

Nearshore Marine Habitats of the Adelaide and Mount Lofty Ranges NRM Region: Values, Threats and Actions



**Report to the Adelaide and Mount Lofty Ranges Natural Resources
Management Board**

Simon Bryars

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Front cover photo: Shallow subtidal reef habitat north of Carrickalinga Head. Photo: Simon Bryars.

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Contents

Acknowledgements.....	3
Executive summary	7
Introduction	11
Purpose of the report	11
Background to the report	11
Scope and aims of the report.....	12
Threats to marine habitats	14
Key threats	14
Nutrients and sediments.....	14
Physical disturbance	15
Other threats to marine habitats.....	15
Methods.....	19
Marine cells.....	19
Habitat classifications	21
Habitat values	24
Threats and Threat Analysis.....	24
Cell summaries.....	28
Results.....	30
F4 – Tokuremoar Reserve	31
F5 – Surfers Beach, Middleton.....	35
F6 – Middleton	39
F7 – Bashams Regional Park	45
F8 – Commodore Point, Horseshoe Bay and Freemans Knob	49
F9 – Knights Beach and Boomer Beach.....	55
F10 – Watson’s Gap to Hindmarsh River	61
F11 – Hindmarsh River to Inman River	67
F12 – Inman River to Rosetta Harbor	75
F13 – The Bluff	83
F14 – Petrel Cove to Newland Head	89
F15 – Newland Head to Parsons Beach	95
F16 – Parsons Beach to Tunk Head.....	99
F17 – Tunk Head to Deep Creek Conservation Park	103
F18 – Deep Creek Conservation Park to Fishery Beach	107

F19 – Fishery Beach to Cape Jervis	113
F20 – Cape Jervis to Rapid Head	119
F21 – Rapid Bay	125
F22 – Second Valley to Lady Bay	131
F23 – Lady Bay to Bungala River	137
F24 – Bungala River to SW bank of Carrickalinga Creek	143
F25 – Carrickalinga Creek to Carrickalinga Head	149
F26 – Carrickalinga Head to Myponga Head.....	155
F27 – Myponga to Sellicks.....	161
MA1 – Sellicks Beach.....	167
MA2 – Silver Sands.....	173
MA3 – Snapper Point	179
MA4 – Port Willunga.....	187
MA5 – Maslin Beach	193
MA6 – Moana	199
MA7 – Seaford	205
MA8 – Port Noarlunga	211
MA9 – Christies Beach	217
MA10 – Port Stanvac.....	225
MA11 – Hallett Cove	233
MA12 – Holdfast Bay	239
MA13 – Patawalonga to Point Malcolm	247
MA14 – Le Fevre Peninsula.....	257
MA15/16/17 – Port River–Barker Inlet Estuary.....	265
MA18 – Gawler River	273
MA19 – Middle Beach.....	281
MA20 – Light River Delta	287
MA21 – Port Prime.....	291
MA22 – Thompson Beach	295
MA23 – Parham	299
MA24 – Middle Spit	305
Regional threats, actions and priorities.....	311
Discussion.....	321
Recommendations	321

Opportunities.....	322
Marine parks	322
Seagrass rehabilitation.....	323
Various programs.....	323
Research programs	323
Further work and knowledge gaps	324
Habitat values	324
Links between potential threats and habitat condition	325
Glossary and abbreviations.....	327
References	329

Executive summary

The Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRM Board) has developed a number of strategies in relation to the marine environment, including “A key strategy identified by Board staff and the Coast, Estuary and Marine Advisory Committee in the development of the Regional NRM Plan was *SS7 Support sustainable marine industries*. Within this Strategy Action SS7.1 Protect fisheries habitat has identified the need to: *Conduct a review of The Fisheries Habitat Inventory to assess and prioritise land-based impacts in the region*”.

Thus the broad purpose of the present report is to provide information that will enable the AMLRNRM Board and partners to assess and prioritise land-based impacts and prioritise works based upon coastal fisheries habitat values in the AMLRNRM region. The present report builds upon three key documents: (1) Bryars (2003) “An Inventory of Important Coastal Fisheries Habitats in South Australia” (referred to above as The Fisheries Habitat Inventory), (2) Caton et al. (2007) “Southern Fleurieu Coastal Action Plan and Conservation Priority Study 2007”, and (3) Caton et al. (2009) “Metropolitan Adelaide and Northern Coastal Action Plan 2009”.

The present report was designed to:

- Complement the two Coastal Action Plans (CAPs) within the AMLRNRM region
- Be a natural extension of the CAPs into the subtidal marine environment
- Cover some of the intertidal marine issues that were not covered in the CAPs
- Utilise more recent nearshore marine habitat mapping
- Collate relevant new information since Bryars (2003)
- Provide a finer level of spatial resolution in habitat descriptions and threat analysis than that provided by Bryars (2003)
- Identify and prioritise existing threats to nearshore marine habitats that require action
- Provide an information source that can inform future developments that may impact nearshore marine habitats

The main aims of the report were to:

1. Create a series of ‘marine cells’ that were compatible with the CAPs coastal cells
2. Summarise key information on benthic habitats, habitat values, and threats to habitats within each marine cell
3. Undertake an analysis of threats to habitats within each marine cell
4. Identify and prioritise actions to mitigate land-based threats to habitats at the spatial scales of marine cell and local government area
5. Identify knowledge gaps and areas for further investigation

The main results section of the report provides a separate summary for each of 46 marine cells, as well as regional summaries for six geographical areas within the AMLRNRM region. The individual cell summaries provide detailed information on cell area, benthic habitats, cell values, habitat values, threats, threat analysis, actions and priority, and further investigations. A diverse mix of seagrass, reef and sand habitats exist within the AMLRNRM region and these nearshore marine habitats have considerable value. A number of local and regional actions to address threats to these valuable habitats were identified and it is recommended that these actions be considered by the various identified key players. It is also apparent that a general theme exists across the 46 marine cells in terms of generic threats and general recommended actions to mitigate these threats.

Stormwater and poor quality catchment water were recognised as issues across most of the AMLRNRM region, while the discharge of wastewater from Waste Water Treatment Plants (WWTPs) is an issue for the Adelaide coastline. Other more-localised threats also exist in some parts of the AMLRNRM region. Five of the six geographical areas have a high level of cumulative threats to nearshore marine habitats: northern Adelaide, Holdfast Bay, southern Adelaide, Yankalilla Bay and Encounter Bay. The southern Fleurieu area has a relatively low level of cumulative threats to nearshore marine habitats.

In many cases the major threats to marine habitats within the AMLRNRM region are already recognised and mitigation actions are currently underway or outlined in existing action plans. For example, wastewater, stormwater and poor quality catchment water are accepted as threats to marine habitats and in many places considerable work has already been done or is underway to address these issues; it is highly recommended that these existing initiatives continue to be supported. Examples of existing initiatives that should benefit nearshore marine habitats within the AMLRNRM region include:

- Adelaide Coastal Water Quality Improvement Plan
- Port Waterways Water Quality Improvement Plan
- Coastal Action Plans
- Bolivar Environment Improvement Program
- Water Proofing Northern Adelaide Initiative
- Salisbury Wetlands
- The planned closure of Penrice Soda Factory in 2013
- Port Road Rejuvenation Project
- Glenelg to Adelaide Park Lands Recycled Water Project
- Adelaide's Living Beaches Program
- Water Proofing the South Initiative
- Aldinga Wastewater Storage and Recovery Scheme
- Southern Adelaide Wetlands
- Christies Beach WWTP Upgrade
- Yankalilla, Normanville and Carrickalinga Stormwater Management Plan
- Hindmarsh and Inman River Estuary Action Plans

'Water Sensitive Urban Design' (WSUD) is a concept which integrates the use and management of stormwater, groundwater and wastewater into urban design and which can reduce environmental harm to receiving coastal waters; WSUD should therefore be encouraged in the AMLRNRM region. It is also recommended that future developments and activities are undertaken in a manner that:

- Enables stormwater retention and/or natural filtration before freshwater enters the marine environment
- Does not disturb or degrade coastal landscapes (e.g., dunes, cliffs, hills)
- Does not degrade coastal catchments
- Does not discharge wastewater to the marine environment
- Minimises or eliminates the need for dredging

The above recommendations may seem obvious but the motto “prevention is better than cure” is particularly pertinent for the marine environment where recovery of degraded habitats can be slow or even non-existent. In some respects many of the right things are already being done but more effort is required to ensure that the same mistakes are not repeated and that actions are commenced to address issues that are not currently being addressed or which have not been recognised until now.

There are a number of opportunities that exist through ongoing or new programs and initiatives which may assist with implementing the proposed actions from the present report, assist with the recovery of degraded habitats, or assist with future protection of habitats. Such opportunities include marine parks, seagrass rehabilitation, wetland construction, wastewater reuse, catchment revegetation programs, and research programs.

While nearshore marine habitats are generally accepted as having some value, there is a paucity of information on location-specific species-habitat associations. Without such information it may be more difficult to convince managers of the importance of protecting habitat from damaging activities at specific locations. It is therefore recommended that further biological surveys be conducted in various locations; these are highlighted in each of the cell descriptions of the results section.

In general for the AMLRNRM region there is a lack of seagrass surveys where the associated fauna are sampled, i.e. species-habitat associations are poorly understood. In addition, while a substantial amount of work has been conducted at specific locations such as Outer Harbor, Section Bank, Christies Beach, Port Stanvac and Holdfast Bay in relation to various anthropogenic disturbances, in general there is a lack of biological surveys that assess the epifauna/infauna of seagrass and sand habitats (including bare sand, invertebrate, and macroalgae) across the AMLRNRM region. In particular, in some cells there is a significant amount of pebble/cobble habitat, but no biological surveys have been undertaken on this habitat type and thus their value is unknown. Seagrass species composition is also undescribed or poorly known in many parts of the AMLRNRM region. Thus, a targeted regional survey of seagrass species composition is warranted.

While there may be many knowledge gaps in species-habitat associations, a large amount of biological survey data does already exist for the AMLRNRM region in various disparate forms, including databases and reports. A useful exercise that was beyond the scope of the present report would be the integration of these data sources into a single GIS database such as the Biological Database of SA (BDBSA) which is maintained by DEWNR. Such a database would enable searches for species that are associated with different habitat types in different parts of the AMLRNRM region and would be invaluable for activities such as assessing development proposals and preparing environmental impact assessments.

The present report has highlighted numerous locations where there is potentially a threat to nearshore habitats from a land-based discharge but there were no habitat condition survey data available to inform the threat analysis. In general, cliff top erosion and poor quality catchment flows were identified as low to moderate threats to the condition of inshore reefs and/or seagrass around much of the Fleurieu Peninsula. Further investigation of reef and/or seagrass condition in specific locations is therefore recommended in the following regions:

- Parsons Beach to Deep Creek Conservation Park (reef)
- Deep Creek Conservation Park to Fishery Beach (reef, seagrass)
- Cape Jervis to Rapid Head (reef, seagrass)
- Rapid Head to Lady Bay (reef, seagrass)
- Yankalilla Bay (reef)
- Myponga to Sellicks (reef, seagrass)
- Seaford to Hallett Cove (seagrass)

Numerous reefs were also identified that have been surveyed specifically for reef condition ('Reef Health') previously, but which require an updated survey. Many of these reefs are currently being surveyed through initiatives by the AMLRNRM Board or as part of the Port Stanvac desalination monitoring program. However, the following reefs are not covered by these recent activities:

- Aldinga Reef (last surveyed in 2007 and requires an update on condition status)
- Southport (last surveyed in 2007 and requires an update on condition status)
- Seacliff Reef (last surveyed in 2007 and requires an update on condition status)
- Broken Bottom (last surveyed in 2007 and requires an update on condition status)
- Semaphore Reef (last surveyed in 2007 and requires an update on condition status especially in relation to impending closure of the Penrice Soda Factory)
- Parham Reef (surveyed once in 2007 and which provides a useful comparison for sites further south)

In addition, a number of locally-important reefs off Adelaide were identified which have not been surveyed previously for reef condition (although these are deeper than traditional reef health survey sites):

- Milkies
- Macs Ground
- Northern Outer

Other specific areas around the AMLRNRM region that were identified for further investigation of identified threats include:

- Rapid Bay (current status of quarry gravel train)
- Victor Harbor (historical nearshore seagrass loss and erosion of seabed adjacent to the Inman River)
- Wirrina Cove (sediments smothering seagrass adjacent to southern breakwater)
- Yankalilla River mouth (sediments smothering reef)
- Myponga River mouth (sediments smothering reef)
- Aldinga Reef (sediments smothering reef)
- Site of disused Port Adelaide WWTP sludge outfall (last surveyed in 2007 for natural seagrass recovery and requires an update on recovery status)
- Port Parham (seagrass scouring and erosion in boating channel)
- Middle Spit (impact of Defence Force range bombing)

Introduction

Purpose of the report

The Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRM Board) has developed a number of strategies in relation to the marine environment, including:

“A key strategy identified by Board staff and the Coast, Estuary and Marine Advisory Committee in the development of the Regional NRM Plan was *SS7 Support sustainable marine industries*. Within this Strategy Action SS7.1 Protect fisheries habitat has identified the need to: *Conduct a review of The Fisheries Habitat Inventory to assess and prioritise land-based impacts in the region*”

Thus the broad purpose of the current project is to provide information that will enable the AMLRNRM Board and partners to assess and prioritise land-based impacts and prioritise works based upon coastal fisheries habitat values in the AMLRNRM region.

Background to the report

The present report builds upon three key documents:

1. Bryars (2003) “An Inventory of Important Coastal Fisheries Habitats in South Australia” (referred to above as The Fisheries Habitat Inventory)
2. Caton et al. (2007) “Southern Fleurieu Coastal Action Plan and Conservation Priority Study 2007”
3. Caton et al. (2009) “Metropolitan Adelaide and Northern Coastal Action Plan 2009”.

Bryars (2003) developed an inventory and habitat maps across South Australia (SA) using 12 habitat types that were considered to be important to the various life stages of 43 fisheries taxa. While Bryars (2003) not only documented habitats that were important to fisheries species, he also provided a broad-scale threat analysis of these habitats. Unfortunately, the natural extension of prioritising the threats and then implementing mitigation activities was never undertaken following the release of the Bryars (2003) report. Furthermore, the mapping and threat analysis was at a very broad-scale compared to the AMLRNRM region and since that time a number of activities have occurred that warrant a revisit of ‘The Fisheries Habitat Inventory’. These activities include: new benthic habitat mapping (DEH 2008), various investigations of the “health condition” of marine habitats (e.g. Collings et al. 2008), collection of catchment and water quality data (e.g. Wilkinson et al. 2005, Fernandes et al. 2008, 2009, 2010), development of various estuary action plans (AECOM Australia Pty Ltd 2010, SKM 2010a, b), and the re-evaluation of threats since Bryars (2003) (e.g. Caton et al. 2007, 2009; Gaylard 2009, EBS Ecology 2010a, b).

Caton et al. (2007, 2009) in their two ‘Coastal Action Plans’ (or CAPs) of the AMLRNRM region assessed the conservation value of coastal habitats and associated species, and prioritised a number of actions based upon a threat analysis to the conservation values. The CAPs focused on coastal terrestrial habitats and species, with inclusion of intertidal habitats in some areas. To enable their respective studies, Bryars (2003) divided the coast into 62 Fisheries Habitat Areas, while Caton et al. (2007, 2009) divided the AMLRNRM region into 51 coastal cells. Unlike the CAPs, Bryars (2003) did not attempt to rank locations based on a value system; rather all habitats that were utilised by the fisheries taxa were considered as ‘important’.

Scope and aims of the report

The present report was designed to:

- Complement the CAPs within the AMLRNRM region
- Be a natural extension of the CAPs into the subtidal marine environment
- Cover some of the intertidal marine issues that were not covered in the CAPs
- Utilise the nearshore marine habitat mapping of DEH (2008)
- Collate relevant new information since Bryars (2003)
- Provide a finer level of spatial resolution in habitat descriptions and threat analysis than that provided by Bryars (2003)
- Identify and prioritise existing threats to nearshore marine habitats that require action
- Provide an information source that can inform future developments that may impact nearshore marine habitats

Since the rudimentary mapping work of Bryars (2003) (and also Edyvane 1999a, b), the nearshore marine benthic habitats of the entire AMLRNRM region have been mapped at a much finer scale out to a depth of around 20 m (DEH 2008). The DEH habitat maps provided the basis for the present report.

Bryars (2003) considered habitats that were important to fisheries species and covered the entire State. The present report evaluates habitats that are important to both fisheries and non-fisheries species, but is restricted to the AMLRNRM region which extends from Middle Spit in upper NE Gulf St Vincent around Fleurieu Peninsula to Middleton in Encounter Bay (Figure 1). Due to its large size and topography, the AMLRNRM region has a wide range of habitats including mangrove forests, saltmarshes, seagrass meadows, reefs, and sandy plains. As some of these habitats were covered in the CAPs, the present report did not consider all habitat types (see 'Habitat classifications' in Methods later). The intertidal habitats of saltmarsh and mangrove were covered in the two CAPs and were not included in the present report. Intertidal reefs and intertidal sand- and mud-flats (including beaches) were included in the present report as they were generally included in the DEH (2008) benthic mapping and were inconsistently reported on in the CAPs (Caton et al. 2007, 2009).

A wide range of threats exist for the marine environment (see Bryars 2003, Marine Biodiversity Decline Working Group 2008). A limited suite of these threats were selected for assessment in the present report, with a deliberate focus on land-based impacts. A summary of threats is provided in the next section.

The main aims of the present report were to:

1. Create a series of 'marine cells'
2. Summarise key information on benthic habitats, habitat values, and threats to habitats within each marine cell
3. Undertake an analysis of threats to habitats within each marine cell
4. Identify and prioritise actions to mitigate land-based threats to habitats at the spatial scales of marine cell and local government area
5. Identify knowledge gaps and areas for further investigation.

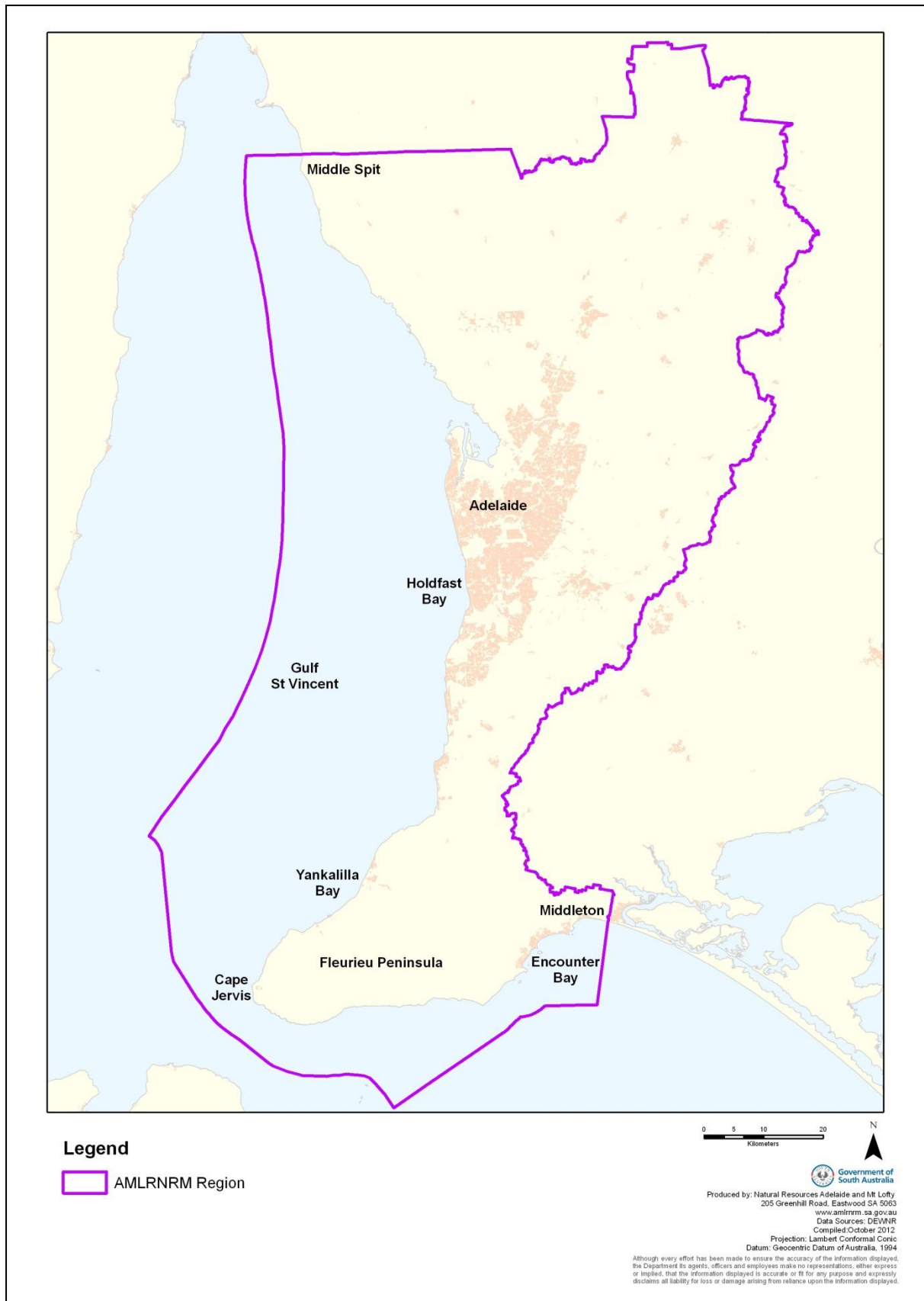


Figure 1. Map showing the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLRNRM) region.

Threats to marine habitats

Key threats

Maintenance of nearshore marine habitats in good condition is critical to the ongoing sustainability and conservation of marine ecosystems in the AMLRNRM region as they form the basis of many food chains. If these habitats are degraded in some way, then species assemblages and ecosystem processes can change. While the importance of nearshore marine habitats is recognised world-wide, marine habitats across the world are under increasing pressure from a range of human-mediated activities and uses (Marine Biodiversity Decline Working Group 2008). The AMLRNRM region is no different; for example, the largest population centre in SA, Adelaide, is situated directly adjacent to Gulf St Vincent (see Figure 1); numerous regional settlements occur around the coastline; and various land-based and marine-based activities and uses occur across the region.

The key threats to marine biodiversity can be categorised as land-based impacts, resource use, marine biosecurity, marine pollution, and climate change (Marine Biodiversity Decline Working Group 2008). DEH (2008) listed current threats to marine environments in Gulf St Vincent as commercial and recreational fisheries, aquaculture, dredging, tourism, transport, mining, waste and stormwater disposal, coastal development/urbanisation and declines in water quality from catchments. Within Gulf St Vincent (and thus much of the AMLRNRM region), many of the key threatening activities to benthic habitats are well documented and include wastewater and stormwater discharges, declines in water quality from catchment flows, dredging, coastal developments, invasive pests and benthic prawn trawling (e.g., see various chapters in Shepherd et al. 2008). However, key threats to marine habitats outside of Gulf St Vincent but still within the AMLRNRM region (i.e. southern coast of Fleurieu Peninsula and Encounter Bay) are less well-documented and understood.

Nutrients and sediments

The actual cause of historical habitat loss or degradation from threatening activities within eastern Gulf St Vincent is generally related to increased levels of nutrients and/or sediments, and also physical disturbance (see next section). Our knowledge base on the mechanistic effects of nutrients and sediments, in particular, on seagrass meadows and macroalgal-dominated reefs has expanded significantly in the past 10 years (e.g. Gorgula and Connell 2004, Russell and Connell 2005, Russell et al. 2005, Connell et al. 2008, Bryars et al. 2011); it is evident from this work that under certain conditions our local reef and seagrass systems can be highly sensitive to even slight increases in nutrients and sediments. It is now generally accepted that increased levels of nutrients can encourage the growth of epiphytes on seagrasses and macroalgae and that under certain conditions the epiphytes can be damaging to the hosts. Sediments can also be damaging through a number of mechanisms but it is now believed that increased sedimentation (and possibly also in conjunction with elevated nutrients) can cause a shift from canopy-forming macroalgae to turfing macroalgae on reefs. In addition, sediment-mediated turfing macroalgae also have potential to affect gorgonian corals (Linares et al. 2012) and possibly other sessile invertebrates on reefs where these species occur (e.g. Aldinga Reef).

Nutrient and sediment inputs to the AMLRNRM coastal region currently occur from a number of freshwater sources including catchment water, stormwater and wastewater (e.g. see Wilkinson et al. 2005). However, it is apparent that prior to European settlement, there were relatively few

freshwater inputs to the coastline around Fleurieu Peninsula and in cases where they did naturally occur the freshwater would likely have had low levels of nutrients and sediments due to natural filtration through native riparian vegetation or coastal dune systems (e.g. see various chapters in Daniels 2010). It is also likely that any flows to the sea would have been steady rather than highly pulsed as is often the case now following heavy rains due to rapid run-off from hard urban surfaces and cleared rural land, as well as sudden discharges from reservoirs. Whilst some estuaries in the AMLRNRM region were a natural part of the coastal system (and as such some freshwater discharges to the marine environment were also natural), the current issue with many of these estuaries is that their catchments have been degraded through clearance of native vegetation, urbanisation and/or flow reduction such that freshwater inputs are highly pulsed and often have high levels of nutrients and/or sediments. Thus, it appears that marine habitats around Fleurieu Peninsula are acclimatised to relatively clear and oligotrophic (low nutrient) coastal waters that received only minor inputs of freshwater with low levels of sediments and nutrients; an historical situation that is quite different to the current situation in many parts of the AMLRNRM region.

Physical disturbance

The threat to marine habitats from physical disturbance is unambiguous. Activities such as dredging, breakwater construction and prawn trawling (see Fishing below) all have an impact on benthic habitats. As the focus of the present report was on nearshore seagrass, reef and sand habitats, activities such as dredging were included in the threat analysis (see later).

Other threats to marine habitats

In addition to nutrients, sediments and physical disturbance there are a number of other potential threats to marine habitats within the AMLRNRM region. These other threats were not dealt with specifically in the current study but are discussed here briefly and some aspects were also noted in the threat analysis (see later).

Climate change (ocean acidification, sea level rise, temperature changes)

Climate change is recognised as a global threat to marine habitats (Marine Biodiversity Decline Working Group 2008), including those within the AMLRNRM region. Caton et al. (2007, 2009) predicted a number of impacts to coastal habitats due to climate change within the AMLRNRM region. Clarke and Simpson (2010) later summarised the climate change predictions from Caton et al. (2007, 2009); their predicted changes/impacts and implications for marine habitats (rather than terrestrial coastal habitats) are summarised in Table 1.

As many of the predicted impacts of climate change are general in nature (e.g. sea level rise) and are dealt with in detail by Clarke and Simpson (2010), it was deemed unnecessary to document them for individual marine cells in the present report. Nonetheless, it is apparent that in some cells the potential impacts will be greater than others due to the different habitat types and topography within each cell. For example, the impacts of sea level rise will be most pronounced on saltmarshes and mangroves in the northern cells to where they are restricted, while in the southern cells sea level rise will be most pronounced on intertidal reefs. Furthermore, climate change may exacerbate present-day threats such as cliff top erosion that leads to increased turbidity and sedimentation of nearshore reefs. Thus, whilst climate change is not covered in the present report, it is certainly acknowledged as a serious threat to marine habitats.

Table 1. Summary of predicted changes and impacts from climate change on marine habitats (adapted from Clarke and Simpson 2010).

Predicted change (from Clarke and Simpson, 2010)	Predicted impact (from Clarke and Simpson, 2010)	Implications for marine habitats
Reduced winter and spring rains (increased aridity)	Estuarine flora and fauna species more vulnerable due to reduced river flows	Some estuaries will become degraded
Temperature rise	Reduction in geographic range of species and ecological communities – affecting distribution, range and abundance of a variety of species (flora and fauna)	Some habitats will shift or disappear
Altered storm frequency and storms of greater magnitude	Increased erosion of clay marl, aeolianite (Caton et al. 2007: p.120) and limestone cliffs from wave erosion (Caton et al. 2009, MA4: no page number)	Nearshore habitats will experience increased turbidity and sedimentation
	Increased erosion of coastal slopes and cliffs from gulying during peak storm events	Nearshore habitats will experience increased turbidity and sedimentation
	Altered beach form, especially at sand beaches	Some beaches will become degraded
	Increased pulses of stormwater exiting to beach and coastal environment	Nearshore habitats will experience increased turbidity and sedimentation
Altered wave climate	Possible increased frequency of long period swell (particularly significant for the Southern Fleurieu where waves are very powerful)	Nearshore habitats will experience increased erosion and disturbance
	Possible changed littoral drift speeds in some places, altering patterns of erosion and deposition	Nearshore habitats will experience increased erosion or increased sedimentation
Sea level rise	Beach recession of between 5–30 metres by 2050 (variation dependant on beach topography, sand supply and littoral sediment movement)	Some beaches will become degraded
	Recession of sand barriers in some places	Some beaches will become degraded
	Changed composition of marine life on nearshore reefs	Some nearshore reefs will become degraded or change
	Saltmarsh, mangrove, swamp paper bark and supra-tidal samphire migration landwards	Some intertidal habitats will shift distribution while others will reduce in range
Increased acidity of gulf waters	Possible detrimental effects on ecological communities by 2050	Some habitats may become degraded or change if habitat-forming species are affected

Marine pollution

The term 'marine pollution' can cover many things including discharges of wastewater and stormwater, oil spills, and discarding of litter. Nutrients and sediments which are also constituents of wastewater and stormwater were discussed earlier and are a particular focus of the present report (see later).

Recent investigations have revealed the potential threat to the marine environment in parts of the AMLRNRM region (i.e., Barker Inlet) from persistent organic pollutants in wastewater treatment plant discharges (Fernandes et al. 2010). However, it was felt that such pollutants were likely to act at the species population level rather than impacting habitat integrity and as such they were not recognised as a key threat within the context of the present report. Nonetheless, the potential exists for such pollutants to impact on sediment infauna which play a key functional role in sand habitats.

Major oil spills during shipping activities are an ongoing threat to intertidal habitats throughout SA. While the likelihood of an accidental major oil spill may be low, the consequences can be major. In addition, the risk of an oil spill is not necessarily related to the locality of port facilities or shipping lanes; as evidenced by the *Era* oil spill in Spencer Gulf where, due to winds and currents, the oil actually came ashore on the opposite side of Spencer Gulf to where the accident occurred. Thus, undertaking a threat analysis for potential oil spills is inherently complex. As the present report is focused on land-based threats, oil spills were not included in the current threat analysis.

Pollution from marine litter (or debris) is a significant issue in the AMLRNRM region with potentially negative impacts on the marine environment (Peters and Flaherty 2011). Whilst marine litter is recognised as a threat to the marine organisms within the AMLRNRM region (particularly through ingestion and entanglement), it does not represent a major threat to habitat condition and as such was not considered further in the present report.

Aquaculture

Some forms of aquaculture can have negative impacts on marine habitats. However, aquaculture was not considered as a threat to marine habitats in the AMLRNRM region as there are no active aquaculture zones within the AMLRNRM region.

Invasive pest species

Wiltshire et al. (2010) provide a detailed summary of introduced marine species in SA, including within the AMLRNRM region. It is apparent that the threat of introduced marine pests is an ongoing issue and that there are numerous species of concern for ecosystems within the AMLRNRM region (see also Westphalen 2008). It was deemed to be beyond the scope of the present report to undertake a risk assessment of the many species already occurring in the region or which might become established. However, an exception to this rule was the two introduced macroalgal species *Caulerpa taxifolia* and *C. racemosa* var. *cylindracea*, which have the potential to change the fundamental characteristics of subtidal soft-bottom habitats such as seagrass meadows and unvegetated soft sediments. Thus, they were included in the threat analysis for the few locations in the AMLRNRM region where they are known to occur. Exotic diseases were not assessed in the present report, but are acknowledged to be a threat to marine species (e.g. the recent abalone virus outbreak in the SE of SA).

Fishing

Overfishing and illegal fishing are recognised threats to species populations and in extreme cases they could influence the habitat structure itself through cascading ecosystem effects. However, fishing (except for prawn trawling – see below) was not considered as a habitat threat in the context of the present report. In addition, the impacts of fishing on species populations are accepted under an Ecologically Sustainable Development (ESD) management framework and the activity is temporally- and spatially-managed by PIRSA Fisheries. However, an exception to this rule was illegal harvesting within protected areas such as the intertidal rocky shore in SA and existing aquatic reserves. In cases where these types of illegal activity are thought to occur, they were included in the description of threats but not the formal threat analysis.

Benthic prawn trawling has been linked to broad-scale changes in deep water benthic habitats throughout Gulf St Vincent (see Tanner 2002). Prawn trawling is known to impact benthic habitats through the physical removal or damage of sessile and sedentary invertebrates such as sponges, razorfish, and hammer oysters. However, while prawn trawling is a recognised threat to benthic habitats in Gulf St Vincent (e.g. Tanner 2002), the impacts of trawling are accepted under an ESD management framework and the activity is temporally- and spatially-managed by PIRSA Fisheries. In addition, prawn trawling in Gulf St Vincent generally occurs in deeper waters beyond the offshore extent of the marine habitat mapping used in the current study. Thus, prawn trawling was not included in the threat analysis.

Methods

The following sections describe the key steps that were required to prepare the present report.

Marine cells

The nearshore marine environment needed to be separated into a number of identifiable spatial units or cells that were compatible with the CAPs coastal cells (see Figure 2).

The CAPs utilised a total of 51 coastal cells (F1–F27 in the Southern Fleurieu CAP, see Caton et al. 2007; and MA1-MA24 in the Metropolitan and Northern CAP, see Caton et al. 2009). For the purposes of consistency, the present report built upon the 51 coastal cells and extended them into the marine environment. Thus, a number of ‘marine cells’ were created that, in most cases, directly abutted the existing coastal cells and extended seaward to the extent mapped by DEH (2008). The exceptions to this rule were:

- F1, F2 and F3 which were excluded from the present report as they lie outside of the AMLRNRM region.
- For the Port River-Barker Inlet estuary, a single ‘marine cell’ was recognised that abutted cells MA15, MA16 and MA17. However, a further complication for this cell was that benthic habitat mapping has not been undertaken by DEH for a large part of the Port River-Barker Inlet system with habitat data being restricted to the Barker Inlet.
- Additional mapping to that depicted in DEH (2008) was available for the upper Gulf St Vincent area (note that since the time of the DEH (2008) report, the AMLRNRM northern boundary has been extended northwards to Middle Spit in upper Gulf St Vincent).

Thus, a total of 46 marine cells were created: F4–F27, MA1–14, MA 15/16/17, and MA 18–MA24 (Figure 2). The numbering (and naming) of marine cells was created in this manner (rather than simply using 1–46) to directly align with the coastal cells in the CAPs.

The delineation of boundaries between marine cells was simply based upon the alongshore coastal cell boundaries, while the offshore direction of the marine cell boundaries tended to follow a perpendicular direction from the coast; it was felt that the precise direction of this boundary was not critical as most of the land-based threats act close to shore and in many cases there was overlap in threatening processes between adjacent marine cells anyway (e.g. nutrient discharge from a Waste Water Treatment Plant (WWTP) outfall will not stop at an imaginary marine cell boundary and therefore needs to be acknowledged in both marine cells either side of a boundary).

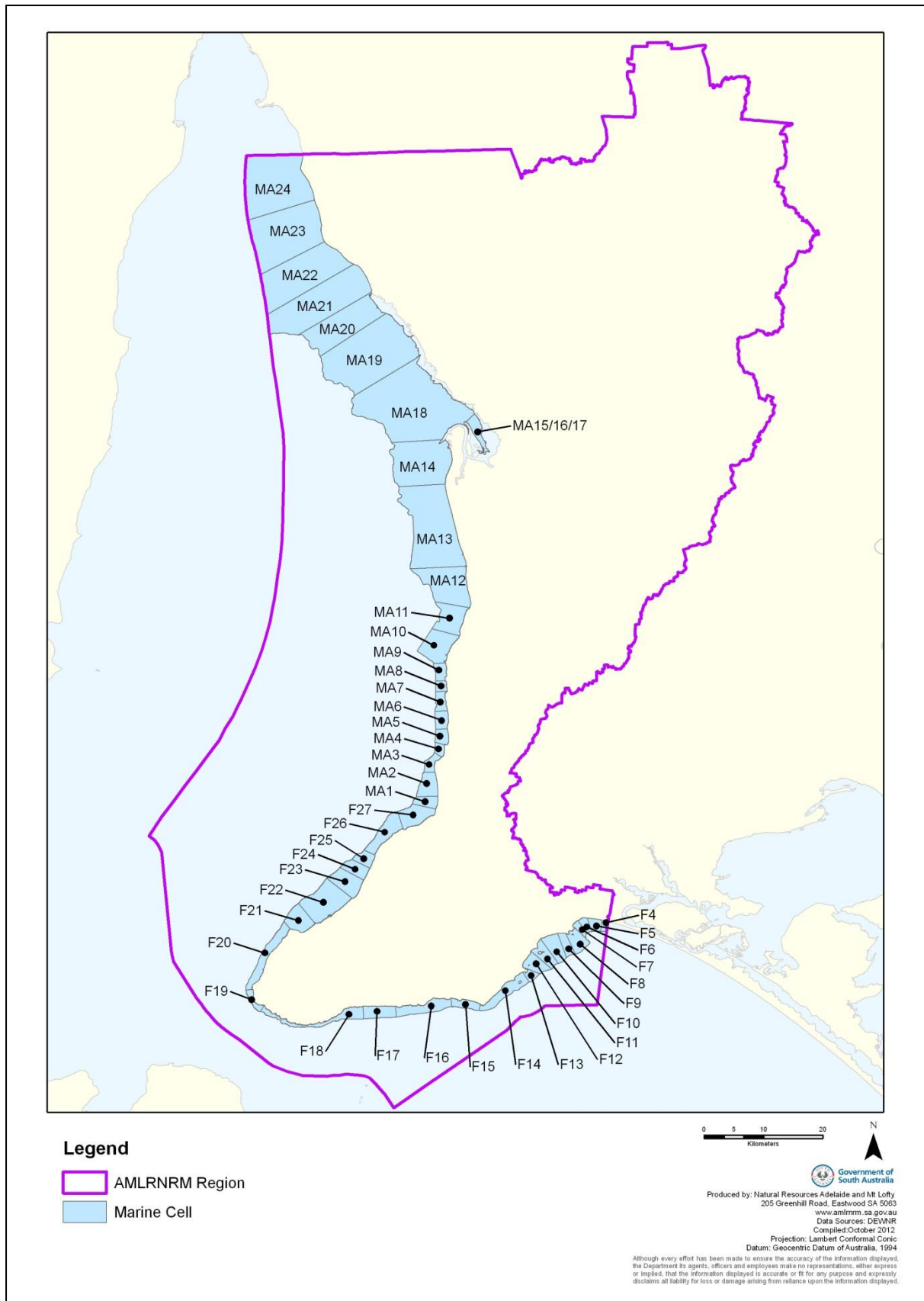


Figure 2. Map of the AMLRNRM region showing the 46 marine cells used in the current study.

Habitat classifications

Detailed information was required on the spatial coverage and distribution of different habitats within each marine cell. A classification system of different habitats was also required that would be suitable for informing the threat analysis and for guiding actions. It was decided that three main habitat groups would be used for describing ecological processes, values and threats, etc. (see later sections): seagrass, reef and sand. Such an approach was chosen for simplicity and also reflects a general lack of understanding about more specific habitat types within the broader habitat groups. Nonetheless, more specific habitat types were utilised for the mapping and habitat descriptions.

A GIS database or layer was supplied by DEWNR that covered the spatial area described in the previous section. DEH (2008) defined 18 habitat types within three broad categories (seagrass, reef, soft bottom) in their mapping of the AMLRNRM region that were relevant to the current study (Table 2).

Table 2. Habitat classifications defined in DEH (2008) that were relevant to the present report.

Habitat group	Habitat type
Seagrass	Seagrass, Continuous, Dense
	Seagrass, Continuous, Medium
	Seagrass, Continuous, Sparse
	Seagrass, Patchy, Dense
	Seagrass, Patchy, Medium
	Seagrass, Patchy, Sparse
Reef	Reef, Continuous, High Profile
	Reef, Continuous, Medium Profile
	Reef, Patchy, Medium Profile
	Reef, Continuous, Low Profile
	Reef, Patchy, Low Profile
Soft bottom	Invertebrate Community, Patchy, Medium
	Invertebrate Community, Patchy, Sparse
	Macroalgae, Continuous, Medium
	Macroalgae, Continuous, Sparse
	Macroalgae, Patchy, Medium
	Macroalgae, Patchy, Sparse
	Unconsolidated Bare Substrate, Continuous

One of the habitat types listed in Table 2 (i.e., Reef, Patchy, Medium Profile) did not actually exist in the GIS database and was therefore excluded. An additional two habitat types under 'saltmarsh/mangrove' that were present in the GIS database (but not shown in Table 2) were not utilised in the current study as these habitats were addressed in the CAPs, they were only partly mapped in DEH (2008), and they were outside the scope of the current study. Due to the habitat classification method utilised in DEH (2008) there were an additional five habitat types within the GIS database that were also not listed in Table 2, but which were associated with a gravel/pebble or cobble substrate that did not logically fit into the habitat groups of seagrass, reef or sand; these habitats were grouped under a fourth category of 'other' for the present report. Unconsolidated bare substrate that was on sand or silt/clay substrate was labelled as 'bare sand' in the present report. So, in total, 22 habitat types were utilised for the current study (Table 3, Figure 3). The areal

coverage and proportions of each of the 22 habitat types, as well as the four habitat groups, were calculated and summarised for each marine cell.

Table 3. Habitat classifications utilised in the present report.

Habitat group	Habitat type
Seagrass	Seagrass, Continuous, Dense
	Seagrass, Continuous, Medium
	Seagrass, Continuous, Sparse
	Seagrass, Patchy, Dense
	Seagrass, Patchy, Medium
	Seagrass, Patchy, Sparse
Reef	Reef, Continuous, High Profile
	Reef, Continuous, Medium Profile
	Reef, Continuous, Low Profile
	Reef, Patchy, Low Profile
Sand	Invertebrate Community, Patchy, Medium
	Invertebrate Community, Patchy, Sparse
	Macroalgae, Continuous, Medium
	Macroalgae, Continuous, Sparse
	Macroalgae, Patchy, Medium
	Macroalgae, Patchy, Sparse
	Sand, Bare, Continuous
Other	Gravel/Pebble, Bare, Continuous
	Gravel/Pebble, Macroalgae, Continuous, Medium
	Gravel/Pebble, Macroalgae, Patchy, Medium
	Gravel/Pebble, Macroalgae, Patchy, Sparse
	Cobble, Macroalgae, Patchy, Medium

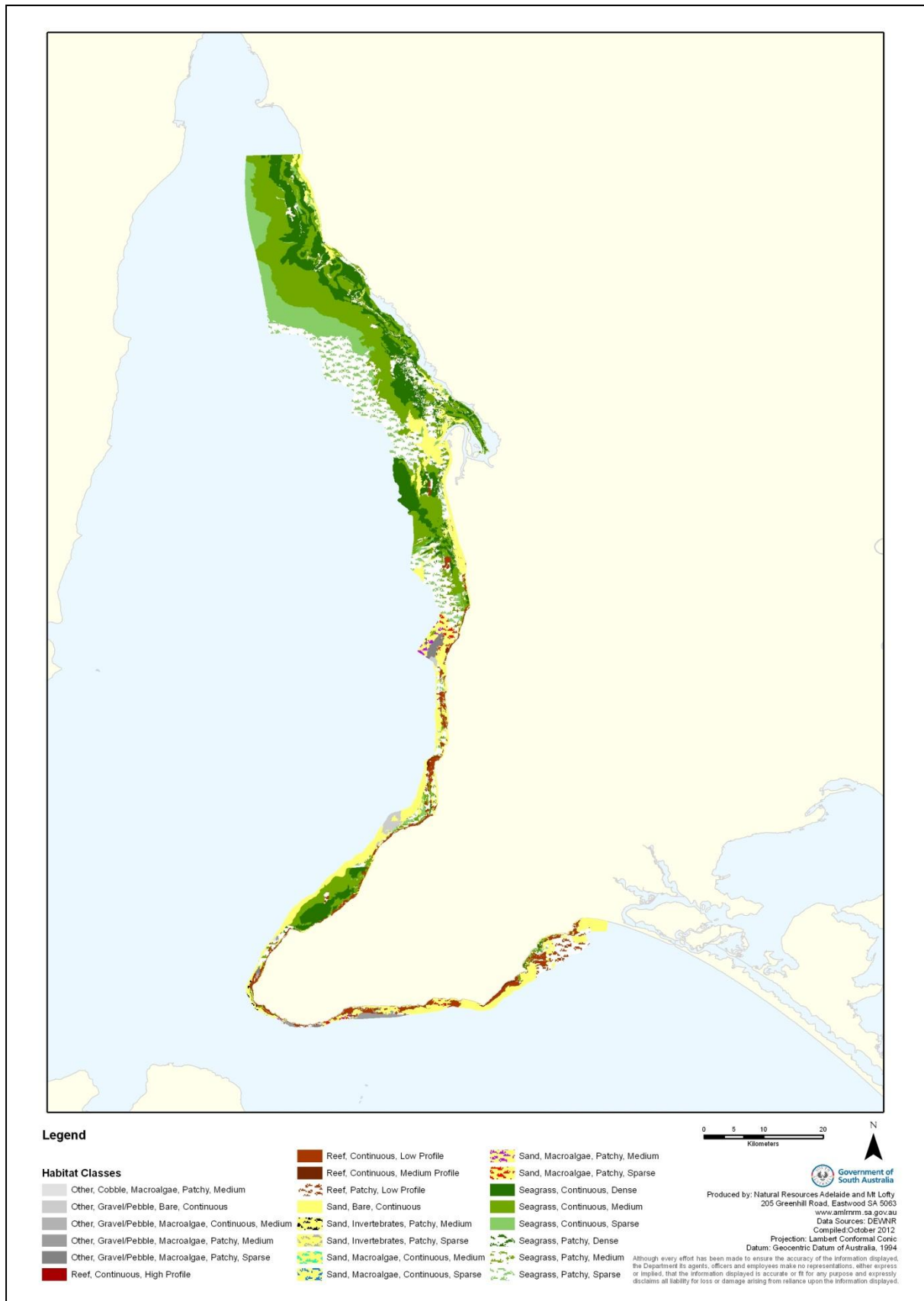


Figure 3. Map showing the distribution of the 22 habitat types across the 46 marine cells within the AMLRNRM region.

Habitat values

All marine habitats have some inherent value in terms of ecosystem services. At the simplest level, some species may have a close association with certain habitats or a species may define the habitat itself (e.g. seagrass). Within this context, a vast array of species is associated with the various habitats in the AMLRNRM region and there is a considerable amount of data available that documents these species groups (e.g. fishes, macroinvertebrates, benthic infauna, macroalgae, plants, birds, and marine mammals). However, it was beyond the scope of the present study to consider all of these species groups. Coastal birds and marine mammals were summarised in the CAPs and as such are not discussed in the present report. The present study instead focused on summarising the diversity of fishes and macroinvertebrates associated with different habitats, as well as the diversity of macroalgae and seagrasses that contribute to reef and seagrass habitats, respectively. Even then, it was beyond the scope of the current study to collate into a single GIS database all of the disparate databases from the various studies on fishes, invertebrates, macroalgae, and seagrasses.

Habitat values for the present study were simply summarised by detailing the main outcomes from published biological surveys (as well as anecdotal information from local experts) within the different marine cells. While habitat values were summarised, they were not given a numerical weighting (as was done in the CAPs). It was felt that doing so was inappropriate given the general lack of knowledge about species inventories across the region and inherent problems with anthropomorphising different habitats; all habitats are valuable in some way, yet to the human eye a colourful reef may appear more valuable than an apparently bare sandy seabed. In addition, it is apparent that species-habitat associations are highly complex and difficult to generalise (e.g. see McDonald 2008). Furthermore, DEWNR have recently documented conservation values for the Encounter Marine Park which encompasses a large proportion of the AMLRNRM region. The marine parks process has also attempted a prioritisation of areas of high conservation value and it was felt unproductive to attempt a similar exercise.

Threats and Threat Analysis

Bryars (2003) identified a wide range of threatening processes to marine and estuarine habitats throughout SA. However, within the context of the known threat from nutrients/sediments and the responsibilities of the AMLRNRM Board, the present report focuses heavily on threats from land-based discharges and some other activities that result in physical disturbance. Thus, key threatening processes that were specifically highlighted and assessed in the present report are:

- Stormwater (drains direct from urbanised areas)
- Wastewater (wastewater treatment plant outfalls and industrial discharges)
- Catchment water (poor water quality due to degraded catchments, coastal cliff erosion, indirect urban stormwater)
- Physical disturbance (dredging, anchoring, trampling, bait digging, crab raking, off-road vehicle use, erosion, sedimentation, smothering by invasive *Caulerpa* species)

The threat analysis was based upon the AS/NZS 4360:1999 risk management framework as outlined in Fletcher et al. (2002) (NB. AS/NZS 4360-1999 has since been superseded by AS/NZS 4360:2004, which was then superseded by AS/NZS ISO 31000:2009; however, the risk assessment process is essentially the same). The threat analysis or risk assessment uses a risk matrix comprised of the

consequence and likelihood of a threat occurring (see Tables 4–6). The consequence table was adapted from Fletcher et al. (2002) using the table for ‘impacts of fisheries on habitats’. It should be noted that alternative (albeit similar) risk assessment frameworks are available (e.g. Campbell and Gallagher 2007), however, the method used here provided a reasonably consistent framework for comparing threats across cells that could then be used to prioritize actions. The risk assessment involves a number of steps: (1) a risk is identified, (2) the likelihood of the risk occurring is evaluated (Table 4), (3) the consequence of the risk occurring is evaluated (Table 5), and (4) a risk value is calculated by multiplying the likelihood value by the consequence value, which is then assigned to a risk category (Table 6). It must be noted that when assessing the risk, the likelihood of the threat or event occurring is a conditional probability. For example, if assessing the risk of an oil spill from shipping activities on mangrove habitat found at a port, while the consequence of the spill could potentially be major, the likelihood of the major consequence actually occurring is probably unlikely.

Table 4. Consequence levels for negative impacts on habitats (modified from Fletcher et al. 2002 to suit the current study).

Level	Impact on habitat
Negligible (0)	No measurable level of negative impact.
Minor (1)	Measurable level of negative impact that is highly localized or affecting <5% of total habitat area.
Moderate (2)	Measurable level of negative impact that is affecting 5–25% of total habitat area.
Severe (3)	Measurable level of negative impact that is affecting 25–50% of total habitat area.
Major (4)	Measurable level of negative impact that is affecting 50–75% of total habitat area.
Catastrophic (5)	Measurable level of negative impact that is affecting >75% of total habitat area. Entire habitat may be impacted.

Table 5. Likelihood levels for negative impacts on habitats (from Fletcher et al. 2002).

Level	Descriptor
Likely (6)	It is expected to occur
Occasional (5)	May occur
Possible (4)	Some evidence to suggest this is possible here
Unlikely (3)	Uncommon, but has been known to occur elsewhere
Rare (2)	May occur in exceptional circumstances
Remote (1)	Never heard of, but not impossible

Table 6. Risk ranking categories based on risk values (from Fletcher et al. 2002).

Risk ranking	Risk value
Negligible (N)	0
Low (L)	1–6
Moderate (M)	7–12
High (H)	13–18
Extreme (E)	>19

The following notes about the threat analysis methodology should be recognized when interpreting any outcomes:

- Impacts were assessed at the spatial scale of the marine cells. Thus it is a reductionist approach that does not account for cumulative impacts across multiple cells. In addition, it may downplay the spatial significance of an impact if there is a relatively large area of a habitat type within a cell, i.e., while the area of habitat affected may be small in relation to the total area of habitat, the actual spatial area could be very large; seagrass loss off Adelaide would be a good example of this situation.
- Threats were assessed within a 5-year timeframe and as such, long-term impacts such as climate change are not factored in. However, it must be acknowledged that climate change may exacerbate existing threats such as cliff top erosion that leads to increased turbidity and sedimentation of nearshore reefs (see Table 1 earlier).
- The risk assessment was undertaken solely by the author who has extensive experience in the use of the Fletcher et al. (2002) framework (e.g. Theil et al. 2004). Nonetheless, there was obviously some level of subjectivity associated with the outcomes from this approach.
- A number of sources of information were utilized to inform the assessment, including aerial photographs (to view possible catchment and coastal degradation/erosion, nearshore sediment plumes from land-based discharges), GIS layers (to view townships, land use, catchment size, water courses entering the marine environment, etc), published information on threats and historical habitat impacts, and published information on land-based discharges (e.g. volumes, nutrient/sediment loads).
- Threats were assessed based upon impacts to the habitat itself; i.e. the substrate and habitat-forming species that define it. In this context, reefs are defined by a hard substrate and a cover of macroalgae and/or sessile invertebrates, seagrass meadows are defined by a soft substrate and a dominant cover of one or more seagrass species, and sand habitats are defined by a soft substrate that is sometimes bare but often with an invertebrate and/or macroalgal assemblage (note that the infauna can also be a critical component of sand habitats).
- The threat analysis deliberately focused on stormwater, catchment water and wastewater due to the known threat from these land-based sources on coastal habitats and the on ground mitigation works that are often possible.
- Threats were often assessed in isolation, e.g. stormwater from a town and catchment water from a nearby creek. In reality the two potential sources of nutrients/sediments may act synergistically on nearshore habitats and collectively represent a greater threat than in isolation.
- While undertaking the threat analysis there was a need to distinguish between known current threats with good causal evidence (e.g. Glenelg WWTP outfall), potential current threats with poor causal evidence (e.g. coastal erosion), and potential future threats (e.g. new coastal developments, desalination plants). Damaging historical activities or events that no longer occur were not considered, e.g. impact of the decommissioned Port Adelaide WWTP sludge outfall on offshore seagrass loss off Adelaide; construction of Wirrina marina. However, activities that have already resulted in damage but which are continuing to have an impact were considered as a known current threat (even though the damage may have ceased to a large degree) e.g. impact of Glenelg WWTP outfalls on inshore seagrass loss off

Adelaide; sedimentation due to the existence of a breakwater. In these cases, if the threat is removed then there is potential for recovery of the habitat.

- The risk assessment doesn't account for long-term impacts on habitats in terms of recovery ability, e.g. seagrasses in some locations may not recover for decades whereas a reef system may recover far quicker.
- For the purposes of the threat analysis, stormwater was defined as freshwater that is derived from urban surfaces and which enters the marine environment directly via a constructed drain or indirectly via catchment water. Catchment water was defined as freshwater that is derived principally from rural and/or natural surfaces and which enters the marine environment directly via a creek or river channel; note that these situations often include an estuary habitat. However, it was sometimes difficult to separate the two sources where stormwater and catchment water are combined and enter via a single channel, e.g. The Torrens River off Adelaide, and in these cases the sources were combined for assessment.
- While a quantitative measure of total habitat area affected by a given threat was assigned to the consequence levels, they are a guide only; rarely is the exact area of impact known in a system.
- In general, there was a lack of data for stormwater and catchment water (e.g., discharge volume to sea, nutrient/sediment loads) that could be used to inform the threat analysis. Consequently, there was a considerable element of intuition, best available information and local knowledge in the threat analyses. For example, a large catchment that is cleared of native vegetation, and which has urban development and no stormwater treatment processing prior to catchment water entering the sea will likely have a higher nutrient/sediment load than a small catchment that is covered with native vegetation. Nonetheless, the risk assessment of threats to water quality by Gaylard (2009) was a useful guide for identifying the major anthropogenic land-based inputs within the Gulf St Vincent part of the AMLRNRM region. The Wilkinson et al. (2005) report from the Adelaide Coastal Waters Study was also invaluable for the Adelaide metropolitan coastline.
- The occurrence of 'Other' habitat types was relatively minor compared to seagrass, reef and sand across the nearshore AMLRNRM region and it was felt that their omission from the threat analyses would not affect the broad outcomes of the study. Furthermore, the ecological value of gravel/pebble and cobble substrates is unknown and threatening processes to such habitats are also difficult to identify.
- Three broad habitat types were utilized for the threat analysis: reef, seagrass and sand. It is recognized that this grouping makes the method simplistic because different sub-categories of habitat and local factors may result in different responses to a threat. For example, it appears that *Amphibolis* seagrass is more sensitive to increased nutrients than *Posidonia* seagrass, and that the amount of wave energy could possibly influence this response (Bryars 2009, Bryars et al. 2011). However, it was beyond the scope of the present report to assess habitats at lower levels of sub-classification than reef, seagrass and sand. Nonetheless, some localized factors were taken into consideration when assigning consequence and likelihood for the three broad habitat types. For example, it is possible that seagrass in a sheltered environment will be more negatively influenced by increased nutrient levels than seagrass in an exposed environment where epiphytes may be naturally cleaned (Bryars 2009). Another example is reef adjacent to a surf beach in a high wave energy environment that may be

better adapted to turbidity and sedimentation than a continuous expanse of reef in a moderate wave energy environment. The proximity of a habitat to a potential source of pollution (e.g. stormwater drain) is also likely to influence its likelihood of a negative consequence and this aspect was definitely considered in the threat analysis; inshore habitats are more likely to be affected by land-based discharges than offshore habitats and were assessed accordingly.

- While nutrients and sediments can be a threat to seagrass and reef habitats, impacts appear to be site-specific. Thus, generalized predictions could not be utilized when conducting threat analyses across different marine cells. In each case, consideration was given to the possible (or known) nutrient/sediment load and the local hydrodynamics. For example, in some areas it is quite likely that the habitats are naturally acclimatized to higher levels of turbidity and/or sedimentation. In this context it is worth noting that our understanding of seagrass/reef health or condition is currently incomplete; for example, a seagrass meadow with high epiphyte loads or a reef with turfing macroalgae is not necessarily unhealthy (e.g. Bryars 2009).

Cell summaries

The AMLRNRM Board requested that the format of the present report have some similarity to the CAPs which provided separate summaries for each coastal cell in a results section (see Caton et al. 2007, 2009). For the purposes of consistency, many of the field names used for summarising information in the results section of the present report were the same or similar to those utilised in the CAPs. However, due to inherent differences between the two studies, complete consistency was not possible.

The Results section of the present report provides information on the following fields for each of the 46 individual marine cells:

Cell detail: a summary of the cell area and dimensions.

Benthic habitats: a summary of the dominant habitat types; a description of the three main habitat groups assessed – seagrass, reef, sand; mention of any recognised estuaries adjacent to the cell; a habitat map of the cell; a table summarising the habitat area statistics of the cell.

Cell values: a brief description of some of the values of the cell in terms of human use.

Habitat values: a summary of what habitats within the cell are regionally significant; a summary of habitat values in terms of fish, invertebrate, seagrass and macroalgal diversity based on published information.

Threats: a summary of the main identified threats to habitats within the cell based on published and anecdotal information.

Threat analysis: a summary table of the formal risk assessment values and outcomes; a brief description of how the risk assessment outcomes were determined.

Actions and Priority: a summary table of habitat components, issues (i.e. identified threats), proposed actions to mitigate identified threats, priority of actions and key players. The priority of an action was rated as Low, Medium or High (to be consistent with the CAPs) and was based mainly upon the risk ranking from the threat analysis, but with subjective modification in some cases: for risk rankings of Low, priority was generally assigned as Low; for risk rankings of Moderate, priority was generally assigned as Medium; and for risk rankings any higher, priority was assigned as High.

Further investigations: a list of new investigations that might be useful for informing the threat analysis and habitat values.

Results

The Results section provides a separate summary for each of the 46 marine cells, as well as regional summaries of recommended actions and priority of actions that were collated from the individual cell summaries.