# Marine Habitats in the Adelaide and Mount Lofty Ranges NRM Region

**Final Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board for the program:**

Facilitate Coast, Marine and Estuarine Planning and Management by Establishing Regional Baselines

Government of South Australia

Department for Environment and Heritage

Adelaide and Mount Lofty Natural Resources Management Board

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# Executive overview

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, consistant at the national scales and encompasses the capacity to incorporate additional data.

Within the AMLR NRM region, the need for large scale (NRM region) assessment capability is a major motivating factor in the development of a Monitoring, Evaluation and Reporting Framework (MERF; AMLR NRM 2008). However, while there is a need for large scale baselines, there is also a need to identify, monitor and manage smaller scale biodiversity and conservation "hotspots" as well as understanding spatiotemporal variability and identifying the physical environmental drivers that structure marine systems across a range of spatial and temporal scales. This knowledge allows for ready identification of threats and appropriately targeted management responses.

Following on from Australian Government's Natural Heritage Trust (NHT) funded mapping of the upper Gulf St Vincent and Spencer Gulf areas in 2005, in 2006 the AMLR NRM board 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 AMLR region. This work included an update of previous broad scale (southern Australia) marine benthic habitat maps produced by CSIRO that covered the whole AMLR 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.

The aims of this study were thus to:

- Establish baselines for coast marine and estuarine biodiversity that will enable monitoring of change in resource condition.
- Develop marine habitat mapping at scales relevant to management for the entire AMLR NRM region.
- Produce biodiversity project reports for key habitats:
    - Intertidal reefs (See companion study - Benkendorff and Thomas 2007).
    - Intertidal soft sediment habitats (See companion study - Dittmann 2008).
    - Estuarine Habitats (See companion study - Gillanders *et al.* 2008).
    - Subtidal reefs extending on research and monitoring undertaken within the framework of Reef Health investigations (this report).

This document comprises three basic sections including;

- A summary of benthic habitat mapping and surveys in southern Australia, with particular reference to the AMLR NRM region. The broader framework for nationally consistent marine habitat mapping is also described.
- A summary of current habitat mapping surveys for ALMR NRM region in terms of major habitat areas and zones of high habitat diversity. Note that the map book

comprising 5 km × 5 km habitat maps developed from this survey are contained in a companion document.

- A summary of investigations into subtidal benthic habitats within the AMLR NRM region, focussing on understanding biodiversity and spatiotemporal dynamics of sites on the Fleurieu Peninsula.

The resulting habitat maps for the AMLR NRM region (see companion Map Book) encompass nearshore waters to a depth of 20 m (or 5 km offshore – whichever came first), covered 20 habitat types spread across reef, seagrass and soft bottomed systems. The maps form an important regional baseline for the AMLR NRM region against which future monitoring may compared and therefore have a potentially significant role in the Monitoring, Evaluation and Reporting Framework (MERF), State of the Region reporting and targeted assessments for specific programs such as the Adelaide Coastal Water Quality Improvement Plan (ACWQIP). The mapping also serves as a valuable resource for comparison within systems at larger scales (i.e. state and national scales) as well as a tool in the identification of hypotheses and development of research. Finally, both the map book and accompanying DVD form a valuable educational resource.

Although some maps maintained a larger number of habitat types, the areas of particular interest for habitat mapping relate to seagrass blowouts on the southern Adelaide coast (see Bryars *et al.* 2006), a large patch of apparently pristine seagrass between Normanville and Rapid Bay and the systems around Encounter Bay. More targeted, highly resolved marine habitat mapping might be undertaken in these areas, although for the zone outside metropolitan Adelaide a greater understanding of the spatial extent and magnitude of any associated threats should be developed, with particular reference to water quality.

Reefs systems on the Fleurieu Peninsula coast were considered with respect to macroalgal, fish and invertebrate composition, following a methodology similar to that employed by Edgar and Barrett (1997, 1999).

Composition of 25 subtidal reef systems surveyed on Fleurieu Peninsula (outside the Adelaide metropolitan area) changed relative to a gradient of position along the shore. Unlike previous research, the energy environment did not correlate with this distribution as well as Maximum Spring Tidal Range or Sea Surface Temperature, although these relationships should not be construed as causative. The macroalgal community composition at each site, particularly larger canopy-forming taxa were the dominant factor determining both similarities within as well as differences between sites across a range of spatial and temporal scales. Although the indices identified in recent Reef Health assessments (see Turner *et al.* 2007) were not applied, there is no evidence to suggest that any of the sites considered was impacted along the lines observed for reefs on the Adelaide metropolitan coast. However, as with habitat mapping, assessment of reef systems should be considered within a context of the available data on threats as well as natural factors that structure reef systems.

Reef sites with high biodiversity (such as Blowhole Beach, Fishery Beach and the Flat Irons) may warrant closer scrutiny. However, as with the results of mapping, understanding the nature and distribution of threats to marine systems on the AMLR NRM coast would likely be a more effective approach to enhancing reef management capability. In addition, there is also a need to a greater understanding of the physical environmental factors that structure reef systems.

## *Conclusions and recommendations*

Both habitat mapping and reef surveys within the AMLR NRM region provide critical baseline observations for future monitoring across a range of scales. However, while potential areas for targeted monitoring can be identified (see below), there is still limited capacity to juxtapose the status of the identified environmental assets with threat levels. Water quality decline, is widely accepted as the major cause for seagrass and reef decline on the Adelaide metropolitan coast and these have been well researched as part of the ACWS (see Fox *et al.* 2007). However, more broadly across the AMLR NRM region our understanding of water quality issues as well as other potential threats to nearshore systems would appear to be relatively low, particularly in spatially referenced (i.e. GIS) terms.

Target areas for focussed monitoring can be identified, including;

- Blowout areas in seagrass beds in the south of Adelaide
- Normanville to Rapid Bay seagrasses
- Encounter Bay

However the nature and extent of threats to seagrass and reef systems is not fully understood for either of the locations outside the Adelaide metropolitan area. It follows that the range of stakeholders with interests in these systems is also probably not fully understood. In addition, there remain gaps in the benthic mapping, for deeper waters wherein there is evidence of substantial environmental decline (see Tanner 2005). There is also the impact of new developments on the AMLR NRM coast, in particular the construction and operation of the desalination plant at Pt Stanvac.

In terms of reef systems within the AMLR NRM region there is solid evidence to suggest that those outside the Adelaide region are relatively “healthy” but there is again, limited data on potential threats at similar spatial scales. Further, the relationships between anthropogenic, biotic and abiotic factors as structuring agents for reef systems at different scales is also unclear.

In terms of moving forward with both benthic mapping reef observations, there are a number of recommendations, including:

- Targeted monitoring related to specified areas (see above), requiring;
    - More resolved habitat mapping (possibly in strip transects across sites),
    - Spatially referenced data related to threats, in particular water quality issues for areas outside metropolitan Adelaide, and
    - Engagements 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 summer/early autumn period.

# Background

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

- Recognition that many environmental stress factors are non-specific,
- Broader understanding of the "collateral damage" 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 engagements with all stakeholders that have interests in the system(s) concerned.

Note that a systems level approach to environmental resource management does not preclude or discount the targeted strategies required for rare, threatened and endangered species, or indeed the specific approaches required for high priority pests. In addition, many fisheries are still managed at the species level despite the trend toward systems level approaches.

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

- Increased understanding of the ecosystem services provided by the resource, which may lead to improved engagements with stakeholders.
- A capacity to prioritise monitoring and management interventions 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 Australian Government's Natural Heritage Trust (NHT) funded mapping of the upper Gulf St Vincent and Spencer Gulf areas in 2005, at the beginning of 2006 the AMLR NRM (in partnership with the NHT) developed a project with the Department for the Environment and Heritage (DEH) to produce a detailed spatial Geographic Information

System (GIS) layer of seafloor habitats within the Adelaide and Mt Lofty Ranges Natural Resource Management (AMLR 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 AMLR 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 for developing habitat maps that will fit within a broader national framework.

A number of biodiversity studies were also carried out to characterise marine habitats in the AMLR region, extending previous work in the case of reefs (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008) and to begin to address the lack of knowledge for estuarine, intertidal reef and mudflat communities.

The following describes a marine habitat mapping program within the AMLR NRM Board with the following objectives;

- Identify the types of marine habitats within the region using remote sensing, acoustic and video survey techniques.
- Initiate biodiversity assessment projects sub-regionally that begin to develop a better understanding of habitat associations across environmental gradients.
- Support key monitoring programs that are adequate to differentiate between natural variation and human-induced change, thus meeting key resource condition targets.

## *Aims*

Aims of this study were thus to:

- Establish baselines for coast marine and estuarine biodiversity that will enable monitoring of change in resource condition.
- Develop marine habitat mapping at scales relevant to management for the inshore waters of the entire AMLR NRM region.
- Produce biodiversity project reports for key habitats:
    - Intertidal reefs (See companion study - Benkendorff and Thomas 2007).
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- A summary of current habitat mapping surveys for ALMR NRM region in terms of major habitat areas and zones of high habitat diversity. Note that the map book comprising 5 km × 5 km habitat maps developed from this survey are contained in a companion document.
- A summary of investigations into subtidal benthic habitats within the AMLR NRM region, focussing on understanding biodiversity and spatiotemporal dynamics of sites on the Fleurieu Peninsula.

## Marine habitat mapping and broad scale surveys in South Australia

Southern Australian marine environments are widely regarded for their complexity, species diversity and level of endemism, including large numbers of species yet to be formally described (e.g. Keough and Butler 1995, Edyvane 1999a, Connell 2007). Apart from high species diversity and endemism, South Australia has a diverse array of reef and soft bottom habitats including (from Baker 2004):

- 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.

Southern temperate marine systems in SA also include some of the largest areas of saltmarsh, mangrove and seagrass systems in Australia, if not globally (Edyvane 1999b).

Current threats to marine environments in Gulf St Vincent derive from a number of sources including (e.g. Edyvane 1996, Baker 2004, Westphalen *et al.* 2004b, Flaherty and Sampson 2005, Turner *et al.* 2007, AMLR NRM 2007):

- Commercial and recreational fisheries,
- Aquaculture,
- Dredging,
- Tourism,
- Transport,
- Mining,
- Waste and stormwater disposal,
- Coastal development/urbanisation and
- Declines in water quality from catchments.

On the Adelaide metropolitan beaches there is also the impact associated with the dredging and dumping of sand for the beach replenishment program (DEH 2000, 2006b). Future threats (or potential threats) to Gulf St Vincent systems might include construction of a desalination plant, marine invasive pests and diseases and the array of impacts that relate to climate change (Flaherty and Sampson 2005, Turner *et al.* 2007).

Both the actual and potential threats are highly varied in extent, frequency and nature of impact on marine systems (GESAMP 2001). The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has an excellent general review of current and emerging marine environmental issues (GESAMP 2001). Moreover, the *Creating a Sustainable Future Volume A - State of the Region Report* for the Adelaide and Mt Lofty Ranges (AMLR) Natural Resources Management (NRM) Board provides a comprehensive summary of most of the above relative to each of the major ecosystem groups as well as rare, threatened and endangered species in Gulf St Vincent (AMLR NRM 2007).

High environmental diversity, coupled with a broad range of threats, presents a particular challenge to marine managers (Turner *et al.* 2006), especially when confronted with the need to embrace integrated multiple-use planning that incorporates environmental, social and economic objectives (Edyvane 1999a). Management of natural systems and resources requires a solid understanding of the status of environmental assets with respect to potential or actual threats. As well as high diversity and endemism and large numbers of potential or actual threats, marine resource managers in southern Australia are confronted by a range of challenges (Edyvane 1996, Baker 2004, FAO 2003, Flaherty and Sampson 2005) including:

- 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.

The following summarises the management frameworks, approaches and history of marine natural resource management in South Australia with particular reference to the AMLR NRM region that encompasses the Adelaide metropolitan coast, Fleurieu Peninsula and a significant portion of Gulf St Vincent (Figure 1). The summary will cover four areas related to marine environmental management including:

- Current marine management regions within the AMLR region,
- The history of habitat mapping within the region,
- Large scale habitat characterisation and comparison studies in reefs, seagrass and soft bottom systems that might support habitat mapping,
- The background to development of a standardised approach to habitat mapping in Australia.


**Figure 1 - Map of the AMLR NRM region showing the area covered by mapping as part of this project.**

## *Marine management regions in South Australia*

### Bioregions

Management of large areas frequently entails dividing the total area in question into smaller units based on changes in the physical and biotic environment. Probably the most widely recognised marine management units in Australia are the Interim/Integrated Marine and Coastal Regionalisation of Australia (IMCRA) bioregions (IMCRA 1998, Commonwealth of Australia 2006).

Differences between regions were based on the integration of data on the distribution of sponges, fish, coral and seagrass species as well as bathymetry, coastal geomorphology, sedimentology, currents, water chemistry and water temperature (IMCRA 1998, Commonwealth of Australia 2006). Regions therefore range substantially in area although rather than rigidly defined borders, the boundaries between bioregions should be considered as ecologically important "biotones" that can alter substantially with seasons and currents (IMCRA 1998). The IMCRA bioregions were developed to be used as surrogates for broader ecosystems and habitats but are not designed for the management of individual species or answering fine scale questions (IMCRA 1998).

The latest version of IMCRA (Version 4.0; Commonwealth of Australia 2006) incorporates coastal regions identified in IMCRA (1998 - v3.3) combined with the national marine bioregionalisation to cover the whole of the exclusive economic zone (EEZ), excluding Antarctica, Heard and MacDonald Islands. This classification places three coastal and two offshore regions within SA, with both gulfs included in the Spencer Gulf IMCRA Province (Commonwealth of Australia 2006), which covers the entire AMLR region.

### Biounits

The South Australian coast has also been divided into smaller "biounits" based on the work undertaken by Edyvane (1999a, b) that incorporated coastal physiographic features and major habitat groups to 30 m depth for the gulfs and 50 m depth for oceanic regions based on a notional "photic" depth (depth to which viable photosynthetic production may still occur). There are 35 biounits defined for the SA coast, with nine occurring within the AMLR region, (AMLR NRM 2007). The *Creating a Sustainable Future Volume A - State of the Region Report* for the AMLR NRM has an excellent summary of the related IMCRA bioregions and smaller biounits (AMLR NRM 2007).

### Relationship to NRM boundaries

It is worth noting that the designation of Australia's NRM zones is largely based on terrestrial catchments, bioregions or State Government management boundaries (Commonwealth Government 2008, Planning SA 2008). As a consequence, the marine borders have little or no relationship to the associated marine systems such that IMCRA bioregions are variously allocated to different NRM regions.

The IMCRA (v3.3 and v4.0) bioregions and the Edyvane (1999a, b) biounits are generally based on integrated information from a spectrum of species groups, related geomorphological and physical environmental factors, and are therefore difficult to relate to specific areas/habitat types that may require management intervention. Further, most of the stress factors identified relative to marine systems relate to coastal development 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. The IMCRA bioregions or the South Australian biounits may be used to as the first layer in defining areas/natural assets or stress factors that may be of particular interest as well as the broader targeting of management activity (IMCRA 1998, Baker 2004). However, the management and monitoring of natural assets requires an understanding of the distribution and status (or "health") of specific habitats or related indicators relative to the potential drivers (both natural and anthropogenic) within these zones.

## *Habitat mapping*

### Benthic communities

The earliest large scale marine habitat mapping of any relevance to the AMLR region are probably the investigations summarised in the "Natural History of the Adelaide Region" (Twidale *et al.* 1976), which includes information on the physical oceanography, geology, subtidal benthic ecology, intertidal ecology and marine fish and mammal species throughout Gulf St Vincent. Many of the aspects considered in Twidale *et al.* (1976), as well as a number of additional factors were included in a more recent summary; "Natural History of Gulf St Vincent" (see Shepherd *et al.* 2008). Importantly, the 1976 summary included an investigation of the subtidal benthic community based on extensive diver surveys conducted throughout Gulf St Vincent during the 1960s (Shepherd and Sprigg 1976). The resulting map included 11 different groups based on substrate and/or benthic community composition (Shepherd and Sprigg 1976):

- *Pinna*-holothurian,
- Ascidian-scallop,
- Bryozoan,
- *Malleus-Pinna,*
- *Heterozostera-Lunulites* (bryozoan),
- Bare sand and shoals,
- Algal debris,
- seagrass meadows,
- Boulder conglomerates,
- Reef and
- Aeolianite reef.

In addition, Shepherd and Sprigg (1976) describe a sponge-bryozoan habitat type from deeper waters in Backstairs Passage (30 – 70 m deep) wherein massive sponges (up to a metre or more in some dimension) are known to occur.

Importantly these observations were amongst the first to note seagrass losses on the Adelaide metropolitan coast and formed a significant baseline against which future observations could be compared.

The 1976 summary also included investigations into the large scale bathymetry of the Gulf and Investigator Strait (Bye 1976).

Tanner (2005) undertook a widespread benthic survey of Gulf St Vincent with the aim of determining the level of change relative to the habitats identified in the Shepherd and Sprigg (1976) habitat survey (Figure 2). Using regularly spaced video and diver observations at depths greater than 5 m throughout the gulf, this survey showed a substantial level of change to benthic systems in the intervening 30 years. Extensive beds of the seagrass *Heterozostera tasmanica* identified by Shepherd and Sprigg (1976) in the southern gulf were no longer apparent and the *Malleus* - *Pinna* (Hammer oyster - Razorfish) assemblage in the south east was also replaced by extensive sand flats (Tanner 2005). 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 (although see seagrass assemblages below; Tanner 2005).

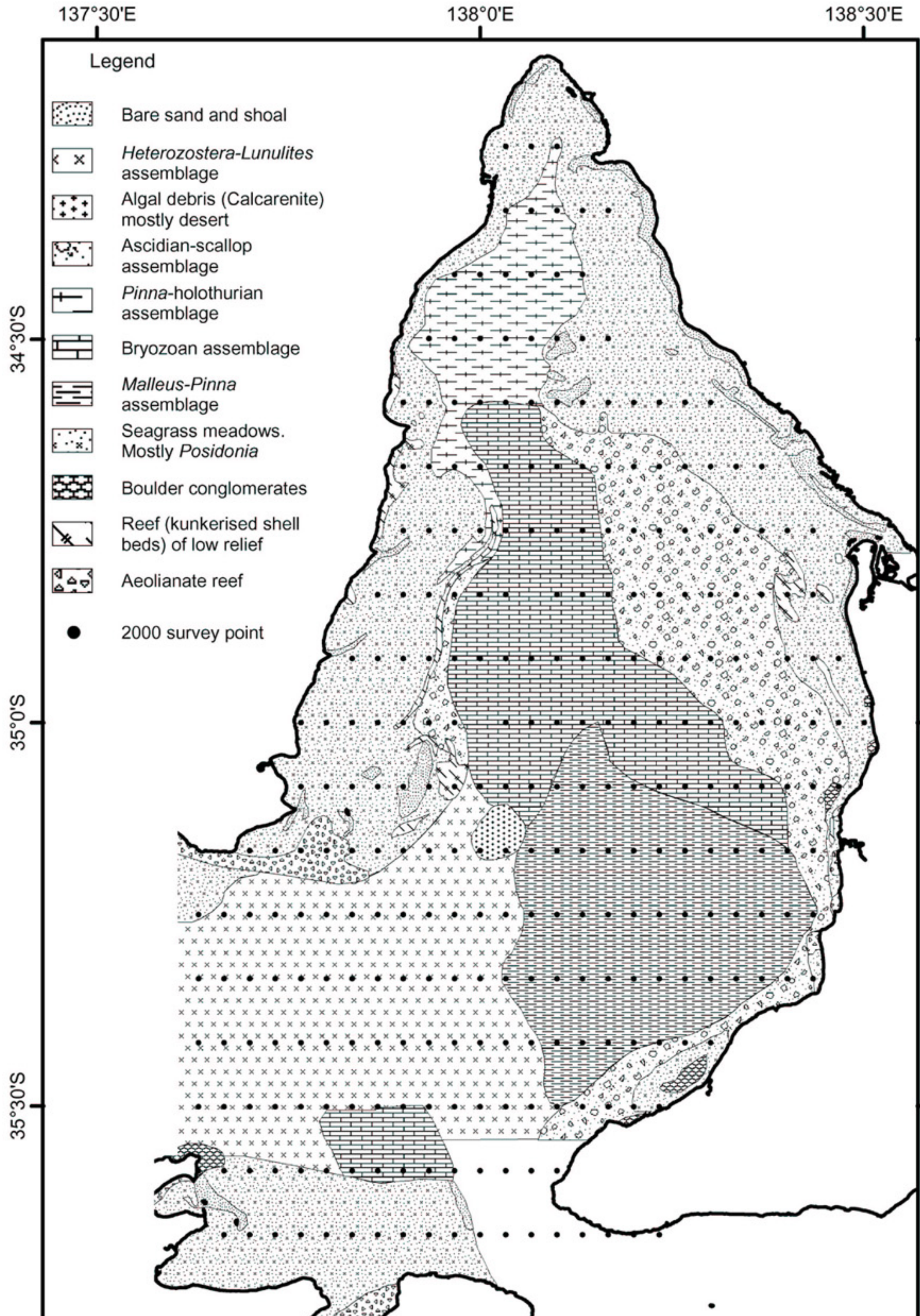



**Figure 2 - Gulf St Vincent showing benthic habitats as defined by Shepherd and Sprigg (1976) overlaid with survey points from Tanner (2005). Figure copied with permission from Tanner (2005).**

Declines in water quality and direct or indirect impacts from prawn trawling were identified as the major candidates for change to these deeper water systems. Turbidity was suggested as the major factor in seagrass loss as the *Heterozostera tasmanica* is close to its maximum depth limit (~39 m; Duarte 1991) such that even a slight decline in water quality will surpass the capacity for the seagrass to survive. Land-based runoff was considered an important potential source for increased turbidity, although more recent data from the Adelaide Coastal Waters Study (ACWS) would suggest that a terrigenous source is less likely (Collings *et al.* 2006, Pattiaratchi *et al.* 2007). Increased turbidity may result as an indirect consequence of prawn trawling (Churchill 1989, Palanques *et al.* 2001) and there is also potential for direct, physical damage, which may also explain the loss of the *Malleus* - *Pinna* assemblage. Finally Svane *et al.* (2008) suggested that discarded bycatch from trawling may influence food web interations through encouragement of scavengers. However, while there is substantial evidence as to the negative effect of trawling operations (e.g. Engle and Kvitek 1998, Collie *et al.* 2000), there is still controversy as to their nature and extent (Tanner 2005). Evidence from the Gulf St Vincent is that prolonged exposure to trawling activities has a substantial impact on benthic communities (Tanner 2003).

It is an arguable point that the Tanner (2005) survey comprises a habitat characterisation and comparison study rather than mapping investigation (it was certainly presented as the former), although the data could be used in this manner through interpolation between points with the similar habitat. What is abundantly clear is that the Shepherd and Sprigg (1976) map is no longer a valid representation of the benthic systems in GSV, particularly in the southern areas.

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

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

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

## Seagrass assemblages

There has been a substantial number of aerial surveys of seagrass loss on the Adelaide metropolitan coast (e.g. EWS 1975, Shepherd *et al.* 1989, Steffensen *et al.* 1989, Hart 1997, EPA 1998, Cameron 2003) culminating with the Adelaide Coastal Waters Study (ACWS) from 2001 to 2006 (Blackburn and Dekker 2006, Fox *et al.* 2007). Most of the data in support of these observations have been collected opportunistically from irregular aerial photographic surveys (Westphalen *et al.* 2004b). Estimates of seagrass loss were improved with the application of orthophotographic modelling techniques (see Hart. 1997, Cameron 2003) to correct for differences between aerial photographs (relative to differences in plane angle, altitude, tipping and the “central perspective” common to ordinary images) such that a more accurate estimate of “minimum” seagrass losses could be derived. Hart. (1997) considered losses from seven different periods (or “epochs”) across three different summary areas. This approach was repeated by Cameron (2003) for the period from 1996 to 2002, with yet further analysis developed through the Adelaide Coastal Waters Study (ACWS) using a Compact Airborne Spectrographic Image (CASI) map along with further analyses of historical data (Blackburn and Dekker 2006).

The rodlines used for sand movement mapping (see below; DEH 2000, 2006b) may also be used to track seagrass loss based on annual observations and acoustic surveys as well as intermittent swath mapping (every ten years; Fotheringham pers. comm. DEH). The technical capacity of these surveys to delineate seagrasses was not achieved until the mid 1990s, but there is nonetheless a substantial dataset available (Fotheringham pers. comm. DEH).

## Broader habitat mapping

Bryars (2003) established a fisheries habitat inventory for South Australia with a view to developing a greater understanding the distribution of 12 basic habitat types (including the associated overlying pelagic component):

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

For subtidal systems, the Bryars (2003) fisheries inventory is limited to a depth of 20 m or 3 km from shore (whichever came first). This limitation was based on a lack of data on deepwater systems as well as the view that shallow near-shore areas were most threatened.

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.

Most of the Bryars (2003) habitat types occur within the AMLR region. However, it is worth noting that only five of the above relate to entirely subtidal systems while the remainder might be considered as intertidal and/or coastal fringe. Within the subtidal component, the Bryars (2003) habitats are coarsely allocated to one of reef, vegetated or unvegetated soft bottom and two beach types (sheltered or unsheltered). From a resource management perspective that includes all stakeholders it is unclear as to whether creation of fisheries habitat areas is an effective approach.

The "Biological Survey of South Australia" database (DEH 2008) 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 2006a, 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 (Opperman 1999). A similar survey of saltmarsh and mangrove habitats was completed by Canty and Hille (2002) and included 69 habitat codes based on five tiered classification using landform, estuarine influence, degree of inundation, vegetation cover and integrity.

For the purposes of State of the Environment reporting, these habitat types were summarised into eight groups (not including mangroves) including (Fotheringham and Coleman 2008):

- Inter-tidal samphire,
- Inter-tidal cyanobacterial mat,
- Inter-tidal sedges,
- Stranded tidal samphire,
- Supra-tidal cyanobacterial mat,
- Supra-tidal *Melaleuca*,
- Supra-tidal samphire and
- Supra-tidal sedges.

It is worth noting that, although there would appear to be limited subtidal habitat mapping related to the AMLR region, there is possibly a large data gap for intertidal systems including beaches, rocky coast and, in particular, mudflats and sandflats. However, mangrove, saltmarsh and intertidal mudflats within the AMLR region have been classified according to a number of different factors including environmental values, conservation status, social, economic and cultural importance, activities and threats (see the AMLR Region Estuaries Information Package; DEH 2007b).

## Sediment movements

The most prolonged and consistent subtidal marine mapping operation within the AMLR region is the ongoing surveys into sand movements along the Adelaide metropolitan coast as part of the beach replenishment program run by the Coast Protection Board (DEH) since 1975 (DEH 2000, 2006b). While long shore movement of sand is a natural phenomenon, the extent and rate of sand movement have been substantially enhanced by anthropogenic activity, mostly related to the loss of the sand dunes to urban developments and alteration of local hydrodynamics (DEH 2000) as well as seagrass losses. On the Adelaide coast, this has resulted in substantial sand losses from southern beaches and gains in the north (DEH 2006b). Apart from the visual and social impact of beach decline, there is also an increased risk of infrastructure and environmental damage and flooding from storm surges (DEH 2006b).

Sand flux estimates were traditionally based on measurements from a series of 39 rod lines approximately every 500 m along the Adelaide coast extending 1-2 km perpendicular to the shore, augmented with data from beach profiling and photopoints observations (DEH 2000). Advances in technology (Global Positioning Systems and accurate depth soundings) have be employed in lieu these methods (DEH 2006b). As a factor that integrates a number of related factors, a map of sand movements should form an important element of understanding near shore processes, particularly when compared to benthic habitats, hydrology and coastal developments.

### Satellite imagery

Satellite remote sensing has provided almost daily data (cloud permitting) on oceanographic, meteorological and hydrodynamic throughout Gulf St Vincent at a resolution of ~ 1 $km^2$ since the 1970s (Petrusevics 2008). Observations include varying degrees of emphasis on either sea surface temperature or visible light imagery from a succession of satellites including:

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

Since the first use of satellite imagery as a monitoring tool there have been significant advances in processing techniques and technology (Petrusevics 2008). Sea surface temperature, sediment and phytoplankton (chlorophyll) blooms can be traced, although supporting data from ground-based platforms are often employed.

### Other potential data sources and GIS layers

Analysis of habitat mapping would benefit from accessing additional information and/or GIS layers related to infrastructure (shipping channels, jetties, breakwaters, etc), coastal inputs (outfalls, rivers and stream), tourist attractions (recreational beaches, boating/fishing or SCUBA diving areas, etc.), aquatic and coastal reserves, Local and State Government planning regions and hydrodynamic modelling. There are a variety of sources for this information, including (amongst others):

- Atlas SA (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),
- The input studies and hydrodynamic modelling developed as part of the Adelaide Coastal Waters Study (see Fox *et al.* 2007),
- A number of management strategies developed by the Coastal Protection Board related to acid sulphate soils, coastal weeds, coastal erosion and beach monitoring (Coastal Planning Information Package see http://www.environment.sa.gov.au/coasts/management.html, accessed May 2008),
- Fisheries stock assessments,
- The Environment Protection Authorities ambient water quality monitoring (Gaylard 2004) and
- Non-mapping environmental studies.

## *Habitat characterisation*

Habitat characterisation studies generally entail a level of comparison between different survey locations, but do interpolate the nature of the intervening habitat and so do not generate maps *per se*. Results of this monitoring and/or research may contribute to habitat mapping either through the generation of maps based on the data obtained (such as the Tanner

2005 study of Gulf St Vincent soft-bottom benthic communities) or as ground truthing for maps created from remotely sensed data. However, habitat characterisation studies are generally constrained to within a broader community type (i.e. seagrass, reefs or soft bottom systems) and/or relate to a specific potential threat (such as a wastewater outfall; e.g. Loo 2001).

There is a wealth of research and monitoring that has been undertaken within the AMLR region, but a summary of these investigations is beyond the scope of this report. The following outlines some of some of the more notable examples that might be employed as a background to current and future habitat mapping based around broader habitat groups.

## Reef systems

Collings (1996) undertook an investigation into spatiotemporal variation in reef systems at eight sites around Cape Jervis and Victor Harbor. This study included quarterly surveys of macroalgal biomass based on destructive samples from the summer of 1991/92 to the summer of 1992/93. Importantly, this study considered the spatial variability of macroalgal communities at different spatial scales (from centimetres to a hundred kilometres).

Connell and Irving (2008) expanded on the approach undertaken by Collings (1996) with a study of variability in reef community structure across spatial scales from 1-10 km, > 100 km and > 1000 km. Within the AMLR, this included observations at Cape Jervis, and demonstrated that biogeography (latitude and longitude of each site) could explain a substantial proportion of the variability between reefs at all scales. Importantly, this study suggested that natural resources management would benefit from placing the impact of a local scale issues (e.g. fisheries, nutrient enrichment, coastal development, etc) within the broader biogeographic context. This approach would suggest that marine environmental monitoring within NRM areas should occur as part of a broader framework and not be constrained to a single region.

Some of the first investigations into reef systems in South Australia were the Shepherd and Womersley (1970, 1971, 1976, 1981) and Shepherd (1981) descriptive surveys of several reef communities including West Island, Pearson Island, St Francis Island, Waterloo Bay and Cape Northumberland. These surveys largely focussed on descriptions of the distribution of flora and fauna relative to depth at each site. However, the only reef site within the AMLR region was that at West Island (Shepherd and Womersley 1970).

The West Island aquatic reserve and other islands around Victor Harbor (in particular Wright Island and Granite Island) have long been employed as sites for marine research and monitoring. Those related to macroalgal systems include (amongst others) investigations into community structure (Turner 1995), species life history, recruitment dynamics (Emmerson and Collings 1998, Hotchkiss 1999, Turner 2004), production ecology and ecophysiology (Cheshire *et al.* 1996a, Fairhead 2002). Most of the above relate to investigations into ecosystems processes and would be unlikely to contribute to habitat mapping.

A series of surveys were undertaken across hard substrate systems on the South Australia coast under the banner of “Reef Health”. These observations began with surveys of reefs on the Adelaide metropolitan shore in 1996 (Cheshire *et al.* 1998). The survey was repeated in 1999 with additional sites in the central and southern areas of the Adelaide coast (Cheshire and Westphalen 2000) and further expanded in 2005 to include sites from around Fleurieu Peninsula and Yorke Peninsula (Turner *et al.* 2007). All surveys found a gradient decline in reef status on the Adelaide metropolitan coast with degraded reefs in the north (Semaphore to Broken Bottom), signs of stress on central reefs (Seacliff to Southport) and healthy reefs in the south (Moana to Aldinga; Turner *et al.* 2007). Importantly, the level of decline on the central reefs appeared to have increased and expanded in successive surveys (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007). While there are natural gradients that might explain these differences, the decline in reef status correlates with the area of seagrass loss, and there is increasing evidence within Australia and elsewhere that increased nutrient and sediment loads are a factor in macroalgal community status (Airoldi 2003, Gorgula and Connell 2004, Turner and Cheshire 2002, Turner 2004).

Reef Health surveys highlight the need for quality baseline data and an ongoing monitoring capacity for reef systems. These surveys sampled relatively large areas of reef (spread over 50 m or more), through use of a rapid, non-destructive survey method called Line Intercept Transects (LIT) and a functional-form approach to taxonomy that precluded a need for identifying biota at the species level. This approach generates data on percent cover of the macroalgal and sessile invertebrate community.

LIT has generally been employed in coral reef systems that can be viewed as a single (albeit convoluted) two dimensional plain (Turner 1995). With three or more canopy layers, LIT surveys of a macroalgal dominated reef will give an assessment of the larger visually dominant species at the expense of smaller less common species/groups, but has substantial advantages over traditional techniques that generally require destructive sampling (Turner 1995). The use of functional groups in reef health observations (notably the 1996 and 1999 surveys) in lieu of species identifications enables surveys to circumvent the high level of diversity in these systems (Miller *et al.* 1998, Cheshire and Westphalen 2000). It is worth noting that, when combined, the LIT and functional group approach may align well with video, acoustic and remote sensing assessment methods in terms of the data resolution and structure.

Importantly, there is ongoing informal reef monitoring undertaken mostly on the Adelaide coast by a community organisation called Reefwatch (http://www.reefwatch.asn.au/, accessed May 2008) using much the same methodology as formal surveys. With a suite of appropriate indicators, a more structured program of surveys and a mechanism for data sharing, Reef Watch observations may serve as an important cost effective means of value-adding on more formal surveys. Community involvement in monitoring has additional advantages over and above the value of the data, including development of conservation projects, communication and ownership of issues, setting priorities, generating policies and/or providing investment (Flaherty and Sampson 2005).

## Seagrass systems

Point characterisation of seagrasses on the Adelaide metropolitan coast began in the 1970s with the Engineering and Water Supply (now SA Water) surveys into near shore seagrass decline (EWS 1975). This survey considered a total of 76 sites that were unevenly distributed along the coast between Outer Harbor and Marino that were sampled annually from 1972-1975. There was also non-fixed sampling north and south of the central Adelaide region as well as intertidal across the rocky coast from Marino to Encounter Bay. While there was some mapping developed from the survey, the sampling intensity was quite crude relative to more advanced methods and only the fixed data could be used for comparison purposes. These observations were enhanced by aerial photographic analysis and descriptive studies of seagrass loss by another EWS report (EWS 1985).

There are a large number of other studies of seagrasses on the Adelaide coast that might offer information in support of marine benthic habitat mapping, most notably the various projects within the Adelaide Coastal Water Study related to coastal inputs, remote sensing, physical process and modelling and ecological processes (see Fox *et al.* 2007 for a summary of the research program).

Extensive seagrass observations have been undertaken by Bryars and Rowling (2008) using video observations at 432 sites along the metropolitan coast to identify major groups (*Amphibolis* spp., *Posidonia* spp., *Halophila* spp., the Zosteraceae group and bare sand) as well as density (dense, medium and sparse). This study showed that accurate observations of seagrass distribution, composition and abundance in South Australia can form important GIS layers relative to known inputs and potential threats. Importantly, this study would likely form an excellent basis for ground truthing aerial imagery as well as ongoing, site-specific monitoring. Like the Tanner (2005) investigation across the broader gulf, these observations have been reported relative to each sampling point rather than interpolation of the community likely to occur between points.

Beyond the Adelaide coast, investigations into seagrass systems within the AMLR NRM region are limited. Cheshire and Miller (1998) undertook an LIT and destructive quadrat investigation into benthic systems at Victor Harbor in the vicinity of a proposed boat ramp development. This survey found a diverse seagrass flora covering an average of 84% of the available substrate.

## Soft bottom systems

Soft bottom systems are often perceived as being species poor and relatively unimportant when compared to reef and seagrass systems (Fairhead *et al.* 2002, Cheshire *et al.* 2002, Baker 2004). Part of this perception relates to a lack of knowledge (Bryars 2003) and the difficulty in obtaining viable data from these systems which are generally deeper and hence more difficult to sample. There is also the perception that there are large (and therefore expendable) areas of bare sand substrate that have little environmental value when compared to other systems such as reefs and seagrasses (Baker 2004).

However, the available data would suggest that unvegetated sandy bottom systems are highly diverse, complex and spatiotemporally dynamic (Cheshire and Kildea 1993, Cheshire *et al.* 1996b, Miller and Cheshire 1999a). In particular, soft bottom systems provide habitat for many basic organisms (i.e. amoebas, foraminifera and larger ciliates) that are the basis for many food chains (Baker 2004 and references therein). Shepherd and Sprigg (1976) indicated that there were substantial differences in benthic community structure throughout Gulf St Vincent, with unvegetated substrates including systems dominated by six different animal groups and four vegetation types (excluding macroalgal dominated reefs). Furthermore, Tanner (2005) indicated substantial changes to these systems with a loss or decline in some community types.

In a prolonged study of the effects of sand dredging for beach replenishment off Pt Stanvac both the epibenthos (organisms living on the seabed) and infauna (organisms living within sediments) were found to be diverse and spatiotemporally variable relative to depth and longshore position. These surveys considered 9-12 sites from 12-24 m deep spread over a large area (~ 2 km long × 1 km wide) south of the Port Stanvac jetty with observations taken on seven occasions between 1992 and 1997 (Miller and Cheshire 1999a). The Pt Stanvac observations were augmented through an investigation of the benthic habitat at a number of the rod lines used for sand movement measurements (Cheshire and Miller 1996). In another companion study, Loo (2001) investigated the influence of the Christies Beach wastewater outfall to the southeast of the dredge site, again focussing on benthic community, in particular the infauna community. As with the dredge related surveys, Loo (2001) found a substantial level of variability on the controls (at Moana further south), although there was a distinctive signature for the outfall consistent with nutrient enrichment. When combined, these surveys constitute one of the best intensive investigations into soft bottom systems in South Australia and the AMLR region. This site also provided one of the first opportunities for benthic video sampling for the purposes of impact assessment within South Australia (see Miller and Cheshire 1999b).

In a related study, Cheshire *et al.* (2002) undertook a range of surveys across the Section Bank, a shallow intertidal shoal off Outer Harbour. This survey investigated habitat types across the area (e.g. bare sand, seagrasses, mangrove and *Pinna bicolor* habitats) with a view to determining the potential impact of dredging.

Areas of soft sediment system are considered as a component of other benthic mapping operations, in particular seagrass mapping. Within the Port River/Barker Inlet system and North Haven area, there have been a number of surveys for the marine pest, *Caulerpa taxifolia*, that have included data on other aspects of the system including seagrasses, bare substrate and other marine pests (Westphalen *et al.* 2004a, Rowling and Tanner 2005, Westphalen and Rowling 2005). However, characterisation of non-vegetated areas is not generally considered other than in terms of seagrass loss and related factors. The expectation (and indeed qualitative observations) is that these areas comprise completely bare sand.

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

A key element to the development of 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,
- Combines physical, geomorphic and biotic data,
- Compatibility with a GIS framework,
- Amenable to currently available data and technology and
- Provides a basis for identifying functional linkages wherein the observed patterns can be related to ecological processes.

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

Within Australia, one of the best examples of a large scale marine habitat mapping program is SEAMAP in Tasmania that has been in operation since around 2001 (Barrett *et al.* 2001). As of 2006 SEAMAP surveys had covered almost 4000 km, mostly on the northern and eastern coast of the state (Lucieer 2006, SEAMAP 2008). The methodology employed by the SEAMAP program is 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 (Table 1; SEAMAP 2008). SEAMAP uses acoustic surveys with a minimum 200 m interval integrated with aerial imagery to determine the top three levels of the classification (Table 1; Barrett *et al.* 2001, SEAMAP 2008). The last level, modifiers, are derived from video data out to a depth of 40 m and relate to localised substrate factors (structure, relief, texture and composition) as well as dominant species assemblages (generally seagrasses and macroalgae; Table 1; Barrett *et al.* 2001, SEAMAP 2008).

**Table 1 – SEAMAP (2008) habitat classification table. Gray shaded headings denote the major classification levels.**

<table>
<tr><th colspan="6">Geomorphic type</th></tr>
<tr><td colspan="3">Consolidated substrate</td><td colspan="3">Unconsolidated substrate</td></tr>
<tr><th colspan="6">Substratum/Ecotype</th></tr>
<tr><td colspan="2">Rocky reef</td><td colspan="2">Unvegetated unconsolidated substrate</td><td colspan="2">Vegetated unconsolidated substrate</td></tr>
<tr><th colspan="6">Substrate ecotype</th></tr>
<tr><td colspan="2">High profile reef<br>Medium profile reef<br>Low profile reef</td><td colspan="2">Gravel<br>Sand<br>Silt<br>Cobble</td><td colspan="2">Seagrasses<br>Algal beds<br>Aquatic macrophytes</td></tr>
<tr><th colspan="6">Modifiers</th></tr>
<tr><td>Modifier</td><td>Eco-Unit</td><td>Modifier</td><td>Eco-Unit</td><td>Modifier</td><td>Eco-Unit</td></tr>
<tr><td>Structure</td><td>Continuous<br>Patchy<br>Guttered<br>Bommies</td><td>Attached epifaunal groups</td><td>Sponges<br>Tunicates</td><td>Structure</td><td>Continuous<br>Patchy<br>Sparse</td></tr>
<tr><td>Relief</td><td>Hills<br>Flat<br>Ripples</td><td>Relief</td><td>Hills<br>Flat<br>Ripples</td><td>Sediment type</td><td>Sand<br>Silty sand<br>Silt<br>Cobble</td></tr>
<tr><td>Substratum texture</td><td>Solid<br>Cobble<br>Boulder</td><td rowspan="2">Substratum texture</td><td rowspan="2">Shelly<br>Worm holes<br>Smooth<br>Hard sand<br>Silty sand</td><td rowspan="2">Biota</td><td rowspan="2">Seagrass example:<br>Heterozostera tasmanica<br>Caulerpa sp.<br>Ruppia sp.<br>Macroalgae<br>Epiphyte</td></tr>
<tr><td>Rock Type</td><td>Dolerite<br>Granite<br>Sandstone<br>Limestone<br>Basalt</td></tr>
<tr><td>Biota</td><td>Macroalgae:<br>e.g. Ecklonia radiata<br>Seagrass:<br>e.g. Amphibolis antarctica<br>Fauna:<br>e.g. Sponges</td><td></td><td></td><td></td><td></td></tr>
</table>

The SEAMAP approach (and by extension that of Allee *et al.* 2000) was used as the basis for marine habitat mapping in the Northern and Yorke NRM region for the upper Spencer Gulf and Gulf St Vincent (DEH 2007a).

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) and the analysis of historical images from a marine habitat mapping perspective is frequently restricted (see Hart. 1997, Cameron 2000). The limitations to detecting habitat differences in aquatic systems from aerial images include (Mount 2003, DEH 2007a, Mount *et al.* 2007):

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

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

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

The following describes a program of marine habitat mapping in the Adelaide Mt Lofty Ranges 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 (< 5 m) that can be employed as a basis for natural resources monitoring and management.

# Benthic habitat mapping in the AMLR NRM region

## *Overview*

Mapping of nearshore marine habitats across the AMLR NRM region included the area from mean high water out to the 20 m depth contour (to a maximum of 5 km offshore). This depth provides a balance of detection resolution while at the same time encompassed the major habitats likely to be impacted by shore based activities, in particular reef and seagrass systems. Information on the distribution of benthic habitats was collected using a combination of techniques that collected data across increasingly smaller scales, including:

- Aerial imagery was used to assess the spatial extent of habitats at the broadest level. Boundaries between habitats such as seagrass, bare substrate and reef are often evident on aerial images and have previously been used to map habitats out to 15 m in South Australia (DEH 2007a provides a simple overview this process and habitat mapping in general).
- Acoustic data (from a single beam sounder) to further define the extent of habitats, 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 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.

## *Digitisation of aerial imagery*

Ortho-rectified aerial imagery used for digitisation of habitat boundaries for the AMLR region was collected by DEH in 2002 at a resolution of 1:20,000. Where the image for a particular area was poor (i.e. retained a high level of reflection from the water surface), DEH images collected in 2000 were used for cross-referencing.

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

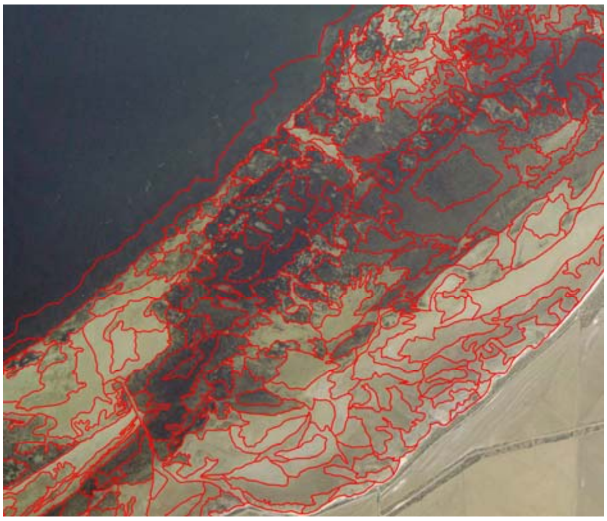


**Figure 3 - Example of habitat delineation on an aerial image.**

## *Field data*

### 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). Ninety-five acoustic (echo sounding) transects were used to increase the confidence of habitat delineation from aerial images and extend mapping beyond what is normally achievable from imagery in this region (i.e. 10 – 15 m).

The acoustic survey was carried out using a pole mounted Simrad EQ60 38/200 kHz transducer. A series of parallel acoustic transects spaced approximately 750 m 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 around 3.5 knots. Acoustic data was collected and stored on the surface control unit hard drive along with differential GPS information.

Several types of information were extracted from acoustic data, including;

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

Acoustic data was classified based on data for two frequencies (38 and 200 KHz) from the logged raw sounder files in Echoview software (by Sonar Data Version 3.50). Classification of different habitats was based on the thickness and intensity of acoustic returns and differences between the two frequencies (Figure 4). 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 4) while regular inconsistencies suggest rough hard bottom (typically reef). Sounder detected bottoms for the two frequencies tend to be the same in areas dominated by bare sand.

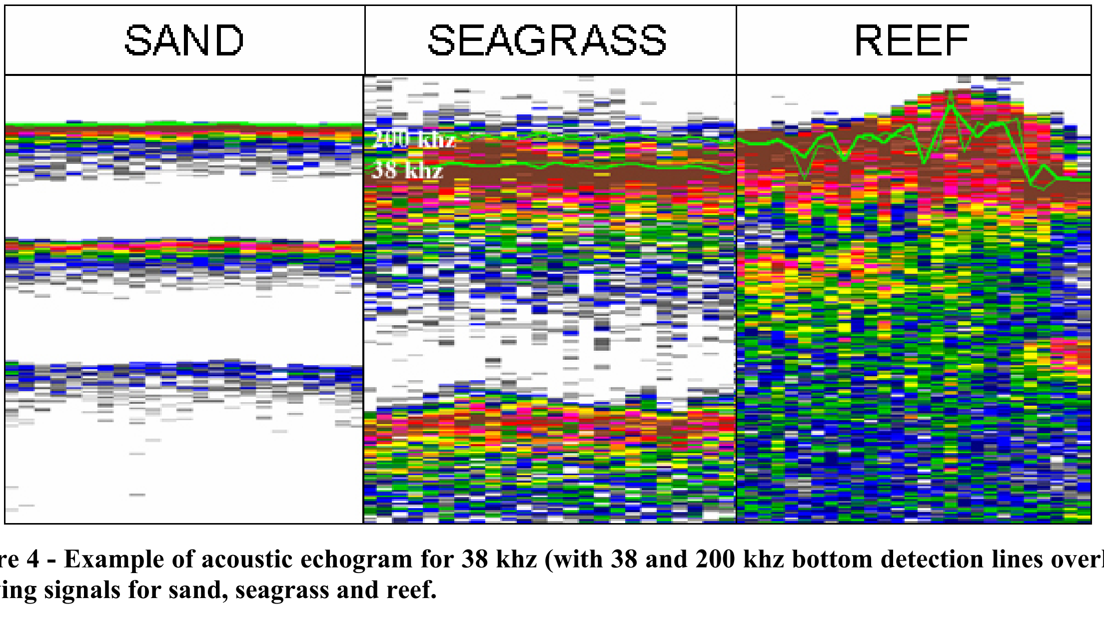



**Figure 4 - Example of acoustic echogram for 38 khz (with 38 and 200 khz bottom detection lines overlaid) showing signals for sand, seagrass and reef.**

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

## Video ground truthing

Video footage was collected along the acoustic transects using a high-resolution, towed underwater video camera (Morphcam by Morphvision), connected to a Sony GVD1000e digital video recording deck. Video drops were made at approximately 300 – 500 m intervals, depending on consistency of sounder returns or when distinct changes were observed on the acoustic echograms. Differential GPS data was simultaneously encoded on the audio track of the videotape to provide position information relative to video footage.

Benthic habitat data was extracted from video footage using a purpose-built visual basic program. The program allows the operator to view videotapes and assign habitat types, which are stored along with the corresponding GPS location from the audio channel. Data were then compiled in a database from which GIS spatial layers were produced. Around 1,500 video observations (combined across DEH and SARDI) were collected and analysed.

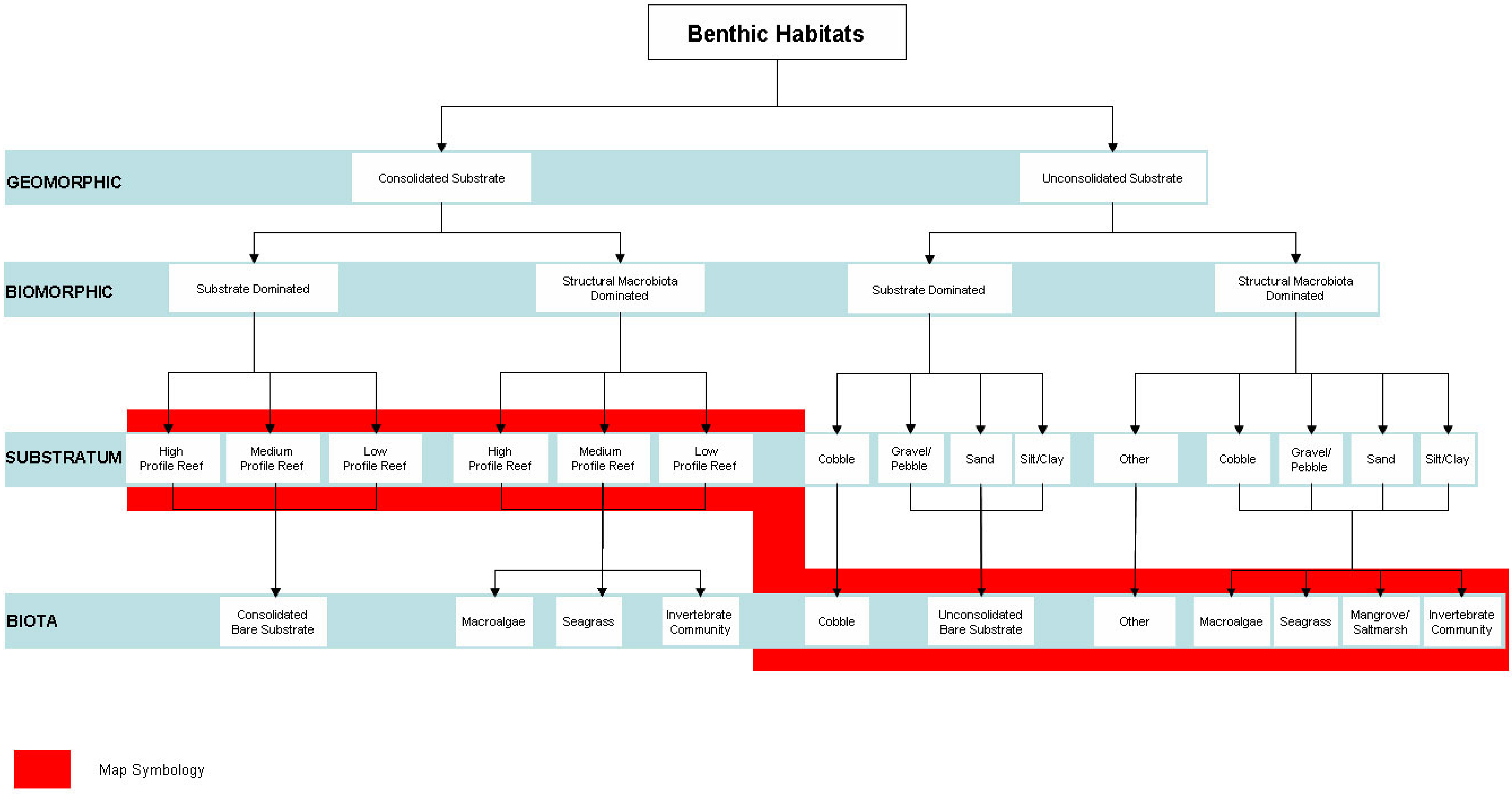
## Classification of habitats/production of maps

The approach used for classification of benthic habitats for marine habitat mapping in the Northern and Yorke NRM region for the upper Spencer Gulf and Gulf St Vincent (see above; DEH 2007a) was modified to include new habitat types encountered in the AMLR region comprising four levels (Figure 5) in line with approaches used elsewhere in Australia and internationally.

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 percent (%) cover were assigned to habitat categories using a visual aid, adapted from Kendall *et al.* (2001; Figure 6). 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 5).

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 bases on the above process is shown in Figure 7.

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Department for Environment and Heritage
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Government of South Australia
Department for Environment and Heritage

**Figure 5 - Flow diagram of benthic habitat classifications. Map symbology is generated based on Substate level classifications for consolidated benthos while video information (available in the associated ARC Reader DVD) is focussed more toward Biota level classifications.**

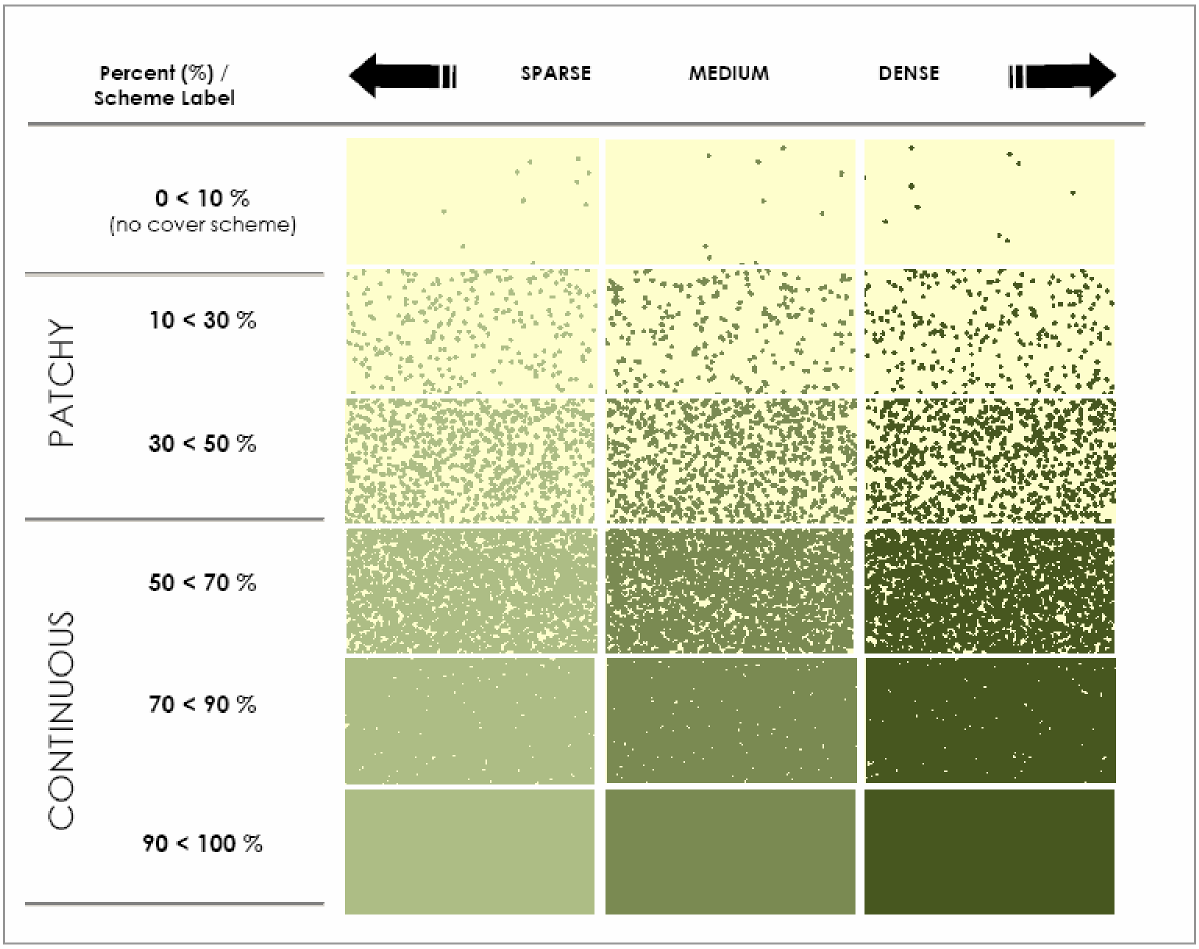


**Figure 6 - Visual aid used for assigning percent cover and relative density (Kendall *et al.* 2001).**

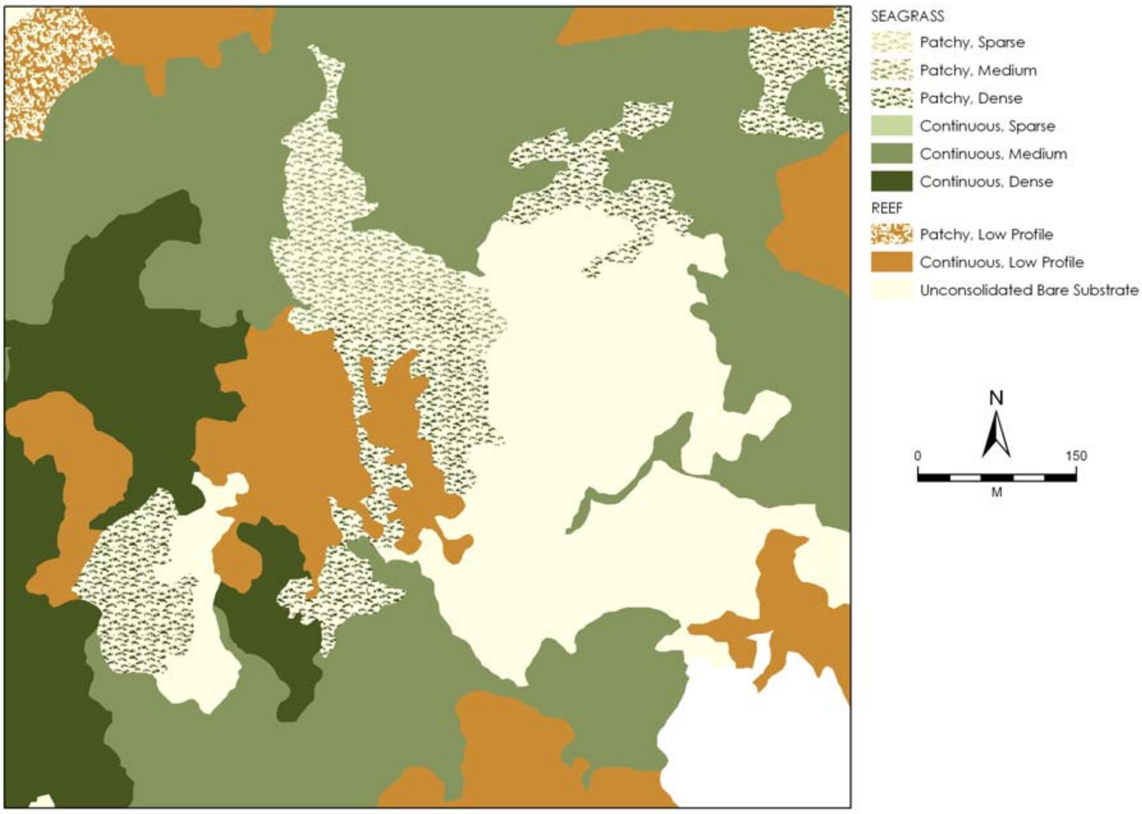


**Figure 7 - Example of a benthic habitat map for the AMLR NRM region.**

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

## Data and map limitations

Maps were based on digitisation of imagery at 1:20,000. 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).

It should be noted that in areas where visibility was poor, interpolation between transects was necessary and such interpolation carries an inherent error. In many such cases, boundaries were classified as 'transitional' meaning the location of the habitat boundary was difficult to define either as a result of these limitations or because no definite boundary existed (i.e. habitat boundaries comprising gradual rather than discrete change).

The spatial accuracy of information in the video spatial layer is dependent on both the accuracy of the DGPS itself (given to be 5 m) and any layback error caused by the camera drifting behind the path of the GPS antenna (maximum ~ 15 m). The spatial error associated with this layer is therefore defined as generally being less than 20 m.

The final maps were assessed separately for habitat accuracy by conducting independent ground truthing survey. One hundred and fifty habitat units or polygons between Cape Jervis and the northern AMLR boundary 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. Sites within the Victor Harbor area were also to be considered but access to these locations was restricted due to closure of the boat ramp. None-the-less, the quality of aerial imagery and the amount and quality of acoustic and video data collected in this area suggest that it is not unreasonable to expect that accuracy in this area will be similar to that of the areas that were assessed.

Alignment between habitat polygons and the video checkpoints confirmed the mapped habitat types in 80% of cases. It follows that for any randomly selected polygon the associated mapped habitat type may be considered reliable 80 % of the time. Using the comparable checkpoints, previous mapping undertaken by CSIRO proved to be accurate 68 % of the time.

## *Summary of mapping observations*

The major results of the mapping process are included within the accompanying map book and interactive DVD. The following comprises a brief summary of the benthic habitat mapping program for the AMLR NRM region that is intended to describe broad patterns observed for major habitat groups. This analysis is not intended to be comprehensive, and its needs to be noted that the underlying GIS data forms an important resource that can be summarised and interpreted in pursuit of a wide variety of agenda.

Benthic habitats recognised within the AMLR NRM region comprise up to eight broad habitat classes, including (Table 2);

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

The above classes have been further differentiated with respect to continuity (Continuous or Patchy) and density (Sparse, Medium, Dense although not for reefs; Table 2; Figure 6), such that there were 20 different habitat groups identified across the AMLR NRM region.

**Table 2 - List of habitat classes and subgroups employed in habitat maps.**

| Group | Habitat Class | Continuity | Density |
|---|---|---|---|
| Intertidal | Saltmarsh/Mangrove | Continuous | Dense |
| | Saltmarsh/Mangrove | Patchy | Medium |
| Seagrass | Seagrass | Continuous | Dense |
| | Seagrass | Continuous | Medium |
| | Seagrass | Continuous | Sparse |
| | Seagrass | Patchy | Dense |
| | Seagrass | Patchy | Medium |
| | Seagrass | Patchy | Sparse |
| Reef | High Profile Reef | Continuous | NA |
| | Medium Profile Reef | Continuous | NA |
| | Medium Profile Reef | Patchy | NA |
| | Low Profile Reef | Continuous | NA |
| | Low Profile Reef | Patchy | NA |
| Soft Bottom | Invertebrate Community | Patchy | Medium |
| | Invertebrate Community | Patchy | Sparse |
| | Macroalgae | Continuous | Medium |
| | Macroalgae | Continuous | Sparse |
| | Macroalgae | Patchy | Medium |
| | Macroalgae | Patchy | Sparse |
| | Unconsolidated Bare Substrate | Continuous | NA |

Marine waters in the AMLR NRM region encompass 4,249 $km^2$ or ~ 44.3 % of the total area. CSIRO marine benthic mapping at a scale of 1:100,000 (see description in Edyvane 1999a) covered 1,150 $km^2$ or 27 % of the total AMLR NRM marine area. While the total area mapped within this investigation is slightly lower at 943 km2 (22 %), the resolution is an order of magnitude higher (1:10,000) and included 1,536 polygons spread across the 20 habitat types (versus 182 polygons and eight habitat types for CSIRO mapping).

Habitat mapping from the nearshore to 20 m depth or 5 km offshore (whichever came first) included areas within the Clinton, Yankalilla, Encounter and a small portion of the Coorong Biounits that occurred within the AMLR NRM region (Edyvane 1999a, b, Figure 8). Fisheries habitat areas (see Bryars 2003) included within the area covered by the current habitat mapping include Port Adealide, Holdfast Bay, Port Noarlunga, Yankalilla Bay, Tunkalilla Beach and Encounter Bay. While much of the habitat mapping used in development of Fisheries habitat areas is based on the Edyvane (1999a) data, the Bryars (2003) maps provide a valuable resource with respect to identifying a range of factors related to each zone including human usage, adjacent land use, local protection, adjacent catchments and threats (actual, perceived and potential). This information might form an important first step in relating marine habitat maps to geographically based data on potential threats/stress factors (see General Discussion).

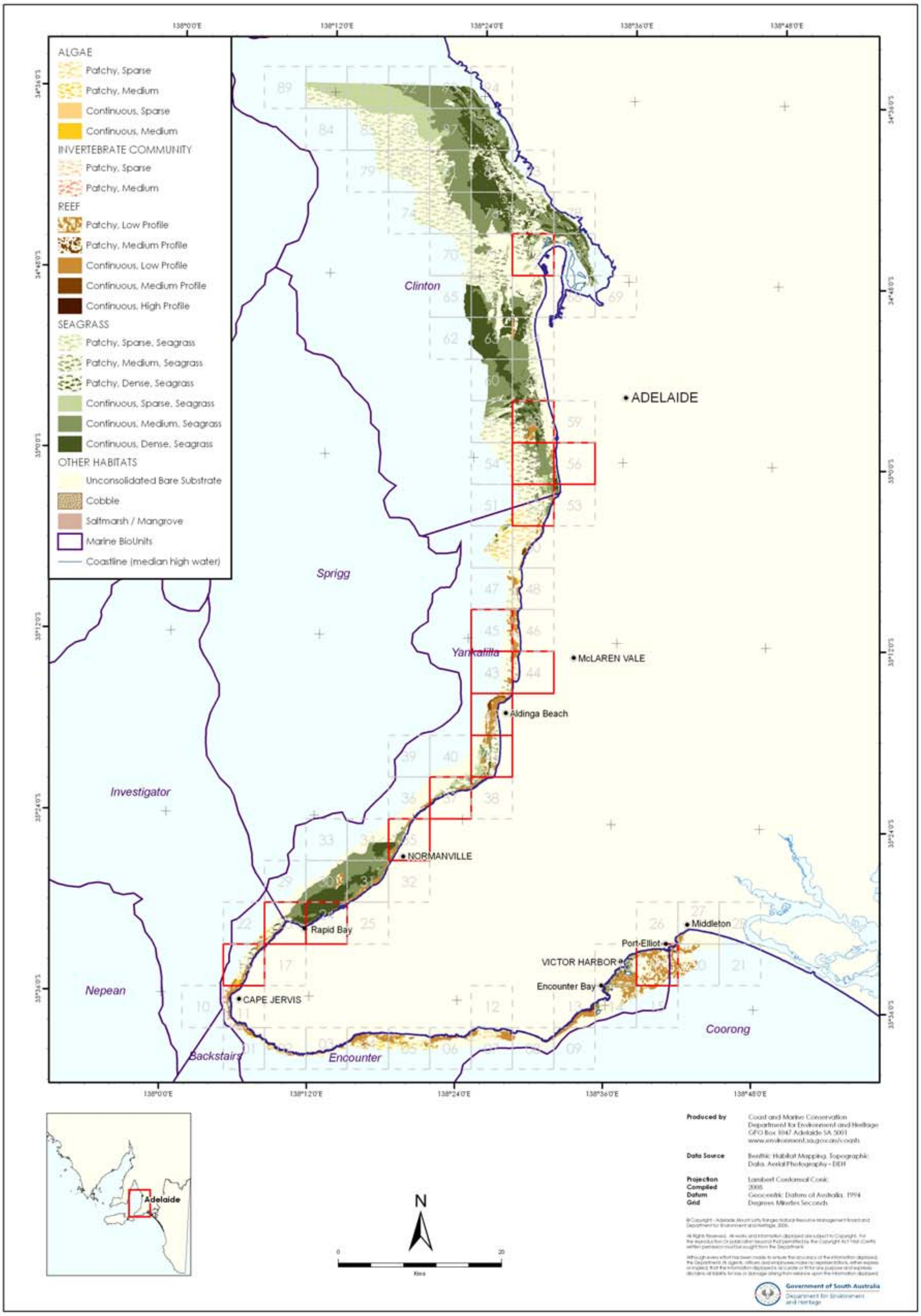


**Figure 8 - The position of 5 km × 5 km maps along the AMLR coast showing the mapped areas relative to biounits as well as maps with a relatively large number of habitat types (eight or more).**

Summary data for the above habitat types in the AMLR NRM within each biounit was considered in terms seagrass, reef and soft bottom groups (Table 2). Owing to the small area concerned (~ 2300 ha), the mapped portion of the Coorong Biounit data was included with the adjacent Encounter Biounit such that percentage cover of each habitat type was considered within three zones:

- The mapped portion of the Clinton Biounit that occurred within the AMLR NRM region (~ 59,600 ha or 23.9 % of the total area of the Clinton Biounit),
- The mapped portion of the Yankalilla Biounit (~ 19,500 ha or 38.5 % of the biounit) and
- The mapped portion of the Encounter Biounit (~ 12,000 ha of 30.5 % of the biounit) combined with the small mapped the Coorong Biounit (~2,300 ha or 0.2 % of the biounit (note that the total areas of the Coorong Biounut is relatively large 1,290,700 ha).

Percent cover of each major habitat group (Reef, Seagrass and Soft Bottom) within each biounit reveals substantial differences in cover relative to habitat, continuity and density (Figure 9). Seagrasses predominantly occur within the GSV biounits (Clinton and Yankalilla) although density and continuity are highly variable. Notably, the area between Normanville and Rapid Head (within the Yankalilla biounit) supports the broadest expanse of seagrasses within the AMLR NRM region outside the metropolitan area (see Map Book; Figure 8). This community is probably less exposed to factors for seagrass degradation known to occur further north (see Fox *et al.* 2007).

Cover of reef systems (including high, medium and low profile systems) and soft bottom habitats (macroalgae, invertebrates and unconsolidated bare substrate) were higher within the Yankalilla and Encounter/Coorong biounits (Figure 9).

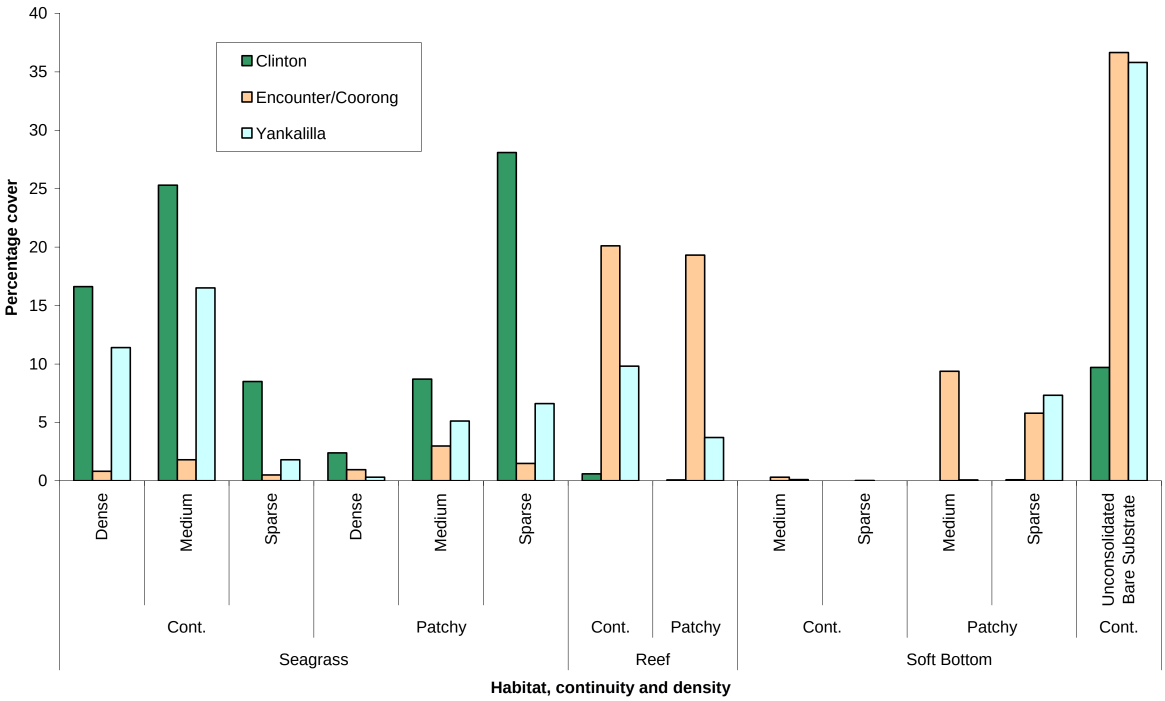


**Figure 9 - Percentage cover of broader habitat types within zones along the AMLR NRM coast.**

With a relatively gently sloping sandy bottom, GSV provides substantial habitat for seagrass species to occur up to their respective depth limits (~ 15-40 m for larger, canopy species - see Westphalen *et al.* 2004b). More steeply sloping seabed will naturally offer a narrower zone within which photosynthetic organisms can occur as may be observed within the more exposed areas outside GSV. However, this does not mean that seagrasses can grow on all shallow sandy substrates. A component of the Adelaide Coastal Waters Study investigated the light climate across a depth profile at Grange and found that nearshore turbidity during periods of stormwater discharge from metropolitan Adelaide, particularly at around 3 m but also at 6 m was high enough to potentially restrict seagrass productivity at certain times (Collings *et al.* 2006). Other factors, including sand coarseness, energy and proximity to a source of propagules are also important potential determinants of seagrass establishment and growth. It is also worth noting that many seagrass species, particularly *Posidonia* spp. are very slow to establish or re-establish (Meehan and West 2000).

The distribution of reef habitats is broadly the opposite to that of seagrasses and is also a reflection of the available substrate (i.e. rock). Given that the availability of reef habitats within the Adelaide region is restricted, declines in their health (e.g. Turner *et al.* 2007, Collings *et al.* 2008) are very important at the local scale. Avoiding serial decline of reef systems as Adelaide's population expands southward is a significant challenge for NRM.

Documented percent cover for seagasses within the Clinton, Yankalilla and Encounter biounits (see AMRL NRM 2007 biounit summary) were all less than the total areas identified from this survey (Table 3), although reef cover was more variable, being higher in Clinton and Encounter but lower in Yankalilla (Table 3). Bare sand (or soft bottom) percentage cover for Clinton is double that defined by the current survey, substantially higher in Yankalilla but much lower in Encounter. Note that this comparison did not include published cover data from the Coorong region as the area concerned is rather small.

**Table 3 – Previously documented percentage cover of different habitat types within the Clinton, Yankalilla and Encounter Biounits versus the cover identified in the current mapping survey. Note that the Coorong data were not included owing to the small portion of this biounit that was mapped (~0.2 %).**

| Source | Habitat type | Clinton | Yankalilla | Encounter |
|---|---|---|---|---|
| Published cover(AMLR NRM 2007) | Seagrass | 84.4 % | 30 % | 5.4 % |
| | Reef | 2.1 % | 7.7 % | 57.8 % |
| | Bare sand | 13.5 % | 62.2 % | 36.9 % |
| Mapped cover from this survey | Seagrass | 89.6% | 41.7% | 8.5 % |
| | Reef | 0.7% | 13.5% | 39.4 % |
| | Bare sand | 9.8% | 43.3% | 52.1 % |

These differences would in part relate to differences in habitat definition between surveys. There is also the fact that a substantial portion of each biounit is not included within the current mapping (see above; note that the seaward boundary of the biounits is bases on the 30 m depth contour; Edyvane 1999a). However, there are also substantial changes that may have occurred in the decade between surveys. Sand movements may expose or cover reef areas, seagrasses may be lost or recovered, in particular amongst faster growing/seasonal species such as *Heterozostera tasmanica* and *Halophila* spp. (see Westphalen et al. 2004b). Increased cover of seagrasses may relate to greater resolving power wthin the current survey. It is worth noting that if sparse seagrass cover is excluded from the data the remainder is within 5 % of the published totals (data not shown).

An examination of the number of different habitats (including differences in continuity and density) within each of the ninety-four 5 km × 5 km map area offers a rough indication of the broader distribution of substrate complexity. Maps with relatively few habitats (3 or less) tended to be those at the depth limit of the mapping (~ 20 m), and often included large unmapped areas, while others retained a high terrestrial area and were similarly constrained (Figure 10). However, most maps (more than 50%) comprised six or more different habitat types, with around 17% having eight or more.

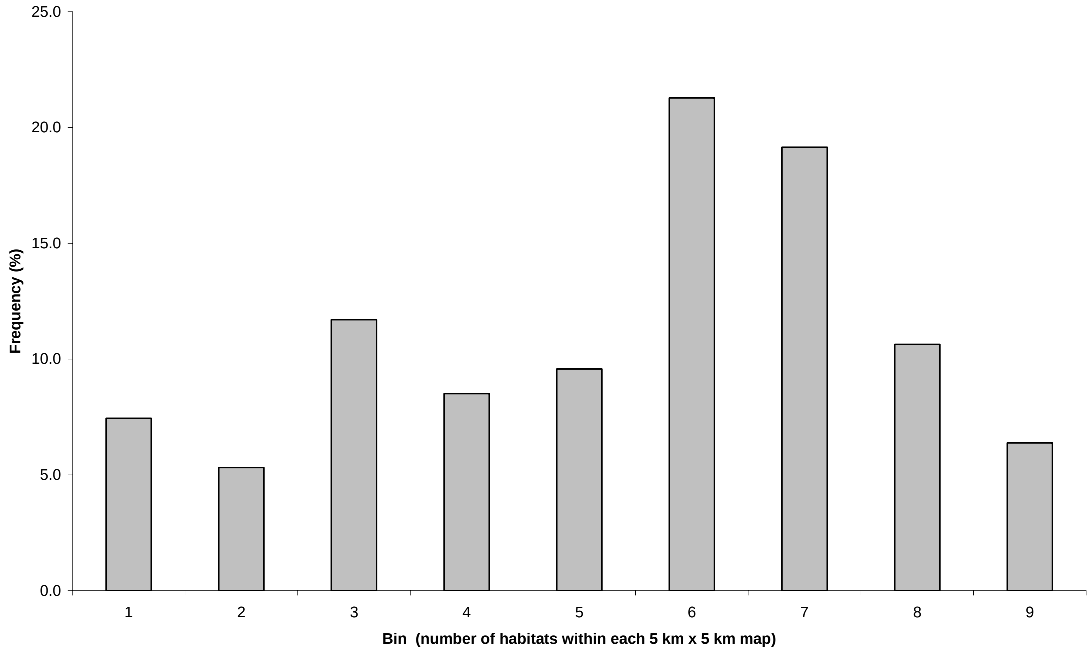


**Figure 10 - Percent frequency distribution of the number of habitats within each 5 km × 5 km map (n = 94).**

Those map areas with a larger number of habitat types were from areas close to shore and mostly within GSV (Figure 8) where there is a greater opportunity seagrass and reef systems to be intermixed, although higher visibility within the near shore strip probably also allows better habitat differentiation (aerial photographs specifically target periods of high water clarity). The Section Bank (Outer Harbour), Holdfast Bay (Glenelg) and the stretch of coast from around Moana to Cape Jervis as well as a single site at Encounter Bay all encompassed at least eight habitat types. Some maps (notably 56 and 44; Figure 8) include only a very small marine area but nonetheless retain a large number of habitat types, largely owing to overlap with adjacent maps.

The Section Bank area (map 72) retains a substantial level of complexity in seagrass continuity and coverage but also included a small area of saltmarsh (see Map Book). Similarly, the Holdfast Bay area (maps 52, 55 and 58; Figure 8) comprised a mixture of seagrass habitats as well as both continuous and patchy low profile reef (see companion Map Book). Diversity in cover/continuity of seagrass communities within the Adelaide metropolitan area are most probably a reflection of seagrass decline (see Westphalen *et al.* 2004b) and therefore presents a situation wherein a large number of different habitat types does not indicate a desirable situation (see Turner *et al.* 2007 on the notion of ecosystem health). Conversely maps from locations further south on the GSV coast as well as the map from Encounter Bay (map 19) include a range of reef types as well as seagrass and some macroalgal cover (Map Book; Figure 8). Both Reef Health and the Adelaide Coastal Waters Study would suggest that these areas are relatively unimpacted. It is therefore important to note that interpretation of habitat maps must be undertaken from an informed context.

## Subtidal reef surveys within the AMLR region

Consideration of reef systems with respect to investigating biodiversity as well as spatiotemporal and physical drivers was based on 25 locations from Carrickalinga to Encounter Bay on the Fleurieu coast (Figure 11). These sites were selected based on the notion of extending the surveys undertaken as part of the Reef Health program (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008), including development of a multiyear dataset. This approach fills a need to increase the available information on reefs within the AMLR region as well as acknowledges that, based on the results of Reef Health, reefs with high biodiversity are less likely to occur on the metropolitan coast were reefs are considered to be variously anthropogenically impacted (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). Given that an aim of this investigation is the examination of natural spatiotemporal variability between reefs, these differences are probably more readily identified without the inclusion of impacted locations from the Adelaide metropolitan area.

A description of each survey site in terms of access, associated terrigenous landscape, possible threats and other related information is included in Appendix A.

### *Reef survey methods*

Reef surveys at each site broadly followed the approaches developed by Edgar and Barrett (1997, 1999), and comprised four 50 m long contiguous transects laid across the reef at around 5 m depth. From each transect observations of composition and abundance were obtained from three different community strata, including;

- General (i.e. non-cryptic) fish species counts using a 10 m wide strip for the length of the transect (5 m estimated on each side).
- Macroalgae, based on counts of species from 50 points within a 0.5 × 0.5 m quadrat placed every 6 m along the transect (eight quadrats per transect). These observations were subsequently amalgamated at the transect level, and
- Invertebrate fauna and cryptic fish, based on counts of species from a 1 m wide strip along the full length of each transect.

All taxa within each observation type were identified as much as possible to species. Samples of any new taxa were collected for later identification, although many taxa were considered at levels other than species (i.e. complexes, genera or families). Analysis using a mixture of taxonomic levels is frequently undertaken for ecological data without loss of information (Warwick 1988a, b, Ferraro and Cole 1995), and represents an analytical method that is particularly important in marine systems in southern Australia where it is frequently not feasible to identify all organisms to species. A full list of the species observed within each observation type as well as the groupings used in analysis (see below) is available in Appendix B.

A range of physical data was obtained from each site, either through direct observation at the time of survey or based on a data interpreted from a number of GIS layers maintained by DEH (Accessed December 2008).

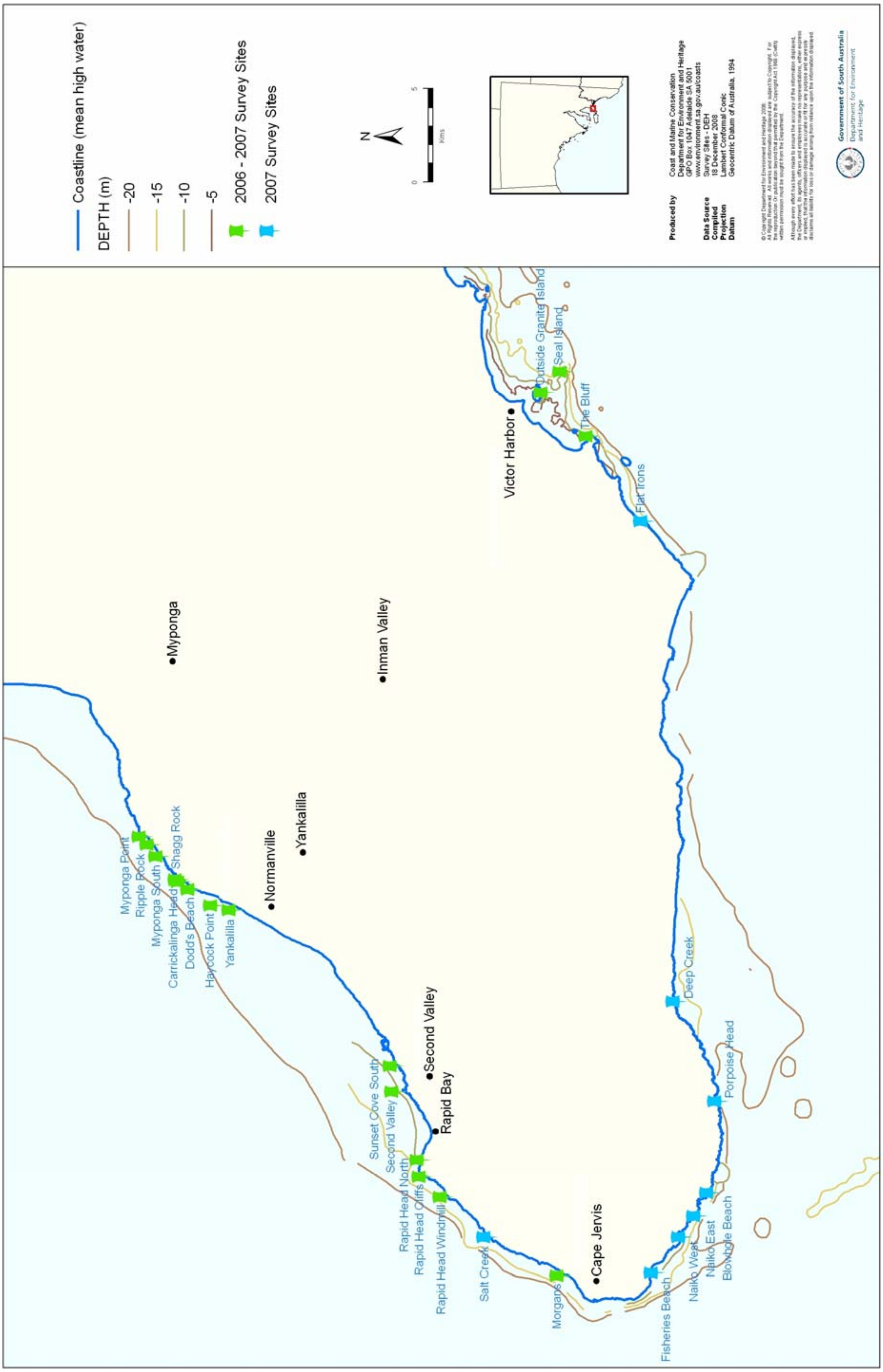


**Figure 11 - Reef survey sites on Fleurieu Peninsula.**

## *Data analyses*

Analyses considered the combined data across all three strata (water column fish, macroalgae, invertebrates and cryptic fish). Analyses were thus based on four replicate transects at each site within each sampling period. Differences in sampling unit size within each observation type (i.e. 8 $m^2$ for macroalgae, 50 $m^2$ for invertebrates and cryptic fish and 500 $m^2$ for water column fish) can be encompassed through standardisation of the data. However, the effectiveness of this approach was tested through a comparison of the raw and standardised counts with density values for each taxon based on observation method (see below).

Data was considered in terms of four basic comparisons targeted toward understanding spatiotemporal differences, biodiversity differences and physical processes that influence the structure of reef systems on Fleurieu Peninsula, including:

- Comparison of reef sites across consecutive years from summer/autumn data for 2006 and 2007 (17 "site-year" pairs; Table 4).
- Comparison of reef sites for all summer/autumn 2007 sites (25 sites; Table 4).
- Seasonal differences comparing spring (September – November) with summer/autumn (December – April) from a subset of 2007 sites (4 sites; Table 4).
- Examination of biodiversity using 2007 summer/autumn data using a range of biodiversity indices. This analysis employed a slightly different suite of taxa relative to the site-year and 2007 site analyses, with substrates (gravel, sand, rock, etc) as well as non-attached drift removed (see Appendix B; Table 4).
- Examination of relationship(s) between physical environmental factors and the observed pattern of differences between sites.

**Table 4 – Sites and labelling employed in analyses.**

| Location | Site | 2007 site comparison | 2006 – 2007 Site-year comparison | | Seasonal Comparison |
|---|---|---|---|---|---|
| CAR | Carrickalinga Head | CARH | CA06 | CA07 | |
| CAR | Dodd's Beach | DODD | DD06 | DD07 | |
| CAR | Haycock Point | HAYP | HA06 | HA07 | |
| CAR | Myponga Point | MYPP | MP06 | MP07 | |
| CAR | Myponga South | MYPS | MS06 | MS07 | |
| CAR | Ripple Rock | RIPP | RI06 | RI07 | |
| CAR | Shagg Rock | SHAG | SH06 | SH07 | |
| CAR | Yankalilla | YANK | YA06 | YA07 | |
| RAP | Morgans | MORG | MG06 | MG07 | |
| RAP | Rapid Head Cliffs | RAHC | RC06 | RC07 | |
| RAP | Rapid Head North | RAHN | RN06 | RN07 | |
| RAP | Rapid Head Windmill | RAHW | RW06 | RW07 | |
| RAP | Salt Creek | SALT | | | |
| RAP | Second Valley | SECV | SV06 | SV07 | |
| RAP | Sunset Cove South | SUNS | SS06 | SS07 | |
| JER | Blowhole Beach | BLOW | | | |
| JER | Deep Creek | DEEP | | | |
| JER | Fisheries Beach | FISH | | | |
| JER | Naiko East | NAWE | | | |
| JER | Naiko West | NAES | | | |
| JER | Porpoise Head | PORP | | | |
| ENC | Flat Irons | FLIR | | | Yes |
| ENC | Outside Granite Island | OTGI | GI06 | GI07 | Yes |
| ENC | Seal Island | SEAL | SE06 | SE07 | Yes |
| ENC | The Bluff | BLUF | BL06 | BL07 | Yes |

Multivariate analyses were conducted using PRIMER (Version 6.1.10), see Clarke and Gorley (2006) for a full description of each of the analyses employed.

The analysis of reef data follows a structure approach that considered the above comparisons data from a range of aspects, including:

- Comparison of taxa counts versus taxa density data to verify that differences in the sampling unit were encompassed within ensuing analyses (PRIMER RELATE analysis).
- Determining the need to consider analyses in terms of raw, standardised and or transformed data (PRIMER RELATE analysis).
- Non-metric Multidimensional Scaling (MDS) analysis to offer a visual representation of the relative similarity between site-year combinations.
- Analysis of the relative variability within sites (i.e. differences between transects; PRIMER MVDISP analysis).
- Analysis for significance differences between samples (PRIMER ANOSIM analysis).
- An examination of the taxa contributing to within-sample similarity and between-sample pairwise dissimilarity (PRIMER SIMPER analysis).
- Correlation analysis of physical environmental factors with sample similarity matrices (PRIMER BEST analysis).
- Analysis of biodiversity (PRIMER).

Univariate analyses of biodiversity indices (ANOVA) were conducted using SYSTAT (Version 12.00.08).

## *Reef survey results*

Results are divided according to the basic order of investigation outlined above.

### Comparison of taxa counts versus taxa density data

Data for the 2006 - 2007 site-year comparison were prepared in terms of both raw counts (number of individuals per taxon) and density (numbers of individuals per taxon per metre squared), each of which was then standardised through division by the total abundance within each sample. Bray-Curtis similarity matrices were derived from count, density, standardised count and standardised density datasets. Pairwise comparisons between these matrices were undertaken using the PRIMER RELATE function (Clarke and Gorley 2006). This analysis comprises a regression of each pair of similarity matrices. The Rho (Greek letter "ρ") derived from the analysis is an indicator of the alignment between the two matrices, analogous to $r^2$ in simple linear regression. The closer that ρ is to one indicates an increasing level of alignment or agreement between matrices. The RELATE function also calculates a significance level which indicates the probability that the observed alignment has occurred purely by chance.

The significance level for all comparisons was 0.1% indicating a low probability that these alignments occurred by chance. Comparison of count, standardised count, density and standardised density similarity matrices indicated a high level of alignment between all pairs (Table 5). There is thus little difference between count and density data matrices when being considered within a multivariate environment and subsequent analyses are thus based on count data.

**Table 5 - Pairwise comparison of count, standardised count, density and standardised density Bray-Curtis similarity matrices using the PRIMER RELATE function. Values represent calculate ρ (Rho) results. All comparisons were significant to 0.1%.**

| | Raw | Standardised count | Density | Standardised density |
|---|---|---|---|---|
| Count | 1 | - | - | - |
| Standardised count | 0.985 | 1 | - | - |
| Density | 0.859 | 0.834 | 1 | - |
| Standardised density | 0.847 | 0.83 | 0.988 | 1 |

## Need for standardisation and/or transformation

Count and standardised data were transformed using four different methods (Square root, 4th root, Log(x+1) and Presence/Absence) after which Bray-Curtis matrices were then developed for each data set. As with the count versus density comparison, the alignment between each of the similarity matrices was considered using a pairwise comparison of using the PRIMER RELATE function (see above).

Presence/absence data had the lowest level of alignment with raw, standardised and transformed count data which would be anticipated given the aggressiveness of this transformation with respect to the base data (Table 6). Otherwise, there is little difference between counts and standardised counts relative to the remaining three transformations.

**Table 6 - Comparison of Bray-Curtis similarity matrices based on count, standardised count and four transformations using the PRIMER RELATE function. Values represent calculate ρ (Rho) results. All comparisons were significant to 0.1%.**

| | Sqare root | 4th root | Log (x + 1) | Presence/ absence | Count |
|---|---|---|---|---|---|
| 4th root | 0.967 | - | - | - | - |
| Log(x + 1) | 0.994 | 0.95 | - | - | - |
| Presence/absence | 0.877 | 0.966 | 0.994 | - | - |
| Raw count | 0.917 | 0.81 | 0.919 | 0.668 | - |
| Standardised count | 0.938 | 0.832 | 0.934 | 0.695 | 0.847 |

All subsequent analyses were conducted based on standardised count data without transformation. This approach was considered to offer the best approach to encompassing outliers and differences in sampling unit size within each method.

## 2007 site comparison

Differences between sites were considered relative to the 2007 observations. Twenty-five reef sites from summer/autumn (December – April) of 2007 (Table 4) were considered based on standardised count data from replicate transects within each site.

Non-metric Multidimensional Scaling (MDS) ordination of all transects within each site resulted in a two dimensional plot with a stress of 0.18 (Figure 12). There are substantial changes in composition between sites relative to their general position along the coast (Figure 12). Transects within each site tended to group together, but with a substantial level of overlap between geographically adjacent sites.

One transect from Second Valley went against this trend, occurring on the fringe of the Carrickalinga sites (Figure 12) which was reflected in the relatively high level of within site variability (see below; Table 7).

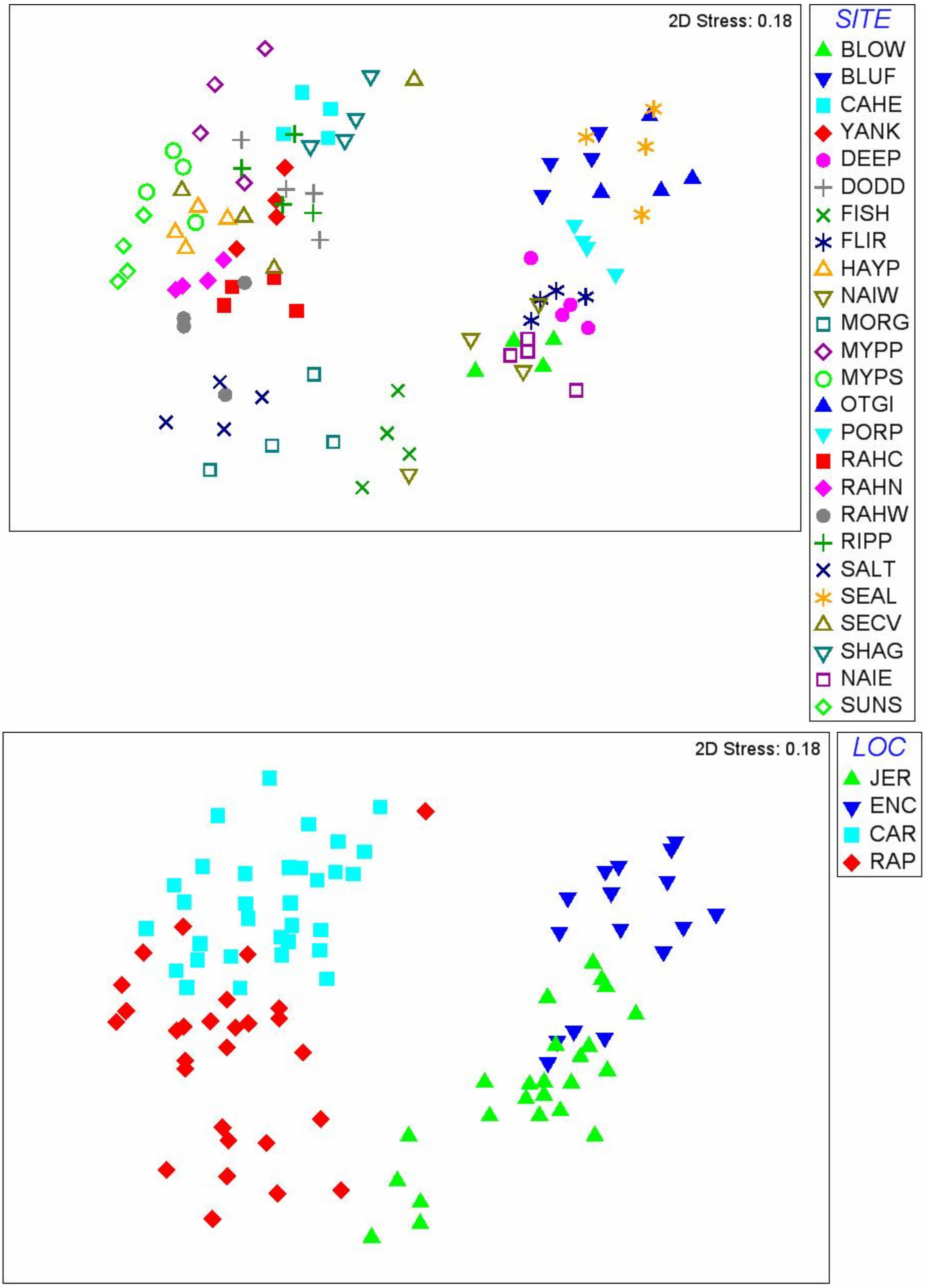


**Figure 12 - MDS ordination in two dimensions (stress = 0.18) of 2007 sites considered in terms of site (top) and their broader location (Bottom; JER = Cape Jervis, ENC = Encounter Bay, CAR = Carrickalinga, RAP = Rapid Bay).**

The gradient between sites was more readily observed when considered in terms of larger scale aggregations of sites (Table 4; Figure 11; Figure 12). Encounter Bay sites (The Bluff, Granite Island, Seal Island, Flat Irons and Porpoise) grade into locations from the Cape Jervis area (Blowhole Beach, Deep Creek, Fisheries Beach, Naiko East, Naiko West and Porpoise Head). In turn Cape Jervis sites overlap with this inside GSV around Rapid Bay (Morgans, Rapid Head Cliffs, Rapid Head North, Rapid Head Windmill, Second Valley and Sunset Cove

South), followed by sites in the Carrickalinga region (Carrickalinga Head, Dodd's Beach, Haycock Point, Myponga Point, Myponga South, Ripple Rock, Shagg Rock and Yankalilla; Figure 12; Table 4). It needs to be noted that the reasons for employing broader geographic groupings is solely a means of assisting the visualisation of differences and gradients within the ordination results and are not intended to imply any biological affiliation within any particular group of sites.

An analysis of the variability within sites in the similarity matrix was undertaken using the PRIMER MVDISP function which examines the relative dispersion of each sample within a single ordination (Clarke and Gorley 2006). Relative differences between transects within sites ranged from 0.54 to 1.49 (Carrickalinga Head and Naiko West respectively), but no pattern relative to each other or broader location (i.e. Encounter Bay, Cape Jervis, Rapid Bay or Carrickalinga; Table 7). Small-scale spatial variation as reflected by differences between transects within each site are therefore site specific.

**Table 7 - PRIMER MVDISP analysis of the relative dispersion of transects within 2007 sites.**

| Order | Site | Dispersion |
|---|---|---|
| 1 | CAHE | 0.543 |
| 2 | RIPP | 0.585 |
| 3 | DODD | 0.618 |
| 4 | PORP | 0.675 |
| 5 | BLOW | 0.678 |
| 6 | SALT | 0.726 |
| 7 | DEEP | 0.792 |
| 8 | RAHN | 0.804 |
| 9 | YANK | 0.863 |
| 10 | BLUF | 0.896 |
| 11 | HAYP | 0.912 |
| 12 | NAIE | 0.956 |
| 13 | RAHC | 1.022 |
| 14 | SEAL | 1.042 |
| 15 | RAHW | 1.057 |
| 16 | OTGI | 1.146 |
| 17 | SHAG | 1.15 |
| 18 | FLIR | 1.163 |
| 19 | FISH | 1.172 |
| 20 | MYPS | 1.183 |
| 21 | MYPP | 1.329 |
| 22 | SUNS | 1.338 |
| 23 | SECV | 1.384 |
| 24 | MORG | 1.47 |
| 25 | NAIW | 1.494 |

Analysis of the similarity (PRIMER ANOSIM; Clarke and Gorley 2006), using site as a one-way factor produced a significant result (Global R = 0.925, Significance level = 0.1%) with only seven of the 300 pairwise comparisons not significant from each other (Table 8), although five of the seven non-significant comparisons were marginal (Significance level = 5.7%). This group comprises sites that tended toward a higher level of within site variation (amongst the top ten of the MVDISP analysis; Table 7), including Naiko West, Myponga Point, Myponga Point South, Flat Irons and Outside Granite Island and/or are geographically relatively close to each other, such as Outside Granite Island and Seal Island, Blowhole Beach and Naiko East, Naiko West and Naiko East or Myponga Point and Myponga Point South (Table 8; Figure 11). Otherwise, ANOSIM results indicate that the ordination gradient relative to position along the Fleurieu Peninsula coast reflects significant differences between most sites.

**Table 8 - PRIMER ANOSIM analysis of 2007 reef sites showing pairwise comparisons (seven out of 300) that were *not* significantly different to each other.**

| Groups | R Statistic | Significance Level (%) |
|---|---|---|
| NAIW, NAIE | -0.073 | 62.9 |
| MYPP, RIPP | 0.271 | 14.3 |
| FLIR, NAIW | 0.365 | 5.7 |
| OTGI, SEAL | 0.323 | 5.7 |
| FLIR, NAIE | 0.479 | 5.7 |
| BLOW, NAIE | 0.448 | 5.7 |
| MYPP, MYPS | 0.385 | 5.7 |

Consideration of the species contributing to similarity within site groups (based on PRIMER SIMPER analysis; Clarke and Gorley 2006 analysis) was dominated by macroalgae which comprised 22 of the 32 taxa that defined 50% of the within site similarity, along with five fish, three substrates and three invertebrates (Table 9). Twelve of the macroalgal species (*Acrocarpia paniculata, Cystophora* spp. (five taxa), *Ecklonia radiata, Sargassum* spp. (three taxa), *Scytothalia dorycarpa* and *Seirococcus axilaris*) are canopy-forming and therefore potentially influential relative to remaining sub-canopy turfing and encrusting species as well as substrate groups. Crustose coralline algae were important at 12 of the 25 sites, with *Trachinops noarlungae* (Yellow-headed hulafish) influential at 10 sites. Eight taxa were influential in terms of contributing to 50% similarity at only one site which might suggest a localised dominance of these groups. However at most sites the number of groups required to attain 50% cumulative similarity required ranged from four to seven taxa (Table 9).

**Table 9 - Summary of SIMPER analysis results for taxa contributions to similarity within each site, using 50% cumulative similarity as the cut off. Values represent average abundance within each site.**

| Sites | BLOW | BLUF | CAHE | DEEP | DODD | FISH | FLIR | HAYP | MORG | MYPP | MYPS | NAIE | NAIW | OTGI | PORP | RAHC | RAHN | RAHW | RIPP | SALT | SEAL | SECV | SHAG | SUNS | YANK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Acrocarpia paniculata* | 2.1 | | | 3.1 | | | 3.9 | | | | | 2.8 | 2.2 | 2.8 | 4.5 | | | | | | | | | | |
| Crustose coralline algae | 3.3 | 3.5 | 2.9 | 3.6 | 2.4 | | 2.6 | | | | | 3.0 | | 5.0 | | | | | | | 5.6 | 2.6 | 2.7 | | 2.8 |
| *Cystophora brownii* | | | | | | | | | | 2.1 | 2 | | | | | | | | | | | | | | |
| *Cystophora expansa* | | | | | | | | 3.4 | 3.8 | | 2.4 | | | | | 2.2 | 2.4 | 3.2 | | 3.6 | | 3.1 | | | 2.9 |
| *Cystophora monilifera* | | | | | | | | | | | | | | | | | 2.4 | | | | | | | | |
| *Cystophora moniliformis* | | | | | | 2.9 | | | 2.2 | | | | 2.5 | | | | | | | | | | | | |
| *Cystophora subfarcinata* | | | | | | 2.8 | | | | 2.9 | | | | | | | | | 2.6 | | | | 3.4 | | |
| Dictyotaceae | | | | | 2.8 | | 2.8 | 2.5 | | 2.4 | 3.4 | | 2.0 | | 2.5 | 2.0 | | 2.2 | 2.1 | 2.8 | | 2.3 | 3.5 | 3.5 | |
| *Ecklonia radiata* | | 4.5 | 3.1 | | 2.6 | | | | | | | | | 4.4 | | | | | | | 5.5 | 2.8 | | | |
| Encrusting brown algae | | | | | 2.9 | | | | | | | | | | | | | | | | | | | | |
| Geniculate corallines | 1.8 | | | 2.7 | | | | | | | | | | | | | | | | | | | | | |
| *Haliptilon roseum* | 2.5 | | | | | 2.2 | | | | | | 2.3 | 1.9 | | | | | | 2.1 | 3.2 | | | | | |
| *Lobospira bicuspidata* | | | | | | 2.5 | | | | | | | | | | | | | | | | | | | |
| *Metagoniolithon* spp | | | | | | | | | 1.5 | | | | | | | | | | | | | | | | |
| *Peyssonnelia* flat | | 2.1 | | | | | | | | | | | | | | | | | | | | | | | |
| *Plocamium* spp | | | | | | | | | | | | | | | 2.5 | | | | | | | | | | |
| *Sargassum decipiens/sonderi* | 2.0 | | | | | | | | | | | | | | | | | | | 3.2 | | | | | |
| *Sargassum* spp (subgenus *Sargassum*) | | | | | | | | 3.7 | 2.1 | | 3.8 | | | | | 2.5 | 2 | 3.2 | | | | | | 3.4 | 2.9 |
| *Sargassum verruculosum* | | | | | | 2.3 | | | 2.5 | | | | | | | | | | | | | | | | |
| *Scytothalia dorycarpa* | 3.4 | | | 4.3 | | | 1.8 | | | | | 2.5 | 2.7 | | | | | | | | | | | | |
| *Seirococcus axillaris* | 4.0 | | | | | | | | | | | 4.1 | | | | | | | | | | | | | |
| Turf | | 2.2 | | | | | | | | | | | | | 2.3 | | | | | | | | | | |
| *Cenolia trichoptera* | | 3.3 | | | | | | 2.0 | | | | | 1.9 | | | | | | | | | | | | |
| *Dinolestes lewini* | | | 1.8 | | | | | | | | | | | | | | | | | | | | | | |
| *Notolabrus tetricus* | | | | 1.6 | | | 1.9 | | 1.6 | | | | | | 2.2 | | | | 1.6 | 2.7 | | | | | |
| *Scorpis aequipinnis* | | | | 1.6 | | | 2.1 | | | | | | | | 2.5 | | | | | | | | | | |
| *Siphamia cephalotes* | | | 3.1 | | 5.3 | | | 1.9 | | 3.3 | | | | | | 5.3 | | | 3.1 | | | | | | |
| Sponge (encrusting) | | | | | | | | | | | | | | | 1.8 | | | | | | | | | | |
| *Trachinops noarlungae* | | | 4.3 | | | | | 3.2 | | | 3.7 | | | | | 2.9 | 6.3 | 4.4 | 4.0 | | | 4.5 | | 4.8 | 3.8 |
| *Turbo undulatus* | | | 3.7 | | | | | | | 2.0 | | | | | | | | | 3.6 | | | | 3.3 | | |
| Bare rock (non - barrens) | | | | | | 2.2 | | | | | | 3.4 | 2.6 | | | | | | | | | | | | |
| Gravel | | | | | | | | | 3.0 | 1.7 | | | | | | | 2.3 | 3.0 | | | | | | | |
| Sand | | | | | | 3.5 | 3.0 | | | | | | | | | | | | | | | | 2.1 | | 4.5 |

In terms of pairwise comparisons, SIMPER results were considered with respect to the ten lowest and highest overall dissimilarities (Table 10 and Table 11 respectively) within the 300 pairs with the aim of highlighting taxa contributing to differences between sites at larger and smaller spatial scales respectively (based on the notion derived from the ordination that geographically closer sites are less dissimilar).

**Table 10 - SIMPER pairwise dissimilarity comparisons for 2007 sites considering the lowest 10 pairs in terms of overall dissimilarity. Values represent average abundance within each site.**

| Pairwise comparison | BLOW & NAIE | | NAIW & NAIE | | MYPP & RIPP | | BLOW & DEEP | | RAHN & RAHW | | CAHE & RIPP | | RAHW & SALT | | BLOW & NAIW | | FLIR & NAIE | | RIPP & SHAG | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average dissimilarity | 41.5 | | 43.2 | | 43.4 | | 43.6 | | 44.5 | | 45 | | 46.4 | | 46.4 | | 46.4 | | 46.6 | |
| *Acrocarpia paniculata* | 2.12 | 2.82 | 2.18 | 2.82 | | | 2.12 | 3.1 | | | | | | | | | 3.91 | 2.82 | | |
| *Amphiroa* spp | | | 0.25 | 1.18 | | | 0.97 | 0 | | | | | | | 0.97 | 0.25 | 1.25 | 1.18 | | |
| *Caulerpa brownii* | | | | | | | | | 0 | 0.67 | | | | | | | | | | |
| *Caulerpa flexilis* complex | 1.21 | 0 | | | | | 1.21 | 0.92 | | | | | | | 1.21 | 0.37 | | | | |
| *Caulocystis* spp | | | | | | | | | | | | | 0.34 | 2.35 | | | | | | |
| Crustose coralline algae | 3.47 | 3.04 | 2.32 | 3.04 | | | | | | | 2.93 | 1.13 | | | 3.47 | 2.32 | | | 1.13 | 2.72 |
| *Cystophora brownii* | | | | | | | | | | | 0 | 1.37 | | | | | | | 1.37 | 0.09 |
| *Cystophora expansa* | | | | | | | | | 2.38 | 3.24 | | | | | | | | | | |
| *Cystophora monilifera* | 0 | 0.67 | | | | | | | 2.41 | 0 | | | | | | | | | | |
| *Cystophora moniliformis* | 1.52 | 1.67 | 2.46 | 1.67 | 1.26 | 0.87 | 1.52 | 1.59 | | | | | | | 1.52 | 2.46 | 1.48 | 1.67 | | |
| *Cystophora racemosa* | | | | | | | | | | | 1.09 | 0 | | | | | | | | |
| *Cystophora siliquosa* complex | 0.83 | 0.15 | | | | | 0.83 | 0 | | | | | | | 0.83 | 0.24 | | | | |
| *Cystophora subfarcinata* | 1.26 | 0.82 | 1.37 | 0.82 | | | 1.26 | 1.04 | | | 0.18 | 2.56 | | | 1.26 | 1.37 | 2.03 | 0.82 | 2.56 | 3.41 |
| *Delisea/Phacelocarpus* complex | | | | | | | | | | | | | | | | | 0.92 | 0.13 | | |
| *Dictyota/Dilophus* complex | 0.86 | 0 | | | | | 0.86 | 0 | | | | | | | 0.86 | 0.14 | | | | |
| Dictyotaceae | 1.75 | 1.77 | 1.99 | 1.77 | | | 1.75 | 1.46 | 1.89 | 2.25 | | | 2.25 | 2.85 | | | 2.85 | 1.77 | 2.06 | 3.48 |
| *Ecklonia radiata* | 0 | 0.96 | 1 | 0.96 | 0.13 | 1.02 | | | 1.91 | 0.75 | 3.09 | 1.02 | 0.75 | 0.4 | 0 | 1 | | | | |
| Encrusting brown algae | | | | | 0.97 | 1.18 | | | | | 0.33 | 1.18 | | | | | | | 1.18 | 1.48 |
| Geniculate corallines | 1.8 | 1.28 | 0.85 | 1.28 | 1.68 | 0 | 1.8 | 2.69 | | | | | | | 1.8 | 0.85 | 1.31 | 1.28 | | |
| *Haliptilon roseum* | | | | | 1.55 | 2.06 | 2.48 | 2.09 | 0.07 | 1.24 | 0 | 2.06 | 1.24 | 3.16 | | | 0.72 | 2.28 | 2.06 | 0 |
| *Metagoniolithon* spp | | | | | | | | | | | | | 0.6 | 1.94 | | | | | | |
| *Osmundaria prolifera* | | | | | | | | | 0 | 0.84 | | | 0.84 | 0 | | | | | | |
| *Peyssonnelia* flat | 1.49 | 0.52 | 0.91 | 0.52 | | | 1.49 | 0.69 | | | | | | | 1.49 | 0.91 | | | | |
| *Phloiocaulon/Halopteris* complex | | | | | | | | | | | | | | | | | 1.02 | 0.13 | | |
| *Sargassum decipiens/sonderi* | 1.96 | 0.87 | 0.41 | 0.87 | | | 1.96 | 0 | 1.19 | 2.08 | | | 2.08 | 3.22 | 1.96 | 0.41 | 0 | 0.87 | | |
| *Sargassum* spp (subgenus *Arthrophycus*) | | | | | | | | | 1.33 | 0.81 | | | | | 0.17 | 0.89 | | | | |
| *Sargassum* spp (subgenus *Sargassum*) | 0.76 | 0 | | | 2.15 | 1.64 | 0.76 | 0 | 2 | 3.2 | | | 3.2 | 2.51 | 0.76 | 0.68 | | | 1.64 | 0.82 |
| *Sargassum varians* | | | | | | | | | | | | | 1.57 | 0.33 | | | | | | |
| *Sargassum verruculosum* | 0.24 | 0.55 | 1.34 | 0.55 | | | | | | | | | | | 0.24 | 1.34 | | | | |
| *Scytothalia dorycarpa* | 3.44 | 2.49 | 2.72 | 2.49 | | | 3.44 | 4.31 | | | | | | | 3.44 | 2.72 | 1.77 | 2.49 | | |
| *Seirococcus axillaris* | | | 2.62 | 4.07 | | | 4.04 | 1.31 | | | | | | | 4.04 | 2.62 | 1.47 | 4.07 | | |
| Turf | 0.78 | 0.33 | | | | | 0.78 | 0.35 | 0.87 | 0.29 | 1.41 | 0.34 | | | | | | | | |
| *Xiphophora chondrophylla* | | | | | | | | | | | | | | | | | 0.98 | 0 | | |
| *Cenolia trichoptera* | 0.29 | 1.07 | 1.87 | 1.07 | | | | | | | | | | | 0.29 | 1.87 | | | | |
| *Dinolestes lewini* | | | | | | | | | | | 1.76 | 0.17 | | | | | | | | |
| *Girella zebra* | | | | | | | | | 0.92 | 0.29 | | | | | | | | | | |
| *Haliotis rubra* complex | | | 0.16 | 0.88 | | | 0.72 | 1.65 | | | | | | | | | | | | |
| *Kyphosus sydneyanus* | | | | | | | | | 0.98 | 0.82 | | | 0.82 | 0.45 | | | | | | |
| *Leptatherina presbyteroides* | | | | | 1.7 | 0 | | | | | | | | | | | | | | |
| *Meuschenia hippocrepis* | | | | | 0.08 | 0.96 | | | | | | | | | | | | | | |
| *Notolabrus tetricus* | | | | | | | | | 1.12 | 1.93 | | | 1.93 | 2.71 | | | | | | |
| Other ascidians | 0.62 | 1.14 | | | | | | | | | | | | | 0.62 | 1.09 | | | | |
| Other sponges | | | | | | | | | | | | | 0.85 | 1.53 | | | | | | |
| *Parapriacanthus elongatus* | | | | | | | | | | | | | 0 | 1.1 | | | | | 0 | 1.67 |
| *Phasianella ventricosa* | | | | | | | | | | | | | | | | | | | 1.11 | 0 |
| *Scorpis aequipinnis* | | | 1.07 | 1.07 | | | | | | | | | | | | | 2.06 | 1.07 | | |
| *Siphamia cephalotes* | | | | | 3.28 | 3.09 | | | | | 3.09 | 3.09 | | | | | | | 3.09 | 0.47 |
| Sponge (encrusting) | | | | | | | 0.62 | 1.56 | | | | | | | | | | | | |
| *Trachinops noarlungae* | | | | | 2.6 | 3.98 | | | 6.28 | 4.45 | 4.33 | 3.98 | 4.45 | 0.6 | | | | | 3.98 | 2.21 |
| *Turbo undulatus* | | | | | 2.05 | 3.6 | 0.23 | 1.56 | | | 3.72 | 3.6 | | | | | | | | |
| Bare rock (non - barrens) | 0.62 | 3.37 | 2.63 | 3.37 | 1.12 | 0.99 | | | 0.22 | 1.16 | 0 | 0.99 | 1.16 | 1.26 | 0.62 | 2.63 | 1.11 | 3.37 | 0.99 | 0.61 |
| Gravel | | | | | 1.74 | 0.91 | | | 2.35 | 2.96 | 0.8 | 0.91 | 2.96 | 1.91 | | | | | 0.91 | 0.88 |
| Sand | 0.61 | 1.04 | 1.88 | 1.04 | 0.31 | 1.14 | 0.61 | 0.64 | | | | | | | 0.61 | 1.88 | 2.99 | 1.04 | 1.14 | 2.14 |

The ten lowest dissimilarity comparisons comprised pairs of sites that are generally geographically close, if not adjacent (Table 10; Figure 11, note not Flat Irons and Naiko East). Macroalgae dominate in determining dissimilarity to 50% comprising 33 of the 53 taxa along with ten species of fish, seven invertebrates and three substrate groups. Sixteen of the macroalgae are from canopy-forming groups, including; *Acrocarpia paniculata*, *Cystophora* spp. (seven taxa), *Sargassum* spp. (five taxa), *Ecklonia radiata, Seirococcus axilaris* and *Scytothalia dorycarpa* (Table 10). From 14 to 21 species were required to achieve at 50%

level of dissimilarity. Eight taxa were influential in seven or more comparisons, but the majority of taxa (34) contributed to three or less (16 related to only one comparison). Differences between adjacent sites thus appear to largely relate to changes in site specific taxa, although note that this does not necessarily infer that these taxa occur only at these sites.

Pairwise comparisons with a high level of dissimilarity (Table 11) were all geographically distinct (Figure 11). Importantly, the top ten dissimilarities all related to differences between Encounter Bay locations (Outside Granite Island, Seal Island and The Bluff) relative to sites from other areas (i.e. Cape Jervis, Rapid Bay and Carrickalinga – Sunset Cove South, Morgans, Myponga Point South, Myponga Point, Rapid Head Windmill and Salt Creek), suggesting that this area is somewhat distinct. However, as with all other comparisons macroalgae are the predominant taxa (23 out of 35 defining up to 50% of the dissimilarity between pairs of sites), followed by fish (six taxa), invertebrates (four taxa) and substrates (two taxa). Twelve of the macroalgae are canopy-forming species, including *Acrocarpia paniculata*, *Cystophora* spp. (four taxa), *Sargassum* spp. (four taxa), *Ecklonia radiata*, *Seirococcus axilaris* and *Scytothalia dorycarpa* (Table 11).

**Table 11 - SIMPER pairwise dissimilarity comparisons for 2007 sites considering the highest 10 pairs in terms of overall dissimilarity. Values represent average abundance within each site.**

| Pairwise comparison | MORG & OTGI | | BLUF & SUNS | | MYPS & SEAL | | RAHW & SEAL | | MYPP & OTGI | | SALT & SEAL | | OTGI & SALT | | MYPS & OTGI | | SEAL & SUNS | | OTGI & SUNS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average dissimilarity | 85.73 | | 86.1 | | 86.19 | | 86.47 | | 86.86 | | 87.45 | | 87.82 | | 88.59 | | 90.84 | | 91 | |
| *Acrocarpia paniculata* | 0 | 2.78 | | | 0 | 2.43 | 0 | 2.43 | 0 | 2.78 | 0 | 2.43 | 2.78 | 0 | 0 | 2.78 | 2.43 | 0 | 2.78 | 0 |
| *Caulocystis* spp | | | 0 | 1.51 | | | | | | | 2.35 | 0 | 0 | 2.35 | | | 0 | 1.51 | | |
| Crustose coralline algae | 1.3 | 5.02 | 3.46 | 0.98 | 0.58 | 5.63 | 1.12 | 5.63 | 0.68 | 5.02 | 0.47 | 5.63 | 5.02 | 0.47 | 0.58 | 5.02 | 5.63 | 0.98 | 5.02 | 0.98 |
| *Cystophora brownii* | | | | | 2 | 0 | | | 2.1 | 0 | | | | | 2 | 0 | | | | |
| *Cystophora expansa* | 3.78 | 0 | 0 | 2.42 | 2.36 | 0 | 3.24 | 0 | | | 3.57 | 0 | 0 | 3.57 | 2.36 | 0 | 0 | 2.42 | 0 | 2.42 |
| *Cystophora moniliformis* | 2.23 | 0 | | | | | | | | | | | | | | | | | | |
| *Cystophora subfarcinata* | | | | | | | | | 2.94 | 0 | | | | | | | | | | |
| *Delisea/Phacelocarpus* complex | 0 | 1.65 | | | | | | | 0 | 1.65 | | | | | 0 | 1.65 | | | 1.65 | 0 |
| Dictyotaceae | | | 0.8 | 3.5 | 3.43 | 0 | 2.25 | 0 | | | 2.85 | 0 | 1.03 | 2.85 | 3.43 | 1.03 | 0 | 3.5 | 1.03 | 3.5 |
| *Ecklonia radiata* | 0 | 4.36 | 4.49 | 0 | 0.27 | 5.55 | 0.75 | 5.55 | 0.13 | 4.36 | 0.4 | 5.55 | 4.36 | 0.4 | 0.27 | 4.36 | 5.55 | 0 | 4.36 | 0 |
| Foliose reds | | | | | 0 | 1.11 | | | | | | | | | | | | | | |
| Geniculate corallines | | | | | | | | | 1.68 | 0 | | | | | | | | | | |
| *Haliptilon roseum* | | | | | | | | | | | 3.16 | 0.75 | 0 | 3.16 | | | | | | |
| *Lobospira bicuspidata* | | | 1.32 | 0 | | | | | | | | | | | | | | | | |
| *Metagoniolithon* spp | 1.46 | 0 | | | | | | | | | 1.94 | 0 | 0 | 1.94 | | | | | | |
| *Peyssonnelia* flat | 0.11 | 2.04 | 2.14 | 0.1 | | | | | 0 | 2.04 | | | 2.04 | 0 | 0 | 2.04 | | | 2.04 | 0.1 |
| *Sargassum decipiens/sonderi* | 1.55 | 0 | | | | | 2.08 | 0 | | | 3.22 | 0 | 0 | 3.22 | | | | | | |
| *Sargassum* spp (subgenus *Sargassum*) | 2.11 | 0 | 0 | 3.39 | 3.84 | 0 | 3.2 | 0 | 2.15 | 0 | 2.51 | 0 | 0 | 2.51 | 3.84 | 0 | 0 | 3.39 | 0 | 3.39 |
| *Sargassum varians* | | | | | | | 1.57 | 0 | | | | | | | | | | | | |
| *Sargassum verruculosum* | 2.48 | 0 | | | | | | | | | | | | | | | | | | |
| *Scytothalia dorycarpa* | 0 | 1.85 | 2.23 | 0 | | | | | 0 | 1.85 | | | | | 0 | 1.85 | | | 1.85 | 0 |
| *Seirococcus axillaris* | 0 | 1.47 | | | | | | | | | | | | | 0 | 1.47 | | | | |
| Turf | | | 2.18 | 0 | | | | | | | | | | | | | | | | |
| *Austrolabrus maculatus* | | | | | 1.36 | 0 | | | | | | | | | | | | | | |
| *Cenolia tasmaniae* | | | | | 2.51 | 0 | | | | | | | | | 2.51 | 0 | | | | |
| *Cenolia trichoptera* | | | 3.26 | 0 | | | | | | | | | | | | | | | | |
| *Leptatherina presbyteroides* | | | | | | | | | 1.7 | 0 | | | | | | | | | | |
| *Notolabrus tetricus* | 1.59 | 0.16 | | | | | 1.93 | 0.43 | | | 2.71 | 0.43 | 0.16 | 2.71 | | | | | | |
| *Scorpis aequipinnis* | | | | | | | | | | | | | | | | | 1.36 | 0 | 1.77 | 0 |
| *Siphamia cephalotes* | | | 0.09 | 3.23 | | | | | 3.28 | 0 | | | | | | | 0 | 3.23 | 0 | 3.23 |
| Sponge (encrusting) | | | 1.71 | 0 | | | | | | | | | | | | | | | | |
| *Trachinops noarlungae* | | | 0 | 4.82 | 3.75 | 0 | 4.45 | 0 | 2.6 | 0 | | | | | 3.75 | 0 | 0 | 4.82 | 0 | 4.82 |
| *Turbo undulatus* | | | | | | | | | | | | | | | | | 1.47 | 0 | | |
| Gravel | 2.97 | 0 | | | | | 2.96 | 0 | 1.74 | 0 | 1.91 | 0 | 0 | 1.91 | | | | | | |
| Sand | 1.69 | 0 | | | 0.92 | 1.57 | 0 | 1.57 | | | | | | | | | | | | |

As should be expected, there are fewer taxa involved in determining the 50% cut off between highly dissimilar sites relative to the number required to differentiate a low level of dissimilarity. This difference relates to both taxa numbers within pairwise comparisons (11-16 versus 14-21 taxa for high and low dissimilarity groups respectively) as well as the overall number of taxa involved (35 and 53 taxa for high and low respectively). However, comparison between the species involved at both high and low dissimilarity comparisons reveals that all but four of the 35 species responsible for 50% dissimilarity between highly dissimilar sites that are geographically remote from each other are also involved in determining low dissimilarity differences between sites that are close together. While dissimilarity between locations may be due to the complete absence of a particular taxon from one of the sites concerned, it may be argued that both larger and smaller scale differences between reefs on the Fleurieu coast are contingent upon changes in the abundance of generally widespread taxa. However, dissimilarities between pairs of sites are also still determined by a unique set of differences. Within the low dissimilarity pairwise comparisons, only 14 of the 53 taxa contributing to 50% of the dissimilarity occur (or are important) at five or more pairs whereas 16 taxa are influential at only one pair. Similarly, 13 of the 35 taxa contributing to 50% of the dissimilarity between highly dissimilar sites are also specific to a single comparison.

Differences between reef locations surveyed in 2007 were thus determined by differences in generally widespread taxa, coupled with small scale changes in localised or at least locally abundant taxa. Macroalgae remain the dominant determinants of both similarity within as well as differences between sites at both smaller (locally adjacent sites) and larger scales (Fleurieu Peninsula), with canopy-forming species important contributors. As before, changes in the canopy macroalgae may act to determine differences in sub-canopy, turfing and encrusting species as well as substrate groups.

## Site-year comparison for 2006 and 2007 sites

The site-year comparison considered each site with data from both 2006 and 2007 summer (December - April) and a depth average 5 m (ranging from 4 – 7 m; Table 4).

MDS ordination of site-year data at the transect level indicated that sites between years tended to overlap (Figure 13), suggesting that spatial differences between reefs were substantially more influential than differences between consecutive years. It needs to be noted that the two dimensional MDS result had a stress level of 0.2, which is somewhat marginal (Clarke and Warwick 2001), although the related three dimensional MDS plot shows the same general groupings of site-year combinations as that in two dimensions and thus indicates the same results with a stress of 0.14. The two dimensional plot was employed for ease of description.

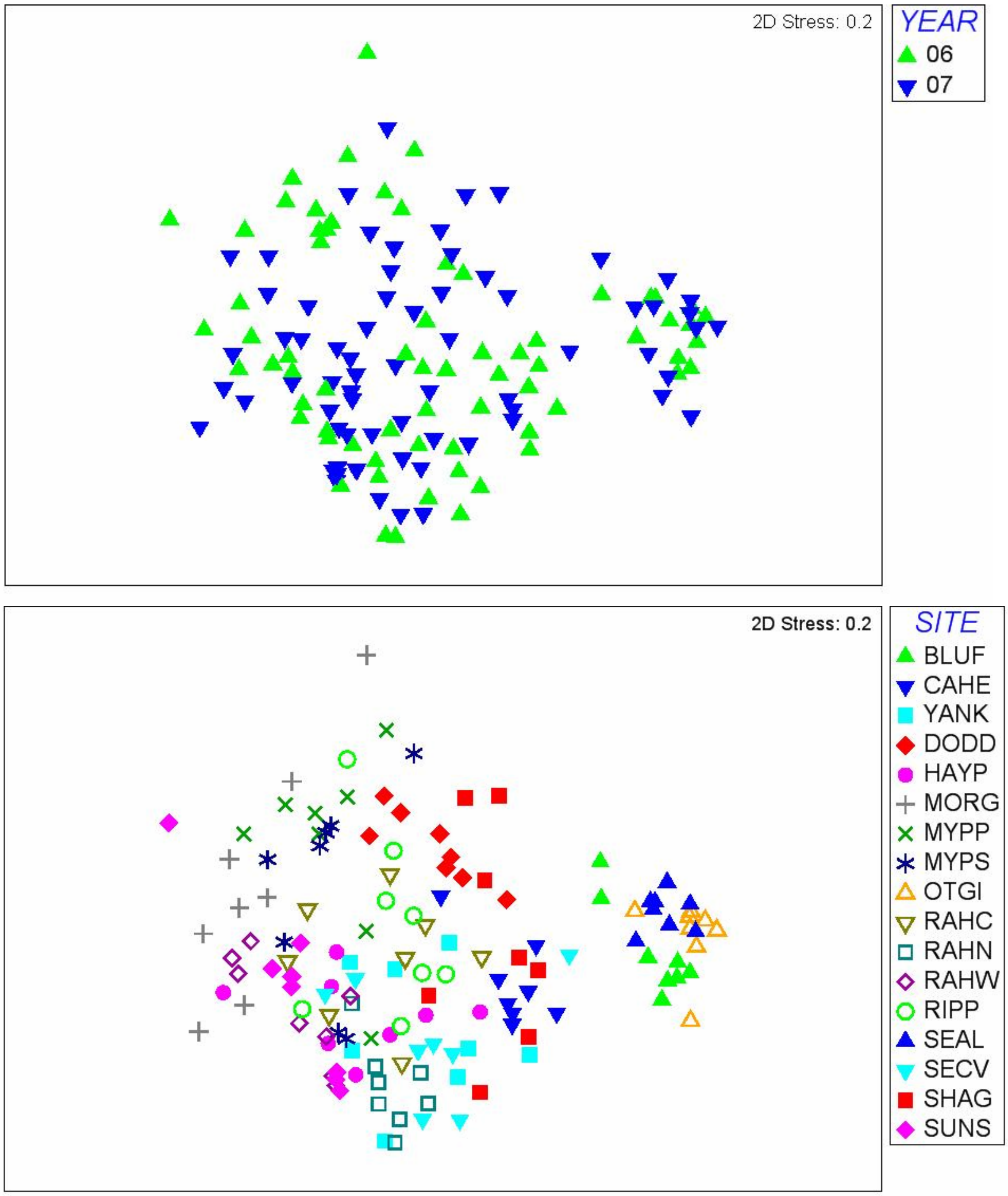


**Figure 13 - MDS ordination in two dimensions of Site-year combinations, labelled with year (top) and site (bottom).**

PRIMER MVDISP analysis of the variability within site-year groups in the similarity matrix (Clarke and Gorley 2006) considered differences between transects within each site-year combination, and thus represents a measure of small scale spatial variability within observations. The results (Table 12) indicate that variability within site-year combinations ranges from around 0.3 to 1.5 (Granite Island 2006 and Second Valley 2007 respectively). However, while there appears to be varying levels of small-scale spatial heterogeneity within site-year combinations, there is no apparent pattern in variability relative to adjacent sites, years or broader location (i.e. Encounter Bay, Rapid Bay or Carrickalinga; Table 4; Table 12). Small scale variability between transects is thus specific to site-year combinations and may be used to infer a need for a higher level of sampling in some locations. The use of contiguous 50 m transects (or a 200 m stretch of reef) will likely entail higher levels of variability than adjacent samples as sampling is more likely to encompass different habitat assemblages. Contiguous transects of this nature also raises the issue of the independence of sampling.

**Table 12 - PRIMER MVDISP analysis of the relative dispersion of transects within each Site-year combination.**

| Order | Site-year | Dispersion | Order cont. | Site-year | Dispersion |
|---|---|---|---|---|---|
| 1 | GI06 | 0.299 | 18 | SV06 | 1.055 |
| 2 | CA06 | 0.403 | 19 | SH06 | 1.055 |
| 3 | SE07 | 0.411 | 20 | RW07 | 1.096 |
| 4 | RN06 | 0.431 | 21 | RI07 | 1.107 |
| 5 | HP06 | 0.527 | 22 | RH06 | 1.15 |
| 6 | BL06 | 0.657 | 23 | DD06 | 1.167 |
| 7 | SE06 | 0.696 | 24 | GI07 | 1.184 |
| 8 | MS06 | 0.698 | 25 | HP07 | 1.254 |
| 9 | BL07 | 0.867 | 26 | SS07 | 1.27 |
| 10 | RN07 | 0.888 | 27 | MS07 | 1.272 |
| 11 | RW06 | 0.901 | 28 | MG06 | 1.299 |
| 12 | YA06 | 0.92 | 29 | SH07 | 1.324 |
| 13 | CA07 | 0.937 | 30 | RI06 | 1.372 |
| 14 | DD07 | 0.943 | 31 | MG07 | 1.39 |
| 15 | MP06 | 0.998 | 32 | MP07 | 1.405 |
| 16 | RH07 | 1.007 | 33 | SS06 | 1.459 |
| 17 | YA07 | 1.029 | 34 | SV07 | 1.53 |

PRIMER ANOSIM using site-year as a one-way factor produced in a significant result (Global R = 0.825, Significance level = 0.1%) with the majority of pairwise comparisons (492 out of 531) indicated a significant difference (results not shown). However, the most relevant comparison for site-year combinations relate to identifying differences between years within sites. While the ordination results suggest that site differences are more important, there were significant differences between years within five of the seventeen site-year pairwise comparisons (i.e. Significance level = 2.9%), including Carrickalinga Head, Dodd's Beach, Myponga Point, Myponga South and Rapid Head Cliffs (Table 13). Of the remainder, six sites were marginally non-significant (Significance level = 5.7%), including The Bluff, Yankalilla, Haycock Point, Morgans, Rapid Head Windmill and Shagg Rock (Table 13). It is potentially disturbing that most of these sites are close to the southern Adelaide metropolitan area and may be under similar threat.

**Table 13 - PRIMER ANOSIM analysis of site-year data, looking at a subset of the pairwise comparisons that considers each site between years.**

| Groups | R Statistic | Significance Level (%) |
|---|---|---|
| SV06, SV07 | -0.042 | 54.3 |
| RI06, RI07 | 0.115 | 31.4 |
| SS06, SS07 | 0.104 | 17.1 |
| RN06, RN07 | 0.167 | 14.3 |
| SE06, SE07 | 0.146 | 14.3 |
| GI06, GI07 | 0.198 | 11.4 |
| BL06, BL07 | 0.333 | 5.7 |
| YA06, YA07 | 0.625 | 5.7 |
| HP06, HP07 | 0.281 | 5.7 |
| MG06, MG07 | 0.333 | 5.7 |
| RW06, RW07 | 0.458 | 5.7 |
| SH06, SH07 | 0.531 | 5.7 |
| CA06, CA07 | 0.656 | 2.9 |
| DD06, DD07 | 0.979 | 2.9 |
| MP06, MP07 | 0.802 | 2.9 |
| MS06, MS07 | 0.479 | 2.9 |
| RH06, RH07 | 0.635 | 2.9 |

PRIMER MVDISP results for the non-significant site-year pairwise comparisons tended to be higher at one or both observations (although not Rapid Head North and Seal Island; Table 12) which may suggest that sampling was not intense enough to discern differences between consecutive years.

PRIMER SIMPER analysis using a cut off of 50% of the cumulative similarity revealed a suite of 18 taxa as the dominant drivers (Table 14). Most of the biotic contributors were macroalgae (12 species or species groups), followed by three fish, two substrates and one invertebrate (Table 14). Again most of the macroalgae comprise larger, canopy-forming species. While macroalgae dominate the group of similarity drivers, in terms of the number of site-year combinations, *Trachinops noarlungae* was by far the most frequent (16 site-year combinations), followed by *Sargassum* spp. subgenus *Sargassum* (7 site-years), *Cystophora expansa* and the Dictyotaceae (6 site-years) and Crustose coralline algae (5 site-years). Seven taxa were important contributors to similarity within only one site-year (Table 7).

**Table 14 - Summary of SIMPER analysis results for taxa contributions to similarity within each site-year combination up to 50% cumulative similarity. Values represent average abundance within each site-year.**

| SITEYEAR | Crustose coralline algae | *Cystophora brownii* | *Cystophora expansa* | *Cystophora moniliformis* | *Cystophora subfarcinata* | Dictyotaceae | *Ecklonia radiata* | Encrusting brown algae | *Haliptilon roseum* | *Sargassum* spp. (subgenus *Arthrophycus*) | *Sargassum* spp. (subgenus *Sargassum*) | *Sargassum verruculosum* | *Notolabrus tetricus* | *Siphamia cephalotes* | *Trachinops noarlungae* | *Turbo undulatus* | Gravel | Sand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BL06 | | | | | | | 26.6 | | | | | | | | | | | |
| BL07 | 12.1 | | | | | | 20.5 | | | | | | | | | | | |
| CA06 | 19.8 | | | | | | | | | | | | | | 18.7 | | | |
| CA07 | | | | | | | | | | | | | | | 20.1 | 14.5 | | |
| DD06 | | | | | 14.6 | 12.9 | | | | | | | | | | | | |
| DD07 | | | | | | | | 8.48 | | | | | | 28.8 | | | | |
| GI06 | 33.8 | | | | | | | | | | | | | | | | | |
| GI07 | 27.4 | | | | | | | | | | | | | | | | | |
| HP06 | | | | | | | | | | | | | | | 26.4 | | | |
| HP07 | | | 12.2 | | | | | | | | 14.1 | | | | | | | |
| MG06 | | | 10.4 | 10.6 | 12.2 | | | | 5.61 | | | 7.38 | | | | | | |
| MG07 | | | 14.4 | | | | | | | | | 7.31 | | | | | 10.9 | |
| MP06 | | | | | | | | | | | 21.7 | | | | | | | |
| MP07 | | 4.47 | | | 8.81 | 5.96 | | | | | | | | 15.1 | | | | |
| MS06 | | 13.0 | | | | 17.3 | | | | | | | | | | | | |
| MS07 | | | | | | | | | | | 15.4 | | | | 19.3 | | | |
| RH06 | | | | | | 4.8 | 9.44 | | | | 14.0 | | 4.46 | | | | | |
| RH07 | | | | | | | | | | | | | | 31.9 | 10.6 | | | |
| RI06 | | | | | | | | | | | | | | | 15.7 | 14.5 | | |
| RI07 | | | | | | | | | | | | | | 10.7 | 16.8 | 13.6 | | |
| RN06 | | | | | | | | | | | | | | | 47.5 | | | |
| RN07 | | | | | | | | | | | | | | | 42.6 | | | |
| RW06 | | | 13.9 | | | | | | | | 17.1 | | | | | | | |
| RW07 | | | 10.7 | | | | | | | | | | | | 27.0 | | | |
| SE06 | | | | | | | 26.7 | | | | | | | | | | | |
| SE07 | 31.7 | | | | | | | | | | | | | | | | | |
| SH06 | | | | | | | | | | | | | | | 29.1 | | | |
| SH07 | | | | | | 12.4 | | | | | | | | | | 11.0 | | |
| SS06 | | | | | | 12.1 | | | | 7.2 | 10.8 | | | | | | | |
| SS07 | | | | | | | | | | | 11.9 | | | | 25.9 | | | |
| SV06 | | | | | | | | | | | | | | | 42 | | | |
| SV07 | | | 10.2 | | | | | | | | | | | | 27.9 | | | |
| YA06 | | | | | | | | | | | | | | | 52.4 | | | |
| YA07 | | | | | | | | | | | | | | | 16.1 | | | 20.6 |

Pairwise comparisons from the SIMPER analysis between site-year combinations were restricted to identifying differences between years within each site (similar to the above MVDISP analysis). Consideration of the cumulative dissimilarity cut off at 50% revealed 30 taxa (22 macroalgae, three substrates, three invertebrates and two fish) as being influential in terms of determining differences between years within sites (Table 15).

**Table 15 - SIMPER analysis results for site-year differences focussing on taxa influential on changes between years within each site. Values represent average abundance within each site-year group.**

| | | | | |
|---|---|---|---|---|
| YA06 & YA07 | 59.52 | | 52.4 16.1 | 0 20.6 |

| Pairwise group | BL06 & BL07 | | CA06 & CA07 | | DD06 & DD07 | | GI06 & GI07 | | HP06 & HP07 | | MG06 & MG07 | | MP06 & MP07 | | MS06 & MS07 | | RH06 & RH07 | | RI06 & RI07 | | RN06 & RN07 | | RW06 & RW07 | | SE06 & SE07 | | SH06 & SH07 | | SS06 & SS07 | | SV06 & SV07 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg Dissimilarity | 42.43 | | 49.15 | | 66.61 | | 40.44 | | 48.38 | | 59.63 | | 68.45 | | 58.23 | | 60.31 | | 52.07 | | 37.17 | | 53.02 | | 35.07 | | 59.72 | | 53.85 | | 49.62 | |
| *Acrocarpia paniculata* | | | | | | | 8.07 | 10.2 | | | | | | | | | | | | | | | | | 6.78 | 6.42 | | | | | | |
| *Amphibolis* spp | | | | | | | | | | | 4.24 | 0.55 | | | | | | | | | | | | | | | | | 10.2 | 2.99 | | |
| Crustose coralline algae | 22 | 12.1 | 19.9 | 9.75 | | | 33.8 | 27.4 | | | | | | | | | | | | | | | | | 25.3 | 31.7 | | | | | | |
| *Cystophora brownii* | | | | | | | | | | | | | | | 13.1 | 4.17 | | | | | | | | | | | | | | | | |
| *Cystophora expansa* | | | | | | | | | 13.9 | 12.25 | 10.4 | 14.4 | | | | | | | | | 3.76 | 6.23 | | | | | | | | | 7.78 | 10.2 |
| *Cystophora monilifera* | | | | | | | | | | | | | | | | | | | | | 7.63 | 6.55 | | | | | | | | | | |
| *Cystophora moniliformis* | | | | | | | | | | | 10.6 | 6.71 | | | | | | | | | | | | | | | | | | | | |
| *Cystophora subfarcinata* | | | | | 1.56 | 4.37 | | | | | 12.2 | 1.51 | | | | | | | | | | | | | | | 5.98 | 14.0 | | | | |
| Dictyotaceae | | | | | | | | | | | | | | | | | | | | | | | | | | | 2.53 | 12.4 | | | | |
| *Ecklonia radiata* | 26.6 | 20.5 | 14.9 | 10.04 | | | 27.1 | 19.1 | 13.9 | 0.91 | | | | | | | 9.44 | 2.97 | | | | | | | 26.7 | 31 | 12.4 | 3.09 | | | 6.41 | 10.0 |
| Encrusting brown algae | | | | | 0 | 8.48 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Filamentous browns | | | | | 15.0 | 0 | | | | | | | 19.6 | 0 | | | | | | | | | | | | | | | | | | |
| Foliose reds | | | | | | | | | | | | | | | | | | | | | | | | | 5.12 | 1.76 | | | | | | |
| *Haliptilon roseum* | | | | | | | | | | | 5.61 | 1.77 | | | 14 | 1.46 | | | 2.66 | 5.04 | | | | | | | | | | | | |
| *Hincksia* spp | | | | | | | | | | | | | | | | | | | 14.6 | 0 | | | | | | | | | | | | |
| *Peyssonnelia* flat | 0.27 | 4.81 | | | | | 0 | 8.33 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Phloiocaulon/Halopteris* complex | | | | | | | | | | | | | | | | | | | | | | | 9.34 | 0 | 3.52 | 1.34 | | | | | | |
| *Sargassum decipiens/sonderi* | | | | | | | | | | | | | | | | | | | | | 5.19 | 2.44 | | | | | | | | | | |
| *Sargassum* spp (subgenus *Sargassum*) | | | | | | | | | | | | | 21.7 | 5.53 | | | 14 | 6.76 | | | | | 17.1 | 10.6 | | | | | 10.8 | 11.9 | 8.14 | 6.44 |
| *Sargassum verruculosum* | | | | | | | | | | | 7.38 | 7.31 | | | | | 5.27 | 4.03 | | | | | | | | | | | | | | |
| *Scytothalia dorycarpa* | 14.2 | 10.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turf | 2.4 | 5.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cenolia tasmaniae* | | | | | | | | | | | | | | | 0 | 12.6 | | | | | | | | | | | | | | | | |
| *Cenolia trichoptera* | | | | | | | | | | | | | | | | | | | | | | | | | 3.62 | 0.63 | | | | | | |
| *Siphamia cephalotes* | | | 0 | 11.49 | 0.16 | 28.8 | | | | | | | 1.02 | 15.1 | | | 2.38 | 31.9 | 1.99 | 10.7 | | | | | | | | | 0.23 | 1.56 | | |
| *Trachinops noarlungae* | | | 18.7 | 20.1 | | | | | 26.4 | 14.5 | | | 0 | 13.7 | 0 | 19.3 | 5.48 | 10.6 | 15.7 | 16.8 | 47.5 | 42.6 | 12.5 | 27.0 | | | 29.1 | 9.28 | 17.1 | 25.9 | 42 | 27.9 |
| *Turbo undulatus* | | | 3.76 | 14.5 | | | | | | | | | | | | | | | 14.5 | 13.6 | | | | | 0.37 | 3.13 | | | | | | |
| Bare rock (non - barrens) | | | | | | | | | 0 | 12.3 | | | | | | | | | | | | | | | | | | | | | | |
| Gravel | | | | | | | | | | | 0 | 10.9 | | | | | | | 3.1 | 2.39 | 0 | 6.08 | 1.01 | 9.12 | | | | | | | | |
| Sand | | | | | | | | | | | 0 | 5.72 | | | | | | | | | | | | | 0.43 | 3.38 | | | | | | |

Differences within each site between years thus also appear to be determined largely by changes in larger, canopy-forming macroalgae, including; *Cystophora* spp., *Sargassum* spp., *Acrocarpia paniculata*, *Ecklonia radiata* and *Scytothalia dorycarpa* (Table 15). *Trachinops noarlungae* was influential at 12 of the 17 pairwise comparisons followed by *Ecklonia radiata* (eight comparisons) and *Sargassum* spp. subgenus *Sargassum* (five comparisons; Table 15), although 13 taxa were influential within only one site-year comparison. From two to eight taxa were required to attain a cumulative dissimilarity of 50% between site-year groups, although most sites (16 out of 17) required four or more. Apart from *Trachinops noarlungae*, *Ecklonia radiata* and *Sargassum* spp. subgenus *Sargassum*, differences between years within a site are thus largely contingent upon changes to a specific group of taxa within each site.

## Seasonal comparison from selected 2007 sites

Four sites from the 2007 were surveyed in both summer/autumn (December –April) and the following spring (September – November). All of the sites considered were in the Encounter Bay region including The Bluff, Flat Irons, Outside Granite Island and Seal Island (Table 4).

Ordination of standardised data at the transect level revealed no dominant trend between seasons, although summer/autumn was possibly more variable than the spring. There was differentiation between season at the Flat Irons and Outside Granite Island, but substantial intermingling of Seal Island and Bluff sites (Figure 14). Reef composition in summer/autumn around Encounter Bay is thus often different but within the spectrum of compositions observed across the general area.

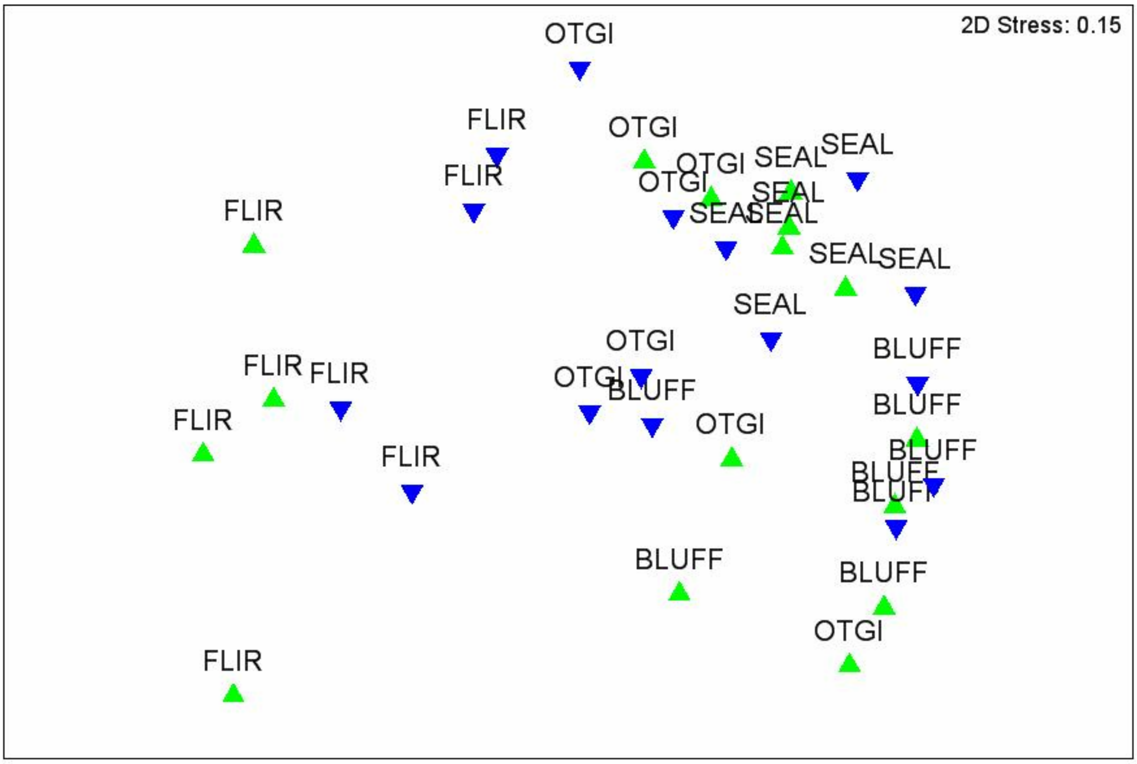


**Figure 14 - MDS ordination in two dimensions of the seasonal changes within sites from the Encounter Bay region. Green triangles = summer/autumn samples, blue triangles = spring.**

Although there were significant differences within the ANOSIM analysis (Global R = 0.599, Significance Level = 0.1%), when considering pairwise comparisons between seasons within each site there were no significant differences (Table 16).

**Table 16 – ANOSIM analysis of seasonal difference within sites.**

| Groups | R - Statistic | Significance Level (%) |
|---|---|---|
| BL1, BL2 | 0.021 | 40 |
| FI1, FI2 | 0.302 | 8.6 |
| GI1, GI2 | 0.031 | 48.6 |
| SE1, SE2 | -0.063 | 57.1 |

SIMPER results for dissimilarity between seasons within sites are once more dominated by macroalgae (Table 17) comprising 10 of the 11 taxa determining up to 50% of the dissimilarity between seasons within each site.

**Table 17 - SIMPER analysis of taxa contributing to within site dissimilarity between seasons up to 50% of the dissimilarity. Note 1 = summer/autumn, 2 = spring.**

| Taxa | BL_1 & BL_2 | | FI_1 & FI_2 | | GI_1 & GI_2 | | SE_1 & SE_2 | |
|---|---|---|---|---|---|---|---|---|
| **Average dissimilarity** | **55.06** | | **41.21** | | **44.88** | | **31.29** | |
| *Acrocarpia paniculata* | | | 16.12 | 14.65 | 10.22 | 17.09 | 6.42 | 6.89 |
| *Cenolia trichoptera* | 10.7 | 7.48 | | | | | | |
| Crustose coralline algae | 12.09 | 17.12 | 7.06 | 21.94 | 27.45 | 33.88 | 31.74 | 31.82 |
| Dictyotaceae | | | 9.8 | 2.21 | | | | |
| *Ecklonia radiata* | 20.49 | 23.52 | | | 19.1 | 7.95 | 31 | 29.8 |
| Geniculate corallines | | | 3.52 | 5.58 | | | | |
| *Peyssonnelia* flat | 4.81 | 6.4 | | | | | 0.48 | 6.26 |
| Sand | | | 12.92 | 0.58 | | | 3.38 | 0.05 |
| *Scytothalia dorycarpa* | 10.08 | 10.31 | | | | | | |
| *Seirococcus axillaris* | | | 2.59 | 6.46 | | | | |
| Turf | 5.6 | 6.53 | | | | | 2.12 | 4.7 |

Given that these comparisons examine only one seasonal difference (i.e. within 2007) a degree of care needs to be undertaken in interpreting the results. For this reason, a detailed analysis of within and between site-season differences was not undertaken. It is also worth noting that unless there is were fixed sampling points for sampling within each site, at least some of the differences observed between observations may relate to small-scale spatial differences in reef composition. There is a substantial body of literature linking changes in reef macroalgal community to seasonal trends within southern Australia, particularly amongst the fucalean species (e.g. *Cystophora* spp., *Sargassum* spp. and *Acrocarpia* spp.; e.g. Edgar 1983, Collings 1996, Edgar *et al.* 2004, Collings *et al.* 2008).

## Physical environmental parameters relative to 2007 observations

Analysis if the physical environmental data from each 2007 site was correlated to biological patterns within similarity data using the PRIMER BEST analysis (Clarke and Gorley 2006) with the number of variables within each comparison limited to two. The average abundance across transects within each site was considered relative to ten environmental variables related to substrate, energy, temperature and relative position (Table 18).

Initial results found that Maximum Spring Tidal Range (MSTR) produced the best correlation with biological data (ρ "Rho" = 0.711; Table 19). Given the observed relationship of sites relative to position along the coast a strong correlation with tidal range was not unexpected. However, while there may be some relationship between tidal range in determining differences between sites (particularly given the relatively shallow depth considered), it needs to be remembered that a correlation does not imply causality.

If MSTR is removed from the analysis, Sea Surface Temperature (SST) related factors for summer and range become more pronounced along with Latitude, although the correlation is poorer (ρ = 0.676; Table 19). Summer SST, SST range and latitude are not independent of each other as reflected in a series of Draftsman Plots (not shown). Possibly the most interesting point is that factors related to the energy environment (relative exposure and aspect) and substrate (substrate and relief) appear to have minimal influence.

**Table 18 - Sites considered in reef surveys as well as the physical data considered for each site. MSTR = maximum spring tidal range, SST = sea surface temperature.**

| SST range (°) |
|---|
| 5.4127 |
| 6.9972 |
| 5.477 |
| 6.9237 |
| 6.3146 |
| 5.6508 |
| 6.8961 |
| 6.4618 |
| 7.2813 |
| 7.2853 |
| 5.7638 |
| 6.0327 |
| 5.9497 |
| 5.3384 |
| 6.3021 |
| 6.4691 |
| 6.2154 |
| 7.2853 |
| 6.2491 |
| 5.7971 |
| 6.9621 |
| 6.9972 |
| 7.1116 |
| 5.8245 |
| 6.8701 |

| Location Name | Latitude | Depth (m) | Relative Exposure | Relief | Substrate | Aspect | MSTR (m) | SST winter (°) | SST summer (°) |
|---|---|---|---|---|---|---|---|---|---|
| Blowhole Beach | S35.65974 | 5 | Moderate | 1 | Metamorphic | 3 | 1.153 | 13.5378 | 18.9505 |
| Carrickalinga Head | S35.398 | 5 | Moderate | 4 | Metamorphic | 4 | 2.23 | 13.5691 | 20.5663 |
| Deep Creek | S35.64086 | 5 | Moderate | 3 | Metamorphic | 3 | 1.153 | 13.344 | 18.821 |
| Dodd's Beach | S35.40416 | 5 | Moderate | 2 | Metamorphic | 4 | 2.23 | 13.5871 | 20.5108 |
| Fisheries Beach | S35.63411 | 5 | Low | 2 | Metamorphic | 3 | 1.153 | 13.2502 | 19.5648 |
| Flat Irons | S35.61781 | 5-7 | Extreme | 3 | Metamorphic | 3 | 1.153 | 13.7712 | 19.422 |
| Haycock Point | S35.41545 | 5 | Moderate | 1 | Metamorphic | 4 | 2.23 | 13.5871 | 20.4832 |
| Morgans | S35.58845 | 5 | Low | 1 | Metamorphic | 4 | 1.746 | 13.2974 | 19.7592 |
| Myponga Point | S35.37988 | 5 | Moderate | 2 | Metamorphic | 4 | 2.23 | 13.2741 | 20.5554 |
| Myponga South | S35.38821 | 5 | Moderate | 2 | Metamorphic | 4 | 2.23 | 13.2741 | 20.5594 |
| Naiko East | S35.65378 | 5 | Moderate | 3 | Metamorphic | 3 | 1.153 | 13.3572 | 19.121 |
| Naiko West | S35.64675 | 5 | Moderate | 3 | Metamorphic | 3 | 1.153 | 13.2042 | 19.2369 |
| Outside Granite Island | S35.56754 | 5 | Extreme | 4 | Granite | 3 | 1.153 | 13.6616 | 19.6113 |
| Porpoise Head | S35.66232 | 5 | Moderate | 3 | Metamorphic | 3 | 1.153 | 13.4877 | 18.8261 |
| Rapid Head Cliffs | S35.52045 | 5 | Moderate | 1 | Metamorphic | 4 | 1.746 | 13.8448 | 20.1469 |
| Rapid Head North | S35.51922 | 5 | Moderate | 1 | Metamorphic | 1 | 1.746 | 13.7344 | 20.2035 |
| Rapid Head Windmill | S35.53085 | 5 | Moderate | 1 | Metamorphic | 4 | 1.746 | 13.8789 | 20.0943 |
| Ripple Rock | S35.38386 | 5 | Moderate | 2 | Metamorphic | 4 | 2.23 | 13.2741 | 20.5594 |
| Salt Creek | S35.5526 | 5 | Moderate | 1 | Metamorphic | 4 | 1.746 | 13.7928 | 20.0419 |
| Seal Island | S35.57618 | 5 | Extreme | 4 | Granite | 1 | 1.153 | 13.7795 | 19.5766 |
| Second Valley | S35.50594 | 5 | Low | 3 | Limestone | 4 | 2.054 | 13.3289 | 20.291 |
| Shagg Rock | S35.39933 | 5 | Moderate | 4 | Limestone | 4 | 2.23 | 13.5691 | 20.5663 |
| Sunset Cove South | S35.50467 | 5 | Moderate | 1 | Limestone | 4 | 2.054 | 13.1953 | 20.3069 |
| The Bluff | S35.58996 | 5 | Extreme | 4 | Granite | 3 | 1.153 | 13.7398 | 19.5643 |
| Yankalilla | S35.42445 | 4-5 | Moderate | 1 | Limestone | 4 | 2.23 | 13.5855 | 20.4556 |

Some care must be taken in the interpretation of these results as they comprise a mixture of ordinal (temperatures, depth, Latitude and MSTR), nominal (relative exposure and relief) and categorical data (substrate and aspect).

**Table 19 - Results of PRIMER BEST analysis examining the correlation between physical factors and the observed biological differences averaged at the site level.**

| All Variables: ρ = 0.711 | Correlation |
|---|---|
| MSTR | 0.711 |
| MSTR, SST Summer | 0.711 |
| MSTR, SST Range | 0.703 |
| Latitude, MSTR | 0.702 |

| | |
|---|---|
| SST Summer | 0.676 |
| SST Summer, SST Range | 0.676 |
| Latitude, SST summer | 0.671 |
| MSTR, SST Winter | 0.643 |
| SST Winter, SST Summer | 0.62 |
| SST Range | 0.619 |

| **Without MSTR: ρ = 0.676** | |
|---|---|
| SST Summer | 0.676 |
| SST Summer, SST Range | 0.676 |
| Latitude, SST Summer | 0.671 |
| SST Winter, SST Summer | 0.62 |
| SST Range | 0.619 |
| Latitude, SST Range | 0.619 |
| Relative Exposure, SST Summer | 0.61 |
| Aspect, SST Range | 0.607 |
| Relief, SST Summer | 0.604 |
| Aspect, SST Summer | 0.6 |

## Biodiversity indicators

Biodiversity data from 2007 sites at the transect level were considered in terms of nine different diversity indices, including (see Clarke and Gorley 2006; Appendix C):

- The total species present within the sample (S),
- The number of individuals within the sample (N),
- Species richness (Margalef, d),
- Shannon-Weiner Diversity (H′),
- Pielou's evenness index (J′),
- Simpson's indices (1-λ′),
- Hill's indices (N1 and N2), and
- Rarefaction looking at the number of species based on the number of observations, in this instance using ES = 329 which was the smallest number of individuals observed across all samples.

Statistical differences in biodiversity within 2007 observations were then considered using ANOVA for each index, with the aim of identifying which approach was most appropriate for looking at diversity differences between sites. In addition, species number (S) and Rarefaction were considered in terms of the Benkendorff and Davis (2002) approach to identification of diversity hotspots.

ANOVAs were significant for all indices (Table 20) which suggest that none of the indices is distinctive with respect to identifying diversity differences between sites and/or that the pattern of biodiversity between and within sites is complex (see Appendix C).

**Table 20 - ANOVA analyses of diversity indices across 2007 reef sites.**

| Factor | SS | df | MS | F-ratio | p-value |
|---|---|---|---|---|---|
| **S** | | | | | |
| Site | 2161.24 | 24 | 90.052 | 4.006 | 0.000 |
| Error | 1685.75 | 75 | 22.477 | | |
| **N** | | | | | |
| Site | 2210929.94 | 24 | 92122.081 | 2.176 | 0.006 |
| Error | 3174841.75 | 75 | 42331.22 | | |
| **d** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Site | 56.102 | 24 | 2.338 | 4.577 | 0.000 |
| Error | 38.304 | 75 | 0.511 | | |
| **Pielou** | | | | | |
| Site | 0.327 | 24 | 0.014 | 3.085 | 0.000 |
| Error | 0.331 | 75 | 0.004 | | |
| **Rarefaction** | | | | | |
| Site | 1973.116 | 24 | 82.213 | 5.13 | 0.000 |
| Error | 1201.882 | 75 | 16.025 | | |
| **Shannon** | | | | | |
| Site | 7.314 | 24 | 0.305 | 3.981 | 0.000 |
| Error | 5.742 | 75 | 0.077 | | |
| **Simpson** | | | | | |
| Site | 0.242 | 24 | 0.01 | 3.032 | 0.000 |
| Error | 0.249 | 75 | 0.003 | | |
| **Hill N1** | | | | | |
| Site | 1231.69 | 24 | 51.32 | 3.792 | 0.000 |
| Error | 1015.098 | 75 | 13.532 | | |
| **Hill N2** | | | | | |
| Site | 649.604 | 24 | 27.067 | 2.96 | 0.000 |
| Error | 685.855 | 75 | 9.145 | | |

Consideration of the top four sites in terms of the average across transects for each index identified a similar suite of sites for most indices except the number of observations (N; Table 21). The number of organisms observed at a site is arguably not as affective an indicator of diversity relative to other measures as it is prone to bias by large numbers of few (or one) taxa, in particular schools of fish that may not actually be resident. However, putting aside these issues, Carrickalinga Head, Rapid Head North, Second Valley and Ripple Rock would be considered important locations based on the number of observations (Table 21). It is worth noting that all of these sites are on the GSV coast of Fleurieu Peninsula.

Otherwise, across the remaining eight indicators seven sites were consistently identified as having high diversity, including Blowhole Beach, Fisheries Beach, Flat Irons, Ripple Rock, Naiko West, Morgans and Naiko East (Table 21). Most of these sites (not Morgans or Ripple Rock) occur along the southern Fleurieu coast, mostly around Cape Jervis (Figure 11).

**Table 21 - The top four locations identified within each diversity index based on the average across value across transects for each site.**

| Order | S | N | d | Pielou | Rarefaction | Shannon | Simpson | Hill_N1 | Hill_N2 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | BLOW | CAHE | BLOW | MORG | BLOW | FISH | FISH | FISH | FISH |
| 2 | RIPP | RAHN | FISH | FISH | FISH | BLOW | MORG | BLOW | MORG |
| 3 | FISH | SECV | FLIR | NAIE | FLIR | MORG | BLOW | MORG | BLOW |
| 4 | FLIR | RIPP | RIPP | BLOW | NAIW | NAIE | NAIE | NAIE | NAIE |

Benkendorff and Davis (2002) developed a cut off approach to identification of biodiversity "hotspots" based around the mean value across all samples combined with 95% confidence limits and multiples of the standard deviation. Consideration of the total number of species (S) and Rarefaction indices with this approach showed substantial differences between the two indices in terms of the number of sites that were highlighted.

Rarefaction identified 22 sites as having index scores above the upper 95% confidence level of which 14 were also higher than the mean + stdev and 3 occurred above the mean + stdev × 2 while no sites were in the mean + stdev × 3 range (Table 22). Conversely species number indicated 11 sites above 95% confidence level and two were higher than the mean + stdev and no sites in either the mean + stdev × 2 or mean + stdev × 3 groups (Table 22). Blowhole Beach and Ripple Rock were important in assessments of both indices, with the addition of Fisheries beach under Rarefaction.

Identification of diversity hotspots is an important component to the development of conservation and management priorities and capability (Benkendorff and Davis 2002). Based on the results of the above, Blowhole Beach, Fisheries Beach, Flat Irons, Ripple Rock, Naiko West, Morgans and Naiko East appear to stand out as being relatively more diverse than other reefs along the Fleurieu coast. However, diversity hotspots may be considered from a number of different aspects, including endemism, the range of available habitats, rare or endangered species and habitats as well as the density of aesthetic, cultural or historical values.

**Table 22 - Consideration of species number (S) and Rarefaction with respect to the cut offs identified by Berkendorff and Davis (2002).**

| Site | S | Upper 95% CL | Mean + Stdev | Mean + Stdev × 2 | Mean + Stdev × 3 | Rarefaction | Upper 95% CL | Mean + Stdev | Mean + Stdev × 2 | Mean + Stdev × 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cut off | | 39.23 | 44.22 | 50.46 | 56.69 | | 32.87 | 37.41 | 43.07 | 48.73 |
| MYPP | 35.5 | | | | | 29.36 | 1 | | | |
| RIPP | 45.25 | 1 | 1 | | | 35.53 | 1 | 1 | 1 | |
| MYPS | 34.5 | | | | | 28.90 | 1 | | | |
| CAHE | 38.25 | | | | | 29.52 | 1 | 1 | | |
| SHAG | 35.75 | | | | | 29.56 | 1 | | | |
| DODD | 34.75 | | | | | 28.54 | 1 | | | |
| HAYP | 35.5 | | | | | 29.41 | 1 | | | |
| YANK | 40.5 | 1 | | | | 33.83 | 1 | 1 | | |
| SUNS | 31.5 | | | | | 25.45 | | | | |
| SECV | 38.25 | | | | | 29.23 | 1 | 1 | | |
| RAHN | 39.25 | 1 | | | | 29.49 | 1 | 1 | | |
| RAHC | 36.5 | | | | | 28.41 | 1 | | | |
| RAHW | 39.5 | 1 | | | | 33.20 | 1 | 1 | | |
| SALT | 35.5 | | | | | 31.48 | 1 | | | |
| MORG | 38.5 | | | | | 35.79 | 1 | 1 | | |
| FISH | 44 | 1 | | | | 38.34 | 1 | 1 | 1 | |
| NAIW | 41.75 | 1 | | | | 36.33 | 1 | 1 | | |
| NAIE | 41 | 1 | | | | 36.14 | 1 | 1 | | |
| BLOW | 47.25 | 1 | 1 | | | 40.72 | 1 | 1 | 1 | |
| PORP | 42.25 | 1 | | | | 35.96 | 1 | 1 | | |
| DEEP | 39.25 | 1 | | | | 33.40 | 1 | 1 | | |
| FLIR | 42.5 | 1 | | | | 37.18 | 1 | 1 | | |
| BLUF | 36.75 | | | | | 31.13 | 1 | | | |
| OTGI | 27.75 | | | | | 23.58 | | | | |
| SEAL | 28.25 | | | | | 23.20 | | | | |
| Total | | 11 | 2 | 0 | 0 | | 22 | 14 | 3 | 0 |

# Discussion

The following provides a summary of the results of marine habitat mapping and reef assessments as well as a contextual framework for their interpretation and possible mechanisms for moving forward.

## *Marine habitat mapping in the AMLR NRM region*

Marine systems within the AMLR NRM region are diverse, extensive and provide broad range of ecosystem services (AMLR NRM 2007). Recent State of the Region reporting as undertaken by the AMLR NRM Board considered marine systems relative to the nine IMCRA biounits within the AMLR region as well as 'Important Marine Habitats', including (AMLR NRM 2007):

- Subtidal reef systems divided across;
    - Metropolitan reefs and
    - Fleurieu Peninsula reefs,
- Seagrass meadows,
- Soft and sandy bottoms,
- Intertidal rocky reefs,
- Sandy and muddy beaches and
- Beach wrack.

The marine habitat mapping approach employed for the AMLR NRM region is broadly reflective of these habitat types although with substantially more information relative to distribution and density. Importantly, the identification of threats to marine systems was also undertaken within each of the above habitats (AMLR NRM 2007), and can therefore be related directly to mapped areas.

In addition, the methodology employed in mapping has placed a substantial emphasis on encompassing the requirements identified by Allee *et al.* (2000) for a national marine habitat classification system (see above). Connell and Irving (2008) suggested that natural resources management would benefit from placing the impact of a local scale issues (e.g. fisheries, nutrient enrichment, coastal development, etc) within the broader biogeographic context. The resources developed through this approach thus comprise not only the baseline maps but also a readily applied and consistent mapping methodology such that the current data are a reliable baseline against which to monitor. The mapping approach thus offers capacity for spatial comparisons with locations outside the AMLR NRM region as well as observations of temporal differences within the region.

This project has also produced an extensive acoustic and video database that provides a valuable baseline for monitoring. Regular resurveys of fixed acoustic survey lines provide an opportunity to monitor shifts in habitat boundaries. This is particularly important in seagrass habitats where acoustics could provide information on the movement of erosion scarps (blowouts) and nature of eroding seagrass beds (habitat fragmentation measures). Highly spatially accurate dual frequency acoustic datasets (such as that collected routinely by the Coast Protection Branch of DEH) can also provide information on actual vegetative cover.

The associated extensive video library provides a snapshot of habitat type and condition during the survey period. This dataset can be further investigated to provide more quantitative measures of benthic biota for comparison with future datasets.

The Monitoring, Evaluation and Reporting Framework (MERF) developed by the AMLR NRM Board (AMLR NRM 2008) noted that a failure to engage in long term monitoring has been a particular issue for NRM organisations resulting in a lack of appropriate time series data at the regional scale. To address this issue, the MERF proposes a shift away from program-based monitoring to a regime focussed on a suite of environmental and management indicators targeted on the twenty-year regional targets identified within the related NRM Plan.

Development of marine habitat maps for the AMLR NRM region has been noted as a component to the MERF relative to seagrass and reef health and coastal water quality with indictors related to distribution and condition of marine habitats. However, both marine habitat mapping and reef habitat assessments have application across a range of MERF Regional Targets, including (AMLR NRM 2008):

- T8 Extent of functional ecosystems,
- T10 Land based impacts on coastal, estuarine and marine processes,
- T11 Seagrass, reef and other coast, estuarine and marine processes,
- T12 Coast, estuarine and marine water quality
- T13 Improve the capacity for people in the community, institutions and regional organisations to sustainably manage our natural resources

At the program level, habitat maps may form a key element in assessment of the success or otherwise of management interventions to address water quality issues on the metropolitan coast (the Adelaide Coastal Water Quality Improvement Plan; see Cheshire *et al*. 2008). Similarly, reef habitat assessments from the Fleurieu coast may contribute to ongoing monitoring though either Reef Health and/or Reefwatch, particularly given the expansion of housing in the southern metropolitan area as well as increased populations around Encounter Bay with concomitant potential for the spread of reef health decline.

Marine maps for the AMLR NRM region comprise a substantial resource for development of large-scale, systems-level management and monitoring capability, as well as the identification of geographically discrete areas of concern and/or potential for research. However, a level of care is needed in interpreting habitat maps, particularly relative to any observed changes in density within a given area between consecutive maps as these may relate to seasonal changes in biomass (including epiphytes) or the movement of non-attached drift. Similarly spatial differences need to be considered within an appropriate context. For example, sparse seagrass cover in the Encounter Bay area should not be considered in the same context as similar seagrass patches on the Adelaide metropolitan coast without obtaining data juxtaposing potential differences between each area, including the physical and water quality environments as well as possible species level differences (seagrass species occurring in different areas may have very different growth habits). This highlights both the value of habitat maps in generation of research questions (i.e. what are the water quality, physical environmental and species composition factors structuring seagrass beds on either side of Fleurieu Peninsula) as well as the danger of making overly simplified comparisons. While habitat mapping is an important element of large scale monitoring, the need to collect/collate and analyse other types of information, including other GIS layers (such as sea surface temperature, chlorophyll *a*, sediment movements, etc.) as well as past and current water quality and physical environmental data is an important component in determining both spatial and temporal differences.

There are a substantial number of studies that may contribute supporting information to benthic habitat mapping either through comparison of habitat distributions or as a means of ground truthing. However, much of data concerned are rather dated (a decade or more in age) and uses habitat types or species summaries that may be difficult to reconcile with extant programs. Those studies that are likely to be most useful include:

- Ongoing sediment budget estimates from the Adelaide coast (DEH 2000, 2006b),
- Ongoing satellite imagery,
- The Tanner (2005) benthic mapping throughout Gulf St Vincent,
- Ongoing stock assessments for commercial and recreational fisheries,
- Ongoing Environment Protection Authorities ambient water quality monitoring (Gaylard 2004),
- The recently completed Bryars and Rowling (2008) seagrass mapping exercise from the Adelaide metropolitan coast,
- Recently completed Reef Health and ongoing Reef Watch monitoring and
- Establishment of a marine parks monitoring and evaluation program.

In terms of factors (habitats) not included within the mapping survey, drifting material (mostly non-attached seagrass and/or macroalgae) would probably be the most problematic. Drift cannot be differentiated at the mapping level, although it may apparent from video ground truthing. Given that distribution and abundance of drift material is probably largely unpredictable, attempting to incorporate this component within a consistent benthic mapping framework is unlikely to produce meaningful results without an extensive (and probably unjustifiable) investment in ground truthing. It is worth noting that the non-inclusion of drift has had no effect on the 80% accuracy identified from ground truthing.

The most obvious gap in marine habitat mapping for the AMLR NRM region relates to the lack of data deeper water (> 20 m), the area which is presents the larger portion of the marine area (Figure 1). Recent investigations for the GSV region have highlighted a substantial level of change in deeper areas over the last 30 years (see Tanner 2005). There is thus a need to develop an understanding of the nature of these systems, the threats imposed upon them as well as identification of remnant high quality deeper water habitat for possible protection. While aerial photographs are quite probably at their limit in terms of penetration depth, acoustic methods can provide a means of expanding our understanding of deeper water areas, particularly when combined with benthic imagery.

Apart from deeper water systems, and bearing in mind the above caveats to map interpretation, three priority areas for more targeted monitoring can be proposed;

- Blowout areas in seagrass beds on the southern metropolitan Adelaide coast.

The ACWS noted that seagrass beds in the Brighton/Seacliff area are subject to moon-shaped gouges (called blowouts). While these patches can occur naturally as a product of disturbance, particularly in areas with higher wave energy, blowouts in the southern Adelaide near shore appear to be expanding (see Hart 1997, Bryars *et al.* 2006). Current mapping resolution may not detect individual blowouts, but should show the total area of bed fragmentation. More highly resolved observations, based on strip transects through the area of concern might be employed to examine the number and size of blowouts and possibly track changes relative to fixed points. Similar monitoring has been suggested as a component of the ACWQIP monitoring and assessment framework (Cheshire *et al.* 2008).

- Encounter Bay

The Encounter Bay area is subject to an increasing resident population as well as large seasonal increases during holiday periods, which places substantial strains on infrastructure (Encounter Bay.com Times; http://www.encounterbay.com/ Accessed December 2008). Having established a baseline in terms of natural environments within the general area some attention should be given to developing an understanding of the magnitude of any associated threats (wastewater and stormwater inputs, fisheries, tourism, marine litter and possibly the impact of changes in water quality at the Murray River mouth).

- Rapid Bay seagrass beds

The most significant area of seagrasses in the AMLR NRM region outside the Adelaide metropolitan area occurs within the zone between Normanville and Rapid Bay. Given the pressure of increasing urban developments as well as land degradation on the Fleurieu Peninsula as a result of prolonged drought, there is a possibility that these seagrasses are at risk. As with the Encounter Bay area, the nature and magnitude of threats, particularly to water quality, need to be appropriately quantified.

Marine habitat mapping within the AMLR NRM region thus has a number of important applications, including:

- Providing a large scale assessment framework and consistent approach across the AMLR NRM region that can be further developed and refined as data and data acquisition improves.
- Benthic habitat mapping that is consistent with a national assessment framework.
- An important baseline and serve to target both short term and log term NRM assessments in line with specific projects as well as the broader Monitoring, Evaluation and Reporting Framework.
- Specific areas for targeted investigation within southern metropolitan Adelaide, Encounter Bay and Normanville to Rapid Bay areas.

## Reef systems on the Fleurieu Peninsula coast

Reefs systems in southern Australia are widely accepted as being diverse (e.g. Edyvane 1996, Edyvane 1999a), productive (Cheshire *et al.* 1996a) and supportive of a broad range of ecosystem services (AMLR NRM 2007). Sustainable management of reef systems is therefore a challenging, particularly given the number and variety of threats to which they are exposed and the often competing requirements from a diverse array of stakeholders (Edyvane 1996).

Reef systems on the Adelaide metropolitan coast are considered to be variously degraded as shown by a series of investigations since 1996 (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). The area of reef system decline correlates with the zone of seagrass loss on the Adelaide metropolitan coast (see Westphalen *et al.* 2004b) and has been attributed to similar causes (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007), namely declines in water quality due to nutrients and sediments from wastewater inputs, stormwater drains and catchment degradation (AMLR NRM 2007, Fox *et al.* 2007). Although some reef sites on the Fleurieu Peninsula have been included within Reef Health investigations (notably eight sites in 2005; see Turner *et al.* 2007), these observations were widely distributed and served mostly in expanding our understanding of the range of reef compositions and structures that can be construed as ‘healthy’ (see Turner *et al.* 2007).

Within the current study, assessment of macroalgal, fish and invertebrate community composition from up to 25 reefs on Fleurieu Peninsula found a substantial gradient of site compositions relative to position along the coast. This gradient was not apparent in Reef Health observations, although there were probably not enough sites in the latter to differentiate this trend. Of the eight sites on the Fleurieu coast considered within Reef Health, six were considered to be "Good" while two rated as "Caution" (see Turner *et al.* 2007). Based on an alignment of the locations surveyed in Reef Health to those surveyed in this study, all of these sites would appear to fit within the spectrum of "healthy" reefs as defined by the Reef Health investigations (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). More recent Reef Health investigations have considered a range of eleven indicators. Consideration of the Fleurieu Peninsula sites with respect to these indices was not attempted as part of the current study as it requires a substantial reconsideration of the data and there would remain some information gaps. In addition, these health indices are considered by their authors to be very much as developmental and not without issues in terms of their definition, calculation or interpretation (see Turner *et al.* 2007, Collings *et al.* 2008)

There are relatively few comparable investigations of reef systems on the Fleurieu coast. However, Collings (1996) undertook an intensive investigation of reef macroalgal communities within eight sites spread across Rapid Bay, Cape Jervis and Encounter Bay areas, comprising nine observations undertaken every three months at each site. Gulf St Vincent reefs were found to be clearly different from sites at Cape Jervis and Encounter Bay, with "wave force" considered the major determinant of these differences. The Collings (1996) results were thus in line with observations from elsewhere on the southern Australian coast (e.g. Shepherd and Sprigg 1976, Shepherd and Womersley 1970, 1971, 1976, 1981, Collings and Cheshire 1998).

That the energy environment is a major determinant of compositional differences between reefs is in contrast to the results of this study, although it should be noted that most studies to this point in time have focussed entirely on the macroalgal component. Consideration of ten physical environmental factors relative to reef composition found that Maximum Spring Tidal Range (MSTR) as well as sea surface temperature (SST summer and summer-winter range) formed the best relationships. Even when removed from the analysis, factors related to the energy environment, chiefly aspect and relative exposure, were not found to be important. That tidal range correlates with reef composition is unsurprising given that both are strongly predicated upon position along the Fleurieu coast. Temperature is a critical factor in the distribution of organisms in marine systems and plays a role, particularly with respect to specific species distributions. However most of the physical factors considered are correlated with each other and therefore position along the coast. It also needs to be noted that these analyses do not necessarily infer a causal mechanism. In all likelihood, reef compositional differences are likely to result from the interaction of a range biotic and abiotic factors the influences of which probably vary both spatially and temporally. Similarly, factors that did not correlate with reef compositional differences observed within the current investigation may be influential on community structure when considered at different spatial scales.

Differences in reef community composition between consecutive years within sites were relatively marginal and lacked a consistent trend across sites. Similarly, differences within reefs across seasons (spring versus summer/autumn) also appeared to be somewhat site specific. However, Collings (1996) found a substantial consistency in terms of seasonal changes across sites, but noted that spring was exceptional with a high level of variability, probably due to differences in macroalgal recruitment. Comparison of seasonal differences would therefore appear to be more informative if constrained to summer versus winter.

It may also be argued that analysis across one pair of consecutive years (2006 versus 2007) and a single season (summer/autumn 2007 versus spring 2007) with a limited number of sites (only four) do not constitute a comprehensive assessment of temporal differences. Further, it is not established that at least some of the observed changes are not actually related to small-scale spatial variability within reefs owing to slight differences in sampling. Ideally, both inter and intra annual assessments should be undertaken from a range of sites and a number of years and should consider the use of fixed sampling points. It should be noted that there was data available for some reef sites from 2005, but these were not considered within the current analysis. Similarly, data for seasonal assessment at some sites was frequently confounded either by depth or lack of alternative seasonal data from the same location. Assessment of reef systems along the lines of the current study on an annual basis is probably not a cost effective monitoring approach. However, this does not preclude frequent monitoring of specific areas of concern or interest (such as Horseshoe Reef in the southern metropolitan area; see Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008).

However, both seasonal and interannual analysis would appear to confirm that monitoring of reef systems is best constrained to a particular time of year (most preferably summer and early autumn) and should probably be undertaken at intervals of three to five years. In the absence of a specific threat, this approach would offer a capacity for consistent assessment of reef locations that is capable of discerning medium term temporal differences. It also appears that surveys require somewhat more structure such that orthogonal data are collected from a range of sites in support of a specific monitoring question (i.e. how does reef composition in summer for sites on the Fleurieu coast change over scales of 3-5 years). Such an approach would constrain observations as well align the survey frequency for Reef Health assessments (assuming these are continued) but at the same time support the broader principles for monitoring identified within the MERF (AMLR NRM 2008).

Reef composition on the Fleurieu Peninsula followed a gradient of change relative to position along the coast with the macroalgal component of each site contributing most to the similarity within sites as well as differences between sites in spatial and temporal terms, including:

- 2006 versus 2007 interannual observations from summer/autumn,
- Summer/autumn versus spring for 2007,
- Close (generally adjacent) sites within 2007 observations, and
- Spatially distinct sites (i.e. those inside versus outside GSV) within 2007 observations.

Importantly, it was often differences within the same taxa that determined both larger and smaller scale dissimilarity (up to 50%). The majority of the taxa responsible for determining differences between as well as similarity within sites were arguably from canopy-forming groups, including:

- *Ecklonia radiata,*
- *Cystophora* spp. (*C. brownii, C. expansa, C. moniliformis, C. monilifera, C. subfarcinata*),
- *Sargassum* spp. (*Sargassum* spp. subgenus *Sargassum, S. decipiens/sonderi, S. varians, S. verruculosum*),
- *Acrocarpia paniculata,*
- *Scytothalia dorycarpa,* and
- *Seirococcus axillaris.*

Minor and subcanopy macroalgal species were more varied but generally included (amongst others):

- Crustose coralline algae,
- Dictyotaceae,
- Encrusting brown algae,
- *Haliptilon roseum,* and
- Turf.

In addition, substrate factors were also frequently important, including:

- Bare rock,
- Gravel, and
- Sand.

Non-macroalgal species that were consistently found to be influential on similarity within as well as differences between reefs included (again amongst others):

- *Siphamia cephalotes* (little siphonfish),
- *Trachinops noarlungae* (yellow headed hulafish), and
- *Turbo undulates* (periwinkle).

Ccnsideration of the sum of all individuals within each species across all samples revealed that *Trachinops noarlungae* topped the list at around than 20,100 individuals, more than twice that of the next highest, Crustose coralline algae (9,500 observations) and *Ecklonia radiata* (9,100 observations). This suggests that count data for *T. noarlungae* is based on estimates of large schools in many instances, which will tend to group around orders of magnitude within sites (i.e. 10s, vesus 100s versus 1000s), and therefore act to drive similarities within as well as dissimilarity between sites. Some consideration might be given to the methods for obtaining data on this species (and possibly other fish), particularly if abundance estimates are being generated for large schools.

*Siphamia cephalotes* and *Turbo undulates* were also amongst the more frequently recorded (~ 4,500 and 3,500 individuals respectively), although numbers for these taxa are within the ranges observed for other species and considered more reliable, particularly for the periwinkle which may be very common. Future surveys might consider the approach used for fish assessments, particularly for species that occur in large schools.

As mentioned in results, it may be argued that changes in cover of canopy-forming macroalgae are responsible for observed differences in sub-canopy, encrusting or turfing species as well as substrate coverage. Similar changes in canopy versus non-canopy changes in cover were noted in reef assessments undertaken by Turner (1995) and Turner *et al.* (2007). It is worth noting that a major determinant of system status within Reef Health investigations has been the cover/abundance of canopy forming macroalgae wherein a loss of these taxa and a proliferation of turfing species and bare substrate indicate a decline in health (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). However, Reef Health assessments employ a rather different survey methodology (based on Line Intercept Transects) as well as a highly truncated approach to taxonomy (functional form). Similarly, Collings (1996) found that species associations between sites on the southern Fleurieu and Encounter Bay areas were determined by canopy species. Regardless of the survey approach, similarity within and differences between reefs within the AMLR NRM coast (and most probably elsewhere on southern Australian coasts) appear to be largely determined by canopy macroalgal cover.

Given the dominance of macroalgae in identifying differences between reefs, it may be argued that the associated fish and invertebrate data are of little value. However, it is equally important to note that the analyses and results presented in this report are a subset of what might be considered and both fish and invertebrate data collected by this investigation may well present an invaluable resource when considered from different perspectives.

There were significant differences in biodiversity indices between locations, with most indices suggesting that sites around Cape Jervis (such as Blowhole Beach and Fishery Beach) as well as the Flat Irons further east were higher in biodiversity and perhaps warrant further monitoring and investigation. It is important to note that these sites did not maintain an extreme level of biodiversity relative to many other sites (see Appendix C) and may constitute short-term spikes in response to localised factors such as spawning events and/or increased food availability. Finally, diversity hotspots may be considered from a number of different aspects, including endemism, the range of available habitats, rare or endangered species and habitats types as well as the density of aesthetic, cultural or historical values. Comparison of the results of this study with diversity levels identified within other investigations was not considered as these indices are strongly predicated upon the taxonomic resolution employed.

In addition, given the high levels of diversity and endemism known to occur on reefs in southern Australia (e.g. Edyvane 1996, Edyvane 1999a), the targeting of management only to biodiversity "hotspots" has arguable utility. Firstly because as noted above these areas of high biodiversity may be transitory, but also because areas with low diversity may still provide critical habitat for a large number of organisms and finally because reefs in southern Australia are intrinsically highly diverse. Consequently, a more even-handed management approach that encompasses a range of locations and/or circumstances is more valid.

Declines in water quality are considered to be the major cause for reef system decline on the Adelaide coast (Cheshire *et al.* 1998, Cheshire and Westphalen 2000, Turner *et al.* 2007, Collings *et al.* 2008). However, the nature of the threats within this zone (wastewater outfalls, stormwater drains and riverine inputs) is well understood, and there are proposals for redressing this problem as a component of the ACWQIP (see above). At the regional scale, rather than manage reefs in location specific terms, it is probably more important to understand more with respect to both the natural and anthropogenic factors that influence reef compositional differences in spatially referenced terms.

Moving forward, the key issues for reefs within the AMLR NRM region would therefore seem to relate to;

- Preventing and preferably reversing reef health further decline of Adelaide metropolitan reefs.
- Preventing expansion of reef decline to areas further south on the GSV coast, as well as other areas where population increases may be expected, such as the Encounter Bay area.
- Identify and quantify in spatially referenced terms the natural and anthropogenic factors that contribute to the structure and function of reef systems within the AMLR NRM region with a view to identifying and managing threats at the regional scale. This would assist targeting of management and survey resources for both reefs and more generally (habitat mapping – see above).

## *Conclusions and recommendations*

Both habitat mapping and reef surveys within the AMLR NRM region provide critical baseline observations for future monitoring across a range of scales. However, while potential areas for targeted monitoring can be identified (see below), there is still limited capacity to juxtapose the status of the identified environmental assets with threat levels. Water quality decline, is widely accepted as the major cause for seagrass and reef decline on the Adelaide metropolitan coast and these have been well researched as part of the ACWS (see Fox *et al.* 2007). However, more broadly across the AMLR NRM region our understanding of water quality issues as well as other potential threats to nearshore systems would appear to be relatively low, particularly in spatially referenced (i.e. GIS) terms.

Target areas for focussed monitoring can be identified, including;

- Blowout areas in seagrass beds in the south of Adelaide
- Normanville to Rapid Bay seagrasses
- Encounter Bay

However the nature and extent of threats to seagrass and reef systems is not fully understood for either of the locations outside the Adelaide metropolitan area. It follows that the range of stakeholders with interests in these systems is also probably not fully understood. In addition, there remain gaps in the benthic mapping, for deeper waters wherein there is evidence of substantial environmental decline (see Tanner 2005). There is also the impact of new developments on the AMLR NRM coast, in particular the construction and operation of the desalination plant at Pt Stanvac.

In terms of reef systems within the AMLR NRM region there is solid evidence to suggest that those outside the Adelaide region are relatively “healthy” but there is again, limited data on potential threats at similar spatial scales. Further, the relationships between anthropogenic, biotic and abiotic factors as structuring agents for reef systems at different scales is also unclear.

In terms of moving forward with both benthic mapping reef observations, there are a number of recommendations, including:

- Targeted monitoring related to specified areas (see above), requiring;
    - More resolved habitat mapping (possibly in strip transects across sites),
    - Spatially referenced data related to threats, in particular water quality issues for areas outside metropolitan Adelaide, and
    - Engagements 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 summer/early autumn period.

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# Appendix A – Reef survey sites

All reef survey sites within the AMLR NRM are roughly evenly divided across the Gulf St Vincent (SVG) IMCRA (Version 4) bioregions that are themselves included within the broader Spencer Gulf province (Commonwealth of Australia 2006; Table 23).

**Table 23 - Sites considered in reef surveys (CAR = Carrickalinga, RAP = Rapid Bay, JER = Cape Jervis, ENC = Encounter Bay).**

| Location | Location Name | Latitude | Longitude | Depth (m) | Sample Year | Season |
|---|---|---|---|---|---|---|
| JER | Blowhole Beach | S35.65974 | E138.15998 | 5 | 07 | Summer/Autumn |
| CAR | Carrickalinga Head | S35.39800 | E138.33591 | 5 | 06/07 | Summer/Autumn |
| JER | Deep Creek | S35.64086 | E138.27266 | 5 | 07 | Summer/Autumn |
| CAR | Dodd's Beach | S35.40416 | E138.33043 | 5 | 06/07 | Summer/Autumn |
| JER | Fisheries Beach | S35.63411 | E138.11183 | 5 | 07 | Summer/Autumn |
| ENC | Flat Irons | S35.61781 | E138.55721 | 5-7 | 07 | Both |
| CAR | Haycock Point | S35.41545 | E138.32130 | 5 | 06/07 | Summer/Autumn |
| RAP | Morgans | S35.58845 | E138.10838 | 5 | 06/07 | Summer/Autumn |
| CAR | Myponga Point | S35.37988 | E138.36069 | 5 | 06/07 | Summer/Autumn |
| CAR | Myponga South | S35.38821 | E138.34923 | 5 | 06/07 | Summer/Autumn |
| JER | Naiko East | S35.65378 | E138.14597 | 5 | 07 | Summer/Autumn |
| JER | Naiko West | S35.64675 | E138.13310 | 5 | 07 | Summer/Autumn |
| ENC | Outside Granite Island | S35.56754 | E138.63158 | 5 | 06/07 | Both |
| JER | Porpoise Head | S35.66232 | E138.21436 | 5 | 07 | Summer/Autumn |
| RAP | Rapid Head Cliffs | S35.52045 | E138.16443 | 5 | 06/07 | Summer/Autumn |
| RAP | Rapid Head North | S35.51922 | E138.17416 | 5 | 06/07 | Summer/Autumn |
| RAP | Rapid Head Windmill | S35.53085 | E138.15289 | 5 | 06/07 | Summer/Autumn |
| CAR | Ripple Rock | S35.38386 | E138.35590 | 5 | 06/07 | Summer/Autumn |
| RAP | Salt Creek | S35.55260 | E138.12984 | 5 | 07 | Summer/Autumn |
| ENC | Seal Island | S35.57618 | E138.64429 | 5 | 06/07 | Both |
| RAP | Second Valley | S35.50594 | E138.21446 | 5 | 06/07 | Summer/Autumn |
| CAR | Shagg Rock | S35.39933 | E138.33457 | 5 | 06/07 | Summer/Autumn |
| RAP | Sunset Cove South | S35.50467 | E138.22924 | 5 | 06/07 | Summer/Autumn |
| ENC | The Bluff | S35.58996 | E138.60645 | 5 | 06/07 | Both |
| CAR | Yankalilla | S35.42445 | E138.31901 | 4-5 | 06/07 | Summer/Autumn |

### Blowhole Beach, Deep Creek and Porpoise Head

These sites are adjacent to the Deep Creek Conservation Park and therefore a relatively well vegetated coast. Access to the Blowhole Beach site, which is a few hundred meters from shore, is best achieved by vessel. Deep Creek can be accessed from shore, although this would require 4WD and permission to pass though locked gates. Porpoise Head requires vessel access.

It is worth noting that the area is subject of strong currents.

### Carrickalinga Head

This site is adjacent to rural (largely un-vegetated) cliffs, although there is a stream outlet from a valley that retains some remnant vegetation. The site is inaccessible from shore, being some 5 km from the nearest boat ramp.

### Dodd's Beach and Shagg Rock

This site is very difficult to access from shore dive, but 4.5 km from a boat ramp. It is adjacent to rural cliffs (largely un-vegetated) fronted by a sandy beach.

### Fisheries Beach

Fisheries Beach is adjacent to rural land and can be accessed as a shore dive.

### Flat Irons

The Flat Irons site is adjacent to high rural cliffs and requires vessel access.

### Haycock Point, Yankalilla

Haycock Point and Yankalilla are adjacent to an urbanised area in the Carrickalinga area (and therefore lightly populated relative to the Adelaide metropolitan area). Access can be achieved from shore, albeit with a long swim.

### Morgans, Naiko East, Naiko West, Salt Creek, Myponga Point, Myponga South and Ripple Rock

These sites are adjacent to rural land and probably require a vessel. Access may be achieved from shore but requires permission to cross private property.

### Outside Granite Island

Vehicle access to Granite Island can permit this site to be dived from shore. Granite Island is itself a conservation park, although it is popular with tourists, including recreational fishers. Outputs from the Inman River at Victor Harbor may impact this site.

### Rapid Head Cliffs, Rapid Head North, Rapid Head Windmill

These sites require a boat to access in most instances (Rapid Head North could be dived from shore with access to private land).

Rapid Head Cliffs and Rapid Head Windmill are adjacent to rural (largely unvegetated) land, but Rapid Head North fronts scree comprised of mine tailings. The latter is thus possibly subject to sedimentation from this debris.

### Seal Island

Seal Island off the coast at Encounter Bay requires boat access.

### Second Valley

Second Valley can be accessed as a shore dive. The site is adjacent to rural land/cliffs as well as the outlet of Parananacooka Creek.

### Sunset Cove South

Sunset Cove requires boat access. It is adjacent to rural land and close to the Wirrina resort marina.

### The Bluff

The Bluff site adjacent to Rosetta Head at Victor Harbor may be accessed from shore.

# Appendix B – Reef taxa employed in analyses

| Taxon | Site Comparison AnalysisID | Use | Biodiversity AnalysisID | Use |
|---|---|---|---|---|
| Acanthaluteres brownii | Acanthaluteres brownii | | Acanthaluteres brownii | |
| Acanthaluteres spilomelanurus | Acanthaluteres spilomelanurus | | Acanthaluteres spilomelanurus | |
| Acanthaluteres vittiger | Acanthaluteres vittiger | | Acanthaluteres vittiger | |
| Achoerodus gouldii | Achoerodus gouldii | | Achoerodus gouldii | |
| Acrocarpia paniculata | Acrocarpia paniculata | | Acrocarpia paniculata | |
| Aetapcus maculatus | Aetapcus maculatus | | Aetapcus maculatus | |
| Amblypneustes ovum | Amblypneustes ovum | | Amblypneustes ovum | |
| Amphibolis spp. | Amphibolis spp. | | Amphibolis spp. | |
| Amphiroa spp. | Amphiroa spp. | | Amphiroa spp. | |
| Ancorina geodides | Ancorina geodides | | Ancorina geodides | |
| Anemones | Anemones | | Anemones | |
| Anoplocapros amygdaloides | Anoplocapros amygdaloides | | Anoplocapros amygdaloides | |
| Anoplocapros lenticularis | Anoplocapros lenticularis | | Anoplocapros lenticularis | |
| Anthaster valvulatus | Anthaster valvulatus | | Anthaster valvulatus | |
| Apjohnia laetevirens | Apjohnia laetevirens | | Apjohnia laetevirens | |
| Aplodactylus arctidens | Aplodactylus arctidens | | Aplodactylus arctidens | |
| Aporometra wilsoni | Aporometra wilsoni | | Aporometra wilsoni | |
| Aracana aurita | Aracana aurita | | Aracana aurita | |
| Arripis georgiana | Arripis georgiana | | Arripis georgiana | |
| Arripis spp. | Arripis spp. | | Arripis spp. | |
| Asparagopsis spp. | Asparagopsis spp. | | Asparagopsis spp. | |
| Aspasmogaster spp. | Aspasmogaster spp. | | Aspasmogaster spp. | |
| Asperococcus bullosus | Asperococcus bullosus | | Asperococcus bullosus | |
| Austrocochlea odontis | Austrocochlea odontis | | Austrocochlea odontis | |
| Austrolabrus maculatus | Austrolabrus maculatus | | Austrolabrus maculatus | |
| Ballia callitricha | Ballia callitricha | | Ballia callitricha | |
| Bare rock (non - barrens) | Bare rock (non - barrens) | | Bare rock (non - barrens) | No |
| Blennid spp. | Blennid spp. | | Blennid spp. | |
| Botryocladia sonderi | Botryocladia sonderi | | Botryocladia sonderi | |
| Bovichtus angustifrons | Bovichtus angustifrons | | Bovichtus angustifrons | |
| Brachaluteres jacksonianus | Brachaluteres jacksonianus | | Brachaluteres jacksonianus | |
| Brown algae unidentified | Brown algae unidentified | No | Brown algae unidentified | No |
| Brown turf | TURF | | TURF | |
| Cabestana tabulata | Cabestana tabulata | | Cabestana tabulata | |
| Caesioperca rasor | Caesioperca rasor | | Caesioperca rasor | |
| Callionymid spp. | Callionymid spp. | | Callionymid spp. | |
| Carpoglossum confluens | Carpoglossum confluens | | Carpoglossum confluens | |
| Carpomitra costata | Carpomitra costata | | Carpomitra costata | |
| Carpopeltis phyllophora | Carpopeltis phyllophora | | Carpopeltis phyllophora | |
| Caulerpa brownii | Caulerpa brownii | | Caulerpa brownii | |
| Caulerpa cactoides | Caulerpa cactoides | | Caulerpa cactoides | |
| Caulerpa flexilis complex | Caulerpa flexilis complex | | Caulerpa flexilis complex | |
| Caulerpa geminata | Caulerpa geminata | | Caulerpa geminata | |
| Caulerpa obscura | Caulerpa obscura | | Caulerpa obscura | |
| Caulerpa scalpelliformis | Caulerpa scalpelliformis | | Caulerpa scalpelliformis | |
| Caulerpa spp. | Caulerpa spp. | | Caulerpa spp. | |
| Caulerpa trifaria | Caulerpa trifaria | | Caulerpa trifaria | |
| Caulocystis spp. | Caulocystis spp. | | Caulocystis spp. | |
| Cenolia tasmaniae | Cenolia tasmaniae | | Cenolia tasmaniae | |
| Cenolia trichoptera | Cenolia trichoptera | | Cenolia trichoptera | |
| Centrostephanus tenuispinus | Centrostephanus tenuispinus | | Centrostephanus tenuispinus | |
| Ceratosoma brevicaudatum | Ceratosoma brevicaudatum | | Ceratosoma brevicaudatum | |
| Champia zostericola | Champia zostericola | | Champia zostericola | |
| Cheilodactylus nigripes | Cheilodactylus nigripes | | Cheilodactylus nigripes | |
| Cheilodactylus spectabilis | Cheilodactylus spectabilis | | Cheilodactylus spectabilis | |
| Chelmonops curiosus | Chelmonops curiosus | | Chelmonops curiosus | |
| Cnidoglanis macrocephalus | Cnidoglanis macrocephalus | | Cnidoglanis macrocephalus | |
| Cochleoceps bicolor | Cochleoceps bicolor | | Cochleoceps bicolor | |
| Codium pomoides | Codium pomoides | | Codium pomoides | |
| Codium spp. | Codium spp. | | Codium spp. | |
| Colpomenia spp. | Colpomenia spp. | | Colpomenia spp. | |
| Conus anemone | Conus anemone | | Conus anemone | |
| Coscinasterias muricata | Coscinasterias muricata | | Coscinasterias muricata | |
| Crustose coralline algae | Crustose coralline algae | | Crustose coralline algae | |
| Cymatium parthenopeum | Cymatium parthenopeum | | Cymatium parthenopeum | |
| Cystophora brownii | Cystophora brownii | | Cystophora brownii | |
| Cystophora expansa | Cystophora expansa | | Cystophora expansa | |
| Cystophora intermedia | Cystophora intermedia | | Cystophora intermedia | |
| Cystophora monilifera | Cystophora monilifera | | Cystophora monilifera | |
| Cystophora moniliformis | Cystophora moniliformis | | Cystophora moniliformis | |
| Cystophora racemosa | Cystophora racemosa | | Cystophora racemosa | |
| Cystophora retroflexa | Cystophora retroflexa | | Cystophora retroflexa | |
| Cystophora siliquosa complex | Cystophora siliquosa complex | | Cystophora siliquosa complex | |
| Cystophora subfarcinata | Cystophora subfarcinata | | Cystophora subfarcinata | |

| Taxon | Site Comparison AnalysisID | Use | Biodiversity AnalysisID | Use |
|---|---|---|---|---|
| Dactylophora nigricans | Dactylophora nigricans | | Dactylophora nigricans | |
| Delisea/Phacelocarpus complex | Delisea/Phacelocarpus complex | | Delisea/Phacelocarpus complex | |
| Dicathais orbita | Dicathais orbita | | Dicathais orbita | |
| Dictyopteris muelleri | Dictyopteris muelleri | | Dictyopteris muelleri | |
| Dictyosphaeria sericea | Dictyosphaeria sericea | | Dictyosphaeria sericea | |
| Dictyota/Dilophus complex | Dictyota/Dilophus complex | | Dictyota/Dilophus complex | |
| Dictyotaceae | Dictyotaceae | | Dictyotaceae | |
| Dinolestes lewini | Dinolestes lewini | | Dinolestes lewini | |
| Diodon nicthemerus | Diodon nicthemerus | | Diodon nicthemerus | |
| Dotalabrus aurantiacus | Dotalabrus aurantiacus | | Dotalabrus aurantiacus | |
| drift | drift | | drift | No |
| Echinaster arcystatus | Echinaster arcystatus | | Echinaster arcystatus | |
| Echinaster glomeratus | Echinaster glomeratus | | Echinaster glomeratus | |
| Ecklonia radiata | Ecklonia radiata | | Ecklonia radiata | |
| Encrusting ascidians | Encrusting ascidians | | Encrusting ascidians | |
| Encrusting brown algae | Encrusting brown algae | | Encrusting brown algae | |
| Encrusting bryozoans | Encrusting bryozoans | | Encrusting bryozoans | |
| Enoplosus armatus | Enoplosus armatus | | Enoplosus armatus | |
| Equichlamys bifrons | Equichlamys bifrons | | Equichlamys bifrons | |
| Erythropodium spp. | Erythropodium spp. | | Erythropodium spp. | |
| Eubalichthys gunnii | Eubalichthys gunnii | | Eubalichthys gunnii | |
| Eubalichthys mosaicus | Eubalichthys mosaicus | | Eubalichthys mosaicus | |
| Eupetrichthys angustipes | Eupetrichthys angustipes | | Eupetrichthys angustipes | |
| Filamentous browns | Filamentous browns | | Filamentous browns | |
| Filamentous red algae | Filamentous red algae | | Filamentous red algae | |
| Foetorepus calauropomus | Foetorepus calauropomus | | Foetorepus calauropomus | |
| Foliose browns | Foliose browns | | Foliose browns | |
| Foliose reds | Foliose reds | | Foliose reds | |
| Fromia polypora | Fromia polypora | | Fromia polypora | |
| Fusinus australis | Fusinus australis | | Fusinus australis | |
| Galeolaria caespitosa | Galeolaria caespitosa | | Galeolaria caespitosa | |
| Geniculate coralline turf | Geniculate coralline turf | | Geniculate coralline turf | |
| Geniculate corallines | Geniculate corallines | | Geniculate corallines | |
| Genypterus tigerinus | Genypterus tigerinus | | Genypterus tigerinus | |
| Girella tricuspidata | Girella tricuspidata | | Girella tricuspidata | |
| Girella zebra | Girella zebra | | Girella zebra | |
| Gloiosaccion brownii | Gloiosaccion brownii | | Gloiosaccion brownii | |
| Glossophora nigricans | Glossophora nigricans | | Glossophora nigricans | |
| Gobiesocid spp. | Gobiesocid spp. | | Gobiesocid spp. | |
| Goniocidaris tubaria | Goniocidaris tubaria | | Goniocidaris tubaria | |
| Gravel | Gravel | | Gravel | No |
| Gurnard perch complex | Gurnard perch complex | | Gurnard perch complex | |
| Haliotis laevigata | Haliotis laevigata | | Haliotis laevigata | |
| Haliotis rubra complex | Haliotis rubra complex | | Haliotis rubra complex | |
| Haliptilon roseum | Haliptilon roseum | | Haliptilon roseum | |
| Halophila ovalis | Halophila ovalis | | Halophila ovalis | |
| Hard bryozoans | Hard bryozoans | | Hard bryozoans | |
| Heliocidaris erythrogramma | Heliocidaris erythrogramma | | Heliocidaris erythrogramma | |
| Herdmania momus | Other ascidians | | Herdmania momus | |
| Hermit crab unidentified | Pagurid spp. | | Pagurid spp. | |
| Heterodontus portusjacksoni | Heterodontus portusjacksoni | | Heterodontus portusjacksoni | |
| Heterozostera tasmanica | Heterozostera tasmanica | | Heterozostera tasmanica | |
| Hildenbrandia spp. | Hildenbrandia spp. | | Hildenbrandia spp. | |
| Hincksia spp. | Hincksia spp. | | Hincksia spp. | |
| Holopneustes spp. | Holopneustes spp. | | Holopneustes spp. | |
| Hydroclathrus clathratus | Hydroclathrus clathratus | | Hydroclathrus clathratus | |
| Hydroids | Hydroids | | Hydroids | |
| Hypoplectrodes nigroruber | Hypoplectrodes nigroruber | | Hypoplectrodes nigroruber | |
| Jasus edwardsii | Jasus edwardsii | | Jasus edwardsii | |
| Kyphosus sydneyanus | Kyphosus sydneyanus | | Kyphosus sydneyanus | |
| Leptatherina presbyteroides | Leptatherina presbyteroides | | Leptatherina presbyteroides | |
| Lobophora variegata | Dictyotaceae | | Lobophora variegata | |
| Lobospira bicuspidata | Lobospira bicuspidata | | Lobospira bicuspidata | |
| Lophurella periclados | Lophurella periclados | | Lophurella periclados | |
| Melanthalia spp. | Melanthalia spp. | | Melanthalia spp. | |
| Membranous reds | Membranous reds | | Membranous reds | |
| Metagoniolithon spp. | Metagoniolithon spp. | | Metagoniolithon spp. | |
| Metamastophora flabellata | Metamastophora flabellata | | Metamastophora flabellata | |
| Meuschenia flavolineata | Meuschenia flavolineata | | Meuschenia flavolineata | |
| Meuschenia freycineti | Meuschenia freycineti | | Meuschenia freycineti | |
| Meuschenia galii | Meuschenia galii | | Meuschenia galii | |
| Meuschenia hippocrepis | Meuschenia hippocrepis | | Meuschenia hippocrepis | |
| Meuschenia venusta | Meuschenia venusta | | Meuschenia venusta | |
| Mitra glabra | Mitra glabra | | Mitra glabra | |
| Muraenichthys australis | Muraenichthys australis | | Muraenichthys australis | |
| Myliobatis australis | Myliobatis australis | | Myliobatis australis | |
| Myriogramme gunniana | Myriogramme gunniana | | Myriogramme gunniana | |

| Taxon | Site Comparison AnalysisID | Use | Biodiversity AnalysisID | Use |
|---|---|---|---|---|
| Nectocarcinus spp. | Nectocarcinus spp. | | Nectocarcinus spp. | |
| Nectria macrobrachia | Nectria macrobrachia | | Nectria macrobrachia | |
| Nectria multispina/ocellata | Nectria multispina/ocellata | | Nectria multispina/ocellata | |
| Nectria saoria | Nectria saoria | | Nectria saoria | |
| Neoodax balteatus | Neoodax balteatus | | Neoodax balteatus | |
| Neophoca cinerea | Neophoca cinerea | | Neophoca cinerea | |
| Nepanthia troughtoni | Nepanthia troughtoni | | Nepanthia troughtoni | |
| Nesogobius spp. | Nesogobius spp. | | Nesogobius spp. | |
| No species found | No species found | No | No species found | No |
| Notolabrus parilus | Notolabrus parilus | | Notolabrus parilus | |
| Notolabrus tetricus | Notolabrus tetricus | | Notolabrus tetricus | |
| Nudibranchs | Nudibranchs | | Nudibranchs | |
| Odax acroptilus | Odax acroptilus | | Odax acroptilus | |
| Odax cyanomelas | Odax cyanomelas | | Odax cyanomelas | |
| Omegophora armilla | Omegophora armilla | | Omegophora armilla | |
| Orectolobus spp. | Orectolobus spp. | | Orectolobus spp. | |
| Osmundaria prolifera | Osmundaria prolifera | | Osmundaria prolifera | |
| Osmundaria spiralis | Osmundaria spiralis | | Osmundaria spiralis | |
| Other ascidians | Other ascidians | | Other ascidians | |
| Other bryozoans | Other bryozoans | | Other bryozoans | |
| Other sponges | Other sponges | | Other sponges | |
| Other turf | TURF | | TURF | |
| Othos dentex | Othos dentex | | Othos dentex | |
| Pachydictyon paniculatum | Pachydictyon paniculatum | | Pachydictyon paniculatum | |
| Pagurid spp. | Pagurid spp. | | Pagurid spp. | |
| Paguristes frontalis | Pagurid spp. | | Paguristes frontalis | |
| Paraplesiops meleagris | Paraplesiops meleagris | | Paraplesiops meleagris | |
| Parapriacanthus elongatus | Parapriacanthus elongatus | | Parapriacanthus elongatus | |
| Parascyllium ferrugineum | Parascyllium ferrugineum | | Parascyllium ferrugineum | |
| Parascyllium variolatum | Parascyllium variolatum | | Parascyllium variolatum | |
| Parequula melbournensis | Parequula melbournensis | | Parequula melbournensis | |
| Parma victoriae | Parma victoriae | | Parma victoriae | |
| Patiriella brevispina | Patiriella brevispina | | Patiriella brevispina | |
| Patiriella calcar | Patiriella calcar | | Patiriella calcar | |
| Pempheris klunzingeri | Pempheris klunzingeri | | Pempheris klunzingeri | |
| Pempheris multiradiata | Pempheris multiradiata | | Pempheris multiradiata | |
| Pempheris ornata | Pempheris ornata | | Pempheris ornata | |
| Pempheris spp. | Pempheris spp. | | Pempheris spp. | |
| Penion mandarinus | Penion mandarinus | | Penion mandarinus | |
| Pentaceropsis recurvirostris | Pentaceropsis recurvirostris | | Pentaceropsis recurvirostris | |
| Pentagonaster dubeni | Pentagonaster dubeni | | Pentagonaster dubeni | |
| Perithalia caudata | Perithalia caudata | | Perithalia caudata | |
| Petricia vernicina | Petricia vernicina | | Petricia vernicina | |
| Peyssonnelia flat | Peyssonnelia flat | | Peyssonnelia flat | |
| Phasianella australis | Phasianella australis | | Phasianella australis | |
| Phasianella ventricosa | Phasianella ventricosa | | Phasianella ventricosa | |
| Phasianotrochus eximius | Phasianotrochus eximius | | Phasianotrochus eximius | |
| Phloiocaulon/Halopteris complex | Phloiocaulon/Halopteris complex | | Phloiocaulon/Halopteris complex | |
| Phyllacanthus irregularis | Phyllacanthus irregularis | | Phyllacanthus irregularis | |
| Pictilabrus laticlavius | Pictilabrus laticlavius | | Pictilabrus laticlavius | |
| Plagusia chabrus | Plagusia chabrus | | Plagusia chabrus | |
| Platycephalid spp. | Platycephalid spp. | | Platycephalid spp. | |
| Platycephalus speculator | Platycephalus speculator | | Platycephalus speculator | |
| Plectaster decanus | Plectaster decanus | | Plectaster decanus | |
| Plesiastrea versipora | Plesiastrea versipora | | Plesiastrea versipora | |
| Pleuroploca australasia | Pleuroploca australasia | | Pleuroploca australasia | |
| Plocamium spp. | Plocamium spp. | | Plocamium spp. | |
| Polyopes constricta | Polyopes constricta | | Polyopes constricta | |
| Posidonia australis | Posidonia australis | | Posidonia australis | |
| Posidonia sinuosa | Posidonia sinuosa | | Posidonia sinuosa | |
| Pseudocaranx dentex | Pseudocaranx dentex | | Pseudocaranx dentex | |
| Pterynotus triformis | Pterynotus triformis | | Pterynotus triformis | |
| Pyura gibbosa | Pyura gibbosa | | Pyura gibbosa | |
| Red Turf | TURF | | TURF | |
| Rhodymenia complex | Rhodymenia complex | | Rhodymenia complex | |
| Sagaminopteron ornatum | Sagaminopteron ornatum | | Sagaminopteron ornatum | |
| Sand | Sand | | Sand | No |
| Sargassum decipiens/sonderi | Sargassum decipiens/sonderi | | Sargassum decipiens/sonderi | |
| Sargassum heteromorphum | Sargassum heteromorphum | | Sargassum heteromorphum | |
| Sargassum spp. (subgenus Arthrophycus) | Sargassum spp. (subgenus Arthrophycus) | | Sargassum spp. (subgenus Arthrophycus) | |
| Sargassum spp. (subgenus Phyllotrichia) | Sargassum spp. (subgenus Phyllotrichia) | | Sargassum spp. (subgenus Phyllotrichia) | |
| Sargassum spp. (subgenus Sargassum) | Sargassum spp. (subgenus Sargassum) | | Sargassum spp. (subgenus Sargassum) | |
| Sargassum varians | Sargassum varians | | Sargassum varians | |

| Taxon | Site Comparison AnalysisID | Use | Biodiversity AnalysisID | Use |
|---|---|---|---|---|
| Sargassum verruculosum | Sargassum verruculosum | | Sargassum verruculosum | |
| Scaberia agardhii | Scaberia agardhii | | Scaberia agardhii | |
| Scobinichthys granulatus | Scobinichthys granulatus | | Scobinichthys granulatus | |
| Scolymia australis | Scolymia australis | | Scolymia australis | |
| Scorpis aequipinnis | Scorpis aequipinnis | | Scorpis aequipinnis | |
| Scorpis georgiana | Scorpis georgiana | | Scorpis georgiana | |
| Scutus antipodes | Scutus antipodes | | Scutus antipodes | |
| Scytothalia dorycarpa | Scytothalia dorycarpa | | Scytothalia dorycarpa | |
| Seirococcus axillaris | Seirococcus axillaris | | Seirococcus axillaris | |
| Sepia apama | Sepia apama | | Sepia apama | |
| Sepioteuthis australis | Sepioteuthis australis | | Sepioteuthis australis | |
| Siphamia cephalotes | Siphamia cephalotes | | Siphamia cephalotes | |
| Siphonognathus attenuatus | Siphonognathus attenuatus | | Siphonognathus attenuatus | |
| Siphonognathus beddomei | Siphonognathus beddomei | | Siphonognathus beddomei | |
| Siphonognathus caninus | Siphonognathus caninus | | Siphonognathus caninus | |
| Siphonognathus radiatus | Siphonognathus radiatus | | Siphonognathus radiatus | |
| Siphonognathus spp. | Siphonognathus spp. | | Siphonognathus spp. | |
| Siphonognathus tanyourus | Siphonognathus tanyourus | | Siphonognathus tanyourus | |
| Soft Bryozoans | Soft Bryozoans | | Soft Bryozoans | |
| Sonderopelta/Peyssonnelia | Sonderopelta/Peyssonnelia | | Sonderopelta/Peyssonnelia | |
| Sphyraena novaehollandiae | Sphyraena novaehollandiae | | Sphyraena novaehollandiae | |
| Sponge (encrusting) | Sponge (encrusting) | | Sponge (encrusting) | |
| Sporochnus/Bellotia complex | Sporochnus/Bellotia complex | | Sporochnus/Bellotia complex | |
| Stichopus spp. | Stichopus spp. | | Stichopus spp. | |
| Survey not done | Survey not done | No | Survey not done | No |
| Tetractenos glaber | Tetractenos glaber | | Tetractenos glaber | |
| Thysanophrys cirronasus | Thysanophrys cirronasus | | Thysanophrys cirronasus | |
| Tilodon sexfasciatus | Tilodon sexfasciatus | | Tilodon sexfasciatus | |
| Tosia australis | Tosia australis | | Tosia australis | |
| Tosia magnifica | Tosia magnifica | | Tosia magnifica | |
| Trachichthys australis | Trachichthys australis | | Trachichthys australis | |
| Trachinops noarlungae | Trachinops noarlungae | | Trachinops noarlungae | |
| Tripterygiid spp. | Tripterygiid spp. | | Tripterygiid spp. | |
| Trizopagurus strigimanus | Trizopagurus strigimanus | | Trizopagurus strigimanus | |
| Turbo jordani | Turbo jordani | | Turbo jordani | |
| Turbo torquatus | Turbo torquatus | | Turbo torquatus | |
| Turbo undulatus | Turbo undulatus | | Turbo undulatus | |
| Ulva spp. | Ulva spp. | | Ulva spp. | |
| Unidentified Crab | Unidentified Crab | No | Unidentified Crab | No |
| Unidentified cryptic fish | Unidentified cryptic fish | | Unidentified cryptic fish | |
| Unidentified fish | Unidentified fish | No | Unidentified fish | No |
| Unidentified pipefish | Unidentified pipefish | | Unidentified pipefish | |
| Uniophora granifera | Uniophora granifera | | Uniophora granifera | |
| Upeneichthys vlamingii | Upeneichthys vlamingii | | Upeneichthys vlamingii | |
| Urolophus gigas | Urolophus gigas | | Urolophus gigas | |
| Vanacampus poecilolaemus | Vanacampus poecilolaemus | | Vanacampus poecilolaemus | |
| Vincentia conspersa | Vincentia conspersa | | Vincentia conspersa | |
| Weedfish | Weedfish | | Weedfish | |
| Xiphophora chondrophylla | Xiphophora chondrophylla | | Xiphophora chondrophylla | |
| Zoanthid spp. | Zoanthid spp. | | Zoanthid spp. | |
| Zoanthus robustus | Zoanthus robustus | | Zoanthus robustus | |
| Zonaria spiralis | Dictyotaceae | | Zonaria spiralis | |
| Zonaria/Distromium complex | Dictyotaceae | | Zonaria/Distromium complex | |

# Appendix C – Biodiversity indices at the transect level

| Sample | S | N | d | Pielou | ES | Shannon | Simpson | Hill_N1 | Hill_N2 |
|---|---|---|---|---|---|---|---|---|---|
| BLOW_1 | 50 | 643 | 7.58 | 0.76 | 42.9 | 2.97 | 0.91 | 19.47 | 11.38 |
| BLOW_2 | 45 | 626 | 6.83 | 0.78 | 38.77 | 2.96 | 0.92 | 19.27 | 12.35 |
| BLOW_3 | 47 | 691 | 7.04 | 0.75 | 40 | 2.87 | 0.90 | 17.69 | 9.81 |
| BLOW_4 | 47 | 614 | 7.17 | 0.83 | 41.2 | 3.19 | 0.94 | 24.16 | 16.31 |
| BLUF_1 | 42 | 678 | 6.29 | 0.79 | 35.86 | 2.95 | 0.92 | 19.15 | 12.81 |
| BLUF_2 | 38 | 694 | 5.66 | 0.70 | 33.09 | 2.56 | 0.87 | 12.96 | 7.45 |
| BLUF_3 | 32 | 709 | 4.72 | 0.73 | 26.42 | 2.52 | 0.88 | 12.41 | 8.24 |
| BLUF_4 | 35 | 689 | 5.20 | 0.72 | 29.16 | 2.56 | 0.88 | 12.96 | 8.38 |
| CAHE_1 | 40 | 586 | 6.12 | 0.76 | 33.38 | 2.82 | 0.91 | 16.80 | 10.48 |
| CAHE_2 | 39 | 898 | 5.59 | 0.71 | 31.28 | 2.59 | 0.88 | 13.38 | 8.04 |
| CAHE_3 | 37 | 978 | 5.23 | 0.68 | 29.44 | 2.47 | 0.86 | 11.81 | 7.05 |
| CAHE_4 | 37 | 1643 | 4.86 | 0.58 | 23.96 | 2.08 | 0.82 | 8.01 | 5.40 |
| YANK_1 | 36 | 391 | 5.86 | 0.81 | 34.67 | 2.89 | 0.93 | 17.95 | 13.04 |
| YANK_2 | 44 | 689 | 6.58 | 0.73 | 35.43 | 2.76 | 0.90 | 15.82 | 10.21 |
| YANK_3 | 41 | 529 | 6.38 | 0.68 | 34.91 | 2.53 | 0.87 | 12.53 | 7.53 |
| YANK_4 | 41 | 812 | 5.97 | 0.62 | 30.3 | 2.29 | 0.82 | 9.89 | 5.41 |
| DEEP_1 | 38 | 632 | 5.74 | 0.69 | 31.09 | 2.53 | 0.87 | 12.51 | 7.48 |
| DEEP_2 | 38 | 648 | 5.72 | 0.73 | 31.24 | 2.66 | 0.90 | 14.27 | 9.51 |
| DEEP_3 | 37 | 668 | 5.54 | 0.77 | 32.34 | 2.79 | 0.90 | 16.35 | 10.36 |
| DEEP_4 | 44 | 580 | 6.76 | 0.85 | 38.91 | 3.20 | 0.95 | 24.48 | 18.34 |
| DODD_1 | 34 | 467 | 5.37 | 0.80 | 31.59 | 2.81 | 0.92 | 16.60 | 12.01 |
| DODD_2 | 34 | 788 | 4.95 | 0.67 | 27.39 | 2.36 | 0.82 | 10.56 | 5.58 |
| DODD_3 | 39 | 964 | 5.53 | 0.61 | 29.06 | 2.25 | 0.79 | 9.51 | 4.82 |
| DODD_4 | 32 | 663 | 4.77 | 0.67 | 26.11 | 2.31 | 0.85 | 10.10 | 6.70 |
| FISH_1 | 46 | 541 | 7.15 | 0.80 | 40.6 | 3.08 | 0.93 | 21.71 | 14.26 |
| FISH_2 | 40 | 433 | 6.42 | 0.82 | 37.04 | 3.02 | 0.93 | 20.51 | 14.42 |
| FISH_3 | 42 | 570 | 6.46 | 0.79 | 36.37 | 2.95 | 0.92 | 19.01 | 12.66 |
| FISH_4 | 48 | 585 | 7.38 | 0.79 | 39.33 | 3.06 | 0.93 | 21.34 | 14.64 |
| FLIR_1 | 51 | 631 | 7.76 | 0.82 | 42.54 | 3.22 | 0.95 | 25.07 | 18.31 |
| FLIR_2 | 44 | 637 | 6.66 | 0.78 | 37.27 | 2.97 | 0.92 | 19.47 | 12.20 |
| FLIR_3 | 37 | 484 | 5.82 | 0.70 | 32.72 | 2.53 | 0.84 | 12.49 | 6.32 |
| FLIR_4 | 38 | 399 | 6.18 | 0.68 | 36.18 | 2.47 | 0.83 | 11.80 | 5.74 |
| HAYP_1 | 39 | 671 | 5.84 | 0.76 | 32.45 | 2.78 | 0.91 | 16.15 | 10.74 |
| HAYP_2 | 34 | 798 | 4.94 | 0.69 | 27.02 | 2.42 | 0.87 | 11.26 | 7.79 |
| HAYP_3 | 31 | 368 | 5.08 | 0.77 | 30.2 | 2.65 | 0.90 | 14.17 | 9.40 |
| HAYP_4 | 38 | 782 | 5.55 | 0.62 | 27.97 | 2.26 | 0.81 | 9.56 | 5.15 |
| NAIE_1 | 32 | 381 | 5.22 | 0.83 | 31.12 | 2.87 | 0.92 | 17.65 | 12.03 |
| NAIE_2 | 35 | 560 | 5.37 | 0.74 | 30.48 | 2.64 | 0.89 | 14.07 | 9.16 |
| NAIE_3 | 44 | 578 | 6.76 | 0.73 | 36.89 | 2.75 | 0.90 | 15.66 | 9.42 |
| NAIE_4 | 53 | 573 | 8.19 | 0.82 | 46.07 | 3.24 | 0.94 | 25.56 | 15.99 |
| MORG_1 | 39 | 460 | 6.20 | 0.75 | 35.17 | 2.73 | 0.90 | 15.34 | 9.46 |
| MORG_2 | 44 | 417 | 7.13 | 0.80 | 41.61 | 3.04 | 0.93 | 21.00 | 13.88 |
| MORG_3 | 37 | 527 | 5.74 | 0.84 | 34.34 | 3.05 | 0.94 | 21.05 | 15.39 |
| MORG_4 | 34 | 438 | 5.43 | 0.81 | 32.05 | 2.87 | 0.92 | 17.63 | 11.74 |
| MYPP_1 | 37 | 684 | 5.52 | 0.71 | 30.5 | 2.57 | 0.88 | 13.07 | 8.44 |
| MYPP_2 | 37 | 697 | 5.50 | 0.68 | 30.64 | 2.47 | 0.84 | 11.79 | 6.08 |
| MYPP_3 | 30 | 875 | 4.28 | 0.69 | 25.03 | 2.35 | 0.83 | 10.43 | 6.00 |
| MYPP_4 | 38 | 727 | 5.62 | 0.75 | 31.26 | 2.74 | 0.91 | 15.55 | 11.09 |
| MYPS_1 | 32 | 639 | 4.80 | 0.72 | 27.6 | 2.48 | 0.84 | 11.92 | 6.31 |
| MYPS_2 | 39 | 676 | 5.83 | 0.68 | 32.99 | 2.48 | 0.83 | 11.88 | 5.81 |
| MYPS_3 | 34 | 696 | 5.04 | 0.68 | 28.39 | 2.38 | 0.86 | 10.83 | 6.97 |
| MYPS_4 | 33 | 789 | 4.80 | 0.67 | 26.6 | 2.34 | 0.85 | 10.40 | 6.52 |
| OTGI_1 | 31 | 651 | 4.63 | 0.68 | 25.24 | 2.33 | 0.86 | 10.25 | 7.21 |
| OTGI_2 | 38 | 485 | 5.98 | 0.74 | 34 | 2.69 | 0.89 | 14.72 | 9.11 |
| OTGI_3 | 19 | 585 | 2.83 | 0.57 | 15.93 | 1.67 | 0.73 | 5.33 | 3.66 |
| OTGI_4 | 23 | 602 | 3.44 | 0.58 | 19.13 | 1.82 | 0.75 | 6.16 | 4.03 |
| PORP_1 | 41 | 597 | 6.26 | 0.78 | 35.32 | 2.90 | 0.92 | 18.20 | 12.80 |
| PORP_2 | 44 | 588 | 6.74 | 0.77 | 37.62 | 2.91 | 0.90 | 18.31 | 10.11 |
| PORP_3 | 39 | 654 | 5.86 | 0.73 | 34.94 | 2.67 | 0.87 | 14.37 | 7.35 |
| PORP_4 | 45 | 739 | 6.66 | 0.79 | 35.96 | 2.99 | 0.93 | 19.87 | 13.99 |
| RAHC_1 | 30 | 775 | 4.36 | 0.65 | 23.76 | 2.21 | 0.79 | 9.09 | 4.69 |
| RAHC_2 | 39 | 927 | 5.56 | 0.64 | 30.14 | 2.35 | 0.80 | 10.46 | 5.05 |
| RAHC_3 | 35 | 897 | 5.00 | 0.67 | 28.14 | 2.37 | 0.80 | 10.68 | 4.95 |
| RAHC_4 | 42 | 907 | 6.02 | 0.73 | 31.58 | 2.73 | 0.89 | 15.40 | 8.71 |
| RAHN_1 | 41 | 493 | 6.45 | 0.76 | 35 | 2.82 | 0.91 | 16.70 | 11.16 |
| RAHN_2 | 38 | 1293 | 5.16 | 0.50 | 24.51 | 1.82 | 0.64 | 6.19 | 2.81 |
| RAHN_3 | 36 | 1257 | 4.90 | 0.53 | 26.71 | 1.88 | 0.64 | 6.57 | 2.79 |
| RAHN_4 | 42 | 1038 | 5.90 | 0.60 | 31.72 | 2.24 | 0.74 | 9.40 | 3.87 |
| RAHW_1 | 40 | 329 | 6.73 | 0.72 | 40 | 2.65 | 0.89 | 14.18 | 8.93 |
| RAHW_2 | 38 | 885 | 5.45 | 0.56 | 28.07 | 2.06 | 0.75 | 7.81 | 4.01 |
| RAHW_3 | 38 | 1025 | 5.34 | 0.58 | 28.44 | 2.10 | 0.73 | 8.18 | 3.70 |
| RAHW_4 | 42 | 611 | 6.39 | 0.75 | 36.28 | 2.79 | 0.89 | 16.22 | 9.37 |
| RIPP_1 | 45 | 688 | 6.73 | 0.71 | 36.09 | 2.72 | 0.90 | 15.19 | 9.48 |
| RIPP_2 | 44 | 1146 | 6.10 | 0.63 | 33.59 | 2.37 | 0.82 | 10.66 | 5.45 |
| RIPP_3 | 46 | 913 | 6.60 | 0.79 | 36.48 | 3.03 | 0.92 | 20.78 | 12.99 |

| Sample | S | N | d | Pielou | ES | Shannon | Simpson | Hill_N1 | Hill_N2 |
|---|---|---|---|---|---|---|---|---|---|
| RIPP_4 | 46 | 768 | 6.77 | 0.79 | 35.97 | 3.02 | 0.93 | 20.45 | 15.00 |
| SALT_1 | 33 | 404 | 5.33 | 0.78 | 31.18 | 2.71 | 0.91 | 15.07 | 10.80 |
| SALT_2 | 29 | 487 | 4.53 | 0.78 | 26.94 | 2.63 | 0.91 | 13.93 | 10.51 |
| SALT_3 | 43 | 723 | 6.38 | 0.75 | 34.51 | 2.83 | 0.91 | 17.00 | 11.19 |
| SALT_4 | 37 | 544 | 5.72 | 0.77 | 33.28 | 2.78 | 0.90 | 16.11 | 10.13 |
| SEAL_1 | 33 | 724 | 4.86 | 0.65 | 26.16 | 2.27 | 0.82 | 9.67 | 5.49 |
| SEAL_2 | 34 | 609 | 5.15 | 0.60 | 27.62 | 2.12 | 0.80 | 8.35 | 4.88 |
| SEAL_3 | 27 | 632 | 4.03 | 0.52 | 21.67 | 1.73 | 0.72 | 5.62 | 3.52 |
| SEAL_4 | 19 | 585 | 2.83 | 0.61 | 17.33 | 1.79 | 0.75 | 5.97 | 4.01 |
| SECV_1 | 27 | 415 | 4.31 | 0.71 | 24.67 | 2.32 | 0.86 | 10.22 | 6.85 |
| SECV_2 | 43 | 571 | 6.62 | 0.77 | 38.31 | 2.91 | 0.91 | 18.29 | 10.87 |
| SECV_3 | 37 | 1034 | 5.19 | 0.67 | 26.67 | 2.40 | 0.83 | 11.06 | 6.02 |
| SECV_4 | 46 | 1710 | 6.05 | 0.45 | 27.27 | 1.72 | 0.58 | 5.58 | 2.38 |
| SHAG_1 | 41 | 742 | 6.05 | 0.72 | 31.1 | 2.69 | 0.90 | 14.69 | 10.11 |
| SHAG_2 | 33 | 770 | 4.82 | 0.72 | 28.73 | 2.51 | 0.85 | 12.35 | 6.83 |
| SHAG_3 | 35 | 666 | 5.23 | 0.77 | 29.04 | 2.72 | 0.91 | 15.21 | 11.32 |
| SHAG_4 | 34 | 632 | 5.12 | 0.71 | 29.37 | 2.50 | 0.86 | 12.13 | 6.85 |
| NAIW_1 | 37 | 480 | 5.83 | 0.67 | 32.57 | 2.42 | 0.85 | 11.27 | 6.73 |
| NAIW_2 | 39 | 585 | 5.96 | 0.73 | 33.75 | 2.68 | 0.89 | 14.63 | 8.80 |
| NAIW_3 | 45 | 673 | 6.76 | 0.76 | 37.57 | 2.91 | 0.91 | 18.33 | 11.33 |
| NAIW_4 | 46 | 556 | 7.12 | 0.82 | 41.42 | 3.14 | 0.94 | 23.14 | 15.31 |
| SUNS_1 | 29 | 667 | 4.31 | 0.64 | 23.61 | 2.17 | 0.80 | 8.75 | 4.91 |
| SUNS_2 | 32 | 593 | 4.86 | 0.69 | 25.27 | 2.40 | 0.88 | 11.02 | 7.94 |
| SUNS_3 | 32 | 1030 | 4.47 | 0.61 | 24.72 | 2.10 | 0.75 | 8.15 | 3.97 |
| SUNS_4 | 33 | 603 | 5.00 | 0.77 | 28.19 | 2.69 | 0.90 | 14.69 | 10.07 |

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