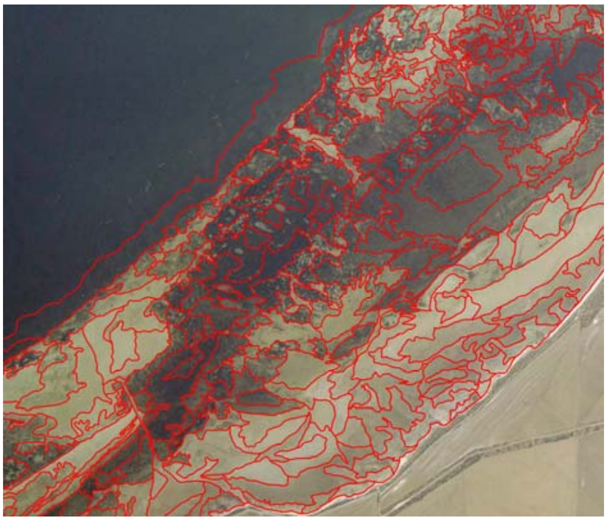

Figure 2 - Example of habitat delineation on an aerial image.

5.3 Video ground truthing

Extensive video ground truthing was carried out to validate mapped polygons derived from the aerial imagery. Proposed video sampling points were selected from imagery of each bay with the aim of maximising evenness of coverage of each bay (access was limited in some of the shallower bays) with a balanced representation of different habitat types. Video footage was collected at each of the pre-determined sampling points using one of two high-resolution, towed underwater video camera systems Morphcam by Morphvision, connected to a Sony GVD1000e digital video recording deck or a Scielex underwater video camera linked to an Archos portable digital hard drive recorder. Each video sample consisted of a 30 second drift. Differential GPS data was simultaneously encoded on the audio track of the videotape to provide position information relative to video footage.

Benthic habitat data was extracted from video footage using a purpose-built Visual Basic program. The program allows the operator to view videotapes and assign habitat types, which are stored along with the corresponding GPS location from the audio channel. Data were then compiled in a database from which GIS spatial layers were produced. Around 4100 video observations were collected and analysed in the EP NRM region.

5.4 Acoustic ground truthing

Interpretation of aerial imagery is subject to uncertainty due to the water clarity/light penetration and sun reflection on the sea surface and becomes less reliable with depth (Mount 2003, DEH 2007a, Mount *et al.* 2007). While the majority of mapping for the eight embayments was derived from aerial imagery, in the deeper margins of Coffin Bay and Denial Bay acoustic survey methods were also used.

Five acoustic (echo sounding) transects were undertaken in both Coffin Bay and Denial Bay to increase the confidence of habitat delineation from aerial images and to extend mapping beyond what is normally achievable from imagery in this region (i.e. 10 – 15 m). These surveys used a pole mounted Simrad EQ60 38/200 kHz transducer across a series of parallel transects spaced ~ 1000 m apart run through the deeper central parts of each bay from between 10 and 15 - 20 m depth. All surveys were conducted at a speed of around 3.5 knots. Acoustic data was collected and stored on the surface control unit hard drive along with differential GPS information. Several types of information were extracted from acoustic data, including;

- Bathymetry (depth),
- Substrate composition,
- Substrate relief and
- Presence of vegetation.

Acoustic data was classified based on data for two frequencies (38 and 200 KHz) from the logged raw sounder files in Echoview software (by Sonar Data Version 3.50). Classification of different habitats was based on the thickness and intensity of acoustic returns and differences between the two frequencies (Figure 3). Harder substrates tend to reflect acoustic energy more strongly thus producing a stronger second echo, while rougher (higher relief) substrates tend to scatter acoustic returns resulting in longer tail on the first echo. Acoustic reflectance above the sounder-detected bottom for the lower frequency (38 kHz) can often signal the presence of vegetation (Lucieer *et al.* 2007), particularly dense seagrass, although consistent differences in sounder-detected bottom between the two frequencies are also a strong indicator for the presence of seagrass (Figure 3) while regular inconsistencies suggest rough hard bottom (typically reef). Sounder-detected bottoms for the two frequencies tend to be the same in areas dominated by bare sand.

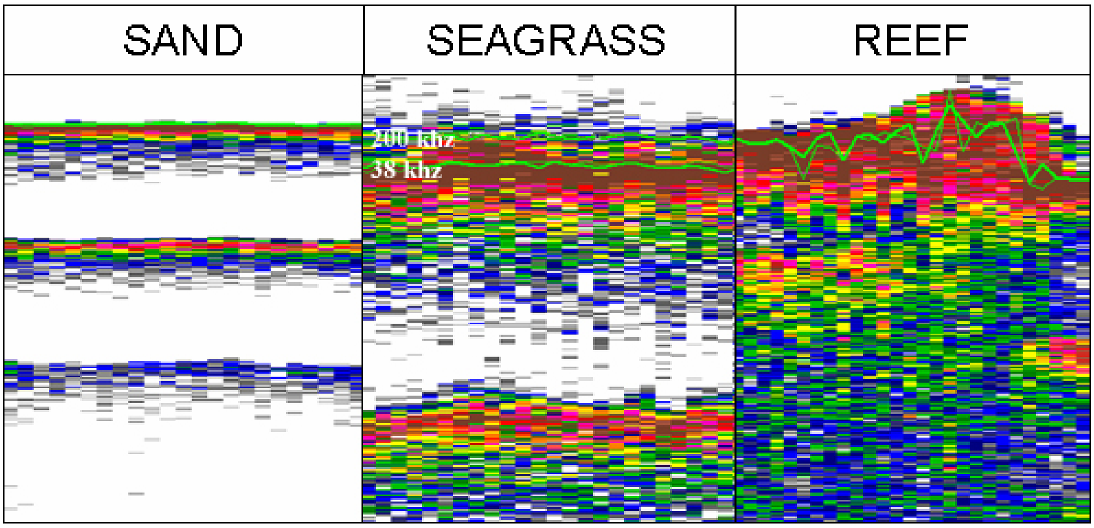

Figure 3 - Example of acoustic echogram for 38 khz (with 38 and 200 khz bottom detection lines overlaid) showing signals for sand, seagrass and reef.

Classified seafloor types based on acoustic data along with spatial geo-referencing information from a differential GPS were used to create a GIS spatial layer of substrate/habitat types.

5.4.1 Classification of habitats/production of maps

The approach used for classification of benthic habitats for marine habitat mapping in the Northern and Yorke NRM region for the upper Spencer Gulf and Gulf St Vincent (see above; DEH 2007a) was modified to include new habitat types encountered in the EP NRM region (and others) comprising four levels (Figure 4; DEH 2009a) in line with approaches used elsewhere in Australia and internationally.

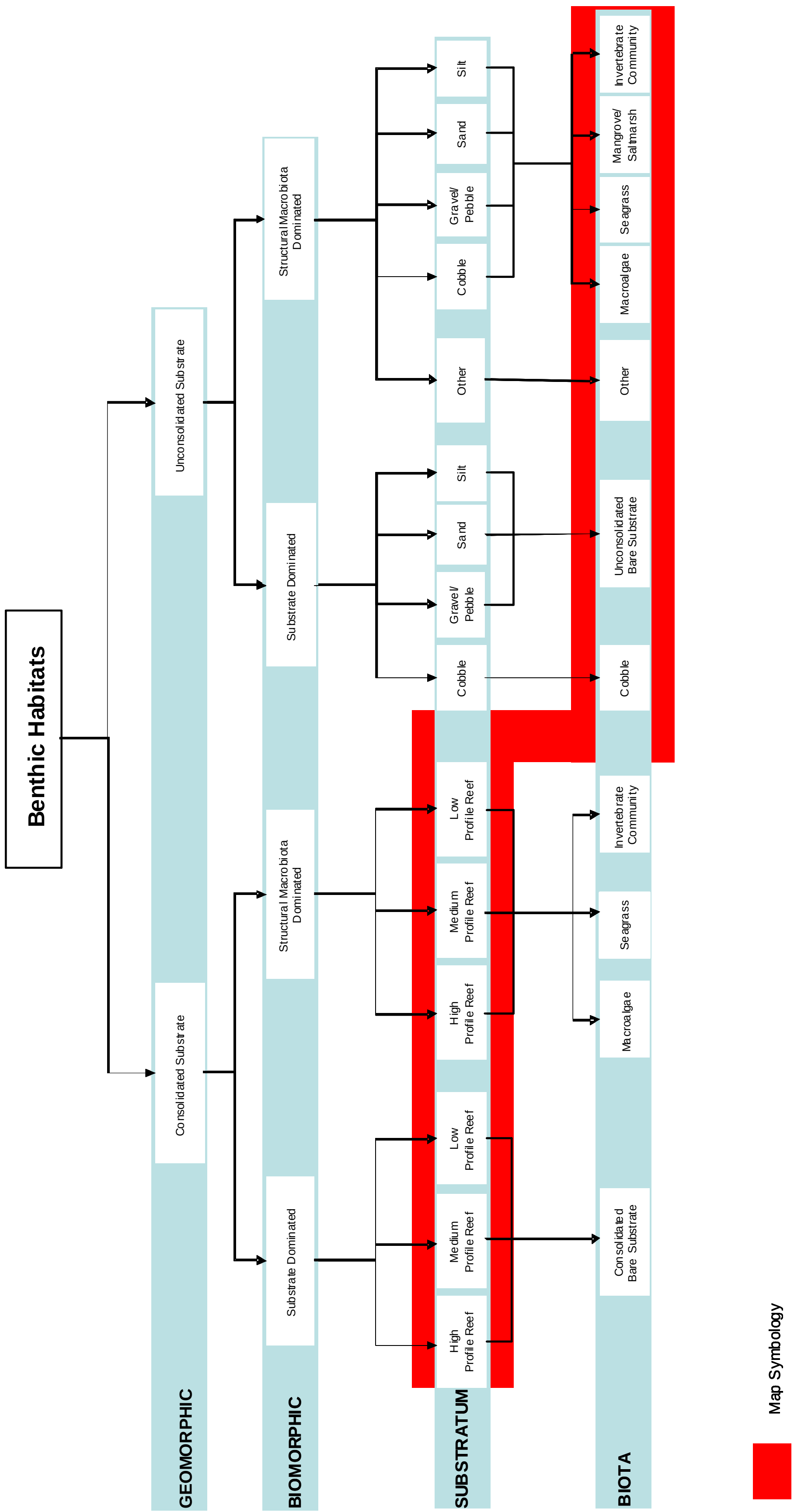

Figure 4 - Flow diagram of benthic habitat classifications. Map symbology is generated based on Substrate level classifications for consolidated benthos while video information (available in the associated ARC Reader DVD) is focussed more toward Biota level classifications.

Digitised habitat polygons were assigned pre-determined benthic habitat classifications based upon information from all spatial layers (imagery, acoustic and video data). In addition, attributes such as density and percentage (%) cover were assigned to habitat categories using a visual aid, adapted from Kendall *et al.* (2001; Figure 5). Habitats were broken down into consolidated and unconsolidated groups and then classified based on whether or not they were dominated by 'Structural Macrobiota' such as habitat forming species (e.g. seagrasses; see Mount *et al.* 2007 for a full description; Figure 4).

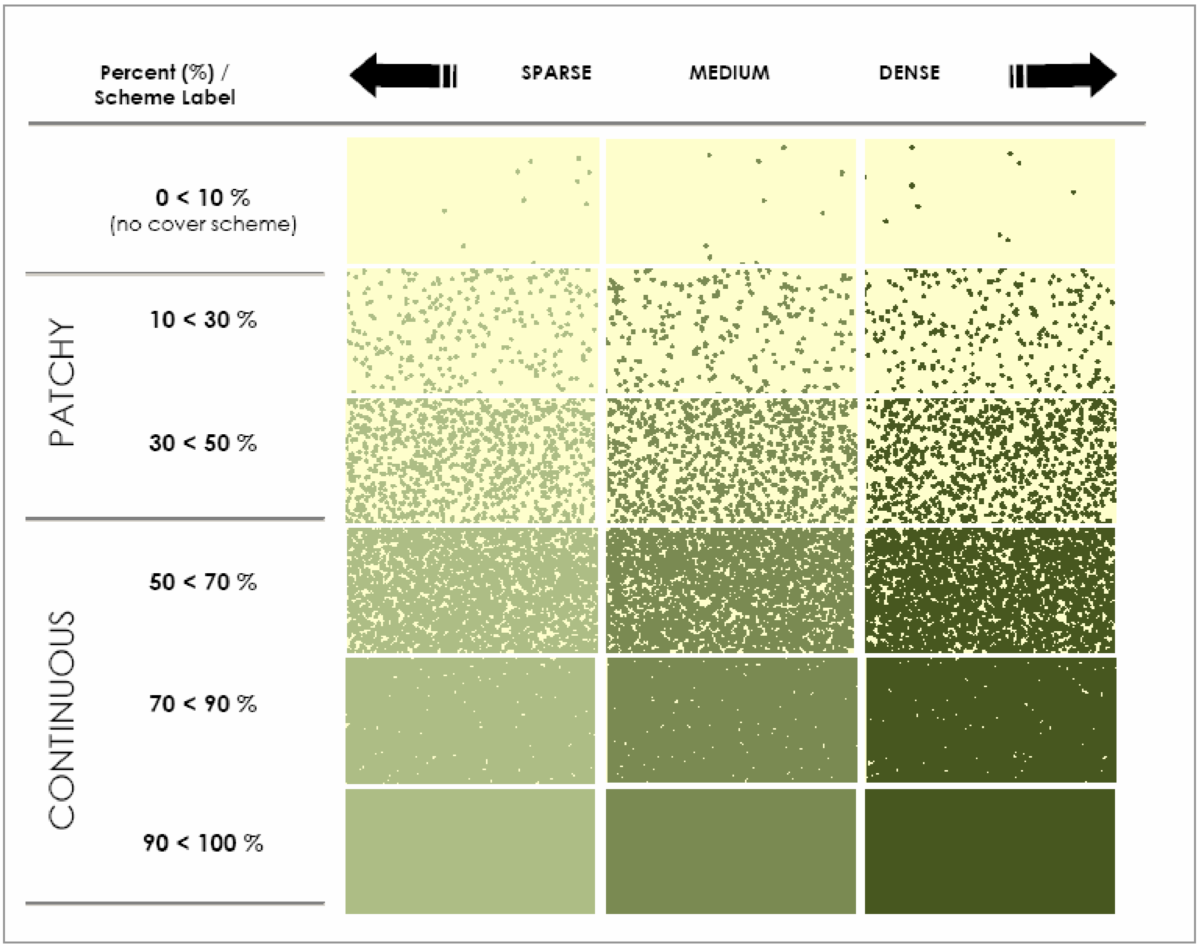

Figure 5 - Visual aid used for assigning percent cover and relative density (Kendall *et al.* 2001).

Maps were produced using classifications across two levels; consolidated habitats (reef) were classified at the level of substratum, since the dominant habitat structure is the reef, whereas unconsolidated habitats were classified at the level of biota since the structural complexity (at the macro scale) more often results from the biota itself (e.g. seagrasses, sponge gardens and *Pinna bicolor* beds).

An example of a benthic habitat map based on the above process is shown in Figure 6.

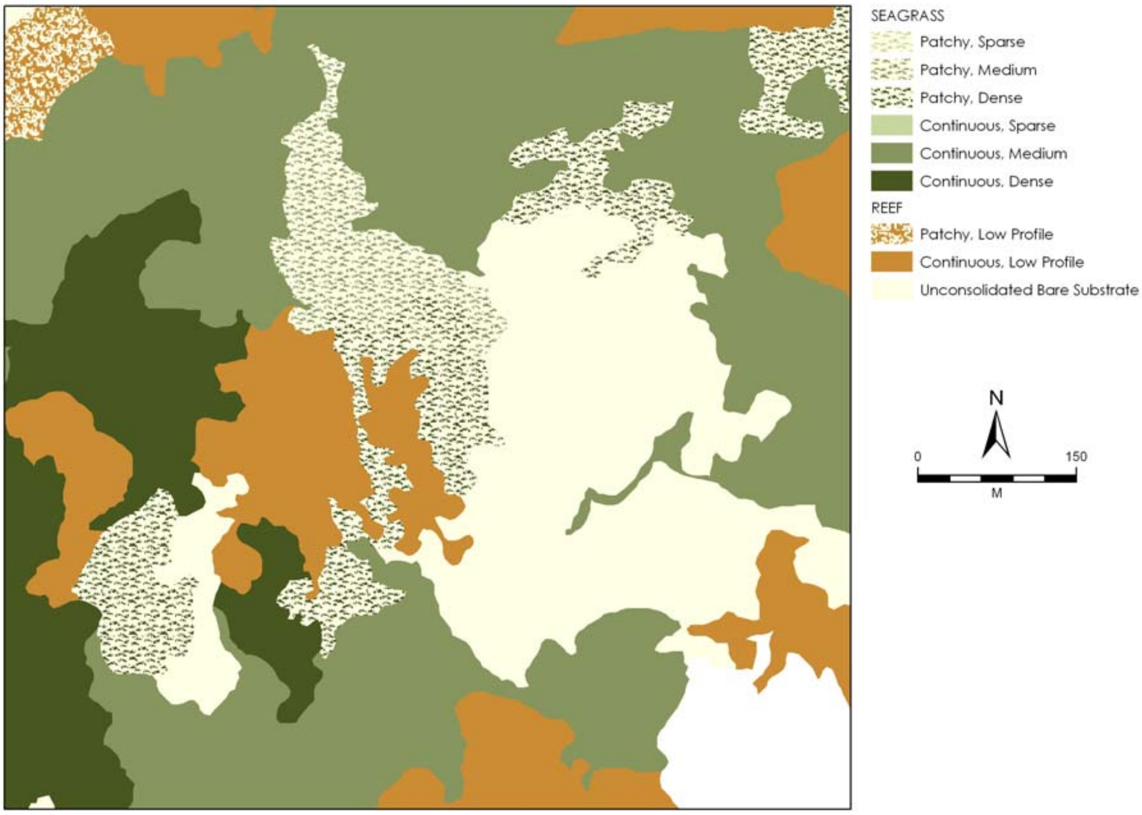

Figure 6 - Example of a benthic habitat map for the EP NRM region.

The interactive Arc Reader DVD component of this report includes a spatial layer showing video drop points and their respective habitat classifications based on the 'Biota' level interpretation. Information in the underlying database also includes a 'modifiers' level, which is derived from identification and description of the biota and substrate at the best taxonomic resolution possible based on the video images. Modifiers are therefore variable in terms of resolution, generally occurring at the genus or family level but range from species in some cases (e.g. *Posidonia coriacea* may be more easily identified from video relative to other *Posidonia* spp.) to broad 'functional group' categories (e.g. foliaceous red macroalgae) in cases where even family differentiation is not possible.

5.4.2 Data and map limitations

Maps were based on digitisation of imagery at 1 m resolution (2 m in False Bay). In areas where the use of imagery was limited, such as the deeper margins of the area mapped, acoustic information was used primarily to identify boundaries. Spatial accuracy of the acoustic information along the survey lines is limited to DGPS capability (defined as 5 m, but generally accurate to ~ 1 m).

In natural systems, transitions from one habitat type to the next are not always clear cut, often occurring as a gradual change over a distance rather than as a discrete boundary. These transitional areas or 'ecotones' make detecting and defining habitat boundaries for the purpose of mapping difficult. For the purpose of this project, habitat boundaries that were apparent (e.g. from differences between video drops or acoustic transects) but whose exact location were unclear due to their transitional nature or water depth and clarity were marked as 'interpolated boundaries'.

The spatial accuracy of information in the video spatial layer is dependent on both the accuracy of the GPS itself and any layback error caused by the camera drifting behind the path of the GPS antenna. Testing of the least accurate GPS used in this study (Garmin GP60 with external aerial) suggested that 99% of the time position accuracy was within 3.2 m. Layback error is estimated at a maximum ~ 15 m. Therefore it is estimated that spatial error associated with this layer can be defined as generally being ≤ 20 m.

Habitat classification accuracy in the final maps was assessed separately by conducting independent ground truthing surveys in Streaky and Smoky Bays. Approximately 50 habitat units or polygons across the two bays were randomly selected and sampled with towed video drops. The resulting footage was processed in the same manner as outlined above and then overlayed on the existing classified habitat units. An accuracy value was then calculated based on the number of correct matches (between classifications and accuracy check points) as a percentage of the total number checked. While it was not possible to return to all bays to assess accuracy, the quality of aerial imagery and the amount and quality of acoustic and video data collected in this area suggest that it is not unreasonable to expect that accuracy in bays not assessed will be similar to that of the bays that were assessed.

Alignment between habitat polygons and the video checkpoints in the surveyed bays confirmed the mapped habitat types in 79% of cases. Although a relatively small number of polygons were sampled in two of the eight bays, if these bays are representative of EP bays in general, it is reasonable to expect that for any randomly selected polygon the associated mapped habitat type may be considered reliable approximately 79% of the time. Using the comparable checkpoints, the previous mapping undertaken by CSIRO (reported in Eddyvane 1999b) proved to be accurate 70% of the time. It should however be noted that these figures apply largely to subtidal areas which were easily accessible by boat since ground truthing carried out in this study was limited to those areas.

6 Benthic mapping observations

The major results of the mapping process are included within the accompanying map book and interactive DVD. The following comprises a brief summary of the benthic habitat mapping program for the EP NRM region conducted as part of this survey that is intended to describe broader observations for the major habitat groups as well as potential areas of interest or possible concern. This analysis is not intended to be comprehensive, and it should be understood that the underlying GIS data forms an important resource that can be summarised and interpreted in pursuit of a wide variety of agenda.

Note that areas mapped as components of other projects, in particular the habitat mapping obtained from the Upper Spencer Gulf (DEH 2007c) as well as seagrass observations by Hart (1999) and Cameron (2002), have not been included. Ultimately, benthic habitat mapping within the EP NRM region should aim for comprehensive coverage, although the field component of this goal is logistically challenging given the length of coast to consider, its relative remoteness and the difficult working environment (i.e. rough seas abutting extensive cliffs).

Rather than comprehensive coverage, benthic mapping has focussed on eight of the larger bays spread along the EP NRM coast. These locations tend to include larger population centres and are therefore more likely to comprise areas of concern for nearshore systems, particularly in relation to human activities such as:

- Point source inputs (stormwater, wastewater, thermal and desalination outfalls),
- Coastal developments (construction, operation and maintenance),
- Shipping and boating related issues (e.g. marine pests, oil spills),
- Access/tourism related activities (e.g. marine litter, wildlife disturbance).

In addition, shallower and more sheltered bays on the EP NRM coast are likely to include both sensitive (relative to the above impacts) and ecologically important habitats, such as seagrasses, mangrove systems and coastal wetlands. These habitats are critically important with respect to provision of ecosystems services including (among others); high productivity, sediment stabilisation and erosion protection, nursery habitat and potential for carbon sequestration (see Westphalen *et al.* 2004, DEH 2007d, EP NRM 2008). The commercial, social, indigenous and historical value of these habitats is therefore significant, although coastal wetlands (including saltmarsh and mangrove habitats) have tended to suffer significant losses in South Australia due to their proximity to port and harbour facilities and/or industrial landscapes (Edyvane 1999a, Flaherty and Sampson 2005).

Habitat mapping covered eight bays spread over five Bioregions but included only six of the 15 Biounits that occur to some extent within the EP NRM region (Table 3; Figure 7; Figure 8). The areas mapped within each bay varied substantially from 48.6 km^2 in Baird Bay to 281 km^2 in Denial Bay.

Marine waters in the EP NRM region encompass ~ 29,000 km^2 or ~ 37 % of the total area. CSIRO marine benthic mapping at a scale of 1:100,000 (see description in Edyvane 1999b) covered 8,223 km^2 of the EP NRM marine area. The total area mapped within the current investigation was ~ 1,204 km^2, substantially less than the area covered by CSIRO. However, the resolution within the latest mapping is substantially higher than CSIRO (including 2,905 polygons within ~ 4.15% of the total marine area, spread across 21 habitat types compared to 964 polygons over ~ 27% using eight habitat types for CSIRO mapping).

Table 2 - Summary of benthic mapping within the EP NRM region.

Bay	Bioregion	Biounit	Depth range (m)	Area surveyed (km^2)
Denial Bay	Murat	Streaky	0 - 10	281.06
Smoky Bay	Murat	Streaky	0 - 10	114.43
Streaky Bay	Murat	Streaky	0 - 30	221.35
Baird Bay	Eyre	Yanerbie	0 - 10	48.6
Coffin Bay	Eyre	Douglas	0 - 5	278.46
Venus Bay	Eyre	Yanerbie	0 - 10	79.67
Franklin Harbor	Spencer Gulf	Franklin	0 - 10	65.53
False Bay	North Spencer Gulf	Yonga	0 - 5	114.98
Total				**1204.07**

Benthic habitat classes recognised within selected bays from the EP NRM region comprise six broad types, including:

- Saltmarsh/mangroves,
- Seagrasses,
- Reefs (low, medium and high profile),
- Invertebrates, which includes large invertebrates that provide substrates/structures which support a community (i.e. *Pinna bicolor* beds, sponge gardens and similar),
- Macroalgae occurring on unconsolidated substrate and
- Unconsolidated bare substrate comprising sand, shell debris, rubble and cobble.

The above classes have been further differentiated with respect to their structure in terms of continuity (Continuous or Patchy) and density (Sparse, Medium, Dense although not for reefs or Unconsolidated bare substrate; Table 3; Figure 5), such that there were 23 different habitat class/structure type combinations identified across the EP NRM region.

All eight bays mapped within this survey are listed as Fisheries Habitat Areas by Bryars (2003; see above). The Bryars (2003) Fisheries Habitat Areas provide a useful basis for comparison with current mapping as they are based on a number of data sources, in particular the CSIRO 1:100,000 mapping (see Edyvane 1999a, b) that has been augmented with additional GIS layers and data sources. This approach was based on recognition of a range of errors in the CSIRO/Edyvane (1999a, b) mapping (Bryars 2003). In addition, the Bryars (2003) maps provide a valuable resource with respect to identifying a range of factors related to each zone including human usage, adjacent land use, local protection, adjacent catchments and threats (actual, perceived and potential).

Benthic cover was broadly allocated to one of four broader groups (Table 3), with total area of each habitat type considered in terms of the percentage of the total area mapped within the host bay. This approach allowed for some level of comparison between bays without the confounding effect of differences in the areas mapped. However, habitat types of particular interest, specifically seagrasses, were also considered in terms of their total area.

Table 3 - List of habitat classes and subgroups employed in habitat maps (NA = Not Applicable).

Group	Habitat class	Structure type	
		Continuity	Density
Intertidal	Saltmarsh/Mangrove	Continuous	Medium
	Saltmarsh/Mangrove	Patchy	Medium
Reef	High Profile Reef	Continuous	NA
	Low Profile Reef	Continuous	NA
	Low Profile Reef	Patchy	NA
	Medium Profile Reef	Continuous	NA
Seagrass	Seagrass	Continuous	Dense
	Seagrass	Continuous	Medium
	Seagrass	Continuous	Sparse
	Seagrass	Patchy	Dense
	Seagrass	Patchy	Medium
	Seagrass	Patchy	Sparse
Soft bottom	Cobble	Continuous	NA
	Invertebrate Community	Continuous	Medium
	Invertebrate Community	Patchy	Medium
	Invertebrate Community	Patchy	Sparse
	Macroalgae	Continuous	Dense
	Macroalgae	Continuous	Medium
	Macroalgae	Continuous	Sparse
	Macroalgae	Patchy	Dense
	Macroalgae	Patchy	Medium
	Macroalgae	Patchy	Sparse
	Unconsolidated Bare Substrate	Continuous	NA

6.1 Proportional cover of broader habitat groups

Medium density Mangrove/Saltmarsh was recorded in both patchy and continuous areas at Baird Bay, Coffin Bay, Franklin Harbor and False Bay at low levels (≤ 0.5% cover – data not shown). However, this low level is an artefact of the sampling method, which is targeted at subtidal systems, rather than a reflection of the actual areas for this habitat type. Bryars (2003) indicates substantial saltmarshes and mangroves in Denial Bay, Smoky Bay and Franklin Harbor, with less extensive areas in Venus Bay, Streaky Bay and False Bay and Saltmarsh only recorded at Baird Bay and Coffin Bay. It is worth noting that Streaky Bay, Coffin Bay and Baird Bay were considered to include coastal wetlands of national importance (Edyvane 1999b), which may include Saltmarsh/Mangrove habitats. The areas of Saltmarsh/Mangrove depicted within the habitat maps developed from this survey are thus not representative of their full extent and should not be employed for management purposes.

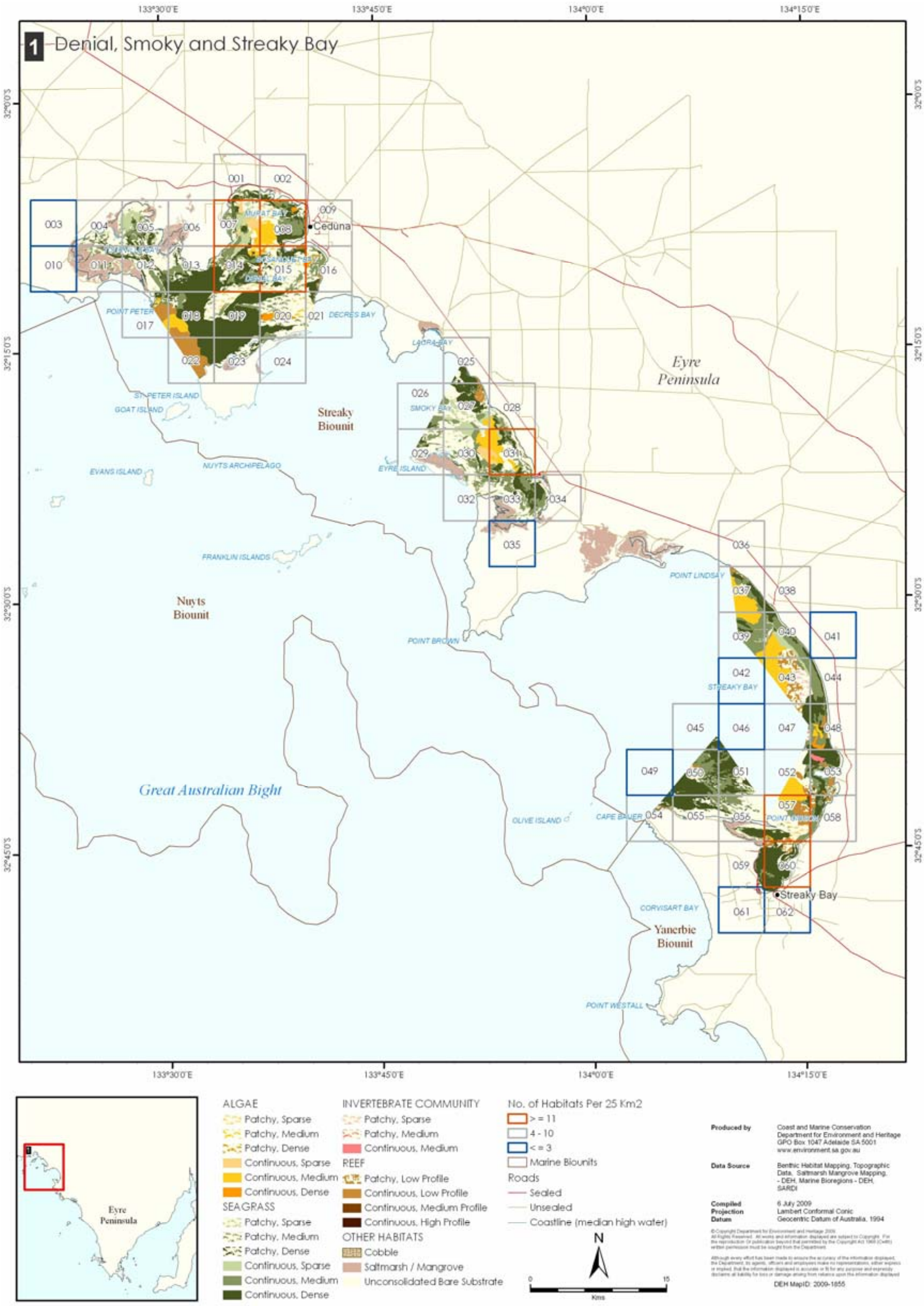

Figure 7 - Location of bays included within benthic habitat mapping for the EP NRM region, showing the position of 5 × 5 km grid squares relative to Biounits for Denial Bay, Smoky Bay and Streaky Bay. Red borders indicate mapped areas with a high number of habitat class/structure type combinations (≥ 11), blue borders indicate low numbers (≤ 3).

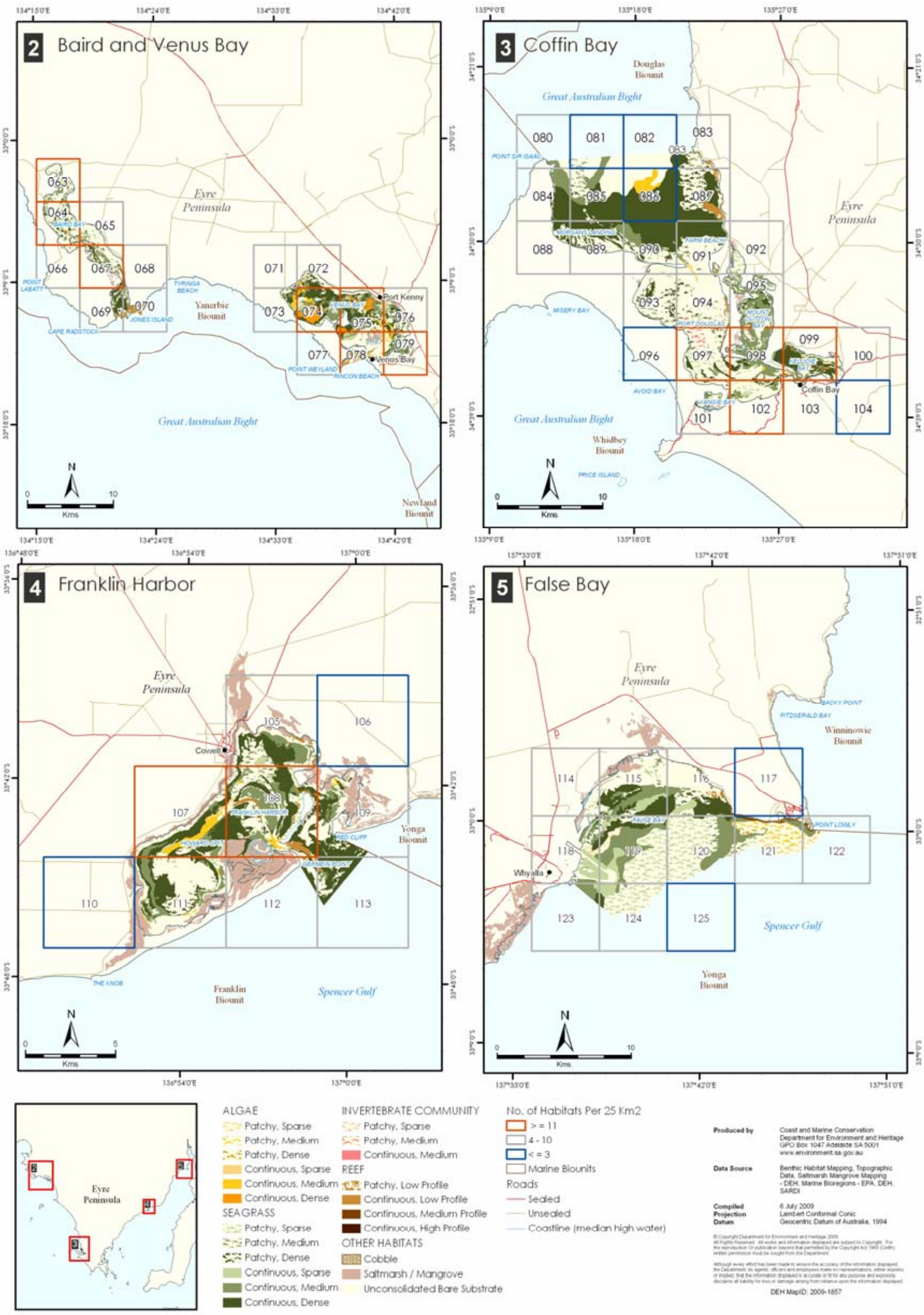

Figure 8 - Location of bays included within benthic habitat mapping for the EP NRM region, showing the position of 5 × 5 km grid squares relative to Biounits for Baird Bay, Venus Bay, Franklin Harbor and False Bay. Red borders indicate mapped areas with a high number of habitat class/structure type combinations (≥ 11), blue borders indicate low numbers (≤ 3).

The Bryars (2003) Fisheries Habitat Areas provide a better indication of the aerial extent of Mangrove and Saltmarsh. However, probably the best resources for assessment of these habitats may be found in coastal, dune and clifftop vegetation surveys by Opperman (1999) as well as saltmarsh and mangrove surveys completed by Canty and Hille (2002), upon which Bryars based his maps for these habitats) as part of the NVIS program (see DEH 2006, DEWR 2007) and the Estuaries Information Package for the EP NRM region (DEH 2007d). Given the importance of these systems to nearshore processes (see above) as well as the broad range of threats they incur (see Cheshire *et al.* 2008), both mangrove and saltmarsh habitats should be viewed as a priority for NRM throughout South Australia.

Total percentage cover of each major habitat group (Reef, Seagrass and Soft Bottom) within each bay reveals substantial differences in cover with respect to habitat, continuity and density (Figure 9). There was no immediately apparent pattern of relative cover for any broad habitat type relative to the Bioregion in which the particular bay occurred (Murat, Eyre, Spencer Gulf or Northern Spencer Gulf), although the representativeness of these observations for the purpose of differentiation at this scale is questionable.

Cover of reef systems (including high, medium and low profile systems) was relatively low in all locations (Figure 9). Benthic habitats mapped in Baird Bay, Denial Bay, Streaky Bay and Venus Bay comprised about 4-5% cover of continuous reef, with around 2% at Franklin Harbor and in Coffin Bay, while all other locations had around 1% or less.

Coffin Bay has previously been shown to have relatively large areas of continuous reef (Edyvane 1999b, Bryars 2003) whereas other reef areas would appear to be less extensive and/or are interspersed with other habitat classes (see Bryars 2003). However, care must be taken when making comparisons to earlier benthic mapping relative to how habitat types are defined. For example, areas comprising mixtures of Reef and Seagrass Meadow and Unvegetated soft bottom described by Bryars (2003) could retain elements of virtually all habitat and structure types used in the current survey except Saltmarsh/Mangrove.

There was no subtidal reef identified within Franklin Harbor from previous mapping (Bryars 2003), although small areas of patchy and continuous reef were found by the current surveys (~ 0.2% and 2.3% respectively; Figure 9). However, the low level of continuous and patchy reef cover within most other bays (less then 2% cover; Figure 9) is broadly supported by the observations from earlier habitat mapping and interpretation (see Edyvane 1999a, b, Bryars 2003). The higher percentage cover of patchy reef in Streaky Bay (7.4%; Figure 9) is not reflected within the Bryars (2003) mapping either as a portion of the recognised reef habitat or as a mixed habitat type.

In development of Fisheries Habitat Areas, Bryars (2003) ignored small ‘insignificant’ patches of habitat, which may have precluded these reef areas. It may also be that the 1:100,000 scale used in development of FHAs and Edyvane (1999a, b) summaries lacked the resolving power to ‘see’ small, isolated patches. Such areas may be of critical importance to local-scale biodiversity and also facilitate species migrations by allowing ‘island hopping’ between patches of favourable habitat. These areas may be targeted as favourable fishing and/or diving locations and may thus incur a disproportionately higher level of anthropogenic exposure relative to larger reefs. However, although this threat was identified in State of the Region Reporting (EP NRM 2008), the major threats to reef systems identified by Cheshire *et al.* (2008) did not relate to fishing or diving pressure, but instead included:

- invasive marine species,
- coastal developments (construction and operation),
- stormwater and industrial discharges (including desalination plants) and
- dredging/modification of benthic habitat.

Greater understanding of the nature of reef systems (distribution patterns and environmental processes) along the EP NRM coast should be derived from the results of recent biodiversity surveys (see above and addendum to this report). Improved knowledge of compositional differences between reefs relative to their spatial and physical environmental context (exposure, geomorphology, water quality, etc.) will assist managers in differentiating natural and anthropogenic drivers of reef structure.

Seagrasses were extensive in all bays, although the level of continuity and density varied substantially. When combined across structural types, seagrass cover ranged from 52% cover at Baird Bay to 75% at False Bay, meaning this habitat class covered the highest proportion of the area mapped within all locations (Figure 9). Given that surveys were targeted at sheltered embayments, a high cover of seagrasses is to be expected as this is their preferred habitat along the exposed west coast of South Australia (Shepherd and Robertson 1989).

Continuous-dense and continuous-medium seagrass assemblages are the major structural types at Streaky Bay (31% and 21% respectively), Franklin Harbor (35% and 14% respectively), Denial Bay (33% and 12%), Smoky Bay (7% and 20%), Venus Bay (25% and 17%) and Coffin Bay (31% and 11%; Figure 9). Continuous-sparse cover was generally around 5% or less (Figure 9). Patchy structure types for Streaky Bay, Franklin Harbor, Denial Bay, Smoky Bay, Venus Bay and Coffin Bay varied substantially, totalling 7-24% across sparse, medium and dense; Figure 9).

Baird Bay and False Bay were still well represented in the continuous-dense and continuous-medium seagrass structure types (13% and 10%, and 11% and 19% respectively; Figure 9) with up to 7% continuous-sparse cover at False Bay. However, these areas retained a greater contribution of patchy structure types, totalling ~ 27-38% of the area surveyed across density levels (Figure 9). In particular, there was a relatively high proportion of patchy-medium and/or patchy-sparse cover in both Smoky Bay (10% and 12% respectively) and False Bay (29% patchy sparse cover).

Seagrasses are critically important to coastal environments and processes (see review Westphalen *et al.* 2004) with losses linked to declines in water quality (notably stormwater, wastewater and industrial discharges as well as catchment decline; Westphalen *et al.* 2004, Fox *et al.* 2007). Given that the bays considered in this survey are both dominated by seagrass and are the focus for regional population centres, industries and maritime transport, the relationship between threats, in particular those related to water quality, relative to coverage of this habitat type is worthy of specific attention.

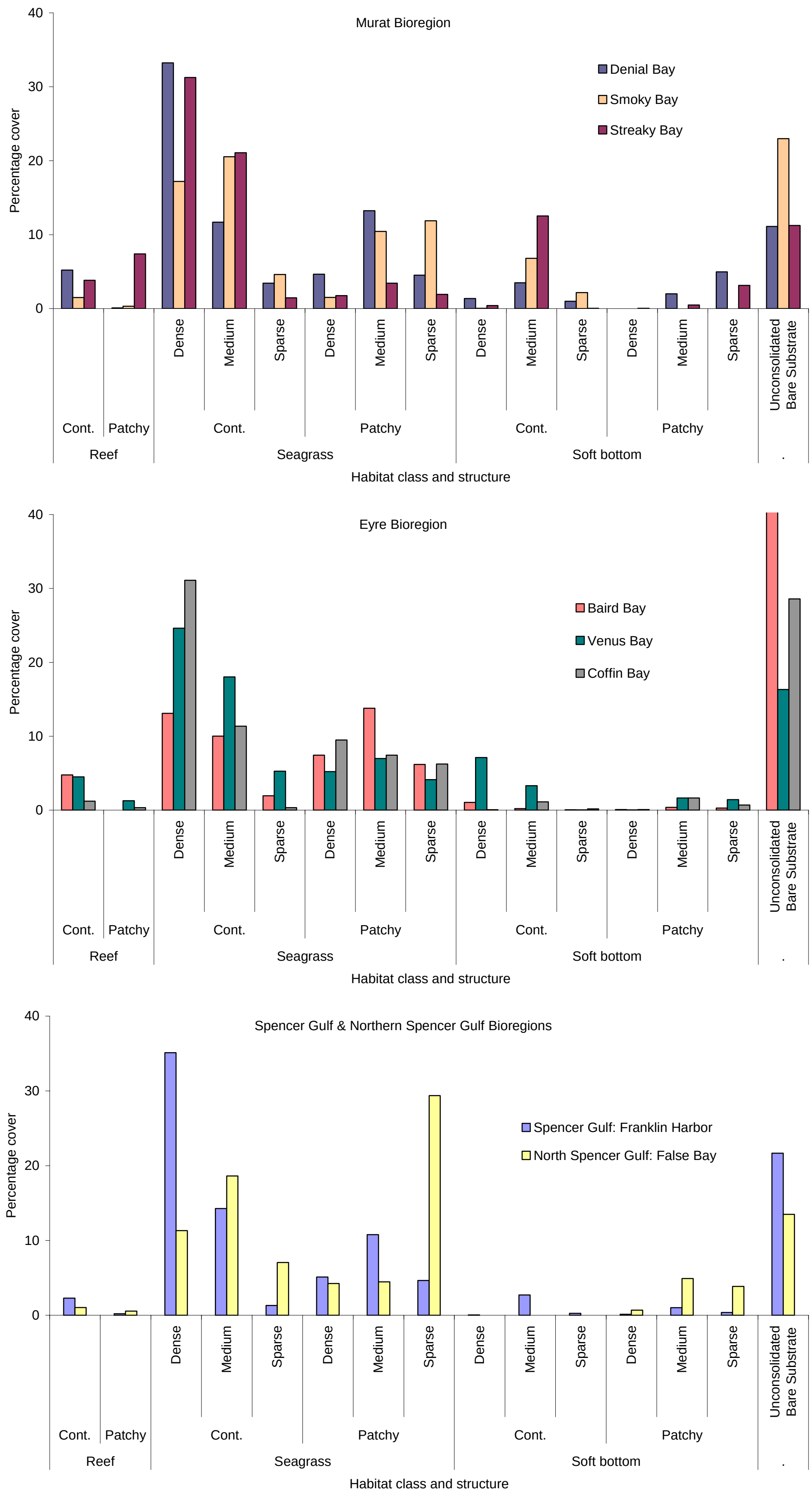

Figure 9 - Percentage cover of broader habitat types within bays along the EP NRM coast. Top = bays within the Eyre Bioregion, Middle = bays within the Murat Bioregion, Bottom = bays within the Spencer Gulf and North Spencer Gulf Bioregions.

The threats to seagrass systems identified by Cheshire *et al.* (2008) within the EP NRM region include:

- Coastal developments (both construction and operation),
- Dredging/modification of benthic habitat,
- Point-source inputs (wastewater, stormwater and industrial),
- Diffuse nutrient inputs and
- Invasive marine species.

A high level of patchy seagrass cover may indicate a failing population due to some form of external stress. Fragmentation of seagrass beds has been noted elsewhere in the South Australia, notably the southern metropolitan Adelaide coast (Bryars *et al.* 2006) as well as Beachport in the State's southeast (Hart and Clarke 2002). However, not all changes in seagrass cover that may be observed in benthic habitat mapping need to be a cause for alarm. For example, some large areas of seagrass loss within Spencer Gulf have been attributed to natural origins (see Seddon 2000). In addition, while many species, particularly *Posidonia* spp. are slow to establish and take a long time to recover from disturbance (Meehan and West 2004), others seagrasses such as the Zosteraceae (*Heterozostera* and *Zostera*) and *Halophila* spp. can vary substantially in cover within and between years (Bryars and Rowling 2008), particularly *Halophila* spp. that are known to be colonising species (Bryars and Neverauskas 2004). Apart from general growth habit, the depth at which seagrasses are growing will also influence continuity and density, although any loss of seagrass cover is a potential cause for concern. A reduction in either continuity and/or density of seagrass cover should therefore serve as a first sign of a need for closer observation to identify the species concerned (particularly *Posidonia* spp. and *Amphibolis* spp.) and the nature of any change. It would seem prudent to recommend that seagrass composition and cover as well as water quality (specifically nutrient levels and turbidity) within Smoky Bay and False Bay where there is a relatively high proportion of patchy-sparse cover should be subject to closer scrutiny.

In absolute terms the total area of seagrass within each bay in the Murat Bioregion was substantial, with Denial Bay at 199 km^2, Smoky Bay at 76 km^2 and Streaky Bay at 134 km^2 (Figure 10). When combined, this area of seagrass (409 km^2) is just under half the area previously reported for the entire Murat Bioregion (880 km^2; Edyvane 1999b) and there remain substantial areas within each bay that are yet to be mapped/ ground truthed. Conversely, the total area of seagrass across bays within each of Eyre, Spencer Gulf and Northern Spencer Gulf Bioregions (261 km^2, 47 km^2 and 86 km^2 respectively) is well within the range reported by Edyvane (1999b; i.e. 1,543 km^2, 1,377 km^2 and 4,136 km^2 respectively). Given the large areas of seagrass known to occur in Spencer Gulf (Edyvane 1999a, b, Seddon 2000, DEH 2007c), relative to the total areas mapped (Table 3), this difference is not unexpected. Outside the sheltered bays on the western EP NRM coast (notably the Murat Bioregion), seagrasses are reported to be patchy (Shepherd and Robertson 1989) and the majority of the seagrass cover can therefore be expected to be incorporated with mapping of the larger embayments.

While CSIRO mapping that was employed within Edyvane (1999a, b) offers indications of the total area of broad habitat types (reefs, seagrasses and soft bottom), there is little information related to either the continuity or density of coverage, which is particularly important for seagrass assessment. In addition, large discrepancies in CSIRO Mapping/Edyvane (1999b) have been observed elsewhere, most notably in the southeast where substantial areas of seagrass around Beachport were mistakenly identified as reef (see Hart and Clarke 2002). These errors highlight the need for a systematic framework for benthic habitat mapping that incorporates a significant investment in ground truthing. In using the CSIRO mapping/Edyvane (1999a, b) interpretations, Bryars (2003) employed a range of additional data sources in response to the need for caution when employing those data in isolation.

Apart from Coffin Bay at 184 km^2, seagrass cover in bays within the Eyre, Spencer Gulf and Northern Spencer Gulf Bioregions was generally lower than that observed in the Murat Bioregion (25 km^2 in Baird Bay up to 86 km^2 in False Bay; Figure 10). However, the bays outside the Murat Bioregion are also substantially smaller (or at least the total area mapped within each was generally lower - see Table 3).

Figure 10 - Total area of seagrass cover within each bay.

Other than Unconsolidated bare substrate, the Soft bottom contribution to most bays was less than 2% across structure types (Figure 9). However, some larger proportional covers were observed at Denial Bay (5% patchy-parse), Streaky Bay (12% continuous-medium), Venus Bay (~ 7% continuous-dense) and False Bay (5% patchy-sparse; Figure 9). However, with a focus on shallow and sheltered bays, the deeper water habitat groups that are more likely to include Soft bottom groups, in particular the invertebrate categories (Table 3), might appear to have less chance of being represented. The maximum depth surveyed varied substantially between bays (ranging from 5 m to 30 m, with most less than 10 m; Table 2). However, 30 m is well within the depth limits of all subtidal seagrasses on the southern Australian coast (see summary Westphalen *et al.* 2004). The presence of bare substrate suggests that seagrass cover may be limited by water quality issues, although factors related to substrate (grain size, biological oxygen demand, nutrient levels, etc) and/or physical disturbance (both natural and anthropogenic) may be factors in determining the proportion of Soft bottom observed within each bay. Collings *et al.* (2006) suggest that light availability may still be a limiting factor for seagrass survival and growth in shallow water where turbidity and/or sedimentation levels are relatively high, even for only a portion of the year. In addition, Seddon (2000) suggested that extreme temperature and low tide can be a cause for substantial areas of seagrass loss. However, these inferences should not be construed to infer that bare sand is a sign of degradation (see below). Rather, it is suggested that development of an understanding of the relationship between seagrasses and bare sand within sheltered environments is required, particularly in light of factors related to issues of land degradation as well as sea temperature increase with the onset of global warming.

Unconsolidated bare substrate was highly varied, ranging from 11% at Streaky Bay and False Bay to 40% at Baird Bay (Figure 9). However, given the diversity of substrates incorporated within this type (sand, shell debris, rubble and cobble), a detailed interpretation of levels of cover and their potential significance is considered unlikely to reveal an interpretation of any value. This habitat type is somewhat loosely defined in that it includes a diverse array of substrates that do not fit within other categories.

Bare sand communities have often been discounted as environmentally unimportant (and therefore expendable) relative to reef and seagrass habitats (Fairhead *et al.* 2002, Baker 2004), although there is substantial data to suggest that these systems are diverse, complex and spatiotemporally dynamic (Cheshire *et al.* 1996b). Deep water systems off the southern Australian coast include some larger sponges (Shepherd and Sprigg 1976) that may be more than a century old (Berquist and Skinner 1982). Although the depth of mapping within the enclosed bays of the EP NRM coast is restricted, considerable care must be taken when looking at threats to this habitat type.

6.2 Areas of high habitat diversity

Mapping of each bay in the map book associated with this report is presented in 5 x 5 km blocks (Projection = Lamberts Conformal Conic; Datum = Geocentric Datum of Australia, 1994; Figure 7; Figure 8). An examination of the number of different habitats (including differences in structure type) across the grid of 125 maps offers a rough indication of the broader distribution of substrate complexity within and between each bay. This information may be used to indicate areas of higher habitat diversity and zones of potential conservation significance.

The average number of habitat class/structure type combinations per map was 7.14 ± 3.26 (mean ± SD). Distribution of map areas with low and high numbers of habitats was determined through an examination of grid areas wherein the number of habitat types was outside one standard deviation of the mean (i.e. ≤ 3 or ≥ 11 habitat class/structure type combinations; see Table 3 for a summary).

Of the 125 map areas that encompass all benthic mapping in this survey, those with relatively few habitats (3 or less) totalled 18 maps (~ 14%; Figure 11) and tended to be those at the fringes of mapping, or close inshore, and often retained large unmapped marine areas or a high proportion of terrestrial coverage (Figure 7; Figure 8). Around two thirds of maps (71%) had eight or fewer habitat class/structure type combinations with eight being the most common (19 maps; Figure 11).

Map areas with 11 or more habitat class/structure type combinations included 20 areas (16% of maps; Figure 11) with representatives in all mapped areas except False Bay (Figure 7; Figure 8). Areas of high habitat diversity retained a high level of coverage and tended to include areas close to shore where there is a greater opportunity for seagrass and reef systems to be intermixed and possibly comprise locations where there is potential for strong, but not necessarily turbulent water flow such as narrower channel areas within bays. Areas might include Streaky Bay (Map 057), Baird Bay (Maps 063, 064 and 067), Venus Bay (Maps 078 and 079), Coffin Bay (Maps 097, 098 and 099) and Franklin Harbor (Maps 107 and 108; Figure 7; Figure 8). Zones of high tidally-induced laminar water flow around constrictions may have the effect of keeping reef areas adjacent to sand and seagrass beds clear of sediments, but at the same time allow seagrasses to persist. However, higher visibility within the near shore strip also allows for better habitat differentiation and therefore it is possible a greater number of habitat class/structure types were mapped in these areas.

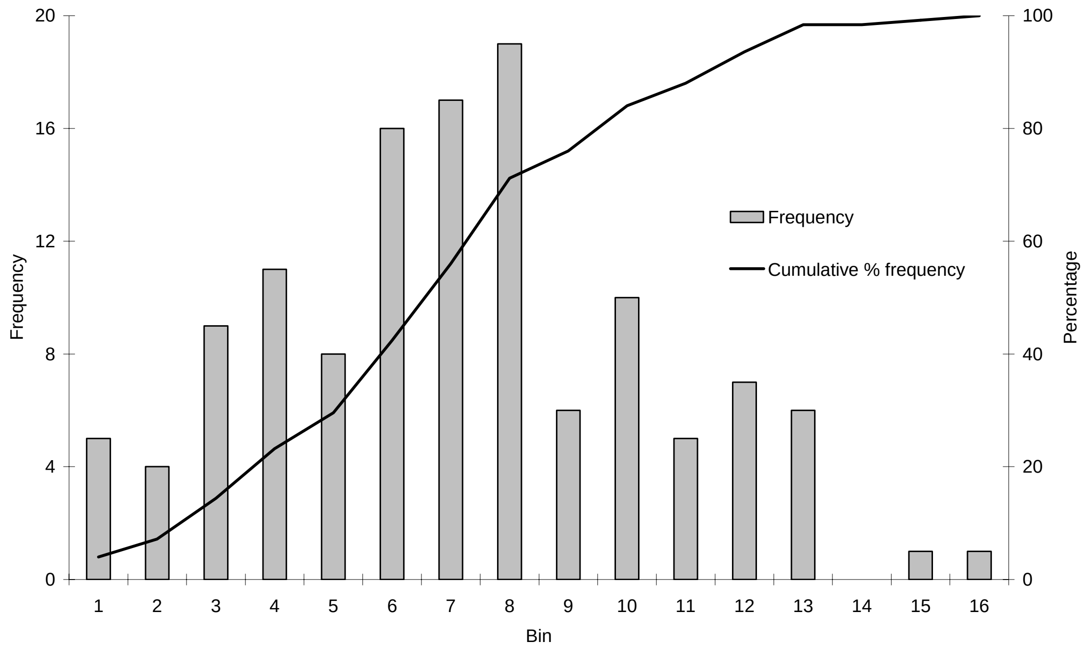

Figure 11 - Frequency distribution and cumulative percentage of the number of habitats within each 5 km × 5 km map (n = 125).

The 5 × 5 km map with the highest number of different habitats (16 in total) was a single area in Franklin Harbor (Map 108), followed by 15 in Coffin Bay (Map 099) and then 13 in six map areas, including Denial Bay (Maps 007, 008 and 016), Venus Bay (Map 075) and Coffin Bay (Map 102; Figure 7; Figure 8; Figure 11). There were 12 habitat types in seven areas; Denial Bay (Map 014), Baird Bay (Map 063 and 067), Venus Bay (074 and 078) and Coffin Bay (097 and 098), with 11 in a further five areas; Smoky Bay (Map 031), Streaky Bay (Map 060), Venus Bay (Map 097) and Franklin Harbor (Map 107; Figure 7; Figure 8; Figure 11). It is worth noting that nearshore areas that tend to retain areas of high diversity are also where the greatest concentration of potential threats is likely to occur (Bryars 2003, AMLR NRM 2007). However, while this approach might be used to identify areas of particular interest/concern, it is also apparent that the number of habitat types within a map grid is to some extent determined by the positioning of the overlaying grid.

It needs to be noted that this approach makes no allowance for the areas of each habitat class/structure type involved and map areas with less than 11 representatives must not be discounted as unimportant or even "typical". Apart from grid positioning, diversity measures at this scale are strongly influenced by differences in structure type (i.e. changes in continuity and density within a habitat class). Many map areas with relatively low diversity are dominated by large areas of seagrass that can also be observed in areas of intermediate or low diversity, including (for example) Denial Bay Maps 013, 014, 018, 019 and 023, Streaky Bay Maps 050, 051, 055 and 060, Coffin Bay Maps 084 – 091 and False Bay Maps 115 and 119 (Figure 7; Figure 8).

As with the high proportional cover of patchy-sparse seagrass cover observed in False Bay and Smoky Bay (Figure 9), areas of high habitat diversity (Figure 7; Figure 8) may warrant targeted attention to understand the nature of the diversity (i.e. what habitat classes are involved), species composition and abundance juxtaposed against potential threats/stress factors. However, regardless of structure type, large areas of seagrass are critically important to nearshore processes and monitoring targeted at these systems may serve as an indicator of overall marine environmental health.

6.3 Conclusions and recommendations

Much of the previous mapping, monitoring or research within the EP NRM region has been focussed within Spencer Gulf (e.g. Shepherd 1975, Cheshire *et al.* 1996a, b, Hart 1999, Seddon 2000, DEH 2007b, Svane *et al.* 2009). To some extent this trend is understandable given the concentration of activities within Spencer Gulf as well as its reputed high level of diversity, extensive seagrass habitats and unique biodiversity (Edyvane 1999a, b). However, the remainder of the EP NRM coast is worthy of a greater emphasis, acknowledging both a greater understanding of the importance of this coast as well as the spread and diversification of threats and pressures to marine systems across the region.

The results of current mapping form an invaluable resource for marine managers within the EP NRM, region serving as a critical baseline against which future changes can be measured. The resulting map books and related interactive DVD will serve as a basis for identifying monitoring and management requirements as well as a driver of basic research and as an educational tool. It needs to be recognised that the underlying GIS data that supports current mapping can be summarised in pursuit of a wide variety of management, monitoring and research agenda over and above the brief present summary.

Targeted areas for future monitoring may include:

- Areas of patchy-sparse seagrass cover within Smoky Bay and False Bay in combination with data on water quality. This will help to determine to what degree these seagrass areas are a product of anthropogenic stress relative to natural factors.
- Large areas of continuous seagrass cover in Denial Bay, Streaky Bay, Coffin Bay and False Bay, again in relation to water quality. Management practices targeted to the maintenance of the health of seagrass beds will likely have a range of additional marine environmental benefits related to water quality and physical disturbance.

- Small, apparently isolated patches of reef in Franklin Harbor that have not been observed in previous habitat mapping. Biodiversity surveys along the lines of those conducted elsewhere on the EP NRM coast may prove useful in determining the relative importance of these patches.
- Areas of high habitat diversity within all bays should perhaps be considered in greater detail to determine the nature of this variability and whether these translate to localised biodiversity hotspots.

Information from the current mapping and an acknowledgement of knowledge gaps has resulted in a range of recommendations including:

- Targeted monitoring related to specific areas of interest (see above).
    - More highly resolved mapping.
    - Spatially referenced data related to threats. Note that although the Cheshire *et al.* (2008) risk assessment included a spatial component, the scale employed is probably too coarse to be of use at the scale of individual bays (although it may serve as a starting point).
    - Engagement with stakeholders at the local scale.
- Note that consideration of factors related to mangrove and saltmarsh management should focus on the Oppermann (1999) and Canty and Hille (2003) vegetation surveys rather than the current mapping, which is targeted at sub-tidal systems.
- Expansion of current mapping to encompass the entire EP NRM coast, including drawing together mapping from alternative sources. Focus should perhaps be given to including areas within those coastal Biounits for which there is less coverage and/or focus on zones of concern based on coastal marine asset threat/risk assessments (Cheshire *et al.* 2008).
- Development of a greater understanding of physical environmental/ geomorphological factors that account for differences in composition between reef, seagrass and soft bottom systems in different locations. Understanding the role of natural drivers for compositional change will better inform managers as to the impact of threats.
    - More spatially and temporally resolved data on water quality.
    - Improved spatial understanding of the range of stakeholders with interests in coastal environments.
- It needs to be acknowledged that the mapping completed within the current program is far from comprehensive (only ~ 4% of the total EP NRM marine area). Additional benthic mapping data may be available at a scale and reliability commensurate to the current program. Some considerations should be given to investigating the potential for incorporating these data to expand the repertoire of benchmarked areas available to development of monitoring frameworks as well as targets for future resurveys.
- Reconsideration of the current mapped areas needs to be undertaken at a temporal scale relevant to NRM program scales (3-5 years).

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Appendix A - List of Bryars (2003) Fisheries Habitat Areas (FHA) that occur in the EP NRM region

FHA	Name	Benthic habitats
1	Nullarbor	- Reef & Unvegetated soft bottom - Sheltered beach
2	Dog Fence Beach	- Reef & Unvegetated soft bottom - Surf beach - Sheltered beach
3	Fowlers Bay	- Reef - Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow - Sheltered beach
4	Point Bell	- Reef - Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow - Sheltered beach
5	Denial Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
6	Smoky Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Surf beach - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
7	St Francis Island	- Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow - Sheltered beach
8	Streaky Bay	- Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
9	Sceale Bay	- Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow - Sheltered beach
10	Anxious Bay	- Reef & Unvegetated soft bottom - Surf beach - Sheltered beach

FHA	Name	Benthic habitats
11	Baird Bay	- Reef & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Tidal flat - Saltmarsh
12	Venus Bay	- Reef - Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
13	Flinders Island	- Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow - Sheltered beach
14	Sheringa Beach	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Surf beach - Sheltered beach
15	Coffin Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat
16	Port Douglas	- Reef - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Saltmarsh
17	Avoid Bay	- Reef & Unvegetated soft bottom - Surf beach - Sheltered beach
18	Greenly Island	- Reef & Unvegetated soft bottom
19	Sleaford Bay	- Reef - Reef & Unvegetated soft bottom - Surf beach - Sheltered beach
20	Thorny Passage	- Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Surf beach - Seagrass meadow & Unvegetated soft bottom - Sheltered beach
21	Neptune Island	- Reef
22	Wedge Island	- Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Sheltered beach
23	Boston Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Estuarine river - Saltmarsh - Artificial habitat

FHA	Name	Benthic habitats
24	Sir Joseph Banks Group	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Unvegetated soft bottom - Sheltered beach
25	Tumby Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Estuarine river - Mangrove forest - Saltmarsh - Artificial habitat
26	Port Neill	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Saltmarsh
27	Arno Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
28	Franklin Harbour	- Seagrass meadow - Unvegetated soft bottom - Sheltered beach - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
29	Lucky Bay	- Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
30	False Bay	- Reef - Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
31	Far Northern Spencer Gulf	- Seagrass meadow - Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh

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