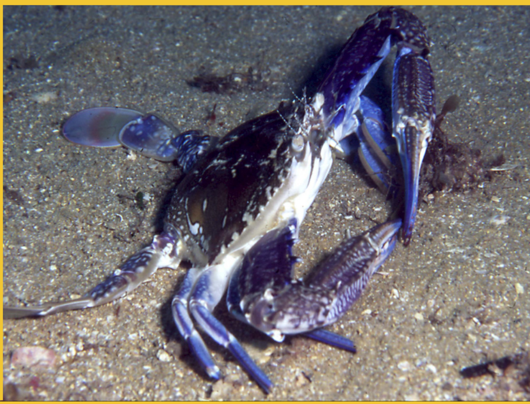
Marine Habitats of the Northern and Yorke NRM Region

Final Report to the Northern and Yorke Natural Resources Management Board for the project: Sustaining Marine Biological Health



By David Miller, Grant Westphalen, Ann Marie Jolley and Yvette Eglinton

Government
of South Australia

Department for Environment
and Heritage

Northern and Yorke Region
Natural Resources Management Board

www.environment.sa.gov.au

Marine Habitats of the Northern and Yorke NRM Region

Final Report to the Northern and Yorke Natural Resources Management Board for the project:

Sustaining Marine Biological Health

December 2009

Coast and Marine Conservation Branch

Department for Environment and Heritage

By

David Miller, Grant Westphalen, Ann Marie Jolley and Yvette Eglinton.

Government of South Australia
Department for Environment and Heritage

For further information, please contact:

Coast and Marine Conservation Branch

Department for Environment and Heritage

GPO Box 1047

Adelaide SA 5001

This publication may be cited as:

Miller, D[1]., Westphalen, G[2]., Jolley, A. M[1]. and Eglinton, Y[1].2009a. *Marine Habitats of the Northern and Yorke NRM Region.* Final Report to the Northern and Yorke Natural Resources Management Board for the project: Sustaining Marine Biological Health. Prepared by the Department for Environment and Heritage, Coast and Marine Conservation Branch.

[1] Department for Environment and Heritage, Coast and Marine Conservation Branch, Adelaide, S.A.

[2] Westphalen Consulting, Adelaide S.A.

Acknowledgements:

Ben Brayford, Dimitri Colella, Shane Holland, Rohan Henry, Ali Bloomfield, Alison Wright, Fab Graziano, Victoria Hendry, Bryan McDonald, Peter Fairweather and all those who gave occasional help in the field.

Table of contents

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 datasets, including habitat mapping, against which specific threats and condition targets can be measured and assessed. Currently, information of this type is limited for the Northern and Yorke (NY) NRM region. Benthic habitat mapping available for the region prior to the commencement of this project is at a scale of 1:100,000, which does not provide adequately for the management needs of NRM Boards.

In 2006, the Department for Environment and Heritage (DEH) was engaged to undertake a program to address this critical knowledge gap. This included a broad scale marine habitat mapping program at a resolution more suited to local management needs and the collection of baseline biodiversity (ie. 1:20,000 or better).

The mapping and underlying GIS data outlined in this report are a valuable resource for managers in the NY NRM region. They provide a critical baseline against which future changes can be measured to help guide planning and management. This report also includes recommendations for future monitoring and research. Information collected as part of the baseline biodiversity survey is reported in a separate document.

Detailed spatial mapping of seafloor habitats encompassed nearshore areas along the whole NY NRM coastline. This generally included habitats from the median high water mark out to a minimum of 3 km (but often a lot further, depending on the availability of imagery).

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
- a separate report by SARDI Aquatic Sciences which includes a summary of baseline biodiversity information from the Yorke Peninsula region.

The total area mapped (~5000km^2) represents 32% of the total marine environment encompassed by the NY NRM region. It forms a more highly resolved baseline dataset than was previously available on important coast and marine habitats in this region.

The extensive seagrass and mangrove/saltmarsh systems of the Northern Gulf areas have been previously identified (Shepherd and Robertson 1989, Seddon 2000, NY NRM 2008), but the results of current mapping suggest that seagrasses are extensive throughout much of the rest of the region. The northern Gulf areas, while certainly important, particularly in terms of seagrass and mangrove/saltmarsh as well as relictual subtropical biota in Spencer Gulf (Edyvane 1999b, Baker 2004), should not detract from the need for management observations and intervention elsewhere within the NY NRM region. Nonetheless, it is likely that as “reverse estuaries” (Edyvane 1999b) both upper Gulf areas are potentially more at risk to factors resulting from climate change.

Reef systems are also widespread and diverse across the NY NRM region. Although they dominate only on the exposed coast at the tip of Yorke Peninsula (within the Pondalowie biounit), there are also large areas of both patchy and continuous reefs within the Tiparra and Wardang biounits.

While there has been some analysis of factors that may influence the structure of reef systems (see DEH 2009c), there is a need to develop a greater understanding of the relationship between physical environmental factors and nearshore benthic systems as a whole (not just reefs). Importantly, there is a need to understand that various factors may be influential at very different spatial scales. Mapping produced through this project is an important resource that can be used in developing hypotheses and targeting research to develop this understanding.

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:

- 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 the 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. fisheries, 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 engagement with all stakeholders who 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 engagement with stakeholders,
- a capacity to prioritise monitoring and management interventions on 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, in 2006 the NY NRM (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 the Northern and Yorke Natural Resource Management (NY NRM) region. This work included an update of previously available broad scale (southern Australia) marine benthic habitat maps produced by CSIRO, covering the inshore waters of the NY NRM coastal region 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 (Mount *et al* 2007).

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. Further, 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 NY NRM region, large scale marine habitat assessment capability would greatly assist the development of State of the Region reporting as well as 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 understand spatiotemporal variability and identify 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.

The following describes a process of marine habitat mapping for the NY NRM region, including three main aspects:

- marine management regions, broadscale marine observations and mapping in the NY NRM region, including what is understood with respect to risks to nearshore systems,
- a brief summary of the results of recent marine habitat mapping the NY NRM 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), South East NRM Board (Miller *et al* 2009a) and the Eyre Peninsula 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, as they deal 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

The aims of this study were to:

- establish baselines for coast, marine and estuarine biodiversity that will enable monitoring of changes in resource condition within the NY NRM region,
- develop marine habitat mapping at scales relevant to management in the NY NRM region,
- generate map books and an interactive DVD of benthic habitat maps at a scale of 5 × 5 km.

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

- current and planned marine management regions within the NY 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,
- current knowledge regarding risks to coast, estuarine and marine systems within the NY NRM region.

From a mapping perspective this document includes:

- a brief summary of the mapping methodology, including ground truthing approaches and,
- some summary statistics of the results of the mapping, including areas that may be of further interest to marine managers.

3 Marine habitat mapping and broad scale surveys in the Northern and Yorke NRM region

Southern Australian nearshore marine systems are widely known 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 is therefore a challenge (Turner *et al.* 2007), especially in light of the broad range of potential or actual threats and also because of:

- 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 coastline (Edyvane 1996, FAO 2003, Baker 2004, Flaherty and Sampson 2005, NY NRM 2008).

Broadscale 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 NY NRM region as the Spencer Gulf and Gulf St Vincent provide a diversity of physical environments ranging from highly exposed temperate rocky coast to shallow, hypersaline sand and mud flats. The NY NRM marine waters are thus important in terms of habitat diversity, biodiversity and ecosystem services. However, both Gulfs are also subject to a range of potential or actual threats, particularly the extensive saltmarsh, mangrove and seagrass systems in their upper reaches (Gulf St Vincent; NY NRM 2008). Management of NY NRM marine assets thus represents a microcosm of the issues confronting near shore environments across southern Australia.

3.1 Marine management regions

Marine habitat management regions within the NY NRM region comprise:

- IMCRA bioregions,
- Edyvane (1999a, b) biounits (based on CSIRO 1:100,000 benthic habitat mapping – see DEH 2007a), and
- Marine Protected Areas.

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. 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 both gulfs included in the Spencer Gulf IMCRA Province (Commonwealth of Australia 2006), which covers the entire NY NRM region. Mesoscale bioregions (that include the coastal regions defined under IMCRA Version 3.0) include eight coastal areas either wholly or partly within South Australia, four of which occur to some degree within the NY NRM region, including:

- Eyre – transitional warm to cold temperate rocky coast,
- Northern Spencer Gulf – confined inverse estuary on tidal coastal plain,
- Spencer Gulf – semi-confined inverse estuary on tidal coastal plain and
- Gulf St Vincent – 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).

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 Australian coast to a depth of around 50 m, with 11 occurring to some extent within the NY NRMR region (Edyvane 1999a, b, NY NRM 2008; Figure 1). See Appendix A for summary data on each of the bioregions within the NY NRM region. For full descriptions of each biounit, see Edyvane (1999b), including information relative to (among others): biogeography, conservation values and status, fisheries, recreation and tourism, science, research and education as well as cultural and historical aspects. Some summary data for these regions within the NY NRM region are also included in the State of the Region report (NY NRM 2008) as well as the Spencer Gulf marine plan (Government of South Australia 2006). Importantly, the latter includes Ecological Rated (ER) zones identified across biounits (see below).

- IMCRA bioregions and/or Edyvane (1999a, b) biounits may be used 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 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 unit can readily resolve.

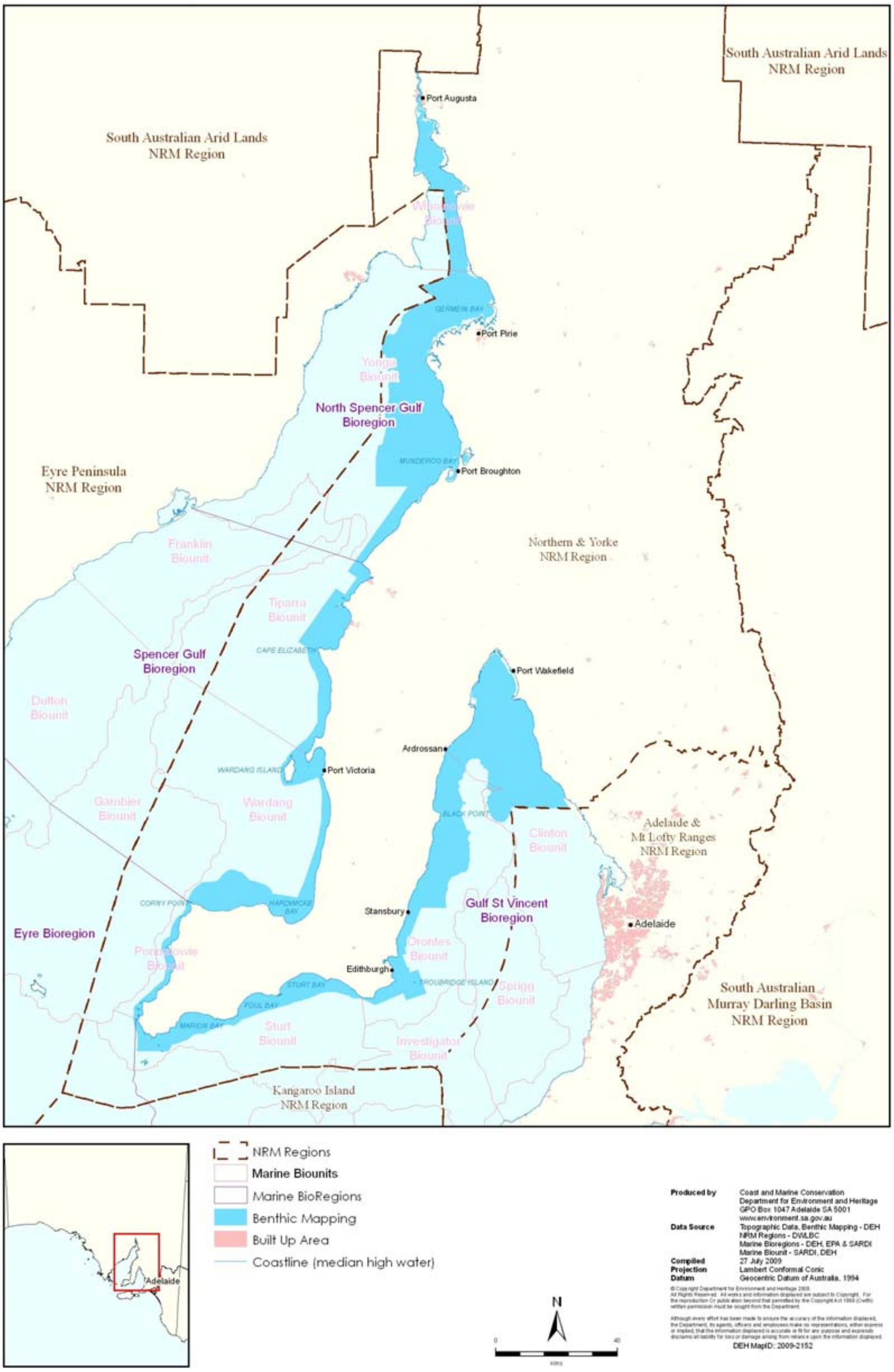


Figure 1 - Map of the NY NRM region showing Edyvane (1999a, b) biounits and the area covered by habitat mapping as part of this project as well as 2007 surveys from the upper Gulfs (DEH 2007b, c).

3.1.3 Marine protected areas

Designation of Marine Protected Areas (MPAs) was based on 14 criteria that include biological, social and cultural aspects (DEH 2009b). The system of 19 MPAs spread along the South Australia coastline will form a key element for the protection and conservation of marine biodiversity and, cultural and historical values, within a framework that will allow for ecologically sustainable development of marine resources. The associated management and monitoring strategies have important implications for NRM throughout the state. DEH (2009b) shows five MPAs that occur to some extent within the NY NRM region including:

- Area 10 Upper Spencer Gulf Marine Park.
- Area 11 Eastern Spencer Gulf Marine Park.
- Area 12 Southern Spencer Gulf Marine Park.
- Area 13 Lower Yorke Peninsula Marine Park.
- Area 14 Upper Gulf St Vincent Marine Park.

Although MPA outer boundaries have been proclaimed, 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 zone**s - 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 NY NRM region. See the draft State of the Region report (NY NRM 2008) for a summary.

3.2 Habitat mapping

As with the rest of the South Australian coast there are the CSIRO 1:100,000 benthic habitat maps that were used by Edyvane (1999a, b) to develop biounit designations.

Marine research and monitoring within the NY NRM region is somewhat weighted toward Gulf St Vincent relative to Spencer Gulf. This difference is largely born out of the greater pressure on marine systems in Gulf St Vincent, in particular the Adelaide metropolitan coast (e.g. Fox *et al.* 2007, Tuner *et al.* 2007). Notably physical environmental monitoring (i.e. water quality, sand movements etc.) and ecosystem health (reef decline and seagrass loss) is more prevalent on the Adelaide metropolitan coast, although control data are often sourced from locations around Yorke Peninsula (i.e. Port Hughes has been employed as a non-metropolitan control in water quality monitoring - see Gaylard 2004).

3.2.1 Benthic communities

The earliest large scale marine habitat mapping of any relevance to the NY NRM region relates to a summary of work undertaken in the Gulf St Vincent up until the mid 1970s. This work relates to physical oceanography, bathymetry, geology, subtidal benthic ecology, intertidal ecology, fish and marine mammals (see "Natural History of the Adelaide Region" Twidale *et al.* 1976). In particular, this summary included large scale subtidal benthic community mapping of Gulf St Vincent based on extensive diver surveys during the 1960s (Shepherd and Sprigg 1976). The resulting map included 11 different habitat groups based on substrate and/or benthic community composition (Shepherd and Sprigg 1976; Figure 2):

- *Pinna*-holothurian,
- Ascidian-scallop,
- Bryozoan,
- *Malleus-Pinna,*
- *Heterozostera-Lunulites* (bryozoan),
- bare sand and shoals,
- algal debris,
- seagrass meadows,
- boulder conglomerates,
- reef and
- Aeolianite reef.

Many of the investigations of Gulf St Vincent considered in the Twidale *et al.* (1976) summary were revisited as components of a recent summary entitled "Natural History of Gulf St Vincent" (see Shepherd *et al.* 2008). Although this summary has a focus on Gulf St Vincent, many of the more general observations will readily apply to Spencer Gulf. For example, general information related to the introduction, spread and management of marine pests in Gulf St Vincent (see Westphalen 2008) will translate directly to Spencer Gulf or even the rest of the southern Australian coast.

Tanner (2005) undertook regularly spaced video and diver observations at depths greater than 5 m throughout Gulf St Vincent with the aim of determining the level of change in the 30 years since the Shepherd and Sprigg (1976) habitat survey (Figure 2). This survey identified a substantial level of change, particularly in the southern Gulf, including a loss of extensive beds of *Heterozostera tasmanica* and the *Malleus - Pinna* (Hammer oyster - Razorfish) assemblage. Bryozoan cover and scallop numbers in the central Gulf area had also both declined, but there was less change in the north, where the *Pinna* and extensive seagrass systems were still present. Prawn trawling operations have been suggested as the major cause for habitat changes in Gulf St Vincent, either directly as a result of physical damage or through declines in water quality due to sediment re-suspension (Tanner 2005). While there is substantial evidence as to the negative effect of trawling operations (e.g. Engel and Kvitek 1998, Collie *et al.* 2000), there is still controversy as to their nature and extent of its impact (Tanner 2005). Evidence from the Gulf St Vincent is that prolonged exposure to trawling activities has a substantial impact on benthic communities (Tanner 2003; see DEH 2009a for a broader summary).

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. However, 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).

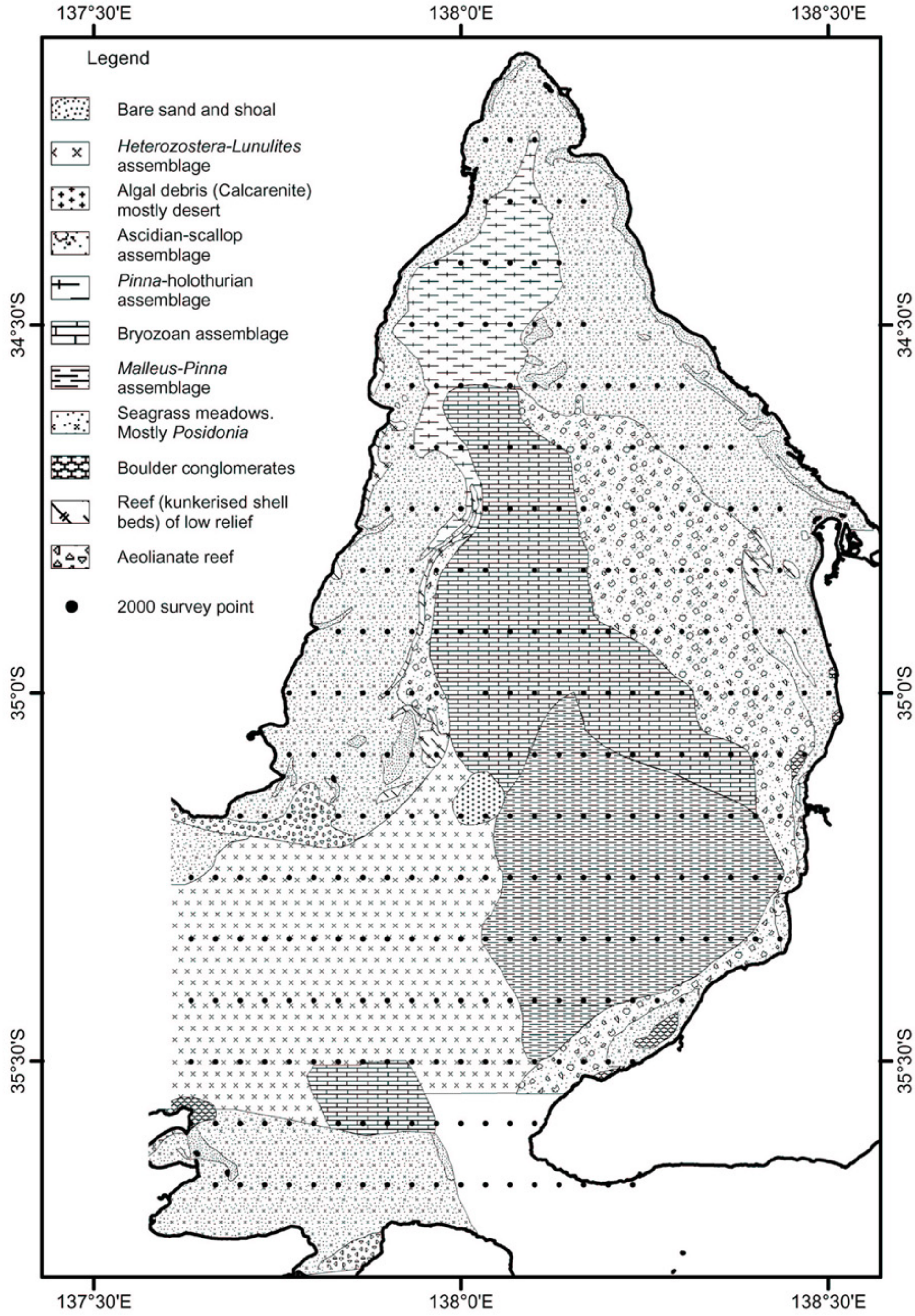


Figure 2 - Gulf St Vincent showing benthic habitats as defined by Shepherd and Sprigg (1976) overlaid with survey points from Tanner (2005). Figure copied with permission from Tanner (2005).

In 2005 through 2006, the NY NRM Board in collaboration with the Department for Environment and Heritage undertook a fine scale habitat (1:10,000) mapping exercise in the upper reaches of Gulf St Vincent and Spencer Gulf to a depth of 15 m (DEH 2007a, b, c). Within the upper Gulf St Vincent, the area mapped began in the Stansbury area and extended through to around the Semaphore region on the Adelaide metropolitan coast (DEH 2007b). In Spencer Gulf, this work 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 (DEH 2007c). 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 (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 and global warming.

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 (habitat and density of cover) and
- cover (extent (%) of the substratum coverage).

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

This approach to mapping has been increasingly adopted as a means of developing consistent approaches to marine benthic habitat mapping, with a similar hierarchical approach employed within the AMLR NRM region (DEH 2009b), in Tasmania (SEAMAP 2008) and internationally (Allee *et al.* 2000).

3.2.2 Fisheries habitat areas

A fisheries habitat inventory for South Australia undertaken by Bryars (2003) assessed coastal near shore assets (up to 20 m depth or 3 km offshore – whichever came first) in terms of 13 basic habitat types (including the 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 habitat.

Areas of the above were included only 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 South Australian coasts, including 12 within the NY NRM region that variously included all of the above habitat types except freshwater spring (see summary information Appendix B).

Appropriate management of commercial and recreational fisheries is a critical component of sustainable marine resource use. However, the Bryars (2003) approach does not offer much by way of engagement with stakeholders, in particular those with needs other than fisheries. In addition, there is the potential to discount small, isolated habitats that have little importance from a fisheries perspective. A large area of reef may be important to a number of fisheries relative to isolated outcrops. However, these same outcrops may be critically important in terms of biodiversity/conservation at local scales. In addition, the resolution of 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.

3.2.3 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 (among others):

- marinas,
- jetty and port facilities,
- aquaculture zoning,
- housing developments,
- stormwater and wastewater outfalls,
- desalination plants 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, of which the availability and relevance in support of benthic habitat mapping is variable.

3.3 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 statewide investigation into coastal, dune and clifftop vegetation that employed 22 broad vegetation types (Oppermann 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 NY NRM region, comprising either river outflows or tidal creeks, some of which (notably the Light River delta) are considered to be important in terms of biodiversity and conservation (DEH 2007d). Most of the catchments within the NY NRM have been modified to some degree, although even in their pristine state many would be ephemeral, often with limited connectivity to the sea. 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 NY NRM region (DEH 2007d).

3.3.1 Satellite imagery

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

Satellite remote sensing has provided 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.

3.3.2 Other potential data sources and GIS layers

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

- infrastructure (shipping channels, jetties, breakwaters, etc),
- coastal inputs (outfalls, rivers and streams),
- 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 is a variety of sources available to support this information, generally at the state level, including (among others):

- the extensive list of GIS layers summarised by Caton *et al.* (2007) as part of "Conservation Assessment of the Northern and Yorke Coast",
- Atlas 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 2005),
- a number of strategies developed by the Coastal Protection Board related to acid sulphate soils, coastal weeds, erosion and beach monitoring (see http://www.environment.sa.gov.au/coasts/management.html, Accessed March 2009),
- water quality monitoring at waste water treatment plants and industrial outfalls,
- fisheries stock assessments,
- non-mapping environmental monitoring and research.

3.4 Reef systems

Similar to seagrass observations, investigations into reef systems have until recently been spatially and temporally patchy. The following summary is by no means comprehensive, but seeks to encompass the major surveys (i.e. reef health surveys, Turner *et al* 2007) as well as indicate the nature of more targeted investigations (i.e. Collings and Cheshire 1998) that might otherwise prove useful.

The earliest well publicised investigations into subtidal reef research in South Australia were ground-breaking observations undertaken by Shepherd and Womersley (1970, 1971, 1976, 1981) and Shepherd (1981) at West Island (AMLR NRM region), Pearson Island, St Francis Island, Waterloo Bay (EP NRM region) and Cape Northumberland (SE NRM region) respectively. These surveys largely focussed on descriptions of the distribution of flora and fauna relative to depth at each site. However, none of these surveys occurred within the NY NRM region.

Collings and Cheshire (1998) compared reef composition and structure between Yorke and Fleurieu Peninsulas relative to physical environment (namely wave energy) and geographic location. Sites on Yorke Peninsula included Magazine Bay (5 m) and Stenhouse Bay (5 m and 9 m). The highest diversity was found at sites with "intermediate" wave energy, but there were a large number of co-occurring species across all locations.

3.4.1 Reef health

Investigations by Turner *et al.* (2007) into the status of reef systems on the South Australian coast included 11 sites around Yorke Peninsula. The survey methodology employed in these surveys makes extensive use of non-destructive observations based on Line Intercept Transects (LIT) that provided cover estimates of visually dominant reef constituents. In addition, the Turner *et al.* (2007) and similar reef health surveys (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008) considered a highly simplified taxonomy in analysis of the macroalgal and invertebrate community assemblages, largely based on "functional form". This approach was essential in development of indices for reef status, but may limit the capacity to discern differences between reefs.

A suite of 11 different indicators of reef status indicated that eight sites were in "Good" condition, with two reefs (Troubridge Point and Cable Hut Bay) within the "Caution" range and a further two locations (Point Souttar and Point Riley) in "Poor" condition. However, the indices were developed largely on the basis of reefs along the Adelaide Metropolitan Coast, where there is substantial evidence of reef decline that correlates with seagrass losses and can be related to terrigenous threats (Fox *et al.* 2007, Turner *et al.* 2007). Turner *et al.* (2007) stressed the need for both refinement of the indices employed in determining reef status as well as maintaining an open mind when confronting the notion of a "healthy" reef (i.e. an unhealthy reef in one location does not necessarily mean that reefs elsewhere with the same composition are themselves unhealthy). Those reefs on Yorke Peninsula with "Caution" and "Poor" index results should therefore be considered as targets for further investigation, particularly with respect to water quality issues (nutrient and sediment inputs) rather than flagging a need for management intervention.

3.4.2 Reef life surveys

Following on from observations by Turner *et al.* (2007) in 2005, DEH undertook a range of additional observations from reef systems in the following year that included nine of the 11 sites considered previously as well as 14 additional locations (23 sites in total; DEH 2009c). The methodology employed in these observations was rather different to that used in Turner *et al.* (2007), adapting an approach described by Edgar and Barrett (1997, 1999) that was less intensive, but nonetheless encompassed a larger reef area. From a ground truthing perspective, these observations may prove to be more useful. However, as an indicator of reef status, especially using the indices developed by Turner *et al.* (2007), the latter approach may be less informative.

Results of both the Reef Health and DEH observations suggest that there is substantial spatiotemporal variability in reef composition and structure along the Yorke Peninsula coast (Turner *et al.* 2007, DEH 2009c). However, the latter survey suggested a pronounced gradient of changes relative to position along the coast (Turner *et al.* 2007, DEH 2009c). While the Turner *et al.* (2007) survey did not show a similar gradient, the fewer number of sites (11 versus 25) and their dispersion along the coast and the simplified taxonomy used in analyses means that detection of such a gradient is less likely. Importantly, the results of the Turner *et al.* (2007) survey do not preclude the possibility of such a gradient.

3.4.3 Other reef surveys

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 West Cape on southern Yorke Peninsula. This study showed that differences between reefs at all scales could largely be explained by biogeography (latitude and longitude of each site). These observations are supported by the results of other reef surveys (e.g. DEH 2009a, DEH 2009c).

Connell and Irving (2008) suggest that management of local scale issues (e.g. fisheries, nutrient enrichment, coastal development etc.) would benefit from placing their impact within a broader biogeographic context. Management of marine assets within NRM areas should therefore occur as part of a broader framework that is necessarily constrained to a particular region. Given the substantial level of overlap for marine planning zones across NRM boundaries (be they, Marine Protected Areas, bioregions or biounits – see above) and the broad spatial context for many of the issues, the need for collaboration between the various NRM Boards is readily apparent.

Observations by the community-based monitoring program "Reef Watch" within the NY NRM region are limited, mostly comprising "Feral or in Peril" observations (42 spread across 13 sites) 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).

3.5 Seagrasses

Seagrass mapping and research in the NY NRM region have tended to focus in the upper gulf areas, where there are large and diverse benthic communities (Shepherd and Robertson 1989, Seddon 2000, NY NRM 2008).

As part of a general summary of seagrass distribution within southern Australia, Shepherd and Robertson (1989) suggest that there are mixed seagrass communities along much of the Spencer Gulf coast, although these observations would appear to be based on somewhat sporadic information. However, Shepherd and Robertson (1989) also summarised a number of targeted seagrass studies/mapping exercises within the NY NRM region, including:

- Shepherd (1983) surveys in the upper Spencer Gulf (Redcliff Point).
- Ward *et al.* (1984, in Shephard and Robertson 1989) seagrasses within Germein Bay as part of investigations into the impacts of lead-zinc smelting operations.

Seddon (2000) investigated the causal mechanism for a sudden and substantial loss of shallow nearshore seagrasses between Warburto Point and Port Germein, mostly *Amphibolis antarctica* and *Posidonia australis*, from the northern Spencer Gulf in 1993. A comparison of aerial photographs of the region before and after the loss events determined that the area of seagrass loss covered 12,717 ha over a 95 km stretch of coast and therefore represented the largest single seagrass loss event recorded in South Australia. The mapping employed in this instance used eight habitat categories (including variations on each type of habitat):

- sand,
- dieback (severe and moderate),
- seagrass (dense, intermediate and sparse),
- deepwater seagrass and
- mangroves.

High ambient temperatures during unusually low tides were considered to be the most likely cause of this loss event, although a precise link could not be established given that the study was initiated well after the loss had occurred (Seddon 2000). Seddon found that the seagrass loss areas were readily colonised by species of *Zostera, Ruppia* and *Lepilaena*.

The motivation and findings of the Seddon (2000) investigation have important implications with respect to the potential impact of global warming on shallow nearshore systems, in particular extensive seagrass communities in the upper Gulfs.

Cameron and Tunn (2006) undertook an extensive mapping investigation and comparison of the seagrass communities between Corny Point and Port Broughton over a 250 km distance, comprising an area of around 2400 km^2. Orthorectified aerial images from 1979 and 1981 were compared to images from 2004 to establish baselines as well as indicate something of the changes that had occurred over 25 years. In spite of numerous limitations to image comparisons, a number of useful observations were possible including (among others):

- there was no substantial decline of the landward seagrass limit over the 25-year interval,
- some blowouts and landward seagrass line recession were evident at Corny Point,
- the 2004 dataset provides a baseline representative of a relatively pristine system.

Importantly, the classification and comparison process encompassed four different classes, each of which included a number of attributes that retained similar spectral qualities (Table 1). This mapping therefore did not comprise direct comparisons of specific habitat types.

Ground truthing undertaken by Gaylard (2008) employed a series of thirteen 200 m video transects and found a high level of agreement on 39% (5 transects) of comparisons and a moderate alignment for the remaining 61% (8 transects). Results of these surveys imply additional small areas of seagrass loss around Point Turton as well as gains in the Moonta Bay and Port Broughton area. However, Cameron and Tunn (2006) acknowledged a number of deficiencies in their dataset including image quality issues for 1979 and 1981 and the use of different operators in the classification of the different image sets. The use of the 2004 seagrass map as a baseline for future comparisons is probably the most useful conclusion from outcome these investigations.

The seagrass mapping undertaken by Cameron and Tunn (2006) is contiguous with the habitat mapping undertaken in the upper reaches of the Spencer Gulf (DEH 2007a, c; see above), but the approach to habitat differentiation is very different.

Table 1 - Classification employed in a comparison of seagrass systems between Corny Point and Port Broughton (from Cameron and Tunn 2006).

Class	Short description	Long description
1	Benthic cover (Type 1)	Dense seagrass or substrate in deep water
2	Benthic cover (Type 2)	Less dense seagrass, or different type of seagrass compared to class 1, or substrate in shallower water than class 1
3	Benthic cover (Type 3)	More scattered seagrass than class 2, or different type of seagrass than classes 1 and 2, or substrate in shallower water than class 2
4	Substrate	Bare substrate in shallow to exposed environments (no cover)

3.6 Soft bottom habitats

Apart from the investigations by Shepherd and Sprigg (1976) and Tanner (2005) in Gulf St Vincent, and investigations conducted by Svane *et al.* (2009) in Spencer Gulf, there appears to be little by way of site comparisons and/or mapping of soft bottom systems within the NY NRM region, particularly within near shore areas.

3.6.1 Aquaculture monitoring

All marine-based aquaculture in South Australia is required to maintain a level of environmental monitoring as part of licensing requirements (Aquaculture Regulations 2005). Aquaculture within the NY NRM zone is not nearly as extensive as in the adjacent Eyre Peninsula region, although expansion and development of new lease areas may be anticipated, in particular the development of oyster farms at Port Broughton, Port Vincent, Stansbury and Coobowie (http://outernode.pir.sa.gov.au/aquaculture/aquaculture_industry/oysters, accessed March 2009).

Since the early 1990s, the South Australia Shellfish Quality Assurance Program (SASQAP) has ensured 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 NY NRM region includes six 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. However, information on the pattern of restrictions placed on SASQAP monitoring areas may form a useful indicator for more targeted investigation.

3.7 Threats to marine systems in the NY NRM region

There is a diverse range of threats to coast, estuarine and marine systems in South Australia derived from an equally varied array of activities and stakeholders (Edyvane 1996). As a component of developing strategic and business plans for the NY NRM board, a semi-quantitative risk assessment for Coast, Estuarine and Marine (CEM) systems was undertaken by Cheshire *et al.* (2007). This risk assessment identified a broad range of threats to coast, estuarine and marine systems within the NY NRM region relative to a range of coast, estuarine and marine assets. The assessment was undertaken relative to five broad zones within the NY NRM region that included Northern Spencer Gulf, Southeast Spencer Gulf, Eyre, Gulf St Vincent and Northern Gulf St Vincent such that the risk assessment retained a broad spatial component.

A total of 23 threats were identified:

- acid Sulphate Soils,
- aquaculture,
- boating and diving,
- coastal development (construction),
- coastal development (operational),
- defence activities,
- desalinisation plant,
- diffuse source chemical contaminants,
- diffuse source nutrients,
- diffuse source sediment inputs,
- dredging,
- Grazing
- litter/rubbish dumping,
- mining impacts
- off-road vehicles/trail bikes/bush camping,
- oil spills,
- pest plants and animals,
- point source–sewage,

- point source-industrial discharge-heavy metal discharge,
- point source-stormwater pipes/drains (major towns),
- pot line and direct harvest fishing,
- prawn trawling, and
- water extraction.

It is worth noting that over half of the above threats have implications for water quality in the form of nutrients, sediments and/or toxicants.

The above threats were considered relative to 12 asset types:

- coastal/veg - dune systems,
- coastal/veg - dune/pebble ridge systems,
- coastal/veg - mangroves/intertidal mudflat/tidal estuary,
- coastal/veg - rocky headland,
- coastal/veg - samphire/salt marsh,
- pelagic - deep water,
- pelagic – inshore,
- peef – intertidal,
- reef – subtidal,
- sand/soft sediment - bays/sandy beaches,
- sand/soft sediment - deep water, and
- seagrass – subtidal.

Both the upper gulfs as well as the southeast area of Spencer Gulf were identified as areas with a relatively high number of moderate to high risks (Cheshire *et al.* 2007). Across the entire region, assets that appeared to be most at risk included:

- subtidal seagrass,
- mangroves/intertidal mudflat/tidal estuary,
- samphire/saltmarsh,
- subtidal reefs,
- intertidal reefs, and
- dune systems.

It needs to be noted that while marine pests were highlighted as presenting the largest number of high risks, this result is to some degree biased by the amalgamation of all pests within a single group (Cheshire *et al.* 2007). Given that the arrival of some form of marine pest within the NY NRM region is more or less inevitable, and that the suite of available pests may result in a broad range of environmental impacts, the result of the assessment is invariably high risk. A better approach suggested by Cheshire *et al.* (2007) is to consider each asset relative to known pests at the species level.

It is worth noting that threats to rare, threatened or endangered species were not included within the Cheshire *et al.* (2007) assessment. However, as with marine pests, it was recommended that this group be considered at the level of species with an appropriate realignment of consequence tables (see Cheshire *et al.* 2007).

State of the Region reporting and associated Strategic Plans for the NY NRM region incorporate assessments of threats to Coast, Estuarine and Marine (CEM) assets. An important element of which is the "Conservation Assessment of the Northern and Yorke Coast" undertaken by Caton *et al.* (2007). Caton *et al.* (2007) divided the NY NRM coast into 131 "cells" ranging in size from 9.5 – 7828 ha, with an average coastal length of 10 km. Divisions between cells were largely based on sub-regional land forms (i.e. sandy bay between headlands, sand dune masses, low cliffs with the same orientation etc.). Within each cell, conservation and threat values were derived based on a wide range of GIS data including;

- coastal assets:
    - vegetation (including species richness, patchiness, threatened species and remnant vegetation),
    - fauna (including species richness, threatened species, focal species),
    - significant habitats relative to faunal groups (birds, reptiles, invertebrates, mammals, amphibians),
    - cultural values (Aboriginal and European) and
    - geological sites of significance.
- threatening processes, many of which related to the clearance, fragmentation and isolation of remaining vegetation:
    - development,
    - recreational access and facilities (4WD access, bush camping),
    - dump sites (both active and discontinued),
    - environmental weeds,
    - unstable dune areas,
    - coastal Acid Sulphate Soils (CASS),
    - erosion,
    - climate change,
    - mining and exploration and

- illegal hunting, poisoning, egg collecting and nest vandalism.

Caton *et al.* (2007) identified a number of general areas of particular significance/concern that included a large number of high risk cells, including:

- saltmarsh coast from Light River delta to Price in Gulf St Vincent,
- saltmarsh coast from Jarrod Point to Winninowie CP in Spencer Gulf and
- dune coast from Cape Elizabeth to Point Turton in western Yorke Peninsula.

Not all of the cells considered to be high priority in terms of either assets or threats necessarily translate to the adjacent marine systems, although most of the threatening processes identified by Caton *et al.* (2007) have relevance with respect to impacts on near-shore water quality, either through increased nutrient and/or sedimentation loads. It is also important to note that many of the GIS layers identified by Caton *et al.* (2007) with respect to coastal features may be related to marine systems both within the NY NRM region and elsewhere on the South Australian coast in many instances.

It is important to realise that although it had a coastal focus, the Caton *et al.* (2007) study related largely to terrestrial assets and threatening processes. Although there is some overlap between the Cheshire *et al.* (2007) and Caton *et al.* (2007) studies through the inclusion of coastal environments (e.g. dunes, mangroves, saltmarsh and estuaries), the Cheshire *et al.* (2007) risk assessment was more focussed on subtidal assets (e.g. reefs, seagrasses, soft bottom and deep water). However, the risk assessment undertaken by Cheshire *et al.* (2007) is in broad agreement with the assessment of coastal systems undertaken by Caton *et al.* (2007).

Both Caton *et al.* (2007) and Cheshire *et al.* (2007) form an important resource in developing a greater understanding of the juxtaposition of coastal and nearshore marine assets, particularly those assets for which there is spatially referenced data. However, those issues of largely maritime origin such as marine pests and oil spills are not considered as they are included as potential rather than extant threats.

In addition, it is important to note that that the 2008 State of the Region report (NY NRM 2008) suggests that five of the 11 commercial fisheries within the region are over fished.

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 Resources 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,
- the capacity to combine physical, geomorphic and biotic data,
- compatibility with a GIS framework,
- amenability to currently available data and technology and
- provision of a basis for identifying functional linkages where 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 also 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 was obtained with a view to terrestrial objectives (Mount *et al.* 2007). The analysis of historical images from a marine habitat mapping perspective is therefore 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 proven 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 broader habitat classification approach, 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 NY 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 in the NY NRM region

5.1 Overview

Mapping of nearshore marine habitats across the NY NRM region included the area from mean high water out to the limits of available aerial imagery. The outer extent of mapping therefore varied but was generally a minimum of 3 km off shore and often extended much further (at most to the 20 m depth contour). This coverage provided a balance of detection resolution while at the same time encompassing 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 compiled data across increasingly smaller scales, including:

- Aerial imagery, which 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 to further define the extent of habitats (mainly side scan sonar although some data from a single beam sounder was used early in the project), particularly in deep 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 Port Broughton to Corny Point region was collected by DEH in 2004 at a resolution of 1:40,000. Imagery for the Corny point to Port Vincent coastline was collected in 2006 at a resolution of 1:20,000.

Habitat boundaries were identified and digitised (digitally traced) based on varying patterns, tones and textures on the orthorectified aerial imagery (Figure 3) using GIS.

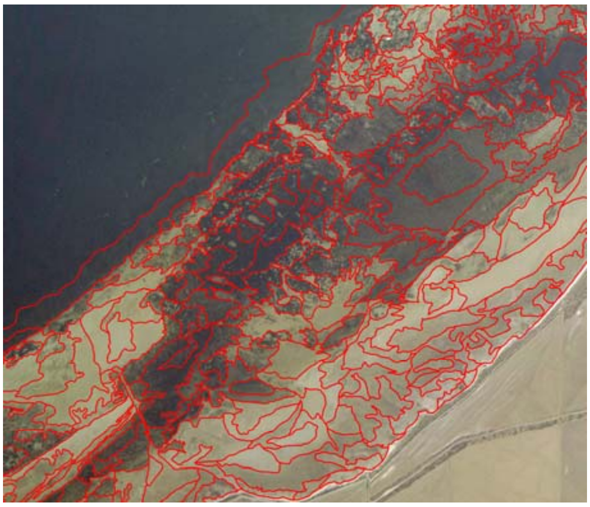


Figure 3 - Example of habitat delineation on an aerial image.

5.3 Field data

5.3.1 Acoustic survey

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). Acoustic surveys (echo sounding) were carried out in some areas where digitisation of aerial imagery alone was difficult due to depth (i.e. beyond 10 m). In areas where imagery was sufficient (close to shore and in the northern parts of the NY NRM region where larger more consistent habitats exist), acoustics were not used. The areas targeted using acoustic techniques were mainly located on the "foot" of Yorke Peninsula (ie from Point Soutter to Troubridge Island)

Two types of acoustic survey were employed (sidescan sonar and single beam sonar, depending on availability of equipment). In both cases a series of parallel acoustic transects spaced approximately 1 km apart were run at right angles to the shore from shallow water to 20 m depth (or 5 km offshore, whichever came first). All surveys were conducted at a vessel speed between 3 and 5 knots. Acoustic data were collected and stored on the surface control unit hard drive along with differential GPS information (using a Furuno GP-37 differential GPS).

The majority of the NY NRM region was surveyed using a sidescan sonar (Yellowfin by Imagenex and Geoswath). Sidescan is a hydroacoustic survey technique that provides an image of the seafloor by emitting fan shaped beams (formed as sound pulses known as pings) on either side of a sonar head. This device is either towed (commonly called a "towed fish", as with the Yellowfin, or pole mounted as with the Geoswath). Different features on the seafloor (e.g. reef habitats or sand habitats) reflect sound differently, thus acoustic returns (or signals) can be georeferenced to provide textural/backscatter images that display the differences (Figure 4).

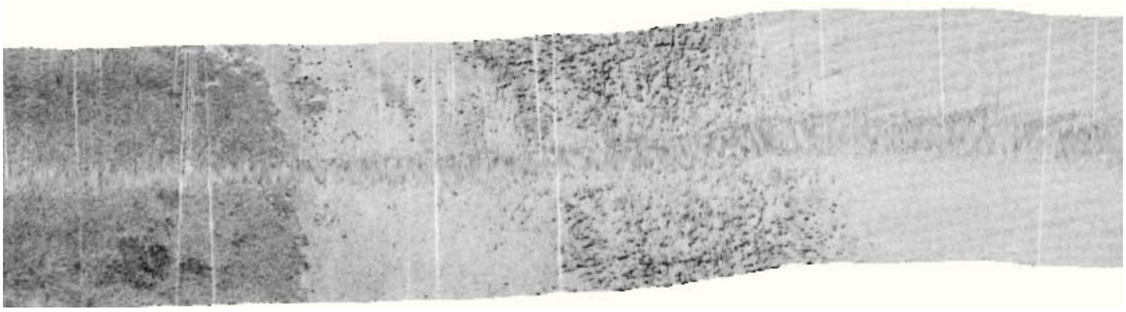


Figure 4 - An example of a processed sidescan track near Troubridge Point showing (from left to right) low reef, sand, coarse rubble/broken reef and sand ripples.

The sidescan sonar survey was carried out using an operating frequency of 330 kHz, with a 100 m range setting (i.e. a swath width of 100 m either side of the vessel). Sidescan data was post processed using Sonarweb Pro software (Chesapeake Technology Inc.) to produce georeferenced images that could be imported into the ARC GIS environment for interpretation against other information (i.e. aerial imagery and video classifications).

Single beam sonar surveys were carried out in the Cape Spencer and Corny Point areas and some parts of Hardwicke Bay using a pole mounted Simrad EQ60 38/200 kHz transducer.

Several types of information were extracted from single beam 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 5). Harder substrates tend to reflect acoustic energy more strongly, 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 the sounder-detected bottom between the two frequencies are also a strong indicator for the presence of seagrass (Figure 5) 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.

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

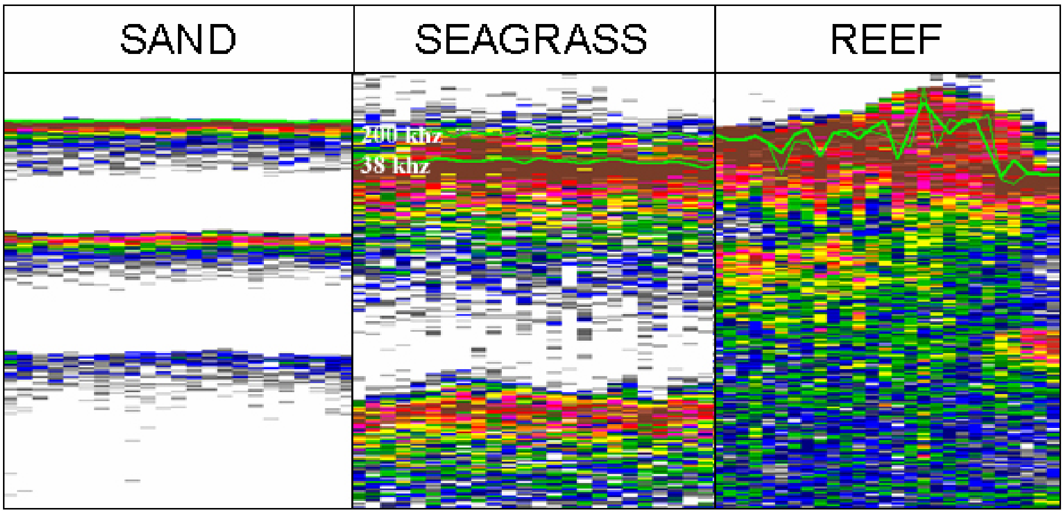


Figure 5 - Example of acoustic echogram for 38 khz (with 38 and 200 khz bottom detection lines overlaid) showing signals for sand, seagrass and reef.

No acoustic surveys were done in the areas north of Balgowan on the western side or north of Troubridge shoals on the eastern side of Yorke Peninsula. This was due to these areas having shallow water running quite far offshore, making them more amenable to reliable classification from aerial imagery.

5.3.2 Video ground truthing

Video footage was collected using one of two strategies. In areas where acoustic data had been collected, video footage was generally collected along the acoustic transects. Where little or no acoustic data was collected, usually in shallower areas where imagery alone was sufficient, video footage was collected either along evenly spaced (1km) transects or based on previously digitised polygons (derived from aerial imagery).

One of two high-resolution, towed underwater video camera systems was used, either a 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. Video drops were made at approximately 300 – 500 m intervals, depending on the consistency of acoustic data or based on the digitisation of aerial imagery. Each video sample consisted of a 30 second drift. GPS data was simultaneously encoded on the audio track of the videotape to provide position information relative to video footage. In all, video footage was collected from well over 2000 ground truth sites spread throughout the NRM region.

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.

5.3.3 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, upper Spencer Gulf and Gulf St Vincent (see above; DEH 2007a) was modified to include new habitat types, comprising four levels (Figure 6) in line with approaches used elsewhere in Australia and internationally.

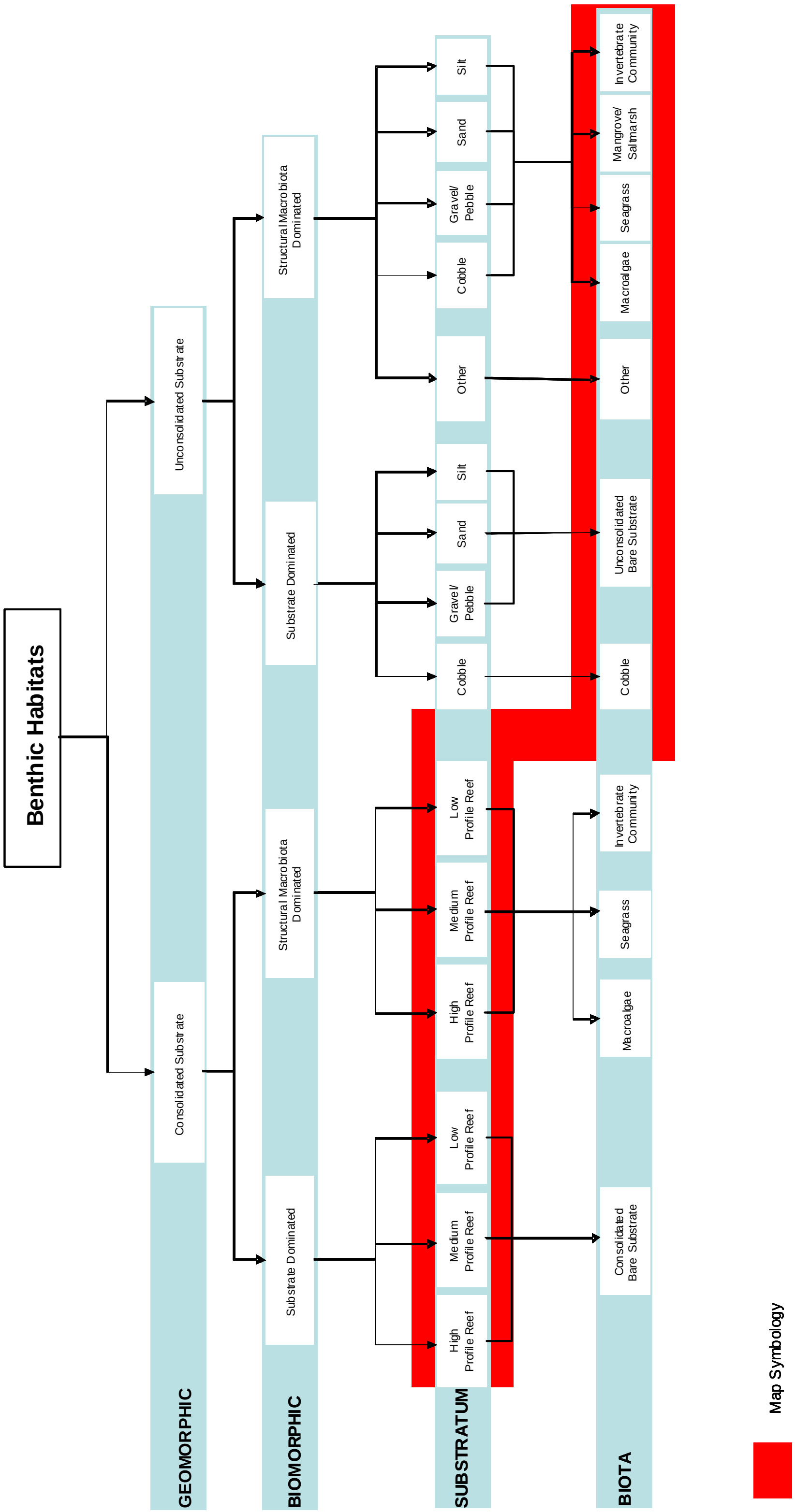

Benthic Habitats
GEOMORPHIC
Consolidated Substrate
Unconsolidated Substrate
BIOMORPHIC
Substrate Dominated
Structural Macrobiota Dominated
Substrate Dominated
Structural Macrobiota Dominated
SUBSTRATUM
High Profile Reef
Medium Profile Reef
Low Profile Reef
High Profile Reef
Medium Profile Reef
Low Profile Reef
Cobble
Gravel/ Pebble
Sand
Silt
Other
Cobble
Gravel/ Pebble
Sand
Silt
BIOTA
Consolidated Bare Substrate
Macroalgae
Seagrass
Invertebrate Community
Cobble
Unconsolidated Bare Substrate
Other
Macroalgae
Seagrass
Mangrove/ Saltmarsh
Invertebrate Community
Map Symbology

Figure 6 - 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 7). 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 6).

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 8.

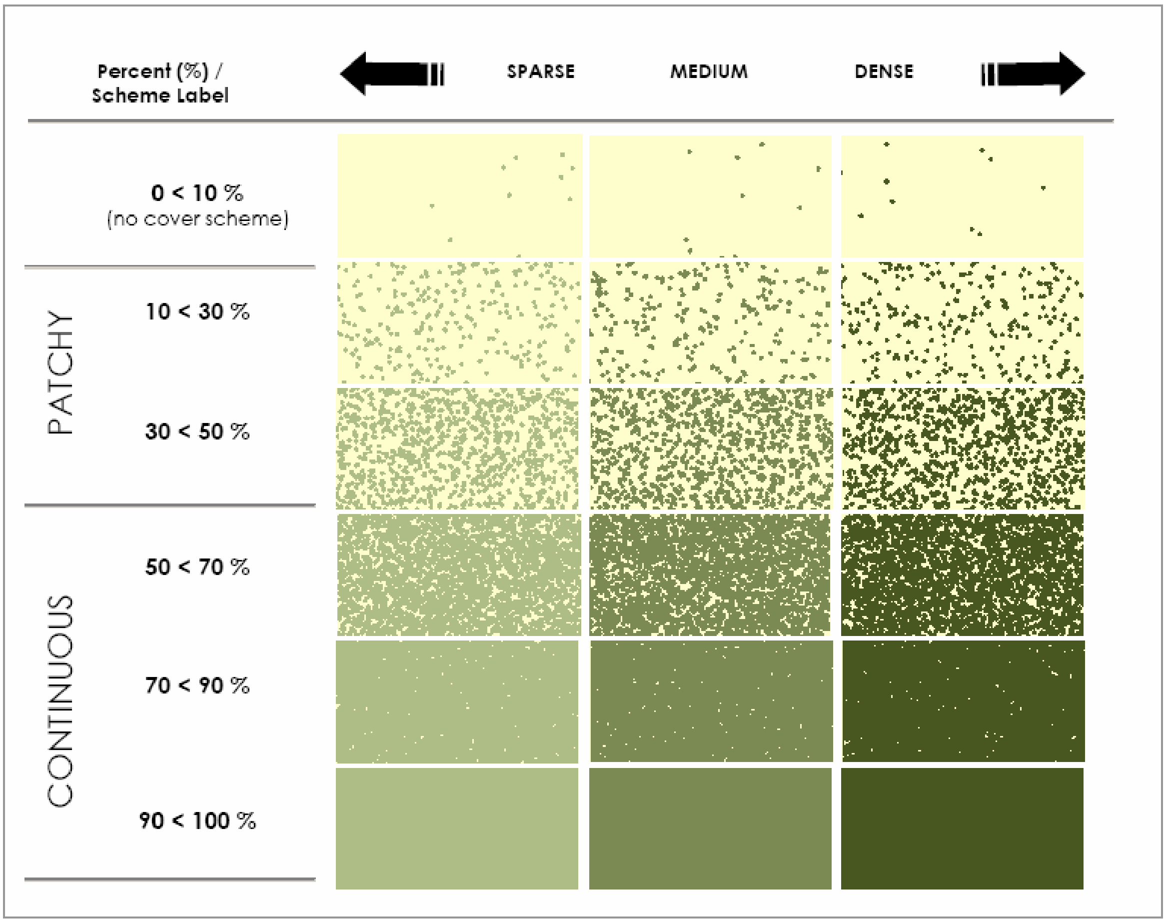


Figure 7 - Visual aid used for assigning percentage cover and relative density (Kendall *et al.* 2001).

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 ranges from species in some cases to broad "functional group" categories (e.g. foliaceous red macroalgae) in cases where even family differentiation is not possible.

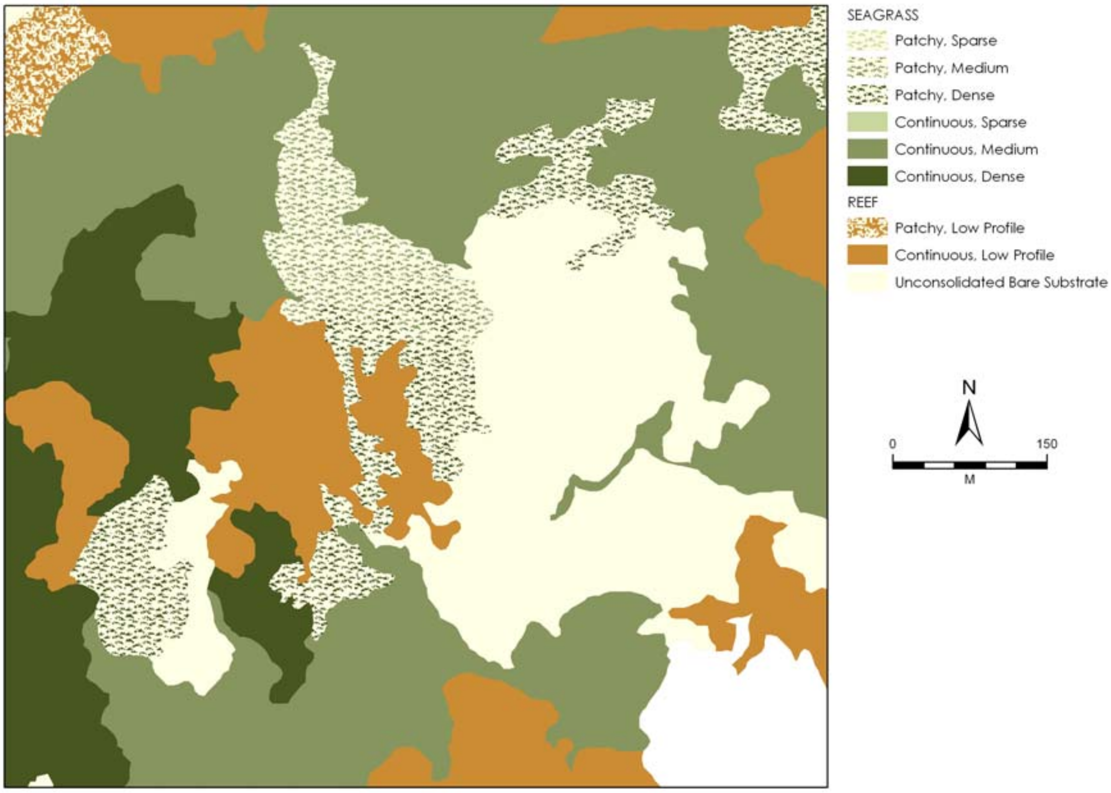


Figure 8 - Example of a benthic habitat map.

5.3.4 Data and map limitations

Maps were based on digitisation of imagery at 1:20,000 or 1:40,000 (depending on area, see above). 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 locations 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 of ~15 m. Therefore it is estimated that spatial error associated with this layer can be defined as generally being less than 20 m.

The final maps were assessed separately for habitat accuracy by conducting an independent ground truthing survey, in which 51 units or polygons within mapped areas 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.

Alignment between habitat polygons and the video checkpoints confirmed the mapped habitat types in 69% of cases. While it is recognised that the number of samples used to check accuracy is relatively small, it does provide an indication that for any randomly selected polygon the associated mapped habitat type is likely to be reliable approximately 69% of the time. Using the comparable checkpoints, previous mapping undertaken by CSIRO proved to be accurate 56% of the time.

6 Summary of mapping observations

The major results of the mapping process are included within the accompanying map books and interactive DVD. Apart from the current mapping observations, this summary includes those areas of the DEH mapping from 2007 from the upper Spencer Gulf and Gulf St Vincent (see DEH 2007b, c) to 15 m depth that occur within the NY NRM region. These earlier surveys employed a more or less identical habitat classification to those used in the current report (see DEH 2007a), although the field observations for ground truthing were different.

The following therefore comprises a brief summary of the outcomes of benthic habitat mapping surveys from the NY NRM region since 2007, which is intended to cover 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 datasets form an important resource that can be summarised and interpreted in pursuit of a wide variety of agendas, including:

- baseline observations for comparison to future monitoring,
- targeting of more spatially resolved mapping in areas of particular interest/concern.
- current habitat status relative to known threats,
- current habitat status relative to physical environmental factors/gradients,
- coast, estuarine and marine planning and
- reporting against NRM targets.

It is important to note that a reassessment of benthic habitats within the entire region should be undertaken every three to five years.

DEH (2007b, c) observations combined with the results of current mapping encompassed the entire NY NRM nearshore coast to a depth of 15 - 20 m (Figure 9). The total area of the NY NRM region is 49,804 km^2, of which the sea below median high water level comprises 15,658 km^2 (~ 31%). CSIRO mapping (see Edyvane 1999b) within the NY NRM region encompassed 7,508 km^2 (~ 48% of the sea area). The total extent of DEH habitat mapping within the region includes 5,012 km^2 or ~ 32% of the sea area. This total does not include a small area above high water mark (~ 5 km^2) that has been otherwise ignored for this summary.

When compared to benthic habitat mapping surveys conducted recently by DEH within other South Australian coastal NRM regions, these observations constitute by far the largest mapped area. For the other coastal NRM regions in SA these include:

- ALMR NRM at 937 km^2 or ~ 22% of the sea area (DEH 2009a)
- EP NRM at 1,205 km^2 which is only ~ 4.15% of the sea area (Miller *et al* 2009b)
- SE NRM at 739 km^2 or ~ 30% of the sea area (Miller *et al* 2009a).

In addition, the NY NRM region is only the second in the State for which there is benthic mapping coverage of the entire coast, with the other being the relatively shorter AMLR NRM coast. However, it is worth noting that other than the EP NRM, which has a very long coastline relative to other regions in South Australia, the proportion of the sea areas covered by current benthic mapping are generally comparable, ranging from 22 - 32%.

The area mapped by CSIRO is still somewhat larger than the current study and may suggest that there is potential to expand benthic mapping. However, CSIRO mapping extended to 30 m depth in some areas, which is well beyond the limits employed in DEH mapping (15 - 20 m). In addition, the patch resolution within the newer mapping is at least five times that of CSIRO, including 4,022 polygons, spread across 28 habitat types compared to 771 polygons using eight habitat types (see Edyvane 1999b). More finely resolved spatial differentiation of benthic patches encourages a more conservative assessment at the outer (deeper) limits. These differences are best observed when comparing the distance offshore achieved by each mapping exercise, with DEH mapping being generally much closer to shore, notably in areas such as Hardwicke Bay and the tip of Yorke Peninsula (Figure 9; Edyvane 1999b).

The benthic mapping encompassed by this study therefore constitutes probably the best balance of spatial coverage versus resolving power within the limits of the current methodology. There may be improvements or changes to benthic maps in some areas where better aerial images and/or image processing allows greater depth penetration. Otherwise, deeper water habitat differentiation at the fringes of the current mapping would most likely require a different approach, probably based around acoustic observations.

In terms of biounits, current benthic mapping included portions of eight of the 11 units that occur to some extent within the NY NRM region, ranging from 15% coverage of the Tiparra Biounit to 58% of Winninowie (Table 2). However, it needs to be noted that biounits vary substantially in size, as does the portion of each occurring within the NY NRM region. Given that biounits within the Gulfs extend to the 30 m depth contour and oceanic units to 50 m (Edyvane 1999b), the portion of each unit that is amenable to mapping with the current methods (i.e. to ~ 15 - 20 m depth depending on the quality of the aerial imagery) is unlikely to be comprehensive.

Table 2 - Summary of benthic mapping within the NY NRM region based on biounits within their respective bioregions. Note that the total area is the total for the biounit rather than thay portion of the biounut that occurs in the NY NRM region.

Bioregion	Biounit	Total Biounit area (km^2)	Area mapped (km^2)	% Mapped
Northern Spencer Gulf	Winninowie	559	324	58
Northern Spencer Gulf	Yonga	4,248	1,544	36
Spencer Gulf	Tiparra	2,433	372	15
Spencer Gulf	Wardang	2,856	563	20
Eyre	Pondalowie	222	93	42
Gulf St Vincent	Sturt	1,832	422	23
Gulf St Vincent	Orontes	1,838	710	39
Gulf St Vincent	Clinton	2,515	984	39
Total		**16,503**	**5,012**	**30**

Benthic habitat classes recognised from NY NRM region comprise five broad types, including:

- mangrove/saltmarsh
- seagrasses,
- reefs (low, medium and high profile),
- macroalgae occurring on unconsolidated substrate and
- unconsolidated bare substrate comprising sand, shell debris and rubble.

The above classes have been further differentiated with respect to their structure in terms of continuity (Continuous or Patchy) and density (Sparse, Medium and Dense, Table 3), such that there were 28 different habitat class/structure type combinations identified across the NY NRM region. However, for the purpose of this summary, reefs are combined within continuity (either patchy or continuous), macroalgae has been labelled as soft bottom and cobble has been included within unconsolidated bare substrate.

All of the eight CSIRO habitat types used in the Edyvane (1999a, b) summary are encompassed within the current mapping classification, although reef substrate composition (such as limestone/calcarenite or granite) is not represented. Substrate composition may be a factor in determining differences between reef areas (see DEH 2009a) although further consideration should also be given to soft bottom and unconsolidated bare substrate that are all too often treated as homogenous. Differences in sediment composition, structure and chemistry are known to be important factors relative to the associated flora and fauna (Shepherd and Sprigg 1976), although in an investigation of the effect of prawn trawling on soft sediment systems in Spencer Gulf, Svane *et al*. (2009) reported a minimal influence of biophysical differences between sites.

The 12 Bryars (2003) Fisheries Habitat Areas that occur within the NY NRM region (Appendix B) encompass 14 habitat classes, although note that many of these are comprised of mixtures (i.e. reef and seagrass and unvegetated sandy bottom combined).

However, some of the Bryars (2003) habitat classes are not represented in the current mapping, including:

- tidal flat,
- tidal creek,
- coastal lagoon and
- artificial substrate.

Most of the above comprise intertidal areas and are therefore not the targets for current mapping and/or may be included within another habitat class (i.e. tidal flat and tidal creek might be included within mangrove/saltmarsh). Both the Edyvane (1999a, b) interpretation of the CSIRO mapping and Bryars (2003) highlight the need for a consistent, readily repeatable approach to habitat mapping as well as the need for care when comparing observations from different surveys.

Table 3 - List of habitat groups used in summary data relative to the mapped habitat class and structure (NA = Not Applicable).

Summary habitat class	Continuity	Density	Mapped habitat class	Structure
Reef	Cont.	NA	High Profile Reef	Continuous, Dense
Reef	Cont.	NA	Low Profile Reef	Continuous, Sparse
Reef	Cont.	NA	Low Profile Reef	Continuous, Medium
Reef	Cont.	NA	Low Profile Reef	Continuous, Dense
Reef	Patchy	NA	Low Profile Reef	Patchy, Sparse
Reef	Patchy	NA	Low Profile Reef	Patchy, Medium
Reef	Patchy	NA	Low Profile Reef	Patchy, Dense
Reef	Cont.	NA	Medium Profile Reef	Continuous, Medium
Reef	Cont.	NA	Medium Profile Reef	Continuous, Dense
Reef	Patchy	NA	Medium Profile Reef	Patchy, Dense
Saltmarsh/Mangrove	Cont.	Dense	Saltmarsh/Mangrove	Continuous, Dense
Saltmarsh/Mangrove	Cont.	Medium	Saltmarsh/Mangrove	Continuous, Medium
Saltmarsh/Mangrove	Cont.	Sparse	Saltmarsh/Mangrove	Continuous, Sparse
Saltmarsh/Mangrove	Patchy	Sparse	Saltmarsh/Mangrove	Patchy, Sparse
Seagrass	Cont.	Dense	Seagrass	Continuous, Dense
Seagrass	Cont.	Medium	Seagrass	Continuous, Medium
Seagrass	Cont.	Sparse	Seagrass	Continuous, Sparse
Seagrass	Patchy	Dense	Seagrass	Patchy, Dense
Seagrass	Patchy	Medium	Seagrass	Patchy, Medium
Seagrass	Patchy	Sparse	Seagrass	Patchy, Sparse
Soft bottom	Cont.	Dense	Macroalgae	Continuous, Dense
Soft bottom	Cont.	Medium	Macroalgae	Continuous, Medium
Soft bottom	Cont.	Sparse	Macroalgae	Continuous, Sparse
Soft bottom	Patchy	Dense	Macroalgae	Patchy, Dense
Soft bottom	Patchy	Medium	Macroalgae	Patchy, Medium
Soft bottom	Patchy	Sparse	Macroalgae	Patchy, Sparse

Unconsolidated Bare Substrate	Cont.	NA	Unconsolidated Bare Substrate	Continuous
Unconsolidated Bare Substrate	Cont.	NA	Cobble	Continuous

The Bryars (2003) Fisheries Habitat Areas (FHAs) nonetheless provide a useful basis for comparison with current mapping as they are based on a number of data sources in addition to the CSIRO 1:100,000 mapping along with additional GIS layers and data sources. This approach was based on recognition of some errors in the CSIRO/Edyvane (1999a, b) mapping and sources (Bryars 2003). In addition, the Bryars (2003) observations provide a valuable resource with respect to identifying a range of factors related to each Fisheries Habitat Area including human usage, adjacent land use, local protection, adjacent catchments and threats (actual, perceived and potential) to each of the major habitat types within each FHA.

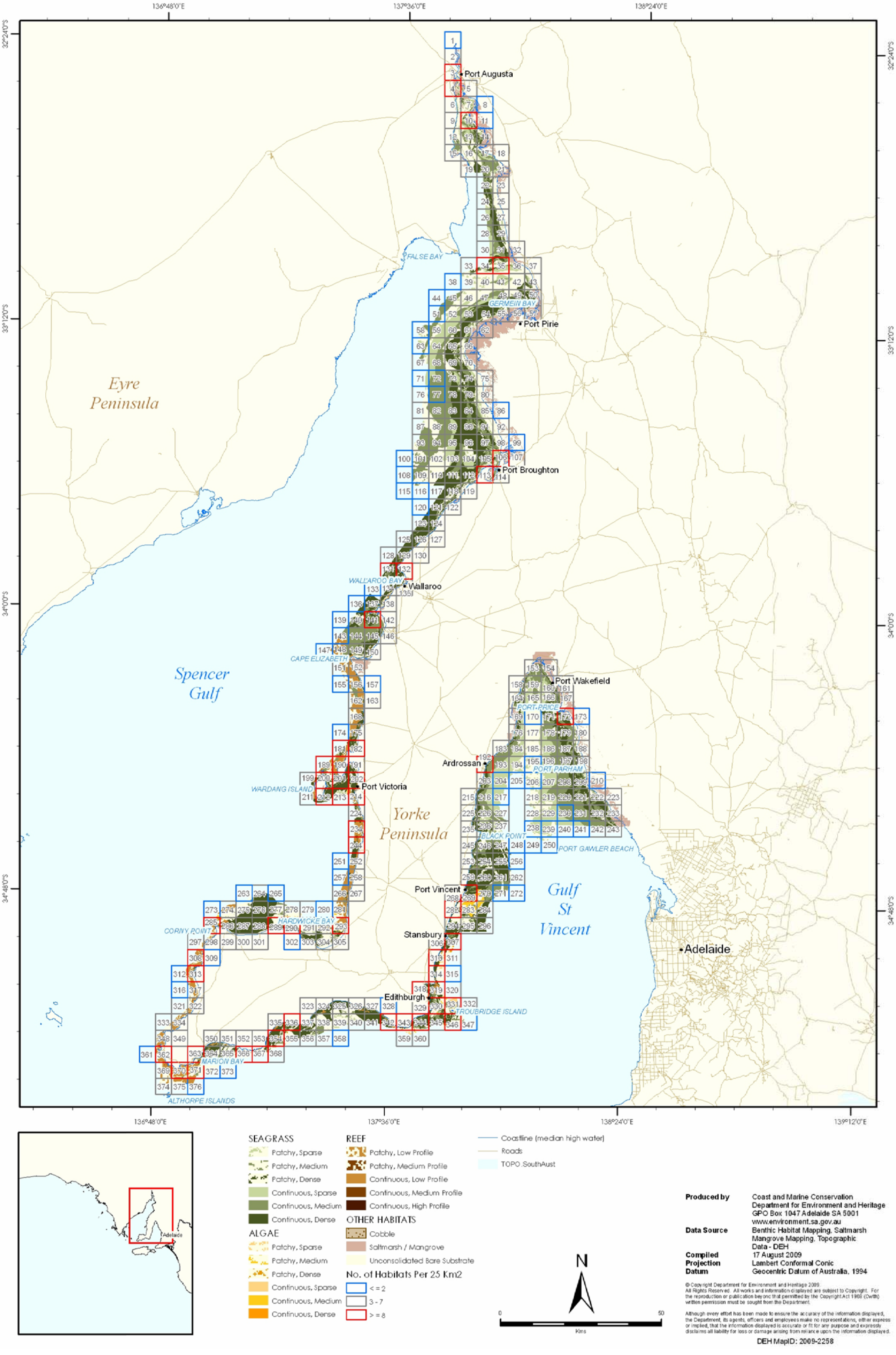


Figure 9 - Benthic habitat mapping for the NY NRM region, showing the position of a 5 × 5 km grid relative to each of the habitats defined in Table 2. Red borders indicate mapped areas with high numbers of habitat class/structure type combinations (≥ 8) blue borders indicate low numbers (≤ 2).

6.1 Proportional cover of broader habitat groups

Benthic cover for each habitat class within the current mapping can be allocated to one of mangrove/saltmarsh, reef, seagrass or soft bottom groups (Table 3). The area of each habitat was considered in terms of the percentage of the total area mapped within each biounit (note not the area of the biounit itself). This approach allowed for some comparison between mapped areas without the confounding effect of differences in coverage. However, habitat types were also considered in terms of their total absolute area.

6.1.1 Mangrove/saltmarsh

Mangrove/saltmarsh habitats were considered separately from the other habitat classes because they generally relate to intertidal areas. Continuous and patchy saltmarsh/mangrove areas across a range of densities were identified in Winninowie, Yonga, Tiparra and Clinton, but the proportion of the mapped area within each totalled less than 1% (0.33, 0.01, 0.03 and 0.1% respectively; data not shown). Bryars (2003) identified extensive areas of mangrove/saltmarsh in the upper Gulfs (FHA 31 - Far North Spencer Gulf, FHA 32 Germein Bay, FHA 41 Far North Gulf St Vincent[1] and FHA 42 Port Adelaide) with smaller areas along the coast (FHA 33 Muderoo Bay, 34 Wallaroo Bay) and saltmarsh only in many others (FHA 35 Wardang, FHA 36 Harwicke Bay, FHA 38 Foul Bay and FHA 39 Salt Creek).

Given that the focus of this investigation is on subtidal systems, the lack of intertidal community types within the current mapping is of little surprise, but it needs to be noted that the areas mapped within the current program are therefore not representative. The best resources for assessment of saltmarsh-like habitats within the NY NRM region include the coastal, dune and clifftop vegetation surveys by Oppermann (1999), saltmarsh and mangrove surveys completed by Canty and Hille (2002) as part of the NVIS program (see DEH 2006, DEWR 2007), and the Estuaries Information Package for the region (DEH 2007d).

6.1.2 Seagrasses

Percentage cover of the various habitat class/structure type combinations revealed substantial differences between biounits (Figure 10). When combined across structure types, seagrasses are the dominant community in all biounits except Pondalowie (3.43% of the mapped area), with total cover ranging from 62.4% in Tiparra to 90.6% in Clinton (Figure 10). In contrast, the Pondalowie biounit is dominated by continuous and patchy reefs (total cover of 66.8%) with the next highest being Tiparra (32.8%), Wardang (18.2%) and Sturt (17.6%). The remaining biounits, Orontes, Yonga, Winninowie and Clinton) were all less than 2% total reef cover (the latter two being zero).

In terms of absolute area of seagrass cover across structure types, the Yonga Biounit was by far the largest with over 1300 km^2, followed by Clinton (892 km^2) and then Orontes (607 km^2; Figure 11). Apart from Pondalowie, the remaining biounits ranged from 225-

[1] Note that this is not the same area as the corresponding bioregion that has a very similar name.

341 km^2. The Yonga biounit is substantially larger than all other biounits that occur in the NY NRM region (4,550 km^2 compared with the next largest, Wardang at 2,800 km^2), encompassing almost the entire western shore of Gulf St Vincent (Edyvane 1999b). A large coverage of seagrass within this area is therefore entirely probable.

While some care needs to be taken when considering absolute coverage, these results highlight the extent of seagrasses within the NY NRM region as a whole, not just the northern Gulf areas where a particular preponderance of seagrasses has been widely reported (e.g. Shepherd and Robertson 1989, Seddon 2000, NY NRM 2008). Rather, seagrasses are prolific in nearly all biounits. Edyvane (1999b) reports that extensive areas of seagrasses have been noted for Winnonowie, Yonga, Tiparra, Sturt, Orontes and Clinton (from 30.4% to 84.4% of the CSIRO mapped area in each unit; Figure 10). Similarly, Bryars (2003) describes large areas of seagrass in the corresponding FHAs, although these areas are depicted as mixtures of seagrass and unvegetated sandy bottom within the Gulf areas and seagrass, reef and unvegetated sandy bottom combinations on more exposed coasts around the tip of Yorke Peninsula.

It is curious to note that Edyvane (1999b) reported virtually no seagrasses within the Pondalowie biounit (0.25 km^2 or 0.1% of the CSIRO mapped area), whereas Bryars (2003) suggests that seagrasses occur along much of this stretch of coast (generally comprising FHA 37 Formby Bay) albeit interspersed with reefs and sandy bottom. Results of the current mapping program confirm that seagrasses are definitely not common in this biounit, but with a total cover of 3.19 km^2 (3.43% of the mapped area) this is more than 12 times larger than the cover reported in the Edyvane (1999b) summary. Given that seagrasses generally favour more sheltered locations (Shepherd and Robertson 1989), it would seem likely that a combination of substrate availability (Pondalowie is the only biounit in the NY NRM region that was dominated by reef systems; Figure 10) and higher water energy exposure limits the capacity for seagrasses on this stretch of coast.

In terms of the structure of seagrass beds (continuity and density) within each biounit, continuous dense seagrass was highest in the Wardang biounit (39% of the mapped area), followed by Orontes (37.5%) and then Sturt, Tiparra and Yonga (28.6-29.6%) with relatively low levels of cover in Winninowie (18.2%) and Clinton (15.3% - note that Pondalowie was less than 2%; Figure 10). Continuous medium seagrasses cover was similar in four biounits (27-31% for Winninowie, Yonga, Tiparra and Clinton) with 18% in Orontes, 6.3% in Sturt and 4.2% in Wardang (again less than 2% in Pondalowie; Figure 10). The continuous medium structure type is therefore an important component to seagrass systems in the NY NRM region. Continuous sparse seagrass cover was highest in Clinton (25%) followed by Winninowie (15.3%) then Yonga (12%) and Orontes (10%), with all other biounits returning zero for this structure type (Figure 10).

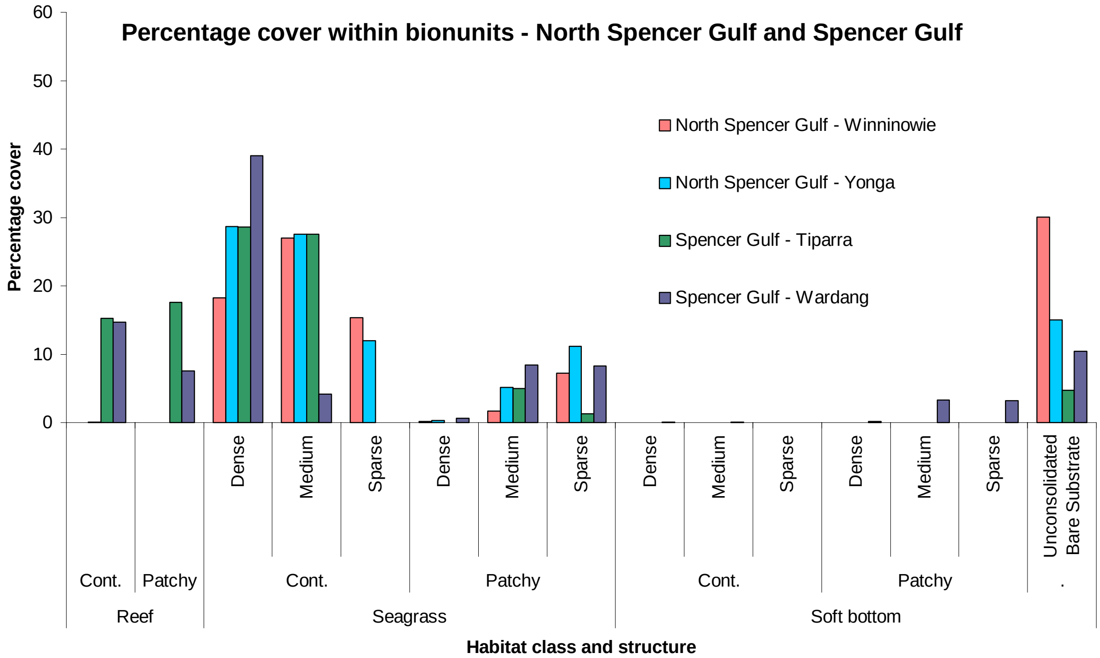
Given the sheltered nature of the upper Gulf areas that would otherwise seem to favour seagrasses (Shepherd and Robertson 1989), the lower proportional cover of continuous dense and relatively higher levels of continuous-sparse seagrasses in the corresponding biounits (Winninowie and Clinton) seems contradictory. However, the upper Gulf areas present other challenges to marine flora and fauna in terms of salinity and temperature variability (Edyvane 1999b) and probably nutrients and turbidity, which may affect seagrass density and growth (see Fox *et al.* 2007). Seddon (2000) investigated a large area (~ 12,000 ha – 1.2 km^2) of seagrass loss from northern Spencer Gulf in the early 1990s and came to the conclusion that extreme temperature and very low tide was the primary cause. Given that this loss event may not have been a one-off and that many seagrass species, in particular *Posidonia* spp. are slow to recover from disturbance (Meehan and West 2000), a degree of patchiness in seagrass cover within the northern areas of Spencer Gulf and Gulf St Vincent may be expected. However, should this model prove to be correct, there are important implications for seagrass systems in these areas in light of the potential impact of global warming.

Patchy dense seagrass cover was less than 1% (less than 0.5% in most instances) for all biounits (Figure 10). Patchy medium cover was highest in Sturt, Orontes and Wardang (~ 8-12%) with 5% in Yonga and Tiparra, 2.5% in Clinton, 1.7% in Winninowie and 0.3% in Pondalowie (Figure 10). Patchy sparse cover was ~ 16.5% of the mapped areas in Sturt and Clinton, 11% in Yonga, 7-8% in Winninowie, Wardang and Orontes, 1.2% in Tiparra and only 0.3% in Pondalowie. In general terms, patchy seagrass cover is relatively less than continuous areas within each biounit. However, any decline in the continuity and/or density of seagrass coverage should be cause for concern and closer investigation. Areas of patchy sparse seagrass cover in the Sturt and Clinton biounits should perhaps warrant further attention with respect to their potential exposure to threats, in particular those that affect water quality. However, it should also be kept in mind that these differences in density may have natural origins.

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). Sheltered embayments as well as the upper Gulf areas that are the preferred habitat for seagrasses are frequently the focus for regional population centres, industries and maritime transport. The relationship between threats, in particular those related to water quality, relative to seagrass health within the region is worthy of specific attention.

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, discrepancies in CSIRO Mapping/Edyvane (1999b) 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) also employed a range of additional data sources in response to the need for caution when employing those data in isolation.

However, relative to reef systems (see below) there is limited data on the nature of seagrass systems within the NY NRM region. Greater understanding of the nature of seagrass systems (species distribution patterns and environmental processes) is required, including improved knowledge of compositional differences between beds relative to their spatial and physical environmental context (exposure, geomorphology, water quality, etc.). This understanding will help managers differentiate natural and anthropogenic drivers (see threats above) of seagrass community structure.



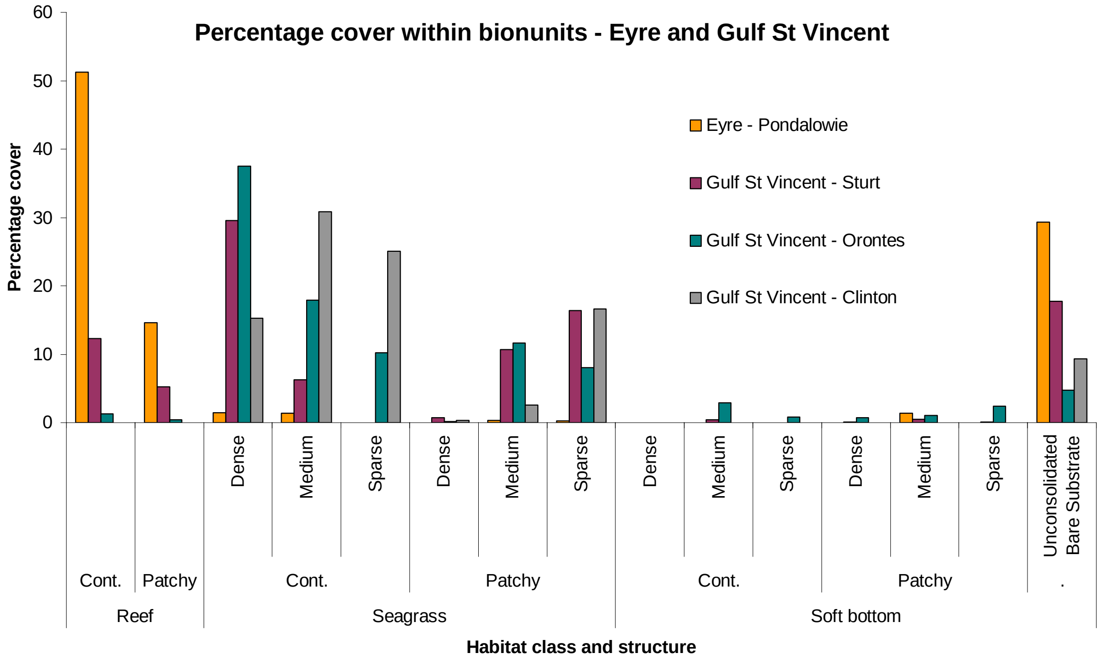


Figure 10 - Percentage cover of broader habitat types within each biounit along the NY NRM coast.

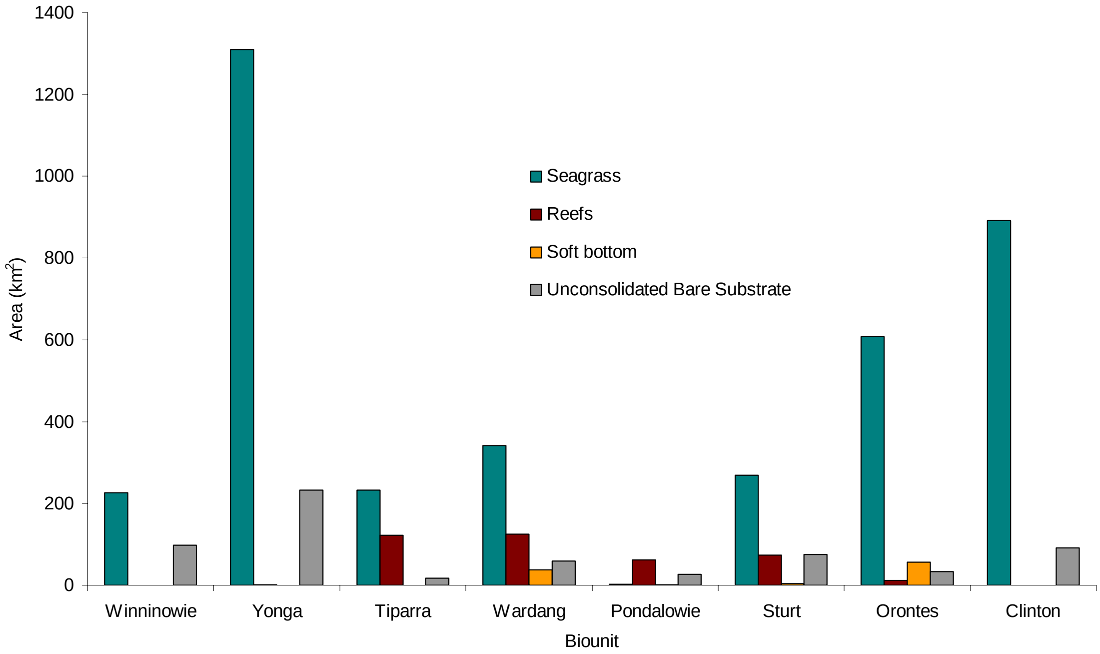


Figure 11 – Absolute area of seagrass, reef, soft bottom and unconsolidated bare substrate cover within the mapped area of each biounit.

6.1.3 Reefs

Reef systems were summarised in terms of continuity (continuous or patchy) but not density (dense, medium or sparse) of cover. The Pondalowie biounit was found to be dominated by continuous reefs (51.2% of the mapped area; Figure 10). The exposed nature of this biounit at the tip of Yorke Peninsula is very similar to the exposed coasts in the SE NRM region that are overwhelmingly reef dominated (Miller *et al* 2009). Tiparra, Wardang and Sturt Biounits had continuous reef cover ranging from 12.3-15.3% with Yonga and Orontes maintaining very low cover (0.1 and 1.2% respectively) while Winnonowie and Clinton had no reefs observed (Figure 10). Patchy reef cover was generally lower than continuous reefs within each biounit. Pondalowie had 14.6% patchy reef cover, while Wardang (7.5%), Sturt (5.2%), Orontes (0.4%) and Yonga (0.01) were also lower (note that the reef coverage in Yonga was very small in both instances). In Tiparra the patchy reef cover was slightly higher than the continuous reef (17.5%).

The relative availability of reef habitats within each of the biounits in the NY NRM region would thus appear to be negatively correlated to their position within either of the Gulfs (Figure 9). Northern biounits (Clinton and Winninowie) have no occurrence of reefs (at least at this scale of observation), with those slightly further south (Yonga and Orontes) having very low cover. Those areas with more (arguably intermediate) exposure (Tiparra, Wardang and Sturt) have relatively more reef, followed by Pondalowie with the highest reef cover and probably the most exposed stretch of coast. Just as seagrasses require more sheltered locations, reef systems require enough water energy to keep them free from sedimentation. Indeed it has been argued that relative to threats to marine systems from declines in water quality, seagrasses are more responsive to nutrient pollution while reefs are more sensitive to water turbidity and sedimentation (Fox *et al.* 2007, Turner *et al.* 2007, Connell *et al.* 2008).

A comparison of the current mapping, the CSIRO mapping and Bryars (2003) FHA compositions reveals a number of discrepancies. Edyvane (1999b) reported the highest proportional reef cover to be in the Wardang and Orontes biounits (~ 37% in each) as opposed to 22.2% for Wardang and ~ 2% for Orontes reported from the current mapping. Pondalowie retained only ~ 16% reef cover relative to 65.9% from current surveys and CSIRO/Edyvane (1999b) reef cover for Tiparra was reported at only 4.4%, whereas the current mapping found a total area of 32.8%. Part of these differences may result from errors in either the CSIRO/Edyvane (1999b – see above) data or current mapping (56% and 69% accuracy respectively based on testing outlined above), but some of this difference is likely to relate to the greater resolving power within the current study. Smaller patches of reef that may be missed within less intensive sampling can be differentiated within the current mapping and may ultimately provide a large cumulative area. This difference may be apparent in the Bryars (2003) habitat maps wherein reef proportional cover would appear to align more with the results of the current mapping[2], provided one considers the areas covered by mixtures of reef with seagrass and/or unvegetated soft bottom.

Small, isolated patches of a particular habitat may be of critical importance to local-scale biodiversity and also facilitate species migrations by allowing "island hopping" between patches of favourable substrate. 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 patches.

When considered in terms of absolute cover across both patchy and continuous reefs, Tiparra and Wardang had the highest level of reef cover (122 km^2 and 125 km^2 respectively), followed by Sturt (74 km^2) and Pondalowie (61 km^2), Orontes (13 km^2) and Yonga (1.6 km^2), with Winninowie and Clinton showing zero (Figure 11). Thus while the proportional cover might suggest that Pondalowie is the most important biounit to consider in terms of reef cover, the Tiparra and Wardang areas support a substantially larger total area.

Reef systems within the NY NRM region have been relatively recently investigated at 11 sites through Reef Health surveys in 2005 (Turner *et al.* 2007) and by DEH (2009c) observations at 23 locations in 2006 (including nine from the preceding Reef Health). The methodologies employed in each survey differed substantially (see above) but nonetheless provide useful information about the nature of reef systems in the NY NRM region.

Reef Health investigations for the NY NRM coast in 2005 considered 11 sites, each of which was assessed relative to a number of indicators of reef status (see Turner *et al.*

[2] Note that the alignment of Bryars (2003) Fisheries Habitat Areas and biounit boundaries within the NY NRM region is limited.

2007). Two sites at Troubridge Point and Cable Hut Bay fitted into a "Caution recommended" health status, suggesting that there were signs of decline at these sites that may warrant further investigation. Another two locations at Point Souttar and Point Riley were designated as being in "Poor" condition, possibly indicating severely impacted systems. However, the indices used to develop this interpretation were based on the results of Reef Health observations from the Adelaide Metropolitan coast (see Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007) of which the extrapolation to areas further afield must be viewed with care. Importantly, the DEH (2009c) observations were considered relative to a smaller number of indices of reef status and found similar "uncertain" status results for Port Riley, Balgowan, Port Rikaby and Cable Bay. However, in all likelihood all of the above reefs are a reflection of the natural state of the system, meaning that there is a need to expand our understanding of what constitutes a "healthy" reef.

Turner *et al.* (2007) make no inference that the indices employed are in any way definitive; rather, that these approaches should be used as a catalyst to the development of more meaningful indices/approaches to understanding reef health and the notion of "health" itself in an environmental context. What is clear is that the health status of a reef must be considered in context with its physical environment, further highlighting the need to develop our understanding of the relationships between biotic and abiotic factors that structure reef systems in southern Australia (DEH 2009c).

DEH (2009c) reef surveys at 25 sites confirmed a high degree of spatiotemporal variability between sites with related diversity in macroalgal and overall reef community composition. NY NRM reefs were found to be rather different from each other in response to a range of environmental biophysical factors and/or disturbance. Importantly, the DEH (2009c) observations found strong gradients between reef community composition relative to position along the coast, with systems found to be strongly influenced by tidal range, temperature, substrate (rock type) and exposure (DEH 2009c). Most, if not all, of these factors change predictably relative to location within each of the Gulfs. However, further information on environmental factors that influence reef community structure is required, in particular those related to water quality.

6.1.4 Soft bottom/Unconsolidated bare substrate

Soft bottom habitats, including macroalgal community patches across structure types (continuity and density, Table 3) ranged from 0% at four sites (Winninowie, Yonga, Tiparra and Clinton) to ~ 1% in Pondalowie and Sturt, 6.7% in Wardang and 7.9% in Orontes (Figure 10). However, unconsolidated bare substrate was a substantially higher proportion of most biounits, with lowest coverage at ~ 5% in Tiparra and Orontes ranging up to 30% in Winninowie (Figure 10). In absolute terms, unconsolidated bare substrate ranged from less than 20 km^2 in Tiparra to 232 km^2 in Yonga (Figure 11). With a depth of observation of less than 20 m, deeper water systems as observed in the southern Gulf regions (see Shepherd and Sprigg 1976) are unlikely to be encountered. However, given the diversity of substrates incorporated within the unconsolidated bare substrate type (sand, shell debris and rubble), a detailed interpretation of levels of cover and their potential significance is considered unlikely to reveal an interpretation of any value. There is little alignment between soft bottom/unconsolidated bare substrate cover from the current mapping to that obtained by CSIRO, with most biounits (Winninowie, Yonga, Tiparra, Wardang and Pondalowie) having less than half the proportional cover to that reported by Edyvane (1999b). The soft bottom/unconsolidated bare substrate habitat types are somewhat loosely defined in that they include a diverse array of substrates that do not fit within other categories. This highlights the need to develop a greater understanding of these systems.

Bare/unconsolidated 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.* 1996). The maximum depth of mapping observations ranged from 15-20 m, which is well within the reported depth tolerances of seagrass species in southern Australia (see summary Westphalen *et al.* 2004). The dynamics of seagrass relative to bare sand communities is also worthy of closer investigation.

6.2 Areas of high habitat diversity

Benthic maps in the map book associated with this report are presented in terms of a series of 5 x 5 km areas (Projection = Lamberts Conformal Conic; Datum = Geocentric Datum of Australia, 1994; Figure 9). An examination of the number of different habitats (including differences in structure type) across the grid of 376 maps offers a rough indication of the broader distribution of substrate complexity within and between each mapped area. This information may be used to indicate areas of higher habitat diversity and therein zones of potential conservation significance.

The average number of habitat class/structure type combinations per map was 5.1 ± 2.6 (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. ≤ 2 or ≥ 8 habitat class/structure type combinations; see Table 3 for a summary). Of the 376 map areas that encompass all benthic mapping in this survey, those with relatively few habitats (two or less) totalled 63 maps (~ 17%) 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 9; Figure 12).

The most frequent number of habitat class/structure types was six (65 maps), although the spread of frequencies was heavily biased to the lower end with around 86% of the maps having seven or fewer habitat class/structure type combinations (Figure 12). Even putting aside those maps at the fringes, the overwhelming tendency was for between three and seven habitat class/structure type combinations per map.

Those maps with 11 or more habitat class/structure type combinations (average + 2 times the standard deviation) totalled 12 maps with the highest (15 habitat class/structure type combinations) being Map 343 near Troubridge Point on Yorke Peninsula (Figure 9). The next highest (14 combinations) was for Map 190 at Reef Point near Port Victoria. Maps with 13 combinations included Map 189, adjacent to Map 190 at Reef Point and Map 132 at Wallaroo (Figure 9). Maps with 12 combinations included five maps (Map 192, Map

285, Map 310, Map 319 and Map 362) while those with 11 combinations included three maps (Map 182, Map 330 and Map 370). These areas occurred mostly around the southern exposed coast of Yorke Peninsula (Figure 9; Figure 12). High diversity maps tend to occur close to shore, where there is more interaction between seagrass and reef systems, but these areas are also where the greatest concentration of threats is likely to occur (Bryars 2003, AMLR NRM 2007). Shallower nearshore areas are also likely to allow greater habitat differentiation from aerial images. 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 grid.

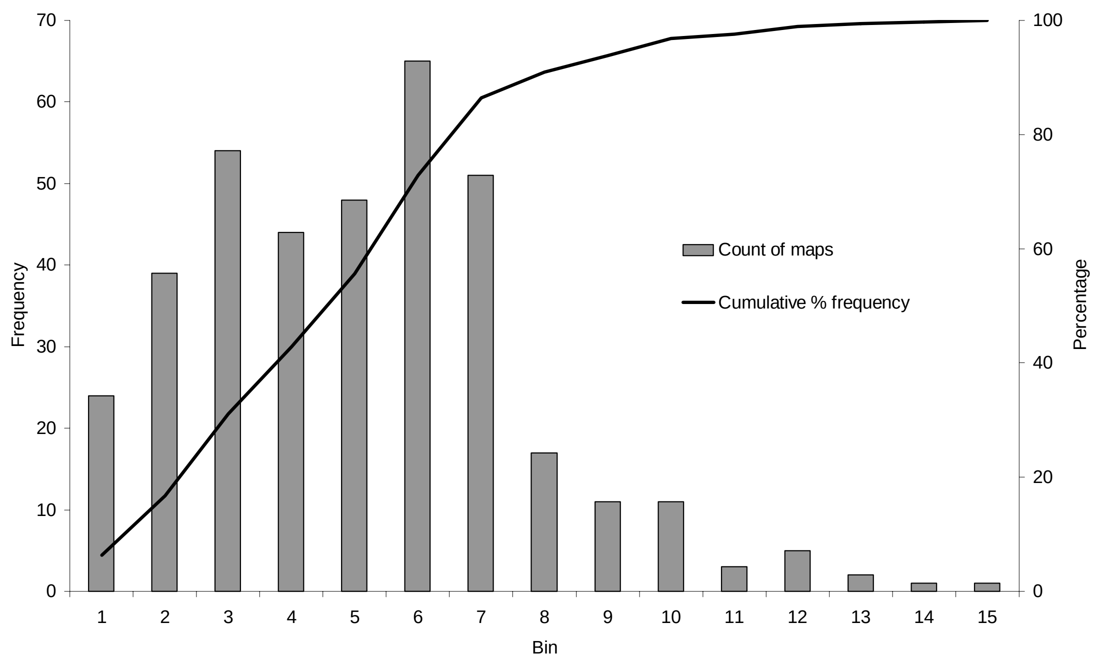


Figure 12 - Frequency distribution and cumulative percentage of the number of habitats within each 5 km × 5 km map (n = 376).

There are arguably 10 areas of particular interest in terms of the diversity of habitat class/structure type combinations (Figure 9), including:

- Port Augusta,
- Port Germein,
- Port Broughton,
- Wallaroo,
- Port Victoria,
- Hardwicke to Corny Point,
- Cape Spencer to Point Yorke,
- Troubridge Point to Port Vincent,

- Ardrossan and
- Sandy Point.

The areas around Port Victoria and Troubridge Point to Port Vincent are probably the most interesting with respect to the number of maps areas retaining a high diversity of habitat class/structure combinations (Figure 9), although there are areas of high diversity spread along the entire NY NRM coast.

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 3-7 representatives should 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 may be dominated by a particular habitat class, in particular large areas of seagrass for which four areas may be included (Figure 9):

- Port Pirie to Port Broughton (Maps 038 – 112),
- Cape Elizabeth (Maps 136-150),
- Upper Gulf St Vincent (Maps 153 – 262 not including those on the western coast of Yorke Peninsula[3]) and
- Corny Point (Maps 275, 276, 277, 286, 287 and 288).

Note that there are other areas of seagrass that may be worthy of closer attention. It is also worth noting that the straight seagrass boundary at the limit of mapping suggests these areas of seagrass are not completely covered by current surveys.

Areas with a large number of habitat class/structure type combinations should warrant closer attention relative the ecophysical factors that drive this diversity, including possible or actual threats and whether these zones also correlate to high species biodiversity. Areas with large expanses of a particular habitat class, in particular seagrasses, should also be considered relative to their respective threat exposure (see above).

6.2.1 Threats

The Cheshire *et al.* (2007) and Caton *et al.* (2007) investigations into threats to coastal, estuarine and marine assets within the NY NRM area (see above) both applied a spatial component. Although Cheshire *et al.* (2007) had a greater focus on subtidal systems, both investigations broadly concur in the overlapping areas (saltmarsh habitats and dune systems). Otherwise, Cheshire *et al.* (2007) identified five asset groups for the NY NRM region that appeared to be highly prone to the identified threats, including:

- subtidal seagrass,
- mangroves/intertidal mudflat/tidal estuary,

[3] Note that the number of maps is sequential in rows across west to east rather than along the coast.

- samphire/saltmarsh,
- subtidal reefs,
- intertidal reefs and
- dune systems.

With the more highly resolved habitat mapping provided by this study, some benefit may be gained from a level of reconsideration of the Cheshire *et al.* (2007) work for subtidal reef and seagrass.

Broader reconsideration of the spatial distribution of threats from across the NY NRM region based on the information from Cheshire *et al.* (2007) and Caton *et al.* (2007) is recommended, particularly with reference to areas of high habitat diversity and large seagrass coverage (see above).

6.3 Conclusions and recommendations

The current benthic habitat mapping within the NY NRM region encompasses probably the best balance of spatial coverage versus resolving power within the limits of current methodologies and provides a significant improvement over earlier interpretations. While there is potential to obtain finer scale observations, these can be more readily targeted to areas of particular interest (see below). However, it must be acknowledged that current mapping is limited in depth (15-20 m) and that deeper water habitats that still encompass the bulk of the marine habitat within the NY NRM region are still poorly known, particularly in Spencer Gulf. However, given that the bulk of the threats to marine systems are located on the nearshore fringe, current mapping therefore includes coverage of the areas most at risk. In addition, management initiatives targeted at nearshore environmental threats may have flow-on effects to deep water systems. However, specific threats to deep water systems should be the focus of further attention.

Comprehensive mapping of nearshore benthic habitat within the NY NRM region provides an invaluable resource for investigation of current status, reporting against NRM management programs and as a baseline against which future observations can be compared. Results of the current mapping confirm both the extent and diversity of nearshore benthic systems within the NY NRM region and highlight the need for an integrated large-scale management approach. Northern Gulf areas were already noted for their extensive seagrass and mangrove/saltmarsh systems (Shepherd and Robertson 1989, Seddon 2000, NY NRM 2008), but the results of current mapping suggest that seagrasses are extensive throughout much of the rest of the region. The northern Gulf areas, while certainly important, particularly in terms of seagrass and mangrove/saltmarsh as well as relictual subtropical biota in Spencer Gulf (Edyvane 1999b, Baker 2004), should not detract from the need to manage observations and intervention elsewhere within NY NRM. However, it is likely that as “reverse estuaries” (Edyvane 1999b), both upper Gulf areas are potentially more at risk to factors resulting from climate change.

Reef systems are also widespread and diverse across the NY NRM region, although they dominate only on the exposed coast at the tip of York Peninsula (within the Pondalowie biounit). However, there are large areas of both patchy and continuous reefs within the Tiparra and Wardang biounits.

While there has been some analysis of factors that may influence the structure of reef systems (see DEH 2009c), there is a need to develop a greater understanding of the relationship between physical environmental factors and nearshore benthic systems as a whole (not just reefs). Importantly, there is a need to understand that factors may be influential at very different spatial scales. Current mapping can thus form an important resource in developing hypotheses and targeting research.

The analysis presented in this summary is not intended to be comprehensive, and it should be understood that the underlying GIS datasets form an important resource that can be summarised and interpreted in pursuit of a wide variety of agenda, including (among others):

- baseline observations for comparison to future monitoring,
- targeting of more spatially resolved mapping in areas of particular interest/concern,
- current habitat status relative to known threats,
- coast, estuarine and marine planning and
- reporting against NRM targets.

Specific areas of interest in terms of habitat diversity include:

- Port Augusta,
- Port Germein,
- Port Broughton,
- Wallaroo,
- Port Victoria,
- Hardwicke to Corny Point,
- Cape Spencer to Point Yorke,
- Troubridge Point to Port Vincent,
- Ardrossan and
- Sandy Point.

Similarly, extensive seagrass areas include:

- Port Pirie to Port Broughton,
- Cape Elizabeth,
- Upper Gulf St Vincent and
- Corny Point.

These areas may warrant more targeted surveys to determine whether habitat diversity is translated into species diversity as well as to investigate the factors, both physical and biological, that may be responsible for generating this diversity of habitats. The potential or actual threats to these areas should be considered as well as their representation relative to MPA zoning (where relevant).

While reef surveys of the NY NRM coast (DEH 2009c) investigated the role of physical environmental factors, there is a need to develop a greater understanding of the broader dynamics of marine habitats in terms of the interaction between seagrass, sand and reef systems. Notwithstanding this need, our understanding of the relationships between community composition and physical environmental factors is still rather limited. Completion of comprehensive habitat mapping for the NY NRM region offers an opportunity to expand this understanding through an examination of current and future trends in community change relative to the physical environment. In particular, there is a need to understand the relationship between water quality and community structure. A reconsideration of the spatial arrangement of the threats to nearshore systems identified by Cheshire *et al.* (2007) and Caton *et al.* (2007) juxtaposed against the results of mapping should be considered.

A number of recommendations can be drawn from the above, including:

- Targeted monitoring related to specified areas (see above), requiring;
  - more resolved habitat mapping and/or targeted observations (i.e. Reef Health),
  - spatially referenced data related to threats, in particular water quality issues, and
  - engagement with stakeholders at the local scale.
- Deep water habitat mapping.
- Understanding reef systems from an NRM perspective, specifically:
  - better spatial data on biotic and abiotic factors that structure reef systems,
  - improved spatial understanding of threats and stakeholders, and
  - research targeted to understanding spatial relationships between threats, natural factors and reef systems.
- Reconsideration of both benthic mapping and reef systems at management/NRM program scales (3-5 years) with a focus on obtaining data within the summer/early autumn period.

For seagrass:

- Assessment of the potential implications of global warming on seagrass systems in the upper Gulfs.
- Patchy sparse seagrass cover in the Sturt and Clinton biounits should be targeted for specific attention to determine if this is a sign of ongoing decline. The

exposure of these areas to threats, in particular those that affect water quality, should be determined.

- Improved knowledge of the nature of seagrass systems is required for the NY NRM region, including compositional differences between beds relative to their spatial and physical environmental context (exposure, geomorphology, water quality, etc.).

For reefs:

- Ongoing assessment of reefs along the lines of Reef Health and/or the Edgar and Barrett (1997)/Edgar and Barrett (1999) surveys are required.
- Further development of our understanding of the relationships between biotic and abiotic factors that structure reef systems in southern Australia (DEH 2009c), in particular those related to water quality.

For soft bottom:

- The soft bottom/unconsolidated bare substrate habitat types used within the current mapping are somewhat loosely defined in that they include a diverse array of substrates that do not fit within other categories. This highlights the need to develop a greater understanding of these systems relative to the distribution of sediment types and their related biota.
- The dynamics of seagrass relative to bare sand communities is also worthy of closer investigation.

For threats:

- More general information on the nature of factors that may influence the structure of benthic systems will assist managers in differentiating natural and anthropogenic drivers (see threats above) of nearshore community structure.
- For subtidal reef and seagrass systems there may be some benefit from a level of reconsideration of Cheshire *et al* (2007), as the current mapping for these habitat types is now far more highly resolved.
- Reconsideration of the spatial distribution of threats from across the NY NRM region based on the information from Cheshire *et al.* (2007) and Caton *et al.* (2007) is recommended, particularly with reference to areas of high habitat diversity and large seagrass coverage (see above).

7 References

Allee RJ, Dethier M, Brown D, Deegan L, Ford RG, Hourigan TF, Maragos J, Schoch C, Sealey K, Twilley R, Weinstein MP and Yaklavish M (2000). *Marine and Estuarine Ecosystem and Habitat Classification.* NOAA Technical Memorandum NMFS-F/SPO-43. US Department of Commerce, National Oceanic and Atmospheric Administration and National Marine Fisheries Service.

AMLR NRM (2007). *Creating a Sustainable Future. A Natural Resources Management Plan for the Adelaide and Mount Loft Ranges Region. Volume A - State of the Region Report.* Draft Consultation Document. Adelaide and Mt Lofty Range Natural Resources Management Board and the Government of South Australia.

Aquaculture Regulations 2005. Aquaculture Regulations 2005 Version 20.11.2008 under the *Aquaculture Act 2001*. Government of South Australia.

Baker JL (2004). *Towards a System of Ecologically Representative Marine Protected Areas in South Australian Marine Bioregions - Technical Report.* Prepared for Coast and Marine Conservation Branch, Department for Environment and Heritage, South Australia.

Barrett N, Sanderson JC, Lawler M, Halley V and Jordon A 2001. *Mapping of inshore marine habitats in southeastern Tasmania for marine protected area planning and marine management.* Tasmanian Aquaculture and Fisheries Institute, Technical Report Series Number 7, University of Tasmania. ISSN 1441-8487.

Boating Industry Association of South Australia (2005). *South Australian Waters: an atlas and guide.* Boating Industry Association and the South Australian Tourism Commission. Wakefield Press.

Bryars S (2003). *An Inventory of Important Coastal Fisheries Habitats in South Australia*. Fish Habitat Program, Primary Industries and Resources South Australia.

Cameron, J. and Tunn, Y. 2006. *Near-shore seagrass change between 1979–81 and 2004 mapped using digital aerial photography: Western Yorke Peninsula, South Australia.* Internal DEH report prepared for Environment Protection Authority, Department of Environment and Heritage, Adelaide.

Canty, D. and Hille, B. 2002. *Coastal salt marsh and mangrove mapping.* Technical Report. Environmental Analysis and Research Unit, Department for Environment and Heritage, Adelaide.

Caton J, Detmar S, Fotheringham D, Haby M. Royal M and Sandercock R. 2007. *Conservation assessment of the Northern and Yorke Coast.* Prepared by the Coastal Protection Branch and the Environment Information Analysis Branch Department for Environment and Heritage SA for the Northern and Yorke Natural Resource Management Board.

Cheshire AC, Butler AJ, Bathgate RS, Westphalen G and Miller DJ. 1996. *The Impact of Sand Dredging on Benthic Community Structure at Port Stanvac Dredge Site: Interim report on the results of surveys 1992 to 1995. Report to the Coast Protection Board, South Australian Department of Environment and Natural Resources.* Department of Botany, The University of Adelaide.

Cheshire A, Westphalen G and Fordham A. 2007. *Northern and Yorke NRM Region: Coast and Marine Risk Assessment*. Results of a workshop organised by Science to Manage Uncertainty and Westphalen Consulting for the Northern and Yorke NRM Board.

Cheshire AC and Westphalen G (2000). *Assessing the status of temperate reefs in Gulf St Vincent IV. Results of the 1999 surveys.* The University of Adelaide, Adelaide.

Cheshire AC, Hall SJ, Havenhand J and Miller D (1998). *Assessing the status of temperate reefs in Gulf St Vincent II: Survey results.* University of Adelaide, 0 86396 631 4, Adelaide.

Collie JS, Hall SJ, Kaiser MJ and Poiner IR (2000). A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology* 69: 785-798.

Collings G, Bryars S, Turner D, Brook J and Theil M (2008). Examining the health of subtidal reef environments in South Australia, Part 4: Assessment of community reef monitoring and status of selected South Australian reefs based on the results of the 2007 surveys. SARDI Publication Number RD. F2008/000511-1 South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Collings GJ and Cheshire AC (1998). Composition of subtidal macroalgal communities of the lower gulf waters of South Australia, with reference to water movement and geographic separation. *Australian Journal of Botany* 46: 657-669.

Commonwealth of Australia (2006). *A guide to the integrated marine and coastal regionalisation of Australia.* Version 4.0. Department of the Environment and Heritage, Canberra, Australia.

Connell SD, Russell BD, Turner DJ, Shepherd SA, Kildea T, Miller D, Airoldi L, Cheshire A. (2008) Recovering a lost baseline: missing kelp forests from a metropolitan coast. *Marine Ecology Progress Series* 360:63-72.

Connell SD (2007). Subtidal temperate rocky habitats: habitat heterogeneity at local to continental scales. *In* Connell SD and Gillanders BM (eds) *Marine Ecology.* Oxford University Press, Melbourne. pp. 378-401.

Connell SD and Irving AD (2008). Integrating ecology with biogeography using landscape characteristics: a case study of subtidal habitat across southern Australia. *Journal of Biogeography*. 35: 1608-1621 .

Connolly RM. 1994. *Effects of oil from the "Era" spill on intertidal seagrasses and associated mobile invertebrates in Spencer Gulf, South Australia.* Report to the Environmental Protection Council, South Australia.

DEH 2006. *Native vegetation information for NRM planning. Fact Sheet.* Department for Environment and Heritage, Adelaide, SA.

DEH 2007a. *Nearshore marine benthic habitat mapping; information for NRM planning – South Australia.* Department for Environment and Heritage, Northern and Yorke Natural Resource Management Board.

DEH 2007b *Nearshore Marine Benthic Habitat Mapping, Upper Gulf St Vincent - South Australia.* Department for Environment and Heritage, Adelaide, SA

DEH 2007c *Nearshore Marine Benthic Habitat Mapping, Northern Spencer Gulf - South Australia.* Department for Environment and Heritage, Adelaide, SA

DEH 2007d. *Northern and Yorke Natural Resources Management Region Estuaries Information Package.* Department for Environment and Heritage, Adelaide, SA.

DEH 2009a. *Marine habitats in the Adelaide and Mt Lofty Ranges NRM region. Final Report to the Adelaide and Mt Lofty Ranges NRM Board for the project: Facilitate coast, marine and estuarine planning and management by establishing regional baselines.* Prepared by Department for Environment and Heritage Coast and Marine Conservation Branch.

DEH 2009b. *Marine Parks; Reserve today, Preserve forever. South Australia's Marine Parks Network for public comment.* Coast and Marine Conservation, Department of Environment and Heritage. Adelaide.

DEH 2009c. *Rocky Reefs of the Northern and Yorke Natural Resources Management Region.* Department for Environment and Heritage, Adelaide, SA.

DEWR (2007). *Australia's Native Vegetation: A summary of Australia's major vegetation groups, 2007.* Department of the Environment and Water Resources, Australian Government, Canberra, ACT.

Edgar GJ and Barrett NS (1997). Short term monitoring of biotic change in Tasmanian marine reserves. *Journal of Experimental Marine Biology and Ecology* 213: 261-279.

Edgar GJ and Barrett NS (1999). Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. *Journal of Experimental Marine Biology and Ecology* 242: 107-144.

Edyvane K (1996). Issues in the South Australian marine environment. *In:* Zann LP, Sutton D (eds) *State of the marine environment report for Australia. Technical annex 3.* Department of the Environment and Heritage, Canberra.

Edyvane K (1999a). *Conserving marine biodiversity in South Australia Part 1 – Background, status and review of approach to marine biodiversity conservation in South Australia.* South Australian Research and Development Institute (SARDI) Aquatic Sciences. May 1999 ISBN 0 7308 5237 7 No. 38.

Edyvane K (1999b). *Conserving marine biodiversity in South Australia Part 2 – Identification of areas of high conservation value in South Australia.* South Australian Research and Development Institute (SARDI) Aquatic Sciences. May 1999 ISBN 0 7308 5238 5 No. 39.

Engle J and Kvitek R (1998). Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. *Conservation Biology* 12: 1204-1214.

EP NRM 2008. State of the Region Report 2008, *Recognising the state of natural resources.* Eyre Peninsula Natural Resource Management Board and the Government of South Australia.

Fairhead VA, Tanner J and Miller D 2002. *Environmental assessment of the biological assemblages at the Port Giles jetty dredging site*. Report prepared for Egis Consulting SA. SARDI Aquatic Sciences, South Australia.

Fairweather PG 1999. Determining the 'health' of estuaries: priorities for ecological research. *Australian Journal of Ecology* 24: 441-451.

FAO (2003). *Fisheries Management 2. Ecosystems approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries. Food and Agriculture Organisation of the United Nations.

Flaherty T and Sampson K (2005). *Taking NRM beyond the shore: Integrating marine and coastal issues into natural resource management.* The Marine and Coastal Community Network. ISBN 1 87500 24 5.

Fox DR, Batley GE, Blackburn D, Bone Y, Bryars S, Cheshire A, Collings G, Ellis D, Fairweather P, Fallowfield H, Harris G, Henderson B, Kämpf J, Nayar S, Pattiaratchi C, Petrusevics P, Townsend M, Westphalen G and Wilkinson J (2007). *The Adelaide Coastal Water Study Final Report, Volume 1.* Prepared for the South Australian Environment Protection Authority. CSIRO Marine and Atmospheric Research.

Gaylard, S (2004). *Ambient water quality monitoring of the Gulf St Vincent metropolitan coastal waters. Report No 2: 1995 – 2002.* Environment Protection Authority, Adelaide.

Gaylard, S. 2008. Western Yorke Peninsula seagrass aerial photography 1979-81 and 2004. Ground truthing and ecological significance. Environment Protection Authority, South Australia.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 2001. *Protecting the oceans from land-based activities – Land-based sources and activities affecting and* *quality and uses of the marine, coastal and associated freshwater environment.* Rep. Stud. GESAMP No. 71, 162 pp.

Government of South Australia 2006. *Draft Spencer Gulf Marine Plan.* Coast and Marine Conservation Branch, Natural and Cultural Heritage, Department for Environment and Heritage, Adelaide.

Hart DGD 1999. *Near-Shore Seagrass Change between 1970s and 1996, mapped using Digital Aerial Orthophotography. Port Lincoln Proper – Boston Bay, South Australia.* Internal DEHAA report.

IMCRA Technical Group 1998. *Interim marine and coastal regionalisation of Australia. An ecosystem classification for marine and coastal environments.* Version 3.3. Environment Australia for the Australian and New Zealand Environment and Conservation Council, Canberra.

Kendall MS, Monaco ME, Buja KR, Christensen JD, Kruer CR. Finkbeiner M, and Warner RA 2001. *Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands.* http://ccma.nos.noaa.gov/products/biogeography/benthic/htm/manual.pdf. Accessed May 2009.

Keough MJ and Butler AJ (1995). Temperate subtidal hard substrata. *In:* Zann LP (ed) *State of the Marine Environment Report for Australia.* Technical Annex 1. Department of the Environment and Heritage, Canberra.

Lucieer V, Lawler M, Morffew M. and Pender A. 2007. *Mapping of inshore marine habitats from Schouten Island to Bicheno on the east coast of Tasmania* NHT/NAP Project No.L0015121.

Meehan AJ and West RJ 2000. Recovery times for a damaged *Posidonia australis* bed in south eastern Australia. *Aquatic Botany* 67: 161-167.

Miller, D., Westphalen, G., Jolley, A. M., Rutherford, H., Colella, D., Holland, S. and Gonzalez, D. 2009a. *Marine Habitats within Selected Areas of the South East NRM Region.* Final Report to the South East Natural Resources Management Board for the program: Sustaining Marine Biological Health. Prepared by the Department for Environment and Heritage, Coast and Marine Conservation Branch.

Miller, D., Westphalen, G., Jolley, A. M., Brayford, B., Eglinton, Y., Hendry, V. Rutherford, H., Colella, D., Holland, S and Gonzalez, D. 2009b. *Marine Habitats within the Sheltered Bays of the Eyre Peninsula NRM Region.* Final Report to the Eyre Peninsula Natural Resources Management Board for the program: Establishing Marine Baselines. Prepared by the Department for Environment and Heritage, Coast and Marine Conservation Branch.

Mount RE 2003. *The application of digital aerial photography to shallow water seabed mapping and monitoring - how deep can you see? Coastal GIS 2003 an integrated* *approach to Australian coastal issues, 7th - 8th July 2003*, Wollongong, University of Wollongong, pp. 139-156.

Mount R, Bricher P and Newton J (2007). *National intertidal/subtidal benthic (NISB) habitat classification scheme. Version 0.1.* Australian Greenhouse Office National Land and Water Resources Audit, School of Geography and Environmental Studies, University of Tasmania.

NY NRM 2008. *Northern and Yorke Regional NRM plan, Volume A: State of the region report 2008, Recognising the state of natural resources.* Northern and Yorke Natural Resource Management Board and the Government of South Australia.

Oppermann A. 1999. *A biological survey of the South Australian coastal dune and clifftop vegetation 1996 – 1999.* Coast and Marine Section, Environmental Protection Agency, Department for Environment, Heritage and Aboriginal Affairs, South Australia.

Petrusevics P. 2008. Satellite remote sensing of Gulf St Vincent. *In:* Shepherd SA, Bryars S, Kirkegaard I, Harbison P and Jennings JT (eds). *Natural History of Gulf St Vincent*. Royal Society of South Australia Inc, pp. 71-80.

PIRSA 2003. *Ecological Assessment of the South Australian Spencer Gulf Prawn Fishery, Gulf St Vincent Prawn Fishery And West Coast Prawn Fishery. Assessment Report Prepared for Environment Australia, against the Guidelines For The Ecologically Sustainable Management Of Fisheries. For the purposes of Part 13 and 13(A) of the Environment Protection and Biodiversity Conservation Act 1999.* Prepared by Primary Industries & Resources South Australia (PIRSA) – Fisheries, in association with the Prawn Fishery Management Committee and the South Australian Research and Development Institute (SARDI) Aquatic Sciences.

SASQAP 2004. *South Australian Shellfish Quality Assurance Program – Annual Report 2003-04.* Primary Industries and Resources South Australia Technical Report Series. Report Book 2004/20.

SEAMAP 2008. *SEAMAP Tasmania.* Tasmanian Marine Aquaculture and Fisheries Institute. http://www.utas.edu.au/tafi/seamap/, accessed May 2008.

Seddon S. 2000. *Causes and ecological consequences of the Spencer Gulf seagrass dieback.* Ph D Thesis, Department of Environmental Biology. Adelaide, University of Adelaide, p. 171.

Shepherd S.A. 1983. Benthic communities of upper Spencer Gulf, South Australia. *Transactions of the Royal Society of South Australia* 107: 69-85.

Shepherd S.A. and Robertson E.L. 1989. Regional studies - seagrasses of South Australia, Victoria and Bass Strait. *In:* Larkum A.W.D., McComb A.J. and Shepherd S.A. Eds. *Biology of seagrasses.* Elsevier, Amsterdam, pp. 211-229.

Shepherd SA (1981). Ecological strategies in a deep water red algal community. *Botanica Marina* 24(8): 457-63.

Shepherd SA and Sprigg RC. 1976. Substrate, sediments and subtidal ecology of Gulf St Vincent and Investigator Strait. *In:* Twidale CR, Tyler MJ and Webb BP (eds) *Natural History of the Adelaide Region.* Royal Society of South Australia, Adelaide, pp 161-174.

Shepherd SA and Womersley HBS (1970). The sublittoral ecology of West Island, South Australia. 1. Environmental features and the algal ecology. *Transactions of the Royal Society of South Australia*, 94, 105–137.

Shepherd SA and Womersley HBS. 1971. Pearson Island expedition 1969. The subtidal ecology of benthic algae. *Transactions of the Royal Society of South Australia* 95: 155-167.

Shepherd SA and Womersley HBS. 1976. The subtidal algae and seagrass ecology of St Francis Island, South Australia. *Transactions of the Royal Society of South Australia* 100: 177-191.

Shepherd SA, Bryars S, Kirkegaard I, Harbison P and Jennings JT (2008). *Natural History of Gulf St Vincent*. Royal Society of South Australia Inc.

Shepherd, S.A. and Womersley, H.B.S. 1981. The algal and seagrass ecology of Waterloo Bay, South Australia. *Aquatic Botany* 11: 305-371.

Svane I, Hammett Z and Lauer P. 2009. Impacts of trawling on benthic macro-fauna and –flora of the Spencer Gulf prawn fishing grounds. *Estuarine Coastal and Shelf Science* (2009), doi:10.1016/j.ecss.2009.03.009.

Tanner JE (2003). The influence of prawn trawling on sessile benthic assemblages in Gulf St Vincent, South Australia. *Canadian Journal of Fisheries and Aquatic Science*s 60: 517-526.

Tanner JE (2005). Three decades of habitat change in Gulf St Vincent, South Australia. *Transactions of the Royal Society of South Australia* 129(1): 65-73.

Turner. D., Kildea. T. and Westphalen, G. 2007. E*xamining the health of subtidal reef environments in South Australia, Part 2: Status of selected South Australian reefs based on the results of the 2005 surveys.* Publication No RD03/0252−6, South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Twidale CR, Tyler MJ and Webb BP (eds) (1976). *Natural History of the Adelaide Region*. Royal Society of South Australia, Adelaide.

Ward TJ, Warren LJ and Tiller KG. 1984. The distribution and effects of metals in the marine environment near a lead-zinc smelter, South Australia. *In.* Nriagu, J. (Ed). *Environmental impacts of smelters.* Wiley, New York. Pp. 1-73.

Wardrop JA, Wagstaff B, Connolly R and Leeder J. 1992. *The distribution and persistence of petroleum hydrocarbons in mangrove swamps impacted by the "Era" oil spill (September 1992).* A report prepared for the Environmental Protection Council. Woodward – Clyde Report No 5182.

Westphalen G, Collings G, Wear R, Fernandes M, Bryars S and Cheshire A (2004) *A review of seagrass loss on the Adelaide metropolitan coastline.* South Australian Research and Development Institute (Aquatic Sciences) Publication No. RD02/0161-10. SARDI Aquatic Sciences, Adelaide.

Westphalen G. 2008. Exotic species in Gulf St Vincent. *In* Shepherd SA, Bryars S, Kirkegaard I, Harbison P and Jennings JT (eds.) *Natural History of Gulf St Vincent*. Royal Society of South Australia Inc.

Appendix A – Biounit summary information (from Edyvane 1999b)

Name	Details
Yonga biounit	
Area:	423,556 ha
Wave energy:	Predominantly low
Geology & Geomorphology:	Pleistocene calcareous shelf covered with sandy dunes
Intertidal habitats:	Extensive mangroves with tidal wetlands, low rocky shore some sandy beach
Subtidal habitats:	Extensive seagrass, reefs and sandy bottom
Note:	Important for seabirds, important for giant cuttlefish
Winninowie biounit	
Area:	55,266 ha
Wave energy:	Very low
Geology & Geomorphology:	Mud mixed with shell debris or sandy bottom
Intertidal habitats:	Mangroves, saltmarshes, mudflats and sandy shores
Subtidal habitats:	Extensive and diverse seagrass, limited in terms of reef habitats
Note:	High salinity at some times of year Significant coast and marine wetlands Important breeding/nursery area for birds, fish and crustaceans Distinct relictual tropical marine flora and fauna
Tiparra biounit	
Area:	243,228 ha
Wave energy:	Low to moderate
Geology & Geomorphology:	Limestone and aeolionite cliffs/reefs, dunes and sandy substrate
Intertidal habitats:	Low rocky shores, bays and sandy beaches
Subtidal habitats:	Extensive seagrass, reefs and sandy bottom
Note:	Tiparra Reef noted for high diversity Seabird breeding and nursery areas
Wardang biounit	
Area:	285,583 ha
Wave energy:	Mostly low to moderate but high in some areas
Geology & Geomorphology:	Limestone cliffs and reefs, dune belts and sandy substrate
Intertidal habitats:	Low rocky shores and sandy beaches
Subtidal habitats:	Seagrass, reefs and sandy bottom
Note:	Pinniped and seabird colonies
Pondalowie biounit	
Area:	22,130 ha
Wave energy:	High
Geology & Geomorphology:	Limestone and aeolionite cliffs and reefs, alternating with wide dune belts and sandy substrate
Intertidal habitats:	Exposed rocky shores and sandy beaches
Subtidal habitats:	Reefs and sandy bottom
Note:	There is very little seagrass Innes National Park

Gambier biounit	
Area:	536,544 ha
Wave energy:	Low
Geology & Geomorphology:	Mostly rocky islets and reefs although there are some dune areas
Intertidal habitats:	Reef, beach and sand flat
Subtidal habitats:	Reefs and seagrass
Note:	Large pinniped colonies Seabird breeding colonies

Name	Details
Sturt & Investigator biounits	
Area:	183,058 & 280,063 ha
Wave energy:	Moderate to high
Geology & Geomorphology:	Limestone and aeolionite cliffs and reefs, dunes and sandy substrate
Intertidal habitats:	Sheltered bays, sandy beaches and rocky shore
Subtidal habitats:	Seagrass, reefs and sandy bottom
Note:	Pinniped colonies
Orontes biounit	
Area:	183,762 ha
Wave energy:	Low
Geology & Geomorphology:	Limestone and clay cliffs, sandy beaches and dunes and muddy tidal flats
Intertidal habitats:	Rocky shores, sandy bays and beaches
Subtidal habitats:	Extensive seagrass, reefs and sandy bottom
Note:	Important seagrass beds Bryozoan diversity on the "Orontes Bank"
Sprigg biounit	
Area:	160,548 ha
Wave energy:	Low to moderate
Geology & Geomorphology:	Sandy to fine muddy substrate
Intertidal habitats:	NA
Subtidal habitats:	Deepwater Gulf St Vincent habitats (see Shepherd and Sprigg 1976, Tanner 2005)
Note:	No description in Edyvane 1999b for this biounit
Clinton biounit	
Area:	249,136 ha
Wave energy:	Very low to moderate
Geology & Geomorphology:	Dunes, long beaches and tidal flats
Intertidal habitats:	Mangroves, tidal wetlands, saltmarsh, sandy beach and some low rocky shore
Subtidal habitats:	Extensive seagrass, some limited reefs and sandy bottom
Note:	High salinity at some times of year Significant coast and marine wetlands Important breeding/nursery area for birds, fish and crustaceans

Appendix B – Bryars (2003) Fisheries Habitat Areas in the NY NRM region

FHA	Name	Benthic habitats
31	Far Northern Spencer Gulf	- Seagrass meadow - Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
32	Germein Bay	- Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
33	Munderoo Bay	- Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
34	Wallaroo Bay	- Reef - Seagrass meadow & Unvegetated soft bottom - Tidal flat - Mangrove forest - Saltmarsh - Artificial habitat
35	Wardang Island	- Reef & Unvegetated soft bottom - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Saltmarsh
36	Hardwicke Bay	- Reef - Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Saltmarsh
37	Formby Bay	- Reef & Seagrass meadow & Unvegetated soft bottom - Reef & Unvegetated soft bottom - Surf beach - Sheltered beach
38	Foul Bay	- Reef & Seagrass meadow & Unvegetated soft bottom - Surf beach - Sheltered beach - Tidal creek - Saltmarsh
39	Salt Creek Bay	- Reef - Reef & Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat - Coastal lagoon - Saltmarsh
40	Port Vincent	- Reef & Seagrass meadow & Unvegetated soft bottom - Sheltered beach - Tidal flat

FHA	Name	Benthic habitats
41	Far north Gulf St Vincent	- Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Mangrove forest - Saltmarsh
42	Port Adelaide	- Seagrass meadow & Unvegetated soft bottom - Tidal flat - Tidal creek - Estuarine river - Mangrove forest - Saltmarsh - Artificial substrate

For further information please contact:
Coast and Marine Conservation Branch
Department for Environment and Heritage
GPO Box 1047
Adelaide SA 5001
Telephone: (08) 8124 4900
Fax: (08) 8214 4920
Website: www.environment.sa.gov.au

Photo Credits: David Muirhead, Ben Brayford, Dimitri Colella, Yvette Eglinton
FIS: 90437
December 2009