Environment Protection Authority

Nearshore Marine Aquatic Ecosystem Condition Reports

Gulf St Vincent bioregional assessment report 2010–11

EPA
South Australia

Nearshore Marine Aquatic Ecosystem Condition Reports – Gulf St Vincent bioregional assessment report 2010–11

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Summary

Aquatic Ecosystem Condition Reports (AECRs) developed by the Environment Protection Authority (EPA) aim to identify, quantify and respond to threats to nearshore marine systems (from 2–15 m depth) based on a pressure–state–response model of environmental reporting (Hammond et al 1995). The aim of AECRs is to convey complex scientific information to the general public using a report card format. In this document, a more detailed scientific evaluation of the processes within each biounit is also provided. A list of projects and/or management responses, targeted at reducing, ameliorating or removing threats on the condition of the biounits are also described.

Monitoring the condition of habitats in South Australia's nearshore waters is fundamental in ensuring that human activities do not pose unnecessary threats to the marine environment. Degradation of habitats and related decline to ecosystem services provided by healthy habitats can result in significant losses to the community of South Australia in terms of biological, economic, social, cultural and indigenous values.

The EPA's Nearshore Monitoring, Evaluation and Reporting (MER) program aims to investigate broad ecological status according to the condition of the dominant subtidal seagrass, reef and unvegetated sand habitats in the nearshore marine waters across the state. Largely based on the biounits developed by Edyvane (1999b), areas with broadly similar geomorphology and habitats have been used as the reporting scale for AECRs.

Seagrass systems largely employ the seagrass condition index developed by Irving et al (2013). Reef systems are assessed at a coarse level by looking at a number of indices developed by Turner et al (2007). Bare sand habitats or atypical habitats are assessed by looking at numerous factors which are explained in detail in Gaylard et al (2013).

The results of the habitats assessment are used to score the condition for the AECRs. In addition to the habitat information, other measures are assessed at each site to evaluate the level of stress on the habitats such as the presence of seagrass epiphytes or opportunistic macroalgae and water nutrient chemistry which provides an understanding of the level of nutrient enrichment and consequently stress on the habitat. Water clarity is also assessed for the potential for poor water clarity or light limitation on the habitats. The methods used in this report are documented in detail in the EPA report, *The South Australian monitoring, reporting and evaluation program for aquatic ecosystems: Monitoring nearshore marine waters, rationale and methodology* (Gaylard et al 2013).

The first step (Tier 1) is an appraisal of ecosystem condition is to undertake a desktop threat assessment for each biounit with the aim of predicting the expected condition. This allows for the optimisation of the number of field monitoring sites in each biounit (within financial and logistical constraints), while ensuring that the program's objective of maintaining an ambient present state perspective is continued.

The subsequent field monitoring program (Tier 2) investigates whether the observed condition (actual state) is similar to the expected condition. If the observed and expected system states are broadly aligned then we can be reasonably confident that we understand the risks posed by the level of human activity in the biounit and the resulting impacts at a biounit scale recognising that there are likely to be more localised impacts. If the observed condition does not match the expected condition then the threats and impacts or some of the biological and chemical processes that are occurring within that biounit may not be fully understood and further work may be required (Tier 3 – see Gaylard *et al* 2013). This may be desirable if the actual state is worse than the predicted but it also may be worthwhile to understand if the system is in better condition than was predicted.

This document details the results of the EPA's Nearshore MER program for the nine biounits in the Gulf St Vincent (GSV) for 2010 and 2011. Normally the AECR and the assessment report will detail the results of the previous year's monitoring. However in this case, the frequency of monitoring required over time as well as trials of various field methodologies were undertaken which produced two years of results. This document details some of the similarities in the sites and in the biounits and determines the AECRs for both 2010 and 2011. While there are small differences within the monitoring between the two years, these were deemed to be insignificant

A Tier 1 assessment was undertaken for all nine biounits within GSV, however a Tier 2 assessment was only undertaken for five of the nine biounits due to limitations in logistical and resources constraints. The biounits which were not assessed in 2010 or 2011 will be prioritised for future monitoring.

Table 1 Work undertaken for the EPA Nearshore MER program 2010–11

Biounit	Tier 1	Tier 2
Sturt	✓	✗
Orontes	✓	✓
Clinton	✓	✓
Adelaide Metro	✓	✓
Yankalilla	✓	✓
Encounter	✓	✗
Backstairs	✓	✗
Nepean	✓	✓
Cassini	✓	✗

The **Sturt Biounit**, extends from West Cape to Troubridge Point on the southern Yorke Peninsula. Sturt experiences faster currents due to the southerly orientation of the shoreline and the compression of water through Investigator Strait. This results in greater flushing within the biounit than most of GSV coupled with low annual rainfall and minimal inputs from industry and urbanisation. The Tier 1 assessment indicates Sturt is likely to be in Very Good condition. Typically the habitat structure is considered to be largely natural, however there may be some initial symptoms of nutrient enrichment or short episodes of temporarily poor water clarity (Gaylard et al 2013). A Tier 2 assessment was not undertaken in Sturt during 2010 or 2011, but will take priority when GSV is revisited in the future.

The **Orontes Biounit** extends from Troubridge Hill to Ardrossan on the eastern side of Yorke Peninsula. The threat assessment and literature review (Tier 1 assessment) predicted that Orontes was likely to be in Good condition, based on the low annual rainfall and minimal industrial inputs. Habitats are slightly impaired with initial symptoms of nutrient enrichment or sedimentation and there may be short term changes to ecosystem function (Gaylard et al 2013). The threat assessment indicated that the key pressures that are likely to be acting on the condition of the nearshore environment are nutrients from a range of sources including high densities of domestic septic tank systems and the dominant agricultural landuse of the Yorke Peninsula.

The Tier 2 assessment for Orontes sampled 14 sites in 2010, and 16 in 2011 were assessed for broad ecological condition. The sites were comprised primarily of *Posidonia* spp dominated seagrass meadows, with smaller amounts of *Halophila* spp, and *Heterozostera* spp and isolated macro-algal communities. The Tier 2 assessment indicated that Orontes was in Very Good condition, which is slightly better than the Tier 1 assessment of Good. The Very Good condition was largely due to over 75% of the area consisted of dense seagrass meadows. However almost all of the seagrass habitats were under significant stress due to dense epiphyte loads on seagrass leaves. Epiphyte loads can vary in density through space and time naturally but in this case the densities did not vary greatly between 2010 and 2011 particularly around Pine Point and Wool Bay. If epiphyte loads are prolonged it can result in seagrass loss due to the blocking of light reaching the seagrass leaves by the epiphytes. Management responses currently being undertaken to reduce these pressures include the council investigating expansion of the community waste management schemes (CWMS) at Port Vincent and Coobowie which will reduce nutrient input from septic tanks.

The **Clinton Biounit** covers the majority of the upper and eastern part of GSV between Ardrossan on the western side of the Gulf around to Marino Rocks, south of the Adelaide CBD. As a part of this MER program the Clinton Biounit has been modified from that proposed by Edyvane (1999c) in order to reflect the increased risk of environmental impacts from a small proportion of the original biounit located in shallow waters (2–5 m) directly adjacent the Adelaide metropolitan coast. As such, this area of shallow waters is captured within the Adelaide Metro Biounit. Tier 1 assessment of Clinton

predicted the likely condition to be Very Good due to minimal terrigenous inputs and low urbanisation of the adjacent coast for the majority of the biounit.

The Tier 2 assessment for Clinton, comprised a total of 24 sites in 2010 and 25 in 2011. Sites were dominated by dense seagrass habitats, consisting mainly of *Posidonia* spp and *Amphibolis* sp The Tier 2 assessment rated the biounit in Very Good condition, consistent with the Tier 1 assessment. While the seagrasses were in good condition there were some areas that had dense epiphyte loads on seagrass suggesting some locations were likely to be under stress from excess nutrients. If dense epiphytes loads are prolonged, seagrasses can suffer reducing in density and area. Epiphyte loads were particularly dense at the head of the gulf as well as around Port Gawler. Management responses currently being undertaken to reduce these pressures include the implementation of the Adelaide Coastal Water Quality Improvement Plan (ACWQIP) which has developed nutrient and sediment reduction targets, including Bolivar wastewater treatment plant (WWTP). In addition SA Water have undertaken major upgrades to facilitate water recycling to market gardens in the Virginia area.

For the purposes of the Nearshore MER program the **Adelaide Metro Biounit** has been excised from the original Clinton Biounit described by Edyvane (1999c). It now extends along the major urbanised areas of the metropolitan coastline from Marino south of the city to the Gawler River including the Port River estuary out to the 5-m bathymetric contour (Figure 1). This region reflects the area shown to have lower flushing and retains relatively poorer quality water that has been shown to have had significant habitat degradation over time (Fox et al 2007; Pattiaratchi et al 2007). Isolating this stretch of coastline in the AECR will allow for more detailed feedback on intensive management responses currently undertaken in this unit which would otherwise be diluted within the much larger Clinton Biounit.

The Tier 1 assessment for the Adelaide Metro Biounit suggests that the heavily modified terrestrial landscape results in increased nutrient and sediment flows from the land to the sea when it rains heavily, coupled with the level and number of potential threats to water quality both present and historical, and the degree of use of the waters along the metropolitan coast, the ecological condition of this biounit is likely to be Poor. A biounit in Poor condition typically has habitats showing significant impacts of nutrient enrichment or sedimentation with severely impaired habitat structure and changes to ecosystem function including but not limited to, reduced biodiversity, productivity and sediment stability (Gaylard et al 2013).

The Adelaide Metro Biounit Tier 2 assessment comprised seven sites sampled in 2010 and eight in 2011. In 2010 the Tier 2 assessment indicated that the biounit was in Fair condition, which is better than the Tier 1 assessment, while in 2011 the observed condition was rated as Good. While this suggests an improvement in condition this result is based upon the need to adjust the location of a number of sites due to sampling difficulties in 2010. In general the condition of the biounit did not change over the period of sampling and the biounit showed that there are some areas where there were intact, dense seagrass meadows, particularly around Semaphore. While in other areas there was seagrass in poor condition or seagrass was totally absent suggesting considerable variability in seagrass extent across the biounit. The region between Grange and Glenelg was particularly impacted with poor seagrass condition.

The entire biounit was under stress from excess nutrients with many locations having dense epiphyte loads, opportunistic macroalgae and elevated turbidity. These findings highlight the patchy nature of seagrass along the metropolitan coast and it is likely that if epiphyte loads are prolonged there is a risk of further degradation of habitats. Management responses currently being undertaken to reduce these pressures include the implementation of the ACWQIP which has set targets for the WWTPs including Bolivar, Glenelg and Christies Beach. This plan also has reduction targets set for suspended solids from stormwater.

The **Yankalilla Biounit** extends from Marino Rocks (north of Hallett Cove) to Rapid Head (Victor Harbor). Yankalilla is more exposed to higher wave energy compared to other biounits, with moderate to high wave energy experienced particularly during winter. The terrestrial landscape has been heavily modified and the biounit receives major freshwater flows from the Onkaparinga River and the Christies Beach WWTP. The Tier 1 assessment suggested that the biounit is likely to be in Fair condition. A biounit in Fair condition typically has impaired habitat structure and is showing impacts from nutrient enrichment. These changes to the habitat are likely to be affecting ecosystem functions including reduced biodiversity, productivity and sediment stability (Gaylard et al 2013).

The Tier 2 assessment of Yankalilla comprised seven sites in both 2010 and 2011. The sites were largely dominated by bare sand or rocky reef habitats. Small areas of seagrass were present and were largely *Posidonia australis* complex seagrass with some areas of *Posidonia coriacea* in the southern part of Yankalilla in response to the higher wave

energies. Where present, seagrass was typically sparse in density and patchy in cover regardless of species. Rocky reefs were in moderate condition with variable abundances of large brown canopy algae and in some cases excessive cover of turfing algae that may suggest some degradation. The biounit was rated in Poor condition, which is slightly lower than the Tier 1 assessment. This was largely due to seagrasses that were likely to be degraded in the northern part of the biounit but there is a need for more sites to be sampled in the southern part of the biounit. As outlined earlier the ACWQIP has set targets for nutrient reduction from the Christies Beach WWTP and reduction targets for suspended solids from stormwater. It is aimed that over time, reductions to meet these targets will improve the condition of the Yankalilla Biounit.

The **Encounter Biounit** extends from Rapid Head on the southwest Fleurieu Peninsula to Port Elliot and borders the Backstairs Biounit which encompasses the Backstairs Passage and the Pages Islands. The terrestrial landscape has been heavily modified for agriculture, and expanding coastal development throughout the Encounter Bay to Port Elliot stretch of coastline is putting considerable strain on infrastructure as well as the quality and quantity of stormwater discharges. A large proportion of the sewage treatment is currently undertaken at the WWTP at Victor Harbor but there are still high densities of septic tanks throughout the biounit which has the potential to add nutrients into the groundwater. The expected condition based on the Tier 1 assessment of Encounter was predicted to be Good, A biounit in Good condition can be described as habitats that are slightly impaired and are beginning to show initial signs of nutrient enrichment. There was no Tier 2 assessment undertaken during either 2010 or 2011, but an assessment will be prioritised in the future when the Gulf St Vincent Bioregion is revisited.

The **Backstairs Biounit** begins east of Penneshaw on Kangaroo Island and extends eastwards into the Southern Ocean encompassing the waters of the Backstairs Passage and the Pages Islands. The northerly aspect of the shoreline provides a predominantly low wave energy environment, with the exception of the far eastern section and the Pages Islands. The Tier 1 assessment predicts Backstairs is in Excellent condition, due to the terrestrial landscape only having been slightly modified, with minimal inputs into the marine environment coupled with likely high-water movement through the Backstairs Passage. A biounit in Excellent condition would typically have habitats considered to be natural and unimpacted and would be consistent with reference condition described by Gaylard et al (2013). There was no Tier 2 assessment undertaken during either 2010 or 2011, but an assessment will be prioritised in the future when the GSV Bioregion is revisited

The **Nepean Biounit** extends from North Cape to Cape Willoughby on the northern coast of Kangaroo Island. The dominant feature is Nepean Bay, large embayment that has low current speeds and is exposed to predominantly offshore winds generating low wave energies. The Tier 1 assessment suggests that the terrestrial landscape has been heavily modified for agriculture coupled with coastal development within a number of small coastal towns. The slow-moving water of the embayment is likely to exacerbate the effect of nutrient and sediment inputs. There is also documented seagrass loss throughout the biounit due to excess nutrients. Consequently the ecological condition of the biounit was given to be Fair. A biounit in Fair condition typically has impaired habitat structure and is showing impacts from nutrient enrichment. These changes to the habitat are likely to be changing ecosystem function including reduced biodiversity, productivity and sediment stability (Gaylard et al 2013).

The Tier 2 assessment of the Nepean Biounit comprised 10 sites sampled in both 2010 and 2011. The sites were dominated by seagrass which ranged from good condition including dense *Posidonia* spp meadows throughout the Bay of Shoals, through to locations in poor condition with patchy, sparse seagrass in poor condition at Western Cove. Nepean as a whole was in Good condition in both 2010 and 2011, which is better than the Tier 1 assessment. However throughout the entire biounit, there were dense seagrass epiphyte loads suggesting nutrient enrichment that may result in seagrass loss. Management responses currently being undertaken to reduce these pressures include the Kangaroo Island Natural Resource Management Board's Catchment to Coast program which focuses on fencing of riparian vegetation and construction of in-stream remediation works such as formed creek crossings in order to exclude livestock from riverbanks and watercourses, reducing erosion and runoff into the Cygnet River. The Kangaroo Island Council are also progressively connecting properties to a CWMS at American River which will reduce nutrient loads into the nearshore environment.

The **Cassini Biounit** extends from Cape Borda to North Cape, encompassing approximately 111 km of the northern Kangaroo Island coastline. The Tier 1 assessment predicts that the Cassini is likely to be in Very Good condition, the terrestrial landscape has been heavily modified for agriculture. However there are only a small number of creeks which may transport nutrients and sediments into nearshore waters but only during rain events. A biounit in Very Good

condition is likely to have habitats that are largely considered to be natural, however there could be some initial symptoms of nutrient enrichment (Gaylard et al 2013). There was no Tier 2 assessment undertaken during either 2010 or 2011, but an assessment will be prioritised in the future when the GSV Bioregion is revisited.

Table 2 Biounits in Gulf St Vincent considered and AECR results, 2010 and 2011

Biounit	AECR Tier 1 Assessment	AECR 2010 Tier 2 Assessment	AECR 2011 Tier 2 Assessment
Sturt	Very Good	Not Assessed	Not Assessed
Orontes	Good	Good	Good
Clinton	Good	Good	Good
Adelaide Metro	Poor	Fair	Good
Yankalilla	Fair	Poor	Poor
Encounter	Good	Not Assessed	Not Assessed
Backstairs	Excellent	Not Assessed	Not Assessed
Nepean	Fair	Good	Good
Cassini	Very Good	Not Assessed	Not Assessed

This is the first standardised bioregion-wide assessment of ecological condition of nearshore habitats to be undertaken in Gulf St Vincent. The assessment indicates that large areas of the shallow nearshore waters throughout the Gulf are subject to nutrient enrichment, and that this is not restricted to the areas adjacent to large industrial discharges but also adjacent some small coastal towns or river discharges. In many circumstances the effects of nutrient enrichment can be exacerbated by low current speeds and poorer flushing within embayments suggesting that these areas are particularly sensitive to any nutrient input. The results of this MER program show that even with relatively small amounts of adjacent human activity there can be observable changes to seagrass and reef condition. If continued unchecked, the activity will lead to habitat loss and significant reductions in ecosystem value including loss of biodiversity, reduction in commercial and recreational fisheries, unstable sediment and potential for beach erosion.

It is likely that many of the management responses detailed throughout the document will help to improve condition of the nearshore waters but it is worthy to note that it has taken 170 years of human activity to degrade the environment, and improvement is likely to be a long-term prospect.

1 Introduction

South Australia has over 4,000 km of coastline which is diverse biologically and geomorphologically. Healthy nearshore waters and especially habitats in good condition are essential in maintaining productive commercial and recreational fisheries, maintaining beach and sand movement, nutrient and carbon cycling and storage, and providing safe and aesthetically pleasing waters which maintains our love of the ocean and our coastal lifestyle (Orth et al 2006). Monitoring the condition of habitats within nearshore waters is fundamental in ensuring that human actions are not degrading the nearshore environments which will result in losses of productivity and 'ecosystem services' (Costanza et al 1997; McArthur and Boland 2006).

The EPA Nearshore Monitoring, Evaluation and Reporting (MER) program aims to investigate broad ecological condition based upon the status of the dominant subtidal habitats in the nearshore marine waters across South Australia, typically seagrass, rocky reefs and unvegetated soft sediment (Edyvane 1999c). In this MER program it is inferred that a healthy habitat will result in a healthy and biodiverse ecosystem.

In order to undertake a Nearshore MER program across the state with the current level of resources, monitoring and reporting of the state's waters are carried out in smaller assessment units. The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) (Commonwealth of Australia 2006) has used a spatial framework that delineates the marine environment throughout Australia's coastal waters into *bioregions* based on collated biological data and inferred ecosystem patterns.

Bioregions are an accepted tool in the description of ecosystem boundaries and considered to be a useful spatial scale for regional planning and also supply a framework for smaller-scale ecologically relevant planning and management (Commonwealth of Australia 2006). There are eight bioregions that span the South Australian coast line. On the west coast is Eucla, Murat and Eyre. Spencer Gulf has been split into two bioregions – Spencer Gulf and Northern Spencer Gulf. Gulf St Vincent (GSV) encompassing Investigator Strait, Backstairs Passage and the northern face of Kangaroo Island. The southeastern part of South Australia is made up of two bioregions, starting at the Fleurieu Peninsula, and to the west are the Coorong and Otway.

At a finer spatial scale within each South Australian bioregion are the *biounits*; the boundaries of which delineate a finer resolution of inferred ecological boundaries and which can be measured in the tens of km inside each IMCRA bioregion (Edyvane 1999b; Edyvane 1999c). The EPA Nearshore MER program has been designed to report using an Aquatic Ecosystem Condition Report (AECR) at a biounit scale, but has the capability to report at the bioregional scale for purposes such as the state of the environment reporting.

In some cases it was seen as pragmatic to modify the IMCRA bioregions to align with the Edyvane (1999c) biounits to ensure consistency and also for logistical reasons. In addition, some biounits have been split to align with areas of particular concern—specifically the Adelaide Metro Biounit has been excised from the larger Clinton Biounit.

1.1 Nearshore marine monitoring framework

The EPA report, *Monitoring nearshore marine waters – rationale and methodology* (Gaylard et al 2013) details the framework and methods undertaken to assess broad ecological condition in South Australian nearshore marine environments. This will not repeat the methodology in detail and should be read in conjunction with the rationale and methodology document.

The Nearshore MER program has been designed using a three-tier assessment framework. The tiers described below outline the process to assess the condition of the marine environment within this MER program.

- **Tier 1** – A literature review and desktop threat assessment are developed to examine pressures on ecological communities within each biounit. This information is used to review and update conceptual models of ecosystem status and tailor the field monitoring to address identifiable threats specific to each bioregion, if required. An *expected* ecosystem condition for each biounit is also developed using the threat assessment and available published literature, particularly historical monitoring.
- **Tier 2** – Using the information from Tier 1 a rapid field assessment program is developed and implemented based on the level of threat (eg the number of sites selected). Monitoring for the Nearshore MER program is undertaken

throughout each biounit across two monitoring periods, autumn and spring, with the results used to develop the *observed* condition.

The information collected from Tiers 1 and 2 is used to prepare an AECR communication tool for each biounit. This rating serves as a broad assessment of the observed ecological condition at the time of sampling, identifies the main pressures that are likely to be driving the observed condition and lists the main management responses that are designed to address the pressures identified.

- **Tier 3** – Noteworthy differences between the *expected* and *observed* conditions for a biounit suggests gaps in our understanding of threats and biological responses, and the biounit will be highlighted as in need of further research. Priority will be given to areas that are worse than predicted but there is also value in understanding further areas that are better than predicted. The publication of the AECR report will still proceed with caution, but a statement of limitations will be made highlighting the need for further detailed work in this unit. This further work may be undertaken by the EPA or another institution, and would likely include methods to investigate the origin of specific pollutants driving the observed condition, but may be reliant upon additional resources.

1.2 Structure of the current report

This report should be read in conjunction with the *Monitoring nearshore marine waters: rationale and methodology* document (Gaylard et al 2013) which describe in detail the methods used to assess the sites and why the parameters have been selected to be assessed.

The current report focuses on the GSV Bioregion and its associated biounits. The report details the Tier 1 assessments for the nine biounits defined for the bioregion (Figure 1), including the predicted condition for each biounit, how this was developed using historical information and an assessment of threats to the nearshore marine environment. The report then details the results of the field program (Tier 2) undertaken for five of the nine biounits to assess current condition of the nearshore habitats including reefs, seagrasses and bare sand habitats.

The body of this document describes in detail the habitats assessed, the some of the ecological processes occurring within various strata that have been measured and whether there are observable biological gradients present that may aid in a determination of the condition, keeping in mind the broad scale nature of the design of the MER program. This information is distilled to an Aquatic Ecosystem Condition Report (AECR) for each biounit (Appendix 4). The reports are designed to convey complex scientific information to the general public in an easily accessible format. In addition to the AECRs, the raw data and a two-minute representative video snapshot will be provided on the EPA website <www.epa.sa.gov.au>.

2 Tier 1 – assessment of Gulf St Vincent Bioregion

Gulf St Vincent is an inverse estuary characterised by high evaporation, relatively low freshwater input and increasing salinity and temperature gradients towards the shallower waters at the head of the Gulf in the north (Nunes Vaz et al 1990). The salinity gradient is not as significant in the lower part of the gulf and Kangaroo Island, but overall ambient salinity of this bioregion is still higher than that of the open ocean. The net circulation of water through the Gulf is generally in a clockwise direction, northwards from the bottom of Yorke Peninsula with removal of water from the Gulf occurring in a southeasterly direction past Cape Jervis towards Port Elliot (Pattiaratchi et al 2007). Wave energy is considered to be low to moderate with regular 'dodge tides' which are periods of up to 12 hours with minimal tidal movement (Bye 1976).

The GSV Bioregion and the biounits therein have been monitored in the Nearshore MER program in order to develop the AECRs (Figure 1). The boundaries of these spatial units have been slightly modified from that proposed by Commonwealth of Australia (2006) and Edyvane (1999c) in order to:

1 align with the Natural Resource Management (NRM) boundaries where possible

2 efficiently use EPA resources

3 address some limitations in boat access and logistics of sampling within the marine environment

4 encompass areas with particular levels of threat/environmental damage.

The southwestern border of the Gulf St Vincent Bioregion is unchanged from that proposed by IMCRA (Commonwealth of Australia 2006), and extends from West Cape on the Yorke Peninsula to Cape Torrens on the northwestern coast of Kangaroo Island. The southeastern border has been modified from the IMCRA bioregion and follows the biounit boundary proposed by Edyvane (1999c), extending from the southwestern tip of Port Elliot to Cape Willoughby on Kangaroo Island.

With respect to biounits, the only change to the delineation of Edyvane (1999c) has been to report on the Clinton Biounit in two sections with the Adelaide nearshore metropolitan coast being reported separately (as Adelaide Metro). Pattiaratchi et al (2007) has shown that the nearshore waters along the Adelaide metropolitan coast move in a longshore direction and that the dispersion rates are low, resulting in land-based discharges such as stormwater and wastewater discharges remaining in the nearshore zone. This new biounit has well-documented water quality issues including nutrient enrichment and poor water clarity. It is the location of a large proportion of the seagrass loss and degradation of a number of nearshore rocky reefs that has been reported over the last 10 years by numerous researchers (Westphalen et al 2004; Bryars et al 2006a; Fox et al 2007; Turner et al 2007; Bryars and Rowling 2008). It is expected that this zone could be considered an area of higher risk of degradation compared to the remainder of the Clinton Biounit due to the intense urbanisation, numerous large land-based discharges and the long residence times.

Monitoring will focus on nearshore environments in a zone of 2–15 m depth, which has been identified as a balance between achieving sensible coverage relative to logistic constraints:

- This zone includes ecosystems in likely proximity to land-based pollution sources (Connell 2007b), a feature firmly established in both the Adelaide Coastal Waters Study into seagrass decline and the Reef Health investigation (Westphalen et al 2004; Turner et al 2007).
- The ecosystems within this zone generally comprise rocky reef, seagrass and/or bare sandy bottom for which there is a considerable and growing body of research related to their responses to disturbance, in particular declines in water quality.
- The 2-m limit allows ready (and safe) access for boats and camera systems without the need to radically adjust the sampling methods, the simplicity and consistency of which is essential in establishing a long-term, spatially varied dataset.
- Although light attenuation from shallow to deep water and distance from shore can vary substantially (Duarte 1991; Masini et al 1995; Collings et al 2006), the 15-m lower limit is less likely to be light limited particularly in offshore areas of the gulfs and oceanic regions. The 15-m profile is considered to be the lower depth limit for many *Posidonia* species but certainly encompasses most of the perennial taxa for which seagrass loss is of primary concern (see summary in Westphalen *et al* 2004). Seagrass decline is often considered to occur in deeper areas first (Westphalen

et al 2004, Collings *et al* 2006). A loss of condition or cover of seagrasses at depth may be the first sign of decline, although it is worth noting that on the Adelaide metropolitan coast, seagrass loss was largely in shallower nearshore areas.

- The 15-m depth places a logistic limit on sampling across seabed with a low level of slope. Conversely, this depth also offers some capacity for spatial coverage in steeper, higher relief systems.

South Australia's network of 19 Marine Protected Areas (MPAs) are multi-use parks with different management zones including 'no take' sanctuary zones, habitat protection zones, general managed use zones and restricted access zones. Of the 19 marine parks, four are found within the GSV Bioregion, including sanctuary zones which are areas designed to have a high level of protection for areas of significance. Areas of significance include rare or unique habitats as well as biogeographically significant populations of rare or threatened marine species, in addition to protecting habitat and taxonomic diversity, as well as notable breeding/spawning/nursery and feeding grounds (Baker 2004). While these parks will be highlighted in the current MER program and the description of the regions, it should be noted that monitoring undertaken for the AECRs was not specifically designed to assess the condition or effectiveness of the marine parks.

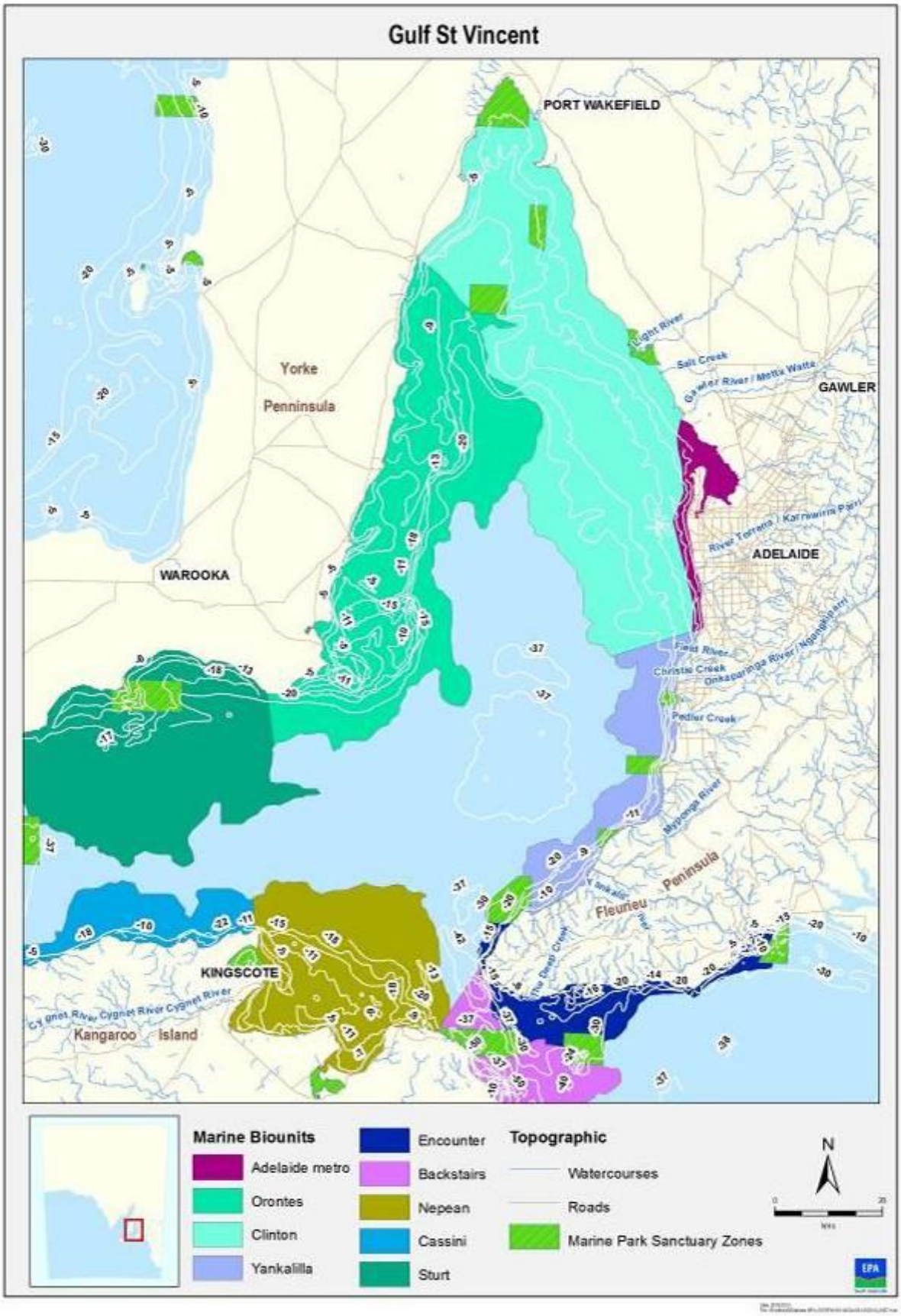

Figure 1 **Map of the Gulf St Vincent Bioregion and associated biounits used for the Nearshore MER program (modified from IMCRA v4.0).**

2.1 Threat assessment

Available data, literature and risk assessments have been consulted to develop a high-level threat assessment for the Tier 1 predicted condition for each biounit (Table 3). This threat assessment details not only anthropogenic inputs into nearshore waters in each biounit but also the transport of pollutants from one biounit into another (where information is available), and also some of the natural factors that may exacerbate nutrient enrichment and decreased water clarity.

Table 3 Tier 1 – Gulf St Vincent threat assessment

Gulf St Vincent	Clinton	Adelaide Metro	Orontes	Yankalilla	Encounter	Backstairs	Nepean	Cassini	Sturt
Areas of restricted water movement or likely low residence time	++	++	++	+	+	◇	++	◇	+
Agricultural runoff	++	O	◇	++	++	◇	++	+	◇
Coastal development	++	++	++	++	++	O	+	◇	+
Dredging	O	++	◇	◇	◇	O	◇	O	O
Historical impacts	O	++	◇	+	+	O	++	O	O
Industrial discharges	++	++	O	+	O	O	O	O	O
Power stations	O	++	O	O	O	O	O	O	O
Septic tanks	+	+	+	+	+	+	+	+	+
Stormwater	◇	++	+	+	+	O	+	◇	◇
WWTP/CWMS	++	++	O	++	+	O	+	O	+
Input aquaculture	O	O	O	O	O	O	O	O	O
Non input aquaculture	O	O	+	O	O	O	+	O	O
Sum of threats									
None	5	3	3	3	4	9	3	6	6
Low	1	0	4	1	1	2	1	4	2
Moderate	2	1	3	5	5	1	5	2	4
High	4	8	2	3	2	0	3	0	0
Sum	17	26	16	20	17	4	20	8	10
Expected condition	Good	Poor	Good	Fair	Good	Excellent	Fair	Very Good	Very Good

Threat assessment scores

Symbol	Consequence	Detail	Score
O	Insignificant	Localised impact with a short duration (days)	0
◇	Low impact	Localised impact but with a moderate duration (weeks to months)	1
+	Moderate impact	Wide or long duration	2
++	High impact	Wide and long duration	3

Where there was significant uncertainty in the load, toxicity or impact of a potential threat the uncertainty was treated by increasing the threat level by one level (ie from low to moderate).

2.2 Tier 1 results – Sturt Biounit

The Sturt Biounit extends from West Cape to Troubridge Point on the southern Yorke Peninsula (Figure 2). The biounit has a diverse range of habitats throughout the sheltered shallow waters, including extensive seagrass meadows and algal dominated platform reefs (Shepherd and Sprigg 1976).

The shoreline of the Sturt Biounit is largely orientated in a southerly direction into Investigator Strait, where strong deeper water tidal currents can be found. These currents contribute to the more oceanic salinity observed in these waters compared to the more hypersaline and warmer waters found in biounits to the north into Gulf St Vincent (Shepherd and Sprigg 1976).

Extensive seagrass meadows occur throughout the bays dotted along the south coast of Sturt accounting for approximately 75% of the inshore habitats. Dominant species of seagrass include *Posidonia sinuosa* and *P angustifolia*, *Amphibolis antarctica* and *Halophila australis*. Macroalgal communities are dominated by the canopy forming species *Ecklonia radiata*, *Sargassum fallax* and a number of *Cystophora* species including *C moniliformis, C racemosa, C siliquosa and C platylobium.* In total reefs account for 15% of the inshore habitats with the remaining 10% consisting of sandy substrate (Edyvane 1999c).

Sturt includes part of the Lower Yorke Peninsula Marine Park, including two sanctuary zones (Figure 2).

Tier 1 threat assessment

There are a number of small coastal towns within Sturt; Port Moorowie has a population of 387 and Marion Bay has approximately 139 permanent residents (Statistics 2012). However the population of these towns swells considerably during peak holiday seasons. Sewage treatment for these towns is largely through septic tanks that have the potential to leach nutrients into shallow groundwaters, which in high densities and with sandy soils can result in nutrients being transported to nearshore marine waters (Reay 2004). There is a Community Wastewater Management System (CWMS) at Foul Bay which treats sewage from approximately 46 dwellings, with the treated effluent subsequently being used for irrigation. The major land use for Sturt is cropping, in particular barley. Annual rainfall is quite low, from 300 to 400 mm (Meteorology 2013) and there are few creeks that would flow regularly to the sea. However it is likely that groundwater would flow towards the sea, potentially transporting nutrients from agricultural land towards the nearshore waters.

Expected condition of the Sturt Biounit

The Sturt Biounit experiences faster currents due to the southerly orientation and the compression of water through Investigator Strait, which results in greater flushing within the biounit than most of GSV (Shepherd and Sprigg 1976). The threat assessment is that the presence of activities or factors may impact on water quality and ecological condition.
It is predicted that the Sturt Biounit is likely to be in Very Good condition (Table 3). Typically for a biounit in Very Good condition the habitat structure is considered to be largely natural, however there may be some initial symptoms of nutrient enrichment or short episodes of temporarily poor water clarity (Gaylard et al 2013).

Figure 2 **Benthic habitats in the nearshore region of the Sturt Biounit. Benthic habitats shown are from the National and State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

2.3 Tier 1 results – Orontes Biounit

The Orontes Biounit extends from Troubridge Hill to Ardrossan on the eastern side of Yoke Peninsula (Figure 3). Orontes has an overall easterly orientation into Gulf St Vincent and typically has low wave energies due to the predominant offshore winds (Edyvane 1999c) and attenuation of oceanic swell through Investigator Strait. The more energetic waters of Investigator Strait erode finer sediment particles, leaving coarse shell grit and sand in the Strait, where finer products are deposited in the quieter waters of Gulf St Vincent as calcareous mud and silts (Shepherd and Sprigg 1976).

Edyvane (1999c) suggests that seagrass meadows represent 56.5% of the inshore areas in the biounit, with rocky reefs representing 36.9% and soft sandy bottom represents 6.6% of Orontes. In shallow waters seagrass meadows occur throughout the sheltered embayments such as Coobowie and Ardrossan with *Posidonia sinuosa and P angustifolia* dominating and *Halophila australis* often adjacent to reef areas and extending to deeper water. Rocky reefs on exposed coasts in Orontes are dominated by the kelp *Ecklonia radiata* and mixed fucoids including *Sargassum linearfolium, S paradoxum, S spinuligerum* and *S lacerifolium* as well as *Cystophora expansa, C monoliformis* and *C brownii*.

The Orontes Biounit straddles the Lower Yorke Peninsula Marine Park and a sanctuary zone is located within Coobowie Bay (Figure 3).

Tier 1 threat assessment

The main population centres in Orontes are the townships of Ardrossan (which borders the Clinton Biounit), with a population of 1,136, Stansbury with a population of 543, Edithburgh with 466 and Port Vincent with a population of 490 (Statistics 2012). The only centralised sewage treatment in Orontes is the CWMS located at Ardrossan, which collects and treats sewage, and reuses the treated wastewater for irrigation of the golf course. The smaller townships and shack communities rely on septic systems. Septic tanks in high densities have been shown to introduce nutrients into the shallow groundwater at a load of between 5–10 kg/dwelling/year (Reay 2004), which when the groundwater moves towards the coast has the potential to introduce a significant load of nutrients into nearshore waters.

The terrestrial environment adjacent to the Orontes Biounit is dominated by agriculture with grain and sheep farming being the main commodities. Agriculture has required the clearance of extensive areas of land adjacent the nearshore marine waters which increases the risk of nutrient and sediment input into nearshore waters. There are two major quarries in the biounit, a limestone quarry at Klein Point and a dolomite quarry at Ardrossan. Quarries can lead to increased suspended solids in any surface water runoff and through spillage of product during transport and port–ship loading (see below).

There are three shipping port facilities in Orontes facilitating the export of grain, dolomite and limestone. Klein Point supports the majority of the exports with around 275 vessel loadings annually, while Port Giles and Ardrossan service around 20 vessels. These port facilities can increase the risk of spillage and dust generated from loading activities and dust from stockpiles and stormwater runoff entering the nearshore waters. The shipping activity in these areas also increases the risk of hydrocarbon spills into waters as a result of spillage or accidents. Shipping activity also increases the risk of introduction of invasive marine pests which can be transported from other parts of Australia or overseas, via hull biofouling or through ballast water discharge and have the potential to cause significant impacts on the marine environment including fisheries and ecosystem services.

The average annual rainfall for Orontes is approximately 300–400 mm, which is less than the average rainfall in the Adelaide Metro Biounit as well as other biounits along Fleurieu Peninsula and Kangaroo Island (Meteorology 2013), and is therefore likely to result in a only minimal or sporadic amount of runoff into the marine environment.

A number of aquaculture leases that farm Pacific oysters (*Crassostrea gigas*) are located in Coobowie Bay, Stansbury and Port Vincent, while a small abalone (*Haliotis rubra*, *H laevigata*, and *H cyclobates*) lease off Giles Point is the only supplementary fed aquaculture production in the area (Primary Industries and Regions SA). Oysters filter water and remove phytoplankton and organic matter from the water column which has the potential to improve water quality, while depositing their own organic matter as psuedofaeces into the water. It is generally thought that the net environmental impact is positive on water quality (Newell 2004), however this result has not been demonstrated in South Australia. Other risk factors from this activity, such as the spread of disease and marine invasive species, could be higher (Crawford 2003). Certain types of aquaculture require additional food sources to be introduced to the marine environment which in high densities could lead to increases in nutrient loading.

There are a number of locations throughout the biounit where the water exchange may be limited due to natural geomorphology and large areas of shallow water which are subject to ambient heating, providing conditions favourable for algal growth. These conditions are likely to exacerbate the biological effect of excess nutrients.

Expected condition of the Orontes Biounit

The threat assessment for the Orontes Biounit suggests that the terrestrial landscape has been heavily modified for agricultural use, which along with two large quarries, results in an increased risk of nutrient and sediment input to the sea during heavy rains. Table 3 details the main threats to water quality in the biounit and predicts that the ecological condition of the biounit is likely to be Good. Typically a biounit in Good condition can be described as having a habitat structure that is slightly impaired and that is beginning to show initial signs of nutrient enrichment and/or suspended sediment. The emergence of filamentous epiphytes in moderate densities on seagrass and sparse opportunistic algae such as *Ulva spp* and *Hincksia spp* are indicators of nutrient enrichment within a biounit (Gaylard et al 2013).

2.4 Tier 1 results – Clinton Biounit

Clinton is the largest biounit in Gulf St Vincent and covers the majority of the upper and eastern part of GSV between Ardrossan on the western side around to Marino Rocks just north of Hallett Cove. As a part of the Nearshore MER program the Clinton Biounit has been modified from that proposed by Edyvane (1999c) in order to reflect the increased risk of environmental impacts from a small proportion of the original biounit along the Adelaide metropolitan coast. A new biounit named Adelaide Metro has been created within Clinton and is constrained to the nearshore coastal waters less than 5 m deep along the metropolitan coast. More detail on this separation and the assessment of the Adelaide Metro Biounit can be found in section 2.5.

The revised Clinton Biounit is sheltered from large waves experienced further south in Gulf St Vincent, particularly the head of the Gulf although there is increasing wave energy at its southern extent towards Marino (Edyvane 1999c). Clinton is dominated by vast seagrass meadows and supports the most extensive mangrove and tidal flats within GSV (Harbison 2008). There are a number of high conservation value marine park sanctuary zones within Clinton, largely based on the extensive areas of mangroves, salt marsh and seagrass beds, which provide food and shelter for juvenile fish including commercially and recreationally desirable species such as garfish, blue swimmer crabs and whiting (Bryars 2003; DEWNR 2012b).

Of the total inshore habitats (<15 m depth) mapped in the State Benthic Habitat Mapping (SBHM) program 8.1% was represented by unconsolidated bare substrate, less than 1% rocky reefs and 91.6% are seagrass habitats (DEWNR 2010). Previous studies on reef condition have been undertaken on a number of reefs off the Adelaide's metropolitan coast in the Clinton Biounit. Semaphore and Broken Bottom reefs were found to be in Poor condition, while Seacliff was given the classification of Caution. Most notably all three reefs were depauperate of large brown canopy algae compared to reefs found further south in GSV as well as a reef further north (Turner et al 2007; Collings et al 2008).

Tier 1 threat assessment

The town of Ardrossan is on the border of the Orontes and Clinton biounits, and is the largest population centre in Clinton with 1,136 people (see threat assessment in section 2.3). Port Wakefield has a population of 556 and in addition there are numerous small coastal towns that have populations of less than 500 people including Port Clinton, Thompson Beach, Tiddy Widdy Beach and Port Parham (Statistics 2012). All of these small coastal towns treat sewage through the use of septic tanks with the exception of much of Port Wakefield, which is connected to a CWMS. Septic tanks in high densities have been shown to introduce nutrients into the shallow groundwater at a load of between 5–10 kg/dwelling/ year (Reay 2004), which when the groundwater moves towards the coast has the potential to introduce a significant load of nutrients into nearshore waters.

The Bolivar WWTP is located within the Adelaide Metro Biounit but its discharge enters the nearshore marine environment at Chapman Creek which is the boundary between Adelaide Metro and Clinton biounits. This discharge is very high in nutrients and other pollutants, and will be transported into the Clinton Biounit particularly during summer when the flow is typically northwards, while in winter the predominant northwesterly winds transport the discharge further south (Pattiaratchi et al 2007), Similarly other discharges from the Adelaide Metro Biounit are also likely to be transported into the Clinton Biounit which may affect water quality and habitat condition such as the Penrice Soda Products ammonia discharge (see section 2.5).

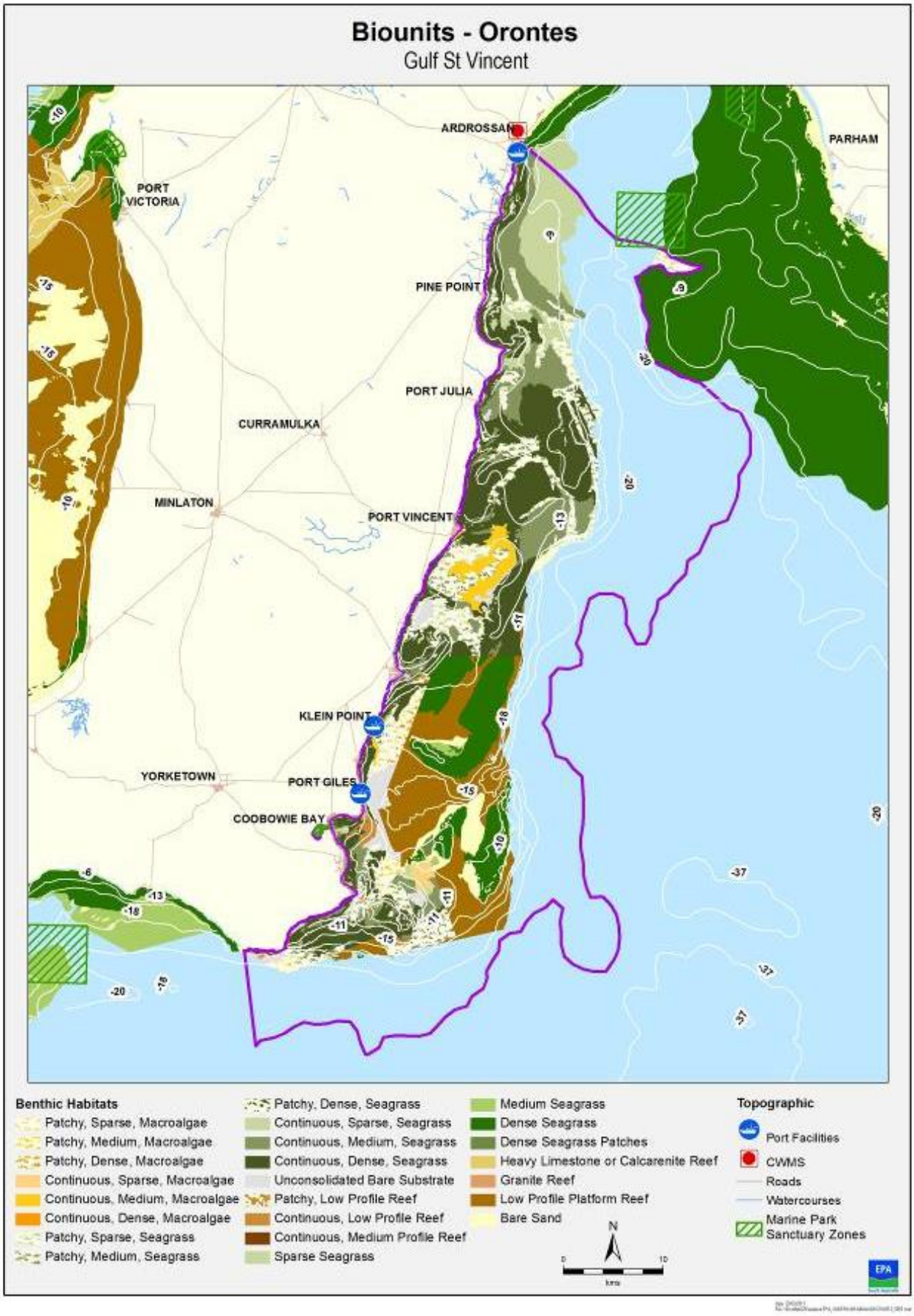

Figure 3 **Benthic habitats in the nearshore region of the Orontes Biounit. Benthic habitats shown are from the National and State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

The majority of the adjacent land around Clinton is coastal wetlands, having been identified as a wetland of national importance (Environment Australia 2001). The presence of mangrove, wetlands and samphire flats in this biounit provides a buffer from the large amount of agricultural activity including the intensive market gardening which occurs in some of the catchments. However, there are a number of rivers/creeks which flow to the marine environment in periods of high flow including the Gawler River and Light River. Monitoring sites on both rivers have been assessed as a part of the EPA's AECR MER program for inland waters, and were both found to be in poor condition, with significant impacts due to nutrient enrichment (EPA 2012a; EPA 2012c). A considerable area along the eastern side of Clinton has been reclaimed for salt production adjacent to mangroves and wetlands in the Barker Inlet to Port Gawler region which has reduced this buffering capacity and ecosystem services provided by mangrove and samphire systems.

Expected condition of the Clinton Biounit

The Tier 1 threat assessment for Clinton detailed the presence and activities of factors that may impact on water quality and ecological condition. This suggested there are relatively few potential threats to water quality coupled (although note the external nutrient inputs from the adjacent Adelaide Metro) with generally low amount of urbanisation (Table 3). The biounit has large intact areas of mangrove and tidal flats, which may act to buffer the nearshore environment from terrestrial inputs. The threat assessment predicts that the condition of Clinton is likely to be Good. Within the Nearshore MER program a biounit in Good condition could typically be described as having a habitat structure that is slightly impaired and that is showing initial signs of nutrient enrichment compared to what is considered to be reference condition. In some locations there may be the emergence of filamentous epiphytes on seagrass and opportunistic algae such as *Ulva* spp and *Hincksia* spp indicating some level of nutrient enrichment (Gaylard et al 2013).

2.5 Tier 1 results – Adelaide Metro Biounit

The Adelaide Metro Biounit has been delineated from the Clinton Biounit to provide better resolution within a specific area of higher risk coastline adjacent the City of Adelaide and the comprehensive body of work describing significant impacts on nearshore habitats within this stretch of coast (eg Fox *et al* 2007). The created biounit boundary extends along the major urbanised areas of the metropolitan coastline from Marino south of the city to the Gawler River including the Port River estuary out to the 5–m bathymetric contour (Figure 5). The Adelaide Metro Biounit reflects the area shown to have lower flushing that retains poorer quality water and as such result in a higher risk of environmental impacts and leads to significant habitat degradation over time (Pattiaratchi et al 2007). Creation of this biounit and related AECR will allow for more detailed feedback on intensive management responses underway in this area which may otherwise be overlooked when considered at the scale of the much larger Clinton Biounit.

Adelaide Metro experiences moderate wave energies from Outer Harbor to Marino Rocks, compared to the upper reaches of the Gulf (Edyvane 1999c; Hemer and Bye 1999). Of the total inshore habitats (<15 m depth) mapped in SBHM program 68.2% comprised seagrass, continuous soft sandy bottoms represent 30.2% and rocky reefs make up only 1.4% of the total areas (DEWNR 2010). However these habitats were mapped after significant historical seagrass loss has already occurred throughout the biounit (Fox et al 2007; Cameron 2008).

Adelaide Metro still has extensive areas of seagrass, including *Posidonia* spp as well as *Amphibolis antarctica and Halophila australis*. Within muddy intertidal areas of Barker Inlet, *Heterozostera tasmanica* or bare substrate dominate (Connolly 1995). On moderately exposed shores the rocky reef macroalgal communities are dominated by *Ecklonia radiata* and mixed fucoids including *Sargassum linearfolium*, *S spinuligerum* and *S lacerifolium* as well as *Cystophora expansa, C monoliformis* and *C brownii* (Edyvane 1999c).

Tier 1 threat assessment

Historically freshwater runoff from the Adelaide Plains would have collected into a network of wetlands known as the Cowandilla Plains (Holmes and Inverson 1976). These wetlands span from Holdfast Bay to the Port River and openings to the sea are at the Patawalonga estuary and through the Old Port Reach of the Port River where the small amount of surface runoff to the sea would have discharged in late winter and in spring (Holmes and Inverson 1976).

The City of Adelaide's population is currently just over 1.2 million people (Statistics 2012). This degree of urbanisation has forever changed the way that stormwater runoff enters the adjacent nearshore marine environment. This runoff discharges directly into nearshore waters through a wide array of drains and variously modified streams and rivers

Figure 4 **Benthic habitats in the nearshore region of the Clinton Biounit. Benthic habitats shown are from the State Benthic Habitat mapping layer (SARDI 2004; DEWNR 2010).**

including the Torrens River, and Brownhill and Sturt Creeks which drain into the Patawalonga and into the nearshore waters at Glenelg. These 'natural' drains comprise the majority of the volume of the runoff entering the coast with the Torrens contributing approximately 29% of the total runoff, while the Patawalonga contribute 18% (Wilkinson et al 2005).

Stormwater contributes approximately 67% of the sediment load discharged into the coastal environment in the Adelaide Metro Biounit. Of this the Torrens River discharges 10% of the total annual suspended solid load (AMLNRM 2013). These suspended sediments have been shown to contribute to the loss of nearshore seagrass along the Adelaide metropolitan coast (Collings et al 2006). When fine particulates enter nearshore waters they can be continually resuspended by wind and wave action prolonging the reduction in light, which can be exacerbated by seagrass loss (Ward et al 1984).

Nutrient discharges have widely been shown to have detrimental impacts on nearshore marine environments (Neverauskas 1989; Shepherd et al 1989; Bryars et al 2006a). This effect is likely to be particularly significant in the otherwise oligotrophic waters of Gulf St Vincent where studies have shown that even small increases in available nutrients loads can have large adverse impacts on benthic communities in the marine environment (Gorgula and Connell 2004; Russell et al 2005; Bryars et al 2011). Historically there has been approximately 6,000 hectares of seagrass lost along the Adelaide metropolitan coast line (Figure 5), although not all of this has been lost within the 5-m bathymetric contour (Westphalen et al 2004; Cameron 2008). The majority of loss has been in the nearshore areas along the metropolitan coast, which is contrary to a commonly accepted model of seagrass loss due to nutrient enrichment, suggests that nutrients drive increases in the growth of epiphytes and a decrease in the available light to the seagrass leaves. Seagrass in deeper water are therefore typically lost first as they have less light available to begin with (Shepherd et al 1989; Duarte 1991; Westphalen et al 2004; Bryars et al 2011).

This seagrass loss has largely been attributed to a number of anthropogenic inputs since the 1940s including high nutrient discharges from WWTPs, sludge outfalls (now decommissioned), and high loads of suspended solids from numerous sources including urban stormwater, dredging and Penrice Soda Products (Neverauskas 1987a; Shepherd et al 1989; EPA 1998; Fox et al 2007). It is likely that slower mixing and dispersion of water in the inshore environment results in discharged material from anthropogenic sources, such as WWTPs, stormwater drains and rivers, remaining in the shallow nearshore marine environment for prolonged periods of time (Pattiaratchi et al 2007).

The spatial footprint of nutrients discharged from WWTPs or Penrice along the Adelaide metropolitan coast is extensive (Fernandes et al 2009; Fernandes et al 2012). The largest plume encroaches on both the Clinton and Adelaide Metro biounits with 130 km^2 of coastal waters adjacent Bolivar and the Port River indicating a widespread nutrient footprint attributed to the Bolivar WWTP and the Penrice discharges, while the Glenelg WWTP displayed a more localised footprint (Fernandes et al 2012).

Gaylard (2009b) highlight a number of discharges from other than WWTP and stormwater that were considered to be a high risk to ecosystem values in the Adelaide region. These discharges included thermal effluent from power stations. In particular the Torrens Island Power Station which discharges heated water into Angus Inlet has resulted in changes in the distribution and abundance of intertidal invertebrates within Barker Inlet and Angus Inlet (Thomas et al 1986). The Pelican Point Power and Osborne Cogeneration stations discharge heated water into the Port River system but are much newer generation plants and water is discharged at only slightly higher temperatures than ambient conditions so the influence of these plants is considerably smaller. The Port River and Barker Inlet have reduced water exchange due to the natural geomorphology and Barker Inlet has large areas of shallow waters and mudflats which are subject to heating by ambient temperatures, thus providing conditions favourable for algal growth when nutrients are in excess (Wade 2002; Pfennig 2008). These conditions are likely to exacerbate the biological effect of excess nutrients.

The Port Stanvac hydrocarbon refinery stopped operating in 2003 and as a result has shifted vessel traffic from one part of the biounit to another resulting in more frequent vessels unloading crude oil and petroleum products at the Port River wharves. On average over 1,000 vessels use the Port River wharves annually, the majority of the vessels consist of container vessels, crude oil vessels, as well as grain, fertiliser and iron ore (Flinders Ports 2013). Consistent with all bulk shipping facilities is a risk of spillage of product into the waters which is particularly evident for commodities such as hydrocarbons, grain and iron ore. In addition to spillage, the physical act of manoeuvring such large vessels within a shallow and narrow river has an impact on the surrounding environment, with increased turbidity plumes associated with ship movements entering or exiting the Port River shipping channel (Figure 8). The 'drag out' of suspended sediment into nearshore waters creates an ecological risk due to decreased light

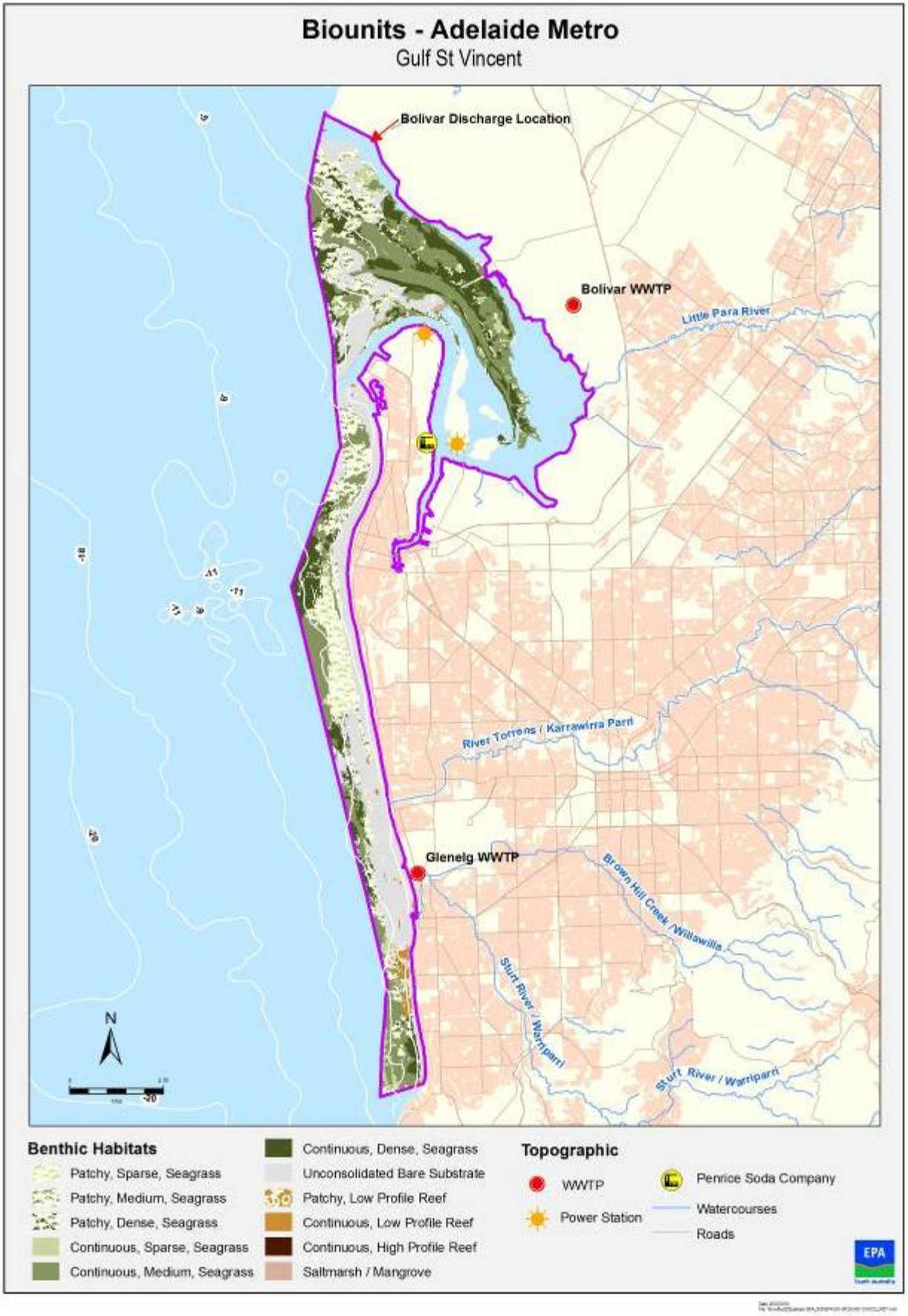

Figure 5 **Benthic habitats in the nearshore region of the Adelaide Metro Biounit. Benthic habitats shown are from the State Benthic Habitat mapping layer (SARDI 2004; DEWNR 2010).**

penetration and more significantly it also has the potential to resuspend and transport contaminated sediments from within the port.

Expected condition of the Adelaide Metro Biounit

The cumulative effect of significant nutrient inputs, suspended sediments from urban stormwater runoff and numerous point and diffuse sources of pollution that ultimately end up in the nearshore waters of the Adelaide Metro Biounit have resulted in the loss of a significant amount of seagrass (Hart 1997; Fox et al 2007; Bryars and Rowling 2008) and the degradation of coastal rocky reefs (Turner et al 2007; Collings et al 2008).

An assessment of threats to water quality concluded that the Adelaide region was at high risk of impacts from nutrients and suspended sediments from wastewater, industrial and stormwater discharges (Gaylard 2009b). The available evidence suggests that the Adelaide Metro Biounit has been heavily modified for over 200 years since European settlement resulting in increased nutrient and sediment flows from the land to the sea when it rains and, coupled with the level and number of potential threats to water quality the condition of the biounit is predicted to be Poor (see Table 3). A biounit in Poor condition is likely to have severely impaired habitats suggesting significant changes to ecosystem function, including reduced biodiversity and productivity as well as reduced sediment stability. The biounit is likely to be under stress from nutrient enrichment and suspended sediments (Gaylard et al 2013).

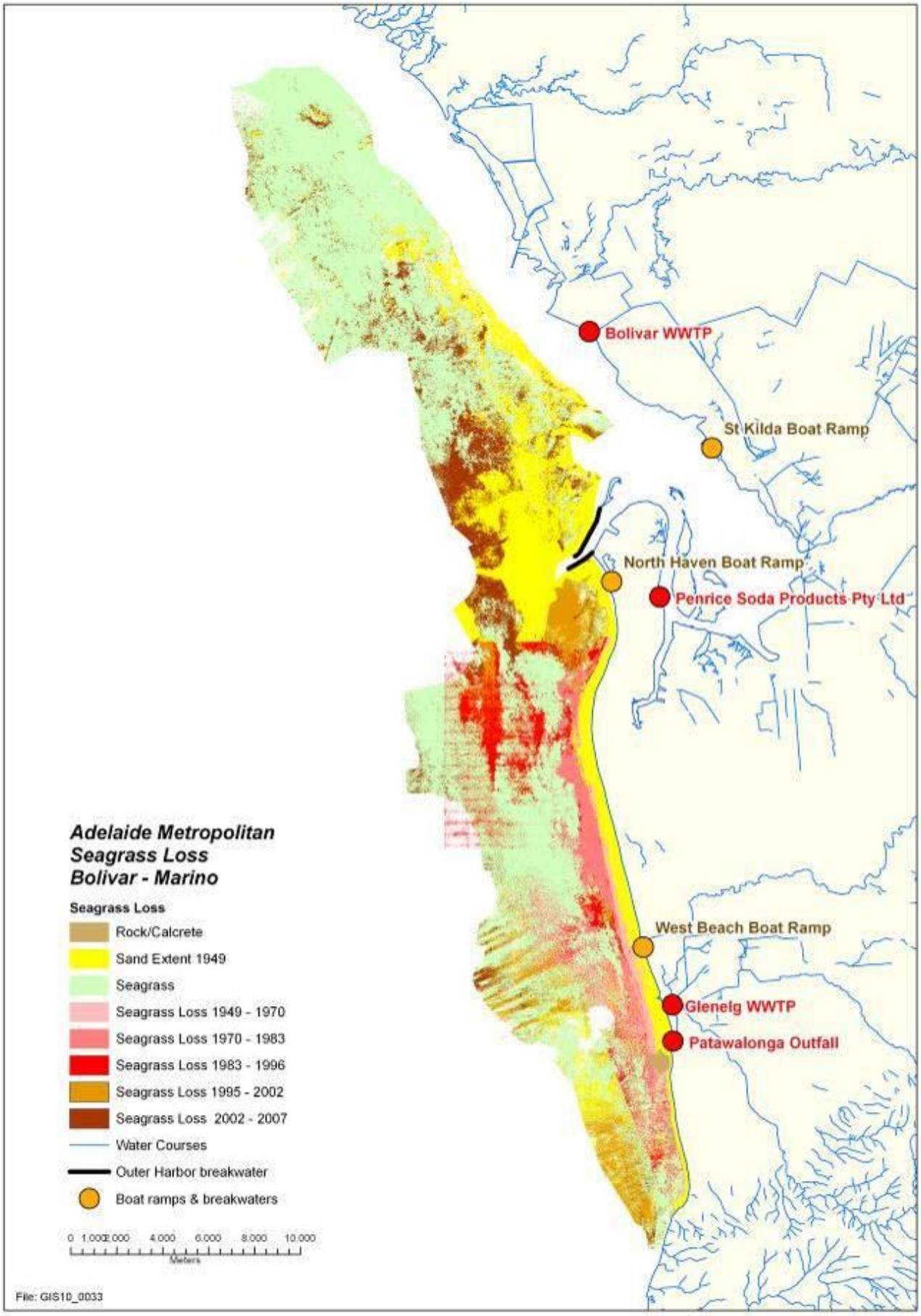

Figure 6 **Seagrass loss along Adelaide metropolitan coast line 1949–2007. The map has been modified by EPA from original version in Seddon (2002).**

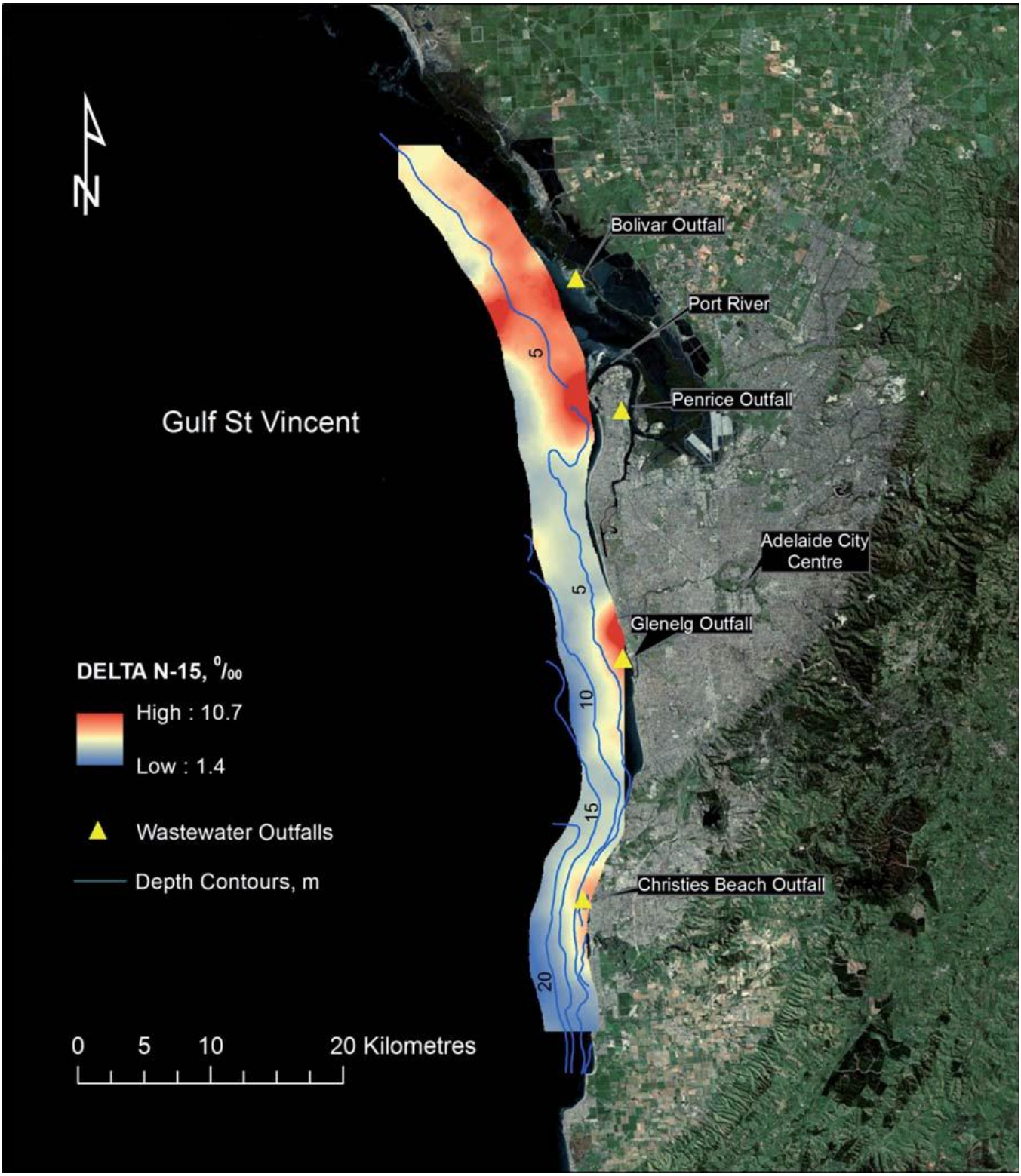

Figure 7 **Surface modelling of δ15N values along the Adelaide coast to indicate the spatial extent of nutrients from WWTP outfalls and Penrice Soda Products (Fernandes et al 2009).**

Figure 8 **Re-suspension of sediment from the Port River shipping channel at Outer Harbor. Source: NearMap 13 October 2012**

2.6 Tier 1 results – Yankalilla Biounit

The Yankalilla Biounit extends from Marino Rocks (north of Hallett Cove) to Rapid Head, and the shoreline is orientated in a westerly direction (Figure 9), meaning that the biounit is for the most part exposed to moderate wave energy with sometimes moderate to high wave energies, particularly during winter (Edyvane 1999c). The Onkaparinga River is a dominant feature of the environment in the north of this biounit.

Of the inshore habitats mapped the Yankalilla Biounit contains 62.2% sandy bottom, 30% seagrass and 7.7% reef. Aldinga and Yankalilla Bays consist of extensive seagrass meadows comprising *Posidonia*, *Amphibolis* and *Halophila* seagrasses (Edyvane 1999c). There is some evidence to suggest that seagrasses from the *Posidonia ostenfeldii* complex inhabit some of the higher energy sandy environments (Bryars et al 2006b). On the moderately exposed shallow reefs the dominant macroalgal communities consist of *Cystophora* spp, *Ecklonia radiata* and *Sargassum* spp with an understorey of *Lobophora* spp, *Caulerpa* spp and red macroalgae (Edyvane 1999c). There are a number of MPAs within this biounit which encompass five sanctuary zones (Figure 9), including the Onkaparinga Estuary and the iconic Noarlunga and Aldinga Reefs which boast diverse marine life and fantastic diving opportunities.

Tier 1 threat assessment

The Yankalilla Biounit is adjacent to a large proportion of the southern Metropolitan Adelaide suburbs, as well as a number of small towns along the Fleurieu Peninsula such as Carrickalinga, Normanville, Second Valley and Rapid Bay. There are a number of small bays which may have reduced water exchange due to the natural geomorphology has and their potential to exacerbate the biological effect of any nutrient discharges at the local scale.

The Christies Beach WWTP is the only major discharge into the marine environment in the Yankalilla Biounit. The small townships along the Fleurieu Peninsula mainly rely on septic tanks for sewage treatment with the exception of Sellicks Beach and Second Valley which has centralise CWMS sewage treatment , and do not discharge to the marine environment.

The Adelaide desalination pilot plant was established in early 2010 on the disused Mobil oil refinery site at Port Stanvac to test the water conditions for the much larger 100-GL desalination plant. This pilot plant was operating during the monitoring periods in 2010 and 2011, however all brine produced through the small desalination process was required to be remixed with fresh water produced by the plant before being discharged, resulting in no excess salt introduced into the marine environment. Construction of the 100-GL Adelaide Desalination Plant (ADP) began in December of 2009 with the aim of desalinated water being produced from September 2011 with low flows of brine being discharged..

The oil refinery received large vessels at the wharf facility to bring in petroleum products for the City of Adelaide. This facility ceased operations in 2003, however, the 400-m exclusion zone around the jetty is still in place resulting in protection of the intertidal and subtidal reefs around the site. The intertidal environments have been noted to be regional biodiversity hotspots for molluscs, echinoderms and red macroalgae (Dutton and Benkendorff 2008) and it is possible that the subtidal environments may share this diversity due to the significant protection afforded by the exclusion zone.

The Onkaparinga estuary has a tidal influence upstream as far as the township of Old Noarlunga where there is a weir blocking further intrusion. The estuary receives minimal freshwater inputs during the summer months creating a lagoon in the lower portion of the estuary. In the winter months, rainfall events discharge nutrients and sediments from the rural and urban catchments into the river and then into the marine environment; which has the potential to impact on nearshore receiving habitats (Gaylard 2009b). In addition to the Onkaparinga River there are numerous other small creeks which may sporadically discharge into nearshore waters during heavy rain. These include Pedler Creek near Moana, Christie Creek, Bungala Creek near Normanville, Field River and Myponga River. The EPA have undertaken AECR monitoring for the inland waters program at Pedler Creek and found that this creek was in Poor condition due to significant nutrient enrichment and accumulated fine sediment (EPA 2012d), which in high rainfall events will be transported to the nearshore marine environment.

Gaylard (2009b) highlight a number of potential sources for threats to water quality within Yankalilla, including the Wirrina Marina at the southern end of the biounit. This facility is a potential source of pollutants for the surrounding waters such as debris and rubbish from vessels as well as sewage, oil and fuel leaks and spills. Marinas also provide a large roosting area over water for a number of shorebirds. These aggregation points contribute to the nutrient load that may enter waters which can have the potential to impact nearshore marine environments (Gaylard 2009b).

The Rapid Bay quarry is located in close proximity to the coast and is surrounded by very steep cliff faces. When the quarry was opened the waste rock was dumped into the bay, which has built up the beach to approximately 2 m above the natural level (District Council of Yankalilla 2013). Transport of this material via shore currents has resulted in the development of sandy beaches in several previously rocky coves northward along the coast. Surface water runoff from large rain events has the potential to reanimate this material causing turbidity plumes that can be seen in the nearshore environment during strong southerly winds extending this material northwards from Rapid Bay (Pattiaratchi et al 2007).

Expected condition of the Yankalilla Biounit

The threat assessment for Yankalilla suggests that there are two main inputs into the marine environment – Christies Beach WWTP and urban runoff from the southern Adelaide suburbs. Table 3 details the major potential threats to water quality and this assessment considers that the condition of the Yankalilla biounit is likely to be Fair. The conceptual models (Appendix 2) suggest that a biounit in Fair condition is likely to have habitats that have been impaired with impacts from nutrient enrichment and/or suspended sediments.

2.7 Tier 1 results – Encounter Biounit

The Encounter Biounit extends from Rapid Head on the southwestern Fleurieu Peninsula to Port Elliot (Figure 10). This biounit has been slightly modified from Edyvane (1999c) to coincide with the Adelaide Mount Lofty Natural Resource Management Board (AMLNRM) boundary. The majority of the coastline of Encounter has a southerly orientation into the Southern Ocean with wave exposure increasing between Cape Jervis to Victor Harbour and Port Elliot (Edyvane 1999c). Portions of marine park sanctuary zones are found at either end of Encounter as well as portions located along the boundary of the biounit in Backstairs Passage.

Of the total inshore habitats mapped in this biounit 36.9% comprised soft sandy bottoms, 57.8% rocky reefs and only 5.4% seagrass meadows (Edyvane 1999c). Seagrass is largely restricted to the sheltered embayments of Encounter Bay (Edyvane 1999c). The seagrass meadows are sparse in this region, comprising *Posidonia sinuosa, P angustifolia, Amphibolis antarctica* and *Halophila australis,* and often occurs adjacent to reef communities and in deeper waters. It is possible that seagrass from the *Posidonia ostenfeldii* complex inhabit this biounit. Exposed reef areas are dominated by a mixture of sponges, hydroids, ascidians and bryozoans. The dominant macroalgal communities are large browns, *Scytothalia dorycarpa, Carpoglossum confluens, Ecklonia radiata, Acrocarpia paniculata* and *Seirococcus axillaris* with species of *Cystophora* and *Sargassum* being less dominant and an understory of red and coralline macroalgae (Edyvane 1999c).

Tier 1 threat assessment

There are a number of large towns within this biounit, the largest being the now joined suburbs of Encounter Bay, Victor Harbor, McCracken and Port Elliot. The population in this area is around 14,500 people (Statistics 2012), but increasing coastal development is likely to be putting considerable strain on the current infrastructure. The only other small coastal town is at Cape Jervis with a population of 202 people and other small dwellings scattered throughout the area. During peak holiday periods the population in the area can be as high as 30,000 people (City of Victor Harbor 2012). Many of these dwellings rely on septic tanks to treat and dispose of sewage, which in high densities can transport considerable loads of nutrients (up to 10 kg/dwelling/year) into shallow groundwater which is likely to be flowing towards the nearshore marine environment (Reay 2004).

The Victor Harbor WWTP historically discharged significant loads of nutrients into the Inman River at Encounter Bay with documented impacts on the water quality and ecology of the river and an EPA AECR rating in 2008 of Fair with evidence of nutrient enrichment (EPA 2012b). In 2009, this WWTP was upgraded with a significant improvement in the quality and quantity of effluent discharged. The Inman River enters the marine environment at Encounter Bay through the Inman estuary,. In addition to the WWTP discharge, the catchment area upstream is predominantly agricultural land and dairy farms and it has been speculated that discharges from the Inman River are responsible for the loss of seagrass directly adjacent the mouth of the river (Tanner et al 2012). The Hindmarsh River also enters the marine environment at Encounter Bay, with a similar agricultural catchment, and there are numerous small creeks along the Fleurieu Peninsula including Deep, Tunkalilla, Callawonga and Waitpinga Creeks which are likely to transport nutrients and sediment from agricultural lands into the nearshore environment in heavy rains.

Figure 9 **Benthic habitats in the nearshore region of the Yankalilla Biounit. Benthic habitats shown are a the National and State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

Urban stormwater runoff in the Encounter Bay to Port Elliot region is likely to discharge a sizeable load of nutrients and sediment into the nearshore waters. This has the potential to not only impact on nearshore habitats but also impact on recreational and aesthetic values which are a significant asset for the region.

There are a number of small bays which may have reduced water exchange due to the natural geomorphology, which has the potential to exacerbate the biological effect of any nutrient discharge at the local scale.

Expected condition of the Encounter Biounit

The threat assessment for the Encounter Biounit suggests that the terrestrial landscape has been heavily modified for agriculture and that expanding coastal development throughout the Encounter Bay to Port Elliot stretch of coastline is putting considerable strain on infrastructure as well as the quality and quantity of stormwater discharges. A large proportion of the sewage treatment is currently undertaken at the Victor Harbor WWTP but there is still high densities of septic tanks throughout the biounit which has the potential to contaminate the groundwater. The Tier 1 assessment details the potential threats to water quality and the assessment considers that the condition of the biounit is likely to be Good (Table 3). The conceptual models (Appendix 2) describe the typical characteristics of a biounit in Good condition for the Nearshore MER program and can be described as habitats that are slightly impaired and are beginning to show initial signs of nutrient enrichment.

2.8 Tier 1 results – Backstairs Biounit

The Backstairs Biounit begins east of Penneshaw on Kangaroo Island and extends eastwards into the Southern Ocean encompassing the waters of the Backstairs Passage and the Pages Islands (Figure 11). The northerly aspect of the shoreline provides a predominantly low wave energy environment, with the exception of the far east of the biounit and The Pages (Edyvane 1999c). The only significant surface water flow into this biounit is the Chapman River, which flows through Lashmar Conservation Park and enters the marine environment at Antechamber Bay but is likely only to flow in heavy rain events.

The total inshore habitats mapped in Backstairs are 6.8% soft sandy bottoms, 41.1% rocky reefs and 52.1% seagrass meadows (Edyvane 1999c). Backstairs Passage experiences strong tidal currents through Investigator Strait. The more exposed shallow reefs are dominated by robust brown algae such as *Ecklonia radiata, Seirococcus axillaris, Acrocarpia paniculata Scytothalia dorycarpa* and *Carpoglossum confluens* with species of *Cystophora* and *Sargassum* being less dominant. Macroalgal communities in the more sheltered locations reef areas are comprised of *Cystophora monolifera, C expansa* and *Sargassum fallax and S heteromorphum* (Edyvane 1999c). Seagrasses are largely confined to Antechamber Bay with *Zostera muelleri* and *Posidonia australis* occur in shallow waters, and *Posidonia sinuosa, Amphibolis antarctica, Heterozostera tasmanica* and *Halophila australis* occur in deeper water (Edyvane 1999c).

The entire Backstairs Biounit is located within the Encounter Marine Park where there are two sanctuary zones; one located around the largest of the three islands in The Pages group, and the second extends in an easterly direction from Penneshaw to the beginning of Antechamber Bay (Figure 11).

Tier 1 threat assessment

There are no substantial coastal towns in close proximity to Backstairs, only occasional small shack communities that are likely to treat sewage through septic tanks. It is possible that the only significant input into the marine environment is from the Chapman River at Antechamber Bay. The creek catchment is largely agricultural land and the Lashmar Conservation Park and the flows transport nutrients and sediment into Antechamber Bay.

Expected condition of the Backstairs Biounit

The threat assessment for Backstairs suggests that the terrestrial landscape has only been slightly modified, with minimal inputs into the marine environment coupled with likely high water movement through the Backstairs Passage. Table 3 details the potential threats to water quality and the condition of the biounit is predicted to be Excellent. The conceptual models suggest that a biounit in Excellent condition would typically have habitats considered to be natural and unimpacted, and would be consistent with the reference condition described by Gaylard et al (2013).

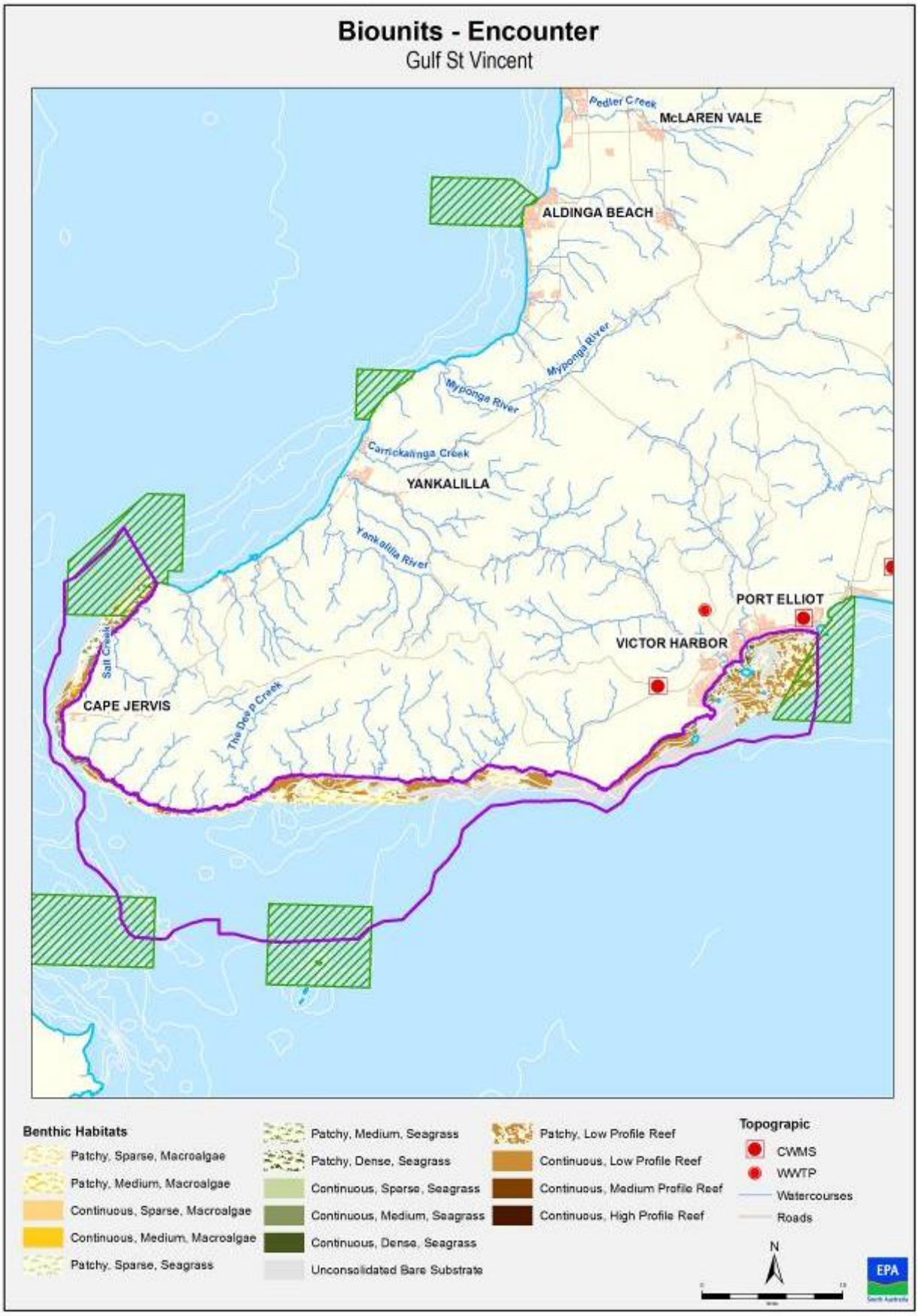

Figure 10 **Benthic habitats in the nearshore region of the Encounter Biounit. Benthic habitats shown are the State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

Figure 11 **Benthic habitats in the nearshore region of the Backstairs Biounit. Benthic habitats shown are from the National Benthic Habitat mapping layer (SARDI 2004; DEWNR 2010).**

2.9 Tier 1 results – Nepean Biounit

The Nepean Biounit extends from North Cape to Cape Willoughby on the north coast of Kangaroo Island (Figure 12), including Nepean Bay and American River.

Of the total inshore habitats mapped within this biounit, 45.9% comprised soft sandy bottoms, 4.5% rocky reefs and 49.6% seagrass meadows (Edyvane 1999c).However it is noted that it is likely that Nepean may have lost seagrass prior to this mapping. The macroalgal communities found in the more sheltered locations of reef areas are *Cystophora* spp and *Sargassum* spp while the understory typically consists of *Caulerpa* spp and mixed sponges, ascidians and bryozoans (Edyvane 1999c).

The extensive seagrasses habitats in Nepean are largely confined to Nepean Bay (encompassing Bay of Shoals, Western Cove, Eastern Cove and Pelican Lagoon) and Hog Bay where *Zostera muelleri* and *Posidonia australis* are dominant in shallow waters and *P sinuosa*, *Amphibolis antarctica, Heterozostera tasmanica* and *Halophila australis* typically occur in deeper waters (Edyvane 1999c).

There are two Marine Park Sanctuary Zones located within Nepean; one to the north of Kingscote within the Bay of Shoals and one in Pelican Lagoon (Figure 12). These areas are considered high conservation value for their shallow seagrass, tidal flat communities and regionally unique coastal wetlands features (DEWNR 2012a).

Tier 1 threat assessment

There are three main coastal towns within Nepean; American River has the smallest population with 216 residents, Penneshaw with 595 people, while the largest population resides at Kingscote with the largest population of 2,034 (Statistics 2012). Kingscote is currently the only town with a CWMS which centralises and treats much of the town's sewage. Treated effluent from this system is used to irrigate the golf course, race course and a number of paddocks (McNicol 2007). The remainder of the dwellings throughout the biounit use septic tanks which has the potential to leach nutrients into shallow groundwater where they can be transported to the nearshore environment (Reay 2004).

The landuse adjacent to the biounit is largely agricultural with the Cygnet River draining the largest catchment on the island. This river drains significant loads of nutrients and sediment into the Cygnet estuary and Nepean Bay. There has been documented seagrass loss throughout Western Cove (Edyvane 1997; Cameron and Hart 2002) and evidence of significant eutrophication and degraded seagrass meadows throughout Nepean Bay (Bryars et al 2003; Gaylard 2005).

There is no reliable natural freshwater supply for Penneshaw and as a result the township relies on desalinated water. The reverse osmosis process used by the desalination plant results in a brine stream being discharged offshore. The brine discharge is relatively small and it is discharged into shallow waters (approximately 7 m depth) around 200 m off the coast where tidal movement is strong resulting in very rapid dilution and dispersion of the brine.

While the Backstairs Passage area is well known to have high current speeds, there are areas with slow moving currents and limited water exchange, particularly throughout a large proportion of the Nepean Biounit due to natural geomorphology (Petrusevics 2000). In many of these areas there are large expanses of shallow water which are subject to ambient heating, providing conditions favourable for algal growth. The biological communities in these areas may be more susceptible to nutrient inputs.

There are five aquaculture licences located in the Nepean Biounit. Two Pacific oyster (Crassostrea gigas) leases and one blue mussel (*Mytilus galloprovincialis*) lease located in Western Cove, and two mixed intertidal leases are located in Eastern Cove both of which are licensed for Pacific oyster, native oyster (*Ostrea angasi*), dough boy and queen scallop (*Mimachlamys asperrimus, Equichlamys bifrons*) and blacklip and greenlip abalone (*Haliotis rubra, H aeviglta*) (Primary Industries and Regions SA). These leases are not supplementary fed but rely rather on natural algal communities. As such it is likely that the environmental impact of these activities is limited.

Expected condition of the Nepean Biounit

The threat assessment for the Nepean Biounit suggests that the terrestrial landscape has been heavily modified for agriculture and there is documented evidence of habitat degradation in localised areas due to nutrient and sediment inputs. Table 3 details the potential threats to water quality; this assessment predicts that the ecological condition of the

Figure 12 **Benthic habitats in the nearshore region of the Nepean Biounit. Benthic habitats shown are from the National Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

biounit is likely to be Fair. The conceptual models for this MER program suggest that a biounit in Fair condition is likely to have a habitat structure that has been impaired with impacts from nutrient enrichment.

2.10 Tier 1 results – Cassini Biounit

The Cassini Biounit extends from Cape Borda to North Cape, encompassing approximately 111 km of the northern Kangaroo Island coastline (Figure 13). The shoreline has a northerly orientation into Investigator Strait where there are significant currents running west to east. Numerous beaches and coves are exposed to moderate to low wave energy (Edyvane 1999c), and there are numerous small creeks dotted along this shoreline that discharge surface runoff into small coves.

The total inshore habitats mapped within this biounit suggested that within Cassini 81.6% are soft sandy bottoms, 14.3% rocky reefs and only 4.2% seagrass meadows (Edyvane 1999c). Seagrass is typically restricted to sheltered embayments such as Emu Bay where seagrasses thrive. In shallow offshore waters, the meadows are typically sparse with *Posidonia sinuosa* and *P angustifolia* found in shallow water and *Heterozostera tasmanica*, *Amphibolis antarctica* and *Halophila australis* found in deeper waters (Edyvane 1999c). The macroalgal communities are typical of those exposed to moderate wave energies, strong swell and tidal currents, with large robust brown algae such as *Scytothalia dorycarpa, Carpoglossum confluens, Ecklonia radiata* and *Acrocarpia paniculata*, with an understory of red, green and coralline macroalgae. In the moderate to sheltered areas like Emu Bay and Stokes Bay reef areas are colonised by *Serococcus axillaris*, with *Ecklonia radiata, Scytothalia* sp, *Melanthalia* sp with *Cystophora* sg being less dominant (Edyvane 1999c).

The majority of the adjacent land use is agricultural, with the Western River Conversation Park and Cape Torrens Conservation Park making up the remainder of the bordering lands. Cassini has two MPA Sanctuary Zones; one located at the western boundary of the biounit and one near Western River Cove (Figure 13).

Tier 1 threat assessment

There are no significant coastal towns bordering Cassini, although holiday shacks occur opposite most of the embayments, particularly Emu Bay where coastal development is expanding considerably. These communities all rely on septic tanks to treat and dispose sewage, which has the potential to transport nutrients into shallow groundwater and eventually to the sea (Reay 2004).

The majority of the adjacent landuse is agriculture with pastures and sheep being the predominant commodities. There are numerous small creeks along the biounit with the majority of flows being dependent on significant rain events. The higher order creeks monitored within the EPA monitoring program show signs of nutrient enrichment as well as increased salinity (EPA 2008).

There are two land-based aquaculture facilities that discharge large volumes of effluent into nearshore waters at Smith Bay. The largest facility has abalone (*Haliotis rubra, H aevigata*), scallops (*Mimachlamys asperrimus* and *Equichlamys bifrons*) and various species of fish (Primary Industries and Regions SA). While the concentrations of nutrients in the water are quite low, the total load of nutrients over time may become important for impacts on adjacent habitats.

Expected condition of the Cassini Biounit

The threat assessment for Cassini suggests that the terrestrial landscape has been heavily modified for agriculture and there are a number of creeks which may transport nutrients and sediments into nearshore waters during significant rain events. Table 3 details the potential threats to water quality; this assessment predicts that the condition of the biounit is likely to be Very Good. The conceptual models suggest that a biounit in Very Good condition is likely to have habitats that are largely considered to be natural, although there could be some initial symptoms of nutrient enrichment (Gaylard et al 2013).

Figure 13 **Benthic habitats in the nearshore region of the Cassini Biounit. Benthic habitats shown are from the National Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

3 Tier 2 – methods

Detailed methods used in the Nearshore MER program can be found in Gaylard et al (2013) this document will only briefly describe the approaches used. For details of the metrics employed in the interpretation of the data refer to the conceptual models in Appendix 2 and Gaylard et al (2013).

The Nearshore MER program has a nested design that operates across different spatial scales for monitoring and reporting. The scales include bioregion ➔ biounit ➔ site (Figure 14). This document details the results of the MER program for the biounits within the Gulf St Vincent bioregion. In the discussion of each biounit, results of individual sites will be discussed which detail reasons behind differences or gradients seen within the biounit. Results will be compared to observations of reference condition determined by Gaylard et al (2013), which used the same methodology in areas remote from anthropogenic disturbance to assess habitat condition and snapshots of water chemistry in order to set a benchmark for comparison. It is unlikely that any location in South Australia is completely unimpacted and additionally it is unlikely that these locations (Flinders and Pearson islands and the Sir Joseph Banks Group of Islands) would serve as adequate 'control sites for all locations being assessed. With this in mind, the locations do provide a starting point to develop the conceptual models.

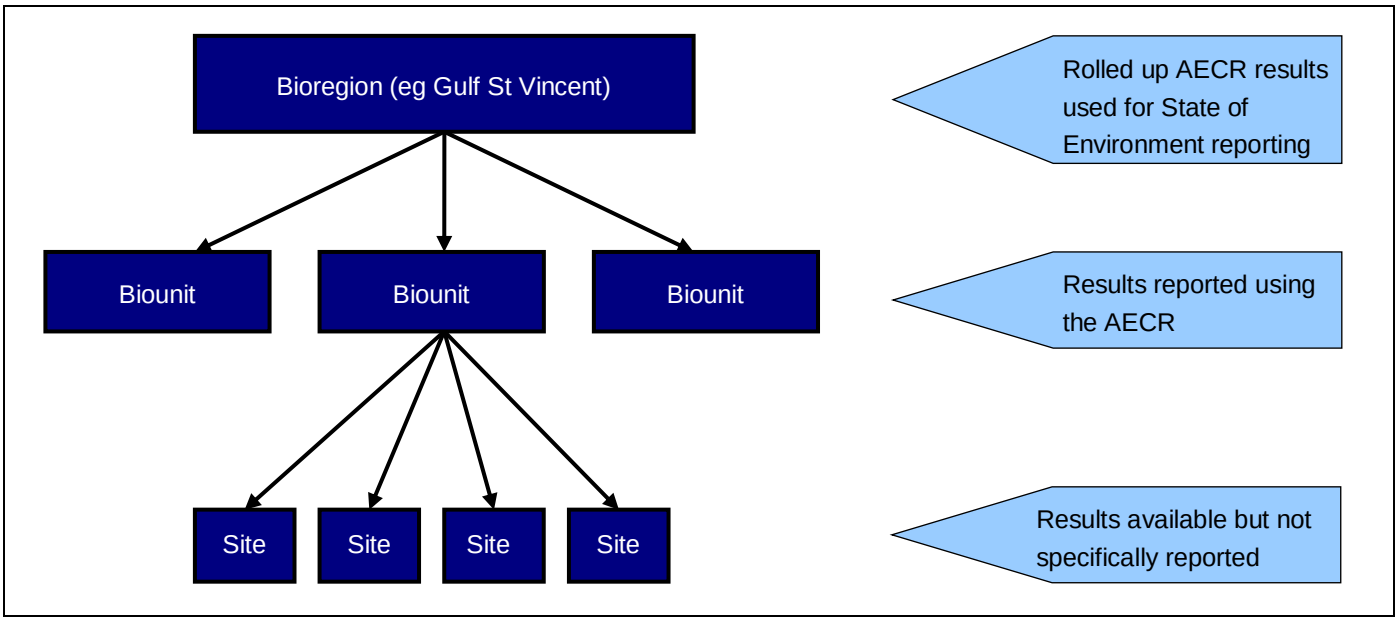

Figure 14 Nested design of nearshore marine monitoring and evaluation program

3.1 Site selection

The number of sites measured under Tier 2 within each biounit was based on the Tier 1 assessment, taking into account a higher number of sites with a perceived increase in potential disturbance,. However this was also limited by available resources. In future years the results of monitoring will allow greater efficiency in site selection. Given finite resources it is unlikely that an optimal number of sites in every biounit will be achieved but this will at least allow for knowledge of uncertainty. Sites were allocated using a stratified random design which overlaid a numbered 500 m x 500 m grid over the waters less than 15 m deep throughout the biounit. A random number generator was used to select grid locations typically allocating double the number of required sites. Final site locations were selected from the random locations by excluding locations in close proximity to hazards such as breaking/fast moving waters or known industrial discharges to ensure an ambient perspective was maintained and clusters of sites were also reduced. Final site positions are included in the attached maps for each biounit.

3.2 Methods at each site

In order to characterise habitats over a site, ten x 50 m underwater video belt transects were undertaken at randomly chosen locations in water between 2–15 m deep (Figure 15). Transects were undertaken using a geo-referenced 450-line

analogue video camera (Scielex/Kongsberg) in a custom-made housing angled at 90 degrees to the seafloor. A live video feed ran directly from the camera into an audio and video encoding system (Geostamp) which overlays a GPS location, direction, speed, date and time strings to the video and recorded to a hard drive. A surface screen allowed operator to position the camera approximately 1 m from the substrate in order to maximise image quality and resolution. This set-up provided a field of view of approximately 1 m^2, whereby each belt transect equates to approximately 50 m^2. Videos were analysed upon return from the field using an in-house video analysis software package. At times, the resolution of the analogue video camera can pixilate when finer detail may be warranted. Therefore a full high definition (HD) video camera (GoPro Hero 2) was synchronised with the analogue camera, the image from which could be employed when analysis demanded a higher resolution for taxonomic identification or finer detail (eg rocky reef assessment). Videos were assessed for a range of biological parameters:

- habitat type (seagrass, rocky reef, unvegetated sand)
- seagrass species, area, density, patchiness, distance between patches
- seagrass epiphyte load
- abundance of opportunistic macroalgae
- cover of large brown canopy algae, small brown algae, filamentous algae, bare substrate, turfing algae
- epi-fauna (crabs, ascidians, bryozoans, etc), faunal tracks, bio-turbation, micro-phytobenthos
- substrate type, particle size, sediment colour
- potential marine invasive species (position highlighted for further investigation)
- presence of any debris, plastics, litter etc.

Quantifying water chemistry at each site was undertaken by sampling three replicate 2.5-litre water grab samples at each transect location mixed into a 25-litre container. After three transects the water in the container was mixed thoroughly and sub-sampled. This process is repeated across the site for all transects (n = 9) to provide a snapshot of water nutrient concentration (total nitrogen, total ammonia, total kjeldahl nitrogen, total oxidised nitrogen, total phosphorus and filtered reactive phosphorus) and turbidity. Samples for soluble nutrients were immediately filtered using a 0.45-µm filter and frozen as soon as practical prior to analysis. At each site one 2-litre grab sample was taken for chlorophyll analysis and immediately iced and placed in darkness. The samples were filtered using a 0.45-µm filter at the end of each day and the filter paper frozen prior to analysis. All samples were frozen and analysed within the laboratory holding times. Compositing water samples in the above manner is commonly used to reduce analytical costs of environmental sampling, and with careful planning may reveal the same information as analysing many samples while still retaining, if not increasing, the precision of sample-based interferences (Patil 1995). A full description of the method for compositing water samples obtained under the Nearshore MER program is described in (ABC Online 2011); Gaylard et al (2013).

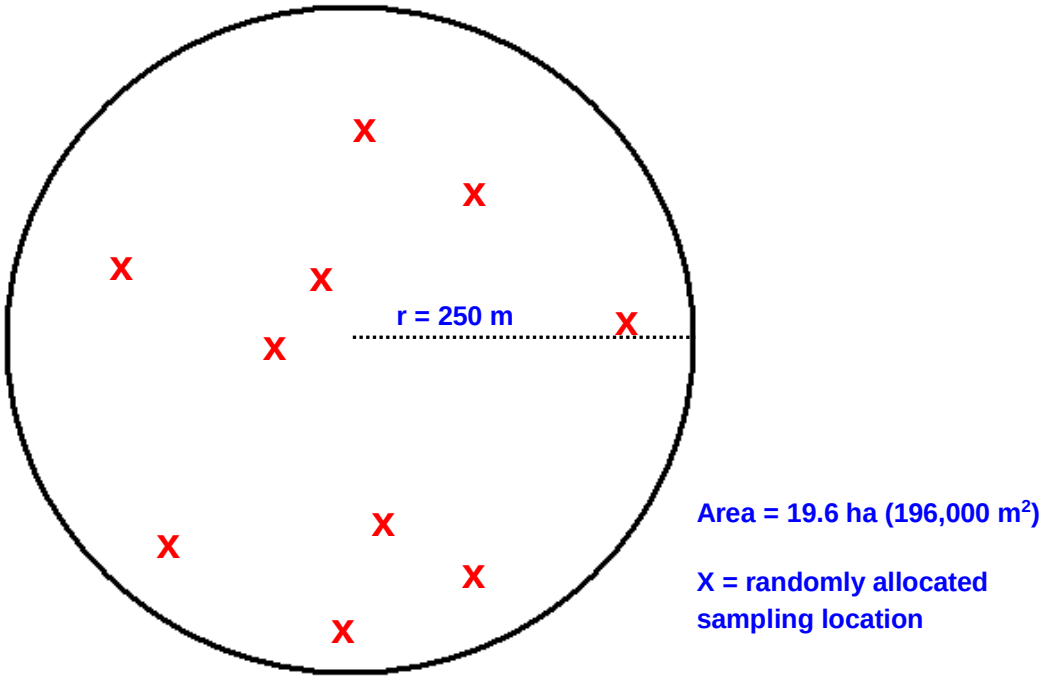

Figure 15 Example of 10 random sampling locations within a site

In the event of water chemistry results being below the reporting limit (LOR) [ie below the detection limit of the analytical equipment], a method of substituting the censored value with half the reporting limit has been adopted. For example the total ammonia LOR is 0.005 mg/L; if a result is recorded as <0.005 mg/L then the result used is 0.0025 mg/L (Ellis and Gilbert 1980). This arbitrary approach does have limitations (see (Helsel 1990) but in the Nearshore MER program it was considered appropriate due to the amount of data generated, the low number of 'non-detects' and the unbiased nature of using half the reporting limit compared to methods that substitute for the reporting limit or allocation to a value of zero (Helsel 1990). All water samples were sent to the Australian Water Quality Centre for analysis.

A multi-parameter sonde (YSI 6920 v2) was used to log water quality parameters including electrical conductivity, pH, dissolved oxygen and chlorophyll *a* at 10-second intervals for a total of approximately 2.5 mins at a static depth at each location (n = ~15 per transect and ~150 per site).

These methods are the same as what was used to define reference condition within the conceptual models outlined in Gaylard et al (2013).

3.2.1 Conceptual models

Gaylard et al (2013) detailed the monitoring methods undertaken to broadly assess ecological condition for AECR, including development of generic conceptual models that have been used to suggest processes of degradation based on established literature and a condition gradient (Appendices 1 and 2). Conceptual models that describe the response of an ecosystem to stress have been used in developing strategies for natural resource management. The models emphasise the maintenance of important ecological characteristics. The condition gradient is a type of conceptual model that relates an observed ecological response to increasing levels of human disturbance (Davies and Jackson 2006). This gradient assumes that habitat condition deteriorates as the degree of human disturbance in the surrounding and adjacent environment increases, and conversely, the best condition occurs where there is little to no human disturbance of the environment (Appendix 1).

Conceptual models have been developed using existing knowledge linked to data collection in the development of this program (Gaylard et al 2013), which establishes a biological condition gradient in response to nutrient enrichment and reduction in water clarity for seagrass, rocky reef and unvegetated sediment habitats in shallow (2–15 m) nearshore waters in South Australia. A description of these models is provided in Appendix 2 and their development is provided in Gaylard et al (2013). Results of the Tier 2 assessment in this program are compared to these conceptual models to describe condition.

3.2.2 Data analyses

The biological, water chemistry and physical data were analysed in order to evaluate a number of different desired outcomes. Each outcome, or question, was assessed by using either univariate statistics to test whether a population is different to another (eg reference population), multivariate statistics which assess a combination of many parameters to look at how similar (or dissimilar) each population is to each other or a combination of both types of test. There are a number of different spatial units the data can be looked at including the entire Gulf St Vincent Bioregion which will discuss a very high level evaluation of results and discuss broad scale changes. Key outcomes at the bioregion scale include:

- Has data acquisition been representative of the known broad habitat types?
- How do various indices change across the bioregion? Are there large scale biological gradients present?
- What are the major determinants in any differences between biounits within the bioregion?

A more detailed assessment can be undertaken on the results of the sites within each biounit. This is the unit of assessment used for the AECR score and allows finer spatial assessment with respect to the location of known pollution sources and smaller scale perturbations. The key outcomes of the biounit level assessment include:

- Has data acquisition been representative of the known broad habitat types?
- What is the Aquatic Ecosystem Condition Report outcome for the biounit?
- How does this compare to the Tier 1 assessment?
- How does the biounit compare to the reference condition?
- Are there any biological gradients within the biounit?
- Is there any relationship between index scores, and water quality and physical observations within the biounit?
- How reliable are the indicators to show differences?

Univariate tests were used to look for differences for specific variables (eg total nitrogen or seagrass epiphyte load) at a number of different levels including whether there were differences between biounits and the reference condition, or whether sites are different to each other within a biounit. Given the highly skewed nature of environmental data (eg water chemistry), the non-parametric Mann Whitney U test was used to test for equality of two test population medians (Helsel 1987; Helsel and Hirsch 2002). All Mann Whitney U tests were undertaken using Minitab 14 with $\alpha = 0.05$.

Multivariate statistics were used to explore similarities within the biological data, which can be used to infer biological gradients within a biounit, or within the bioregion. Groupings can also be used to show how similar in multivariate space the biounits within the bioregion, or sites within a biounit, were to the reference condition. Groupings were defined using a SIMPER analysis after converting to a Bray Curtis similarity matrix.

Non-metric multi-dimensional scaling (nMDS) ordination plots were used to visually see similarities between sites as well as between biounits (Clarke and Warwick 2001). In most circumstances a stress value of below 0.1 was acceptable as this is generally considered to give a good ordination with no real prospect of misleading similarities. Principal components analysis (PCA) was undertaken on water chemistry data after the Euclidian distance was normalised and transformed using either the square root or the log (x+1) transformation. All multivariate statistics were undertaken using Primer 6.0.

Statement of limitations

Gaylard et al (2013) detail the rationale and methods that the Nearshore MER program uses to define and assess ecological condition. It should again be stressed that the ecological condition rating developed for this monitoring program is designed to be a broad overview using rapid assessment techniques which is then reviewed by a panel of experts to ensure consistency with the conceptual models and in line with the current level of understanding in the marine environment. The MER program is designed to be iterative and may change relative to increased understanding of disturbance gradients, seagrass, temperate reef and sandy bottom systems as South Australia is developed.

The broad regional focus of the Tiers 1 and 2 aspects of the MER program is not designed to provide scientific certainty or casual relationships between specific potential pollution sources and observed environmental impacts. Rather, site-specific uncertainty and casual relationships may be further investigated by specific projects under Tier 3 (section 1.1).

A key overlying premise is that the program assumes clear gradients in the natural environment. However, the vast diversity of southern Australian marine systems are more likely coupled with any number of response gradients, which makes categorisation of habitats based on broad index scores difficult. Results need to be couched in the acknowledgment that while the program is designed to be a broad overview, we should not blindly follow index results if there are problems with the representativeness of sites or common sense suggests otherwise. All technical reports are peer reviewed by experienced independent South Australian marine scientists as to whether the index results align with common sense (as apposed to perception). If discrepancies are highlighted then further work will be needed to investigate, whether the conceptual models need reviewing for that biounit, or whether our understanding on the marine environment is accurate.

It is accepted that even though there are problems with the concept of ecological ‘health or condition’ and ‘report cards’ due to the oversimplification of inherently complex multi-dimensional systems, the potential benefits arising from the increased accessibility of the biological information to the wider community makes it a useful concept. It is hoped that a diagnosis of poor condition will raise community and political concern, and result in action to manage the issues highlighted (Deeley and Paling 1999). It should also be noted that an assessment of poor condition does not necessarily mean that a particular location is degraded due to anthropogenic means, and where possible this will be conveyed through the AECR format.

4 Tier 2 – evaluation of ecological condition in the bioregions

The Nearshore MER program undertook monitoring throughout autumn and spring in each reporting year. Site allocations are as follows:

- 62 sites in five biounits during 2010: autumn (23 February–12 April) and spring (13 October–18 November)
- 66 sites in five biounits during 2011: autumn (6 April–5 May) and spring (14 September–28 October).

The MER program for the GSV Bioregion during 2010 and 2011 were constrained to five of the nine biounits. The biounits that were not monitored will be made a high priority for future monitoring. In addition to the biounits that were unable to be monitored there were a number of sites which could be not be sampled or data was lost due to corrupted video files. These circumstances were considered rare and are highlighted in the individual biounit assessment and it is considered unlikely to have impact on the overall biounit results.

Analyses/comparisons for the GSV Bioregion include:

- Has data acquisition been representative of the known broad habitat types?
- How do various indices change across the bioregion – are there biological gradients present?
- What are the major determinants in any differences between biounits within the bioregion?

4.1.1 Habitat

Seagrass was the dominant habitat for both 2010 and 2011 with an average cover of 55.0% and 59.6% respectively across all sites and an overall average of 57.3% for two years (Figure 16). The amount of bare substrate cover slightly reduced from 33.7% in 2010 to 29.8% in 2011 with an overall average of 31.7%. Reefs comprised 11.3% in 2010 and 10.6% in 2011 of the total area monitored with an overall average of 10.9% (Figure 16). The reefs monitored were quite isolated which is consistent with the sandy substrate of the majority of the Gulf (Edyvane 1999c).

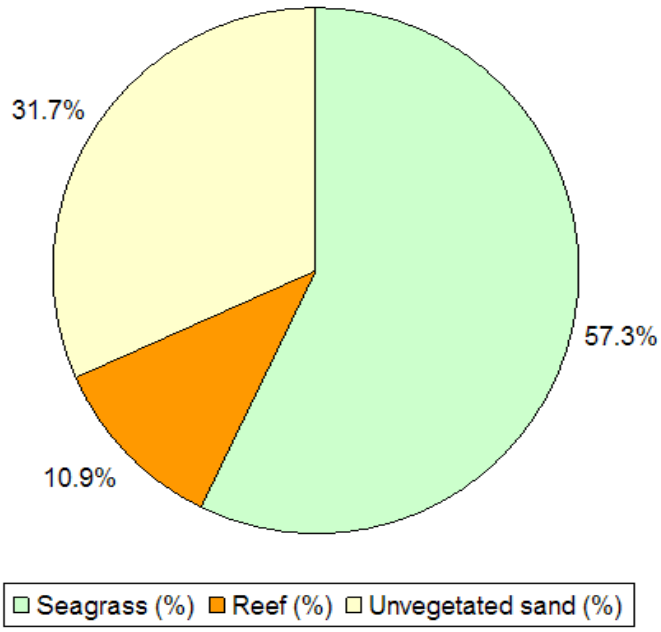

Figure 16 Average benthic habitat composition for sites within the Gulf St Vincent Bioregion for 2010 and 2011 combined.

In order to investigate whether the habitats monitored were an adequate representation of the nearshore Gulf, the National Benthic Habitat Mapping or NBHM (SARDI 2004) for the GSV Bioregion was compared. This work indicated that in waters less than 15 m deep, 69.1% of the area comprised seagrass, 17.1% bare sand and 13.8% rocky reef (SARDI

2004). The habitat composition derived from the current Nearshore MER is broadly comparable to those values. While the EPA program is not designed as a mapping exercise, the results show that the data is representative of the composition of habitats found in the Gulf. Additionally the NBHM program was relatively coarse with limited accuracy in some areas. The Department of Environment, Water and Natural Resources (DEWNR) have undertaken State Benthic Habitat Mapping (SBHM) across many areas which is of a higher resolution and higher accuracy, but coverage at this time is incomplete. Where possible comparisons will be made to the state benthic habitat GIS layer, but in areas where the state coverage is lacking comparisons will be made to the national layer.

The average habitat structure index (HSI) indicates that seagrass condition did not significantly vary between 2010 and 2011 (Mann Whitney $p = 0.5528$). Spatial differences can be seen in HSI when averaged for the biounit (Figure 17) and HSI was found to be much higher in the lower energy environments including Orontes and Clinton, while the condition was variable in other biounits (Figure 17). The variability in the condition index across the biounit is indicated by the error bars and is relatively high in the Adelaide Metro Biounit, while relatively low in the Clinton Biounit. This finding is interesting as it has been shown that as the level of disturbance increases, the variability in the environmental data also increases (Odum et al 1979; Warwick and Clarke 1993). In this case disturbance could also be the amount of wave energy. However the Adelaide Metro biounit has large areas with documented seagrass loss, which is reflected in the consistently second lowest HSI for the bioregion. The Yankalilla Biounit showed the lowest HSI, regardless of year, which is unlikely due to significant seagrass loss (other than possibly in some of the northern section of the biounit) but is more likely due to the random nature of the site selection which sampled many sites were clustered towards the north of the biounit. This biounit has higher wave energy than the other biounits and there was also a number of sites where *Posidonia ostenfeldii* complex seagrasses were found not growing in continuous meadows which could be mistaken for patchy (and possibly degraded seagrass). These factors may be affecting calculation of the HSI for seagrasses habitats within the bioregion. In future more sites in the south of the biounit will be developed to aid the classification of Yankalilla.

Some reefs were surveyed throughout the bioregion, given the predominance of seagrass habitats throughout Gulf St Vincent (Shepherd and Sprigg 1976). Given the small amount of rocky reef encountered the confidence in the results is likely to be low. A further discussion on each reef including the amount of data collected is included in the discussion of each biounit.

A key indicator of a shallow South Australian reef typically in good condition is the cover of robust brown canopy macroalgae such as *Ecklonia radiata, Cystophora spp* and *Sargassum spp*. Impacted reefs often have large areas of turfing algae or bare substrate (Cheshire et al 1998; Turner et al 2007). The reef composition throughout the sites monitored in this MER program shows that the cover of large brown canopy algae was variable (Figure 18).

Yankalilla Biounit had the highest average canopy algae cover and also the highest number of reefs surveyed. This is consistent with the composition of the sites monitored and the mapping undertaken for this biounit (section 5.5). The Adelaide Metro Biounit had the lowest amount of large brown macroalgae cover and also had the highest proportion of turfing algae or bare substrate, however it also had the lowest number of reefs sampled and therefore confidence in these findings is likely to be low (Figure 18).

This program did not specifically look at the same reefs as the Reef Health program, so these results should be viewed as a broad scale extrapolation for the biounit based on small sample sizes. As such they should be seen as largely speculative when the number of reefs is low or the number of quadrats sampled on each reef is also low. However the findings are consistent with the results of other researchers assessing the condition of reefs throughout shallow GSV waters who suggested the reefs within the Adelaide Metro Biounit had very little cover of large brown macroalgae and classified as in Poor condition. Reefs within the Yankalilla Biounit had high covers of large brown macroalgae and were in either Caution (moderate) or Good condition (Collings et al 2008). It should also be pointed out that the Reef Health program assessed considerably more indices than in this broad-scale assessment.

Interannual variation was substantial in some circumstances (eg Orontes: Figure 18) which is also likely to be due to different reefs being sampled in the random program between years where substrate complexity, wave energy and other local environmental variables may affect species composition within the biounit, Seasonal differences in the same reef have been shown to be considerable at times, particularly in the large brown canopy macroalgae such as *Sargassum* spp shedding fronds during winter (Edgar et al 2004). Where the reefs were sampled in both autumn and spring the maximum brown algal cover was used to overcome this problem but in some cases the random nature of transect selection did not cover the same reefs in both seasons.

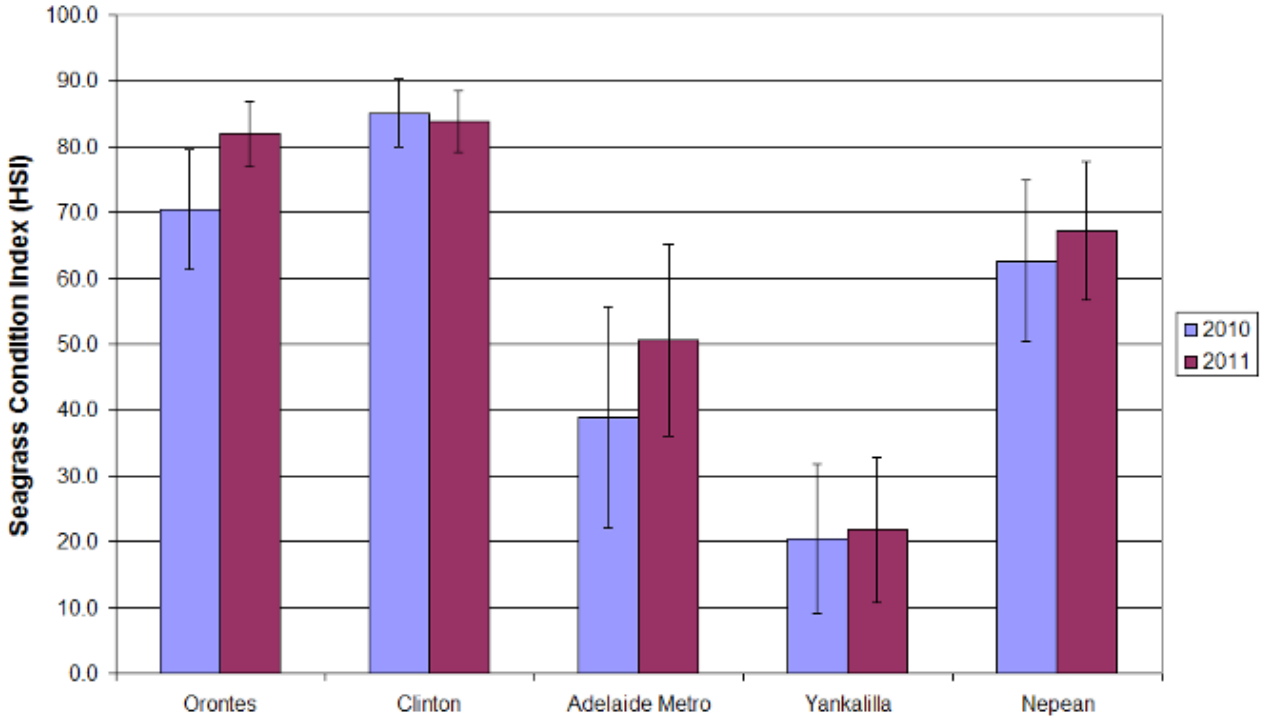

Figure 17 **Average seagrass HSI in the Gulf St Vincent Bioregion, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).**

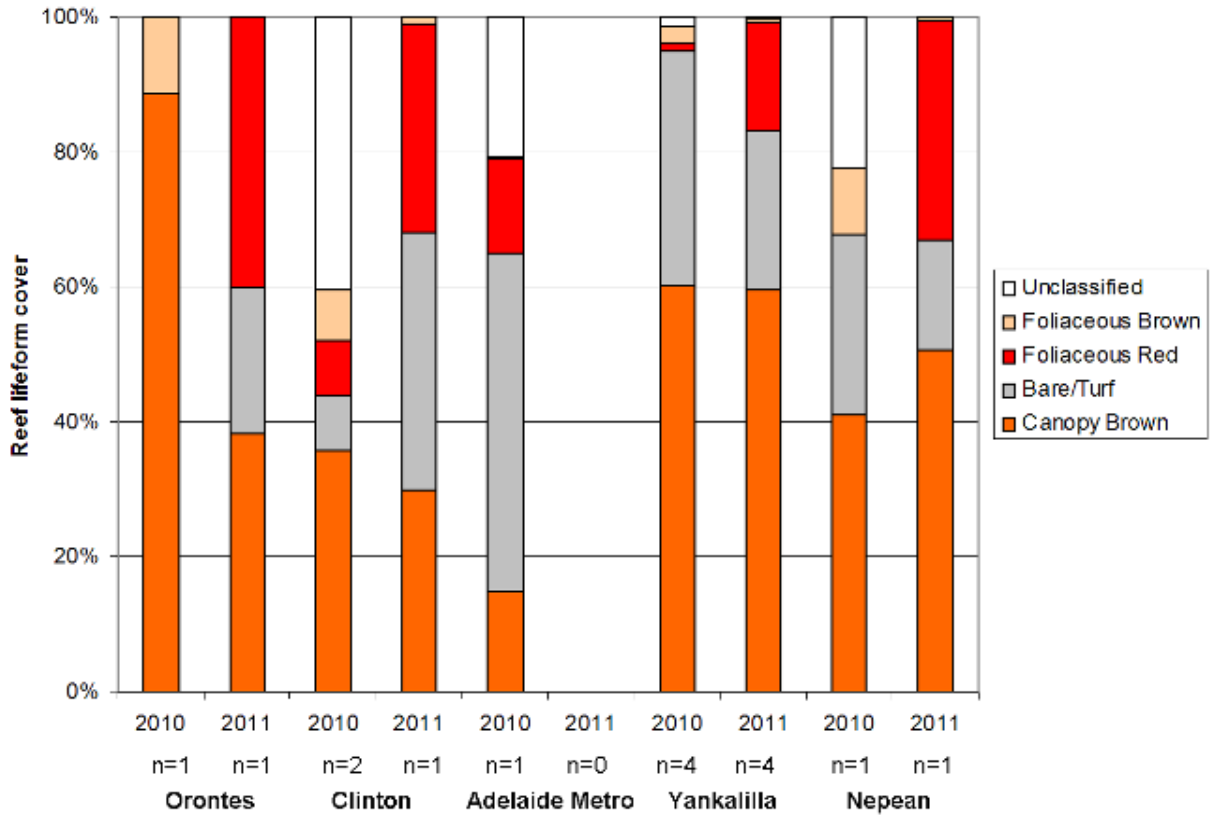

Figure 18 **Average reef life form composition in the Gulf St Vincent Bioregion, 2010 and 2011. The number of reefs surveyed in each biounit is indicated by (n).**

4.1.2 Modifiers

Gaylard et al (2013) details a range of parameters which investigate aspects or processes that can contribute to the stress on the habitats, and if sustained, contribute to the degradation and possible loss of habitats (Kendrick and Burt 1997). In many cases the duration of a stressor is critical (eg seagrass epiphytes) and this may have a substantial effect on the condition of the habitat over time (Neverauskas 1988; Shepherd et al 1989). Habitat 'modifiers' can be transient or the habitat may be resilient to tolerate the presence of small amounts or short duration of their effects. Gaylard et al (2013) suggests conceptual models describing the change in the modifier with increasing disturbance.

As the MER program is only able to assess habitat condition twice in a year there is uncertainty as to whether these modifiers are actually degrading the habitat condition or whether their presence is transient and not resulting in impact on the habitat. The modifier parameters have not been included in the calculation of the AECR rating but their role in habitat modification is well understood, so this information can be used to show whether the habitats observed may be under stress.

Similarly, many water chemistry parameters can be variable through space and time, and therefore these snapshots are not representative of the same time scales that the biological information represent (months to years). Nonetheless, the water chemistry data do give a useful insight into the nutrient availability at the time of sampling and how this may relate to the presence of epiphytes and opportunistic macroalgae, and providing a more complete picture of nutrient status.

Multivariate statistics were used to look at similarities in biounits within the Gulf St Vincent Bioregion investigating whether there are any broad biological gradients present. The relative similarities in seagrass area, density and patchiness, macroalgal area, area of bare sand, epiphyte load and opportunistic macroalgae averaged for each biounit are displayed in an nMDS plot. The distance between the points shown on the plot suggest how similar composition of the biounits are, so points that are closer together are quite similar, while points that are located away from each other are different. There is a clear gradient in the biounits which can be attributed to the area and patchiness of seagrass present. The HSI, which summarises seagrass area, density, patchiness and species (Irving et al 2013) for Clinton had the highest HSI, followed by Orontes, while Adelaide Metro and Yankalilla have the least (Figure 17) which is consistent with the nMDS gradient shown in Figure 19.

The relatively small distance between many of the same biounits between each years shows that in most circumstances there is not a lot of interannual variation within the biounit. This is consistent with the relatively long-lived nature of the dominant *Posidonia* spp and *Amphibolis* spp seagrasses in the Gulf St Vincent Bioregion (Section 2). The parameters which are more variable in space and time are epiphyte load and the opportunistic macroalgae (such as *Ulva* spp and *Hincksia* spp). In many cases these types of algae have been shown to have a distinct seasonality in their abundance and composition (Borowitzka et al 2006) including in South Australia (Bryars et al 2011). It is possible that the gradient in habitat composition may be influenced by a north-to-south (except Nepean) gradient which could be related to changes in wave energy and has been shown to increase further south in the Gulf and be a key influence on biological community composition (Cheshire and Collings 1998; Edyvane 1999c).

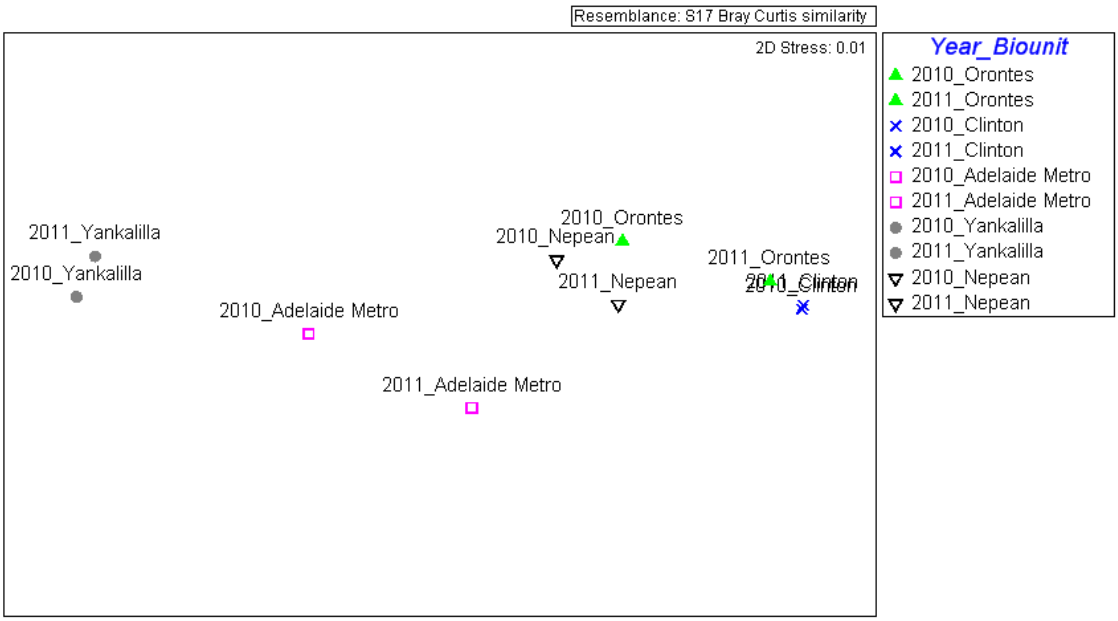

Figure 19 **nMDS plot for the relative similarities in seagrass area, density and patchiness, macroalgal area, area of bare sand, epiphyte load and opportunistic macroalgae within each biounit for each year**

The conceptual models (Appendix 2) and the data compiled in Gaylard et al (2013) reflect the physical, biological and chemical attributes that may be typical in South Australian nearshore habitats located in waters between 2–15 m deep when in Excellent condition. This work also shows how attributes may change along a disturbance gradient relating to declining condition (Appendix 1). In order to demonstrate how sites assessed in the current MER program fit within the conceptual models, reference points were created using the information within the models (Appendix 2). The reference points created included five replicates showing variability within the parameters measured rather than just one conceptual condition. The spread of these points, particularly in the Very Poor points, fits with the work showing that as the level of disturbance increases, the variability in the data also increases (Odum et al 1979; Warwick and Clarke 1993). Overlaying the sites sampled in this MER with the reference points shows where the composition of the sites fit within the conceptual models.

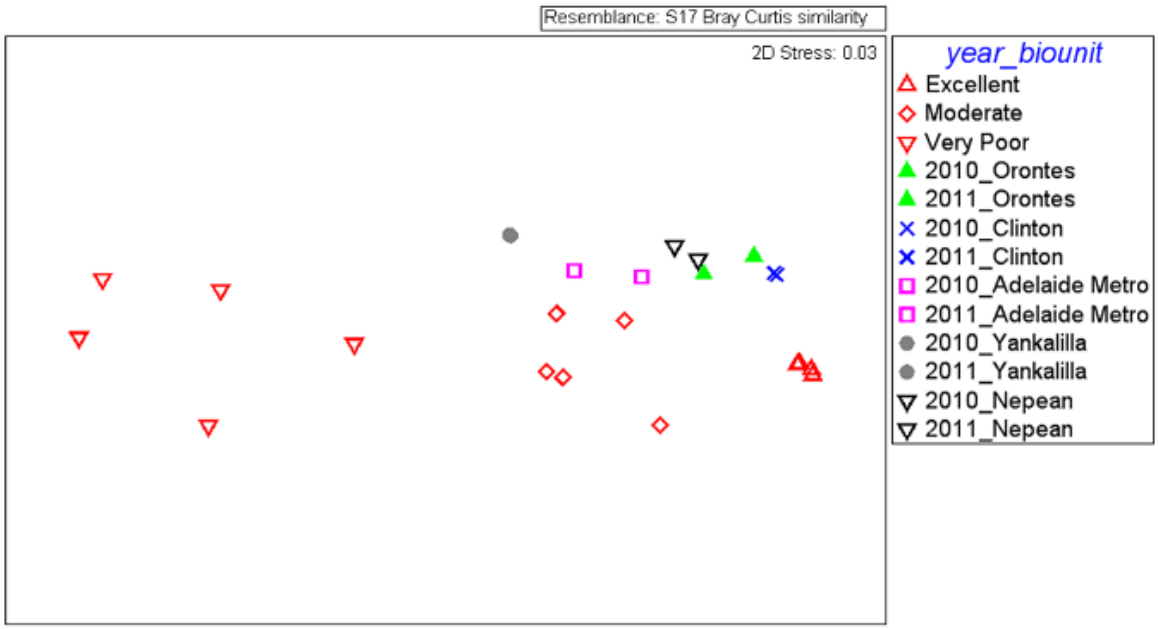

Figure 20 **nMDS plot for the relative similarities in seagrass area, density and patchiness, macroalgal area, area of bare sand, epiphyte load and opportunistic macroalgae within each biounit for each year with reference points overlaid**

The biounits were similar to the Moderate and Excellent reference points, rather than being similar to the Very Poor points (Figure 20). This suggests that the condition of the biounits is within the scope of the conceptual models. The Clinton and Orontes biounits are separate from Excellent due to the influence of the modifiers (seagrass epiphyte load and opportunistic macroalgae) that have been included in this multivariate assessment. This shows that these biounits are not similar to the conceptual Excellent condition. This is likely due to the elevated epiphyte loads throughout these biounits. A more detailed assessment of each biounit including the scoring of the habitat within the conceptual models for the AECR will be undertaken within each biounit assessment section.

There were regular observations of epiphytes on seagrass and opportunistic macroalgae such as Hincksia spp and Ulva spp throughout all biounits in Gulf St Vincent (Figure 21 and 22). The conceptual models suggest that very little filamentous epiphytes on seagrass is likely to be the unimpacted (Excellent) state, however further research on this is needed, particularly in low flow environments. The current monitoring shows that all biounits have symptoms of nutrient enrichment, with the Nepean Biounit having the highest with respect to both seagrass epiphyte loads and presence of opportunistic macroalgae (Figure 21 and 22). If high densities of epiphytes on seagrass are prolonged the amount of light reaching seagrasses may fall below a critical value and seagrasses can be lost (Neverauskas 1988; Shepherd et al 1989).

Literature suggests that as nutrient loading increases in a region these types of algae can thrive and have the potential to impact on seagrass and reef systems (Neverauskas 1987b; Neverauskas 1987a; Neverauskas 1989; Shepherd et al 1989; Gorgula and Connell 2004; Bryars et al 2011). The driving factors behind seagrass epiphytes and opportunistic macroalgae will vary between locations but typically include nutrient availability, water current speeds, water temperature, adjacent habitats and light availability (Borowitzka et al 2006; Phillips 2006; Lovelock et al 2008). These findings will be explored further in the respective biounit sections to allow for discussion on site-specific factors such as localised nutrient availability. It is also worthy to note that the conceptual models suggest there should be little to no opportunistic macroalgae at locations indicative of Excellent condition (Appendix 2), which is consistent with observations in remote areas including Flinders and Pearson Islands, and the Sir Joseph Banks Group of Islands (Gaylard et al 2013).

In addition to the biological data collected in the Nearshore MER program, two snapshots of water chemistry and chlorophyll variables were also sampled at each site to investigate further differences between locations, comparison to reference locations and to aid the interpretation of the biological data.

Across GSV, Orontes and Nepean had substantial seagrass epiphyte loads compared to the other biounits (eg Clinton) which did not fit the possible geographical gradient observed in the HSI (Figure 21). This verifies that there are other factors which can contribute to seagrass epiphyte loads as described earlier. The difference in years also did not appear to heavily affect the seagrass epiphyte load with biounit seagrass epiphyte loads being relatively consistent between 2010 and 2011, with the exception of Nepean which did have substantial inter-annual variation (Figure 21). This finding adds weight to the reliability of seagrass epiphyte loads as an indicator. The presence of opportunistic macroalgae, however, is much more variable across years with considerable differences seen within the same biounit between years (Figure 22) which somewhat confounds the ability to interpret the data other than it being an indicator of nutrient enrichment.

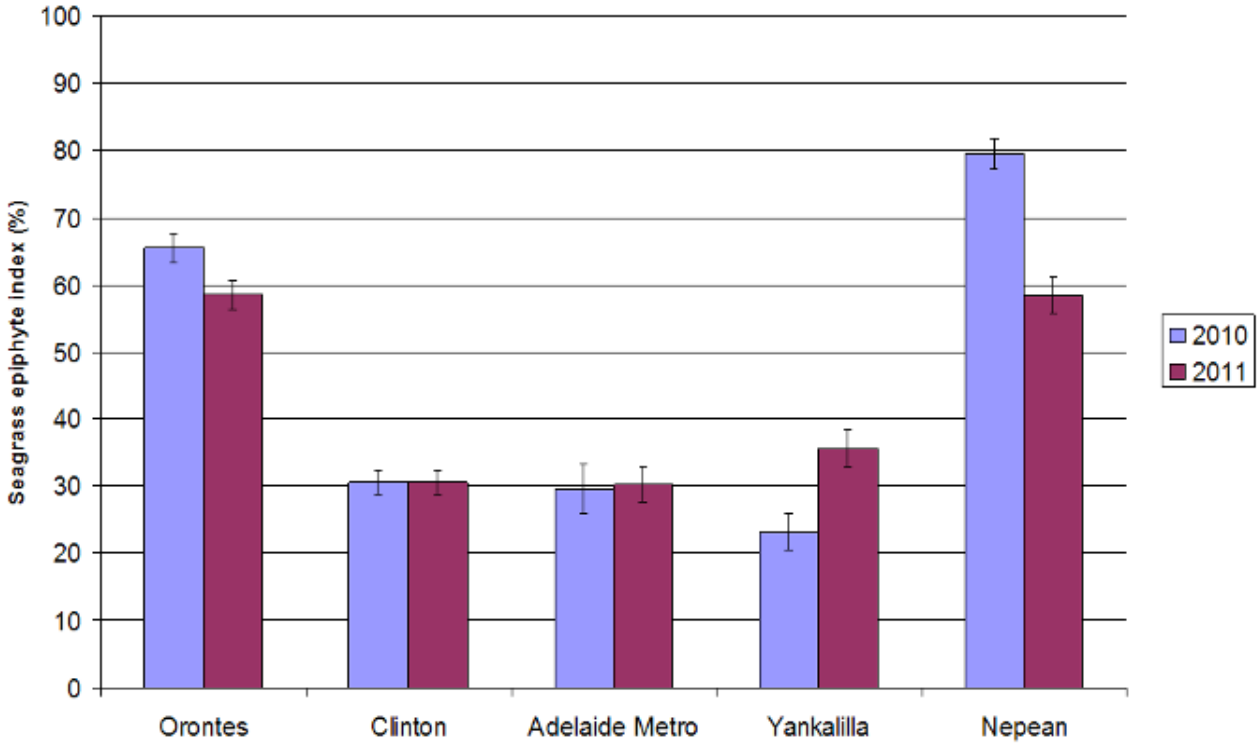

Figure 21 **Average biounit seagrass epiphyte load in Gulf St Vincent, 2010 and 2011. Error bars represent the standard error.**

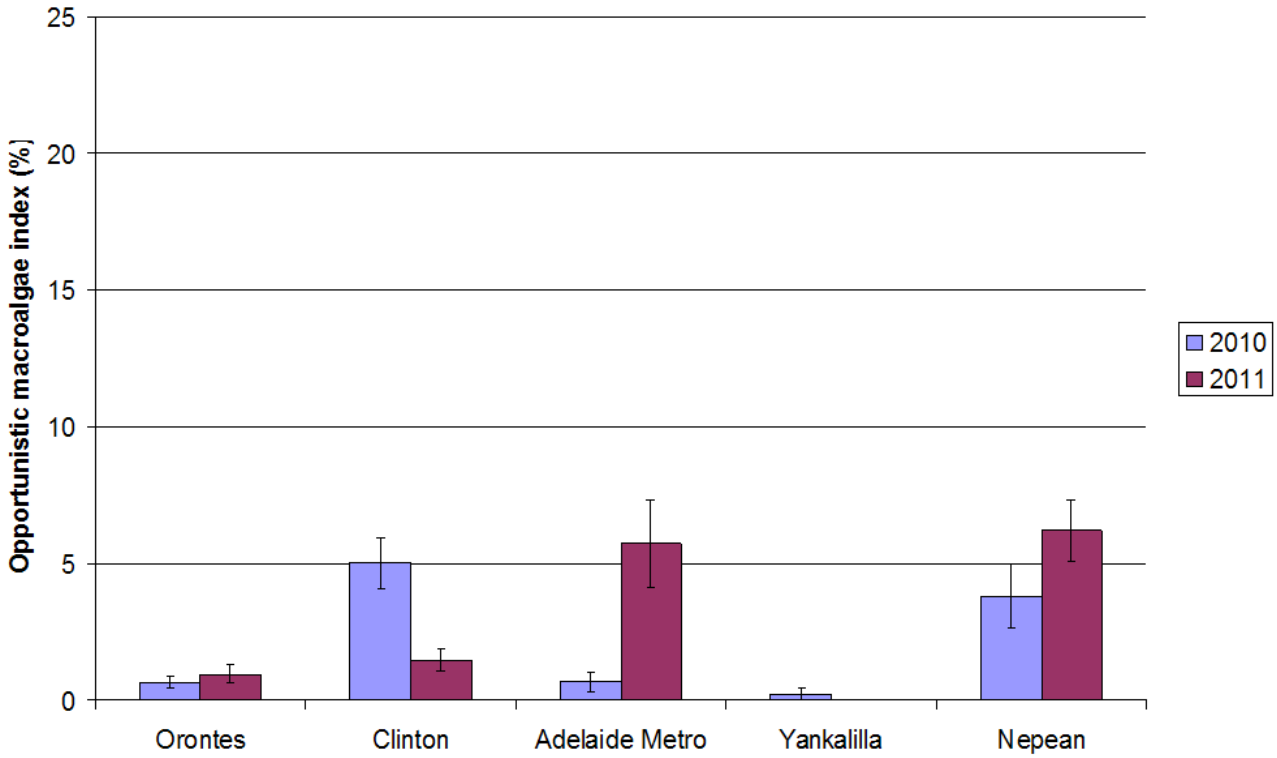

Figure 22 **Average biounit opportunistic macroalgae abundance in Gulf St Vincent, 2010 and 2011. Error bars represent the standard error.**

In many circumstances sampling of water chemistry in marine waters focuses on the soluble (inorganic) fractions of nutrients as they are the fraction that are readily bio-available to plants and algae, and are therefore a more immediate

indicator for potential primary productivity (Guildford and Hecky 2000; Hoyer et al 2002; Smith 2006). However, in low nutrient water with a high potential for productivity, the concentration of inorganic N and the rapid uptake by biological material results in the inorganic fractions being largely undetectable by analytical methods (Guildford and Hecky 2000). Souchu *et al* (2010) has shown that total nitrogen may be a better indicator than dissolved inorganic nitrogen (DIN) to manage eutrophication in some marine systems and it has also been shown that consistent with freshwater environments.

Summarising water chemistry for the entire bioregion is likely to be of little value due to the large spatial variation throughout the Gulf and the short nature of the sampling snapshot within this program. Identifying smaller spatial differences within a biounit has some value, and a more detailed analysis water quality data will be undertaken in each biounit.

4.1.3 Conclusions

The results for the GSV Bioregion suggest that the location and habitat types monitored in this MER program were broadly consistent with the mapping programs undertaken, suggesting that this work is broadly representative of the types of habitats present. Seagrass habitats were the most dominant habitat type in the area monitored and the condition of these habitats varied across the Gulf with dense and intact seagrass meadows in the north (Clinton) and west (Orontes) of the Gulf, patchy or fragmented seagrass throughout Adelaide Metro, and sparse and patchy seagrass in the sites monitored in Yankalilla. The quality of the data and the long lived nature of the dominant seagrasses in the Gulf suggest that the sampling program for these habitats provides high quality and reliable information to make broad-scale assessment of seagrass condition.

There appears to be a geographical gradient in the seagrass condition which may be related to the amount of wave energy. However we know that there have been large areas of seagrass loss along the Adelaide metropolitan coast which indicates that this is not the only reasons behind the changes in seagrass condition. The seagrass epiphyte load information suggests that there are other factors that may be influencing habitat composition and nutrient enrichment than just geographical location.

Reef habitat condition was more variable than seagrasses and as such the reliability in the results was considered low due to the small number of reefs sampled in the program. It is likely that due to their small and isolated extent in the Gulfs that a more targeted program to assess reef condition would generate more reliable results (eg Reef Watch and/or Reef Life Survey). However the data collected in this program were consistent with more detailed programs suggesting that for the broad assessment nature of this program the methods used here are adequate. There were no significant naturally unvegetated sediment habitats monitored in this program.

While it is accepted that the modifiers can be more transient in nature than the habitat parameters, the results indicated that the inter-annual variability was actually quite low particularly with respect to seagrass epiphytes (Figure 21) suggesting that the results are likely to be reliable and that the frequency of sampling is reasonable for the broad-scale assessments of these parameters. The results indicated that all biounits through Gulf St Vincent were exposed to some degree of an excess of nutrients which is likely to be putting various degrees of stress on the seagrass habitats. Of particular concern was the Nepean Biounit which had dense epiphyte loads in both years of monitoring and has also been shown to have lost substantial seagrass meadows due to the runoff from the Cygnet River (Edyvane 1997). Other important findings suggest that the Orontes Biounit is also under considerable stress from epiphyte growth which may impact on seagrass meadows in the future. This is a cause for concern as there is a wealth of information showing that prolonged seagrass epiphyte loads can result in seagrass loss (Neverauskas 1988; Shepherd et al 1989; Bryars et al 2011) and that loss of biological habitats can result in losses of productivity, biodiversity, fisheries production, sand stability and beach erosion which all have a significant financial and ecological impact on all South Australians.

5 Tier 2 – evaluation of ecological condition in the biounits

Five of the nine biounits highlighted within the Tier 1 assessment were sampled throughout the Gulf St Vincent Bioregion in the 2010 and 2011 programs. The number of sites within each biounit varied depending on the size of the biounit, the perceived level of impact and the resources available. A breakdown of the sites within each biounit is in Table 4. A full site list is included in Appendix 3.

Table 4 Breakdown of sites sampled each season in 2010 and 2011

Biounit	Autumn 2010	Spring 2010	Autumn 2011	Spring 2011
Sturt	0	0	0	0
Orontes	14	14	16	16
Clinton	24	24	19 biol 25 chem	25
Adelaide Metro	7	7	8	8
Yankalilla	7	7	7	7
Encounter	0	0	0	0
Backstairs	0	0	0	0
Nepean	10	10 biol 9 chem	10	10
Cassini	0	0	0	0

A small number of site locations were adjusted in 2011 from the 2010 locations. In some circumstances when assigning sites using the random selection method the location may be sub-optimal due to the limitations and assumptions of the monitoring methods. During 2010, these sub-optimal sites were sampled to assess limitations of the methods. In 2011, six sub-optimal sites were adjusted in response to anomalies in the random site selection including issues around the water being too shallow to sample safely or proximity to significant point source discharge which is contrary to the objectives of the program. The adjustment of these sites is not believed to have affected the overall results of the program in 2010. In addition, a number of new sites were added in 2011 to increase spatial resolution and statistical power.

The conceptual models describe the disturbance gradient for habitats as well as some of the other indicators which look at the aspects or processes (modifiers) that can contribute to the degradation of the seagrass, reef and unvegetated sediment habitats (Appendix 2). Many of these processes could be seen as seasonal or episodic but contribute to the stress on the habitat (Kendrick and Burt 1997). The duration of their influence is critical in many circumstances (eg seagrass epiphytes) and this may have a critical effect on the condition of the habitat over time (Neverauskas 1988; Shepherd et al 1989). These habitat modifiers can be transient or the habitat may be resilient to tolerate the presence of small amounts or short duration of their effects. These conceptual models describe the change in the modifier with increasing disturbance. As the MER program is only able to look at two snapshots throughout the year, there is uncertainty as to whether these modifiers are actually degrading the habitat condition or are transient. These parameters are important to understand, however will not be included in the calculation of the AECR rating as the scale of observation is not necessarily commensurate with their influence on the condition of the habitat. As such, results will be included in the detailed discussion for each site and biounit within the assessment report. They can also be used to suggest whether the habitat is currently under stress and whether the habitat condition may change over time if that stress continues.

This section documents the results of the Tier 2 monitoring program in the biounits within the Gulf St Vincent Bioregion in 2010 and 2011. The key questions being assessed within each biounit are:

- What is the AECR outcome for the biounit?
- How does this compare to the Tier 1 assessment?
- How does the biounit compare to the reference condition?
- Are there any biological gradients within the biounit?
- Are there any relationship between index scores and water quality and physical observations within the biounit?
- How reliable are the indicators to show differences?

Normally an assessment report will detail the results of only one year of monitoring, however during the trialling phase of the Nearshore MER program, two consecutive years were sampled to investigate inter-annual variability and also to further refine the field methods. In future, all reports will be based on one year of data collected in spring and autumn in each bioregion.

5.1 Tier 2 results – Sturt Biounit

The Tier 1 assessment in section 2.1 suggests the Sturt Biounit was predicted to be in Very Good condition. Sturt was not sampled in 2010 or 2011 due to logistical and resource constraints. As a result no AECR has been developed, but the biounit will become a priority in the next sampling event for Gulf St Vincent.

5.2 Tier 2 results – Orontes Biounit

The Tier 1 assessment predicted the Orontes to be in Good condition (section 2.2 and Table 3). In total 14 sites were sampled in 2010 and 16 sites were sampled in 2011 (Figure 23). Sites m0065 and m0066 were added to the biounit in the Coobowie area in 2011 to add power to the biounit assessment. The enclosed nature of parts of the Orontes Biounit is likely to have an influence over the water chemistry and the habitats within these locations. Some areas are likely to have reduced exchange with Gulf St Vincent which could exacerbate the effects of any nutrient inputs and therefore could be seen as being more susceptible to pollutant inputs if they were to occur.

5.2.1 Habitat

Sites were dominated by seagrass in 2010 and 2011 with an average over the two years of 79.4% cover (73.8% in 2010; 83.4% in 2011) [Figure 24]. Across both 2010 and 2011 bare sand had an average of 16.1% cover (20.4% and 13.1% for 2010 to 2011, respectively). Macroalgal reef had the smallest proportion of habitats with an average of 4.5% cover (5.8% in 2010; 3.3% in 2011). In order to assess whether the sites sampled within Orontes were representative of the known habitats present, the SBHM program undertaken by DEWNR documented that the habitats less than 15 m deep in Orontes are comprised of 86% seagrass, 9% rocky reef habitats and 5% of unvegetated sediments (modified from (DEWNR 2010). Overall the sites monitored in Orontes are broadly consistent with the SBHM.

Sites including m0013: Vincent outer, m0015: Stansbury and m0016: Orontes all had very high seagrass cover and high HSI suggesting that the seagrasses were in good condition (Figure 25). While the average cover for the biounit was relatively high there were a number of sites that had low seagrass cover and seagrass in potentially poor condition. These included m008: Rogues Point and m0018: Klein Point which had 41.3% and 39.3% respectively, in 2010. In 2011 both of these sites increased slightly in seagrass cover and condition but they were still considered to be in poor condition.

Between 2010 and 2011 there was small variation in seagrass condition (Figure 25) and there was no significant difference in condition or area between years [Mann Whitney $p = 0.8267$ (area) $p = 0.2447$ (HSI)]. It should be highlighted that the slight increase in seagrass cover and condition between 2010 and 2011 is likely to be due to the inclusion of the two sites in the south of the biounit – m0065: Coobowie Bay North and m0066: Coobowie Bay South which both had dense cover of *Posidonia* spp, seagrass which is likely to have increased (although not significantly) the area and condition of the biounit.

There were only two very small patches of rocky reef encountered within the sites monitored in the Orontes biounit. These were located at m0021: Troubridge Island (2010) and m0009: Pine Point North (2011). Even though the both sites were assessed in both years, the patches of reef were very small and were not encountered in both years due to the random nature of the transect placement. At both sites the area of reef was very small resulting in a limited number of quadrats able to be assessed.

The large brown macroalgal canopy cover for m0021: Troubridge Island was very high with an average of 88% cover and there were no observations of bare substrate or turfing algae (Figure 26). While m0009: Pine Point North however, had a lower cover of brown canopy macroalgae (38%) and there was 21% cover of bare substrate or turfing algae. Even though both sites were sampled in autumn of their respective years there were likely to be substantial variability in the reef complexity, substrate type, wave and current exposure which all may affect the composition of the communities on the reef. Additionally the very small isolated nature of the reef extent and low number of quadrats able to be sampled due to the random nature of the program suggest that reliability in these indicators is likely to be low.

Bare sand comprised 16.1% of the area however in all cases seagrass was present on the site suggesting that this represents sand patches within seagrass habitats rather than naturally occurring unvegetated sediment habitats (Figure 24).

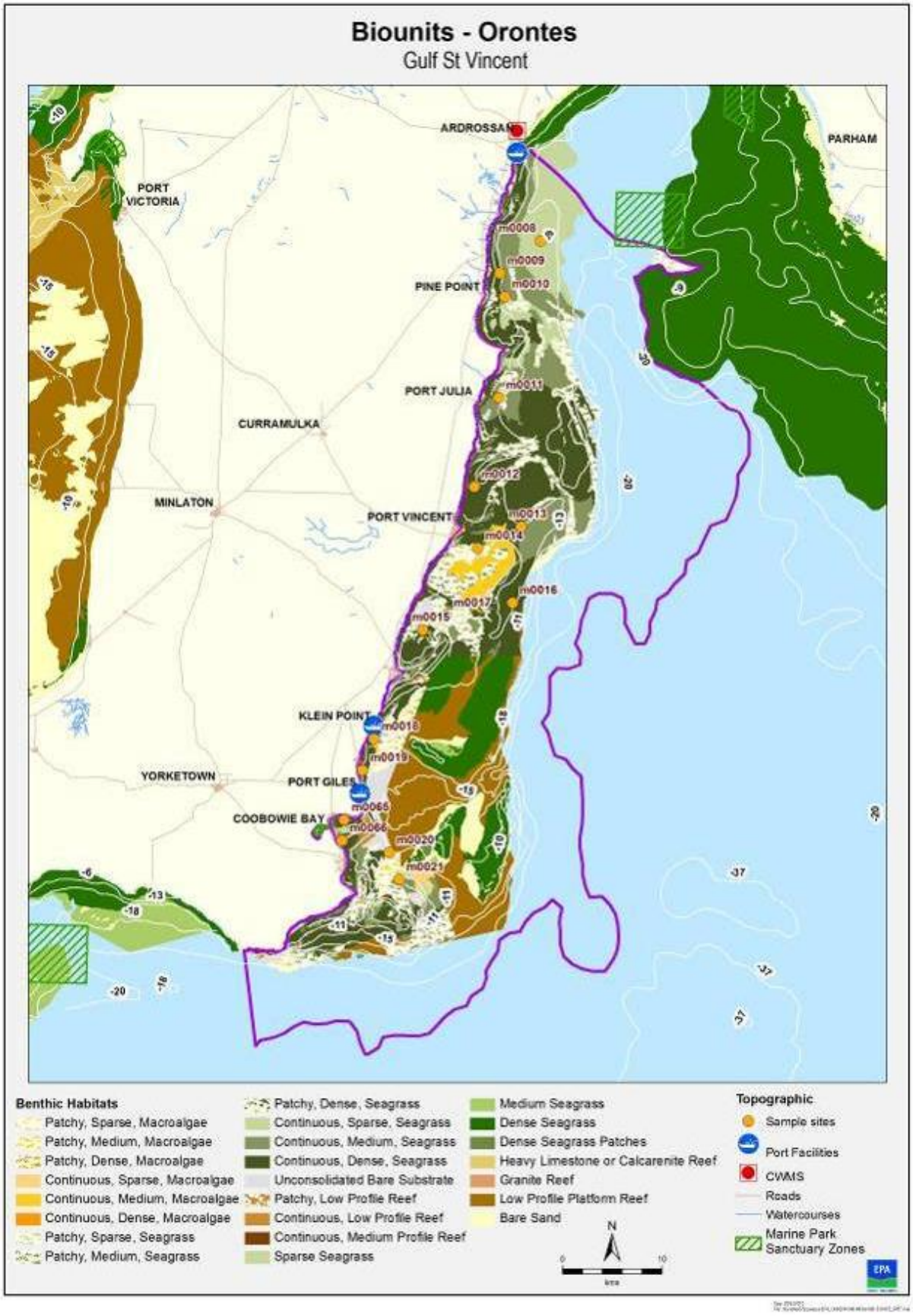

Figure 23 **EPA monitoring sites sampled in the nearshore region of the Orontes Biounit, 2010 and 2011. Benthic habitats shown are from the National and State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

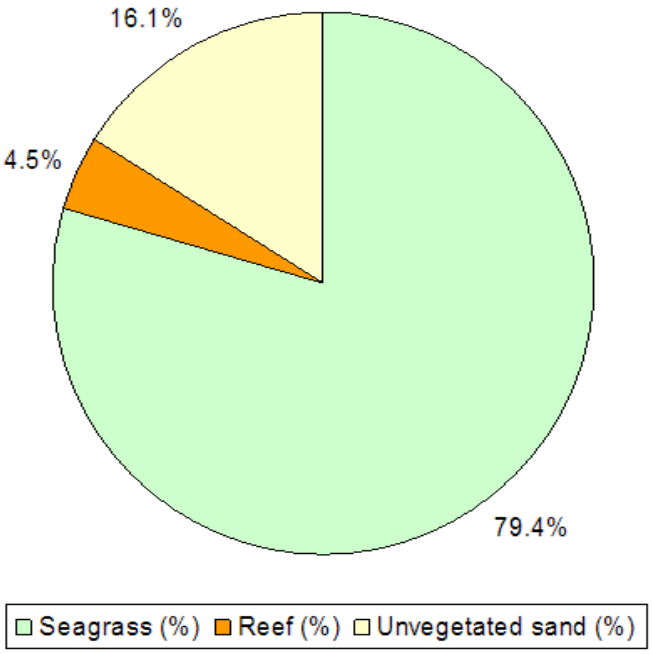

Figure 24 **Average benthic habitat composition of the sites within the areas sampled within the Orontes Biounit**

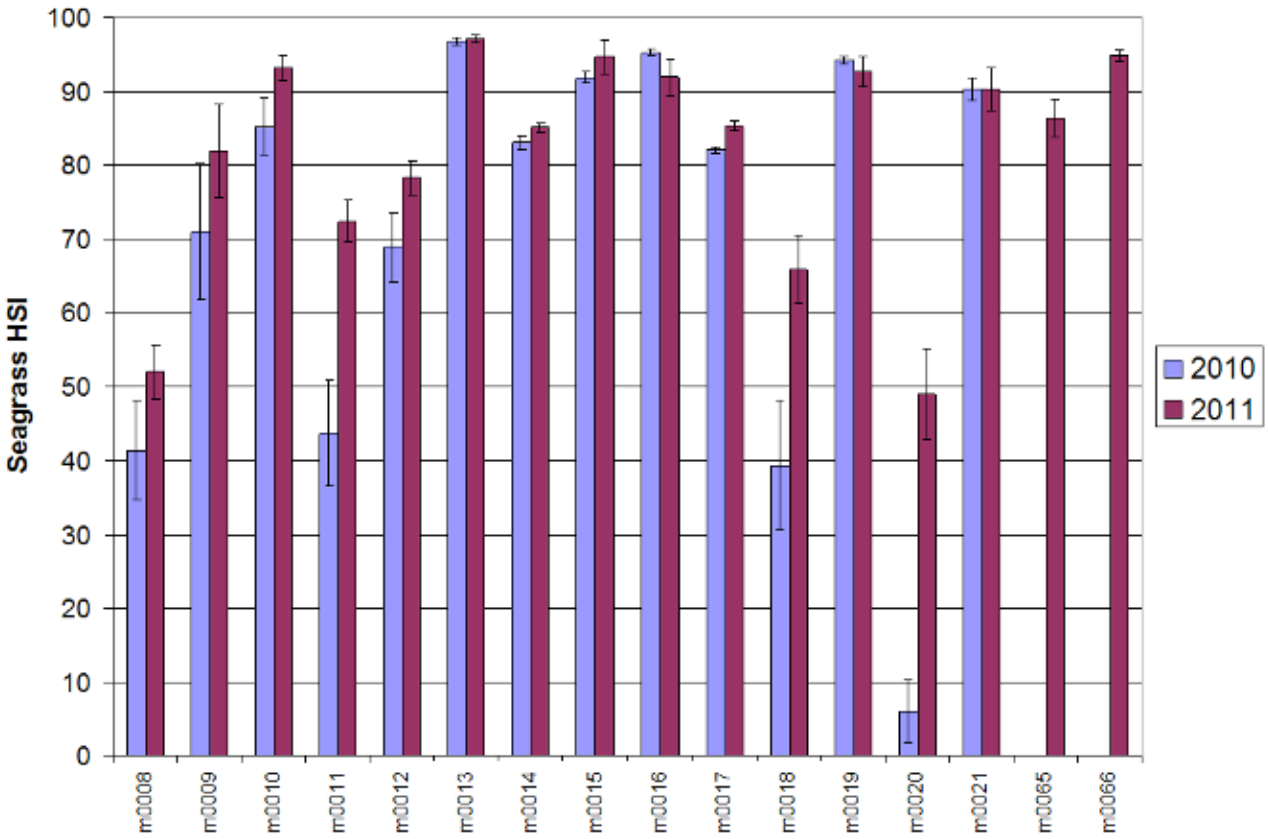

Figure 25 **Average seagrass condition (HSI) in the Orontes Biounit, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).**

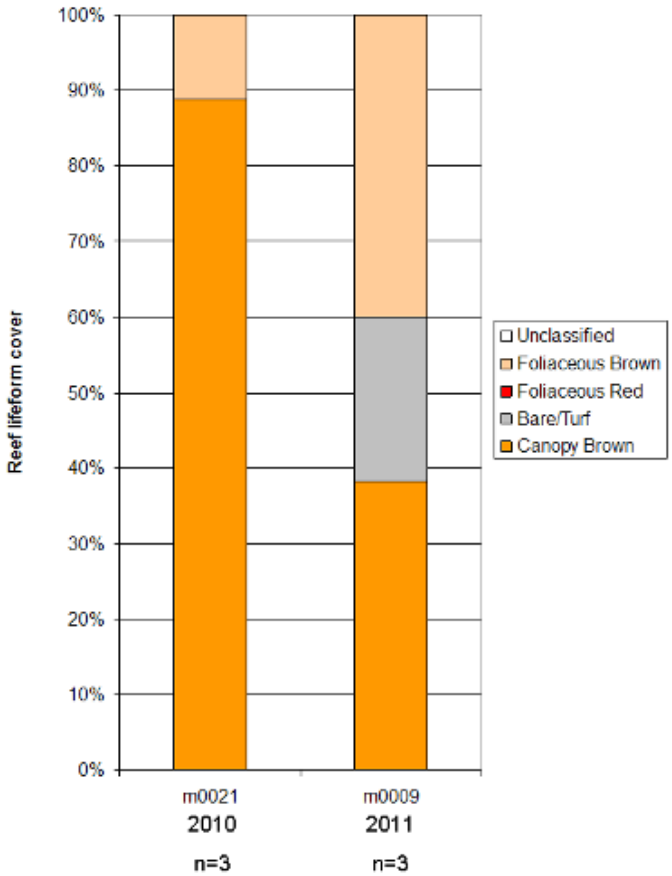

Figure 26 Average cover of reef life forms in the Orontes Biounit. Number of quadrats assessed indicated by (n).

5.2.2 Aquatic Ecosystem Condition Report

The results of the Nearshore MER program determined that the habitat condition, when adjusted for the proportion of habitats monitored in Orontes, was 71 out of 100 in 2010 and 2011 resulting in the biounit classification being Very Good for both years using the AECR classification system.

The Tier 1 threat assessment predicted the biounit was in Good condition, indicating that the observed condition is slightly better than predicted in both years monitored. The AECR is available in Appendix 4.

5.2.3 Modifiers

Section 5.1.1 discusses the effects that increased epiphyte loads can have in seagrass systems. There is a vast amount of literature which demonstrates that increases in epiphyte loads in seagrass can result in the reduction of light to the seagrass leaves to the point that the seagrass will not be able to survive, and the seagrass meadows will thin and eventually be lost (Neverauskas 1988; Shepherd et al 1989; Bryars et al 2011). A discussion on modifiers used in the Nearshore MER program can be found in Gaylard et al (2013).

Throughout the Orontes Biounit there were multiple indicators suggesting nutrient enrichment compared to the reference condition. Seagrass epiphyte loads were considered dense throughout many areas within the biounit, particularly around Pine Point (Figure 27), and this was consistent between years (Mann Whitney $p = 0.8191$). Other sites where there were dense epiphyte load on seagrass included m0019: Wool Bay, particularly during 2010. Overall during 2010 the epiphytes loads were significantly higher in autumn than during spring (Mann Whitney $p = 0.0196$), however in 2011 there was no difference between the seasons.

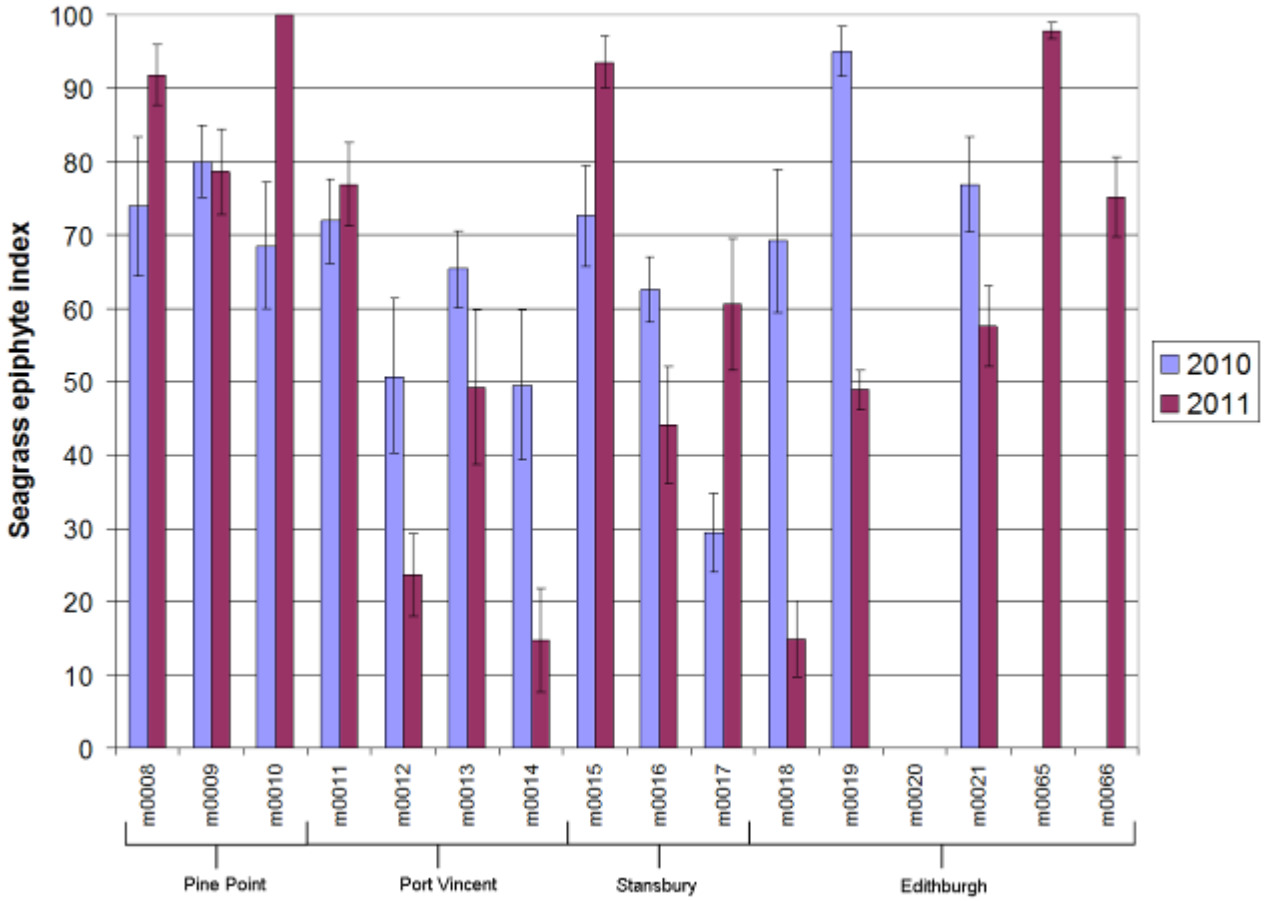

Figure 27 Average epiphytic index for sites in the Orontes Biounit, 2010 and 2011. Error bars are standard errors. Epiphyte load index (0 = sparse; 100 = dense).

The Orontes Biounit is typified by an easterly shoreline orientation which results in predominantly offshore winds and low wave energies (Edyvane 1999a). In addition to this there are areas likely to have reduced current flow and increased water residence times due to the natural geomorphology. This may result in an exacerbation of epiphyte growth on seagrasses for a number of reasons including a higher nutrient exposure time for uptake (Berendse and Aerts 1987) and/or less abrasion of epiphytes from seagrass leaves due to water movement (Kitting 1984; van Montfrans et al 1984). While natural factors are exacerbating the symptoms of nutrient enrichment the overall cause is still an increase in nutrients and the impact on the seagrass is likely to be due to the epiphyte load and not from the nutrient concentration driving the nutrient load. Even small inputs of nitrogen into slow moving waters (or being transported into) could have a considerable effect on seagrass systems.

Multivariate statistics were used to look for biological gradients or similarities across the biounit. The nMDS for Orontes shows most of the sites clustered in a loose cloud tending towards the Excellent reference sites (Figure 28). Although seagrass area varies considerably between sites closer to the Moderate reference sites and those closer to the Excellent reference sites, the continuity of seagrass habitat is largely good (<70). One point sits apart from the main cluster and directly below one of the Very Poor reference points. This site is m0020: Edithburgh in 2010 which is characterised as having a seagrass area <5% that was sparse in density (Figure 25). The seagrass on this site was found to be *Halophila* sp which largely considered an ephemeral species that colonises rapidly but can also disappear rapidly (Clarke and Kirkman 1989). This is likely to explain why the same site in 2011 had a seagrass area of over 45% It is unclear as this stage whether the lack of *Posidonia* spp is an indicator of degradation or recent loss. In order to investigate this further, extensive baseline information and further in-depth surveys would need to be undertaken.

Interestingly this site also had one of the highest total nitrogen concentrations within the biounit for autumn 2010 at 0.340 mg/L as well as a relatively high chlorophyll concentration of 0.710 µg/L. An adjacent site m0021: Troubridge Island also had elevated total nitrogen, DIN and chlorophyll in the water for the same season.

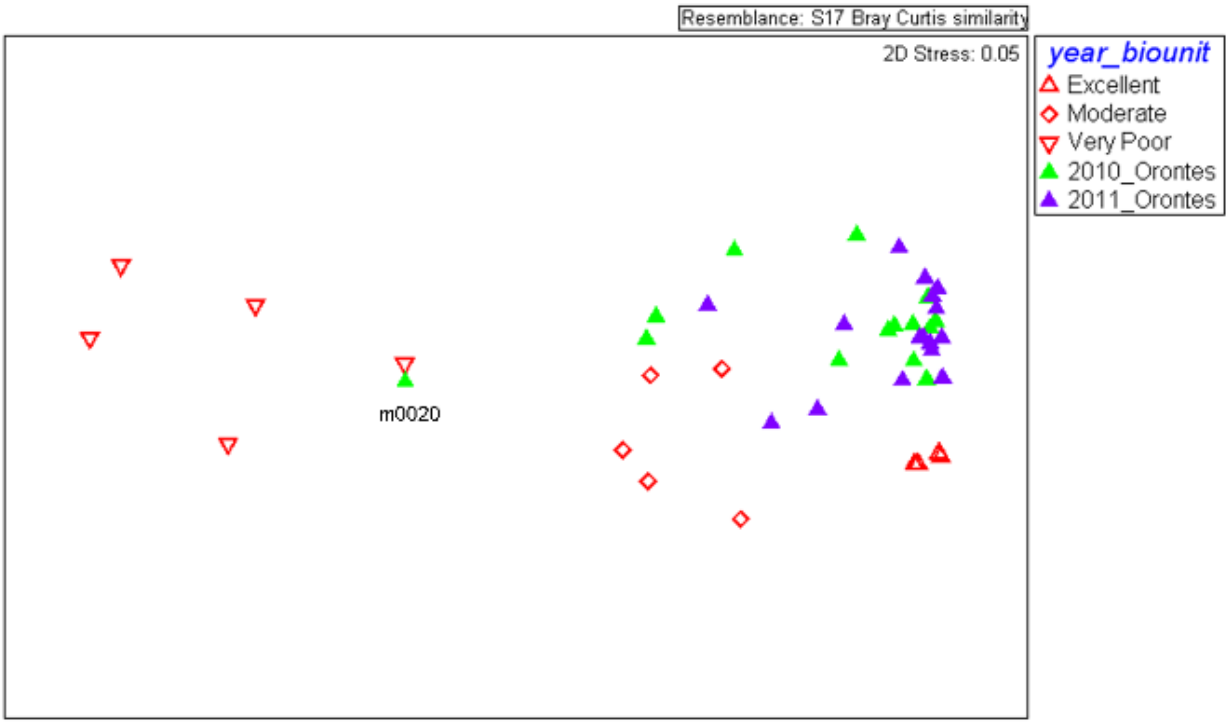

Figure 28 **nMDS plot for habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae within the Orontes Biounit, 2010 and 2011. Reference points suggesting condition overlaid and site m0020 labelled.**

The amount of nitrogen in the waters was variable between years. In 2010 the total nitrogen was significantly higher than the reference condition (Gaylard et al 2013). However, in 2011 the total nitrogen throughout the biounit was significantly reduced (Mann Whitney p = 0.0000) and also significantly lower than seen in locations considered to be in reference condition (Table 5). There was a relatively large difference in total nitrogen concentrations between years, which highlights the variability in water chemistry sampling and may reflect very localised changes in specific nutrient availability at the time of sampling in relation to variables such as recent rainfall. Conversely the amount of dissolved nitrogen in the water was significantly higher in 2011 compared to 2010 (Mann Whitney p = 0.0000) and both the 2010 and 2011 results were significantly lower than the reference condition results (Table 5). It is likely that the low amounts of dissolved nitrogen in the waters may be due to uptake of the dissolved nitrogen by biological material including the dense abundances of epiphytes on the seagrasses. This has been observed in many locations throughout South Australia (Gaylard 2005; Gaylard 2009a) and the world (Iizumi and Hattori 1982; Hemminga et al 1991; Udy and Dennison 1997).

Throughout all of the water chemistry results it was only turbidity that was consistently, significantly higher than the reference values (Table 5) over 2010 and 2011. While the results were significantly higher than reference locations the results are not what would be considered to be high compared to locations impacted by poor water clarity (Gaylard et al 2013). It is worthy to note aerial observations by Shepherd and Sprigg (1976) suggesting that '…successive clouds of turbid water, daily introduce many tonnes of material to settle out in quieter waters. This is most noticeable along the whole of the outer edge of the Orontes platform, north from about Troubridge Island....' (Shepherd and Sprigg 1976).

Table 5 **Water chemistry and chlorophyll *a* values – Orontes Biounit 2010 and 2011**

	Dissolved inorganic nitrogen (µg/L)		**Total nitrogen (mg/L)**		**Filtered reactive phosphorus (mg/L)**		**Total phosphorus (mg/L)**		**Turbidity (NTU)**		**Chlorophyll *a* (µg/L)**	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Median	0.001	0.004	0.210	0.100	0.003	0.002	0.015	0.018	0.260	0.270	0.360	0.400

St Dev	0.008	0.006	0.088	0.033	0.001	0.002	0.008	0.006	0.128	0.343	0.152	0.265
n	84	96	84	96	83	96	84	96	84	96	72	72
Reference median	0.018		0.150		0.005		0.015		0.190		0.627	
Mann Whitney significant at p<0.05	0.00	0.00	0.0020	0.00	0.00	0.00	0.5542	0.0178	0.00	0.00	0.00	0.00

5.2.4 Conclusions

Overall, the condition of the Orontes Biounit that spans from Troubridge Hill to Ardrossan on the eastern side of Yorke Peninsula was found to be in Very Good condition in both 2010 and 2011 using the Nearshore MER program criteria. Within the biounit there were a number of areas that show multiple signs of nutrient enrichment and are likely to be under substantial stress. Seagrass condition is strongly affected by the amount of light reaching the plant, which can be decreased by turbidity and an increased epiphyte load on seagrass leaves. Prolonged stress from a reduction in light can lead to loss of seagrass and habitat degradation.

The results from the Orontes Biounit show only a slight reduction in seagrass condition compared to the reference state but there were considerable seagrass epiphyte loads throughout the biounit suggesting nutrient enrichment, with the areas to the north of the biounit likely to be under stress as well as some of the areas with lower flow (eg Coobowie).

It is possible that the natural geomorphology of the biounit may be influencing the effects of nutrient enrichment. As a result even small inputs of nutrients into nearshore waters may have a large effect on some habitats.

5.2.5 Pressures and management responses

Section 2.3 and Table 3 outlines the threat assessment for the Orontes Biounit and highlights the key nutrient and sediment input sources to the nearshore marine environment. The main potential input sources for nutrient entering the marine environment are likely to be runoff from agricultural lands, leakage or overflow from septic waste systems and community wastewater management systems (CWMS).

The Orontes Biounit has a low annual rainfall, which reduces the likelihood of surface water runoff, however when surface water does reach the nearshore environment, it would likely be relatively high in nutrients and sediments due to the long intervals between sufficiently large rainfall events that create surface water runoff allowing pollutants to build up. There is also the possibility of nutrient rich groundwater reaching nearshore marine waters.

Port facilities at Klein Point support the majority of the shipping within Orontes, with substantial limestone exports. Grain exports from Port Giles can be up to a million tonnes while the port facility at Ardrossan exports dolomite. These port facilities increase the risk of spillage from loading activities and dust from stockpiles and stormwater runoff entering the nearshore waters. The increased shipping activity in these areas also results in a risk of minor or major hydrocarbon spills into waters as a result of spillage, bilge water discharge or from a major accident. While the volumes of shipping exports and vessel movements have changed over the period between 2010 and 2011 it is unlikely to have significantly changed the pressures on the biounit.

It must be stressed that the findings in the current report do not show causative links to any source but only show the condition of the habitat and a snapshot of some of the factors that can modify the habitat at the time of sampling. More detailed studies are required to determine fate and transport of nutrient sources with linkages to the results shown here in order to target nutrient mitigation activities to ensure that activities are optimal for reducing impacts on ecological condition.

Table 6 Pressures and management responses for the Orontes Biounit 2010 and 2011

Pressures	Management responses

Failing and/or high density of onsite wastewater treatment (septic) systems in some coastal towns. This is probably most significant in the Stansbury, Port Vincent and Edithburgh areas. Overflowing septic systems contribute nutrients to nearshore marine waters through shallow subsurface or occasional overland flows.	The District Council of Yorke Peninsula is investigating the expansion of the current community wastewater management scheme (CWMS) at Port Vincent. A CWMS at Coobowie to replace the onsite septic systems will also be investigated.
Stormwater runoff from urban coastal areas, discharging nutrients and sediments to the nearshore marine waters.	The District Council of Yorke Peninsula requires maximum retention and use of stormwater when allotments are developed.
There are oyster farms near Coobowie Bay, Stansbury and Port Vincent to filter out phytoplankton from the water column although the overall effect on nutrient loads remains uncertain.	Primary Industries and Regions SA research has indicated that sedimentation due to oyster waste production has negligible impacts to the surrounding environment (Wear *et al* 2004).

5.3 Tier 2 results – Clinton Biounit

The Tier 1 assessment predicted the Clinton Biounit to be in Good condition (Section 2.3). In total 24 sites were sampled in 2010 and 25 sites were sampled in 2011 in both autumn and spring. Biological data from sites m0001 through to m0006 located at the northernmost section of GSV were not assessed during autumn 2011 due to an equipment failure. However, water chemistry and physical data from this period were still included in the assessment along with the complete spring data set. As described in section 2.3 the biounit is large and has few direct inputs but it is likely that nutrient inputs from large industrial sources located in the Adelaide Metro Biounit would be transported into the biounit. There are areas within Clinton that are likely to have reduced currents and higher water residence times to exacerbate the effect of any nutrient input.

Figure 29 **EPA monitoring sites sampled in the nearshore region of the Clinton Biounit, 2010 and 2011. Benthic habitats shown are from the State Benthic Habitat mapping layer (SARDI 2004; DEWNR 2010).**

5.3.1 Habitat

The sites were dominated by seagrass with the average of 87.6% in 2010 and 83.4% in 2011, resulting in an overall average of 86.5% (Figure 30). Across the two years the average proportion of bare sand was consistently less than 10% and there was only a very small proportion of rocky reef habitat sampled with an overall average of 3.4% (Figure 30). In order to assess how representative were the sites monitored in the current program, the data was compared to the SBHM. This program calculated the benthic habitats in Clinton (less than 15 depth) comprised 92% seagrass, 0.2% reef and 8% bare sand (modified from (DEWNR 2010). The results show good agreement to the SBHM.

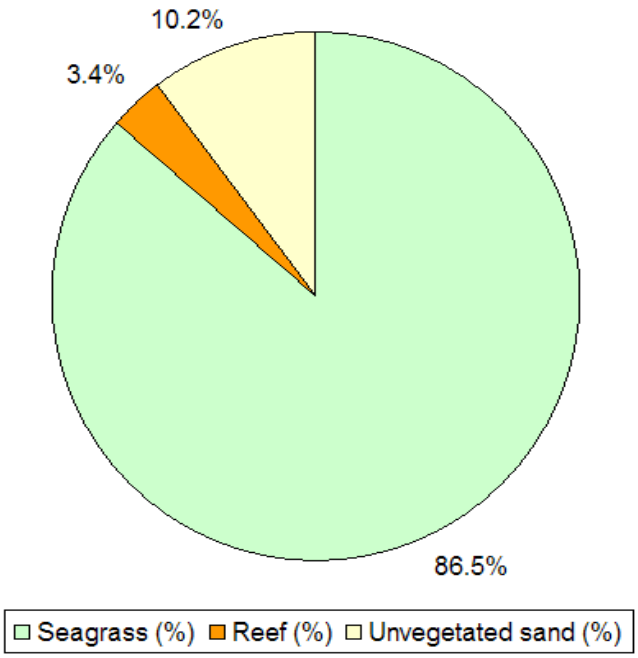

Figure 30 Average benthic habitat composition of the sites within the sites within the Clinton Biounit across 2010 and 2011

Figure 31 depicts the HSI for sites within the biounit over 2010 and 2011. Over three quarters of sites had a HSI of over 85 out of 100 suggesting that the majority of the seagrass in the biounit was in Very Good condition. In almost every site there is a very close agreement between the HSI in 2010 and 2011 suggesting that seagrass condition is stable at this time and any changes that may be occurring are likely to change at greater timeframes that the annual sampling undertaken here. Site m004: Price had the lowest HSI within the biounit with 29.2 in 2010 and 19.2 in 2011. Interrogation of the sites indicates that the seagrass at this site was sparse and patchy *Posidonia* spp which was likely to be in poor condition.

There were two reefs monitored in Clinton in 2010 and only one in 2011. On each occasion the assessment was undertaken in spring allowing comparison without seasonal influences. The site m0038: Somerton was sampled in both 2010 and 2011 which aids in inter-annual comparisons at this site. It should be noted that there is a limited number of quadrats were sampled in this program and as such there is likely to be low reliability in the results. The average cover of large brown canopy algae was generally moderate with cover typically around 30–40% (Figure 32).

Of the two reefs sampled in 2010, m0030: West Lakes had a higher cover of brown canopy algae than the m0038: Somerton inner in the same year, which is likely to be influenced by reef complexity, substrate type, water flow and the amount of sedimentation of the reef. Between years, the reef assessed at m0038: Somerton inner, the cover of large brown algae was reasonably stable although lower than the criteria indicating Good condition (Turner et al 2007; Gaylard et al 2013). This reef also increased in the cover of turfing algae and/or bare substrate (Figure 32), which has been shown to be an indicator of nutrient enrichment or sedimentation (Gorgula and Connell 2004). More detailed monitoring would need to be surveyed to have a higher degree of confidence in this result or whether this was a long-term change or natural variability.

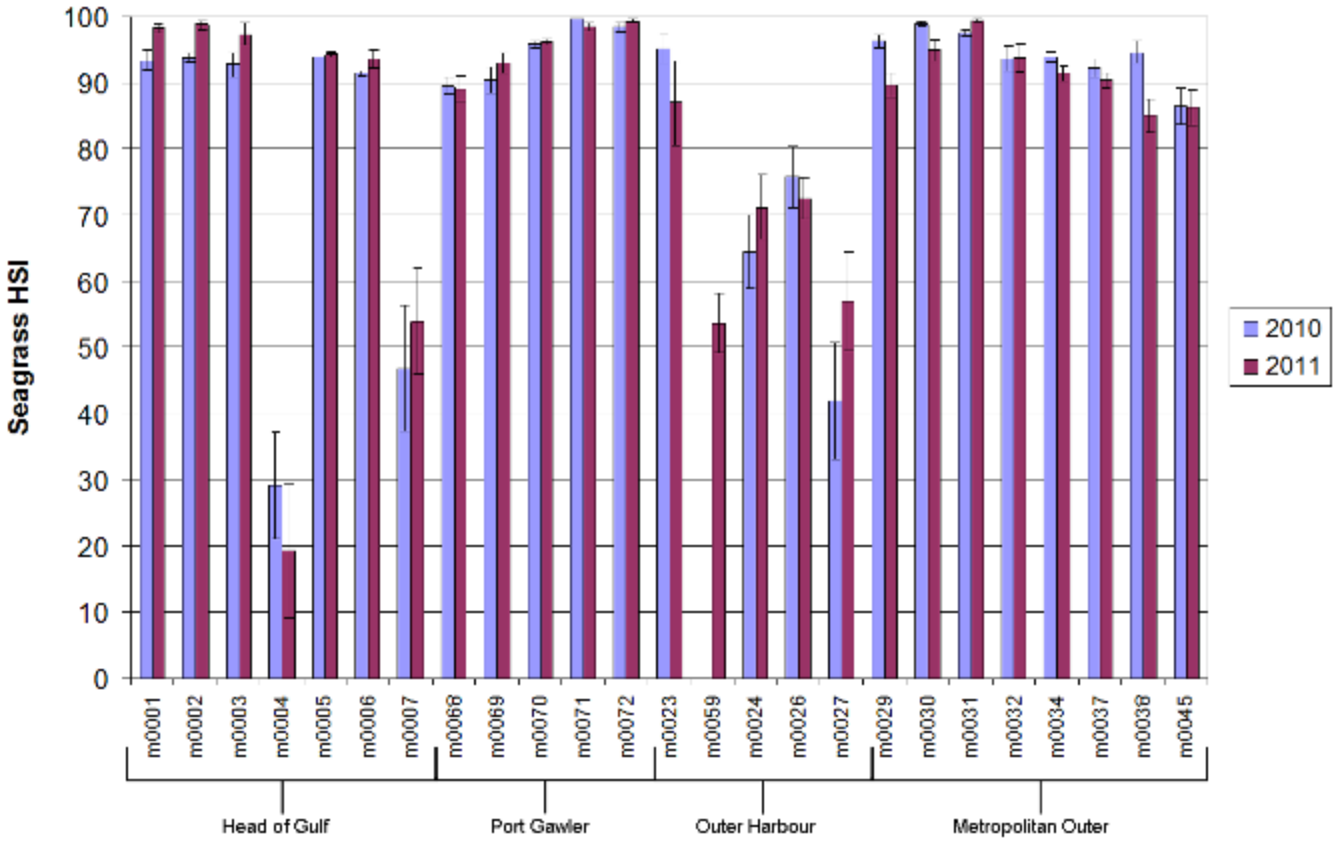

Figure 31 **Average seagrass condition (HSI) in the Clinton Biounit, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).**

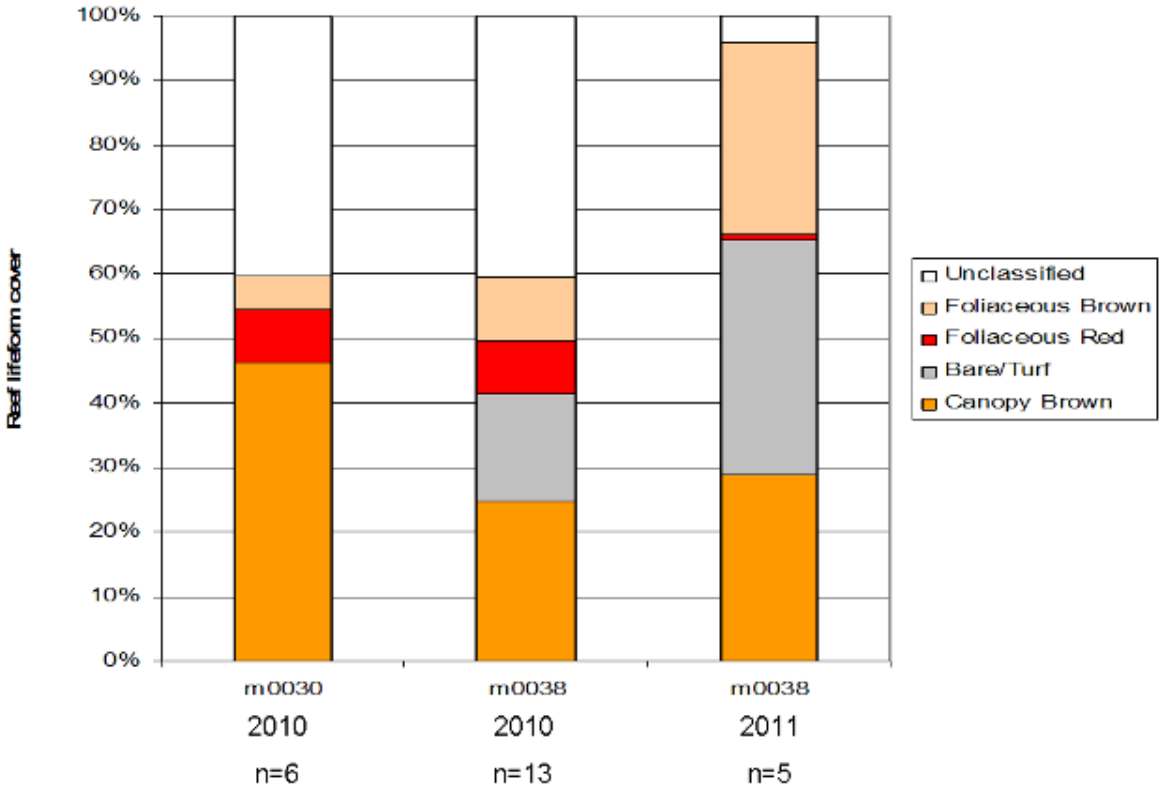

Figure 32 **Average cover of reef life forms in the Clinton Biounit. Number of quadrats assessed indicated by (n).**

5.3.2 Aquatic Ecosystem Condition Report

Habitat condition scores were 74.4 in 2010 and 85.1 in 2011 resulting in a Very Good rating for both years. The Tier 1 threat assessment predicted the biounit would be in good condition, so the observed condition is slightly higher than expected (see section 2.4). The AECR is available in Appendix 4.

5.3.3 Modifiers

The seagrass epiphyte loads throughout Clinton highlighted a number of locations with very dense epiphyte loads including sites at the head of the Gulf (eg m0001: Port Clinton and m0002: Sandy Point) as well as adjacent Port Gawler (eg m0071: Port Prime and m0072: Parham South) [Figure 33]. Sites located in the more offshore waters of the Adelaide coast had generally low amounts of epiphytes. There was also considerable variation in epiphyte load within the same site at many locations between 2010 and 2011 with the latter being typically denser in epiphyte loads. However, while this was noticeable at some sites, it was not significant across the biounit (Mann Whitney p = 0.7338).

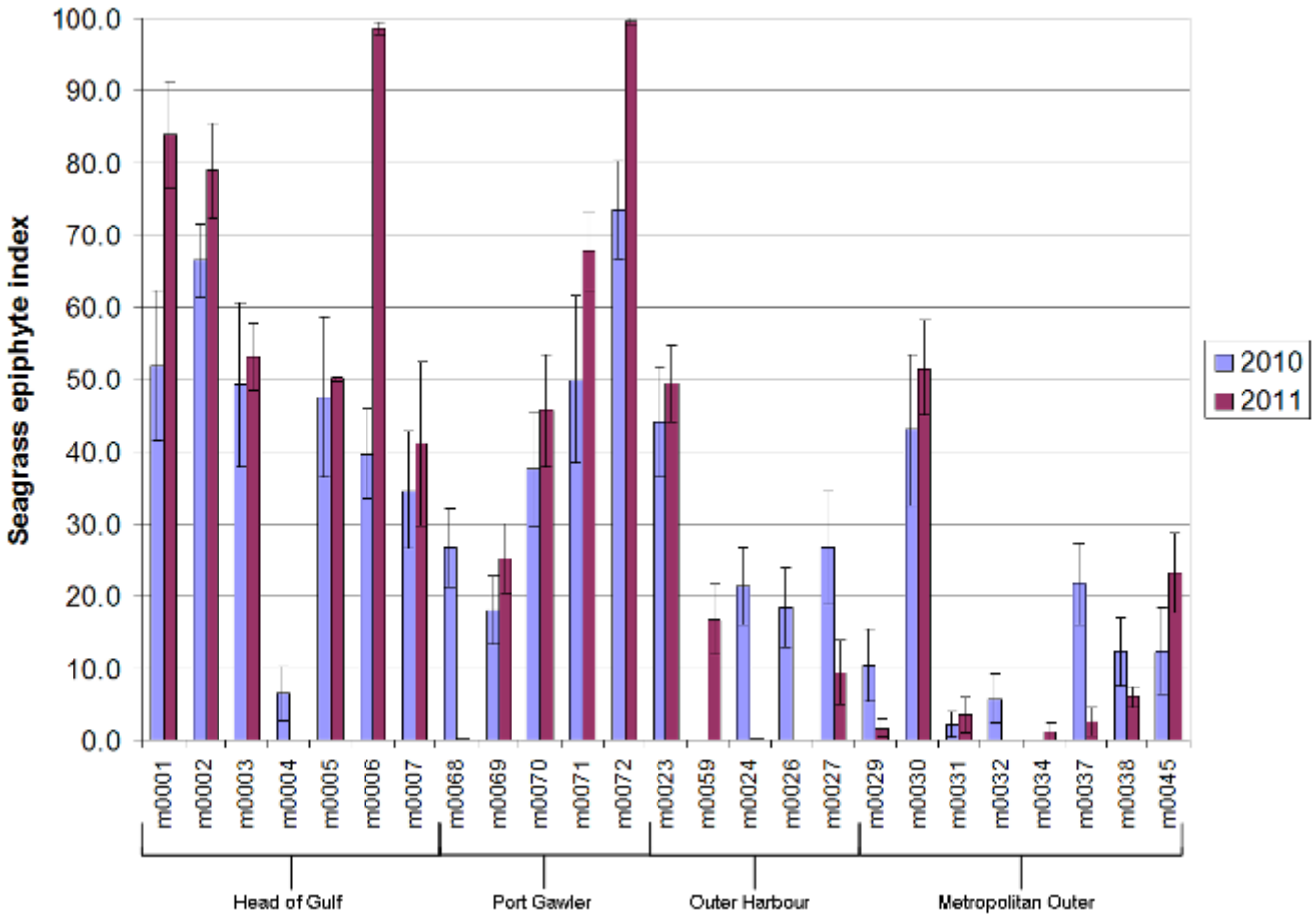

Figure 33 Average epiphytic index for the sites in the Clinton Biounit, 2010 and 2011. Error bars are standard errors. Epiphyte load index (0 = sparse; 100 = dense).

In order to investigate whether there are biological gradients through the biounit, multivariate statistics were used to look at similarities in biological composition at sites within the Clinton biounit. The bulk of the sites are clustered tightly in group above the Excellent reference sites which is consistent with the high seagrass cover shown in Figure 31. There were two points in the middle of the plot which are similar to the Moderate reference points, which were m0004: Price in 2010 and 2011. This placement appears to be related to the lower seagrass area (~18% average of both years) and sparser density in comparison to other sites in Clinton. Sites adjacent m0004: Price had an increased cover of seagrass and increasing density tending towards the main group. The other noteworthy point is m0006: Sandy Point South from

2010 that is placed to the far right on the plot. This suggests that the majority of sites were quite similar within Clinton and align well with the AECR classification (and therefore the conceptual models) for the biounit.

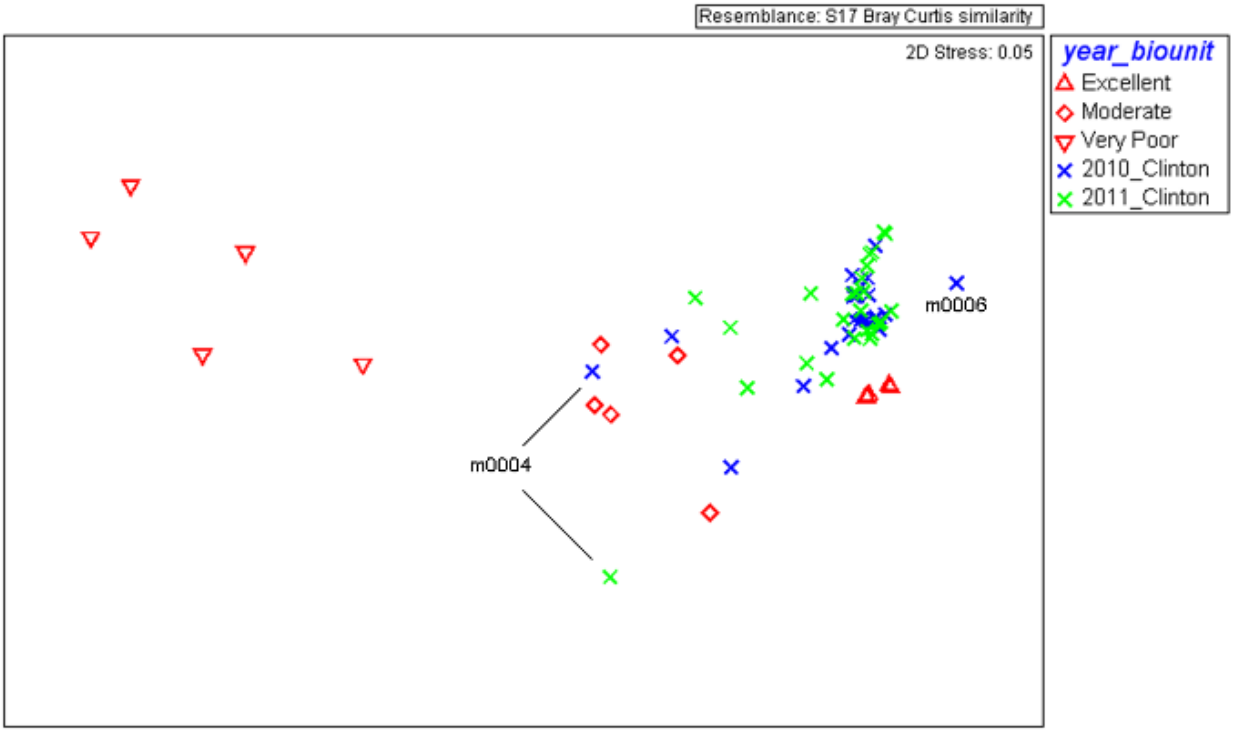

Figure 34 nMDS plot for habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae at monitoring sites in the Clinton Biounit, 2010 and 2011. Reference points suggesting condition overlaid and sites m0004 and m0006 labelled.

Table 7 shows the results from water chemistry throughout the Clinton Biounit collected during 2010 and 2011. The results show that total nitrogen in 2010, and total phosphorus and turbidity in both 2010 and 2011 were significantly higher than the reference locations. The average total nitrogen in 2010 was affected by a number of samples that had very high total nitrogen measurements including values of 2.41 mg/L at m003: Proof Range, 2.08 mg/L at m004: Price and a number of samples above 1.0 mg/L at sites m001: Port Clinton, m002: Sandy Point and m005: Bald Spit.

All of these locations are towards the head of the Gulf which has extensive mangrove and salt marsh communities and is used for spawning and juvenile development of many species including blue swimmer crab, southern calamari and garfish (Bryars 2003). It is possible that these high results may be related to a high amount of detritus or organic material in the water at the time of sampling.

Total nitrogen was significantly lower than the reference value in 2011 (Mann Whitney $p = 0.0000$) where similarly high samples were not found. However, if the elevated samples are removed from the 2010 data set, total nitrogen is still significantly higher than 2011 ($p = 0.0000$) suggesting that these samples were not the only reason behind higher total nitrogen levels in 2010.

The amount of dissolved inorganic nitrogen (ie total ammonia + oxidised nitrogen) in the Clinton Biounit was typically lower than what was observed in reference locations (Table 7). This may be related to the uptake of dissolved nitrogen by the high amount of biological material including seagrass epiphytes.

Table 7 Water chemistry and chlorophyll *a* values – Clinton Biounit 2010 and 2011

	Dissolved inorganic nitrogen (mg/L)		Total nitrogen (mg/L)		Filtered reactive phosphorus (mg/L)		Total phosphorus (mg/L)		Turbidity (NTU)		Chlorophyll *a* (µg/L)	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Median	0.009	0.004	0.185	0.14	0.003	0.006	0.018	0.019	0.300	0.210	0.405	0.305
St Dev	0.019	0.182	0.344	0.055	0.002	0.006	0.042	0.010	0.284	0.204	0.326	0.207
n	144	150	144	150	144	150	144	150	144	150	40	30
Reference median	0.018		0.150		0.005		0.015		0.190		0.627	
Mann Whitney significant at p<0.05	0.00	0.00	0.0252	0.0040	0.00	0.3390	0.0012	0.0011	0.00	0.0134	0.0971	0.00

5.3.4 Conclusions

Overall, the condition of the Clinton Biounit, which spans from Ardrossan around to the deeper (>5 m) waters offshore from Marino Rocks was found to be Very Good in both years of sampling. Almost all sites throughout the biounit had dense and continuous *Posidonia* spp seagrass suggesting that the meadows were largely intact and in good condition However, the biounit showed some initial symptoms of nutrient enrichment with elevated nitrogen concentrations compared to reference, sparse to moderate epiphyte loads on seagrass, and a number of locations that had dense epiphytes including adjacent Port Gawler. These symptoms may be exerting stress on some of the the seagrass habitats.

It is possible that the natural geomorphology of the biounit may be influencing some of the signs of nutrient enrichment. As a result, even small inputs of nutrients into nearshore waters may have a large effect on the signs of nutrient enrichment.

5.3.5 Pressures and management responses

Section 2.3 discusses the threat assessment for the Clinton Biounit and highlights the key nutrient input sources to the marine environment. The main input sources are likely to be nutrients transported from the Adelaide Metro Biounit into the Clinton Biounit from sources including the Bolivar WWTP and Penrice Soda Products. These large nutrient sources will deliver nutrients into the Clinton Biounit through wind and tidal transport, particularly during summer with the predominant southerly winds (Pattiaratchi et al 2007). These sources are discussed in more detail in Section 2.4, as well as Bryars et al (2006a) and Gaylard (2009b). Other nutrient sources in the Clinton Biounit include the management of sewage through septic tank systems from the combined population of over 1,200 residents.

It must be stressed that the findings in the current report do not show causative links to any source but only the condition of the habitat and snapshot a of some of the factors that can modify the habitat at the time of sampling. More detailed studies are required to determine fate and transport of nutrient sources with linkages to the results shown here in order to target nutrient mitigation activities to ensure that activities are optimal for reducing impacts on ecological condition.

Table 8 Pressures and management responses for the Clinton Biounit 2010 and 2011

Pressures	Management responses
Stormwater runoff from the northern Adelaide metropolitan area and coastal towns discharging to nearshore marine waters adds significant nutrient and sediment loads to these environments.	The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) highlights sediment and coloured dissolved organic matter reduction strategies to reduce the impact of stormwater on the nearshore coastal environment. The Adelaide and Mount Lofty Ranges NRM Board has a well developed stormwater quality improvement, harvesting and reuse program which has installed (and maintains) gross pollutant (and silt) traps in several watercourses across the region to catch litter, debris and silt in order to minimise impacts and damage to seagrass in the receiving marine environment. Stormwater captured is also treated through artificial wetlands across the region, which acts as suspended solid and nutrient filters. These wetlands also provide important habitat for many native species.
Nutrient load discharged (over several decades) by the wastewater treatment plant at Bolivar.	The ACWQIP has targets for reducing nutrient discharges from Bolivar WWTP. Since the mid 1990s, SA Water has made a significant investment in reducing nutrient discharge loads from Bolivar WWTP. This included a major upgrade to the Bolivar plant including the development of a large water recycling scheme that delivers treated wastewater for irrigation to market gardens in the Virginia area. This investment has resulted in a significant reduction in nutrient loads from the plant.
Failing and/or high density of onsite wastewater treatment (septic) systems in some coastal towns. This is probably most significant in the Port Clinton, Port Parham and Thompson Beach areas. Overflowing septic systems contribute nutrients to nearshore marine waters through shallow sub-surface or occasional overland flows.	The District Council of Mallala is not planning to operate community wastewater management schemes in coastal townships. However, the council does require that onsite wastewater treatment systems are compliant with the Public Health (Wastewater) Regulations 2013. Tighter restrictions are also expected to apply to new applicants for onsite wastewater management systems, in keeping with new legislation (South Australian Public Health Act 2011)
Penrice Soda Products at Osborne contributed high nutrient (as ammonia) loads into the Port River over several decades. This nutrient enriched water has been transported into the nearshore marine waters of the Clinton Biounit.	Penrice Soda Products at Osborne will close its soda ash plant in June 2013. This will result in a dramatic reduction in ammonia discharge to the Port River.

5.4 Tier 2 results – Adelaide Metro Biounit

The Tier 1 assessment predicted that the Adelaide Metro Biounit would be in Poor condition due to the high level of urbanisation and numerous inputs of nutrients and sediment into the nearshore marine environment (section 2.3 and Table 3). In total, seven sites were monitored in 2010 and eight sites during 2011 for broad ecological condition. Of the seven sites in 2010, m0033: Henley Beach South and m0036: Glenelg were found to be in water less than 2 m. As a result these two sites were adjusted slightly to place them in deeper water for the 2011 monitoring program and the sites were renamed to avoid confusion. In addition to the adjustment of these sites a further site m0059: Salt pans inner was added as a new site in 2011 to provide more detail to the biounit and to try to increase the representativeness of the sites in relation to the habitat mapping.

A fundamental part of assessing habitats using the conceptual models defined in Appendix 2 is an understanding of whether seagrass could naturally grow at a particular location if it is not detected during the monitoring program. This assessment informs whether the seagrass condition model can be applied at this site. One site: m0036: Glenelg was found to have no seagrass present within any transect throughout he site.

A seagrass likelihood assessment was undertaken for this site to look for any obvious factors that may exclude seagrass [section 3 and Gaylard et al (2013)]. A literature search of historical data was undertaken as well as a more detailed investigation of the video data. The variables considered were estimates of wave energy based on fetch, sediment particle size, proximity to existing seagrass, other evidence of nutrient stress and other factors that may have contributed to seagrass loss prior to the monitoring.

Table 9 Seagrass likelihood reconstruction assessment for Glenelg: m0036

Parameter	Outcome
Depth	1–4 m
Particle size	Sand (63µm–2mm)
Profile	Flat (<25cm)
Wave energy	Low
Adjacent seagrass	very close (<500 m)
Other evidence	–
Conclusion	Potential for seagrass in area

The results of this investigation showed that the site had been mapped as part of the National and State Benthic habitat mapping programs, with both maps showing the site is located in bare sand substrate. Since both of these programs were carried out post-1995, it is likely that seagrass loss may have already occurred, particularly in light of the fact that large-scale historical land development began around 170 years earlier. This site is in close proximity to the Patawalonga mouth, an ephemeral estuary draining the Cowandilla Plains (Holmes and Inverson 1976), and would have been affected by early coastal development.

Table 9 shows the likelihood assessment which suggests that seagrass could have been in the area historically and the current physical parameters are comparable to those nearby currently supporting seagrass communities. It is noted that parts of the site are very shallow and outside of the parameters of the seagrass conceptual models.

Figure 35 **EPA monitoring sites sampled in the nearshore region of the Adelaide Metro Biounit, 2010 and 2011. Benthic habitats shown are from the State Benthic Habitat mapping layer (SARDI 2004; DEWNR 2010).**

5.4.1 Habitat

Bare unvegetated substrate constituted almost half (49.7%) of the benthic habitat averaged for 2010 and 2011 (54.4% and 44.5% respectively), whereas 37.4% and 48.0% of the sites comprised seagrass (see Figure 36 which shows average values across both years). Rocky reef habitat comprised less than 8% in both years. In order to assess whether the composition of sites was representative of the known habitat communities, the NBHM and SBHM programs were compared. These programs documented that seagrass represented 44.3% and 68.4% of the biounit for each mapping program respectively, while reef comprised 0.7 and 1.3% and bare sand represented 30.8% and 54.9% (modified from (SARDI 2004; DEWNR 2010). The habitats assessed within the current MER are comparable to the mapped proportions, however slightly overestimates the reef coverage (Figure 36). This highlights the differences in the resolution of the mapping programs as well as the likely dynamic nature of the environment.

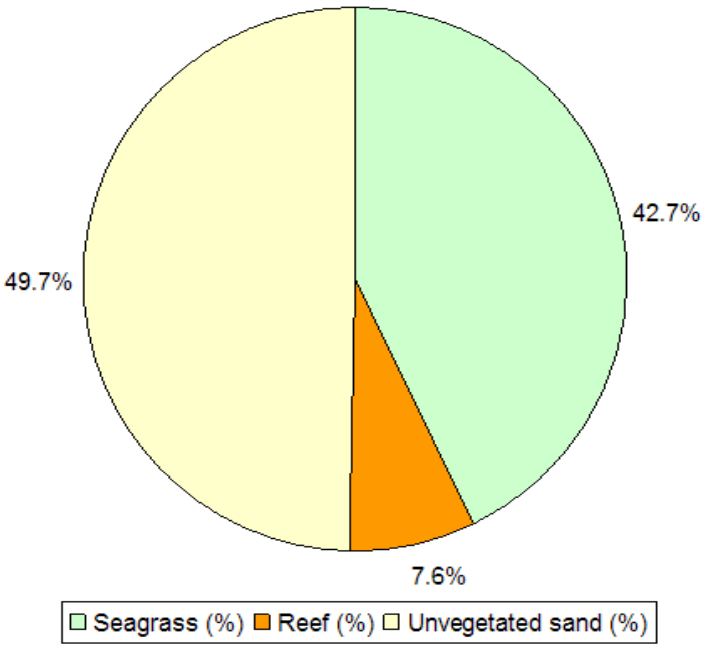

Figure 36 Average benthic habitat composition of the sites within the areas sampled within the Adelaide Metro Biounit

The seagrass habitat structure index (HSI) for each site within the Adelaide Metro Biounit in 2010 and 2011 is shown in Figure 37. The HSI was lower in 2010 than in 2011, determined to be 36 and 51 respectively. While this appears to be an improvement it is actually an artefact of the relocation of a number of sites between 2010 and 2011 and the patchy nature of the seagrass extent throughout the biounit. Sites including m0028: Semaphore Inner and m0042: Grange North had HSI above 80 out of 100 and appear to be in Very Good condition, while m0033: Henley South, m0035: West Beach Inner, m0036: Glenelg, and m0061: Glenelg outer were assessed as having a seagrass condition below 20, indicating poorer condition.

The site at m0044: Grange was variable with a HSI of 6.5 out of 100 in 2010 and 33.2 in 2011 suggesting very patchy seagrass coverage over the site. The site m0025: Barker Inlet was also variable but this is likely to be due to the very heterogeneous habitat coverage in this area with the seagrass present being *Heterozostera* spp which has been shown to be quite transient (Kuo and McComb 1998) and also a substantial coverage of small algae in both 2010 and 2011, suggesting mixed assemblages. It should be noted that in the process of altering a number of sites due to the water depth (see section 5.4) the average seagrass area and condition have increased.

Even though the habitat composition of the biounit suggests that 7.6% of the biounit comprised rocky reef (Figure 36), in reality the amount that was able to be classified using the conceptual models was much lower. For the purposes of mapping, rocky reef and small algal communities were grouped but it is often unclear of the substrate that these algal communities reside and whether large brown macroalgae would be present in these areas in an unimpacted state. This is particularly relevant in areas that are likely to be impacted by nutrients or sediment as impacted reefs are often devoid of

large brown canopy algae with a proliferation of turfing or small foliose algae which can look like a small algal community. In these circumstances where there is significant uncertainty in whether to apply the conceptual models the conservative approach has been adopted and the transect has been excluded, from the habitat condition assessment. In this case the small proportion of reef measured suggests that this has not affected the classification. This highlights the need for a condition gradient for small algal communities in order to assess condition when it is likely that the reef may not naturally support the habitat composition used in the conceptual models.

In total, one small section of reef was assessed at m0033: Henley Beach South In 2010. This reef was very small and only a small number of quadrats were able to be studied without being confounded by autocorrelation. The reef was 14.8% cover of large brown canopy algae and over 50% was covered by either bare substrate or turfing algae, suggesting that it was likely to be impacted by nutrients or sediment.

As stated earlier, 49.7% of the sites monitored in the Adelaide Metro Biounit comprised bare sand. However the unvegetated sediment conceptual models were not used to classify condition as at each location as seagrass was either present to some degree or the reconstruction assessment could not find obvious reasons that would exclude seagrass presence (see Table 9).

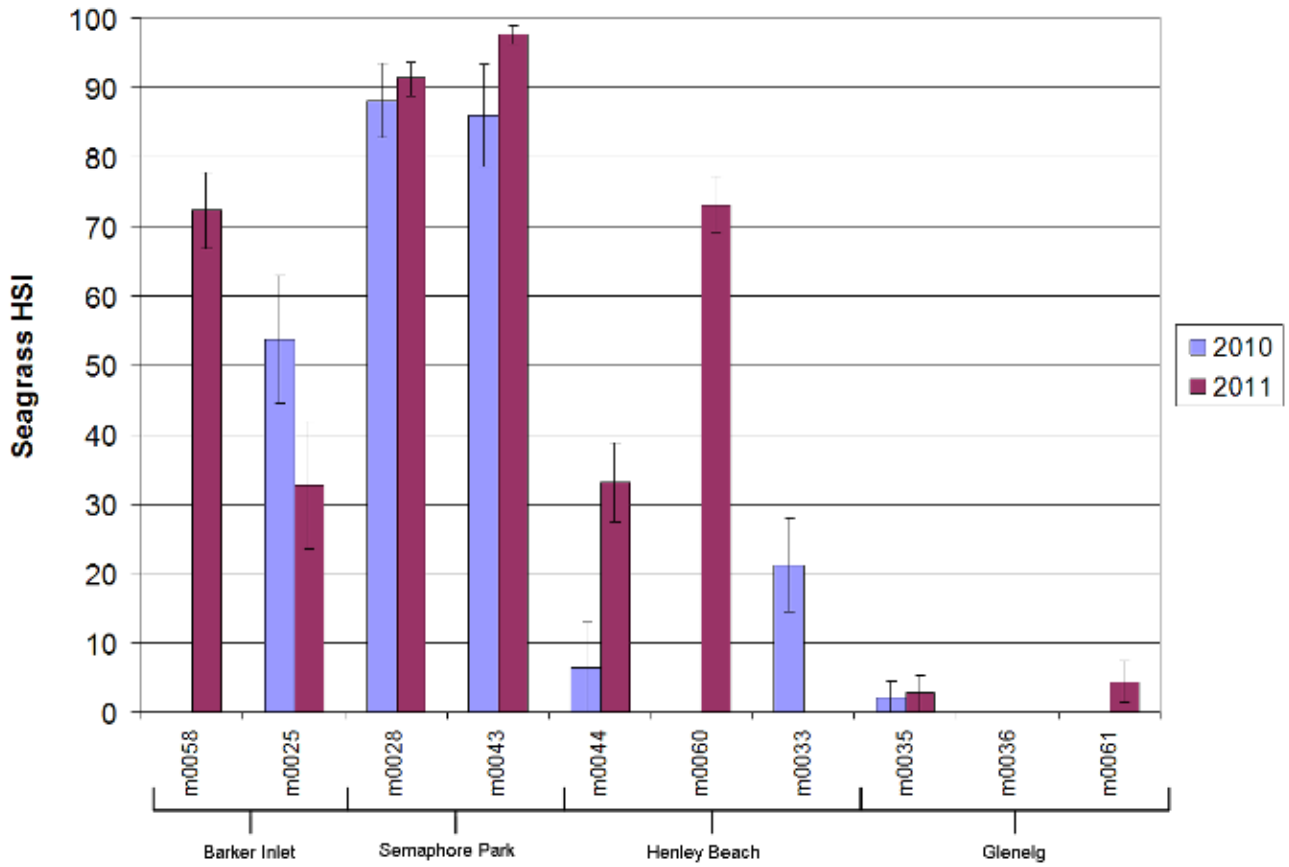

Figure 37 Average seagrass condition (HSI) in the Adelaide Metro Biounit, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).

5.4.2 Aquatic Ecosystem Condition Report

The habitat condition of the Adelaide Metro Biounit was 38.8 in 2010 which was classified as Fair and in 2011 the result was 50.9 resulting in the classification being Good, both results reflect a higher observed condition than predicted.

The proportion of rocky reef habitat was very low in this biounit, therefore the key factor for determining the AECR score was the seagrass condition. The results suggest a general improvement in condition, an assessment of change in individual sites showed very little change over the 12-month sampling period, with the increase in condition actually related to the addition of the sites replacing a number of previous sites that were determined to be too shallow for reliable measurement. In order to test this, a Mann Whitney U test was undertaken to test the population medians assessing

whether the seagrass area or condition were different between 2010 and 2011 looking at only the sites that were assessed in both 2010 and 2011. These tests indicated that there was no significant difference between the seagrass area or condition when only the sites monitored in both years were assessed [Mann Whitney p = 0.6761 (Area) and p = 0.8345 (HSI)].

The AECR results seem surprising given the known habitat loss throughout the biounit, however the Nearshore MER program clearly shows areas that are heavily impacted (eg Grange to Glenelg), but also nearby areas that are still intact (eg Semaphore Park) and across the biounit, the average suggested the habitat condition was Fair or Good (also see sections 5.4.3 and 5.4.4). The AECR is available in Appendix 4.

5.4.3 Modifiers

The sites located near Barker Inlet (m0058 and m0025) show dense epiphyte loads (Figure 38) which is not surprising given the large nutrient inputs in the region (Section 2.5). Additional measures such as the opportunistic macroalgal index can be an additional sign of local eutrophication beyond epiphyte load, particularly when seagrass is absent. The site at m0025: Barker Inlet showed the highest opportunistic macroalgal index (39.1%) in 2011, while two other sites with notable opportunistic macroalgal index were m0035: West Beach inner in 2010 (4.3%) and m0044: Grange in 2011 (6.5%). These sites had seagrass that was generally in poorer condition with HSI values less than 30, as well as considerable epiphyte loads suggesting these sites are likely to be under substantial stress from nutrient enrichment.

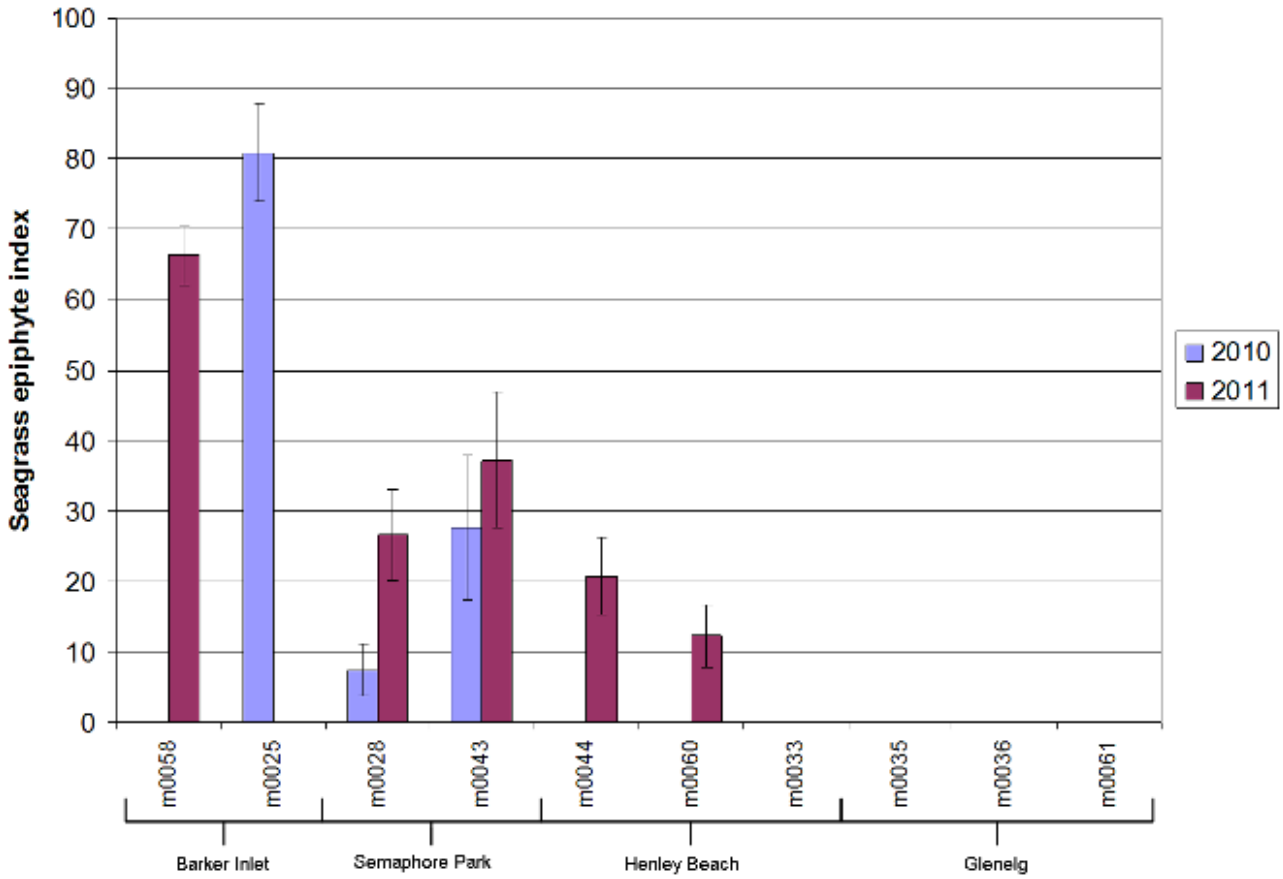

Figure 38 Average epiphytic index for the sites in the Adelaide Metropolitan Biounit, 2010 and 2011. Error bars are standard errors. Epiphyte load index (0 = sparse; 100 = dense).

Multivariate statistics have been used to examine whether biological gradients or other patterns were present in the Adelaide Metro data. The sites within the biounit are spread broadly across the plot, with most of the points positioned between the Excellent and Moderate reference sites (Figure 39). Notable points within the plot include the point at the top right of the plot m0025: Barker inlet for 2010 and 2011 which was close to a moderate reference point. This site is quite different for a number of possible reasons. Firstly it is quite enclosed within the Barker Inlet but still sitting within a

channel where there is a high amount of tidal flow and additionally the area is known to be impacted by nutrients from a number of large industrial discharges. These factors are likely to be influencing the habitats observed as well as the amount and variability of modifiers such as seagrass epiphyte load (Figure 38), opportunistic macroalgae (*Ulva* spp) and the water chemistry. A cluster of points comprised m0035 in 2010 and 2011, m0036: Glenelg in 2010, m0044: Grange in 2010 and m0061: Glenelg in 2011, were positioned around a number of Poor reference sites (Figure 39). These sites were found to be characterised as having a low seagrass area (and high cover of bare sand) and what seagrass does remain on these sites is patchy in coverage and sparse in density.

The sites that were closely aligned with the Excellent reference points are those located in deeper water (up to 5 m). This cluster of sites include m0043: Grange North, m0028: Semaphore Park Inner, and m0060: Torrens in 2011. These sites are characterised with seagrass area above 70% that is largely continuous and dense, suggesting good condition. These site locations are interesting given the documented seagrass loss along the nearshore waters between Grange and Glenelg (Westphalen et al 2004; Bryars et al 2006a; Cameron 2008) with many of these sites included within or adjacent to the boundaries. This highlights the patchy nature of seagrass loss along the metropolitan coast, particularly at m0060: Torrens where aerial photography showed the site was located at the very edge of the seagrass where cover is patchy but dense seagrass existed. This is likely to be the edge of the highly impacted area described by Westphalen et al (2004).

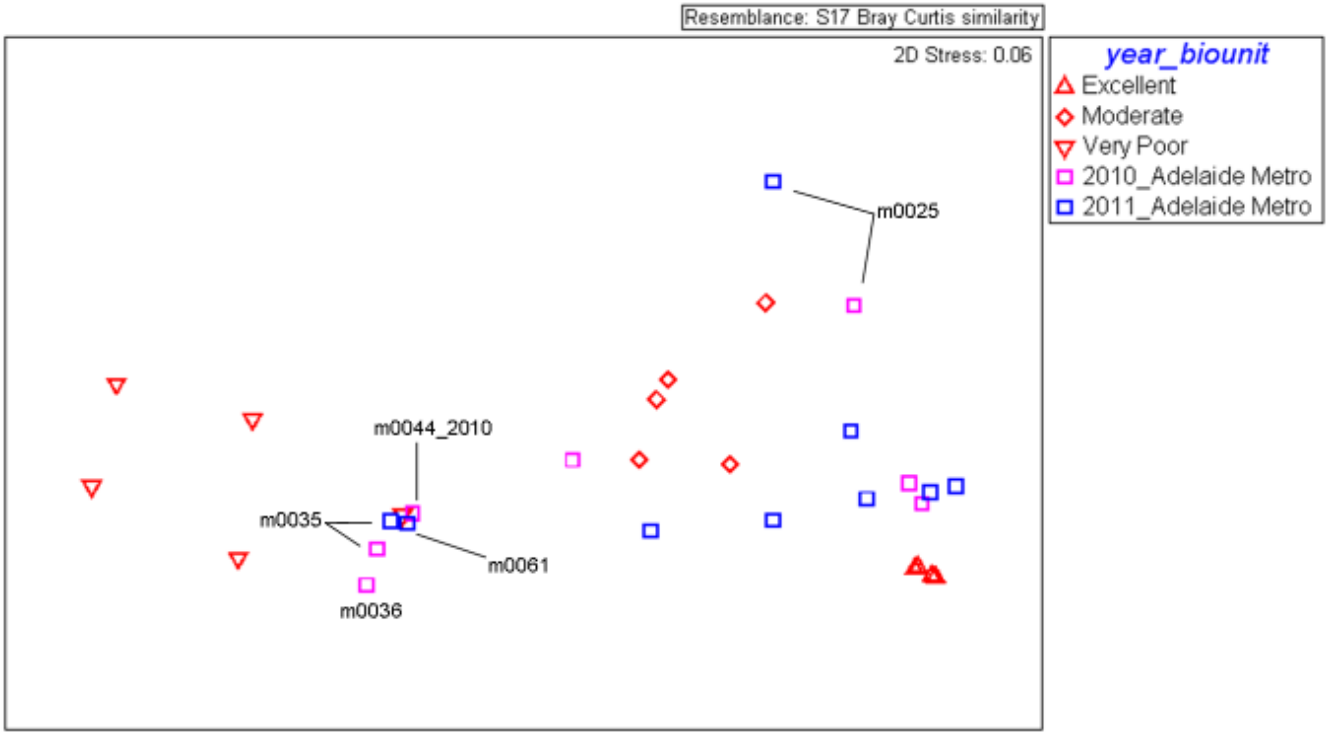

Figure 39 nMDS plot for habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae at monitoring sites in the Adelaide Metro Biounit, 2010 and 2011. Reference points suggesting condition overlaid.

The water chemistry results showed significant differences compared to reference locations which is unsurprising given the long history of coastal development and industrial discharges along the metropolitan coast (Westphalen et al 2004; Gaylard 2009b). Total nitrogen was highest in 2010 and was significantly higher than in 2011 (Mann Whitney $p = 0.0168$) [Table 10]. On further investigation of the 2010 results it was observed that two locations were far higher than the remainder of the biounit. These sites were m0035: West Beach Inner which recorded TN values of 1.04 mg/L and 1.31 mg/L with a third replicate of 0.21 mg/L, and m0036: Glenelg which recorded 1.06 mg/L and 1.61 mg/L with the third replicate of 0.17 mg/L. While it is possible that these samples are anomalous, the locations are both adjacent a number of large nutrient discharges (Glenelg WWTP and stormwater outlets) and given the compositing protocol outlined in Gaylard et al (2013) these high values are less likely to be sampling error and therefore important to include in the assessment. The remainder of the replicates throughout the biounit during spring were all below 0.21 mg/L.

The site m0025: Barker Inlet also showed elevated nitrogen values throughout the sampling periods. With the exception of spring 2010 all replicates sampled at m0025: Barker Inlet were over the 85th percentile for the biounit for total nitrogen. In 2011 the DIN values were greater than the 90th percentile for the biounit for the two years combined suggesting a large influx of dissolved inorganic nitrogen into these waters which explains the high epiphyte loads observed at this site in 2010 and potentially at m0058: Black Pole Inner in 2011. Epiphyte loads in Barker Inlet may have also been affected by the seagrass species present with Heterozostera sp recorded throughout the site with a higher leaf turnover rate compared to Posidonia sp which may reduce the epiphyte load recorded in the snapshot depending on the leaf age (Borum 1987; Peterson et al 2007).

Table 10 Water chemistry and chlorophyll *a* values – Adelaide Metro Biounit 2010 and 2011

	Dissolved inorganic nitrogen (mg/L)		**Total nitrogen (mg/L)**		**Filtered reactive phosphorus (mg/L)**		**Total phosphorus (mg/L)**		**Turbidity (NTU)**		**Chlorophyll *a* (µg/L)**	
	2010	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Median	0.019	0.004	0.220	0.155	0.004	0.009	0.028	0.026	0.525	0.475	0.570	0.490
St Dev	0.024	0.083	0.324	0.136	0.004	0.006	0.059	0.010	0.314	0.449	0.375	0.376
n	42	48	42	48	42	48	42	48	42	48	14	15
Reference median	0.018		0.150		0.005		0.015		0.190		0.627	
Mann Whitney significant at p<0.05	0.4616	0.00	0.0001	0.8940	0.0096	0.0046	0.00	0.00	0.00	0.00	0.9201	0.3529

Throughout the biounit there was also significantly greater total phosphorus compared to reference locations in both 2010 and 2011 (Table 10). Similarly the water turbidity was also significantly higher during both years than observed in reference locations which is consistent with findings of previous studies suggesting that the nearshore waters along Adelaide's metropolitan coast are being impacted by terrestrial runoff (Collings et al 2006; Fox et al 2007).

5.4.4 Conclusions

Overall the condition of the Adelaide Metro Biounit, which spans the shallow waters from the Gawler River to Marino (and including the Port River estuary), was determined to be in Fair condition in 2010 and then was classified as Good in 2011.

The Adelaide metropolitan coast is a low to moderate wave energy environment dominated by extensive seagrass habitats. Many of these habitats have been impacted over the last 50 years due to poor water quality (Gaylard 2004) from various sources including terrestrial and industrial inputs, resulting in the loss of over 6,000 hectares of seagrass from Adelaide's coastline, much of which has been within the delineation the Adelaide Metro Biounit (Hart 1997; Westphalen et al 2004; Fox et al 2007; Cameron 2008). The Port River and Barker Inlet region have large areas of shallow, warm waters which have reduced flushing with the Gulf waters, resulting in favourable conditions for algal growth, andlikely to exacerbate the deleterious biological effects of excess nutrients on seagrass.

Throughout the biounit there were numerous symptoms indicating some areas were under stress from nutrient enrichment. Many locations showed dense epiphyte loads and opportunistic macroalgae, and in some locations water chemistry results were supportive of an excess of dissolved nutrients suggesting gross eutrophication after uptake by biological material. The biounit was also likely to be under stress due to significantly greater turbidity, and this is

consistent with previous studies suggesting that within the nearshore waters both nutrient and suspended sediments are key drivers of ecological condition (Fox et al 2007).

While these broad-scale reports suggest the condition of the entire biounit is currently Fair to Good, there is ample evidence within this survey to show that particular areas within the biounit are in worse condition. The sites between Glenelg and Grange were particularly impacted due to loss of seagrass from these locations where it has been shown (Westphalen et al 2004) but the overall biounit classification has been bolstered by dense seagrass coverage in other sites highlighting the patchy nature of seagrass loss along the metropolitan coast.

5.4.5 Pressures and management responses

Section 2.4 discusses the threat assessment for the Adelaide Metro Biounit and highlights the key nutrient input sources to the biounit which may influence the water quality and ecological condition. The two largest nutrient inputs into the Adelaide Metro Biounit are the Bolivar WWTP which discharged 660 tonnes of nitrogen in 2009–10 and 770 tonnes in 2010–11 (Australian Government 2012) and the Penrice Soda Products factory (located within the Port River) which discharged 750 tonnes of ammonia in 2009–10 and 700 tonnes in 2010–11 (Australian Government 2012). The likely extent of both of these inputs is demonstrated in Figure 40, which shows that the plume to encompass both the Adelaide Metro and Clinton biounits.

The Glenelg WWTP discharges nutrient-rich effluent into the nearshore waters at Glenelg and contributed 200 tonnes of nitrogen in 2009–10 and 180 tonnes in 2010–11 (Australian Government 2012). Again, the extent of the plume from this facility is demonstrated in Figure 40, but is likely to vary considerably based on the prevailing weather conditions.

There are a number of creeks and stormwater drains along the metropolitan coast. The largest discharge of these is the Torrens River, which runs through metropolitan Adelaide and discharges at West Beach. In 2012, the Torrens River discharged approximately 1,100 tonnes of suspended solids and 30 tonnes of nitrogen, the majority of these loads entered the nearshore environment during winter (AMLNRM 2013).

In addition to the Torrens River, there is a vast network of drains which channel stormwater from the Adelaide plains into the nearshore waters of the Adelaide Metro Biounit. These discharges can affect the water clarity of the nearshore waters and result in considerable turbidity plumes which are likely to be retained in the nearshore waters for up to 10 days (Pattiaratchi et al 2007). However, this period of poor water clarity can be extended by subsequent rainfall events discharging additional sediment into the nearshore waters resulting in discoloured water for extended periods of time and affectinglight penetration for inshore seagrasses (Collings et al 2006), and lower aesthetic values for swimmers. Other discharges into the biounit include the Little Para River and Dry Creek which drain catchments into the Port River at Barker Inlet.

There are numerous other sources of sediment or causes of water discolouration. Large stormwater events are well known to discharge large volumes of sediment into the nearshore waters but smaller runoff events also contribute sediment in the form of fine particulates (EPA, unpublished data). These fine particulates settle in the nearshore environment where it is possible that they are easily and continually resuspended by wind and wave action, contributing to discoloured water during typical summer seabreeze events.

In addition to land-based runoff there are numerous structures which have been built in the nearshore waters to facilitate the passage of vessels into marinas or boat ramps. These structures hinder normal longshore drift movement of sand along the beach and accumulate sediment and detrital seagrass which can affect vessel navigation. As a result these structures require frequent dredging to allow safe passage for vessels. In many circumstances the dredged material is discharged back into the nearshore waters where both the suspended sediments and detritial seagrass can result in turbid plumes in shallow waters and accumulation of detrital biomass (S Gaylard, personal observations). Similarly, Figure 8 depicts a number of aerial photographs showing increased turbidity plumes from ship movements entering/exiting the Port River.

It must be stressed that the findings in the current report do not show causative links to any source but only the condition of the habitat and snapshot of some of the factors that can modify the habitat at the time of sampling. More detailed studies are required to determine fate and transport of nutrient sources with linkages to the results shown here in order to target nutrient mitigation activities to ensure that activities are optimal for reducing impacts on ecological condition.

Figure 40 Dredge spoil and detritus accumulation on North Haven beach from Nearmap, 2 October 2012

Table 11 Pressures and management responses for the Adelaide Metro Biounit 2010 and 2011

Pressures	Management responses
Nutrient load discharged (over several decades) by two WWTP along the Adelaide metropolitan coast at Glenelg and Bolivar. The Port Adelaide plant was decommissioned in 2004.	The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) has targets for reducing nutrient discharges from Glenelg and Bolivar WWTPs. Since the mid 1990s, SA Water has made a significant investment in reducing pollution loads to the Adelaide metropolitan coastal waters. This has included major upgrades to the Bolivar and Glenelg WWTPs, closure of the Port Adelaide WWTP and development of two large-scale water recycling schemes taking treated wastewater from Bolivar to the Virginia area, and from Glenelg to Adelaide (including the Adelaide Parklands). These investments have resulted in a significant reduction in nutrient loads to coastal waters. In addition, SA Water has commenced a comprehensive marine research program to inform future investments in wastewater treatment and reuse, and continually monitors and reviews treatment plant performance.

Pressures	Management responses
Sediment and highly coloured runoff from Adelaide metropolitan stormwater entering the nearshore marine waters	The ACWQIP highlights sediment and coloured dissolved organic matter reduction strategies to reduce the impact of stormwater on the nearshore coastal environment. The Adelaide and Mount Lofty Ranges NRM Board has a well-developed stormwater quality improvement, harvesting and reuse program which has installed (and maintains) gross pollutant (and silt) traps in several watercourses across the region to catch litter, debris and silt in order to minimise impacts and damage to seagrass in the receiving marine environment. Stormwater captured is also treated through artificial wetlands across the region, which act as suspended solid and nutrient filters. These wetlands also provide important habitat for many native species.
Penrice Soda Products at Osborne contributed high nutrient (as ammonia) loads into the Port River over several decades. This nutrient-enriched water was transported into the nearshore marine waters of the Adelaide Metropolitan Biounit.	Penrice Soda Products closed its soda ash plant in June 2013. The ammonia discharge will consequently drop from approximately 670 tonnes per year to almost zero by the end of 2013.
Dredging operations discharge turbid water containing high amount of dead seagrass into the nearshore waters	Dredging is a licensed activity under the *Environment Protection Act 1993* and is regulated through conditions on licences requiring suitable management of dredge spoil and discharge water, and that monitoring programs are in place. In addition the EPA: • is required to be informed of dredging activities prior to work commencing • assesses dredging as a referable activity under the *Development Act 1993* • provides conditions to development applications for the proper management of dredging operations.

5.5 Tier 2 results – Yankalilla Biounit

The Tier 1 assessment predicted that the Yankalilla Biounit is in Fair condition (section 2.5 and Table 3). The Fair condition was expected because large areas of the adjacent land have been heavily urbanised even though the southern portion of the biounit is limited in its urban development or industrial use. Seven sites were monitored in 2010 and 2011 and a number of sites were altered between the monitoring periods (Figure 41). The sites at m0022: Sellicks, m0040: Southport, m0041: Seaford and m0047: O'Sullivans Beach were replaced with alternative sites at m0062: O'Sullivan Beach outer, m0063: Southport outer, m0064: Seaford outer and m0067: Sellicks outer (Figure 41). These sites were moved due to them all being located in relatively shallow water and m0047: O'Sullivans Beach was moved due to its proximity to the Christies Beach WWTP.

As outlined in section 3, a fundamental part of assessing habitats using the conceptual models defined in Appendix 2 is an understanding of whether seagrass could naturally grow at a particular location, if it is not already present. Undertaking this reconstruction will allow a determination as to whether the seagrass conceptual models are appropriate or whether the unvegetated sediment models are to be used. One site m0047: O'Sullivans Beach was found to contain bare sand for the entire site during 2010. A reconstruction based on available literature and site-specific factors was then

conducted to determine any obvious factors that may exclude seagrass at this location or any key stressors that may have resulted in loss of habitat prior to the 2010 monitoring. Variables included an estimate of wave energy based on fetch, sediment particle size determined from video, turbidity, substrate composition, proximity to other seagrass meadows and any other evidence of impacts from nutrient enrichment or the presence of stressors that may have contributed to loss (Table 12).

The results of this investigation showed that the site had been mapped as part of the National and State Benthic habitat mapping programs, with both outputs showing the site is located in bare sand substrate; this suggests that the site is likely to have been bare sand prior to 1995 when the National Benthic habitat mapping program was undertaken. The site is very close to the Christies Beach WWTP, which is located less than 200 m from m0047: O'Sullivans Beach. Table 12 shows the parameters and assessment of the likelihood of the presence of factors excluding seagrass growth. It has been concluded there is nothing natural at this site that may be excluding seagrass growth.

Table 12 Seagrass likelihood reconstruction assessment for m0047: O'Sullivans Beach

Parameter	Outcome: m0047: O'Sullivans Beach
Depth	4–9 m
Particle size	Sand (63 µm–2 mm)
Profile	Flat (<25 cm)
Wave energy	Moderate
Adjacent seagrass	Very close (<500 m)
Other supporting information	Less than 200 m from the Christies Beach WWTP discharge
Conclusion	Potential for seagrass in area

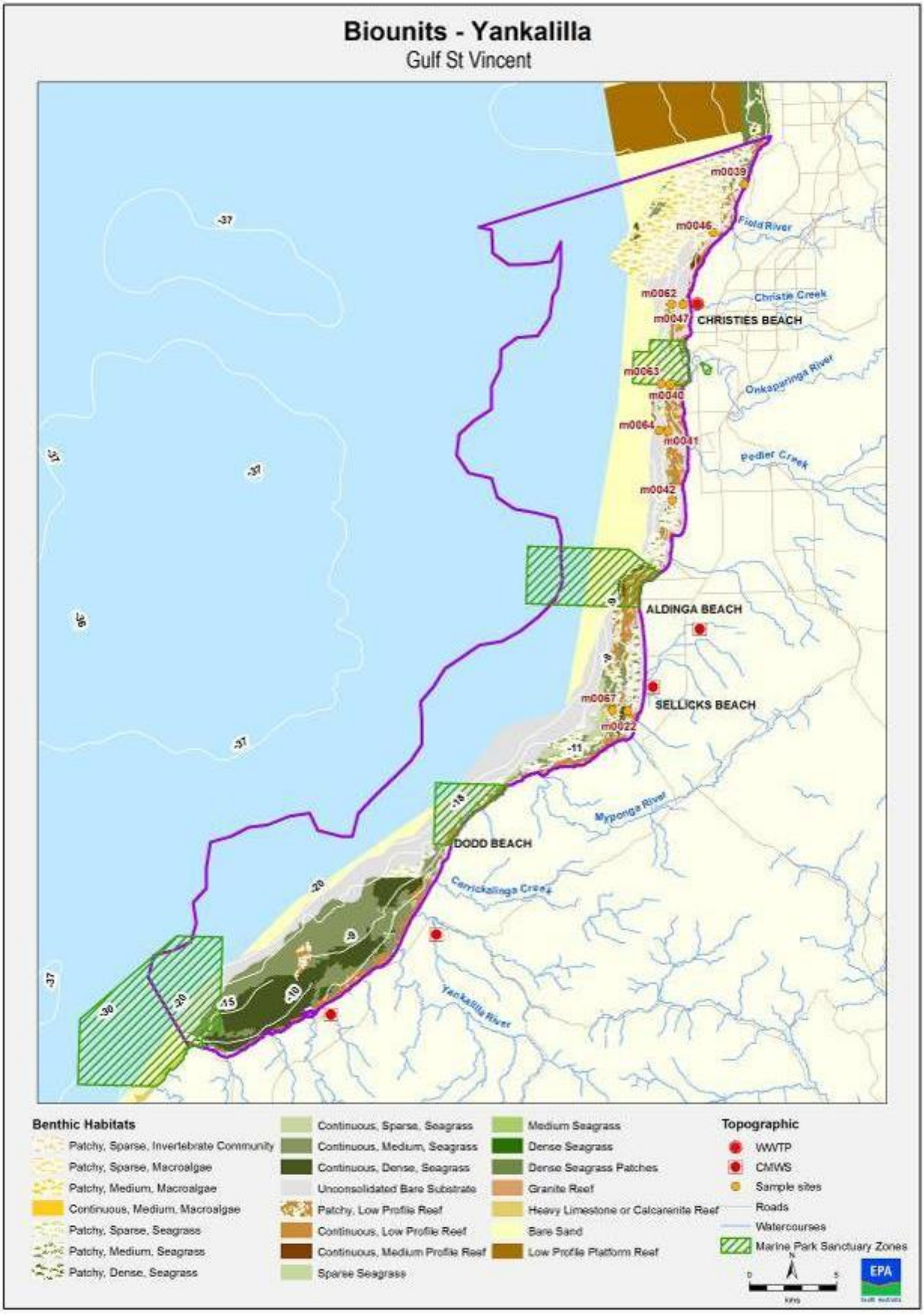

Figure 41 **EPA monitoring sites sampled in the nearshore region of the Yankalilla Biounit, 2010 and 2011. Benthic habitats shown are from the National and State Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

5.5.1 Habitat

Bare sand was the dominant habitat during 2010 and 2011 comprising 56.2% of the total habitat area. The proportion of seagrass habitat was 13.8% while there was an average of 30.0% rocky reef habitat (Figure 42). The habitat composition differed slightly from the National and State Benthic habitat mapping outputs, which calculated that the area comprised 50% seagrass, 33% reef and 16% bare sand (adjusted for the area between 0–15 m deep to reflect the area reported in the current Nearshore MER program) [modified from (SARDI 2004; DEWNR 2010). The previous mapping indicates large seagrass meadows between Rapid Bay and the Normanville region which were not assessed in the current program due to the random nature of the site allocation (Figure 41). Therefore the Yankalilla Biounit assessment in the AECR program appears to be under-represented by seagrass habitats.

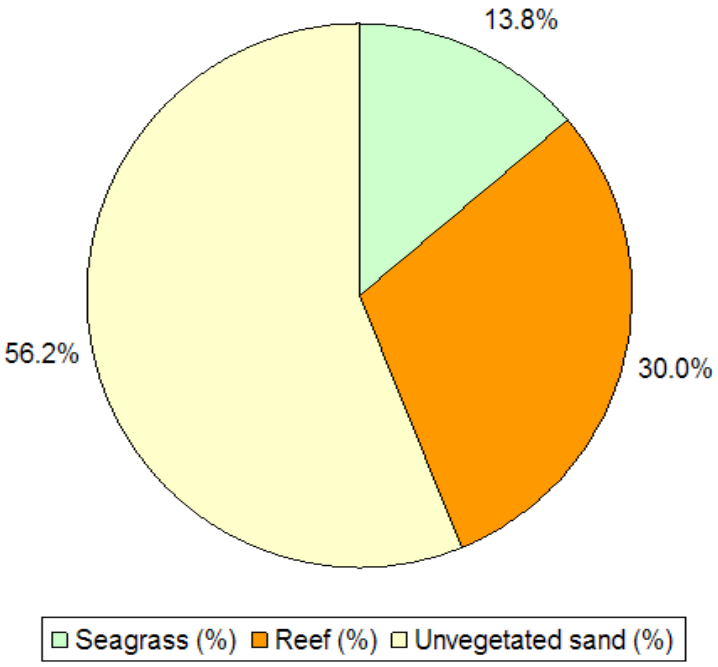

Figure 42 Average benthic habitat composition of the sites within the areas sampled within the Yankalilla Biounit

At two sites there was considerable uncertainty in the species of seagrass and it was considered highly likely that *Posidonia ostenfeldii* group seagrasses were observed. The rationale behind this conclusion was the clumping nature of seagrass within the video, and observed from aerial photographs, and observations from literature suggesting the presence of seagrass from this group in the area (Edyvane 1999c). The conceptual models described in detail in Gaylard et al (2013). Appendix 2 states that seagrass from this group grows in clumps rather than in dense meadows (Kuo & Cambridge). As such the seagrass condition index method is not compatible with this group (see Irving *et al* 2013).

In these locations more consideration has been given to modifying factors than the specific seagrass area parameter as this will underestimate condition by assuming seagrass has been lost from a dense continuous meadow. It is likely that the only ways to assess the condition of clumping seagrass types would be methods such as physical shoot counts on fixed clumps or using aerial photography for wider distributional changes.

In order to display measures of the seagrass habitat at each of the sites within the Yankalilla Biounit the seagrass cover (rather than HSI) has been displayed in Figure 43. The sites with suspected *P ostenfeldii* group seagrass (likely to be *P coriacea*) are m0022: Sellicks and m0042: Maslins Beach. Throughout the biounit there were a number of sites with seagrass sampled in both 2010 and 2011, and the seagrass cover was low with the exception of m0046: Port Stanvac and m0067: Sellicks outer (Figure 43).

This sparse and patchy condition of the seagrasses and expansive areas of bare sand in shallow waters suggest seagrass habitats in poor condition which was particularly evident in the region between O'Sullivans Beach and Seaford (Figure 43). The Port Stanvac site was seen to have patchy *Posidonia* seagrass, mixed with areas of bare sand and also small algal communities presenting very heterogeneous habitats throughout the site. The site m0067: Sellicks outer

consisted of patches of dense *Amphibolis sp* seagrass rather than the adjacent *P ostenfeldii* group as seen in m0022: Sellicks.

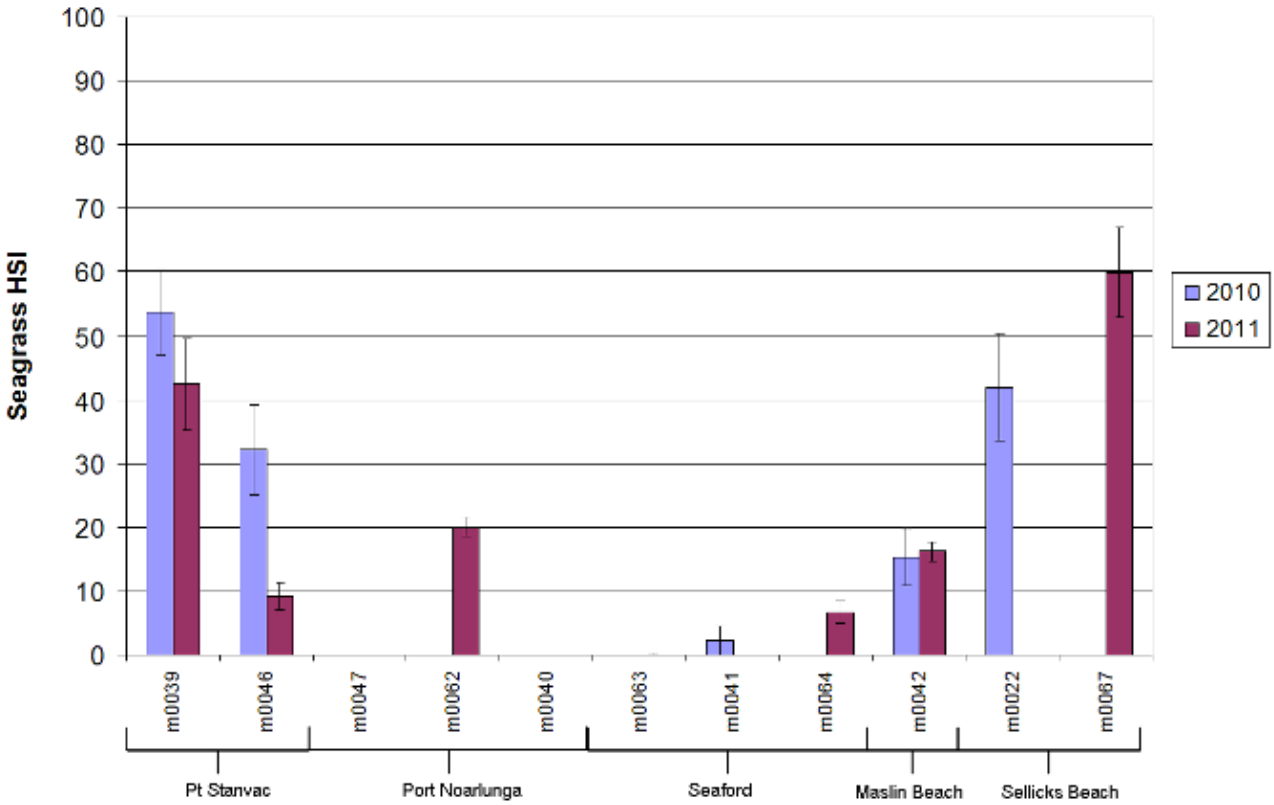

Figure 43 Average seagrass cover (%) in the Yankallila Biounit, 2010 and 2011. Error bars indicate the standard error.

A number of sections of rocky reef habitat were encountered within the Yankalilla Biounit and the broad assessment of reef condition was undertaken to assess their condition. The average reef condition was considered to be moderate using the basic index system in the MER program. The average cover of robust brown canopy algae (Ecklonia radiata, *Cystophora* spp, *Sargassum* spp, etc.) was found to be 60.7% in 2010 and 64.6% in 2011 which is considered good, but the cover of bare substrate or turfing algae was found to be higher in 2010 than 2011 with 34.3% and 24.5%, respectively.

The site that was covered with the most reef was site m0040: Southport which was scored as rocky reef habitat for almost three quarters of the transects throughout 2010. Fifty (50) point intersect quadrats were able to be assessed for each season monitored and the reef was found to be in good condition according to the basic classification system. The results were a cover of 70.8% large robust canopy algae and a low amount of bare cover or turfing algae (23.6%). Turner et al (2007) and also Collings et al (2008) showed the results of the Reef Health Survey program comparing 1999, 2005 and 2007 scientific diver surveys. These reports suggested that Southport was in the intermediate (Caution) category in 1999 and 2005 but classified as good in 2007. It should be noted that these programs used substantially more indices than the current assessment. Comparing similar parameters from the two studies suggests that the reef had a similar composition of robust brown algae and bare or turfing algae in 2010 and 2011 than what was recorded in 1999, 2005 and in 2007 (Turner et al 2007; Collings et al 2008).

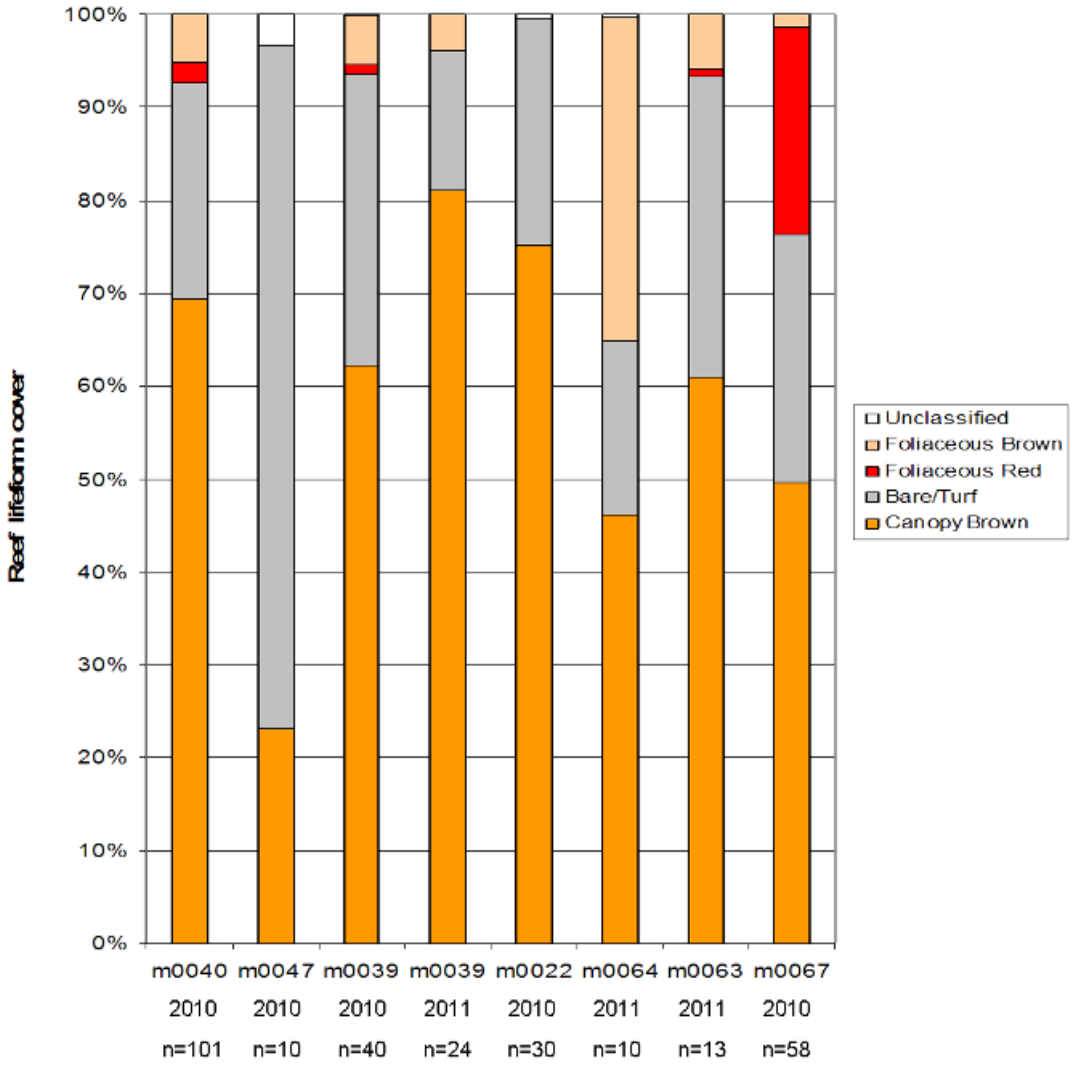

Figure 44 Average cover of reef lifeforms in the Yankalilla Biounit, 2010 and 2011. Number of quadrats assessed indicated by (n).

5.5.2 Aquatic Ecosystem Condition Report

The overall condition of Yankalilla assessed to be in Poor condition for both years, received an AECR score of 18 out of 100 in 2010 and 19 in 2011. This result in not consistent with the predicted condition of Fair from the Tier 1 assessment. Given the likely presence of *Posidonia ostenfeldii* group of seagrass which do not fit the conceptual models, a sensitivity analysis was undertaken on the seagrass condition for the biounit. The seagrass condition of these sites was doubled to suggest a much higher seagrass condition to compensate for the reduced condition using the Irving et al (2013) method (due to under-estimation of cover) and the AECR calculation was rerun. The result of this was that the Yankalilla Biounit was still considered to be Poor suggesting that the potentially under-estimated condition of these two sites within the whole biounit did not have a large influence on the AECR result. The AECR is available in Appendix 4.

It should be noted that this biounit is in need of comprehensive monitoring including rapid assessment techniques for P. ostenfeldii group of seagrasses, an understanding of a model of degradation due to nutrient enrichment, and this MER program would benefit from additional sites to gain greater spatial coverage throughout the biounit.

5.5.3 Modifiers

The change in annual epiphyte load between years was difficult to ascertain due to the site changes between years and the low amount of seagrass habitat found. During 2010 epiphytes were denser in spring than in autumn which was a trend that was not apparent in 2011. In many cases there were considerable epiphyte loads even when seagrass cover was low (eg m0062: O'Sullivans Beach outer) and there were no clear patterns in epiphyte load throughout the biounit. However, m0062: O'Sullivans Beach outer consistently showed the highest epiphyte index throughout the biounit and it is

possible that the remaining seagrass may be under considerable stress not only at this location but at other sites monitored.

Other work have investigated seagrass epiphyte load in Yankalilla Bay near the Bungala River and Carrackalinga Creek discharges and found that epiphyte loads were not related to the proximity of the ephemeral creek discharges but there was a gradient in epiphyte loads that increased with depth. Overall, the epiphytes loads were typically below 20% (Tanner et al 2012), which is on the lower end compared to the current study. Nonetheless, this may be related to sampling season as the current study observed higher epiphyte loads in the spring of 2010 than the autumn, while in 2011 there was no difference with season, while Tanner et al (2012) only sampled once, in autumn.

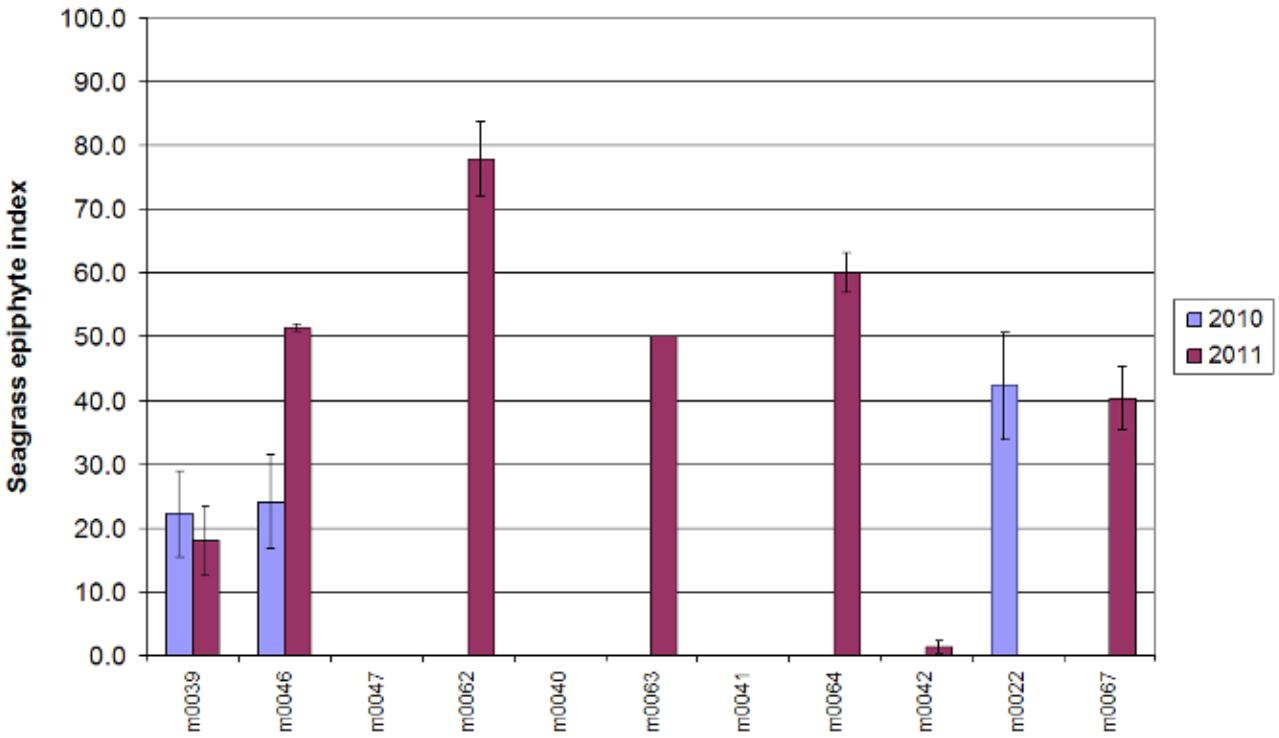

Figure 45 Average epiphytic index for the sites in the Yankalilla Biounit, 2010 and 2011. Error bars are standard errors. Epiphyte load index (0 = sparse; 100 = dense).

Multivariate statistics were used to look for patterns in the biological data or whether there were broad gradients present. The bulk of the sites are loosely spread between the Moderate and Very Poor reference points with considerable variation in the vertical plane (Figure 46). Many of the sites monitored in the Yankalilla Biounit had mixed habitats with varying cover of reef, seagrass and bare sand over the sites. This heterogeneous composition can be seen in the nMDS with the five sites towards the bottom of the middle of the plot m0040, m0041, m0046, m0063 and m0064. These sites were found to be mixtures of rocky reef and bare sand with m0040 comprised almost 75% reef habitat, while the point set furthest to the right on the plot represented m0047: O' Sullivans Beach. Although this site also has a very small cover of reef (~ 6%), it differs from the others discussed in that the rest of the site is bare sand and does not support any seagrass at all. The site m0046: Port Stanvac is the site within the cluster that is closest to the reference points, is likely due to it comprising ~23% seagrass.

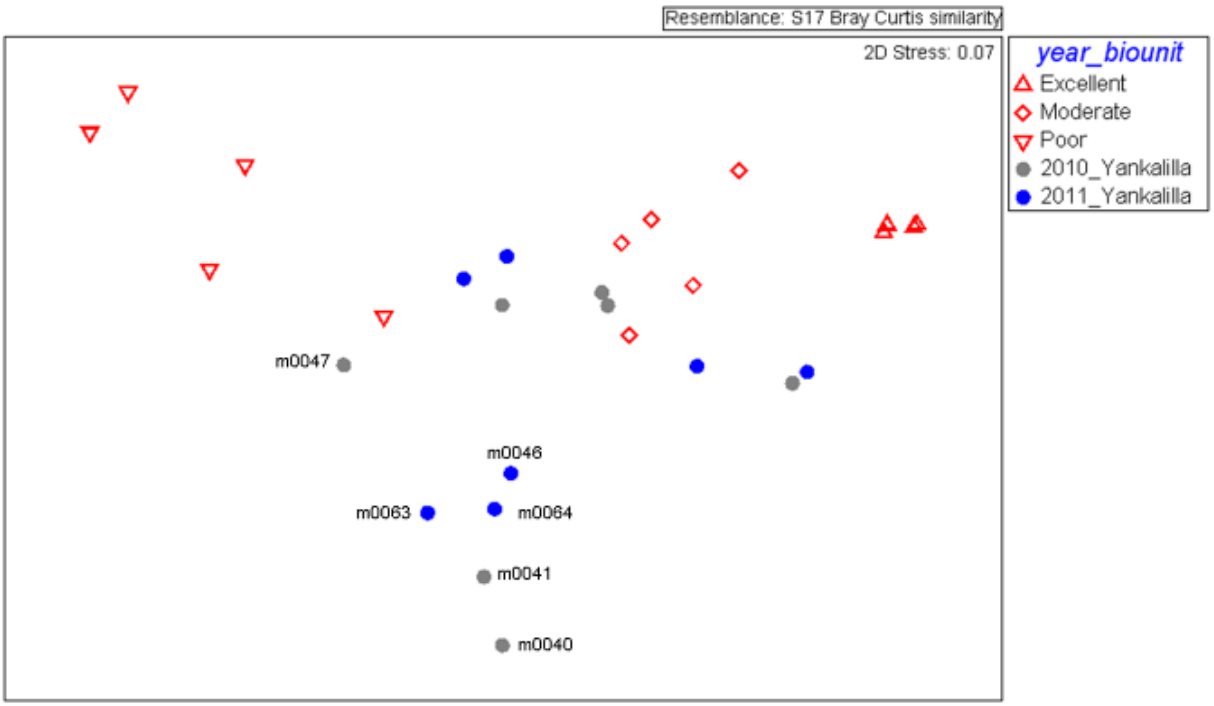

Figure 46 **nMDS plot for habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae at monitoring sites in the Yankalilla Biounit, 2010 and 2011. Reference points suggesting condition overlaid.**

Table 13 **Water chemistry and chlorophyll *a* values – Yankalilla Biounit 2010 and 2011**

	Dissolved inorganic nitrogen (mg/L)		Total nitrogen (mg/L)		Filtered reactive phosphorus (mg/L)		Total phosphorus (mg/L)		Turbidity (NTU)		Chlorophyll *a* (µg/L)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Median	0.013	0.004	0.180	0.090	0.003	0.006	0.014	0.012	0.210	0.220	0.320	0.345
St Dev	0.008	0.010	0.115	0.036	0.002	0.006	0.009	0.008	0.064	0.052	0.387	0.128
n	42	42	42	42	42	42	42	42	42	42	14	14
Reference median	0.018		0.150		0.005		0.015		0.190		0.627	
Mann Whitney significant at p<0.05	0.002	0.00	0.112	0.00	0.00	0.059	0.464	0.041	0.220	0.198	0.009	0.00

Water quality was generally found to be very similar to the locations considered as reference (see Gaylard *et al* 2013) and in many cases the nutrient concentrations were significantly less than those locations, particularly during the 2011 survey. The typical water flow and wave energy in Yankalilla is higher than in biounits situated further north in the Gulf, providing rapid mixing of any terrestrial inputs. The moderate load of epiphytes on seagrasses at numerous sites within this biounit suggests that nutrients are sufficient to encourage the growth of opportunistic algae on seagrass and its possible that the rapid uptake of these nutrients by opportunistic algae will deplete these nutrients in the water column and may mask the detection of water column nutrient levels entering coastal waters.

5.5.4 Conclusions

Overall, the condition of the Yankalilla Biounit, which spans from Marino Rocks to Rapid Head, was assessed to be in Poor condition. The monitoring showed the seagrasses present were sparse in density and patchy in coverage, particularly in the north of the biounit. Nonetheless, it is noted that at a small number of sites towards the mid section of the biounit, *Posidonia ostenfeldii* seagrass was observed as they were known to grow in clumps rather than in meadows. However, this is occurrence is unlikely to have significantly changed the condition assessment of the biounit. Reef communities in the Yankalilla Biounit were typically in Moderate condition with variable cover of robust brown canopy algae and bare or turfing algae.

There was evidence of nutrient enrichment with considerable epiphyte loads on seagrasses even though the water column nutrient levels were low. The seagrass cover and the prevalence of epiphyte loads suggest that some areas of the biounit were under nutrient stress and some habitats were in Poor condition. The region between O'Sullivans Beach and Seaford stood out due to the very low cover of seagrass, and at times high epiphyte loads.

5.5.5 Pressures and management responses

Section 2.5 discusses the threat assessment for the Yankalilla biounit and highlights the key nutrient input sources to the nearshore marine environment. The largest discharge into the marine environment is the Christies Beach WWTP which discharges significant nutrient loads into the waters offshore from O'Sullivans Beach with an average nitrogen load of 140 tonnes in 2009–10 and 200 tonnes in 2010–11 (Government 2013b). Small coastal towns along the Fleurieu Peninsula largely use on-site septic systems to treat and dispose of sewage. High densities of septic systems on sandy soils have the potential to introduce significant nutrient loads into shallow groundwater which could be transported to the nearshore environment.

The northern section of the biounit is heavily urbanised which creates and discharges considerable volumes of stormwater into the nearshore marine environment throughout the extensive network of stormwater drains and creeks. The largest discharge is the Onkaparinga River, which can be a substantial discharge flowing to the marine environment at Southport when there is sufficient rain in the catchment. The lower reaches of the river is mostly a tidal estuary, however during rain events the river flushes deposited nutrients, sand and silt from the surrounding rural and urban catchment.

Similarly, the Myponga River also flows into this biounit, and in this case flows are dependent on rainfall and controlled releases of water from Myponga Reservoir. There are numerous other smaller ephemeral creek discharges, particularly in the southern parts of the biounit, as this area has a higher average rainfall than many of the other biounits in GSV (Commonwealth of Australia 2013) suggesting the potential for more runoff into the marine environment from the largely agricultural catchments.

The Adelaide desalination plant, located at Lonsdale, began discharging in September 2011 with extremely low flows to the marine environment (Tim Kildea SA Water, pers comms). Prior to this, the pilot plant used for testing water constituents and trialling methods operated throughout 2010. All brine was remixed with product water which resulted in no net change to the salinity of the discharge.

The oil refinery located at Port Stanvac operated between 1963 and 2003 to refine hydrocarbons for Adelaide. There have been two major oil spills in the past. In 1982 the 'Esso Gippsland' caused an oil spill which polluted the beaches between Seaford and Aldinga. The second major spill was in 1999 where the pipe connecting the refinery and vessel discharged 230 tonnes of oil. Dispersants were used to break up the spill with the remainder impacting on Sellicks Beach (Government 2013a).

The Wirrina Marina is located at the southern end of the biounit and can be a potential source of pollutants and marine pests. Effluent discharges, a creek discharge into the marina and bird roosting sites could potentially introduce significant loads of nutrients into the shallow and tidal-restricted waters of the marina where they could affect algal growth. The marina has recently been infested with an invasive marine pest the European fan worm (*Sabella spallanzanii*) which has also transferred to new locations including Kangaroo Island and can affect biodiversity.

Table 14 Pressures and management responses for the Yankalilla Biounit 2010 and 2011

Pressures	Management responses
Nutrient load discharged (over several decades) by the Christies Beach WWTP	The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) has targets for reducing nutrient discharges from the Christies Beach WWTP. In order to accommodate urban growth and improve environmental performance, SA Water has heavily invested in upgrading the Christies Beach WWTP. This upgrade has improved effluent quality and has enabled the development of the Southern Urban Reuse Scheme and large-scale irrigation of vineyards. This investment has resulted in a significant reduction in nutrient loads discharges to marine waters from the plant. SA Water has commenced a comprehensive marine research program to inform future investments in wastewater treatment and reuse, and continually monitors and reviews treatment plant performance.
Sediment and highly coloured runoff from Adelaide metropolitan stormwater entering the nearshore marine waters	The Adelaide Coastal Water Quality Improvement Plan (ACWQIP) highlights sediment and coloured dissolved organic matter reduction strategies to reduce the impact of stormwater on the nearshore coastal environment. The Adelaide and Mount Lofty Ranges NRM Board has a well developed-stormwater quality improvement, harvesting and reuse program which has installed (and maintains) gross pollutant (and silt) traps in several watercourses across the region to catch litter, debris and silt in order to minimise impacts and damage to seagrass in the receiving marine environment. Stormwater captured is also treated through artificial wetlands across the region, which acts as suspended solid and nutrient filters. These wetlands also provide important habitat for many native species.
The Adelaide desalination plant was under construction in 2010 which may have discharged sediments into nearshore waters at Hallett Cove	A pilot desalination plant was operated to inform the design of the Adelaide desalination plant. During the operation of the pilot plant, brine was combined with freshwater to ensure salinity in the discharge was equivalent to that of sea water prior to its discharge. Only a very small volume was discharged.
The Adelaide desalination plant was in a commissioning phase in 2011, discharging variable volumes of brine into nearshore waters	The Adelaide desalination plant was constructed as a climate independent water source for Adelaide to provide water security for the city for the next 100 years. During the commissioning phase, the plant was operated in accordance with all conditions specified in its EPA licence including comprehensive water quality and ecological monitoring of the marine environment. Results of these monitoring programs are available on the EPA website.
Dredging operations discharge turbid water containing high amount of dead seagrass into the nearshore waters	Dredging is a licensed activity under the *Environment Protection Act 1993* and is regulated through conditions on licences requiring suitable management of dredge spoil and discharge water, and that monitoring programs are in place. In addition the EPA: • is required to be informed of dredging activities prior to work commencing • assesses dredging as a referable activity under the *Development Act 1993* • provides conditions to development applications for the proper management of dredging operations.

5.6 Tier 2 results – Encounter Biounit

The Tier 1 assessment in section 2.6 predicts the Encounter Biounit to be in Good condition. The biounit was not sampled in 2010 or 2011 due to logistical and resource constraints. As a result no AECR has been developed, but the biounit will become a priority in the next sampling event for Gulf St Vincent.

5.7 Tier 2 results – Backstairs Biounit

The Tier 1 assessment in section 2.7 predicted the Backstairs Biounit to be in Very Good condition. The biounit was not sampled in 2010 or 2011 due to logistical and resource constraints. As a result no AECR has been developed, but the biounit will become a priority in the next sampling event for Gulf St Vincent.

5.8 Tier 2 results – Nepean Biounit

The Tier 1 assessment predicted that the Nepean Biounit to be in Fair condition (section 2.8 and Table 3). Within this biounit there are several areas where the current speeds are slow, increasing the water residence times. This can exacerbate the effect of nutrient inputs making these areas more susceptible to habitat degradation.

Ten sites were monitored in 2010 and 2011 (Figure 47) and across both surveys no site was consistently bare sand. It should be noted the National benthic habitat mapping indicated that a number of sites were located on bare sand. However, many of these sites were subsequently found to have substantial seagrass meadows (eg m0051: inside spit recorded over 85% seagrass cover in 2010 and 2011). This discrepancy highlights the coarse nature of many previous mapping activities where data is often interpolated based on adjacent sites which may be located large distances apart. Such techniques can lead to inaccuracies in mapping, especially in heterogeneous habitats. Inaccuracy was not limited to just that site, and inconsistent mapping classifications were also found around m0052, m0053 and m0057.

5.8.1 Habitat

The sites monitored within Nepean were dominated by seagrass, with 62.3% seagrass in 2010 and 66.4% in 2011, giving an average of 64.3% (Figure 48). Only a small amount of reef habitat was recorded with 9.1% in 2010 and 9.2% in 2011 (Figure 48). The remaining 28.6% and 24.4% of the area covered was bare sand in 2010 and 2011 respectively. The National benthic habitat mapping program estimated that the biounit (less than 15 m depth) consisted of 48.9% seagrass and 48.7% bare sand, with the remainder being rocky reef (modified from (SARDI 2004). At a broad scale this is largely consistent with the habitat composition of the sites monitored as a part of the current MER program.

The seagrass condition index for Nepean found that half of the sites had extensive seagrass with HSI results above 70 out of 100 for both years, and m0048: Outside spit and m0049: Bay of Shoals having dense and continuous seagrass with HSI results above 98 in each year suggesting healthy meadows. The sites within Western Cove had highly variable with seagrass coverage between years as well as across the biounit. This variability is likely to be related to the presence of more ephemeral seagrass species in these areas including *Halophila* sp at m0053: Kingscote and *Heterozostera* sp at m0054: Western Cove outer.

There have been numerous studies that have shown that the Western Cove area has lost significant amounts of seagrass (Edyvane 1997) and this may be reflected in Figure 49 where a broad inverse relationship can be seen between distance from the Cygnet River (located at Western Cove) and seagrass condition. Sites located close to the Cygnet River had low and variable seagrass cover suggesting a degraded state, compared to sites distant from the Cygnet River having dense and continuous seagrass (Figure 43). Large parts of Nepean Bay have been shown to be highly disturbed with seagrass loss (Edyvane 1997), poor seagrass cover (Bryars et al 2003), and poor water quality (Gaylard 2005) leading to the conclusion of the region being eutrophic (Bryars et al 2003; Gaylard 2005)

Figure 47 **EPA monitoring sites sampled in the nearshore region of the Nepean Biounit, 2010 and 2011. Benthic habitats shown are from the National Benthic Habitat mapping layers (SARDI 2004; DEWNR 2010).**

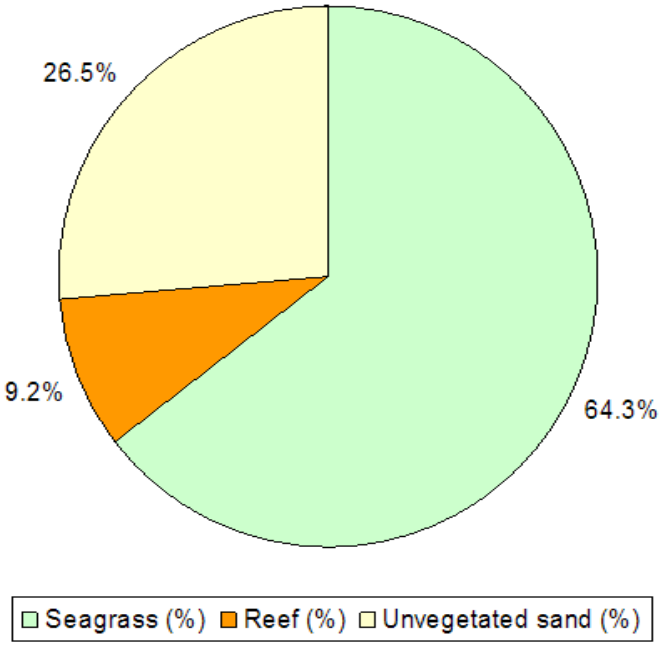

Figure 48 **Average benthic habitat composition of the sites within the sites within the Nepean Biounit across 2010 and 2011**

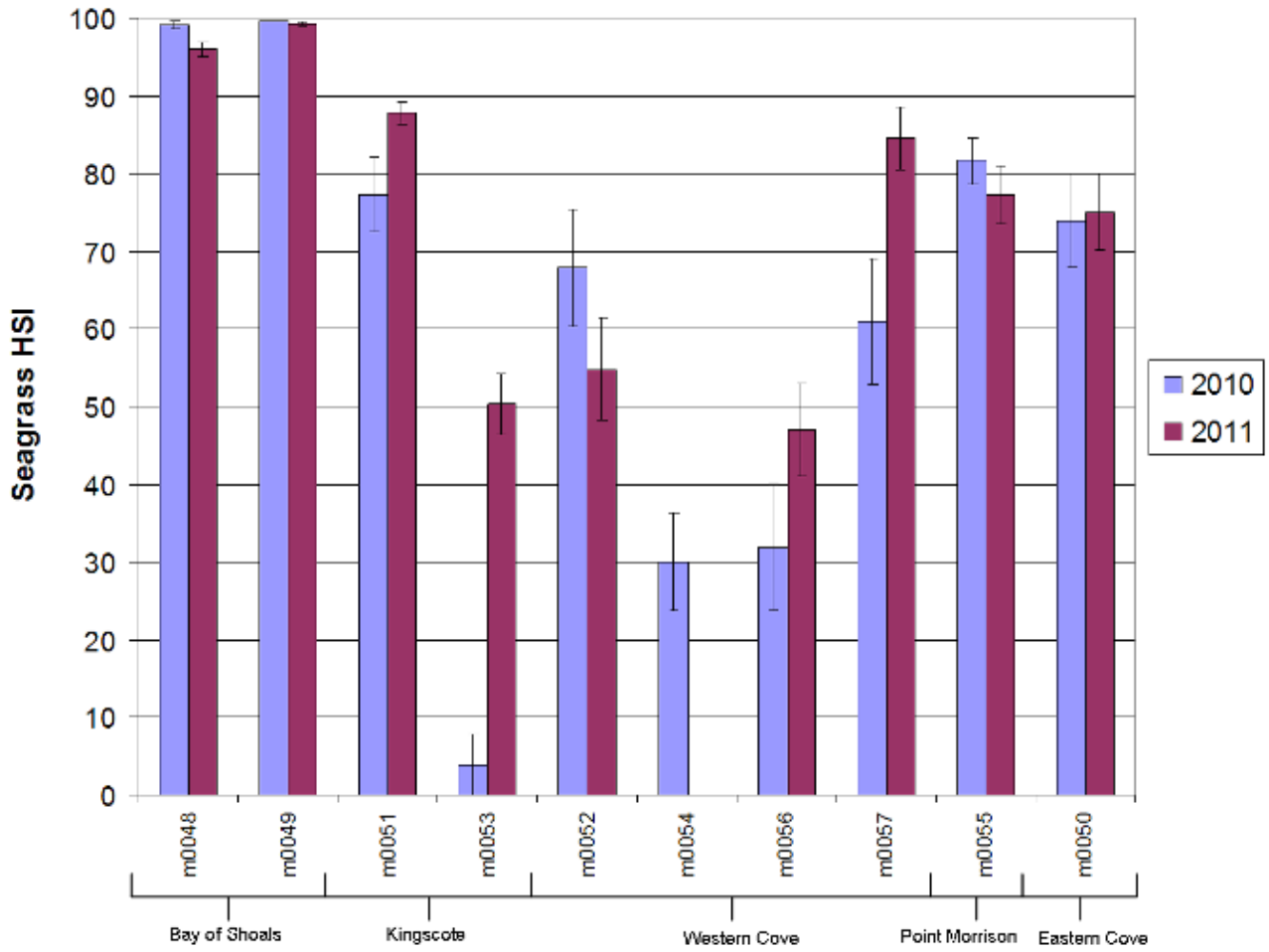

Figure 49 **Average seagrass condition (HSI) in the Nepean Biounit, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).**

Bryars et al (2003) undertook a seagrass survey throughout Nepean Bay using divers. While the location of sites differed from those in the current program, many were located in similar areas and broad comparisons can be made. In most circumstances where sites were considered similar, the results between the two surveys were similar with largely consistent seagrass cover. The site used by Bryars et al (2003) located in southwest Western Cove sampled in 1999 showed very sparse seagrass (13% cover *Posidonia sinuosa*). The current survey sampled a site located in close proximity to the SW Western Cove site (~ 500 m) and the site showed a similar proportion of *Posidonia* sp seagrass (17% in both 2010 and 2011). However, there was consistent but sparse coverage of *Halophila* sp in the current program (21% in 2010 and 10% in 2011) which may be colonising into the area where there has been historical loss, or alternatively the surveys of Bryars et al (2003) may have not have encountered *Halophila* sp due to its inherent temporal variability.

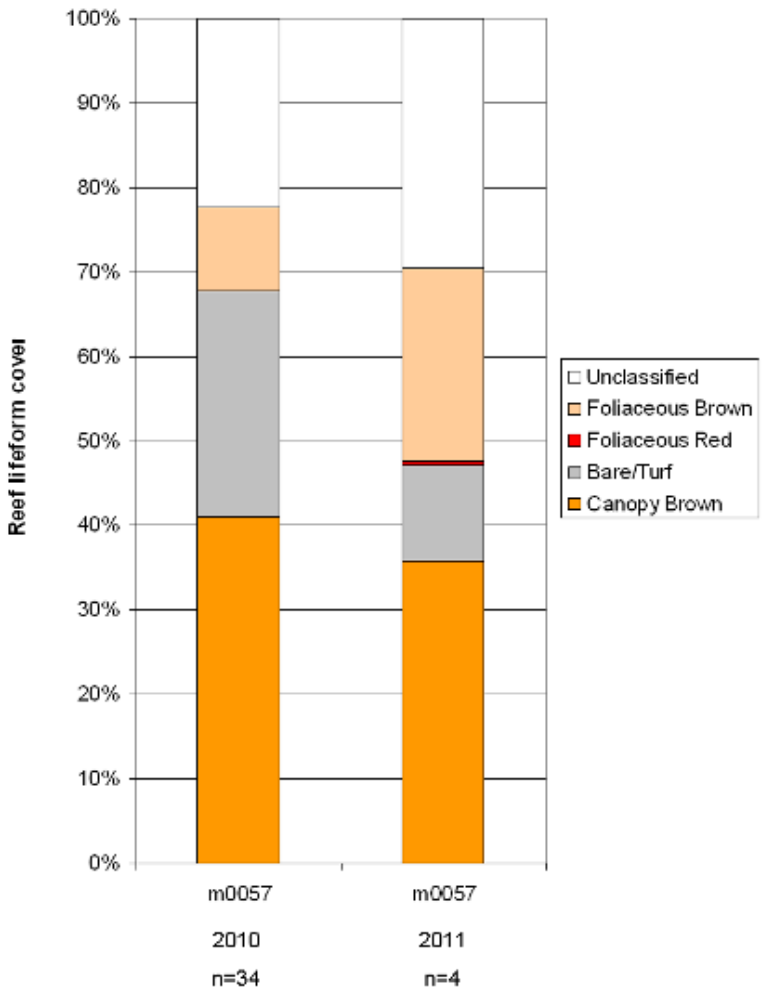

Figure 50 Average cover of reef lifeforms in the Nepean Biounit. Number of quadrats assessed indicated by (n)

The reef habitat assessment is limited to one reef m0057: Frenchmans, which was sampled in both 2010 and 2011. Even though the number of quadrats sampled varied between years, the results are consistent with 41% and 36% cover of large brown canopy macroalgae in 2010 and 2011 respectively. The amount of bare or turfing algae cover changed between years from 27% cover in 2010 to 11% in 2011. It is unsure whether this reflects a change in condition, or small-scale habitat heterogeneity.

5.8.2 Aquatic Ecosystem Condition Report

The results of the Nearshore MER program determined that the habitat condition of Nepean was 62.6 in 2010 and 56.5 in 2011 resulting in the biounit classification being Good for both years. The Tier 1 threat assessment predicted that the condition of this biounit would be Good (section 2.8), which is consistent with the results of the Tier 2 program. The AECR is available in Appendix 4.

5.8.3 Modifiers

The results of both surveys showed that while in some places there were still extensive seagrass meadows (Figure 49) many of these locations have dense epiphyte loads, particularly seen in the 2010 survey (Figure 51). These dense epiphyte loads are likely to be contributing to significant stress on the seagrass by reducing the amount of light available for photosynthesis, which over time can result in seagrass loss (Shepherd et al 1989; Bryars et al 2011). Throughout the biounit there was no significant difference in epiphyte load between 2010 and 2011 (Mann Whitney p = 0.0748), however at a number of sites there were significant changes between years (eg m0055 and m0050) and reasons behind these differences are currently unknown.

There were a number of locations where there was abundant opportunistic macroalgae (eg *Ulva* sp and *Hincksia* sordida), which in the current MER program has been used as an additional measure of nutrient enrichment (Gaylard et al 2013). Sites where this algae were prevalent included m0054: Western Cove outer and m0057: Frenchmans in 2010 and m0054: Western Cove in 2011. The lack of seagrass and epiphytes that would likely to be taking up the nutrients (see other biounits), may have left a niche for the macroalgae to thrive. This theory is consistent with observations of drift macroalgae in this area (Edyvane 1997; Bryars et al 2003).

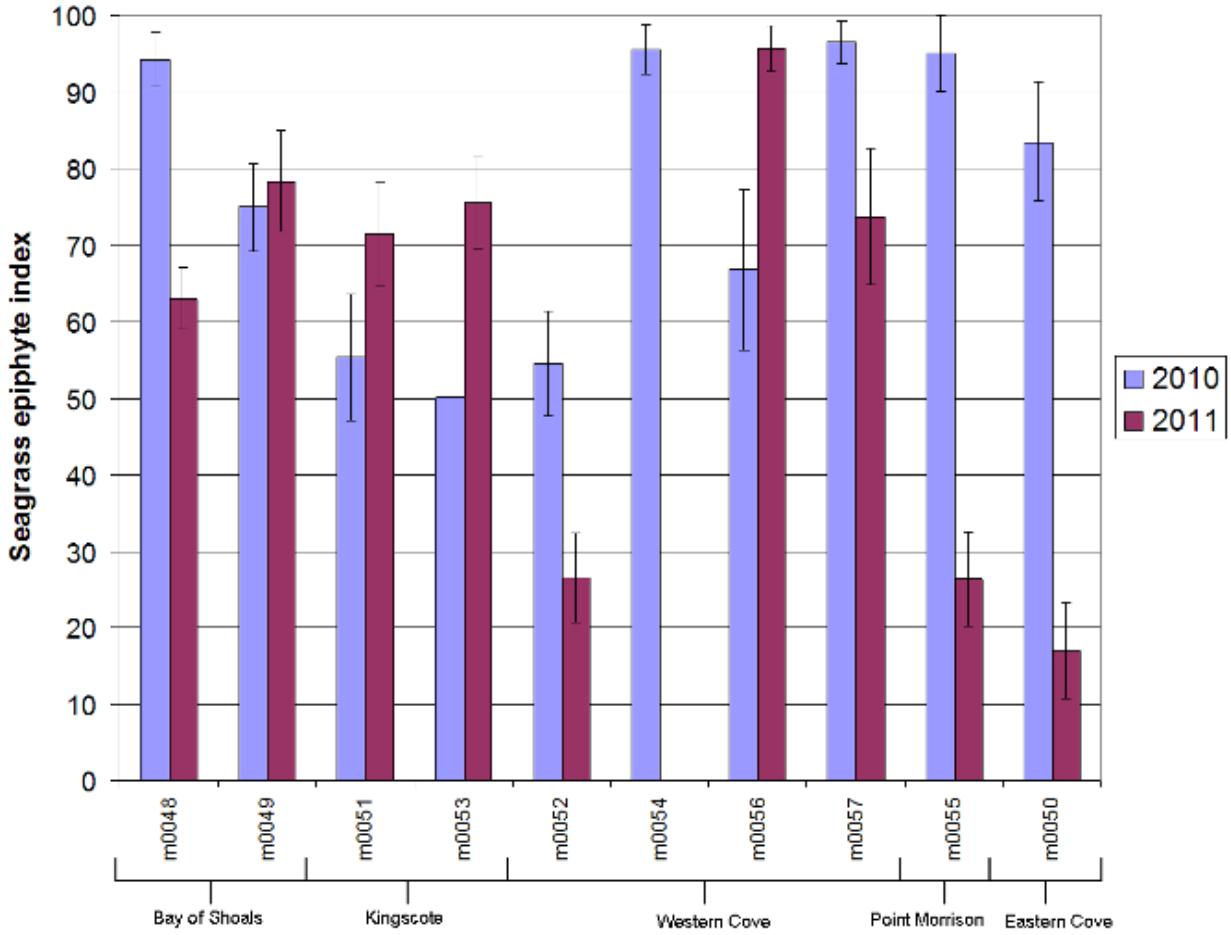

Figure 51 Average seagrass epiphyte load in the Nepean Biounit, 2010 and 2011. Error bars indicate the standard error. HSI is out of 100 (0 = poor condition; 100 = good condition).

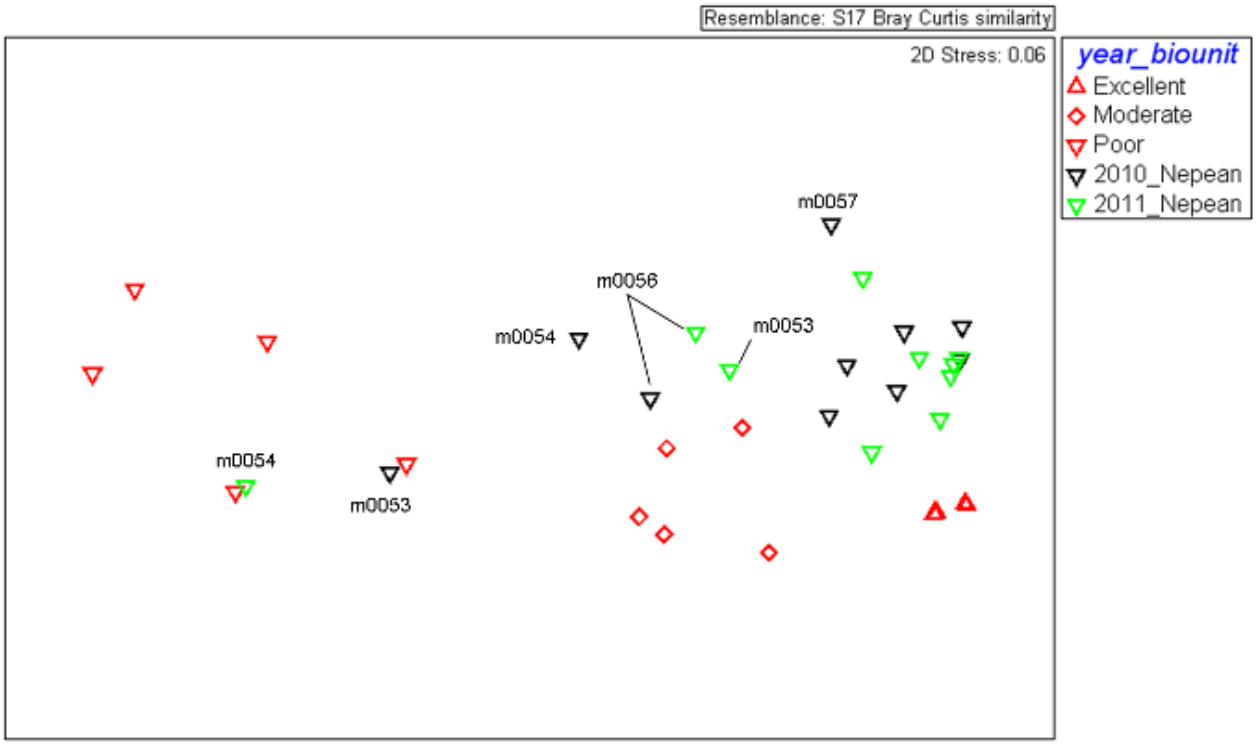

Figure 52 nMDS plot for habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae at monitoring sites in the Nepean Biounit, 2010 and 2011. Reference points suggesting condition overlaid.

An investigation of patterns or gradients in the data was undertaken using multivariate statistics. The broad spread of points were positioned largely above the Moderate and Excellent reference points (Figure 52), with two points distinct from this broad group sitting nearest to the Very Poor reference points. These sites are m0053: Kingscote in 2010 and m0054: Western Cove Outer in 2011. Interrogation of the data indicated that m0053: Kingscote had seagrass cover below 5% but moderate epiphyte loads, while m0054: Western Cove Outer was found to be bare sand. Interestingly there was considerable cover of seagrass in the subsequent years for both sites. The site m0054: Western Cove outer has 30% seagrass in 2010 which had then changed to bare sand in 2011, and site m0053: Kingscote went from 4% seagrass in 2010 to 42% seagrass cover in 2011. Detailed assessment showed that both of these sites comprised the more transient seagrass species *Halophila* spp and *Heterzostera* spp, and their cover can fluctuate over relatively short time periods compared to the long-lived species *Posidonia* spp and *Amphibolis* spp (Clarke and Kirkman 1989). The uppermost point on the plot is m0057: Frenchmans, distinct from other sites within the Nepean Biounit comprised over 40% reef.

The gradient in seagrass condition proximate to the outflow of the Cygnet River is replicated in the nMDS with the sites closest to the Cygnet (m0056, m0054 and m0053) being position towards the left of the plot. It is possible that if the plot only incorporated *Posidonia* spp or *Amphibolis* spp seagrass then this delineation could have been more distinct. This adds weight to the conclusions of Edyvane (1997) that flows from this river are likely to be having an adverse impact on seagrass in Nepean Bay, rather than other potential nutrient sources.

The results of the water chemistry analysis for the Nepean Biounit showed that only turbidity was significantly greater than the reference value for both years (Table 13) and in most cases the nutrient concentrations were significantly less than observed in areas considered as reference. This highlights the fact that nutrient enrichment is likely to be a relative state rather than a specific threshold or trigger concentration.

Changes in local nutrient loads are likely to have a significant influence on symptoms of nutrient enrichment including epiphyte growth, and presence of opportunistic macroalgae. Site-specific factors such as nutrient inputs, water flow, light availability and adjacent habitats all can contribute to the expression of symptoms of nutrient enrichment. The site

m0054: Western Cove outer was also consistently higher in total nitrogen than most other sites in the biounit in both years.

The epiphyte loads (Figure 51) and the presence of opportunistic macroalgae suggests that nutrients are present at sufficient levels to encourage epiphytes and opportunistic algae and the uptake of nutrients by this biomass may be resulting in the very low dissolved nutrients values seen in Table 15.

Table 15 Water chemistry and chlorophyll *a* values – Nepean Biounit 2010–11

	Dissolved inorganic nitrogen (mg/L)		Total nitrogen (mg/L)		Filtered reactive phosphorus (mg/L)		Total phosphorus (mg/L)		Turbidity (NTU)		Chlorophyll *a* (µg/L)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Median	0.005	0.005	0.140	0.120	0.003	0.003	0.015	0.012	0.230	0.220	0.460	0.525
St Dev	0.005	0.005	0.049	0.086	0.001	0.010	0.023	0.007	0.094	0.275	0.254	0.325
n	57	60	57	60	57	60	57	60	57	60	17	16
Reference median	0.018		0.150		0.005		0.015		0.190		0.627	
Mann Whitney significant at p <0.05	0.000	0.000	0.149	0.000	0.000	0.000	0.866	0.000	0.019	0.032	0.025	0.337

5.8.4 Conclusions

Overall, the condition of Nepean, which spans from North Cape through to Cape Willoughby, was considered Good. This good condition is largely attributed to the extensive areas of intact seagrass, even though some areas in close proximity to Western Cove were severely degraded.

A number of sites in the biounit showed variability in seagrass coverage which can in part be attributed to more ephemeral seagrass species including *Heterozostera* spp and *Halophila* spp. There are multiple lines of evidence suggesting that even though the nutrient concentrations in the water are very low, the region was still eutrophic and that many of the sites monitored are likely to be under significant stress due to nutrient enrichment. It is possible that the low current speeds and high water residence times typical of Nepean Bay are exacerbating the symptoms of nutrient enrichment from the discharges into the region.

5.8.5 Pressures and management responses

Section 2.9 discusses the threat assessment for the Nepean Biounit and highlights the key nutrient input sources to the nearshore marine environment. The major nutrient and sediment discharge into the biounit is Cygnet River which drains a large proportion of the agricultural land on Kangaroo Island. The river drains into Nepean Bay near Brownlow and the discharge has been partly attributed for the loss of almost 2,700 ha of seagrass from Western Cove (Edyvane 1997). Stormwater runoff from the small coastal towns can also affect water quality and potentially impact on the receiving environment. Estimates of stormwater quality and quantity are currently unknown and likely to be minor.

The Kingscote CWMS is located in the supratidal zone in close proximity to the marine environment at Brownlow. The system services approximately 870 dwellings and takes the effluent to a series of lagoons where 100% of the treated wastewater is reused through irrigation to the golf and race courses (McNicol 2007). Historically, it is believed lagoons for this system leaked into the shallow groundwater as there have also been a number of overflows which have discharged partially treated wastewater into the intertidal zone. However over the last 10 years there have been a number of upgrades to the system (Gaylard 2011).

The CWMS manages effluent from a proportion of the town of Kingscote. However, for other dwellings within Kingscote and other small coastal towns (eg Island Beach) the sewage is treated and disposed via on-site septic tanks systems. High densities of septic systems in sandy soils have the potential to introduce significant loads of nutrients into shallow groundwater which can be transported into the nearshore marine environment.

Penneshaw is located on the eastern side of Nepean Bay and SA Water has built a desalination plant to cater for the town's potable water needs. The plant is dependent on demand and available storage, and during months of high demand the plant can discharge up to 4.3–4.6 KL a day and approximately half of this during wetter months. The brine is discharged through a series of diffusers using duckbill valves to ensure efficient mixing.

Table 16 Pressures and management responses for the Nepean Biounit 2010 and 2011

Pressures	Management responses
High nutrient loads in runoff discharged from the Cygnet River into the nearshore waters of Western Cove	Natural Resources Kangaroo Island (NR KI) is addressing the Cygnet River nutrient loads through the Australian Government-funded Catchment to Coast (C2C) project, which commenced in 2009 and will continue until 2018. C2C focuses on fencing of riparian vegetation and construction of in-stream remediation works such as formed creek crossings in order to exclude livestock from riverbanks and watercourses, thereby reducing erosion and runoff. Onground works are guided by a catchment model developed by the EPA that identifies subcatchments that contribute the greatest nutrient and sediment loads to Cygnet River. Outcomes are measured and assessed through weekly and monthly water quality and flow monitoring at two sites in the Cygnet River and monitoring of seagrass condition and extent at seven sites in Western Cove.
Failing and/or high density of onsite wastewater treatment (septic) systems in some coastal towns. This is probably most significant in the American River, Island Beach and Penneshaw areas. Overflowing septic systems contribute nutrients to nearshore marine waters through shallow subsurface or occasional overland flows.	The Kangaroo Island Council commissioned the American River CWMS in 2010, and this includes a WWTP and facultative lagoons. American River properties have progressively been connected to a CWMS with remaining developed properties with septic trenches connecting by June 2014. The Penneshaw CWMS remains in consultation between council/ LGA/community action groups. Stage 1 implementation is expected in 2014. An Island Beach CWMS is on a long-term plan and lodged with the LGA in 2009.

Pressures	Management responses
	Natural Resources Kangaroo Island (NR KI) has submitted a proposal for funding under the Caring for our Country Target Area Grants for a four-year project that will deliver plans for integrated stormwater management in Kingscote. The project involves collaboration between NR KI, Department for Environment, Water and Natural Resources and the Kangaroo Island Council to establish strategies to retain and reuse stormwater and design and install filtration mechanisms to remove pollutants and sediments. In 2009–10 additional emergency storage tanking was installed at pump stations, to supplement the existing overflow tanking. W&G Engineers designed and supervised the construction, to increase the capacity of these tanks with regard to power outages. NR KI also has an emergency manual that highlights actions to connect generators/pumps to maintain low levels in pump stations for periods of extended power outages.
Stormwater runoff from the Kingscote area, discharging nutrients and sediments to Nepean Bay	The Penneshaw desalination plant is a relatively small plant. It was built and is operated by SA Water to provide potable water for the residents and visitors to Penneshaw. The desalination plant is operated in accordance with EPA licence conditions. Sea water is treated to remove salt and in doing so, a small amount of 'brine' is created and discharged back to the sea. SA Water monitors the quality of brine being discharged as well as the quality of water offshore of the discharge.
The Penneshaw desalination plant discharges small volumes of wastewater with elevated salinity	The Kingscote CWMS is operated by the Kangaroo Island Council. Two of the three CWMS facultative lagoons were relined in 2010 and a third storage lagoon is planned to be relined by about 2015 in two stages. An aerobic WWTP will also be constructed and commissioned at this time. Groundwater monitoring has indicated that infrastructure upgrades have been successful in preventing nutrient from this facility entering the Cygnet estuary and Nepean Bay.

5.9 Tier 2 results – Cassini Biounit

The Tier 1 assessment in section 2.9 predicted the Cassini Biounit to be in Very Good condition. Cassini was not sampled in 2010 or 2011 due to logistical and resource constraints. As a result no AECR has been developed, but the biounit will become a priority in the next sampling event for Gulf St Vincent.

6 Concluding remarks

This is the first standardised bioregion-wide assessment of ecological condition of nearshore habitats to be undertaken in Gulf St Vincent. The assessment indicates that large areas of the shallow nearshore waters throughout Gulf St Vincent are subjected to nutrient enrichment, and that this is not restricted to the areas adjacent to large industrial discharges but also has been observed adjacent some small coastal towns or river discharges. In many circumstances the effects of nutrient enrichment can be exacerbated by low current speeds and poorer flushing within embayments suggesting that these areas are particularly sensitive to any nutrient input.

The results of this MER program show that even with relatively small amounts of adjacent human activity there can be observable changes to seagrass and reef condition which if continued unchecked, may result in habitat loss and substantial reductions in ecosystem value including loss of biodiversity, reduction in commercial and recreational fisheries, unstable sediment and potential for increased beach erosion. Significant historical habitat degradation of seagrass meadows and reef communities has already been observed throughout the Adelaide Metro and Nepean biounits, including seagrass loss and declines in reef condition (Edyvane 1997; Westphalen et al 2004; Connell et al 2008). The changes to habitats observed in these areas are likely to have been initiated by prolonged increases in epiphyte loads, decreases in seagrass density and/or fragmentation of seagrass meadows beyond natural variation, or decreases in water clarity. The Nearshore MER program shows that many of these initial symptoms are occurring in other biounits and should be considered as early warning indicators for habitat decline into the future.

The Nearshore MER program is an iterative program and as our understanding increases, new metrics could be added to better assess condition of habitats, particularly the response of habitats to subtle increases in nutrients or decreased light. This will ensure that the program uses the best available information and the outcomes of the program are robust.

There are a number of aspects that need further refinement including our understanding of reference condition and the variability within those habitats and modifiers in 'un-impacted' locations. For example chlorophyll a concentration has shown to be a particularly ineffective metric to define condition. In all biounits assessed the chlorophyll concentrations were lower than what was observed in the reference locations. There are a number of possibilities for this occurrence including competition for dissolved nutrients between phytoplankton, opportunistic macroalgae, seagrass epiphytes, seagrass and other benthic primary producers that suggest that the role phytoplankton plays in the nearshore environment is not as great as previously through (see (Cloern 2001). Alternatively, the assessment of reference condition needs further refinement.

In future years the Nearshore MER program will cycle through other bioregions in the state looking at the condition of habitats in nearshore waters. This will further inform condition gradients outside of the Gulf and provide a foundation of knowledge of the response of marine communities to human activity. Gulf St Vincent will be reassessed after the cycle has been completed and the biounits that were not assessed during the current surveys will be prioritised.

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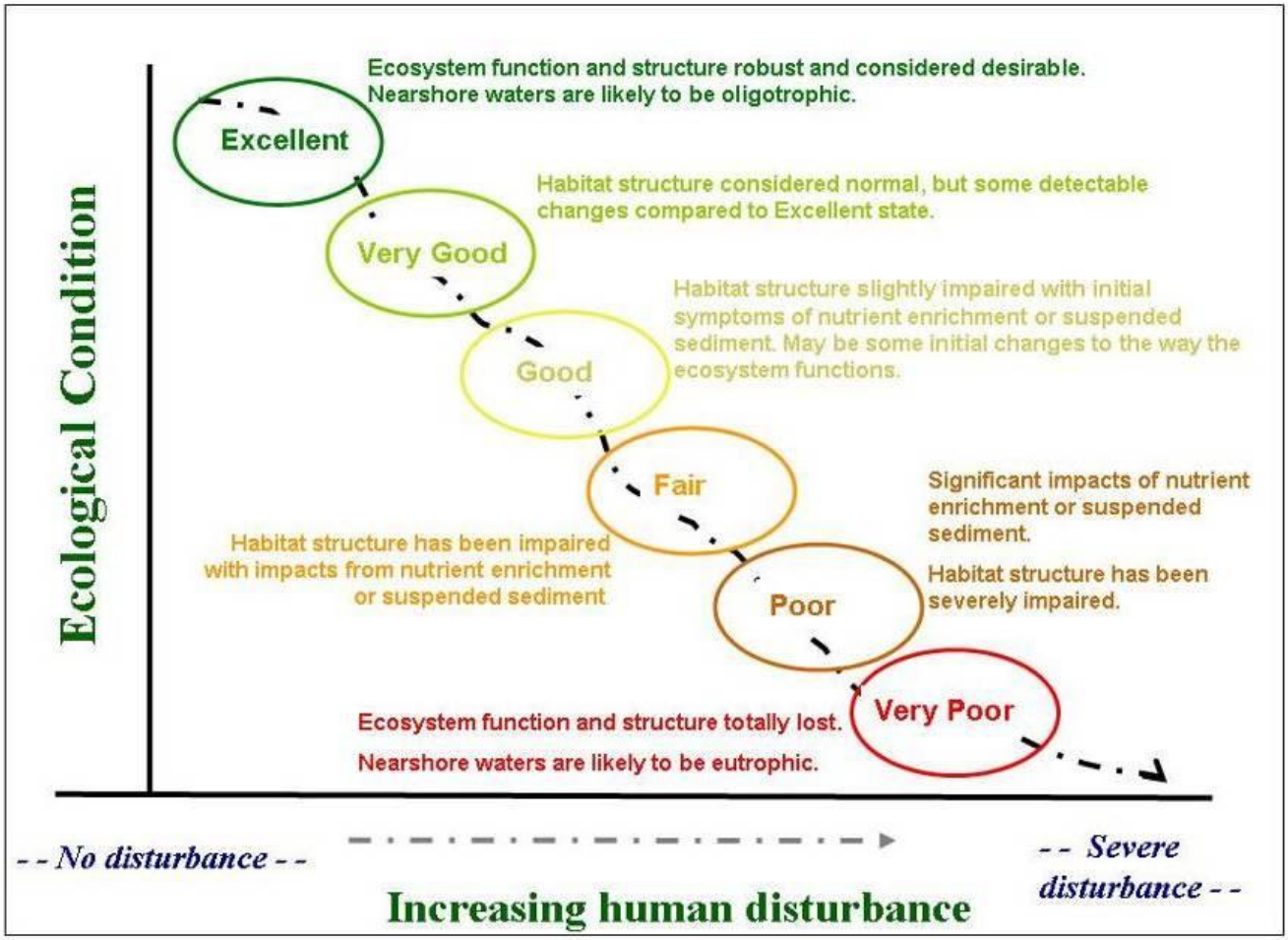
Appendix 1 Ecological condition gradient



Appendix 2 Conceptual models for Gulf St Vincent 2010–11

Gaylard et al (2013) detailed the monitoring methods undertaken to broadly assess ecological condition for the development of AECRs, including development of generic conceptual models that have been used to suggest processes of degradation based on established literature and to develop a condition gradient (Appendix 1).

The overarching assumption is that as habitat condition degrades the biodiversity and ecosystem services also degrade, which holds true for many other temperate locations around the world (Duarte 2002; Waycott et al 2009). Conceptual models that describe the response of an ecosystem to stress have been used in developing strategies for natural resource management that put emphasis on the maintenance of important ecological characteristics. The condition gradient is a type of conceptual model that relates an observed ecological response to increasing levels of human disturbance (Davies and Jackson 2006). This gradient assumes habitat condition deteriorates as the degree of human disturbance in the surrounding and adjacent environment increases, and conversely, the best condition occurs where there is little to no human disturbance of the environment.

This section addresses whether the major habitats in Gulf St Vincent allow the use of the generic conceptual models provided in (Gaylard et al 2013) in order to ensure that the assumptions of those models are still reasonable for this bioregion.

Seagrass

The ecological information summarised for each biounit (Section 2) indicates that many of the biounits are dominated by seagrass meadows comprising mainly of *Amphibolis antarctica* and/or species from the *Posidonia australis* group (P sinuosa, P australis and P angustifolia) with little to no recorded occurrences of the *Posidonia ostenfeldii* group. This suggests that the conceptual model of seagrass degradation along a gradient of decreasing light outlined in Gaylard et al (2013) would be applicable in this bioregion.

A fundamental aspect of the Nearshore MER program is the assessment of whether the benthic habitats have changed over time. Humans have altered the landscape throughout Gulf St Vincent for over 150 years which is likely to have influenced the nearshore benthic habitats. Without knowledge of historical (pre–1950s) benthic habitat composition and extent, it can be hard to determine whether habitats including seagrass may have existed in an area, or has been lost due to disturbance, or whether bare sand is a natural state. In order to establish whether seagrass may have been present naturally at a site, this program has used methods adapted from Bryars and Rowling (2008) who established a coarse habitat reconstruction for each sampling area to determine if seagrass has been present prior to monitoring.

If seagrass is currently present in the sampling area then it is likely that it was also historically present (ie pre-European settlement). As used by Bryars and Rowling (2008), this assumption is robust in gulfs and sheltered bays due to the slow growing and colonising ability of the dominant Amphibolis and Posidonia genera. In areas where seagrass is absent and there is no historical evidence of seagrass presence, an assessment will be made based on a range of known variables to attempt to determine whether seagrass was likely to have been present historically to determine the likelihood of change over time due to current activities (Gaylard et al 2013).

Seagrass condition is described for areas that are considered to be likely to be suitable for growth and uses the Habitat Structure Index (HSI) described in (Irving et al 2013). This HSI method quantifies habitat condition using seagrass density, area, species (or genus) and the proximity between patches to describe the continuity of a meadow in relation to a dense and continuous meadow as found in Posidonia australis complex and *Amphibolis* spp genera (Irving et al 2013). As outlined in (Irving et al 2013) the HSI does not consider seagrass genera that may not grow in continuous meadows such as the Posidonia ostenfeldii complex. Seagrass condition has been described using the conceptual seagrass condition gradient in Table 1 and detailed in (Gaylard et al 2013).

Table 17 Conceptual seagrass condition gradient

Component	Excellent	Very Good	Good	Fair	Poor	Very Poor
Seagrass *Posidonia australis* complex seagrass cover	Dense meadows of seagrass typically *Posidonia australis* group and/or *Amphibolis* spp	Generally dense seagrass meadows Seagrass condition may start to become more variable	Moderate density or dense patches of seagrass	Moderate density of seagrass in frequent patches or uniform sparse seagrass coverage.	Seagrass would typically be sparse and patchy	Seagrass totally lost where previously inhabited
Seagrass condition using the habitat structure index (HSI)	HSI >90	Habitat structure reducing and/or becoming more variable. HSI between 70–89	HSI between 50–69	HSI between 30 and 49	HSI between 10 and 29	HSI below 10

Rocky reefs in Gulf St Vincent

With respect to rocky reef communities, Edyvane (1999c) outlines the key species that dominate both shallow and deeper reefs in the GSV bioregion. The canopy species noted are largely consistent with the broad premise that in waters less than 15 m deep, large canopy forming brown algae dominate reefs throughout southern Australia (Shepherd and Sprigg 1976; Turner et al 2007). Rocky reef systems are complex multi-layered communities and a rapid assessment based on remote observations may not fully capture the level of accuracy compared to measurements obtained using SCUBA. However the use of photo quadrats and video has become increasingly used to assess canopy assemblages (Leujak and Ormond 2007; Lirman et al 2007; Lirman et al 2008; Parravicini et al 2009), and is deemed sufficient for the broad-scale assessment used in this MER program. The condition of rocky reefs was described using the conceptual rocky reef condition gradient in Table 2 and detail including the numerous assumptions and limitations based on the Turner et al (2007) reef status indices.

Table 18 Conceptual rocky reef condition gradient

Component	Excellent	Very Good	Good	Fair	Poor	Very Poor
Robust brown macroalgal cover (Fucales and Laminariales)	Reef dominated by Fucales or Laminariales with areal cover of robust brown macroalgae greater than 40%			Cover of robust brown macroalgae below 40%		
Turfing algae	Areal cover of turfing algae less than 25%			Areal cover of turfing algae greater than 25%		
Bare substrate	Bare rock substrate on reef less than 20%			Bare rock substrate greater than 20%		

Unvegetated sediments

Unvegetated sediments dominate areas that are unsuitable for seagrass or macroalgal growth for a range of factors including water current speeds/wave energy, light availability (depth) and/or unsuitable/unstable substrate. Our

knowledge of ecological processes and responses of bare sandy substrate to disturbance in Southern Australia is limited, and often based on very costly sampling and analysis of infauna. Establishing a condition gradient is thus difficult when using remote video assessment methods.

Brown et al (1987) and also Cheshire (1996) have described a range of epi-faunal indicators of organic enrichment radiating from sea cage tuna farms, which suggest a shift in species composition towards an increase in deposit feeding organisms compared to control locations. These species may be amenable to video monitoring techniques, depending on image quality (Cheshire 1996). The condition of unvegetated sediments will be described using the simplistic conceptual condition gradient described in Table 3, but note the limitations and assumptions outlined in (Gaylard et al 2013).

Table 19 Conceptual condition gradient for unvegetated sediments

Component	Excellent	Very Good	Good	Fair	Poor	Very Poor
Unvegetated sediments				Prevalence of deposit feeding epi-benthic animals	Dominance in deposit feeding epi-benthic animals compared to reference condition	

Within Gulf St Vincent the dominant habitat on soft sediment is seagrass. As a seagrass habitat degrades for whatever reason the habitat generally becomes bare sand. The delineation between seagrass habitats, severely degraded seagrass habitats where the seagrass has been lost due to disturbance, and naturally unvegetated sediments is very difficult especially when reaching deeper depths where light may naturally limit the extent of seagrass.

The Nearshore MER program has set a cut-off point of 15-m depth which is designed to help overcome this delineation where natural light attenuation through water may be a key factor in seagrass survival. Gaylard et al (2013) describes a process of assessment undertaken where unvegetated sediment habitats are encountered in the GSV. This assessment looks at a number of key factors that may contribute to the likelihood of seagrass being able to survive or have previously survived at that location. Where seagrass is determined not to be able to survive, a coarse conceptual model of the condition of unvegetated sediment (Table 3) will be used to describe condition.

Multivariate comparisons

The conceptual models and the data compiled in Gaylard et al (2013) reflect the physical, biological and chemical attributes that may be typical in South Australian nearshore habitats that are in located in waters between 2–15 m deep when in Excellent condition. This work also shows how attributes may change along a disturbance gradient relating to declining condition. In order to show how sites assessed in this MER program fit within the conceptual models, reference points were created using the information within the models to show how these attributes changed in comparison to data collected in this MER program and displayed using a nMDS plot (Figure 53). Overlaying the sites sampled in this MER with the reference points will show where the composition of the sites fit with the conceptual models and whether there are biological gradients present in the data or other patterns that may help interpret the data in relation to pollution sources, natural variation or other factors.

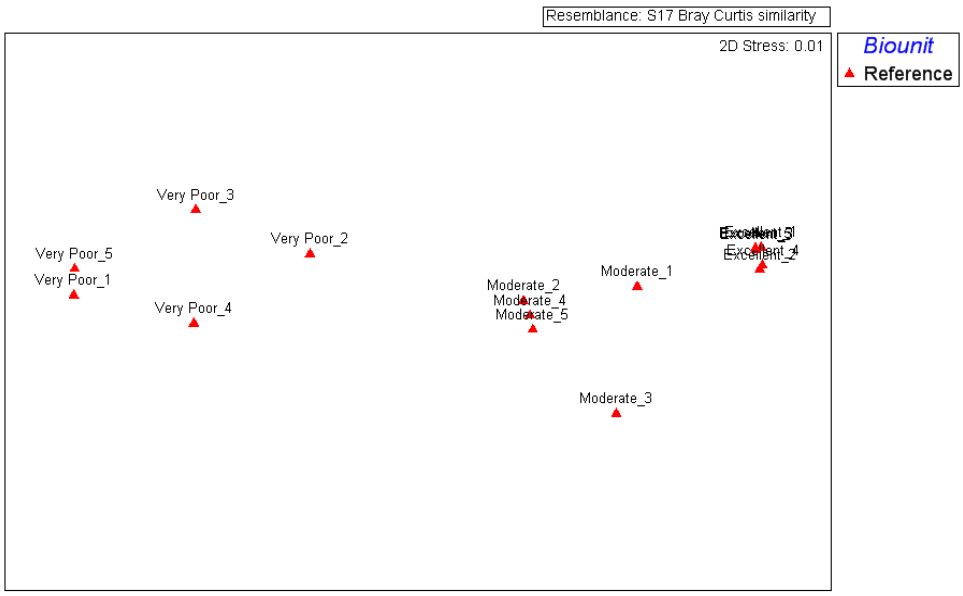


Figure 53 **Reference points reflecting the conceptual models of habitat disturbance in GSV nearshore marine environment incorporating habitat composition, seagrass density and patchiness, seagrass epiphyte load and opportunistic macroalgae. Based on models in (Gaylard et al 2013).**

Table 20 **Conclusions for the broad-scale condition of the biounit based on the conceptual models**

Component	Excellent	Very Good	Good	Fair	Poor	Very Poor
Ecosystem	Structure and function of habitats considered in natural or unimpacted condition. Nearshore waters are likely to be oligotrophic Adequate light for a maximum photic zone	Habitat structure considered natural, but some detectable changes compared to Excellent state Habitat changes are unlikely to be leading to changes in Ecosystem function Any detrimental effects are limited to small pockets and quickly reversible	Habitat structure slightly impaired with initial symptoms of nutrient enrichment or suspended sediment May be some initial changes to ecosystem function Detrimental effects limited to site level changes but limited to short-term recovery	Habitat structure has been impaired with impacts from nutrient enrichment or suspended sediment These habitat changes are likely to be changing ecosystem function including resilience, biodiversity, productivity and sediment stability Detrimental effects may extend to numerous sites or small areas where longer-term recovery is required	Habitat structure has been severely impaired leading to significant changes to ecosystem function including resilience, biodiversity, productivity and sediment stability Significant impacts of nutrient enrichment or suspended sediment Detrimental effects may extend to numerous sites and possibly long-term recovery	Ecosystem function and structure totally lost. Nearshore waters are likely to be eutrophic Detrimental effects at a regional scale and recovery may not be possible

Appendix 3 List of site numbers and locations

Biounit	Site	Latitude	Longitude	Sampled 2010	Sampled 2011	Description
Clinton	m0001	–34.2456	138.0429	✓	✓	Port Clinton
Clinton	m0002	–34.2378	138.0885	✓	✓	Sandy Point
Clinton	m0003	–34.2828	138.1057	✓	✓	Proof Range
Clinton	m0004	–34.2671	138.0457	✓	✓	Price
Clinton	m0005	–34.3135	138.1164	✓	✓	Bald Spit
Clinton	m0006	–34.3335	138.1428	✓	✓	Sandy Point south
Clinton	m0007	–34.4113	137.9725	✓	✓	Ardrossan north
Orontes	m0008	–34.5165	137.9441	✓	✓	Rouges Point
Orontes	m0009	–34.5469	137.9002	✓	✓	Pine Point north
Orontes	m0010	–34.5683	137.9062	✓	✓	Pine Point
Orontes	m0011	–34.6599	137.9029	✓	✓	Port Julia
Orontes	m0012	–34.7415	137.8783	✓	✓	Red Cliffs
Orontes	m0013	–34.7767	137.9314	✓	✓	Vincent outer
Orontes	m0014	–34.7971	137.8843	✓	✓	Vincent inner
Orontes	m0015	–34.8728	137.8259	✓	✓	Stansbury
Orontes	m0016	–34.8459	137.9241	✓	✓	Orontes Bank
Orontes	m0017	–34.8591	137.8514	✓	✓	Stansbury north
Orontes	m0018	–34.9731	137.7752	✓	✓	Klein Point
Orontes	m0019	–35.0015	137.7636	✓	✓	Wool Bay
Orontes	m0020	–35.0757	137.7955	✓	✓	Edithburgh
Orontes	m0021	–35.1003	137.807	✓	✓	Troubridge Island
Yankalilla	m0022	–35.3376	138.4378	✓	✗	Sellicks

Biounit	Site	Latitude	Longitude	Sampled 2010	Sampled 2011	Description
Clinton	m0023	–34.708	138.4333	✓	✓	Port Gawler
Clinton	m0024	–34.7827	138.4191	✓	✓	Outer Harbor
Adelaide Metro	m0025	–34.76	138.5286	✓	✓	Barker Inlet
Clinton	m0026	–34.7857	138.4306	✓	✓	Outer Harbour north
Clinton	m0027	–34.7974	138.4151	✓	✓	Outer Harbour south
Adelaide Metro	m0028	–34.858	138.4565	✓	✓	Semaphore Park inner
Clinton	m0029	–34.8623	138.4237	✓	✓	Semaphore Park outer
Clinton	m0030	–34.869	138.4526	✓	✓	West Lakes
Clinton	m0031	-34.8785	138.4342	✓	✓	Tennyson
Clinton	m0032	–34.9241	138.4568	✓	✓	Henley Beach
Adelaide Metro	m0033	–34.9304	138.496	✓	✗	Henley Beach south
Clinton	m0034	–34.9535	138.4747	✓	✓	West Beach outer
Adelaide Metro	m0035	–34.9545	138.4966	✓	✗	West Beach Inner
Adelaide Metro	m0036	–34.9712	138.5086	✓	✓	Glenelg
Clinton	m0037	–34.9953	138.4823	✓	✓	Somerton outer
Clinton	m0038	–34.9994	138.4965	✓	✓	Somerton inner
Yankalilla	m0039	–35.0614	138.5007	✓	✓	Hallett Cove
Yankalilla	m0040	–35.1668	138.4581	✓	✗	Southport
Yankalilla	m0041	–35.1912	138.4577	✓	✗	Seaford
Yankalilla	m0042	–35.2274	138.4616	✓	✓	Maslin Beach
Adelaide Metro	m0043	–34.8901	138.468	✓	✓	Grange north
Adelaide Metro	m0044	–34.9085	138.4809	✓	✓	Grange
Clinton	m0045	–35.0215	138.4937	✓	✓	Brighton

Biounit	Site	Latitude	Longitude	Sampled 2010	Sampled 2011	Description
Yankalilla	m0046	–35.0871	138.4822	✓	✓	Port Stanvac
Yankalilla	m0047	–35.1253	138.4646	✓	✓	O'Sullivans Beach
Nepean	m0048	–35.6018	137.659	✓	✓	Outside Spit
Nepean	m0049	–35.6174	137.5979	✓	✓	Bay of Shoals
Nepean	m0050	–35.7798	137.8387	✓	✓	Eastern Cove
Nepean	m0051	–35.6511	137.6759	✓	✓	Inside Spit
Nepean	m0052	–35.6462	137.7461	✓	✓	Nepean offshore
Nepean	m0053	–35.6597	137.6548	✓	✓	Kingscote
Nepean	m0054	–35.6913	137.6509	✓	✓	Western Cove outer
Nepean	m0055	–35.6937	137.7738	✓	✓	Point Morrison
Nepean	m0056	–35.7109	137.615	✓	✓	Western Cove inner
Nepean	m0057	–35.7238	137.7118	✓	✓	Frenchmans
Adelaide Metro	m0058	–34.7244	138.4721	✗	✓	Black Pole inner
Clinton	m0059	–34.7419	138.4181	✗	✓	Black Pole outer
Adelaide Metro	m0060	–34.9303	138.4826	✗	✓	Torrens
Adelaide Metro	m0061	–34.9712	138.4989	✗	✓	Glenelg
Yankalilla	m0062	–35.1251	138.4574	✗	✓	O'Sullivans Beach outer
Yankalilla	m0063	–35.1668	138.4523	✗	✓	Southport outer
Yankalilla	m0064	–35.1912	138.4518	✗	✓	Seaford outer
Orontes	m0065	–35.047	137.7447	✗	✓	Coobowie Bay north
Orontes	m0066	–35.0659	137.743	✗	✓	Coobowie Bay south
Yankalilla	m0067	–35.3377	138.4284	✗	✓	Sellicks Outer
Clinton	m0068	–34.6173	138.2495	✓	✓	Port Gawler outer

Biounit	Site	Latitude	Longitude	Sampled 2010	Sampled 2011	Description
Clinton	m0069	–34.6498	138.3194	✓	✓	Port Gawler south
Clinton	m0070	–34.6174	138.3398	✓	✓	Port Gawler north
Clinton	m0071	–34.5797	138.3126	✓	✓	Port Prime
Clinton	m0072	–34.526	138.2544	✓	✓	Port Parham south

Appendix 4 Aquatic Ecosystem Condition Reports

Orontes Biounit 2010

Orontes Biounit 2011

Clinton Biounit 2010

Clinton Biounit 2011

Adelaide Metro Biounit 2010

Adelaide Metro Biounit 2011

Yankalilla Biounit 2010

Yankalilla Biounit 2011

Nepean Biounit 2010

Nepean Biounit 2011