Biodiversity and Conservation of Macroalgae in the Adelaide and Mount Lofty Ranges NRM Region, including an assessment of biodiversity and distribution of macroalgae in the Gulf St Vincent Bioregion

A report prepared by Janine L. Baker and Dr C. Frederico D. Gurgel
for the Adelaide and Mount Lofty Ranges Natural Resources Management Board

May 2011

Government of South Australia
Adelaide and Mount Lofty Ranges
Natural Resources Management Board

BIODIVERSITY AND CONSERVATION OF MACROALGAE IN THE ADELAIDE & MT LOFTY RANGES NRM REGION

including an assessment of biodiversity and distribution of macroalgae in the Gulf St Vincent Bioregion

---

REPORT TO ADELAIDE AND MT LOFTY RANGES NATURAL RESOURCES MANAGEMENT BOARD

Janine L. Baker[1] and Dr C. Frederico D. Gurgel[2]

[1] J. L. Baker, Marine Ecologist: jannebaker@adam.com.au

[2] School of Earth and Environmental Sciences, University of Adelaide (fred.gurgel@adelaide.edu.au); South Australia State Herbarium, Department of Environment and Natural Resources; and South Australia Research and Development Institute, Aquatic Sciences.

AUGUST 2010

(Updated MAY 2011)

Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

Board of the Botanic Gardens and State Herbarium

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Department of Environment and Natural Resources

Cover Photos: (Left) K. Smith, (Right) J. Baker

CONTENTS

Citation

This report may be cited as:

Baker, J.L. and Gurgel, C.F.D. (2010) *Biodiversity and Conservation of Macroalgae in the Adelaide & Mt Lofty Ranges NRM Region*, including an assessment of biodiversity and distribution of macroalgae in the Gulf St Vincent Bioregion. Report to Adelaide & Mt Lofty Ranges Natural Resources Management Board.

Executive Summary

This report summarises the distribution and species composition of marine macroalgae in the AMLR NRM region based on data of herbarium records from the South Australian State Herbarium and the Australian Virtual Herbarium databases. The geographically and taxonomically updated datasets used in this assessment are an amalgamation of many thousands of herbarium records deposited in the seven biggest Australian herbarium collections, dated from the 1850s to 2009. This report also summarises the number and location of South Australian endemic species, and the known distribution of introduced and potentially cryptogenic macroalgae in the AMLR NRM region, including Aquatic Reserves and the Encounter Marine Park. Additionally, we updated and revised a previous national assessment of threatened macroalgae that included examples of potentially rare and threatened species in Gulf St Vincent. Conservation recommendations are made, for protecting habitats which support macroalgae as a major component, and monitoring of activities that threaten such habitats.

Recommendations include:

- Continued restoration and management of rivers and land upstream to stop erosion and reduce the amount of sediment and nutrients that enters rivers and creeks (and thus ends up on coastal reefs), and continued treatment and recycling of wastewaters on land, and reduction of effluent-rich flows to the sea. Of benefit is the AMLR NRM Board's long-term and regular water quality monitoring to improve coastal water quality and the condition of marine and coastal habitats.

- Where possible, particular protection of existing Aquatic Reserves and proposed Sanctuary Zones of marine parks from physical impacts, nutrient enrichment, and sedimentation, especially those which are known to provide habitat for apparently endemic / limited range species of macroalgae.

- Surveys to better determine the composition, distribution and abundance of South Australian rare and endemic species of macroalgae, particularly in Aquatic Reserves and MPA sanctuary zones, and also in port areas.

- More information on the macroalgal species composition / biodiversity from data-poor areas such as upper north-eastern part of Gulf St Vincent; much of the Fleurieu Peninsula; much of the central gulf region, and much of the coastal area from Cape Jervis to Encounter Bay, including Aquatic Reserves and Parks

- Targeted studies to determine the current distribution and relative abundance of species known only from very few records

- Establishment of a reliable and sensitive monitoring program for Aquatic Reserves, ports and harbour areas and other coastal waters, not only for marine pest species but also to generate baseline data to detect a plethora of marine impacts caused by either local or global stressors. Continuation of the SA Government's current monitoring program for *Caulerpa taxifolia* is recommended.

- Consideration of the invasive possibilities of *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*), and development of measures to control such an occurrence. Also recommended is survey and monitoring of various species of *Ulva*, *Cladophora* and *Hincksia* that may be introduced or cryptogenic, in nutrient-rich locations (such as port areas, and estuaries), as these species have the potential to bloom.

- Increased public awareness about potential vectors that may aid the spread of introduced macroalgae.

- Determine of the status of macroalgal species so far considered cryptogenic, using modern techniques in molecular biology.

List of Tables

List of Figures

Acknowledgments

The authors would like to thank the Adelaide and Mt Lofty Ranges (AMLR) Natural Resources Management Board for enabling this project to be undertaken. We thank Mr Tony Flaherty of the AMLR NRM Board for advice and support. Thanks also to Ms Jacquie Oates, GIS Analyst at GIS & Image Services, Science Resource Centre; Mr Rex Croft (programmer, DENR), and Ms Amanda Gaetjens, GIS Analyst (Marine Programs, DENR), for providing a number of GIS files for analysis. We would also like to thank Ms Carolyn Ricci of the State Herbarium of South Australia for checking a number of herbarium specimens. Thanks to staff at University of Adelaide (School of Earth & Environmental Sciences, and Adelaide Research & Innovation) for assisting with contract arrangements, and providing library access.

1. Introduction

The marine flora of the State of South Australia lies within the temperate Flindersian Marine Biogeographic Province which displays a transitional warm to cool temperate biota of south-western Australia (**Figure 1**). However, it also contains elements of the cool temperate biota of south-eastern Australia (the Maugean Province) (Womersley 1990, Waters et al. 2010).

The state of South Australia is divided into eight Natural Resource Management (NRM) Regions, seven of which have coastline (**Figure 2**). From west to east they are: the Alinytjara Wilurara NRM (AW NRM), the Eyre Peninsula NRM (EP NRM), the Northern & Yorke Peninsula NRM (N&YP NRM), the Adelaide and Mount Lofty Ranges NRM (AMLR NRM), the Kangaroo Island NRM (KI NRM), the SA Murray Darling Basin NRM (MDB NRM) and the South East NRM (SE NRM). The AMLR NRM is one of the best known phycologically, due to the long history of collecting along the easily accessible metropolitan areas of Adelaide, southern Fleurieu Peninsula beaches (e.g. Aldinga, Sellicks) and areas in Encounter Bay, such as Victor Harbor and Port Elliot.

Additionally, a variety of phycological research projects have taken place in the area over a long period, due to the proximity of the AMLR NRM coastal region to the South Australian State Herbarium, universities (i.e. The University of Adelaide, University of SA and Flinders University), and other research institutions (e.g. South Australian Research and Development Institute, Aquatic Sciences Division). Examples of phycological projects that have been undertaken in and around the region, include the following:

- *throughout Gulf St Vincent*: benthic samples were taken during the late 1960s, as part of a project to map in detail the benthic habitats of Gulf St Vincent and Investigator Strait (Shepherd and Sprigg, 1976). Herbarium samples were taken of canopy flora, and also of plants in the middle and lower strata, to describe common species at each 5m depth increment (from 0m – 30m) and the level of water movement. The 1960s study was repeated almost three decades later to assess temporal changes to the benthos (Tanner, 2005),

- *West Island in Encounter Bay*: extensive collections were made during the late 1960s as part of a project to document the ecology of the island‘s macroalgae (Shepherd and Womersley, 1970, Shepherd and Watson, 1970),

- *various locations in AMLR NRM*: collections of macroalgae were made during representative habitat sampling, using 1m quadrats in eastern Gulf St Vincent (GSV) and along the gulf waters of the Fleurieu Peninsula (SARDI data, cited in Edyvane, 1999 and 2008), and in and around Encounter Bay, including the lower Fleurieu Peninsula between Tunkalilla and Pt Elliot (SARDI data, cited in Baker and Edyvane, 1996, Edyvane, 1999, Baker, 2004),

- *artificial reefs off the Glenelg and West Beach area, and also the reef at Port Noarlunga*: herbarium specimens were collected during the 1980s,

- *Port Stanvac area (metropolitan Adelaide):* selected samples were lodged with SA State Herbarium during a marine characterisation study and environmental impact assessment for the desalination plant being developed in the area (2008-2009).

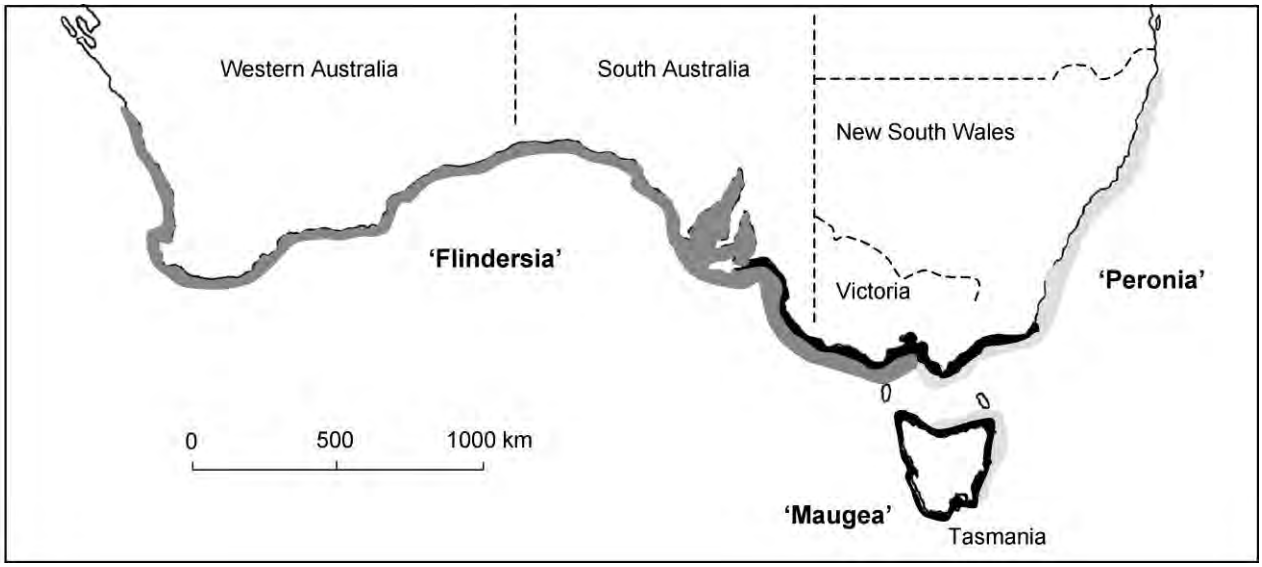


Figure 1: Marine biogeographic provinces in southern Australia: Flindersian (dark grey), Maugean (black), and Peronian (light grey). Modified from Waters et al. (2010).

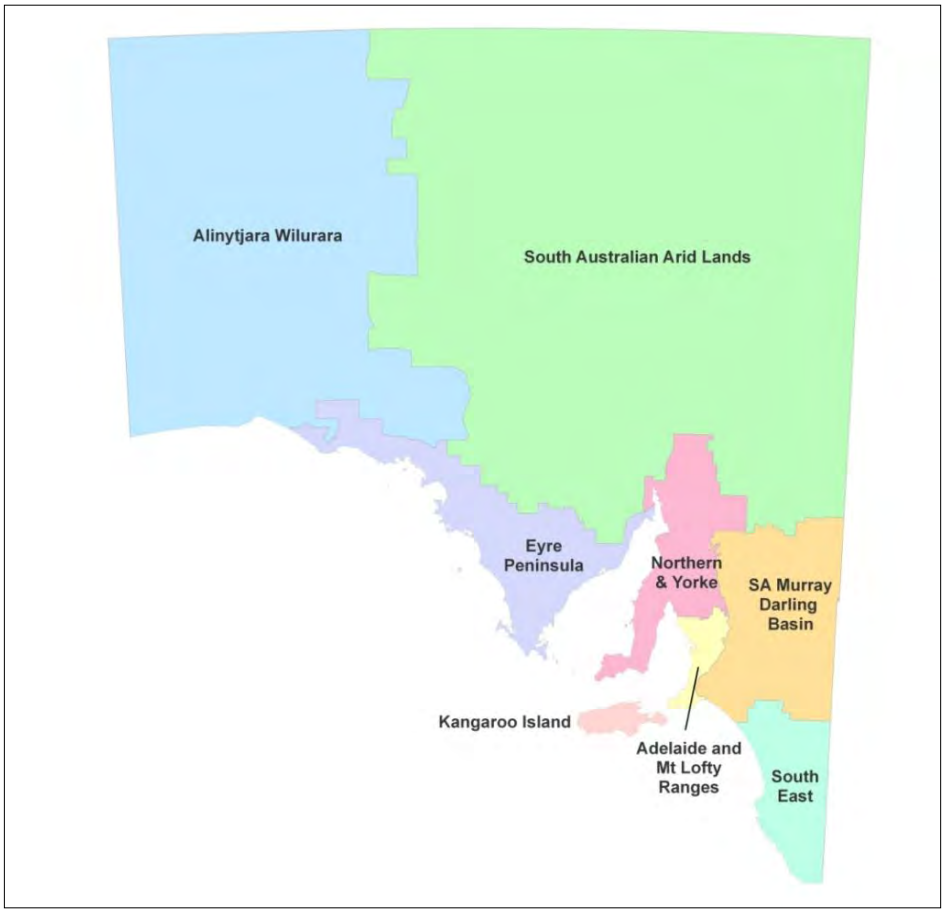


Figure 2: South Australia's Natural Resource Management Regions

Adjacent to the AMLR NRM region, herbarium specimens have been collected in several places, including (i) Investigator Strait north of Kangaroo Island, where detailed collections of macroalgae were made during benthic sampling to 41m deep (J.E. Watson, 1971), and (ii) a reef at 10m depth east of Troubridge Island, where many specimens from a community of red macroalgae were collected by S.A. Shepherd during the late 1960s.

Many random collections across AMLR NRM coast also became important specimens to characterise the southern Australian flora as a whole, many of which were new taxa. These taxa have been documented extensively in the life-long work of Prof. Bryan Womersley, through his book series *The Marine Benthic Flora of Southern Australia* (Womersley 1983, 1987, 1999, 2000, 2003, 2005).

Research which assessed and monitored the benthos in parts of the AMLR NRM region, but for which macroalgae collections did not form a significant part of the projects, is not discussed in detail here. Examples include the reef health assessment work of Cheshire et al. (1997, 1998), works of Turner and colleagues (Turner, 2005, Turner and Kildea, 2006, Turner et al., 2007), benthic habitat classification (e.g. Bryars, 2003) and more recently, on-going benthic habitat mapping carried out by Department of Environment and Natural Resources (former DEH 2008).

Studies of the variability in reef community structure across various spatial scales have also been undertaken, and include some sites in the AMLR NRM (e.g. Collings, 1998, Connell and Irving, 2008). For example, in lower gulf waters, including Cape Jervis area, an ecological study of canopy macroalgae, particularly species in *Cystophora* and *Sargassum*, was undertaken over space and time (Collings 1998, Cheshire and Collings 1998).

Project Aims

Despite the numerous research projects related to macroalgae that have been undertaken in the AMLR NRM region over several decades (particularly after 1944), coupled with more than 100 years of specimen collecting (such as the work of Harvey, from 1854 to 1859), there is still no detailed and up-to-date assessment of the overall species composition and diversity of macroalgae in the AMLR NRM region. **This report aims to provide that information by summarising the herbarium records for AMLR NRM from the South Australian State Herbarium and other major Australian herbaria, at various organisational scales, from State-wide down to 10km^2 grid cells**. Additionally, a previous national assessment of threatened macroalgae included examples of potentially rare and threatened species in Gulf St Vincent (and therefore in AMLR NRM) (Cheshire et al., 2000 and the associated database by Turner, 2000). The current report updates that assessment with more accurate and detailed information about the distribution and status of such species in the AMLR NRM region. This report also aims to summarise the number and location of introduced and potentially cryptogenic macroalgae in the AMLR NRM region. Conservation recommendations for the AMLR NRM marine flora are provided, along with the recognition of persisting gaps in knowledge that require further research.

2. Materials and Methods

Two main databases were used to generate the two datasets analysed in this report. One corresponded to the South Australian State Herbarium database (also known as ADHerb, version of March 2010) composed of ~ 77,000 macroalgal records. The other was the Australian Virtual Herbarium database (AVH 2010, www.ersa.edu.au/avh/) which encompasses macroalgal herbarium records from all seven major herbaria in Australia with ~ 94,000 records: PERTH, DNA, CAN, BRI, NSW, AD and HOB (herbarium abbreviations follow Holmgreen et al. 1990). Both data bases are an amalgamation of herbarium records from the 1850s to 2009.

The first data set included summed records of each species of macroalgae, for each NRM region in South Australia. Undetermined species recorded entered as genus only (e.g. ~~"~~*Rhodymenia* sp.") were removed from the data set. After cleaning (i.e. removal of irrelevant taxa and erroneous records), this data set contained 1,072 valid species of macroalgae. This number corresponds closely to the total number of macroalgal species in the state.

The second main data set used for this project was composed of ~7,845 geo-referenced individual records of macroalgae within the Adelaide and Mt Lofty Ranges NRM region, (after data cleaning).

In both data sets, the taxonomy for each species was checked, and updated where necessary, using the current literature, in addition to databases such as Algaebase (Guiry and Guiry 2010), Australian Virtual Herbarium online tool (www.sapac.edu.au/avh/), and the Australian Marine Algal Names Index (Cowan, 2006). A referenced list of updated names for various taxa which were known in the South Australian herbarium databases under their previous names (now junior synonyms), is available from the authors.

From the two main data sets, supplementary data sets were created such as total number of genera per NRM region, and total number of species per main group of macroalgae (Chlorophyta, Phaeophyceae, Rhodophyta, and Corallinales in Rhodophyta) per NRM region. Intra-specific ranks such as subspecies, varieties, forms and ecads were not considered distinct taxa, hence were collapsed into a single species. Species records were also translated into presence / absence for additional analysis. Datasets were also created for endemic species, introduced species, and cryptogenic species, according to literature discussed in other sections of this report.

It is very important to notice that the quality of the data and the extent of the levels of macroalgal diversity and floristic composition described in this report are directly related to the attributes of herbarium databases. Species that have not been databased in either ADHerb or AVH, and where not mentioned in the publications herein referred, were certainly not included in this report. This might represent a gap in our data. However the magnitude of records that have now been databased is comprehensive, producing highly robust macroalgal datasets, the best to date.

Software used to summarise the contents include ESRI's ARCView and Spatial Analyst, PRIMER-E (Clarke and Gorley 2006), Microsoft Excel and Microsoft Access.

3. Results and Discussion

3.1 Comparison between NRM Regions

The total number of species of macroalgae recorded in each NRM region, according to South Australian State Herbarium records, is shown in **Figure 3**. The number of species recorded in the AMLR NRM region (748) is only slightly surpassed by the Kangaroo Island NRM (753 species). The large number of species recorded in both NRM regions likely reflects the larger sampling effort in both areas during earlier decades of the 20th century rather than a truly smaller species richness found in other NRM regions. **Appendix 1** lists all species of marine macroalgae recorded in the AMLR NRM region.

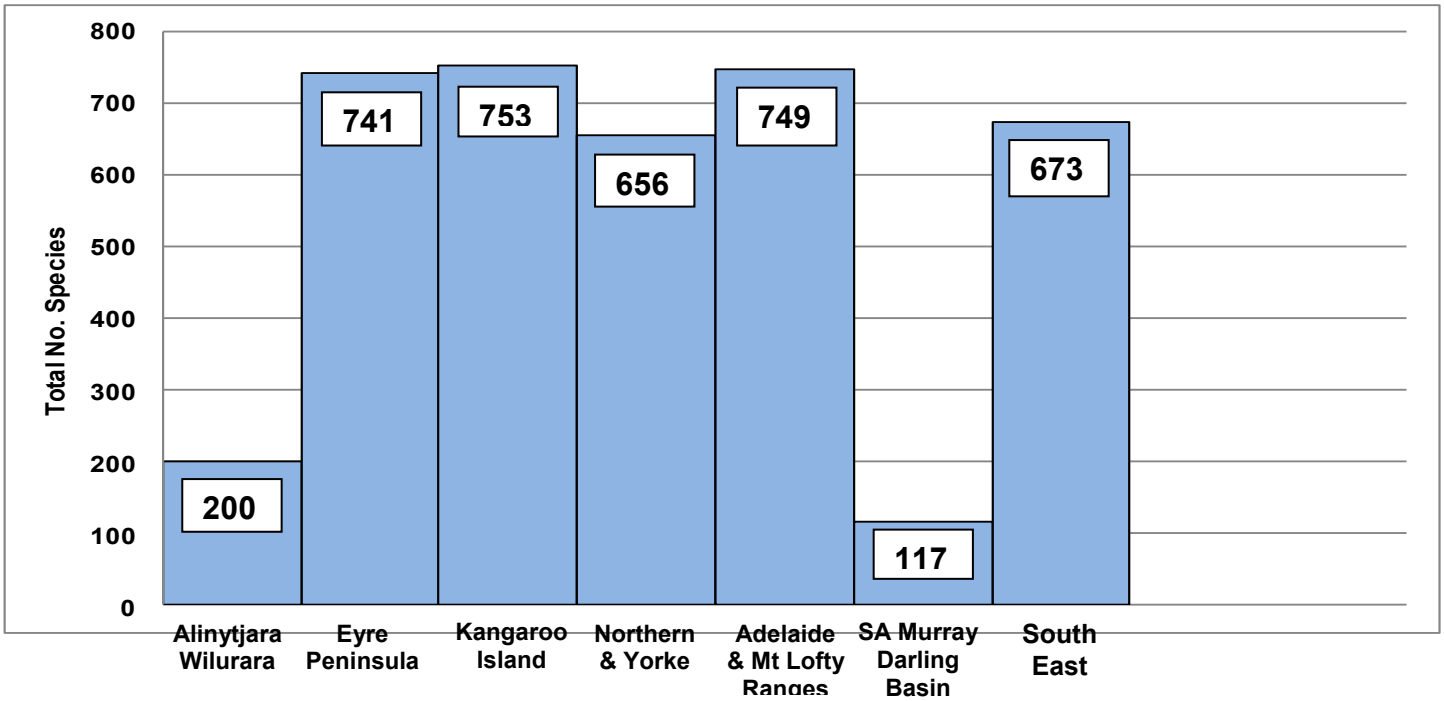


Figure 3: Total number of species present in SA State Herbarium collections of macroalgae, from each Natural Resources Management (NRM) region in South Australia.

The similarity between NRM regions in terms of number of species of macroalgae, according to SA State Herbarium records, is shown in a non-metric multidimensional scaling plot (MDS plot, **Figure 4**). The Jaccard coefficient (Jaccard, 1901, Romesburg, 1984) was used to compute similarity, because it is one of the most suitable coefficients for use with binary data (but see Tulloss, 1997 for improvement), and is not affected by joint absences (i.e. double zero values, when comparing species in two sets of data). Give the opportunistic nature of the herbarium data over more than 100 years, it was decided that joint absence of a species from any two NRM regions being compared should not contribute to the determination of similarity, because it is it not known how many of the ~~j~~oint absence" species do occur in either or both regions, but have not yet been sampled. This is particularly the case for small epiphytic species which are easy to overlook unless specifically searched for with targetted surveys, which rarely occurs.

As shown in the Jaccard similarity matrix, and less obvious in the non-metric MDS plot, the two most floristically similar NRM regions are the EP NRM and KI NRM which share 613 species (57%). However, these two NRM regions grouped highly close to the AMLR NRM and the NYP NRM regions. Therefore, species composition of macroalgae between those 4 regions is likely to be similar based on historical macroalgal records. This is not surprising, given that these 4 NRM regions are four of the 5 best sampled in South Australia (the fifth being the SE NRM). Moreover, these four NRM are the most central across the State, hence share similar oceanography, compared with NRM regions at the edges of the State, such as the warm AW NRM in the far west, and the cooler SE NRM in the far east, to the Victorian border.

As shown in **Figure 4**, NRM regions which are not related to each other, nor to the 4 similar NRM regions discussed above, are (i) the AW NRM for which only 200 species have been recorded ,(ii) the MDB NRM where only 116 species have been recorded , and (iii) the SE NRM. Few of the 116 species recorded from the MDB NRM are reef-dwelling species, compared to the marine flora of other NRM regions where rocky reefs are one of the dominant habitat types. The SE NRM is the least similar NRM to the remaining SA's NRM regions despite the fact that total recorded species number is similar to some of the central coast NRMs. This is because the SE NRM contains a high proportion of cool temperate species typical of the cold Maugean Biogeography Province compared to other NRM regions in SA (Waters et al. in press). Therefore the marine flora of SE NRM has much in common with those of Victoria and Tasmania rather than to the other regions of the SA coast.

	AMLR	AW	EP	KI	NY	MDB
AW	22.323					
EP	63.987	24.142				
KI	63.043	23.157	69.659			
NY	62.688	25.513	64.935	66.038		
MDB	14.135	17.037	13.963	13.316	14.71	
SE	59.484	21.419	55.556	59.933	52.759	15.52

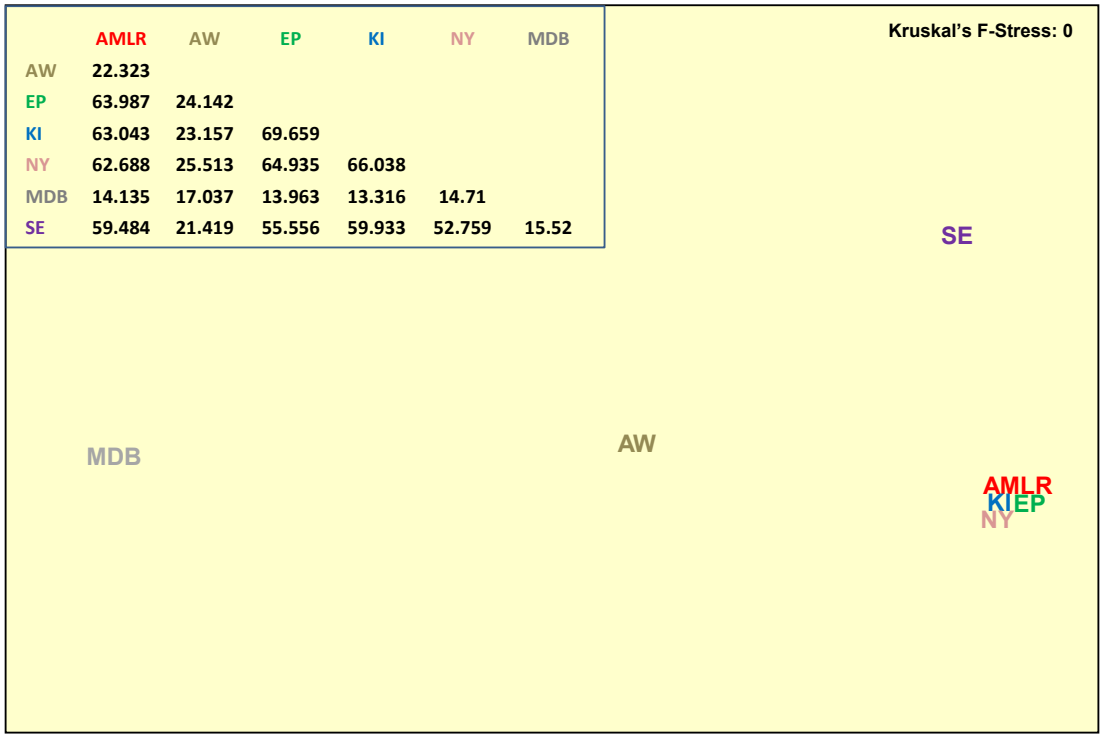


Figure 4: Jaccard association matrix for binary data (top left), and non-metric MDS plot showing similarities between NRM regions in terms of macroalgal species composition, according to SA State Herbarium records.

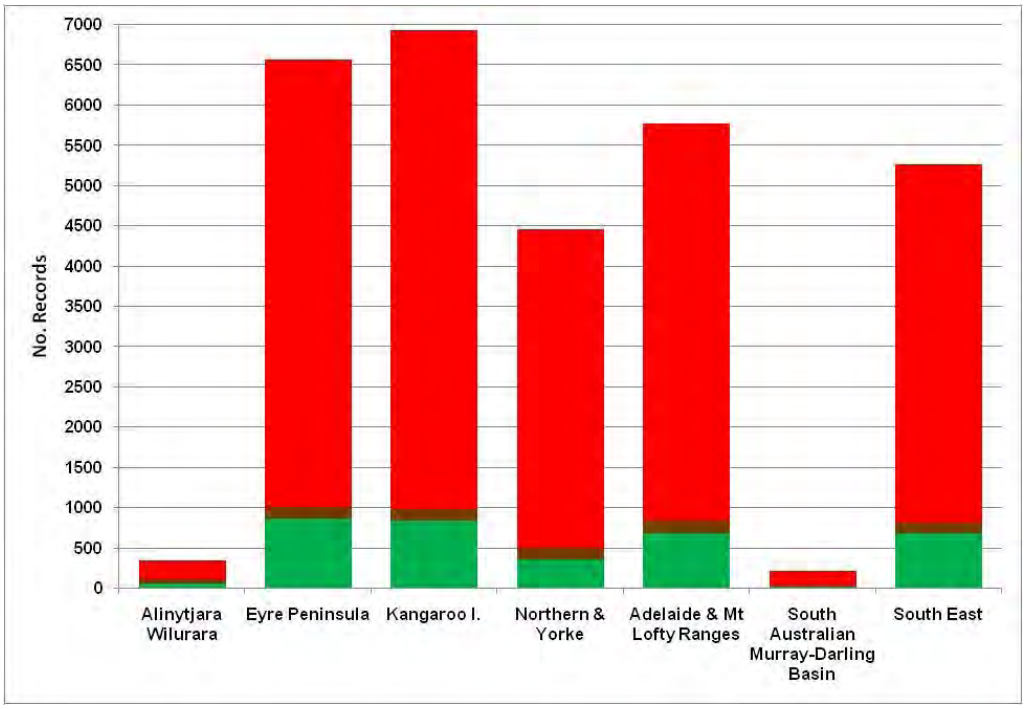


Figure 5: Total number of macroalgal records present in SA State Herbarium collections, from each Natural Resources Management (NRM) region in South Australia. Green bars = Chlorophyta, brown bars = Phaeophyceae, red bars = Rhodophyta, including Corallinaceae.

The number of herbarium records of Chlorophyta (green), Phaeophyceae (brown) and Rhodophyta (red, including coralline) macroalgae recorded in each Natural Resources Management region in South Australia is shown in **Figure 5**. For marine species so far, approximately 676 herbarium records in Chlorophyta have been recorded in the AMLR NRM region, lower than the number from KI NRM (839) and EP NRM (867), but similar to the SE NRM (679). The largest number of brown macroalgae recorded come from EP NRM (2,336 records) followed by KI NRM (2,312) and AMLR NRM (2,242). The largest number of red algal records comes from KI NRM region (5,947) which is more than any other in South Australia. This can be explained partly not only by the extensive collections of HBS Womersley conducted during the middle decades of the 20th century (when numerous small red epiphytes and other taxa were collected and later described) but also by a likely high species-richness of this biogeographical boundary region, which contains both warmer western and cooler south-eastern water and flora. Extensive collections of red macroalgae have also been made from species-rich regions such as EP NRM (5,549 records), AMLR NRM (4,934), and the SE NRM (4,456). As is obvious from **Figure 5**, few records of macroalgae have been collected from the remote AW NRM region and along the MDB NRM.

Species richness of the common canopy-forming foundation taxa *Cystophora* and *Sargassum* in all of the South Australian NRM regions is indicated in **Tables 1** and **2**, respectfully. Reefs in the EP, KI and AMLR NRM regions support the largest number of species in *Cystophora*, with 17, 16 and 16 species recorded, respectively. These regions contain a mix of western species (e.g. *C. pectinata, C. gracilis*), as well as species broadly distributed across southern Australia (e.g. *C. monilifera*, *C. moniliformis*, *C. subfarcinata*, *C. platylobium,* and most others in **Table 1**). The coastline along the three most central NRM regions of SA also contain a mix of wave-exposed and more sheltered reefs, hence these regions can support species of *Cystophora* which require each type of environment to flourish. It has been shown recently that high macroalgal diversity is correlated to high habitat heterogeneity (Kershwell 2006) which seems to be the case in along the centre of SA whereas range of distinct marine habitats are present (e.g. inverse estuaries, normal estuaries, mangroves, salt marshes, mud flats, seagrass beds of varying species composition, limestone reefs of varying depths, intertidal rocky shores, exposed and protected sites, etc). The number of *Cystophora* and *Sargassum* species recorded for the AW NRM region may be artificially low, because although reefs are one of the dominant nearshore habitat types in much of the region, the sampling effort in that relatively remote and less accessible region has been much lower compared to NRM regions to the east. This is evidenced by a recent report on the status of the genus *Sargassum* in that region (Gurgel 2010). As would be expected, the number of reef canopy-forming species in the MDB NRM region is low, given the lack of reef (hard substrate) in the area.

The genus *Sargassum*, including its three subgenera *Phyllotrichia*, *Arthrophycus* and *Sargassum*, is well represented in 6 of the 7 South Australian NRM regions. Fifteen species have been recorded in the AMLR NRM, EP and NYP regions, including the tropical and subtropical species *Sargassum decurrens*. Records of the south-eastern species *S. vestitum*, from locations in the AW (East Coombra), KI (Seal Bay), NYP (Althorpe Island) and AMLR (Port Vincent, Carrickalinga and Port Elliot) NRM regions are unusual, given that the species does not normally occur north of Robe in south eastern SA (Womersley, 1987), and most records are from rough water coasts in Victoria and Tasmania. It is also noted that there are several records even further west of the previously published range, from the Perth and Rottnest Island areas in WA (DEC and WA Herbarium, 2010, Australian Virtual Herbarium, 2010). Reefs in three of the centrally positioned NRM regions in SA (AMLR NRM, EP and NYP) are situated, in some places, in warm temperate areas which support a greater number of *Sargassum* species than do colder, more exposed coasts of the South East.

Table 1: Species richness of *Cystophora* in SA's NRM regions. AW = Alinytjara Wilurara, EYR = Eyre, KI = Kangaroo Island, NYP= Northern and Yorke Peninsula, AMLR = Adelaide and & Mt Lofty Ranges, MDB = South Australian Murray-Darling Basin and SE = South East NRM. Grey shading indicates presence of that species. # = species identity of specimen(s) is being checked at SA State Herbarium.

Species	AW	EYR	KI	NYP	AMLR	MDB	SE
Cystophora botryocystis							
Cystophora brownii							
Cystophora congesta							
Cystophora cuspidata							
Cystophora expansa							
Cystophora gracilis							
Cystophora grevillea							
Cystophora intermedia							
Cystophora monilifera							
Cystophora moniliformis							
Cystophora pectinata							
Cystophora platylobium							
Cystophora polycystidea							
Cystophora racemosa							
Cystophora retorta							
Cystophora retroflexa **#**							
Cystophora siliquosa							
Cystophora subfarcinata							
Total No. Species Recorded	**8**	**17**	**16**	**14**	**16**	**3**	**14**

Table 2: Species richness of *Sargassum* in SA's NRM regions. AW = Alinytjara Wilurara, EYR = Eyre, KI = Kangaroo Island, NYP= Northern and Yorke Peninsula, AMLR = Adelaide and & Mt Lofty Ranges, MDB = South Australian Murray-Darling Basin and SE = South East NRM. Grey shading indicates presence of that species.

Species	AW	EYR	KI	NY	AMLR	MDB	SE
Sargassum decipiens							
Sargassum decurrens							
Sargassum distichum							
Sargassum fallax							
Sargassum heteromorphum							
Sargassum kendrickii							
Sargassum lacerifolium							
Sargassum linearifolium							
Sargassum paradoxum							
Sargassum podacanthum							
Sargassum sonderi							
Sargassum spinuligerum							
Sargassum tristichum							
Sargassum varians							
Sargassum verruculosum							
Sargassum vestitum							
Total No. Species Recorded	**8**	**15**	**13**	**15**	**15**	**0**	**11**

The presence of other major common and canopy-forming species (i.e. foundation-species) and other large species in Phaeophyceae, is shown in **Table 3**. The most common and widespread species on subtidal reefs in southern Australia, the kelp *Ecklonia radiata*, occurs in all NRM regions in South Australia. A few of the canopy-forming taxa are associated with the cooler waters, such as *Durvillaea potatorum* (bull kelp), *Phyllospora comosa* (crayweed) and *Macrocystis pyrifera* (giant kelp). Records of *M. pyrifera* (formerly known in South Australia as *M. angustifolia*) in NRM regions other than the South East are from drift specimens. *Macrocystis pyrifera* does not grow in the SA's gulf regions which are considered too warm for this species. It is noted that the three species in **Table 3** not recorded for the SE NRM region (*Caulocystis uvifera*, *Scytothalia dorycarpa*, and the largely shallow subtidal species *Xiphophora chondrophylla*) all have a broad southern Australian distribution, and extend further east into Victoria and Tasmania, hence it is likely that these species do occur in the SE NRM, but have not been sampled. The biodiversity of canopy-forming brown algal foundation species in the AMLR NRM is high one of the highest across SA (~ 40 species) contributing to the maintenance of a high overall macroalgal biodiversity in the region.

Table 3: Presence in SA's NRM regions of common canopy-forming species and other large species in Phaeophyceae. AW = Alinytjara Wilurara, EYR = Eyre, KI = Kangaroo Island, NY = Northern and Yorke, AMLR = Adelaide & Mt Lofty Ranges, MDB = South Australian Murray-Darling Basin,SE = South East. Grey shading indicates presence of that species. Species in *Myriodesma* are not included, due to their lower densities and lesser abundance as canopy flora in most areas.

Species	AW	EYR	KI	NY	AMLR	MDB	SE
Acrocarpia paniculata							
Caulocystis cephalornithos							
Caulocystis uvifera							
Carpoglossum confluens							
Durvillaea potatorum							
Eckonia radiata							
Macrocystis pyrifera			(drift)	(drift)	(drift)		
Phyllospora comosa							
Scaberia agardhii							
Scytothalia dorycarpa							
Seirococcus axillaris							
Xiphophora chondrophylla							

3.2 Overview of Macroalgal distribution and diversity in the AMLR NRM Region

Total Macroalgal Biodiversity

The distribution of SA State Herbarium macroalgal records along the AMLR NRM region is shown in **Figure 6**. The seaward boundary of the management region is indicated. The collection in the data set (more than 7,800 records) includes herbarium samples dating from the mid 1800s to 2009.

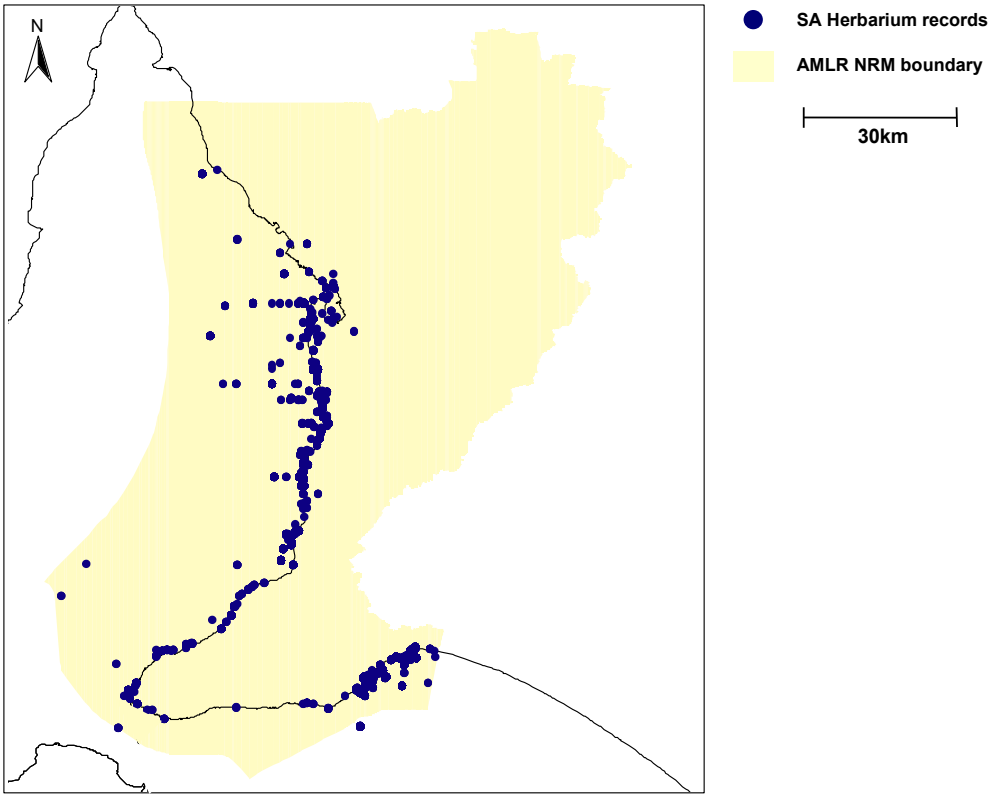


Figure 6: Distribution of about 7,800 geo-referenced historical macroalgal records along the AMLR NRM coastal region (source: ADHerb 2010).

The density map of the number of *records* of macroalgae in SA State Herbarium collections organised in 10km x 10km grid cells along the AMLR NRM region is shown in **Figure 7**. The total number of recorded *species* of macroalgae per 10km^2 grid cell along the AMLR NRM region is shown in **Figure 8**, based on collections of the SA State Herbarium and data from the Australian Virtual Herbarium database. Well sampled areas include:

- The ports (Port Adelaide, Outer Harbour and Port Stanvac)
- Parts of the metropolitan coast (particularly the beaches between Largs / Semaphore and Marino)
- Sellicks Beach area (many records from beach wash)
- Aquatic Reserves such as Port Noarlunga and Aldinga Reef area
- Parts of Encounter Bay, including Rosetta Head, Port Elliot, and, in particular, West Island Aquatic Reserve where intense sampling effort occurred during the late 1960s as part of a project to document the macroalgal ecology of the island (Shepherd and Womersley, 1970, Shepherd and Watson, 1970). Further collecting of macroalgae has been undertaken at West Island by faculty and students of the University of Adelaide since the early 1990's as part of specific projects in phycology and algal physiology (e.g. Cheshire et al. 1996, Fairhead and Cheshire 2004a, 2004b). It is perhaps worth mentioning that most specimens collected in surveys and ecological studies are often not deposited in the SA State Herbarium.

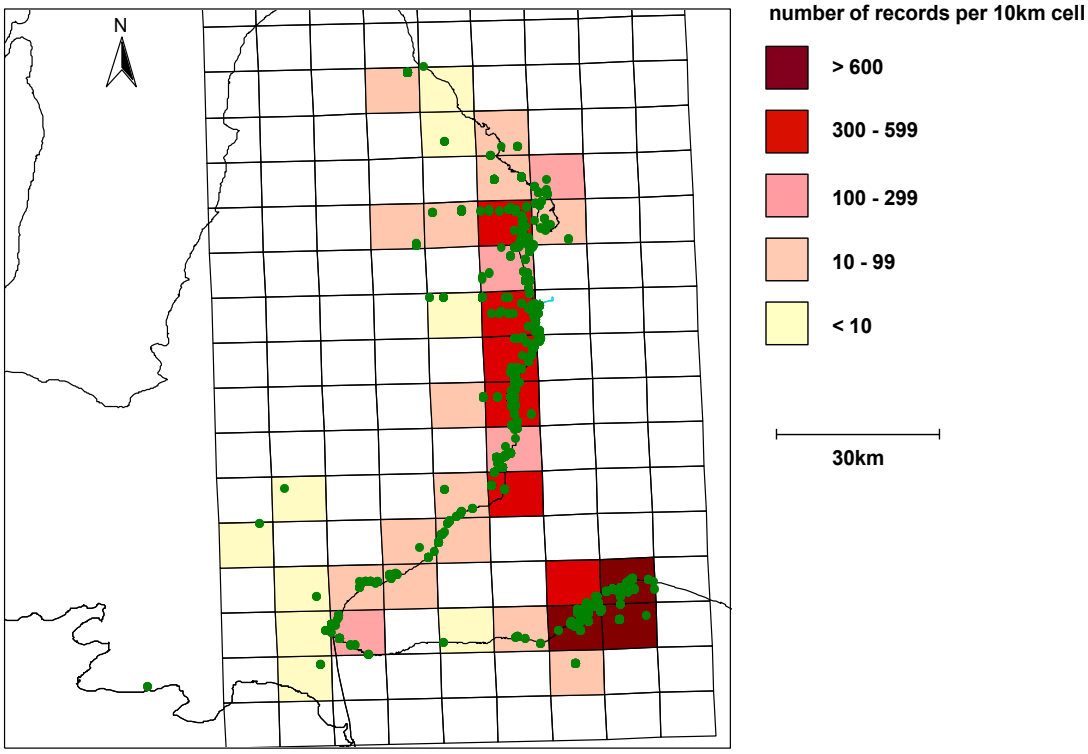


Figure 7: Density map of the total number of benthic macroalgal records from the SA State Herbarium, organised in 10km^2 grid cells along the Adelaide & Mount Lofty Range Natural Resource Management region (AMLR NRM). Phycologically, Encounter Bay area and the metropolitan area are the best sampled regions in the AMLR NRM.

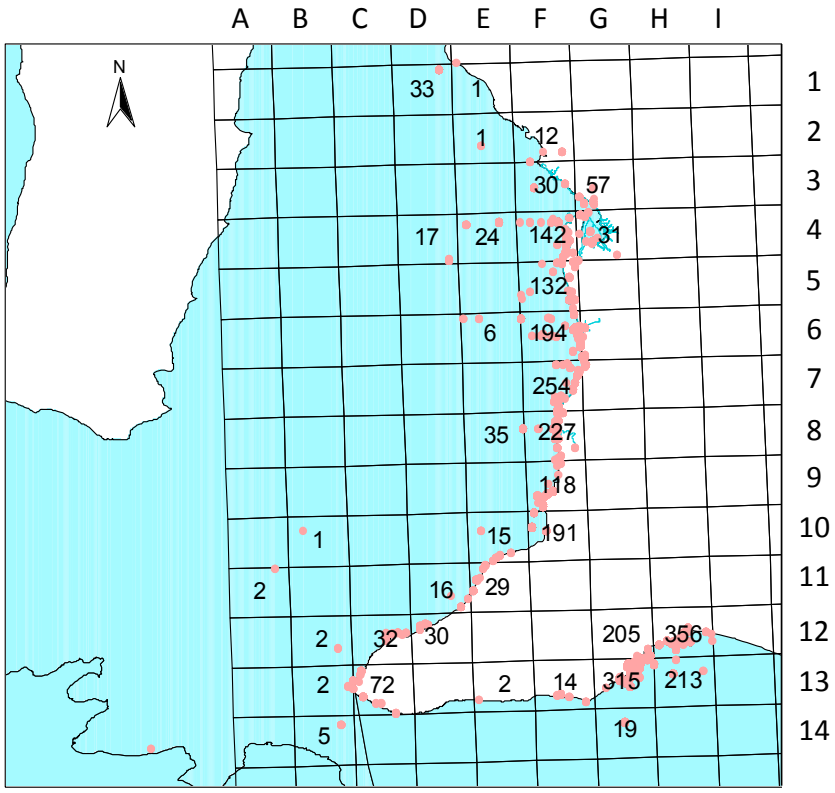


Figure 8: Total number of benthic macroalgal species per 10km^2 grid cell along the AMLR NRM region, based on collections of the SA State Herbarium (ADHerb 2010) and data from the Australian Virtual Herbarium database.

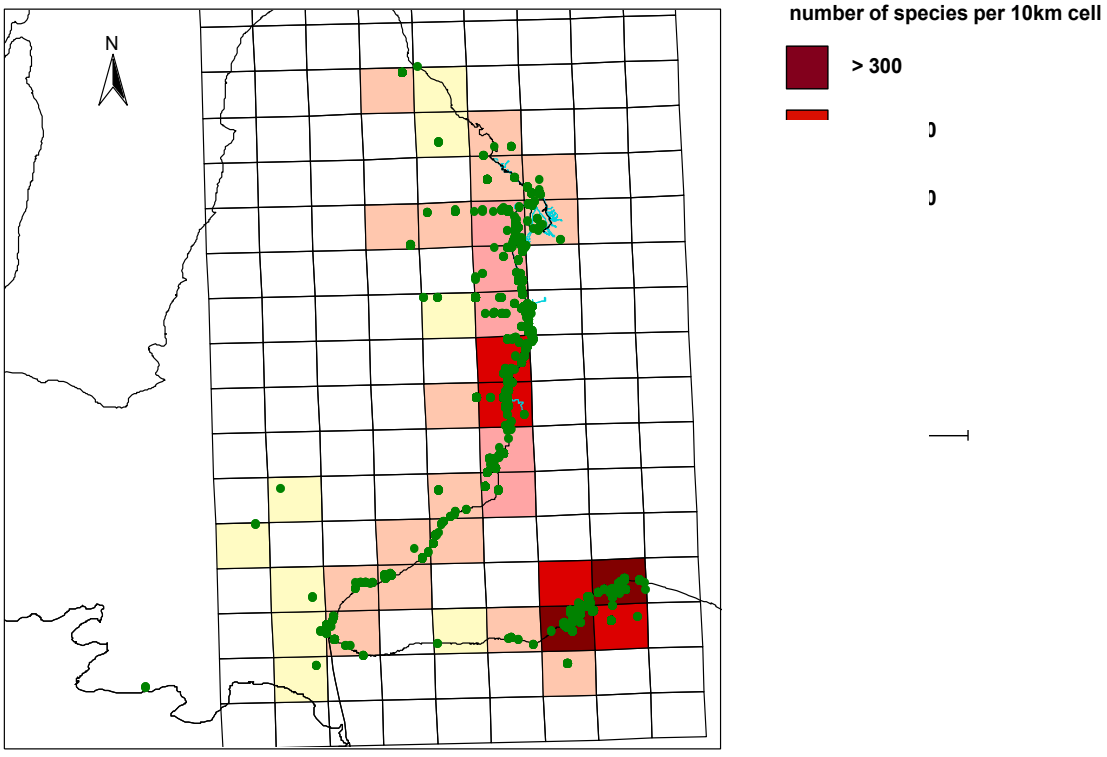


Figure 9: Density map of total number of macroalgal species per 10 km^2 cells in the AMLR NRM region, based on data from ADHerb 2010 and the Australian Virtual Herbarium database.

The number of species of macroalgae per 10km^2 cell in the AMLR NRM region is also shown in **Figure 9**, as a gradient map. There is a strong positive correlation between the number of records per cell and the number of species per cell, i.e. species richness (N = 36, Spearman rho = 0.96). While some areas are species rich due to the variety of habitats and oceanographic conditions (e.g. Encounter Bay), others appear to be species-poor due to lack of collections. Areas with low species richness in **Figures 7, 8** and **9** most likely identify regions where more studies are needed in order to assess their true macroalgal richness and diversity, rather than representing true species poverty and low diversity. For example, it is known that Backstairs Passage is rich in red macroalgae, possibly due to the deeper depth of the water there compared with adjacent gulf waters, strong currents, and lack of coastal pollution; however, the probable species richness of the area is not obvious from the data collected, due to the relative lack of accessibility that this area poses for subtidal collecting. Nevertheless, it remains to be tested the extent to which species-poor sites reflect lack of studies and surveys in the area, rather than true paucity of species numbers.

On a 10km by 10km grid cell basis, recorded species richness is highest in: the coastal strip from Outer Harbour through to Aldinga, and also in the 4 grid cells that encompass Encounter Bay. Brief discussions about the areas where the greatest numbers of species have been recorded are found below. Code numbers correspond to those in **Figure 8**:

- *F4 - Semaphore to Outer Harbour area:* 382 geo-referenced records area known from the area, comprising 142 species. Some species are known in the area from multiple records, including *Cladophora hutchinsioides*, *Hypnea charoides*, *Polysiphonia decipiens*, and *Pollexfenia pedicellata*. Many of the species recorded in the area are small red epiphytes, small brown species in the Dictyotaceae, or green macroalgae (see section below on Chlorophyta):
- *F5 - West Lakes Shore – Tennyson – Grange* area: 222 records comprising 132 species have been recorded in this area, with multiple records for *Cladophora hutchinsioides* and *Pollexfenia pedicellata* (as also recorded for the Outer Harbour area further north). Six of the eight southern Australian species of *Plocamium* have been recorded in this area. Two of South Australia's most serious invasive species of macroalgae (*Caulerpa taxifolia* and *Codium fragile* ssp. *fragile* = ssp. *tomentosoides*) have been recorded in the area, as well as several species of cryptogenic origin (see section below).
- *F6 - Henley Beach, West Beach and Glenelg area*: 498 records comprising 194 species have been recorded for this region. Examples of species known from multiple records (e.g. 8 to 15 samples) include: *Champia zostericola*, *Cystophora monilifera*, *Dictyopteris muelleri*, *Discosporangium mesarthrocarpum*, *Echinothamnion hystrix*, *Halopteris ramulosa*, *Heterosiphonia muelleri*, *Laurencia filiformis*, *Lobophora variegata*, *Peyssonnelia capensis*, *Ptilothamnion schmitzii*, and *Rhodymenia sonderi*. Eighty three species are known from a single record. Some of these are epiphytes (e.g. *Callithamnion obstipum* is apparently known from only 5 herbarium records across southern Australia (source: ADHerb 2010, AVH 2010, and Womersley, 1998).
- *F7 - South Brighton, Marino, Hallett Cove and Port Stanvac* area*:* 719 herbarium records comprising 254 species. Examples of species known from multiple records (e.g. 8 – 15 samples) include: *Antithamnionella ternifolia*, *Ceramium macilentum*, *Cladostephus spongiosus*, *Cystophora monilifera* and *C. subfarcinata*, *Ecklonia radiata*, *Laurencia majuscula*, *L. filiformis*, *Plocamium mertensii*, *Polysiphonia sertularioides*, *Rhodymenia sonderi*, *Ulva rigida*, *Zonaria angustata* and 5 species of *Sargassum* (*S. distichum*, *S. fallax*, *S. lacerifolium*, *S. linearifolium*, *S. spinuligerum*). Single specimen records account for 106 species in the area, including 5 *Cystophora*, 4 *Codium*, 4 *Dasya*, 4 *Polysiphonia*, and 3 *Mychodea* species.
- *F8 – South Port Stanvac to Port Noarlunga and Seaford* area: 510 records from 227 species. Examples of species known from multiple records (e.g. 8 - 23 samples) include: *Ceramium filiculum*, *Chondria angustissima*, *Cystophora subfarcinata*, *Ecklonia radiata*, *Elachista nigra* (a possibly introduced epiphyte), *Lobophora variegata*, *Pterosiphonia pennata*, and *Sargassum lacerifolium*. One hundred and nine species are known in the area from a single record, including:

    - endemic species such as *Medeiothamnion repens*, *Callithamnion shepherdii*, and *Flabellonema codii;*
    - Western Australian species for which South Australia is the eastern limit of the range (i.e. *Ditria expleta*, *Gibsmithia womersleyi*, and *Guiryella repens*);
    - uncommon species known from few records in South Australia, such as *Doxodasya hirta, Trithamnion eubryanii* and the cool to cold temperate *Porphyra woolhouseae;*
    - numerous small red epiphytes and species are either potentially introduced (e.g. *Chondria arcuata*) or cryptogenic (e.g. *Acinetospora crinita*).
- *F9 – Maslins, Port Willunga and Aldinga* area: 300 records, comprising 118 species. Several species known from multiple records (8 - 12 specimens) include *Ecklonia radiata*, *Elachista nigra*, *Martensia australis*, *Sphacelaria bracteata*, *Sargassum lacerifolium* and *S. linearifolium*. Fifty five species recorded in the area are known from a single herbarium record, including possibly endemic species in South Australia such as *Corynophlaea cristata*, *Strepsithalia leathesiae,* and *Myriactula filiformis,* and several species of cryptogenic origin.
- *F10 - Silver Sands and Sellicks area*: 518 records, comprising 191 species. Examples of species known from multiple records (e.g. 8 to 26 samples) include *Botryocladia sonderi*, *Corynophlaea cystophorae*, *Cystophora monilifera* and C. *polycystidea*, *Distromium multifidum*, *Giraudia sphacelarioides*, *Laurencia aldingensis* and *L. majuscula*, *Leathesia marina*, *Pneophyllum fragile*, *P. confervicola* and *P. limitatum*, *Polycerea nigrescens*, *Spyridia filamentosa* and *Tinocladia australis*. Ninety four species in the area are known from a single herbarium record, including the endemic species *Flabellonema* codii, the rare species *Interthamnion attenuatum*, and the tropical species *Dictyota bifurca*, known from Queensland and the Northern Territory.

At the scale of 10km^2 grid cells, one of the most species-rich squares is the southern Encounter Bay area, which includes Rosetta Head, and West Island. From this area (G13 in **Figure 8**), 1,343 records are known, representing 315 species. Some species are known from a relatively large number of records. For example, there are 20 or more records of *Colaconema caespitosum*, *Gelidium australe*, *Hormosira banksii*, *Nizymenia australis*, *Plocamium angustum*, *P. cartilagineum* and *Pterocladia lucida* in the SA State Herbarium. A large number of species (113) are known in the area from a single herbarium record, including endemic species (e.g. *Haraldia australica* and *Acrotrichium amphibolis*), species with disjunct distributions (e.g. *Sphacelaria implicata,* known from South Australia and New Zealand), and cryptogenic species such as *Acinetospora crinita*, *Cladophora dalmatica*, *Feldmannia globifera and Prasiola stipitata.*

More than 1,400 of the records come from the Port Elliot area of Encounter Bay (H12, **Figure 8**), representing 356 species, the largest number of algal species and records from any 10 kilometre square grid cell in the AMLR NRM area. Most of these records are from the South Australian State Herbarium, but there are also more than 328 records from other herbaria in Australia (AVH). An additional 701 records (and 213 species) come from just 3 locations in deeper waters south and south-east of Port Elliot (H13, **Figure 8**), indicating the intensity of pointy collections and studies conducted at those specific locations. Many of the records from that area are multiple samples of common species, such as *Caulocystis cephalornithos*, *Corynophlaea cystophorae*, *Cystophora monilifera*, *Hormosira banksii* and *Leathesia marina*. A possibly endemic species (*Flabellonema codii*) has also been recorded in the area.

Poorly sampled areas of the AMLR NRM area include:
- The northern boundary area of AMLR NRM
- most of the lower Fleurieu Peninsula, particularly the southern coast between Cape Jervis and Encounter Bay, which includes places such as Tunkalilla area, and Deep Creek Conservation Park (cell D13 in **Figure 8**), Backstairs Passage and surrounds
- most of the central gulf region (i.e. deeper water habitats), particularly reef areas deeper than 10 metres.

Chlorophyta

More species of green macroalgae have been recorded in AMLR NRM region than in any other of South Australia's NRM regions (**Figure 10**), despite a lower total number of records of this algal group in this NRM (676 records) when compared with other NRMs in SA (e.g. EP = 867 records, KI = 839 records). The high number of green algal species in AMLR NRM likely reflects:

- a large number of species of opportunistic macroalgae in the genera *Ulva* (11 species) and *Cladophora* (17 species), many of which bloom in disturbed and eutrophic conditions, such as occur at a number of metropolitan locations, including the Port River – Barker Inlet system
- a large number (14) of species in the genus *Codium*, commonly found in the understorey on reefs, with some species also occurring in sandy habitats. *Codium* species (including several sub-species) are as abundant in AMLR NRM as in the cooler waters of the SE NRM. *Codium* species tally in the SE NRM compared with AMLR NRM is surpassed only by the recorded presence an introduced species, *Codium fragile* ssp. *fragile* in the latter (see section **3.6** below).
- a large number of species and varieties of *Caulerpa* in AMLR NRM region (21) is comparable with the number recorded for several other of the reef-dominated bioregions.

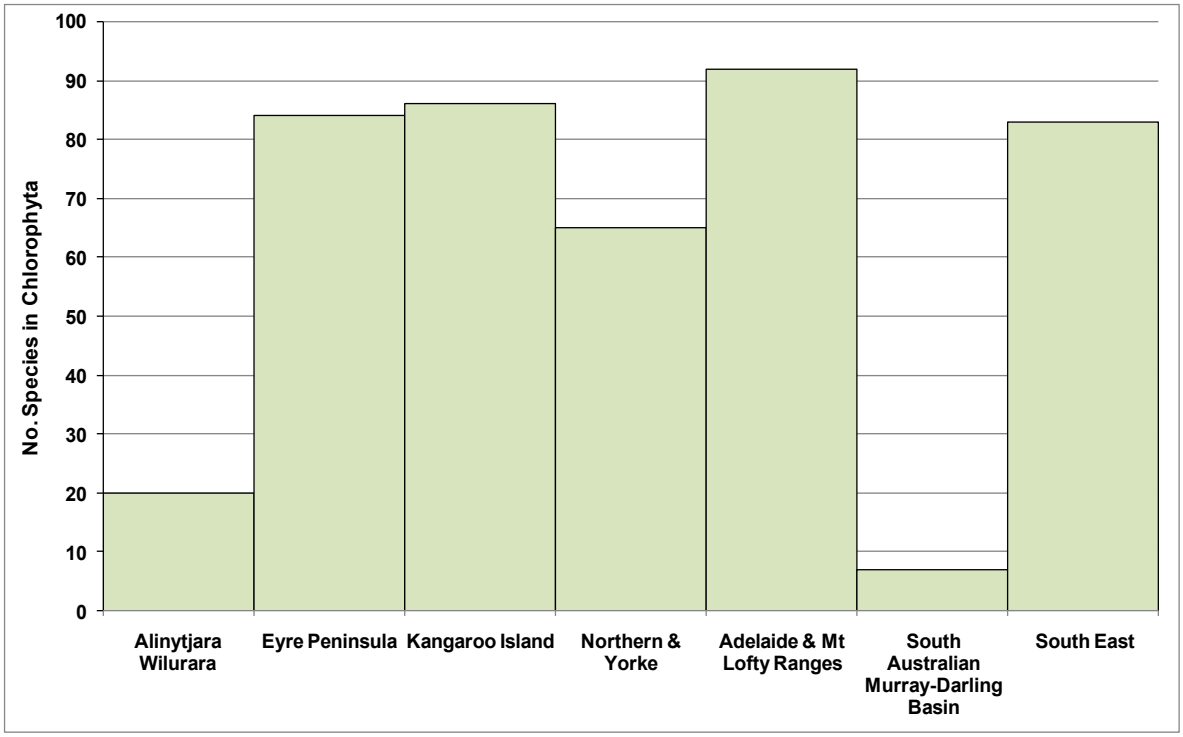


Figure 10: Total number of Chlorophyta species per NRM region in South Australia, based on collections of the SA State Herbarium.

The number of records of green macroalgae per 10km^2 grid cell in the AMLR NRM region is shown in **Figure 11** below. Recorded numbers of green macroalgae are highest in the following areas:

- LeFevre Peninsula, particularly between Semaphore and Outer Harbour, where at least 70 records of 7 species of *Caulerpa* have been recorded (including 2 introduced species), as well as various species in the Cladophoraceae (e.g. *Cladophora hutchinsioides*, *Rhizoclonium curvatum,* and species of *Chaetomorpha* such as *C. linum* and *C. indica*), and 5 *Codium* species (*C. mamillosum*, *C. muelleri*, *C. pomoides*, *C. spongiosum* and the introduced *C. fragile* spp. *fragile*)

- Southern metropolitan area between Seacliff and Port Stanvac, where 34 records of 6 species in *Ulva* have been recorded, as well as several species of *Cladophora* and *Codium*
- Encounter Bay area, including Rosetta Head, West Island, Port Elliot, deeper waters south of Port Elliot, and nearby locations. This area is rich in species of *Caulerpa* (10 species) and also supports less commonly known species such as *Acrochaete viridis*, *Blidingia minima*, *Gayralia oxysperma*, *Microdictyon umbilicatum* and *Pilinia novae-zelandiae*. Common reef understorey species such as *Dictyosphaeria sericea* and *Apjohnia laetevirens* are also found in this area. In southern Encounter Bay, 44 of 84 records of green macroalgae in the records database come from seasonally abundant, opportunistic species of *Ulva* and *Cladophora*. In deeper waters south of Port Elliot, 87 records were recorded from a single location, including 8 species of *Caulerpa*, and multiple records of *Apjohnia laetevirens*, *Codium galeatum*, *Struvea plumosa* and *Ulva compressa*. Due to the presence of a marine research station at West Island, collection effort at this particular location is disproportionately high compared with most other parts of the AMLR NRM region.

There are few to no herbarium records of green macroalgae at most locations along the Fleurieu Peninsula, despite the prevalence of reefs in this area (e.g. Myponga, Carrickalinga, Rapid Head, Rapid Bay, Second Valley, Cape Jervis), **Figure 11**. Green macroalgae would also be present in the vicinity of small creeks along the Fleurieu. The lack of records from this area represents a paucity of collecting effort compared with other locations, rather than a lack of green macroalgae in the area. As is the case with other major groups of macroalgae, there are few records of Chlorophyta in the Backstairs Passage area, and also along the foot of Fleurieu Peninsula eastwards to the Newland Head / Waitpinga area, due to inaccessibility, as discussed above in relation to **Figures 7**, **8** and **9**.

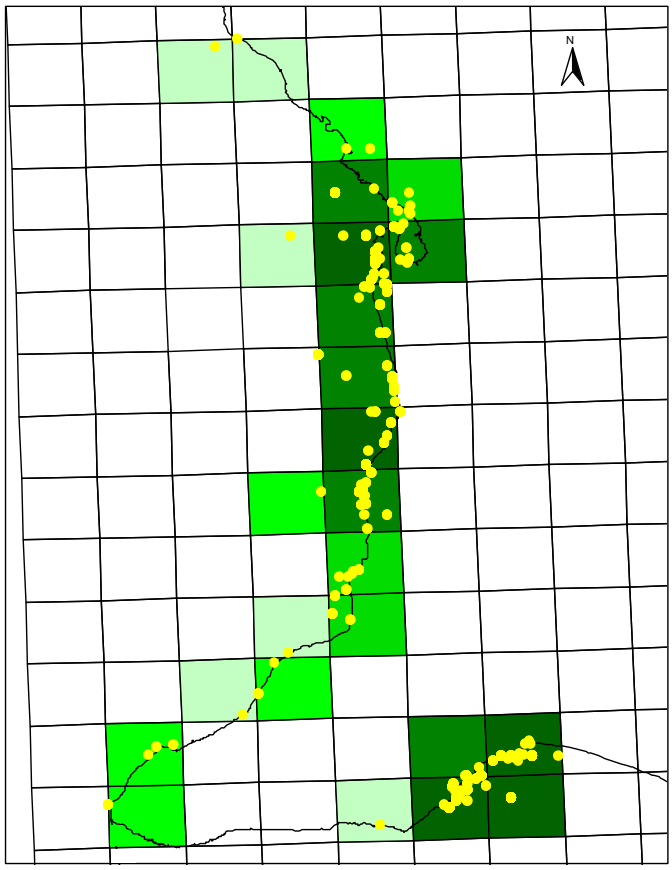


Figure 11: Density map of the total number of green macroalgal records per 10km^2 grid cell, based on data from ADHerb 2010 and the Australian Virtual Herbarium database.

Phaeophyceae

The AMLR contains the largest number of recorded brown macroalgae compared to all other NRM regions in South Australia (**Figure 12**). This reflects not only the richness of canopy-forming species such as *Sargassum* spp. and *Cystophora* spp. (**Tables 1** and **2**) but also of understorey genera such as *Dictyota* (11 species) and numerous small epiphytes. Examples of the latter include 9 species of *Sphacelaria* and 3 species of *Myriactula*.

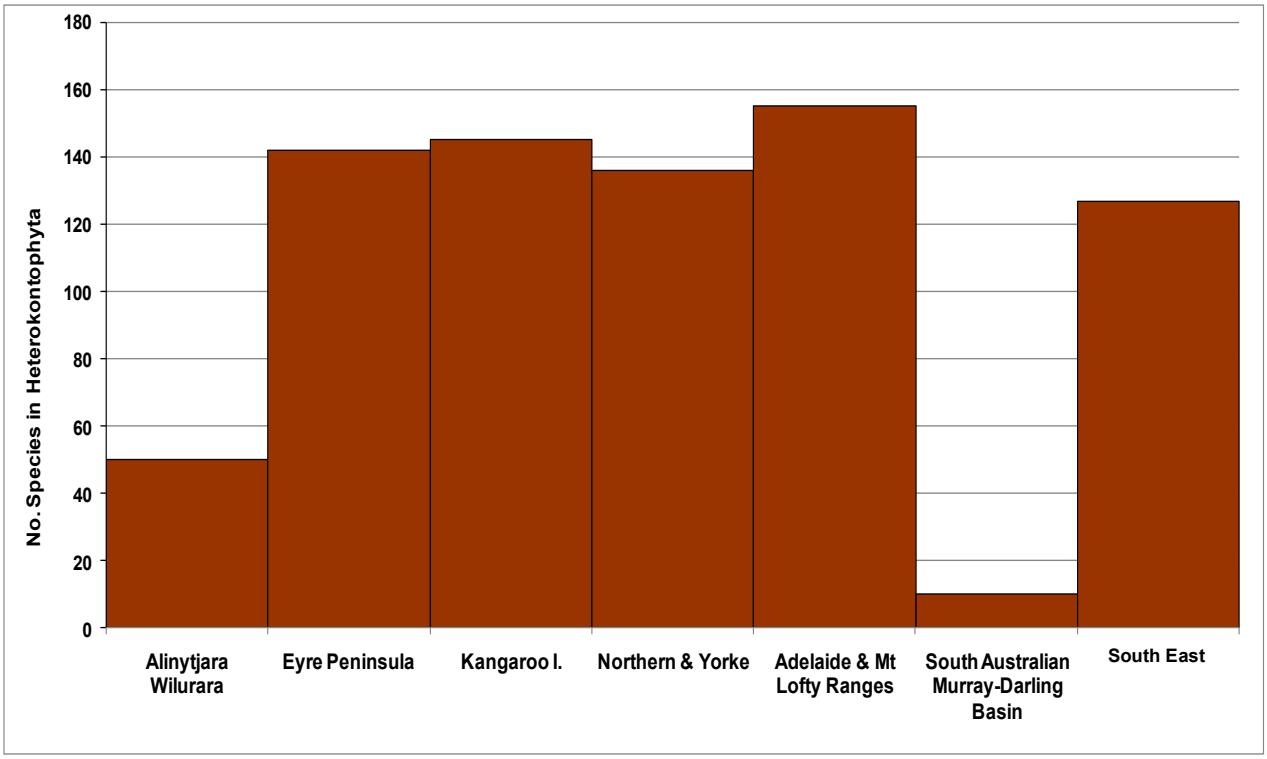


Figure 12: Total number of species in Phaeophyceae present in SA State Herbarium collections of macroalgae, from each NRM region in South Australia.

The distribution of records of brown macroalgae per 10km^2 grid cell in the AMLR NRM region is shown in **Figure 13**. Overall there are 2,242 records across the AMLR NRM which also contributes to the highest brown algal species number in this NRM based on herbarium records, i.e. 154 species.

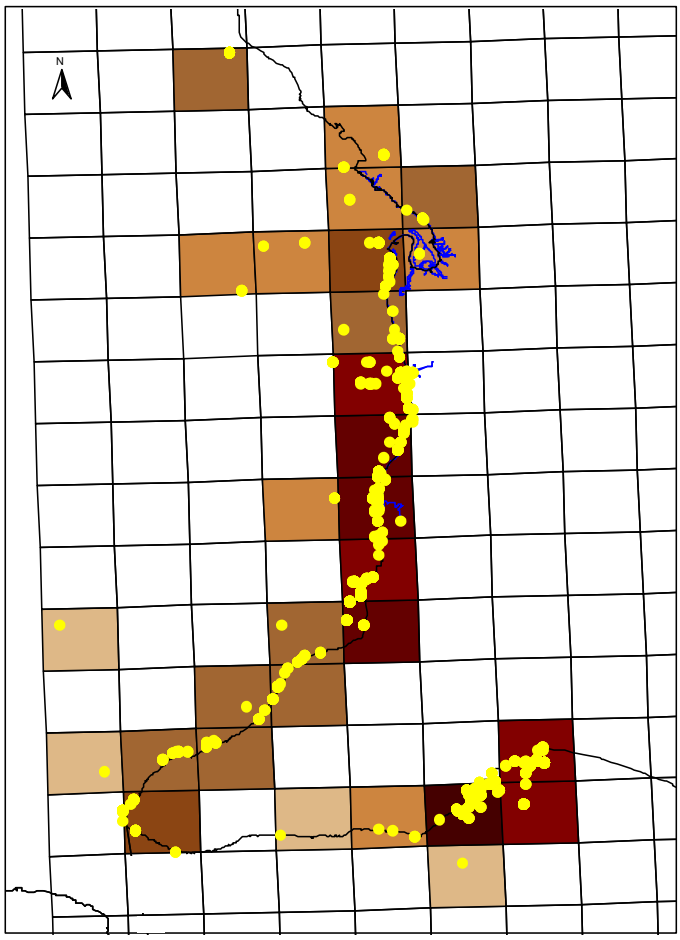


Figure 13: Density map of the total number of brown macroalgal records per 10km^2 grid cell, based on data from ADHerb 2010 and the Australian Virtual Herbarium database.

At a finer scale, areas in which the number of both records and species of brown macroalgae are highest include the following (grid cell numbering corresponds to **Figure 8**):

- Southern and western Encounter Bay areas (grid cell G13) include offshore records from Rosetta Head, West Island, and reefs such as "Whalebones". Collectively, 408 records corresponding to **89** species of brown macroalgae have been recorded from there including multiple records of common species such as *Ecklonia radiata*, *Glossophora nigricans*, *Halopteris funicularis*, *Hormosira banksii*, and *Lobospira bicuspidata*. Single records of more uncommon species include *Giraudia robusta*, *Myriotrichia clavaeformis*, *Petalonia fascia*, *Rugulopteryx okamurae,* the cryptogenic *Feldmannia globifera*, and the SA endemic *Acrotrichium amphibolis*. The canopy-forming genus *Cystophora* is rich in the area with 9 species, as is *Sargassum* with 8 species.
- Port Elliot area (grid cell H12): 176 records corresponding to **69** species of brown macroalgae have been recorded, including multiple records of *Acrocarpia paniculata*, *Dictyopteris muelleri*, and *Dictyota diemensis*, to name a few. A number of records are from the mid 20th century, collected in the drift by Professor H.B.S. Womersley (University of Adelaide). As with the southern and western Encounter Bay area, 9 species of *Cystophora* have been recorded in the Port Elliot area, including the uncommon south-eastern Australian species *Cystophora cuspidata*.
- Deeper waters south of Port Elliot (grid cell H13): 200 records of brown macroalgae comprising **65** species have been recorded in the area, including multiple records of *Corynophlaea cystophorae* (13), *Hormosira banksii* (12), and *Caulocystis cephalornithos* (8).
- Outer Harbour area (grid cell F4): 67 records of brown macroalgae comprising 30 species have been recorded from the 10km^2 area, some known from multiple records (e.g. 10 records of *Zonaria crenata*), and 14 species from single records.

- The metropolitan coast, including beaches, shallow subtidal habitats and offshore reefs off West Beach, Glenelg to Brighton area (grid cell F6): 145 records of **58** species have been recorded, including multiple records of *Cystophora monilifera*, *Dictyopteris muelleri*, *Halopteris ramulosa*, *Lobophora variegata*, and the probably introduced species *Discosporangium mesarthrocarpum*. In this area, 8 species of *Cystophora* and 8 species of *Sargassum* have been recorded.
- The southern metropolitan coast (e.g. Seacliff, Marino, Hallett Cove, Port Stanvac, grid cell F7): 250 records of brown macroalgae comprising **69** species have been recorded. There are multiple records of some species (e.g. *Cladostephus spongiosus*, *Cystophora moniliformis* and *C. subfarcinata*, *Ecklonia radiata*, *Sargassum spinuligerum* and several other *Sargassum* species). The area is rich in canopy-forming fucoids, with 11 species of *Cystophora* and 11 species of *Sargassum*. Three species of the common reef understorey brown *Zonaria* have been recorded in the area, and also 3 species of the opportunistic epiphytic alga *Hincksia*.
- Port Noarlunga area (including Christies Beach and Moana area, grid cell F8): 203 records of **70** species have been recorded. Species known from multiple records include *Cladostephus spongiosus*, *Cystophora subfarcinata*, *Ecklonia radiata*, *Elachista nigra*, *Lobophora variegata*, and *Sargassum lacerifolium*. Species records from single specimens include the possibly South Australian endemic *Flabellonema codii*, and the cosmopolitan *Petalonia fascia*, the latter recorded in more than 40 countries.
- Maslins – Port Willunga area (grid cell F9): 170 records comprising **56** species. Species known in the area from multiple records include *Ecklonia radiata*, *Elachista nigra*, *Sargassum lacerifolium* and *S. linearifolium*, and the south-eastern Australian species *Sphacelaria bracteata,* for which Eyre Peninsula may be the western-most extent of its distribution. Almost half of the species (including common species) recorded in the area are known from a single herbarium record, and examples of less commonly recorded species include the cryptogenic *Feldmannia irregularis*, and the SA endemics *Corynophlaea cristata* and *Strepsithalia leathesiae*.
- Aldinga area (including Silver Sands and Sellicks, grid cell F10): 217 records of **63** species of brown macroalgae are known from only 3 locations in this area, indicating the high intensity of collecting effort in those few locations, compared with other parts of the upper Fleurieu Peninsula. Some species are known in the area from multiple records (e.g. 14 records of *Leathesia marina*, 10 of *Cystophora monilifera*, 9 of *Distromium multifidum*, *Giraudia sphacelarioides*, and *Polycerea nigrescens*, and 8 of *Cystophora polycystidea*, *Corynophlaea cystophorae* and *Tinocladia australis*. The South Australian endemic species *Flabellonema codii* has also been recorded in the area.

Rhodophyta

A large number of species of red macroalgae (Rhodophyta) have been recorded in AMLR NRM region, totalling 472 species, excluding members of the order Corallinales (**Figure 14**). Together with EP NRM (485 species) and KI NRM (486 species), the AMLR NRM supports the greatest red macroalgal biodiversity in SA, despite a considerably smaller number of herbarium records from AMLR NRM (4,528 records compared to 5,648 and 5,188 records for KI NRM and EP NRM, respectively). Together with SE NRM, the AMLR NRM region is richest in species of *Plocamium*, i.e. 8 species each. Other species-rich genera in this region include *Laurencia* (11 species in AMLR NRM, as in NY NRM), the small epiphytes *Audouinella* (11 species in AMLR NRM, more than the number recorded in any other NRM region), and *Trithamnion* (4 species each in AMLR NRM and KI NRM). Other genera with abundant species in AMLR NRM (e.g. *Ceramium*, *Chondria*, *Dasya*, *Heterosiphonia*, *Mychodea*, *Polysiphonia*) are similarly species-rich in several other NRM regions, including EP, NY, KI and SE NRMs. So far, 26 species of red macroalgae have been recorded in AMLRN NRM and no other SA NRM region (**Table 4**), and these are discussed in a later section of this report.

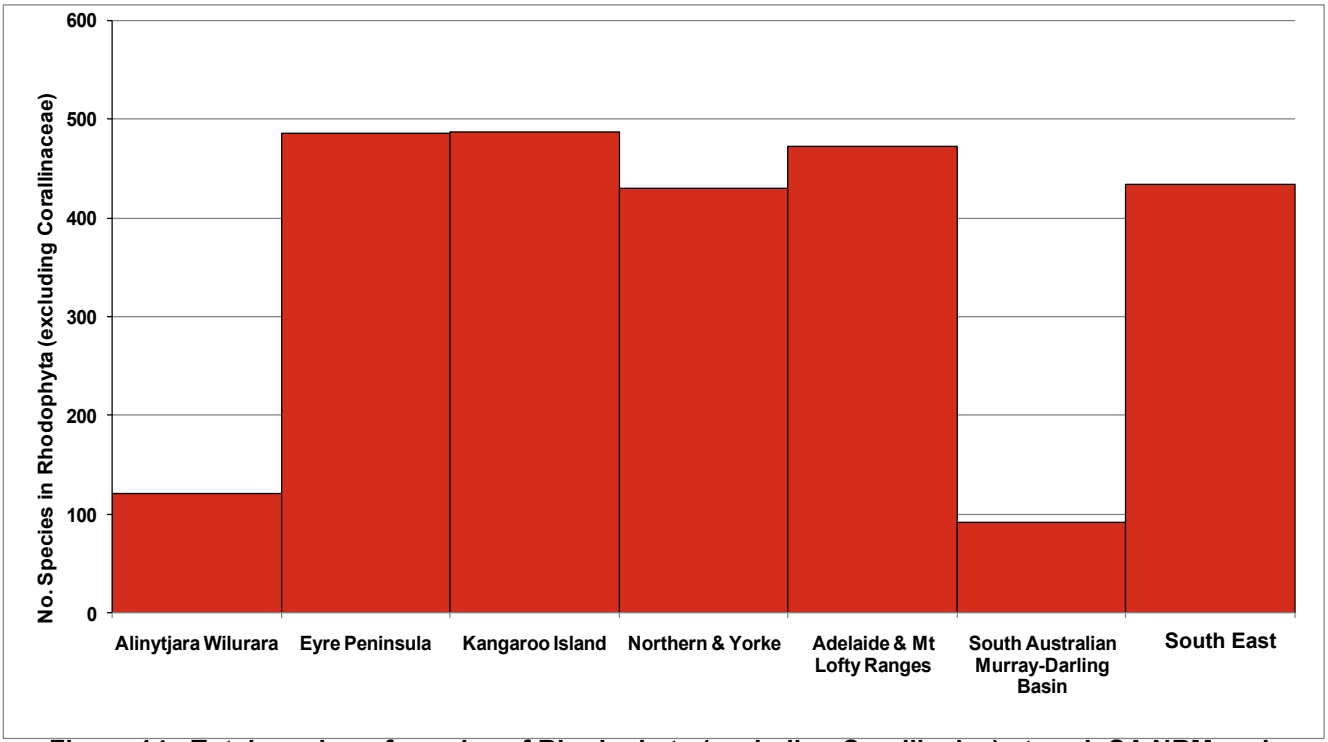


Figure 14: Total number of species of Rhodophyta (excluding Corallinales) at each SA NRM region, based on collections in the SA State Herbarium.

Almost 600 out the 4,528 herbarium records of red macroalgae in AMLR NRM come from only two 10km^2 grid cells along the Adelaide metropolitan coast (**Figure 15**). This reflects the accessibility of the metropolitan area for collecting and the lack of studies conducted in most of the remaining regions (but see below, for Encounter Bay). Approximately 68 species in Rhodophyta recorded from the metropolitan areas are known from a single record, and examples of these include *Acrosorium ciliolatum*, *Amansia serrata*, *Chamaethamnion schizandra*, *Dichotomaria australis*, *Doxodasya hirta* (for which there may be only 5 herbarium records known across southern Australia), *Erythrotrichia carnea*, *Ganonema farinosum*, *Lomentaria monochlamydea*, *Peyssonnelia inamoena*, *Polysiphonia isogona*, *Polysiphonia mollis*, *Radiathamnion speleotis* (known from 7 herbarium records from South Australia and Victoria), *Rhodymeniocolax austrina*, *Scinaia acuta* (formerly *S. australis*), *Trithamnion eubryanii* (known from only 5 herbarium records in South Australia and Victoria) and *Trithamnion vulgare.* Many of the uncommonly recorded red algal species in the AMLR NRM region are small epiphytes.

In the southern Encounter Bay area, including Rosetta Head and West Island, 1,043 records and 243 species of red macroalgae have been recorded. Many of these are known from the West Island Aquatic Reserve, where targeted collecting occurred during the late 1960s (by Dr S.A. Shepherd). Further collections were made during later decades by staff and students at University of Adelaide, as discussed above. For some of the species in this area, there are multiple records, such as *Gelidium australe*, *Inkyuleea mariana, Laurencia filiformis*, *Nizymenia australis*, *Plocamium angustum*, *Plocamium cartilagineum*, *Pterocladia lucida*, and *Rhodophyllis membranacea.* There are also examples of species known from one record in the area, such as *Bornetia tenuis*, *Chondria foliifera*, *Coeloclonium tasmanicum*, *Crouania shepleyana*, *Dasya baldockii*, *Dasya haffiae*, *Dasya quadrispora*, *Epiglossum smithiae*, *Gigartina sonderi*, *Haraldia australica*, *Medeiothamnion halurus*, *Myriogramme gunniana*, *Perischelia glomulifera*, *Pollexfenia lobata*, *Porphyra columbina*, *Protokuetzingia australasica*, *Scinaia tsinglanensis*, *Tikvahiella candida*, *Tsengia comosa*, and several other species.

In the Port Elliot area there is a large number of records of red macroalgae (1,175 records representing 261 species). For some of the red macroalgal species in this region there are multiple records, which increases the total number of records compared with other locations. Examples include *Ballia callitricha*, *Callophycus laxus*, *Callophyllis lambertii*, *C. rangiferina*, *Cladurus elatus*, *Colaconema caespitosum*, *Colacodasya australica*, *Curdiea angustata*, *Dasyphila preissii*, *Doxodasya lanuginosa*, *Hymenena curdieana*, *Hymenocladia usnea*, *Lejolisia aegagropila*, *Nizymenia australis*, *Rhodophyllis multipartita*, *Pterocladia lucida*, *Shepleya wattsii, Wrangelia nobilis*, and species in the genera *Audouinella*, *Gelidium*, *Heterosiphonia*, *Laurencia*, *Mychodea*, *Plocamium* and *Phacelocarpus*, and *Pollexfenia*. In contrast, 80 of the species are known in the area from single records, including numerous small red epiphytes, and a number of uncommon larger species such as *Cryptonemia digitata*, known from south eastern South Australia and Victoria. The drift specimen of *Cryptonemia digitata* from Port Elliot is apparently one of only two known in South Australia (the other from Robe), and although numerous specimens were collected in Port Phillip Bay in Victoria during the late 19th century, it has only rarely been recorded since (Womersley 1994, State Herbarium of South Australia 2007, AVH 2010). Another example of an uncommon species in the area is *Thamnoclonium lemannianum*, a Western Australian species for which the Port Elliot record is the only published example in South Australia.

In deeper waters offshore from Port Elliot (e.g. eastern Encounter Bay), 414 records in Rhodophyta have been recorded from as few as three locations, reflecting the intensity of collecting effort in that area compared with other parts of the AMLR NRM region. Many of the records from that area are multiple samples of common species.

As is the case with the total number of records of macroalgae per cell, there are relatively few records of red macroalgae along the Fleurieu Peninsula, despite the prevalence of reefs in this area where red macroalgae occur in abundance (from Myponga to Cape Jervis). The lack of records from this area represents a paucity of collecting effort along the Fleurieu, compared with other locations, rather than a lack of red macroalgae in the area. There is also a paucity of data from waters deeper than 10m off the metropolitan coast, and throughout the deeper waters of Gulf St Vincent in general, particularly the central grounds where prawn trawling operates. Diver records and photographs indicate the presence of red algae in abundance on patch reefs on the eastern side of Gulf St Vincent (e.g. in deeper waters off the Glenelg area), but there are relatively few herbarium records (e.g. **Figure 15**). As is the case with other major groups of macroalgae, there are few records of Rhodophyta in the Backstairs Passage area, and also along the foot of Fleurieu Peninsula eastwards to the Newland Head / Waitpinga area, due to inaccessibility, as discussed above in relation to **Figures 7**, **8** and **9**.

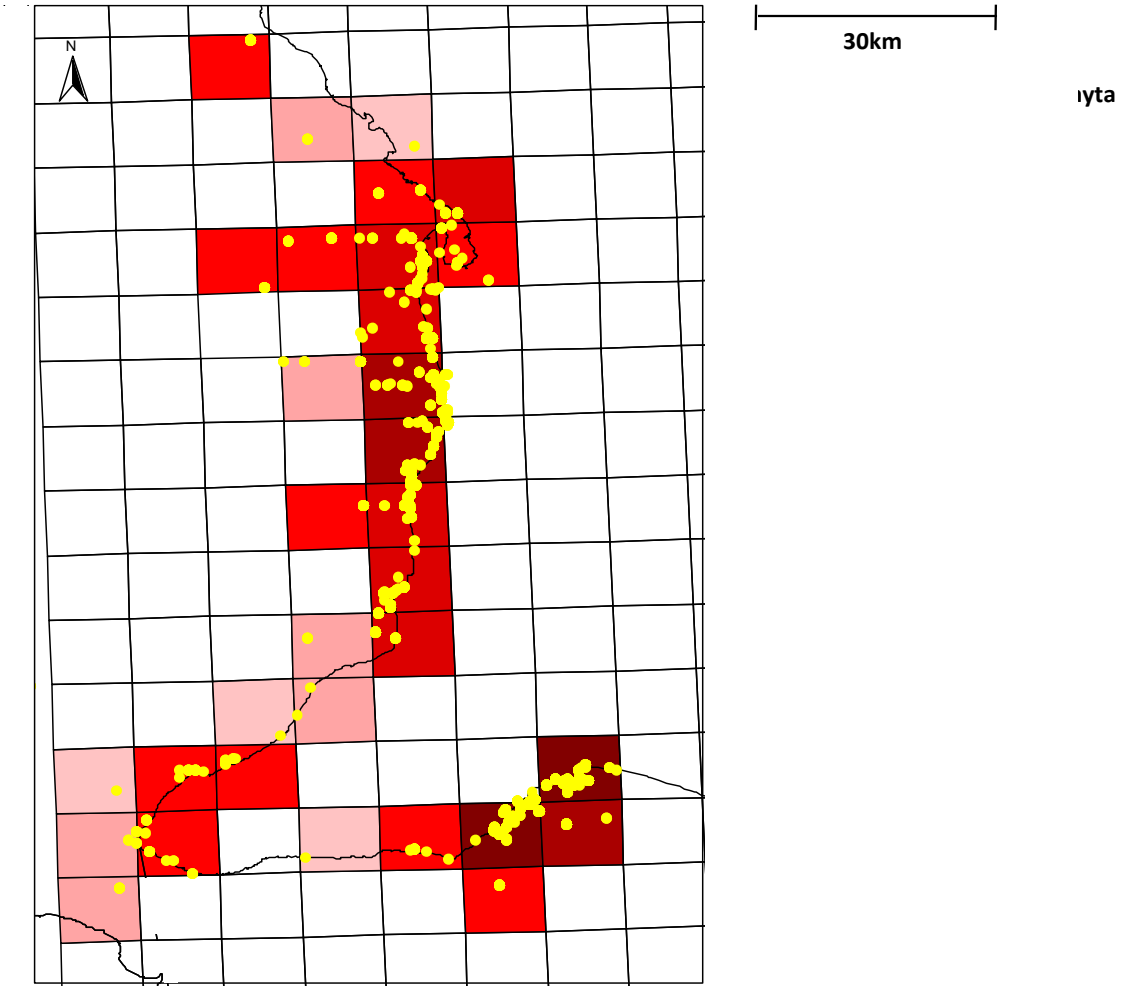


Figure 15: Density map of the total number of red macroalgal records per 10 km^2 grid cell, based on data from ADHerb 2010 and the Australian Virtual Herbarium.

Corallinales

Twenty nine *species* of coralline macroalgae have been recorded in the AMLRN NRM, the same number recorded in EP NRM and the SE NRM, and less than the number recorded in KI NRM (35 species). However, the greatest number of *records* of corallines (406) have come from AMLR NRM (**Figure 16**), due to the comparatively large number of records (80 in total) of three species of *Pneophyllum* (an epiphyte that grows on seagrasses and other macroalgae) that were either uncommonly recorded or absent in other NRM regions. Additionally, there are numerous examples recorded in AMLRN MRM of common coralline species such as *Haliptilon roseum*, *Cheilosporum sagittatum* and *Metagoniolithon stelliferum*.

Figure 17 shows the number of records of coralline macroalgae per 10km^2 cell in the AMLR NRM region. Numbers recorded are highest in the following areas (grid cell numbering corresponds to **Figure 8**):

- The St Kilda area north of the Port River – Barker Inlet system (grid cell G3), due to the abundance of specimens of the coralline epiphyte *Pneophyllum confervicola* (22 records) and *P. fragile* (10 records). The former is considered cryptogenic in South Australia (see section **3.6** below). There are also eight records of the cosmopolitan encrusting epiphyte *Hydrolithon farinosum* in this grid cell.

- Silver Sands – Sellicks area (grid cell F10): 78 specimens have been recorded from two locations, representing 17 species. Species known in the area from multiple records include *Pneophyllum limitatum* (26 records), *P. confervicola* (13 records), *P. fragile* (8 records), and *Hydrolithon farinosum*. Species recorded from a single record include the epilithic and epiphytic encrusting algae *Mesophyllum engelhartii* (known from southern Australia, New Zealand and South Africa) and *M. macroblastum* (also known from the Mediterranean). In Australia, *M. macroblastum* has been recorded from SA, Victoria and Tasmania (Womersley 1996, Cowan 2006, Guiry and Guiry 2010).
- Southern Encounter Bay area (grid cell G13): 87 specimens have been recorded, representing 12 species. Species with multiple records include *Cheilosporum sagittatum* (15 records), *Corallina officinalis* (8 records), *Haliptilon roseum* (19 records), *Melobesia membranacea* (12 records) and *Metamastophora flabellata* (8 records). Species known from single records in the area include the tiny coralline *Choreonema thuretii*, epiphytic on larger corallines such as *Haliptilon roseum*, and species of *Janis*.

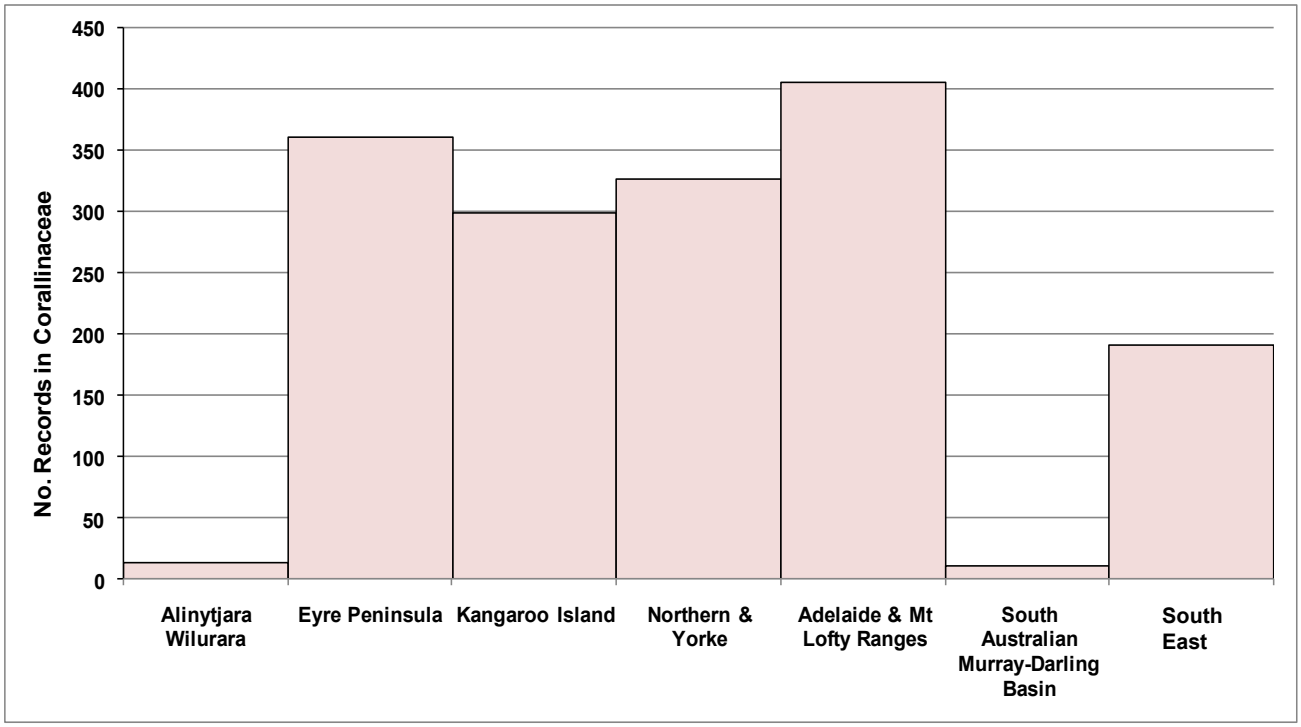


Figure 16: Number of records in Corallinales per NRM region, based on collections in the SA State Herbarium.

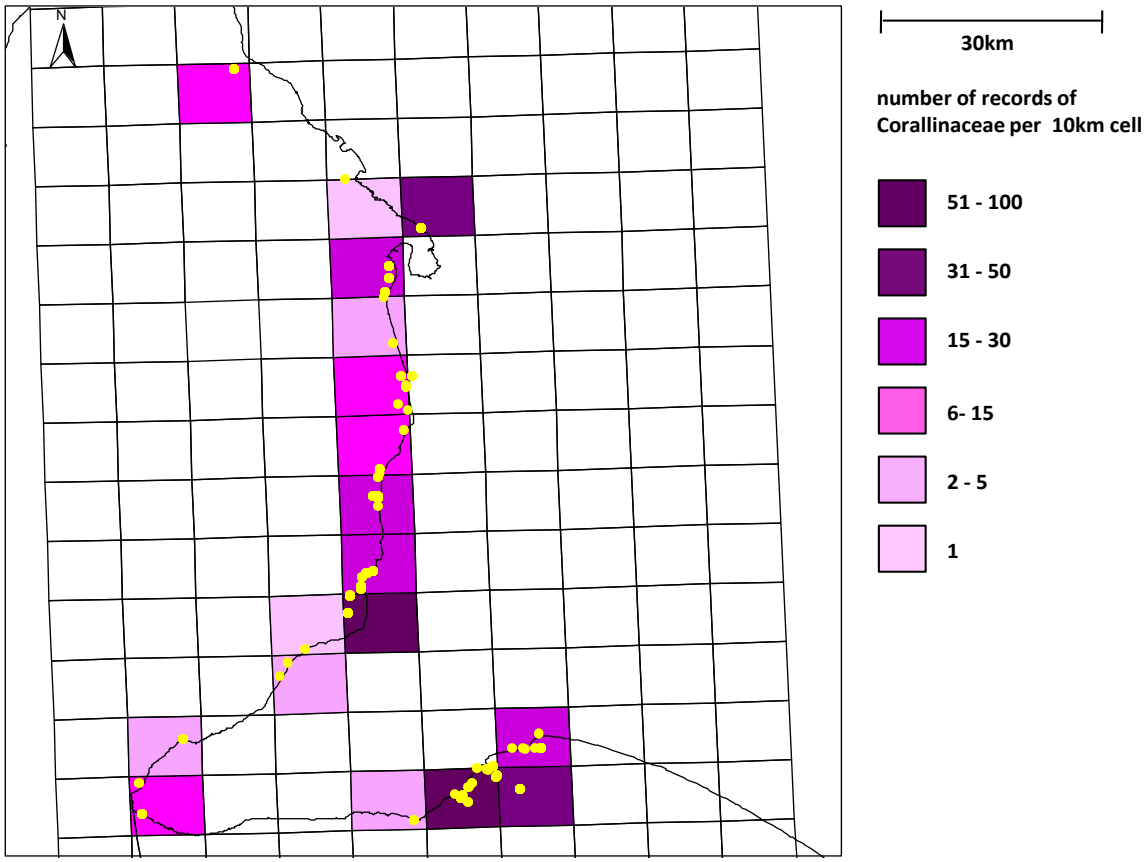


Figure 17: Density map of the total number of Corallinales records (Rhodophyta) per 10 km^2 grid cells, based on ADHerb 2010 and data from the Australian Virtual Herbarium.

Comparison between 10km Grid Cells

There is a difference in the species composition of macroalgae between different parts of the AMLR NRM (**Figure 18**), with a greater number of cooler water (Maugean province) species present in the exposed Encounter Bay region facing the southern Ocean, compared with the more protected gulf waters.

Of the 8 most speciose 10km^2 grid cells in the AMLR NRM, species records unique to the Henley Beach - West Beach - Glenelg area (M1 in **Figure 18**) include the rhodophytes *Bonnemaisonia australis*, *Chamaethamnion schizandra*, *Chondria bulbosa*, *Colaconema bonnemaisoniae*, *Herposiphonia rostrata*, *Holotrichia comosa*, *Laurencia tasmanica*, *Polysiphonia atricapilla*, *Polyopes tenuis*, *Rhodymeniocolax austrina*, and *Schottera nicaeensis,* amongst several others.

In the South Brighton - Marino - Hallett Cove - Port Stanvac area (M2, **Figure 18**), there are 28 species not recorded in the other 7 other grid cells, including the following (amongst others):

- several opportunistic, fast growing chlorophytes (*Cladophora hutchinsioides*, *Cladophora sericea*, *Ulva flexuosa*)
- the greens *Bryopsis gemellipara*, *Caulerpa remotifolia* and *Codium harveyi*
- the common mat-forming intertidal species *Capreolia implexa*
- two species in the red genus *Lomentaria*
- numerous small red epiphytes (e.g. species in *Antithamnionella*, *Audouinella* and *Hirsutithallia*)
- the red alga *Alleynea bicornis* (which can grow in waters deeper than 30m in some areas of southern Australia), and
- the introduced brown species *Arthrocladia villosa*.

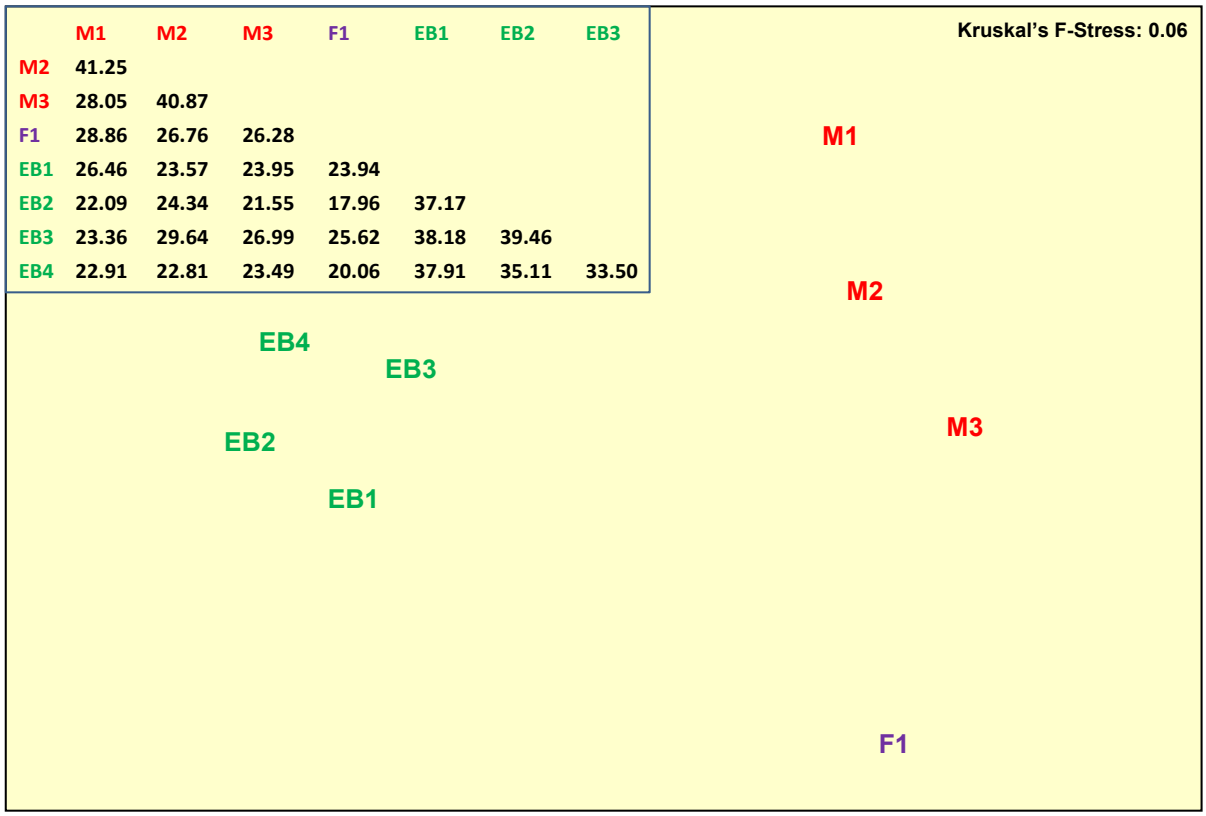


Figure 18: Jaccard association matrix for binary data (top left), and non-metric MDS plot showing similarities between 8 of the 10km^2 grid cells in AMLR NRM region for which there are most species in the SA State Herbarium data sets. M1, M2, M3 = 3 grid cells in the metropolitan area (F6, F7 and F8 in Figure 8); F1 = one grid cell in the upper Fleurieu Peninsula (= F10 in Figure 8), and EB1, EB2, EB3, EB4 = 4 grid cells in the Encounter Bay area, including Port Elliot (= G12, H12, G13, H13 in Figure 8).

Species records unique to the Port Stanvac – Port Noarlunga – Seaford grid cell (M3 in **Figure 18**), i.e. not yet found in the other 7 most speciose cells, include several species in *Chondria*; the small epilithic *Audouinella floridula*; various small epiphytes (e.g. two species in *Callithamnion*, and the two species in *Mazoyerella* known in South Australia), *Codium lucasii* and *C. perriniae*, plus 15 other exclusive taxa.

At the site in the upper Fleurieu (Aldinga South – Silver Sands – Sellicks area: F1 in **Figure 18**), the species composition in our datasets show sufficient difference for it to not group with any other of the 7 AMLR NRM sites for which the largest number of species of macroalgae have been recorded (**Figure 18**). Distinguishing species records from this location include 31 unique species composed primarily of small epiphytes. The unique red algal records in this site include the tiny European species *Audouinella humilis*; the multi-branched *Ceramium australe* (which grows on seagrasses); the cosmopolitan coralline epiphytes *Hydrolithon farinosum*, *Mesophyllum macroblastum*, and *Neogoniolithon brassica-florida*, 4 species of the encrusting coralline epiphyte *Pneophyllum* (two species of which may be cryptogenic within SA), two species in *Chondrophycus*, and the minute turfing red *Parviphycus antipai* (formerly *Gelidiella antipai*, known from few locations in Europe, Africa, the Americas, Pacific island, South Australia and Lord Howe Island). In terms of brown macroalgae, unique records in F1 (**Figure 18**) are *Dictyopteris gracilis, Dictyota bifurca*, *Dictyota polyclada*, the cosmopolitan *Stilophora tenella,* and the small brown epiphyte *Sphacelaria implicata,* the later known only from South Australia and New Zealand. Some of the Chlorophytes recorded at the upper Fleurieu site and at no other well studied site in AMLR NRM include the cosmopolitan species *Ulvella lens* (see **Table 4**), and the ~~p~~elty" green *Avrainvillea clavatiramea*, which reportedly grows mainly in deeper water (14-27m) or in murky, sandy, shallow environs (Baldock 2005b).

Sites in Encounter Bay and Port Elliot area (EB1-EB4 in **Figure 18**) formed a distinctive cluster hence share a more similar macroalgal composition with each other than with other sites. Some of the species found in the Encounter Bay and/or Port Elliot area, but not in the 3 most speciose 10km grid cells in the metropolitan area, nor in upper Fleurieu (Aldinga South to Sellicks area), include the following reef species (in alphabetical order): *Amansia pinnatifida*, *Apjohnia laetevirens*, *Ballia callitricha*, *Callophycus laxus, Callophyllis lambertii*, *Caulerpa sedoides*, *Chaetomorpha coliformis*, *Codium galeatum*, *Dictyomenia tridens*, *Euptilota articulata*, *Heterosiphonia curdieana*, *Homoeostrichus sinclairii*, *Laurencia elata*, *Lenormandia latifolia*, *Metamastophora flabellata*, *Mychodea hamata*, *Nizymenia australis*, *Peltasta australis*, *Phacelocarpus apodus* and *P. peperocarpos*, *Plocamium costatum*, *P. patagiatum* and *P. leptophyllum*, *Rhodophyllis multipartita* and *Seirococcus axillaris*. Some of these, such as *Nizymenia australis* and *Peltasta australis*, are typically associated with cooler waters of south-eastern Australia (Maugean province: Womersley 1990; Waters et al. 2010).

Species recorded waters offshore from Port Elliot (EB4 in **Figure 18**) and in none of the other most species-rich grid cells in Encounter Bay, upper Fleurieu or metropolitan area include *Areschougia stuartii*, *Caulerpa cliftonii*, *Gigartina disticha*, the corallines *Jania adhaerens* and *Lithophyllum prototypum*, *Macrothamnion secundum*, *Myriactula haydenii*, *Myriodesma leptophyllum*, *Rhodymenia leptophylla*, and the South Australian endemic *Strepsithalia leathesiae* and *Tylocolax microcarpus.* Some of these are known mainly from cooler waters in south-eastern Australia (e.g. *Areschougia stuartii*), or from deeper waters on rough water coasts (*Gigartina disticha*).

Numerous (36) species have been recorded only in the Bluff and/or West Island area (EB3) but in none of the other 7 grid cells compared in **Figure 18.** These are:

- the possibly endemic species *Acrotrichium amphibolis* (a brown epiphyte) and *Haraldia australica* (a small red alga)
- numerous small red epiphytes, some of which have been uncommonly recorded (e.g. *Antithamnion pinnafolium*, *Antithamnionella multiramosa*, *Callithamnion confertum, Herposiphonia filipendula*) or are widespread in temperate Australia (e.g. *Amoenothamnion planktonicum, Porphyropsis minuta*)
- the tiny coralline epiphyte *Choreonema thuretii*
- various species in Dasyaceae, including *Dasya baldockii* and *D. ceramioides*
- the European green species *Prasiola stipitata* (discussed in other parts of this report)
- the broadly distributed red alga *Stenogramme interrupta;* and *Heterosiphonia microcladioides*, the latter a small multi-branched alga which grows on bryozoans and other hard surfaces
- western species such as *Callophycus harveyanus,* and
- cool water (Maugean province) species such as *Dasythamniella plumigera, Rhodymenia verrucosa, Wetherbeella foliosa, Zymurgia chondriopsidea,* and the uncommonly recorded deeper water species *Chondria foliifera.*

3.3 Species for which South Australian occurrence may be limited to AMLR NRM Region

Some species recorded from AMLR NRM coastline have not been found anywhere else in South Australia. If this distribution is true and not an artefact of inadequate sampling over the State, then AMLR NRM would be the exclusive holder of these species in the State. **Table 4** below lists these species. Five of them are also endemic with very short distributional ranges (i.e. found so far only in AMLR NRM and nowhere else in the planet, see following section), 6 of the species are introduced, more than a dozen are possibly of cryptogenic origin (i.e. broadly distributed, and it is not known whether they are native to South Australia, or were introduced during the 1800s or 1900s), and the rest are Australian endemics hence with wide distribution along the temperate Australian coastline.

There are 26 species of red macroalgae recorded only in the AMLR NRM region, and in no other parts of South Australia, ranging from cosmopolitan species of broad global distribution, such as *Stylonema alsidii*, to cooler water Maugean Province species that are more common in Victoria in Tasmania (e.g. *Erythronaema ceramioides*), and also western species for which South Australia is the eastern limit of their distribution (e.g. *Thamnoclonium lemannianum*). Most of the endemic and non-endemic species recorded only in AMLR NRM are small epiphytes. South Australian endemics are discussed in more detail below in the section on endemic species.

Examples of species recorded in the AMLR NRM and no other parts in South Australia, but are known from other parts of southern Australia include the following (with notes on distribution from Cowan 2006, Womersley 2004, Guiry and Guiry 2010, and datasets here analysed):

- *Thamnoclonium lemannianum:* known from one record in South Australia, and approximately 10 records in southern WA. This species was not included in the treatment of the family it belongs, Halymeniaceae, in Womersley (1994).
- *Chamaethamnion schizandra*: Known from South Australia (Womersley 2003) and possibly also Victoria. According to Silva et al. (1996) the lectotype is from Port Phillip Bay, Victoria, and that type locality was reportedly first recorded by Falkenberg (1901 in Guiry and Guiry 2010).The precise type locality is unknown, and the type is presumed to be in Herb. Falkenberg, Naples (Womersley 2003). The South Australian material comes from drift in the Brighton area (1965) and the Grange tyre reef, about 7km offshore from Grange in Gulf St Vincent (1985). Both specimens were found growing on species of *Micropeuce* (SA State Herbarium data).
- *Doxodasya hirta*: An uncommonly recorded red alga which grows 2 to 10cm long, and is known from approximately 5 records in 3 locations, in southern Western Australia (e.g. Recherche Archipelago), South Australia and Victoria (e.g. Port Phillip Bay, the type locality). Records in SA are from jetty pylons at Port Stanvac (3m deep) and the Port Noarlunga tyre reef (19m deep).
- *Interthamnion attenuatum:* a minute (1-2mm) epiphyte known from reef pools at the type locality at Aldinga in South Australia, and from Ninepin Point and Bruny Island in Tasmania. This species appears to be known from less than 5 records. All examples were epiphytic on species of the brown alga *Zonaria.*
- *Camontagnea hirsuta*: known from New Zealand, 7 records in Tasmania and one South Australian record from West Island (collected in 1982).
- *Dictyomenia angusta:* known from WA, SA and Victoria. There are only 6 records from one locality in SA, and one in Victoria.
- *Erythronaema ceramioides*: Known from SA, Victoria and Tasmania. There are few records (e.g. a total of 9 specimens, from one locality in each of SA and Tasmania, and 2 localities in Victoria, are included in State Herbarium of South Australia, 2007, and Australian Virtual Herbarium, 2010).

A number of species of possibly cryptogenic origin in AMLR NRM are discussed below, in the section on introduced and cryptogenic species.

Table 4: Species recorded in the AMLR NRM and in other parts of southern Australia and the world, but not in any other of SA's NRM regions. (I) = introduced species. LHI = Lord Howe Island, NI = Norfolk Island, NSW = New South Wales, NT = Northern Territory, NZ = New Zealand, PNG = Papua New Guinea, QLD = Queensland, SA = South Australia (i.e. species has been found along the AMRL NRM coastline, but in no other part of SA), TAS = Tasmania, VIC = Victoria, WA = Western Australia. # = species identity unverifiable for this report.

Group	Species	No. Records from AMLR NRM	Distribution
Green Macroalgae	*Caulerpa taxifolia* **(I)**	13	Europe, Africa, Atlantic Islands, SW Asia, Mexico, Hawaii, Central America and Caribbean, Sth America, Indian Ocean islands, China, Japan, SE Asia, Pacific islands, PNG, NZ, Australia (WA, SA, QLD, NSW, NI, LHI).
	Cladophora montagneana	1	Africa, Nth America, Central America, Sth America, Australia (WA, SA).
	Codium fragile ssp. *fragile* (= ssp. *tomentosoides*) **(I)**	5	Europe, Atlantic islands, Nth Africa, Turkey, Nth America, Japan, Australia (SA, VIC, TAS), and NZ.
	Prasiola stipitata	1	Europe, Nth America, Sth America, NZ, Australia (VIC, TAS, SA).
	Rhizoclonium curvatum	7	NZ, Australia (SA, possibly TAS)
	Ulvella lens	1	Europe, Africa, India and other parts of SW Asia, Atlantic islands, Nth America, Central America and Caribbean, Sth America, Indian Ocean islands: Japan, Hawaii, SE Asia, Pacific islands, Australia (LHI, SA, WA).
Brown Macroalgae	*Acrotrichium amphibolis*	1	Australia (SA)
	Arthrocladia villosa **(I)**	1	Europe, Africa, Nth America, Atlantic islands, Australia (SA).
	Cystophora retroflexa **#**	1	NZ, Chatham Is., Australia (NSW, VIC, TAS, SA).
	Dictyota bifurca **#**	1	Australia (NT, QLD, NSW, SA).
	Discosporangium mesarthrocarpum	9	Europe, Turkey, Atlantic islands, Africa, Hawaii, Australia (SA).
	Myriactula filiformis	1	Australia (SA)
	Myrionema latipilosum	2	Australia (SA)
	Strepsithalia leathesiae	2	Australia (SA)
Red Macroalgae	*Anotrichium subtile*	2	Australia (NSW, VIC,SA).
	Antithamnionella spirographidis **(I)**	5	Europe, Atlantic islands, Russia, Nth America, China, Japan, Korea, Vietnam, Australia (NSW, VIC, SA).
	Audouinella barbadense / barbadensis *(= Acrochaetium barbadense)*	1	Atlantic islands, Nth America, Mexico, Caribbean, Sth America, Indian Ocean islands, Vietnam, French Polynesia, Hawaii, NZ, Australia (LHI, SA).

Table 4 (cont.):

Group	Species	No. Records from AMLR NRM	Distribution
	Audouinella plumosa	1	Sth Africa, Nth America, Mexico, Japan, Korea, Australia (QLD, VIC, SA).
	Bornetia tenuis	5	Sth Africa, India, Australia (NSW, VIC, SA)
	Caloglossa ogasawaraensis	5	Africa, India and Sri Lanka, Japan, China, Indonesia, Malaysia, Singapore, Vietnam, Philippines, Fiji, NZ, Australia (SA, NSW, QLD, NT, WA)
	Camontagnea hirsuta	1	NZ, Australia (TAS, SA)
	Chamaethamnion schizandra	2	Australia (SA, VIC?)
	Chondria arcuata **(I)**	1	North America, Mexico, Africa, Korea, French Polynesia, Hawaii, NZ, Australia (VIC, SA).
	Colaconema garbaryi	4	Africa, Nth America, Fiji, and Australia (QLD, VIC, SA).
	Cottoniella fusiformis **(I)**	5	Atlantic islands, Nth Africa, Pakistan, Australia (SA).
	Cryptopleura ramosa	1	Europe, Africa, Atlantic islands, Nth America, Sth America, China, Korea, Australia (QLD, VIC, SA)
	Dictyomenia angusta	4	Australia (VIC, SA, WA)
	Doxodasya hirta	2	Australia (VIC, SA, WA)
	Erythronaema ceramioides	3	Australia (TAS, VIC, SA)
	Interthamnion attenuatum	~ 3	Australia (TAS, SA)
	Phycodrys australasica	1	Korea, Australia (NSW, LHI, NI, VIC, SA, WA).
	Porphyra woolhouseae	4	Sth America, Falkland Is., NZ, Australia (TAS, VIC, SA, Macquarie I.), Antarctica and subantarctic islands.
	Porphyridium purpureum	1	Europe, China, Sth America, Micronesia, NZ, Australia (QLD, SA).
	Rhipidothamnion secundum	6	Australia (QLD, NSW, VIC, SA)
	Stylonema alsidii	2	Europe, Africa, Atlantic islands, India and other parts of SW Asia, Japan, Korea, Nth America, Caribbean, Sth America, Indian Ocean islands, SE Asia, Pacific islands, PNG, NZ, Australia (QLD, LHI, NSW, VIC, TAS, SA, WA).
	Scinaia acuta	2	Atlantic islands, NZ, Australia (NSW, VIC, TAS, SA).
	Scageliopsis patens	7	Europe, Atlantic islands, PNG, Australia (NSW, TAS, SA, WA).

Table 4 (cont.):

Group	Species	No. Records from AMLR NRM	Distribution
	Sahlingia subintegra	3	Europe, Africa, Atlantic islands, India and other parts of SW Asia, Nth America, Central America and Caribbean, Sth America, Japan, SE Asia, Pacific islands, Indian Ocean islands, Campbell I., Australia (NSW, VIC, TAS, SA, WA).
	Thamnoclonium lemannianum	1	Australia (SA, WA).
	Trematocarpus affinis / Trematocarpus flabellatus	1	Sth Africa, Australia (SA).
Coralline Red Macroalgae	*Pneophyllum confervicola*	35	Europe, Africa, India, Indian Ocean islands, Atlantic Ocean islands, Japan, Australia (QLD, SA).
	Pneophyllum limitatum	27	Europe, Australia (SA).

3.4 South Australian Endemic Species in AMLR NRM Region

Table 5 compares the number of South Australian endemic species recorded in each NRM region. The highest number (28) has been recorded in the KI NRM, followed by EP NRM (22), and AMLR NRM (18). Many of the endemic species, of both red and brown macroalgae are small epiphytes, some known from a single collection. Two examples include *Acrotrichium amphibolis* and *Strepsithalia leathesiae,* discussed in **Table 6**.

Table 5: Number of species considered endemic in SA per NRM region, according to AVH 2010 database records.

NRM Region	No. SA Endemic Species in Herbarium Collections
Alinytjara Wilurara	0
Adelaide and Mt Lofty Ranges	18
Eyre Peninsula	22
Northern and Yorke	14
Kangaroo Island	28
South Australian Murray-Darling Basin	0
South East	9

Of the possibly endemic red macroalgae in AMLR NRM, examples include *Bonnemaisonia spinescens*, *Pterothamnion flexile*, *Euptilocladia villosa*, *Callithamnion shepherdii*, *Callithamnion circinnatum*, *Tylocolax microcarpus*, *Medeiothamnion repens* and *Haraldia australica.* Five of the endemic red macroalgae known in AMLR NRM , are very small epiphytes. For example, *Heterothamnion sessile* has been recorded growing on *Cystophora*. *Crouania destriana* and *Antithamnionella multiramosa* have been recorded growing on coralline algae. More widespread examples of South Australian endemics that are not exclusive to the AMLR NRM region include *Flabellonema codii*, *Corynophlaea cristata*, and *Spatoglossum australasicum*, which are discussed in **Table 6**.

Table 6: South Australian endemic species recorded in the AMLR NRM region. Species marked in gray shading have been recorded so far exclusively in the AMLR NRM region (but see note on *Callithamnion circinnatum* which might be present in Tasmania, based on unverified records). Source: Cowan 2006; Womersley 1987, 1996, 1998 and 2003; Guiry and Guiry 2010; ADHerb 2010; and AVH 2010.

Species No.	Species Name	Description	No. Records In the AMLR NRM Region
Brown Macroalgae			
1	*Acrotrichium amphibolis*	A brown epiphyte, the single member of a genus resembling *Myriactula*, and recorded on *Amphibolis antarctica* seagrass in Encounter Bay in 1981.	1
2	*Corynophlaea cristata*	A soft, mucoid, brown epiphyte found on *Cystophora* species and recorded so far only from Point Westall in the eastern Great Australian Bight (GAB), several islands in the Sir Joseph Banks Group in Spencer Gulf, and Aldinga Reef in Gulf St Vincent.	1
3	*Flabellonema codii*	A small brown epiphyte, which is found on the utricle ends of the green ball-like alga *Codium mamillosum*, and has been recorded at various locations in SA, from Eyre Peninsula to Encounter Bay.	8
4	*Myriactula filiformis*	A small epiphyte found on *Cystophora*. Apparently known only from SA from a drift specimen collected in 1977 at Aldinga Beach.	1
5	*Myrionema latipilosum*	A small brown epiphyte on *Zostera* seagrass known only from type collection taken in 1977 from the Onkaparinga Estuary.	2
6	*Spatoglossum australasicum*	A dichotomously-branched brown alga, which grows to about 16 cm tall (Womersley 1987), and has been recorded from Port Julia, Brighton jetty, and LeFevre Peninsula in Gulf St Vincent (the latter specimens collected by Mueller in 1852), Port Bonython loading terminal in Spencer Gulf (collected by J. Brook in 2009), and Nobby Island on southern Kangaroo Island (collected by J. Baker in 1994).	6
7	*Strepsithalia leathesiae*	A small brown epiphyte, which forms patches on the surface of the brown alga *Leathesia difformis*, and has been recorded so far only on a rock platform at Aldinga.	2

Table 6 (cont).

Species No.	Species Name	Description	No. Records In the AMLR NRM Region
Red Macroalgae			
8	*Antithamnionella multiramosa*	A small red epiphyte on coralline algae such as *Corallina officinalis* and *Haliptilon roseum*. This species is known from at least 14 records in SA, ranging from Greenly Beach on Eyre Peninsula to West Island out of Encounter Bay.	11
9	*Bonnemaisonia spinescens*	A delicate, multi-branched alga which grows to about 8cm long, and has been found in various locations in Gulf St Vincent, Investigator Strait and Backstairs Passage, from 10 to 41 m deep.	3
10	*Callithamnion circinnatum*	A densely tufted, multi-branched red alga which grows up to 12cm long and has been recorded from: Elliston and Crinoline Point on Eyre Peninsula, 15m deep off Crag Point in northern Spencer Gulf, Noarlunga tyre reef, and Aldinga reef in GSV. It is noted that there is an unverified record in the SA State Herbarium database of a specimen from Tasmania collected in 1948 and more recently identified as *Callithamnion circinnatum*. However, Tasmania is not included as part of the distribution in published references (e.g. Womersley 1998).	3
11	*Callithamnion shepherdii*	A small fluffy red alga, recorded from various locations in S.A., ranging from Waldegrave I. in the eastern GAB, through to American River on Kangaroo Island, and several locations in Gulf St Vincent.	2
12	*Crouania destriana*	A small red epiphyte that occurs on the surface of coralline macroalgae such as *Metagoniolithon*, *Amphiroa* and *Sporolithon*. Known from approximately 14 specimens, ranging from Point Lowly in northern Spencer Gulf to Cape Northumberland near the Victorian border. AMLR NRM specimen is from Fishery Beach near Cape Jervis.	1
13	*Euptilocladia villosa*	A spongy, multi-branched alga, 5 to 15cm long, recorded from various locations in South Australia ranging from Topgallant Island in the eastern GAB, through to Cape Northumberland in the South East.	1
14	*Haraldia australica*	A red alga known so far only from several old records in South Australia, including Rocky Point (1950) and Muston / American River (1950) on Kangaroo Island, and West Island out of Encounter Bay (1966).	1
15	*Heterothamnion sessile*	A small red epiphyte, closely related to *Heterothamnnion muelleri*, growing on drift specimens of *Cystophora platylobium* and known so far from old records from Victor Harbor (1963) and Seal Bay, Kangaroo Island (1966).	1
16	*Medeiothamnion repens*	A small red epiphyte found growing on *Cystophora* species and recorded from a number of South Australian locations, ranging from Elliston in the eastern GAB, through to Port MacDonnell in the South East.	1
17	*Pterothamnion flexile*	A multi-branched red alga, 4 to 8cm long, known from off Outer Harbour (found growing on old shells, at 20 – 25m deep, in 1975) and Point Lowly in the Spencer Gulf (record from 1987 collections from artificial reef at 14 m deep).	1
18	*Tylocolax microcarpus*	A small red epiphyte found on *Lenormandia spectabilis* and recorded from Point Avoid and Wanna on the Eyre Peninsula, Vivonne Bay and Pennington Bay on southern Kangaroo Island, and Encounter Bay.	2

The location of endemic red and brown species of macroalgae in the AMRL NRM region is shown in **Figure 19**. Endemic species of macroalgae apparently are concentrated around the Outer Harbour, Port Noarlunga (with 5 species recorded in the area – see the section below on Aquatic Reserves), and Encounter Bay areas (**Figure 19**). There are no records of endemic green macroalgae species for in the AMLR NRM coast, as at 2010.

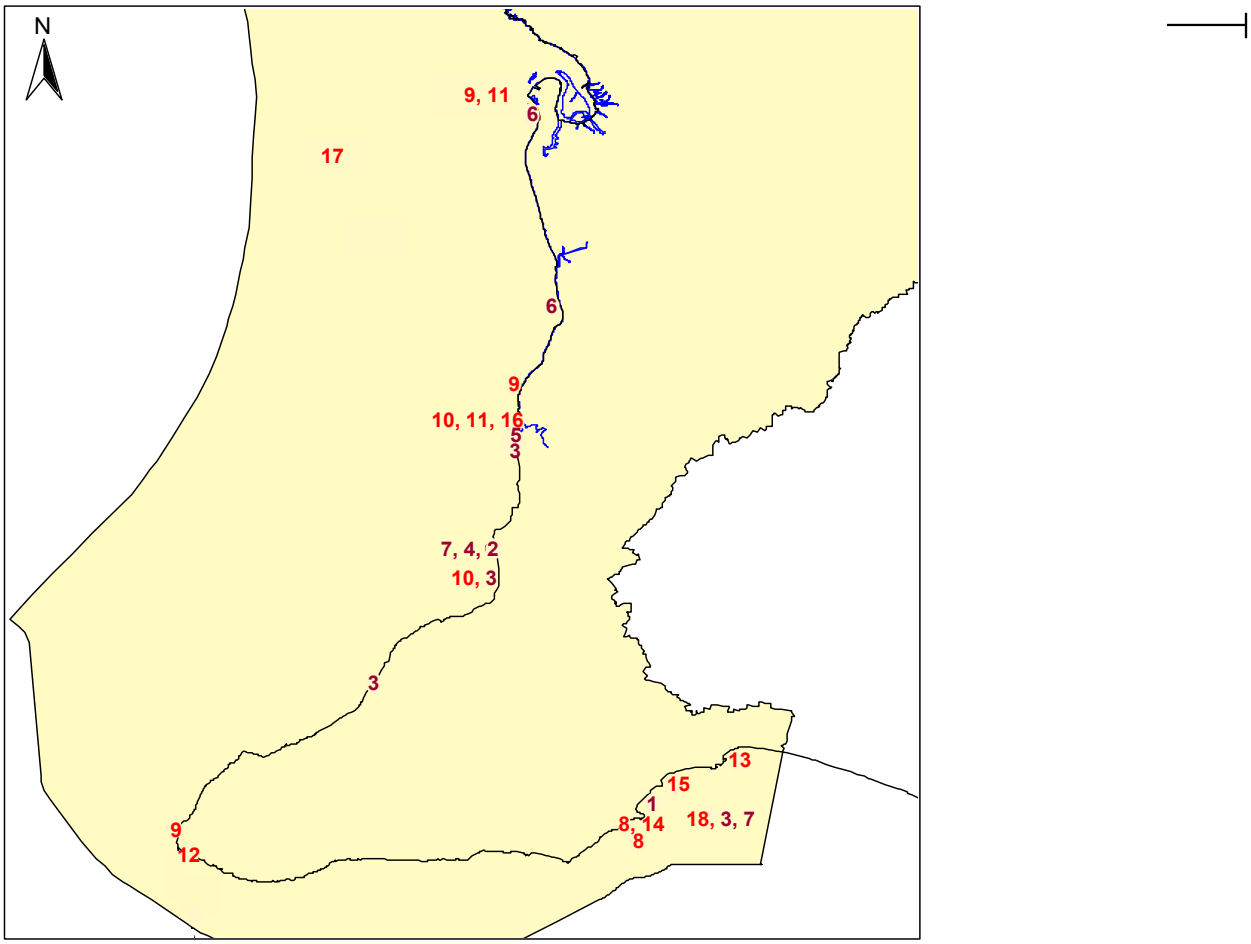


Figure 19: Distribution of South Australian endemic species of macroalgae recorded in AMLR NRM region. Species numbers correspond to those in Table 6. Red numbers correspond to Rhodophyta taxa. Brown numbers correspond to Phaeophyceae taxa.

3.5 Possibly Rare Species in AMLR NRM Region

Figure 20 shows the distribution of records of macroalgae considered by Womersley (2004, 2005), and/or Baldock and Ricci (2005) to be ~~r~~are" in South Australia. Baldock and Ricci (2005) is a revision of the Womersley (2004) list, to include species known from restricted habitats within the AMLR NRM region. Some of the species in Womersley (2004, 2005) and Baldock and Ricci (2005) were introduced to South Australia, while several are endemic within South Australia (**Table 7**). Also included in the Womersley and Baldock and Ricci lists was a code for abundance (~~r~~are", ~~p~~lentiful" or ~~u~~nknown") at sites where the species have been recorded, and an indication of which species are known only from old records (i.e. 50+ years). Recommendations to help resolve pending problems associated with each record were provided. **Table 7** below indicates which species in the Womersley and/or Baldock and Ricci lists are endemic within SA, and which are found in other parts of southern Australia, and/or other parts of the world.

The definition of rarity used the aforementioned authors related to the inclusion of (i) *species known from single or very few records*, and (ii) *species known from restricted habitats in southern Australia*.

Note: the AMLR NRM record of *Kallymenia rubra* is drift, and the AMLRN MRM record of *Gigartina wehliae* is not only old (collected from Port Elliot in 1898, by J. Hussey) but also possibly from drift as well. It is also noted that, according to Aziz et al. (2008), the southern Australian species *Kallymenia rubra* has been recorded from Bangladesh.

According to **Figure 20**, the distribution of species considered by Womersley and/or Baldock and Ricci to be rare (NB not all species would qualify for listing as rare – see below), seems to be evenly spread across the AMLR NRM coast. Areas with no records correspond to regions historically and comparatively poorly sampled. This is a pattern followed by the overall number of records per site, total and division-related species richness values across the AMLR NRM coastline.

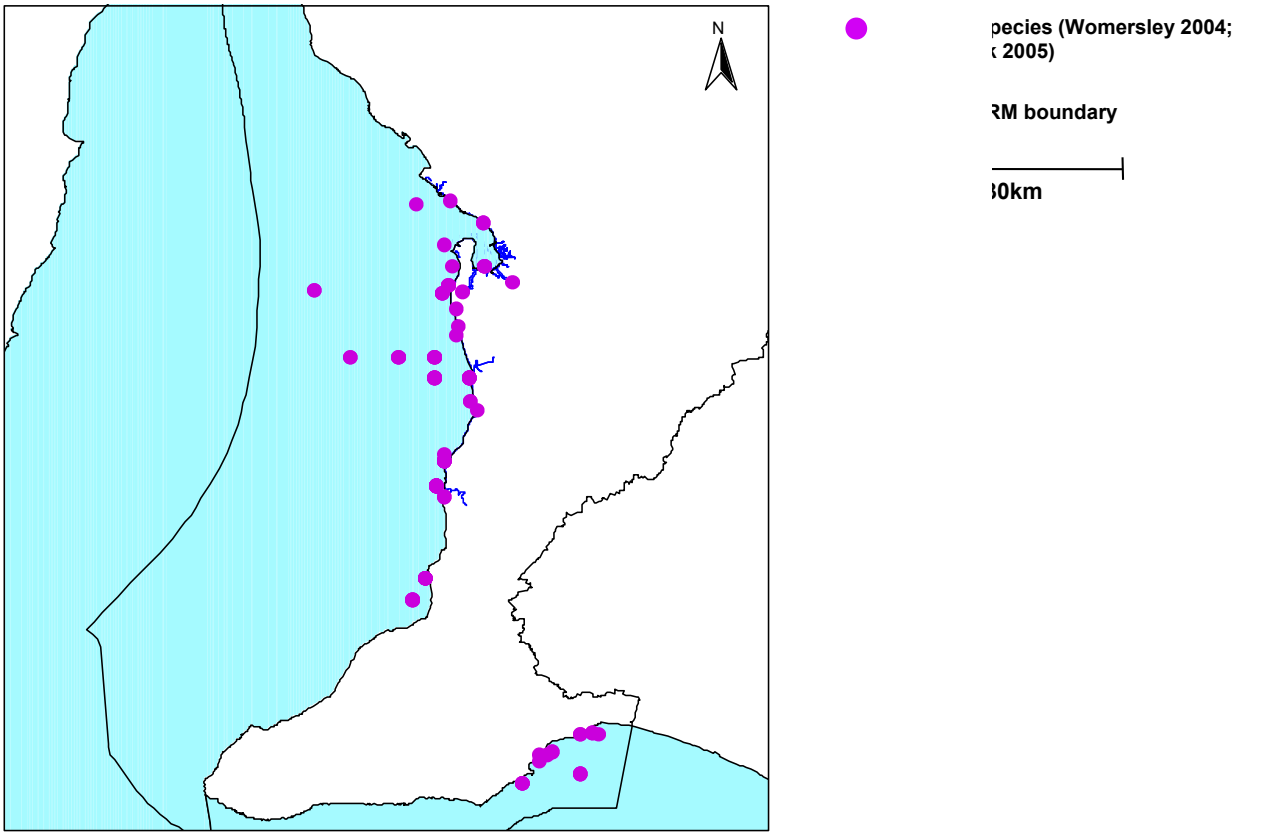


Figure 20: Distribution of records of macroalgae considered by Womersley (2004), and Baldock and Ricci (2005) to be rare in South Australia. Rare species include taxa known from single or very few records, or found from restricted habitats in southern Australia. *Note: includes some introduced and some potentially cryptogenic species.*

Table 7: Macroalgae present in the AMLR NRM region that are either known from single or very few records, or known from restricted habitats according to the compilations provided by Womersley (2004, 2005), and Baldock and Ricci (2005). The definition of rarity used by those authors is described in the text. This list includes a mix of SA endemic, southern Australian, globally distributed, cryptogenic and introduced species. A number of the species – discussed in this report – are not considered here to satisfy formal criteria for listing as rare in South Australia, nationally or globally. SA = South Australia. Gray shading indicates presence.

Taxa	SA Endemic	Southern Australia	Global OR Countries in addition to Australia	Introduced in SA	Cryptogenic in SA	No. Records in (a) SA & (b) Australia
Green Macroalgae						
Cladophora rhizoclonioidea						(a) 2 (b) ~ 6
Brown Macroalgae						
Acrotrichium amphibolis						(a) 1 (b) 1
Discosporangium mesarthrocarpum						(a) 9 (b) 9
Halothrix ephemeralis						(a) 8 (b) >10
Myriactula filiformis						(a) 1 (b) 1
Myrionema latipilosum						(a) 2 (b) 2
Strepsithalia leathesiae						(a) 2 (b) 2
Red Macroalgae						
Anotrichium subtile						(a) 2 (b) 8
Antithamnionella glandifera						(a) 4 (b) 5
Bangia atropurpurea						(a) 17 (b) 68
Bornetia tenuis						(a) 5 (b) > 5
Callithamnion circinnatum		(possibly)				(a) 6 (b) 7
Callithamnion confertum						(a) 8 (b) ~ 11
Caloglossa ogasawaraensis						(a) 5 (b) 21
Chamaethamnion schizandra						(a) 2 (b) > 2

Table 7 (cont.):

Taxa	SA Endemic	Southern Australia	Global OR Countries in addition to Australia	Introduced in SA	Cryptogenic in SA	No. Records in (a) SA & (b) Australia
Cottoniella fusiformis						(a) 5 (b) 5?
Doxodasya hirta						(a) 2 (b) 5
Erythronaema ceramioides						(a) 3 (b) > 11
Gibsmithia womersleyi						(a) 4 (b) 10
Gigartina wehliae						(a) 7 (b) ~ 12
Haraldia australica						(a) 12 (b) 12
Heterothamnion sessile						(a) 3 (b) 3
Interthamnion attenuatum						(a) 1 (b) 4
Kallymenia rubra			(possibly)			(a) 4 (b) > 4
Porphyra woolhouseae / woolhousiae						(a) 4 (b) 13
Porphyridium purpureum						(a) 1 (b) > 1
Scageliopsis patens						(a) 7 (b) 13
Pterothamnion flexile						(a) 2 (b) 2
Rhipidothamnion secundum		(also QLD)				(a) 6 (b) 29
Trematocarpus affinis						(a) 1 (b) >1
Tylocolax microcarpus						(a) 7 (b) 7

In South Australia, the *National Parks and Wildlife Act* has a schedule for listing species as ~~r~~are", but macroalgae are not included. The category of rare may relate to either: a reduced area of occupancy and/or extent of occurrence, a sharp decline in abundance, small population sizes, and/or restricted extent of occurrence or area of occupancy, with specific criteria for each of those categories. At a global scale, the categories of the IUCN's Red List of Threatened Species (IUCN, 2001) no longer includes a category of ~~r~~are", but some species which may qualify as rare due to very small or restricted population (with evidence of fluctuation or decline), or very restricted geographic range, may instead be listed *critically endangered*, *endangered* or *vulnerable*, depending on specific numeric criteria.

For example, according to IUCN criteria, if a species is known from 5 or fewer locations, it may satisfy criteria for listing as vulnerable. Many other criteria, including those relating to extent of occurrence and area of occupancy are also used to assess status, as shown in **Table 8** below.

It is important to note that species assessments using the criteria should only be undertaken using all known data on range, and number of records. Also, even if a species qualifies for listing using any of the categories or criteria listed in **Table 8** below, the accuracy of the assessment is time-specific, and may be revised in future as better information becomes available regarding distribution and relative abundance. This is particularly true for many marine plant and invertebrate species, which are known from very few, opportunistically collected records, and the true distribution may be much broader (and abundance may be considerably higher), than is considered from the currently available records. For most of the small marine plant species, particularly epiphytes, targetted searches of records have not been undertaken, and the few examples known were incidental, recorded during surveys undertaken for some other purpose.

One of the most important metrics to estimate rarity refers to the area of occupancy. In the marine environment, however, area of occupancy and extent of occurrence can be difficult to apply in terms of square kilometres, due to the three dimensional nature of the sea. In this case, depth range should also be considered rather than a linear distance along a coast (hence volume instead of area is often the preferred spatial unit). However, the choice of spatial scale can vary according to which species is under study, and the nature of the benthos (e.g. with or without extreme changes in depth such as sand plains versus canyons). Also, some macroalgal species can survive for weeks as drift, or have microscopic life stages, or comprise delicate epiphytes without known distribution. Consequently, many species which may not genuinely be uncommon or rare, are known from very few records.

Moreover, a number of species which may qualify as rare may not necessarily be vulnerable (if there are no threatening processes occurring) and a number of species may not qualify for listing as rare, but could be considered threatened if threatening processes are widespread and continuous.

It is noted that a previous national assessment of threatened species of macroalgae in Australia (Cheshire et al. 2000), defined the ~~"v~~ulnerable" category as:

- *species that are reported to occur at five or fewer locations but are broadly distributed (range >500 km),*or
- *species that have five or fewer known locations and occur within 500 km of coastline*.

In that report (Cheshire et al. 2000) ~~"v~~ulnerable, potentially endangered" species were defined as:

- *species that have been recorded from only one location or have a distribution restricted to less than 50 km of coastline.*

Such an approach is useful for defining potentially threatened species if the known distributions and number of records have been correctly determined, which was not the case for numerous species listed in that report. For example, a number of species previously considered threatened in South Australia by Cheshire et al. (2000) would not currently qualify for listing as such, due to the actual number of records known and/or their geographic range now being larger than previously determined. Inaccuracies in assessment can result from relying on published volumes, which summarise distribution, and not conducing thorough literature for each species searches (e.g. of museum data or herbarium records, published papers, and taxonomically validated survey data). A full list of corrections for temperate (southern Australian species) included as threatened or endangered in the Cheshire et al. (2000) report which would not qualify for listing as such, is available from J. Baker.

Table 8: Summary of the IUCN Red List Categories and Criteria (from IUCN Shark Specialist Group 2007)

Summary of the five criteria (A-E) used to evaluate if a species belongs in a category of threat (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A-E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible **AND** understood **AND** have ceased, based on and specifying any of the following: **(a)** direct observation **(b)** an index of abundance appropriate to the taxon **(c)** a decline in AOO, EOO and/or habitat quality **(d)** actual or potential levels of exploitation **(e)** effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1			
A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.			
A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.			
B. Geographic range in the form of either B1 (extent or occurrence) AND/OR B2 (area or occupancy)			
B1. Extent of occurrence	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following:			
(a) Severely fragmented, **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			
C. Small population size and decline			
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
(a) (i) # mature individuals in each subpopulation:	< 50	< 250	< 1,000
(a) (ii) or % individuals in one sub-population at least	90%	95%	100%
(b) extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
Either: Number of mature individuals	≤ 50	≤ 250	**D1.** ≤ 1,000
			AND/OR
	Restricted area of occupancy		**D2.** AOO < 20 km² or # locations ≤ 5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max)	≥ 20% in 20 years or 5 generations (100 years max)	≥ 10% in 100 years

Table 9 shows the species previously listed by Cheshire et al. (2000), Womersley (2004, 2005), and/or Baldock and Ricci (2005), which were considered by those authors to be rare or threatened in South Australia, but would not qualify as such according to our assessment. Many taxa would also not qualify for listing as rare nationally in Australia, or globally, using formal criteria such as those associated with the IUCN threatened species categories. For example, many of the species in **Table 9** are broadly distributed (and some are introduced to South Australia), therefore are not considered rare, despite some being known from few records in South Australia. For instance, *Scageliopsis patens* is found in Europe (Portugal and Spain), Atlantic islands such as the Azores, Papua New Guinea, and four states in Australia hence is not considered here to be a rare or threatened species (source: Guiry and Guiry 2010, ADHerb 2010, AVH 2010). However, this species was previously included as a ~~v~~ulnerable, potentially endangered species" in the report of Cheshire et al. (2000) with the assumption that it had a distribution restricted to less than 50km of coastline. As with a number of the other species listed in **Table 9** below, it is likely that the inaccurate Cheshire et al. (2000) assessments were based on the incomplete details of distribution published in the volumes of Womersley, and it is also possible that inadequate searches of herbarium records (including those in other States) were undertaken for that national assessment of threatened species.

A number of species that do not qualify for rare or threatened species status as per **Table 9**, are discussed in more detail below, in **Tables 12** and **13** (on introduced and possibly cryptogenic species).

Table 9: Species present in the AMLR NRM region that were previously listed as rare and/or threatened, including vulnerable or endangered (according to Cheshire et al. 2000, Womersley 2004, 2005, and/or Baldock and Ricci 2005) but which would not qualify as such in South Australia, Australia, and/or globally. GAB = Great Australian Bight; NSW = New South Wales; NT = Northern Territory; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria.

Taxa	Justification for Species Not Qualifying as Rare or Threatened in South Australia or southern Australia (for more information, see Table 12 on introduced species and Table 13 on species which are possibly cryptogenic).
Apoglossum spathulatum	A red alga, often epiphytic, epizootic or epilithic, known in Australia from at least 146 records in SA, WA, VIC, TAS and Lord Howe Island. This species also occurs in Africa, South East Asia, India and South America.
Bangia atropurpurea	Cosmopolitan distribution, known from more than 40 countries; 17 records from numerous locations in SA, and 68 records from 6 States of Australia
Bonnemaisonia australis	A delicate, multi-branched alga from 4cm to 12cm high, known from at least 16 records in WA, SA, VIC and TAS. Most records are from the gulfs region in SA.
Bornetia tenuis	Known from South Africa, India and 3 States of Australia (NSW, VIC and SA). There are few records in SA, mostly from metropolitan beaches (e.g. on jetty piles) and in Encounter Bay.
Callithamnion confertum	A small, (to 20mm long) multi-branched red epiphyte from south-eastern Australia, with at least 11 records known collectively from South Australia, Victoria and northern TAS. Eight of the records are from SA, spread over 4 NRM regions. The type specimen is from Robe, on the green alga *Caulerpa brownii* in shallow subtidal pools
Caloglossa ogasawaraensis	Although known in SA from only 5 records (all in AMLR NRM region), this cryptogenic species is broadly distributed, known from at least 17 countries, and 5 States in Australia.
Chauviniella coriifolia	A multi-branched red alga known from at least 57 records, collectively from in WA, SA, VIC and QLD.
Chondria angustissima	A tangled, multi-branched red epiphyte with a broad distribution (WA through to NSW). Known from at least 14 records in 4 States.

Table 9 (cont.):

Taxa	Justification for Species Not Qualifying as Rare or Threatened in South Australia or southern Australia (for more information, see Table 12 on introduced species and Table 13 on species which are possibly cryptogenic).
Cirrulicarpus nanus	A cartilaginous red alga between 5cm and 15cm high, known from at least 52 specimens in more than 30 localities, collectively in WA, SA, VIC and TAS.
Cladophora hutchinsioides	A filamentous, multi-branched green alga, 5cm – 20cm high, known from at least 17 records in WA, SA, VIC and NSW. Also recorded in Japan and Korea (Hoek and Chihara 2000; Lee 2008, cited in Guiry and Guiry 2010).
Cladophora rhizoclonioidea	A green alga that forms hair-like masses. Known from approximately 8 specimens in WA, SA, VIC. Likely to be more widespread than current records indicate.
Codium spinescens	A green alga known from at least 26 records in 8 locations in SA and WA. Most records are from WA. Several of the SA records are from the Head of GAB, and the AMLR NRM record is from the drift.
Cottoniella fusiformis	Introduced to South Australia (5 records from at least 4 locations), and also known from various Atlantic islands (Canary Is., Madeira, Salvage Is.), Libya in Africa, and Pakistan.
Dictyomenia sonderi	A medium - large (to 40cm) red alga with fringed laterals, widespread across southern WA and SA, and known from at least 125 records in more than 35 locations.
Dictyota bifurca	A tropical and subtropical brown alga known from 15 herbarium records, collectively from NT, QLD, NSW and one record in SA (Aldinga).
Discosporangium mesarthrocarpum	A Mediterranean species, recorded in Europe (7 countries, mainly Mediterranean), Turkey, several Atlantic islands, Morocco in Africa, Hawaii. In Australia, known from SA (9 records). Within the AMLR NRM, a 1987 record from an artificial tyre reef of Glenelg is notable.
Ditria expleta	An inconspicuous red epiphyte, prostrate on host plants of the brown *Zonaria* and *Lobophora*. Known from at least 16 records, mostly in SA, but ranging from the Houtman Abrolhos in WA through to Kangaroo Island in SA.
Echinothamnion hookeri	A multi-brancehd red alga known from at least 149 specimens in SA, VIC and TAS. There are also records from WA and QLD, less commonly.
Halothrix ephemeralis	A brown epiphyte that is seasonally prolific on *Heterozostera* seagrass. Known from at least 10 records in SA, VIC and TAS.
Gigartina disticha	A red alga known from at least 48 records across south-western and southern WA and SA. South Australian records range from the eastern GAB through to the South East.
Herposiphonia rostrata	A small red alga, epiphytic on the seagrass *Amphibolis*, and known from at least 32 specimens in WA, SA and VIC.
Heterosiphonia callithamnium	A small (to 3cm high) red epiphyte, known from at least 35 specimens in SA and WA. SA specimens come from at least 9 locations, in eastern GAB and the gulfs.
Macrothamnion pellucidum	A multi-branched red alga between 10cm and 30cm high, known from at least 145 records across southern Australia (WA, SA, VIC, TAS).

Table 9 (cont.):

Taxa	Justification for Species Not Qualifying as Rare or Threatened in South Australia or southern Australia (for more information, see Table 12 on introduced species and Table 13 on species which are possibly cryptogenic).
Mazoyerella arachnoidea	A small, densely-tufted red epiphyte, known from approximately 10 records in at least 8 locations, in WA (Penguin Island specimen, collected by J. Huisman), SA and TAS.
Myrionema ramulans	A small brown alga epiphytic on *Sargassum* and *Cystophora* species, and known from 6 records in SA, VIC and TAS. It is likely that the species is more abundant within the range than the few current records indicate.
Polysiphonia amphibolis	A red alga that is a common epiphyte on seagrasses and coralline algae in SA and WA.
Porphyridium purpureum	A microscopic red alga with global distribution in fresh, brackish and seawater. The SA record is from West Island, epiphytic on the brown alga *Dictyota fenestrata* (Womersley, 1994).
Pseudolithoderma australe / australis	A crustose brown alga that is epilithic, and also grows on plastic waste in the sea. Known from at least 12 records in 8 locations, collectively in SA (from where most records have been collected) and TAS.
Rhipidothamnion secundum	A multi-branched red alga, to 7cm long, from a monospecific genus. Although known in SA from only 6 records (all in AMLR NRM, including a record from the Glenelg ~~b~~locks"), it also occurs in three other States of Australia (QLD, all along the NSW coast, and VIC), with at least 29 herbarium records known. As mentioned for examples from VIC (Womersley 1998), it is possible that southern Australian records are introductions from eastern Australia.
Scageliopis patens	Found in Europe, Atlantic islands, Papua New Guinea, and four states in Australia
Stilopsis harveyana	A medium to large (10cm – 35cm) brown epiphyte, known from at least 22 records in WA, SA, VIC, TAS and NSW.

On the other hand, a number of species identified by Cheshire et al. (2000), Womersley (2004) and/or Baldock and Ricci (2005), as well as several others not included in those lists, may indeed qualify as rare in South Australia, and in some cases also nationally. However, more information is required on distribution, and comparison with examples from other localities is needed to confirm their true status. In particular, some of the small epiphytes may be more widespread than records indicate, but targeted searches have not been made, and existing records are opportunistic. Examples of possibly rare species in AMLR NRM region are included in **Table 10**, and locations where these species have been recorded are shown in **Figure 21**.

Table 10: Species found in AMLR NRM region which may qualify for formal listing as are, or another category of threat, in South Australia and/or nationally. Species numbers correspond to those on Figure 21. GAB = Great Australian Bight; SA = South Australia.

Species Number	Name of Potentially Rare Species in AMLR NRM	Description and Justification
1	*Acrotrichium amphibolis*	A small brown epiphyte, and the single member of a genus resembling *Myriactula*, recorded on *Amphibolis antarctica* seagrass in Encounter Bay in 1981 (Womersley 1987). This species is apparently known only from a single location.
2	*Antithamnionella multiramosa*	SA endemic. Known from at least 14 records over 3 South Australian NRM regions hence may not be rare at a State-wide but of limited distribution on a national scale.
3	*Bonnemaisonia spinescens*	SA endemic. Known from at least 9 records over south Australian 3 NRM regions hence may not be rare at a State-wide but of limited distribution on a national scale.
4	*Callithamnion shepherdi*	A possibly endemic species recorded from various locations in SA, from Waldegrave I. in the eastern GAB, through to American River on Kangaroo Island, and several locations in Gulf St Vincent.
5	*Callithamnion circinnatum*	A densely tufted, multi-branched red, which grows up to 12cm long, and has been recorded from Elliston and Crinoline Point on Eyre Peninsula, 15m deep off Crag Point in northern Spencer Gulf, Noarlunga tyre reef and Aldinga reef in GSV. It is noted that there is an unverified record in the SA State Herbarium database, of a specimen from Tasmania, collected 1948 and more recently identified as *Callithamnion circinnatum*, however, Tasmania is not included as part of the distribution in published references (e.g. Womersley 1998, Cowan 2006, Guiry and Guiry 2010).
6	*Corynophlaea cristata*	An epiphyte found on *Cystophora* species, and known from only 4 records in two South Australian NRM regions.
7	*Crouania destriana*	SA endemic. Known from at least 18 records over 4 South Australian NRM regions hence may not be rare at a State-wide but of limited distribution on a national scale.
8	*Flabellonema codii*	SA endemic epiphyte. Known from at least 11 records over 3 south Australian NRM regions hence may not be rare at a State-wide but of limited distribution on a national scale.
9	*Gigartina wehliae*	A cartilaginous, multi-branched red, 5 – 15cm tall, recorded in SA, Victoria and Tasmania, mainly from drift specimens. Known from approximately 12 records nationally, 6 records from 3 locations in SA, and a specimen collected in 1994, from Point Labatt in the eastern Great Australian Bight during a SARDI benthic survey (identified by K. Edyvane and confirmed by HBS Womersley). The AMLR NRM record is of 4 drift specimens collected from Port Elliot in 1898.
10	*Gibsmithia womersleyi*	A multi-branched, mucilaginous plant from 3 to 48cm high (Womersley, 1994), known from approximately 10 records, collectively from southern WA (Hopetoun and Esperance) and locations in SA including Pearson Islands and Waterloo Bay in the eastern GAB, Emu Bay on Kangaroo Island, and one location in the AMLR NRM.
11	*Haraldia australica*	A red alga, apparently known only from several old records in South Australia, including Rocky Point (1950) and Muston / American River (1950) on Kangaroo Island, and West Island out of Encounter Bay (1966) (Womersley, 2003, State Herbarium of South Australia, 2010).

Table 10 (cont.):

Species Number	Name of Potentially Rare Species in AMLR NRM	Description and Justification
12	*Heterothamnion sessile*	A small brown alga, epiphytic on species of *Cystophora*. Apparently known only from South Australia, from 3 records (Seal Bay on Kangaroo Island – collected 1966, and Victor Harbor in AMLR NRM region – collected 1963).
13	*Kallymenia rubra*	Known from 4 records in South Australia (Waldegrave I. and Elliston in the eastern GAB, and a drift specimen from Port Elliot in the AMLR NMRM region), and a similarly small number nationally. There are only 3 records in the Australian Virtual Herbarium (2010), the most recent being a specimen collected in 2006 from Crawfish Rock in Victoria. If the record of Aziz et al. (2008) from Bangladesh is correct, and the species is not imported into that country, then *Kallymenia rubra* could not be considered endemic to southern Australia, and would not qualify for listing as a rare species on a global scale, using IUCN criteria.
14	*Myriactula filiformis*	A small epiphyte found on *Cystophora*, and apparently known only from a simgle drift specimen collected in 1977 at Aldinga Beach, SA (Cowan 2006, Guiry and Guiry 2010)
15	*Myrionema latipilosum*	A small brown epiphyte known only from type collection taken in 1977 from the Onkaparinga Estuary, on *Zostera* seagrass.
16	*Porphyra woolhouseae*	A fine, sheet-like epiphytic red alga, known from only 4 records in SA. This cool and cold water species is also found in Victoria and Tasmania, as well as New Zealand, South America, the Falkland Islands, Antarctica and subantarctic islands.
17	*Pterothamnion flexile*	A multi-branched red alga, 4 to 8cm tall, known from off Outer Harbour in AMLR NRM (found growing on old shells, at 20 – 25m deep, in 1975) and Point Lowly in Spencer Gulf (record from artificial reef at 14m deep, collected in 1987)
18	*Strepsithalia leathesiae*	A small brown epiphyte, which forms patches on the surface of the brown alga *Leathesia difformis*, and foundonly on a rock platform at Aldinga, SA
19	*Spatoglossum australasicum*	SA endemic. Known from at least 9 records over 2 South Australian NRM regions (some of which are old) hence may not be rare at a State-wide but of limited distribution on a national scale.
20	*Trematocarpus affinis*	Known from South Africa, and apparently also from several specimens collected from 1m to 8m deep at West Island in SA in 1967 (Womersley 1994). The relationship between the South African and SA specimens should be determined. Note: Stegenga et al. (1997) and Cowan (2006) consider this to be a synonym of *Trematocarpus flabellatus*.
21	*Tylocolax microcarpus*	A small red epiphyte found on *Lenormandia spectabilis* (Womersley 2003), know only from 7 specimens collected in SA from Point Avoid (1975) and Wanna (1959) on Eyre Peninsula, Vivonne Bay (1948) and Pennington Bay (1957) on southern Kangaroo Island, and an old record collected by J.B. Cleland from Encounter Bay.

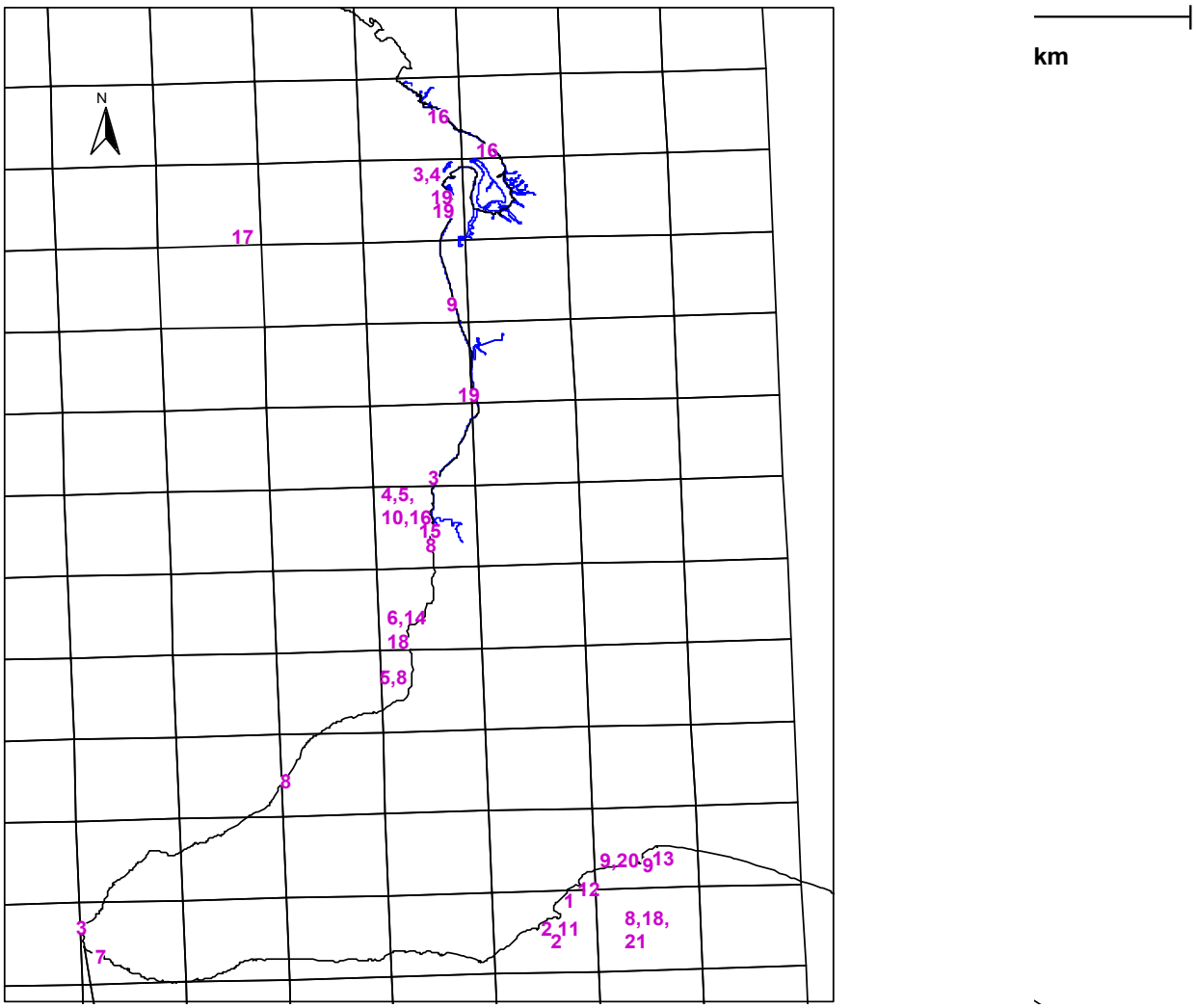


Figure 21: Distribution of benthic macroalgal species found in AMLR NRM region which may qualify for formal listing under a category of threat, in South Australia and/or nationally. Species numbers correspond to those in Table 10.

Thus far, records of possibly rare species (including South Australian endemics) are concentrated in the most frequently or most intentively sampled areas, such as Port Noarlunga area, Aldinga and Encounter Bay, and it is notable that there are Aquatic Reserves in all of these locations. Additionally, four potentially rare species have been recorded from the Outer Harbour area, which is a highly modified and industrialised area next to a major port facility. It is noted that a number of the records of potentially rare species in the AMLR NRM area are old (e.g. from the middle of the 20th century, and even the 19th century in some cases), and it is not certain if some of those species still exist in areas where they were originally collected.

Additionally, a small brown filamentous species, *Zosterocarpus australica* (Womersley, 1987), is known from Investigator Strait in deeper water, to the west of the AMLR NRM (see supplementary report).

According to literature searches by J. Baker, an additional 39 species of macroalgae may qualify for listing as Rare in SA, but these have not been recorded in the AMLR NRM region, and are thus not discussed here.

Species listed in Womersley (2004, 2005) as rare and/or Cheshire et al. (2000) as threatened (vulnerable or endangered), but for which the status is less clear, include:

- *Anotrichium subtile*: A small red species often found on artificial substrates (Baldock in Womersley 1998). Known in SA from jetty piles at Semaphore jetty (collected in 1968), and from Port Phillip Bay, Victoria, and various locations in New South Wales (Botany Bay, and two locations near the NSW / Victorian border).

- *Antithamnionella glandifera*: A small red epiphyte, known from 3 locations in AMLR NRM region (collected in: 1963 from 5 - 8km off Outer Harbour at 16m depth,1975on old shells 20 km WSW of Outer Harbor, and 1977 a specimen from jetty pylon at Port Stanvac). Outside SA this species has been found in Tasmania (on a barge off Beauty Point, 1964). Given the location of these records, it is possible that this species is an introduction, despite lack of published records from countries other then Australia (Womersley, 1998) and Korea (Lee 2008).

- *Caulerpa alternans*: A less common *Caulerpa* species, known from at least 14 specimens in SA, mostly in waters deeper than 14m (and to ~ 40m), in southern Gulf St Vincent, Investigator Strait, and off NE Kangaroo Island, plus one specimen from Lacepede Bay. Several specimens from Port Phillip Heads area in VIC (including the type) are from the late 19th century. It is possible that the habitat of this species has been inadequately sampled, hence the species may be more widespread than current records indicate.

- *Ceramium cupulatum*: A small (to 1cm high) red alga, epiphytic on *Haliptilon* and other corallines, and known from several specimens in SA and VIC. Womersley (1998) considered that a record from Diego Garcia is of a related species, not *C. cupulatum*; however, Cowan (2006) and Guiry and Guiry (2010) included the Diego Garcia Atoll, and also the Seychelles in the distribution of *C. cupulatum*, based on Silva et al. (1996).

- *Chamaethamnion schizandra*: Known from SA (Womersley 2003) and possibly Victoria. According to Silva et al. (1996), the lectotype is from Port Phillip Bay, Victoria, but the exact type locality remains unknown. The South Australian material comes from the eastern side of Gulf St Vincent, hence most likely from AMLR NRM from specimens collected in 1965 and 1985.

- *Cladophora rhizoclonioidea*: A green alga recorded in SA and Tasmania (Womersley 1984), western Victoria (ADHerb: 1959 and 1985 records) and Western Australia (Huisman and Walker 1990). There are two herbarium records of this species in SA, one from the type locality (Nora Creina), and the other from West Island out of Encounter Bay, on coralline turf.

- *Cryptonemia kallymenioides:* Known from at least 40 records, almost all of these from 6 locations in southern WA. SA records come from a ~~-s~~eamount" off Cannan Reefs in the GAB (22-30m deep), and possibly also from an unspecified location in the Encounter Bay area (AVH record). It is possible that the habitat of this species (caves and undercuts in deeper water) has been inadequately sampled, and the species may be more widespread than current records indicate.

- *Dictyopteris gracilis:* a medium to large (10cm – 30cm), multi-branched brown epiphyte formerly known only from SA (e.g. Baldock 2003; Guiry and Guiry 2010); however there is a West Australian museum record from near Esperance.

- *Doxodasya hirta*: A red alga known from southern Western Australia (e.g. Recherche Archipelago – WA Herbarium specimen collected in 2003), SA and Victoria (e.g. Port Phillip Bay). Records in SA are from Port Stanvac and Port Noarlunga.

- *Erythronaema ceramioides*: a multi-branched red alga (4 - 12cm tall) from south-eastern Australia, with at least 11 records known collectively from SA, Victoria and northern Tasmania. Known in SA from shore rocks near Port Noarlunga jetty (Womersley 1994).

- *Guiryella repens*: a small red epiphyte, known from few records, but with a broad distribution, known from Houtman Abrolhos in WA through to Gulf St Vincent in SA.

- *Halothrix ephemeralis:* a small brown epiphyte found for only about 6 weeks of the year on *Heterozostera* seagrass (Womersley 1987). This species is known from SA, Victoria and Tasmania. According to Womersley (1987) may not be specifically distinct from the Japanese species *Halothrix tortuosa*.

- *Interthamnion attenuatum*: a very small (1-2mm long) red epiphyte known from SA and Tasmania. The South Australian specimen is the type, epiphytic on the brown alga *Zonaria spiralis*, collected from a shallow subtidal pool at Aldinga in 1965. The three known Tasmanian specimens were also collected as epiphytes on *Zonaria*, at Bruny Island in 1986 and Ninepin Point in 1994 (Womersley 1998).

3.6 Introduced and Possibly Cryptogenic Species in AMLR NRM Region

Table 11 below shows the number of introduced and cryptogenic species in each NRM region, according to herbarium collections. A search of State, national and international literature and databases was undertaken to determine the status of all potentially introduced and cryptogenic species in SA. The highest number of introduced species in SA has been recorded in the AMLR NRM region. Similarly, AMLR NRM region also contains the highest number of potentially introduced species, for which the origin of the South Australian records is uncertain (i.e. cryptogenic).

It is important to note however, that some cryptogenic species are probably native but have been identified with names of taxa from other parts of the world, based on morphological similarities only. This means that most of these species are either truly cosmopolitan or represent new cryptic species (i.e. undescribed, possibly endemic, and genetically distinct but with no morphological differences from their Atlantic and European counterparts). Some highly diverse and morphologically simple genera such as *Ulva, Cladophora, Gracilaria, Ectocarpus,* and *Grateloupia* are prime examples. In these cases, the implementation of molecular assisted taxonomic identifications is highly advantageous. Molecular surveys of taxonomically problematic taxa have confirmed the presence of introduced species in many parts of the world, solved species complexes, and resulted in discovery of new taxa as well (e.g. De Clerk et al. 2005, Gurgel et al. 2004, Le Gall and Saunders 2010).

Table 11: Number of species introduced to South Australia based on herbarium collections, for each NRM Region

NRM Region	No. Introduced Species in Herbarium Collections	No. Cryptogenic Species in Herbarium Collections
Alinytjara Wilurara	0	1
Adelaide and Mt Lofty Ranges	15	38
Eyre Peninsula	6	22
Northern and Yorke	0	15
Kangaroo Island	3	19
South Australian Murray-Darling Basin	0	2
South East	4	26

Details about each introduced species in AMLR NRM region are described in **Table 12**. This list is based on the AdHerb (2010) data base which contains information about all Australian macroalgal herbarium records deposited in the SA State Herbarium. Introduced species in the AMLR NRM region currently comprise 6 species of green algae, 4 species of brown algae, and 5 species of red algae. Of these, the species of most concern are *Caulerpa taxifolia* (number one priority), *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*), and *Caulerpa racemosa* var. *cylindracea*.

It is noted that **Table 12** includes only those species known from location-specific records listed in ADHerb database. Several other introduced species in the AMLR NRM region that have been recorded either recently or in the past, either did not have specimens deposited in the SA State Herbarium, or do not have accurate distributional data. For example, several specimens of *Polysiphonia brodiei* that have been recorded in the South East and Kangaroo Island, but the single record from the AMLR NRM is not specific, possibly from Backstairs Passage (Wiltshire et al. 2010). Another introduced species, *Solieria filiformis* (known mainly from Africa, Atlantic islands and the Americas) has been recorded from Port Stanvac in 2008 but the record has not been confirmed, deposited or data based by SA State Herbarium (data from SARDI data, cited by Wiltshire et al. 2010).

Table 12 summarises the distribution of *Caulerpa taxifolia*. This invasive species, which can grow on a variety of substrates such as rock, sand, mud and dead seagrasses, was first recognised in South Australia in 2002, in West Lakes and the Port River. The species is native in tropical Australia, but various strains are of major concern in areas where they are not native (such as temperate waters), due to the ability of *C. taxifolia* to (i) spread rapidly, either vegetatively by growth of the stolons, or by regeneration from broken-off fragments as small as 1 square centimetre, with growth up to a centimetre or more per day, and (ii) cover large areas of substrate: the invasive aquarium strain is able to occupy up to 100% of the available substrate (NIMPIS 2010). *C. taxifolia* can live as individual plants or grow to form dense blankets covering large areas of substrate. The alga is large (with stems up to 2.8 metres long, but this is exceptional) and dense (e.g. more than 200 fronds may grow off the stems). Typically, a plant produces up to six ramifications and reaches a length of 1-1.5m in autumn (NIMPIS 2010). In areas of dense infestation, native seagrasses and macroalgae can be displaced. Such habitat change may also have flow-on negative impacts, including degradation of feeding areas and nursery habitats, and potential reduction in species richness and diversity. *Caulerpa taxifolia* contains a toxin that makes it distasteful; hence few animals eat it (PIRSA 2009c).

According to Wiltshire and Rowling (2009) and Wiltshire (2010), *C. taxifolia* has expanded its range in SA, and cannot be eradicated with current technology. Eradication attempts have been made since the early 2000s when this species was first discovered in the AMLR NRM region (e.g. Cheshire et al. 2002). Annual surveys of distribution in SA have been undertaken since 2003, and these are important in the management of the invasion. **Figure 22** shows the previous distribution of *C. taxifolia* in the Port River – Barker Inlet system, as at March 2006. During a survey in 2009 in the Port River – Barker Inlet system, downstream distribution and abundance were lower in some parts of the area surveyed (such as the Barker Inlet area and the western section of the Port River), than were recorded in 2007 and 2008 (Wiltshire and Rowling 2009). In 2010, a survey in the area (**Figure 23**) showed that although the pattern of distribution of *C. taxifolia* in that area had changed little in the 5 years to 2010, the density of *C. taxifolia* has decreased throughout much of the survey area. However, areas in which highest density was previously recorded have remained as such. Highest densities have been found in areas impacted by thermal effluent from the Torrens Island power station, and high nutrients from industrial run-off in the area. Areas of greatest accumulation include North Arm – Eastern Passage; along the Port River to the west of Torrens Island, and the Angas Inlet – Barker Inlet junction (Wiltshire 2010).

In South Australia, an environmental risk assessment for *Caulerpa taxifolia* is being developed to examine the physiological tolerances of the species, and the factors associated with colonisation success and growth. The biological features of invaded sites (such as the Port River system) and control sites are being compared, and changes to invaded environments are being quantified, as part of a risk analysis framework to determine areas at risk of *C. taxifolia* colonisation (MISA 2010), or spread of current infestations.

Codium fragile ssp. *tomentosoides* (= *Codium fragile* spp. *fragile*) from Japan is another introduced green macroalgae of concern. Recent molecular studies suggest that the name *Codium fragile* ssp. *tomentosoides* may be a junior synonym of *Codium fragile* ssp. *fragile* (Brodie et al. 2007, Provan et al. 2008, Bridgwood 2010). Regardless of the taxonomy or subspecies status, this introduced species is now considered one of the 10 most damaging marine pest introductions in Australia, based on results from 126 questionnaires (Hayes et al. 2005). *Codium fragile* ssp. *fragile*, which can reproduce both sexually and vegetatively, may settle on native algae and shellfish, wharf pilings and jetties. In some areas, large wracks of this alga rot on beaches after storms (Trowbridge 1999, CRIMP / NIMPIS 2002). *Codium fragile* ssp. *fragile* can tolerate large variations in salinity and temperature, which enables it to colonise a wide range of environments (Bégin and Scheibling 2003). Potential impacts are considered to include smothering of mussels and scallops (which can affect feeding ability, and also impede harvesting in aquaculture facilities), fouling of nets and ropes (which also aid dispersion of the alga), fouling of pylons, jetties and beaches, and also ecological impacts due to habitat degradation, and reduction in diversity of native species in heavily infested areas (Bridgwood 2010). *Codium fragile* ssp. *fragile* has been introduced to New Zealand, where it was first noticed during the 1970s, and has become abundant in the intertidal and shallow subtidal, dying back in autumn / winter and regenerated each spring from a perennial holdfast (Trowbridge 1995, Bridgwood 2010). In the northern hemisphere, this species was introduced in Nova Scotia in the late 1980‘s and now occurs along 1,200 km of eastern Canadian waters, forming dense stands in both intertidal and subtidal habitats (D‘Amours and Scheibling 2007, Bégin and Scheibling 2003, Kusakina et al. 2006, Bridgwood 2010). In that North West Atlantic region, this species is considered a ~~s~~erious nuisance” (MarLIN, undated). *Codium fragile* ssp. *fragile* is also of concern in Europe. For example, in an analysis of species traits which facilitate introduction and predominance, this species was ranked number 1 in terms of risk, out of 113 species of introduced macroalgae in Europe (Nyberg and Wallentinus 2005). Trowbridge (1999) identified the potential of interbreeding as being a possible risk with native Australian con-specific *Codium* species. The impacts in southern Australia have been considerably less than those associated with *Caulerpa taxifolia*. In South Australia, there are records of *Codium fragile* ssp. *fragile* from American River on Kangaroo I. (2008), and locations in the AMLR NRM region, including North Haven (2008) and West Lakes (2002) (ADHerb 2010). The distribution and spread of *Codium fragile* ssp. *fragile* has been considered of lower concern in South Australia than the highly invasive *Caulerpa taxifolia*.

A third species of concern, the sub-tropical *Caulerpa racemosa* var. *cylindracea*, has been recorded in the AMLR NRM region from (i) St Kilda boat ramp, (ii) Bolivar (especially adjacent to and south of the outfall creek), (iii) Garden I., (iv) western reaches of Port River, (v) Outer Harbour and North Haven area, (vi) Semaphore reef, and (vii) O‘Sullivans Beach boat ramp (Turner et al. 2007, Wiltshire and Rowling 2009, Wiltshire 2010; ADHerb 2010). Although the variety occurs naturally in Western Australia, it has the capacity to be highly invasive, as has occurred in the Mediterranean (Klein 2007, Klein and Verlaque 2008). The *cylindracea* variety was first recorded in South Australia in 2001- 2002, on a settlement sheet in the Port Adelaide River, and is now well established in the Port River estuary and along the metropolitan Adelaide coast (Baldock 2005). Surveys during the late 2000s (e.g. Rowling 2008) did not record this species in deeper waters where Outer Harbour dredge spoil is dumped, even though the variety occurs in the Outer Harbour area. This species has been recorded on a various surfaces, such as boat ramps, revetments, and dead seagrass rhizomes (Wiltshire and Rowling 2009). The current and potential future impacts of this species in South Australia are still being determined.

Figure 22: Distribution of *Caulerpa taxifolia* in the Port River – Barker Inlet system, Adelaide, South Australia, as of March 2006. Figure (c) PIRSA, from PIRSA (2006).

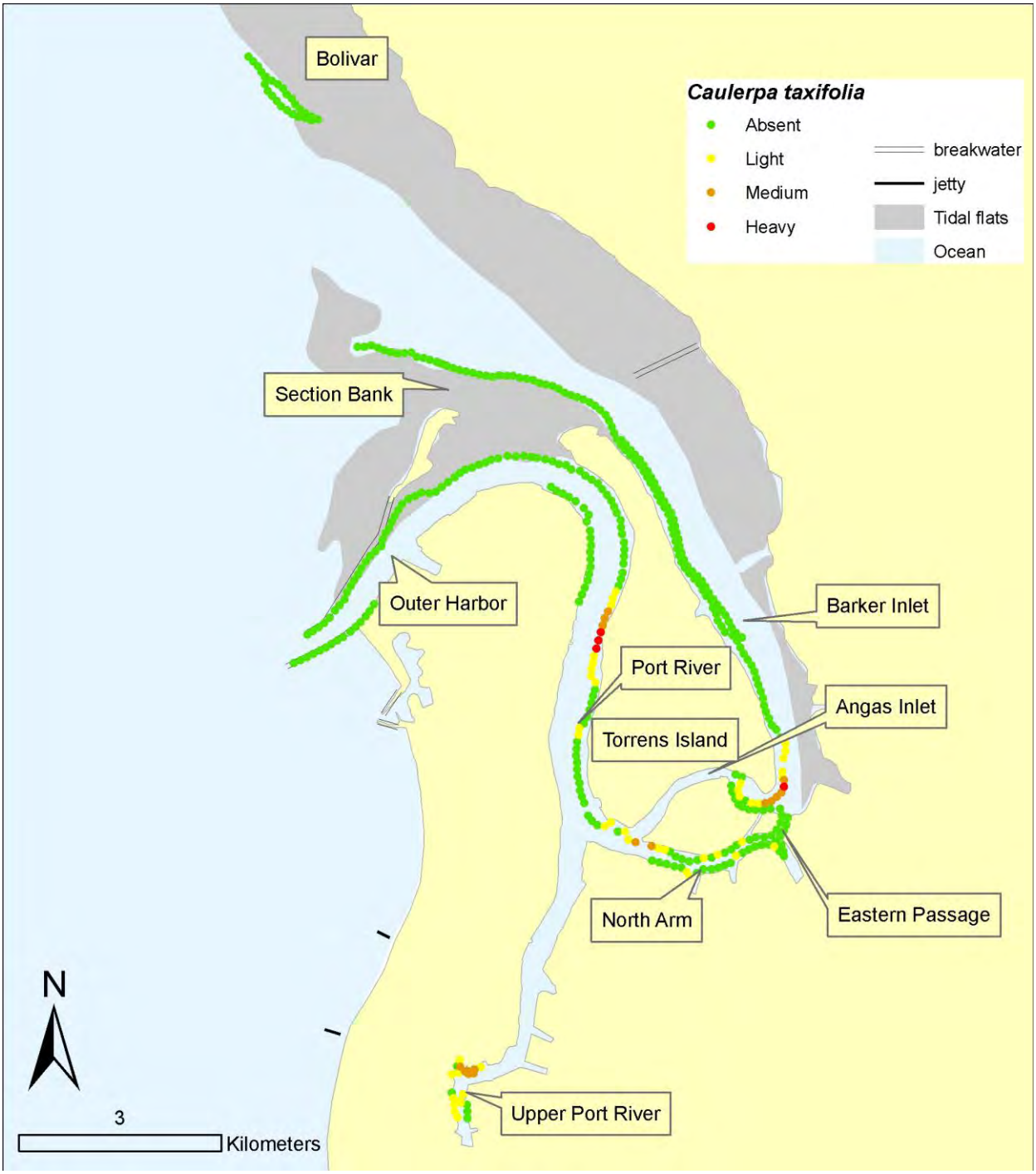


Figure 23: Distribution of *Caulerpa taxifolia* in the Port River – Barker Inlet system and Bolivar coast area, Adelaide, South Australia, according to 2010 surveys. Figure (c) SARDI Aquatic Sciences, from Wiltshire (2010).

Table 12: Introduced macroalgal species in the AMLR NRM region known from location-specific records in ADHerb 2010 database. Species status determined according to information from CRIMP / NIMPIS 2002, Hewitt et al. 2004, Hayes et al. 2005, Silva et al. 2006, Cowan 2006, Womersley 1984, 1987, 1994, 1996, 2003, 2004, 2005, CSIRO 2006, Guiry and Guiry 2010, Baldock 2010, Wiltshire et al. 2010 and record dates in ADHerb 2010). Note: a number of globally distributed *Audouinella* species have been excluded from the table below, because these are known from very few Australian records, and status in southern Australia is hard to determine. Numbers in parentheses in the species column refer to the number of records of each species in the ADHerb data base, which, in the case of some species, does not include all records known from South Australia (e.g. AVH 2010). State abbreviations are listed in the caption for Table 9.

Species	Type Locality	Distribution	Notes
Green Macroalgae			
Caulerpa racemosa var. *cylindracea* **(13)**	Western Australia	Australian records from WA (where it is endemic), NT, QLD and SA. SA records from St Kilda boat ramp and Bolivar (Wiltshire and Rowling 2009), Garden I., Port River, Outer Harbour / North Haven area and O'Sullivans Beach boat ramp / marina.	Endemic to WA, but invasive and now globally widespread (Klein and Verlaque 2008). Has aggressively spread through the Mediterranean Sea since the early 1990s (now in 9 European countries).
Caulerpa taxifolia **(13)**	St. Croix, Virgin Islands	Pantropical: 11 countries in Africa, several Atlantic Islands, 6 countries in SW Asia, Mexico, Hawaii, Central America and Caribbean (11 countries), several countries in Sth America, 6 Indian Ocean islands, China, Japan, 6 countries in SE Asia, at least 4 groups of Pacific islands, Papua New Guinea, New Zealand. In Australia, known from WA, Norfolk I. and Lord Howe I. Invasive populations recorded in Europe (4 Mediterranean countries), California (USA). In Australia, occurs in Queensland, and invasive incursions recorded in SA and 14 estuaries in NSW. SA records from locations in GSV, including Bolivar (Wiltshire and Rowling 2009), Outer Harbour / North Haven, Port River – Barker Inlet system and West Lakes.	One of the most significant invasive marine plant species ever known in southern Australia.
Cladophora prolifera **(7)**	Mediterranean	Widespread warm temperate Europe and Africa, numerous Atlantic islands, few countries in SA and SE Asia, few states in Nth America, Central America and Caribbean and Sth America, few islands in Indian and Pacific oceans, Australia and New Zealand. In Australia, recorded from all States except NT and TAS. SA records from Fowlers Bay in GAB (1994), Muston (American River on Kangaroo I) (1996), Granite I. (1981), and locations in GSV such as The Dredge wreck off Glenelg (2005), Semaphore (2005) and St Kilda (1972). This species is common in Gulf St Vincent / AMLR NRM region (see map in Wiltshire et al. 2010).	Forms blooms in some countries (e.g. Schramm and Booth, 1981). Hewitt et al. (2004), Hayes et al. (2005) and CSIRO (2006) reported this species to be non-native in Australia. Listed in Hayes et al. (2005) report on introduced pests as low priority introduced species in Australia. There is a very large literature on this species. The occurrence in Australia has been linked with that of the introduced opisthobranch *Aplysiopsis formosa* considered to be an introduction from the North Atlantic / Mediterranean (Fuhrer et al. 1988, cited by Hayes et al. 2005). Has colonised and is locally abundant on exposed coastal rock platforms, also in deep water. However, these locations are close to international shipping lanes. Shipping must be considered a potential vector for the introduction of this species

			(Lewis 1999 in Hayes et al. 2005).

Table 12 (cont.):

Species	Type Locality	Distribution	Notes
Codium fragile ssp. *tomentosoides* (= *Codium fragile ssp. fragile*) **(5)** (Brodie et al. 2007, Provan et al. 2008, considered this to be a junior synonym of *Codium fragile* ssp. *fragile*)	Japan (as *Codium fragile* ssp. *fragile*)	Widespread in Europe (~ 11 countries). Also recorded at a few Atlantic islands, few parts of Nth Africa, Turkey, Nth America (11 states), Japan, Australia, and New Zealand. In Australia, known from SA, VIC and TAS. SA records from American River on Kangaroo I. (2008), locations in GSV including North Haven (2008) and West Lakes (2002).	Hayes et al. (2005) and CSIRO (2006) reported this species to be non-native in Australia. An introduced species in south-eastern Australia which settles on native algae and shellfish, fouls fishing nets, and in some areas large wracks of this species rot on beaches after storms (CRIMP / NIMPIS 2002, Campbell and Hewitt 1999, Trowbridge 1999)
Ulva fasciata **(1)**	Alexandria, Egypt	Nearly pantropical. Widespread in Africa (~ 21 countries), Europe (~ 6 countries), various Indian Ocean islands, 5 Atlantic islands, SW Asia (9 countries), Atlantic USA (6 states), Hawaii, Central America / Caribbean (13 locations), and Sth America (~ 5 countries), China, Japan, Korea, Taiwan, SE Asia (4 countries), Papua New Guinea, Australia and New Zealand. In Australia, records from WA, SA, VIC, NSW, QLD and Norfolk I. SA State Herbarium records from Wanna near Pt Lincoln (1959), and West Lakes in GSV (1980). An *Ulva* reported to be this species has also been found in the Glenelg area (SARDI data, cited by Wiltshire et al. 2010).	Considered to be a possible introduction into Australia (CRIMP / NIMPIS 2002, Parliament of Victoria, undated, CSIRO 2006) but molecular confirmation is necessary. Hewitt et al. (2004) reported this species to be introduced in Australia from the Mediterranean. Plants are often associated with high-nutrient areas (e.g. mangroves, bird roosting islands), polluted areas, near freshwater sources or in the vicinity of ports. Although there are no major impacts of this species in Australian waters, it is considered probable that it could become a fouling nuisance in industries that utilise shallow water areas (CRIMP / NIMPIS 2002). Hayes et al. (2005) reported that *U. fasciata* can dominate/out compete and limit resources of native species.
Ulva taeniata **(5)**	Monterey, California, USA.	Recorded in few locations in Nth America, Central America and Sth America, India, Turkey, Pakistan, Korea, Australia and New Zealand. Originally from west coast USA, now considered to be naturalised in New Zealand and Australia (Baldock 2010).In Australia, known from WA, SA, VIC and TAS. SA records from eastern GAB, such as Elliston (1970) and Sheringa (1981), Wanna (1959), Pennington Bay (1948) and Vivonne Bay (1950) on Kangaroo I., Victor Harbor (1980), Robe (1960) and Beachport (1960). Recent unverified record from Pt Stanvac in GSV (Dutton and Benkendorff 2008).	CSIRO (2006) reported this species to be cryptogenic in Australia. Baldock (2010) reported this species to be introduced or adventive.

Table 12 (cont.):

Species	Type Locality	Distribution	Notes
Brown Macroalgae			
Arthrocladia villosa **(1)**	Cornwall, England	Widespread Europe (> 15 countries, particularly Mediterranean), 2 countries in Africa, USA (6 states), few Atlantic islands, and Australia. In Australia, known from SA (Port Stanvac). No records in SA State Herbarium on-line database.	CSIRO (2006) reported this species to be non-native in Australia. However molecular confirmation to distinguish Australian populations from populations from other parts of the world is necessary. Skinner and Womersley (1983) recorded unattached plants from 4-5m deep at Port Stanvac (1981) in GSV, where international ships berth, and at the time, it was not known whether the species was established (or would establish) in South Australia.
Discosporangium mesarthrocarpum **(9)**	Dalmatia (Adriatic Sea), Mediterranean	Recorded in Europe (7 countries, mainly Mediterranean), Turkey, Atlantic islands, Morocco in Africa, Hawaii. In Australia, known from SA. Records from Grange and Glenelg, on artificial tyre reefs (1987)	Reported by Aquenal (2001) to be an introduced species in Australia. CSIRO (2006) reported this species to be cryptogenic in Australia.
Elachista nigra **(40)**		Recorded in Japan and Korea, California and Australia (Guiry and Guiry 2010). Introduced to California (Kitayama et al. 2005) and possibly in Australia (Womersley 1987). In Australia, known from NSW, SA and WA, and may have been first identified as present in 1976 (Womersley 1987; Hayes et al. 2005). In AMLR NRM region, 39 records, on *Ecklonia radiata*. Examples include Port Stanvac, Seaford, Aldinga Reef in GSV, and Rosetta Head and Frenchmans Rock near Pullen Island in Encounter Bay.	A small epiphyte, which is found on kelps such as *Ecklonia* and *Undaria*. Formerly known as *Elachista orbicularis*.
Striaria attenuata **(1)**	Isle of Bute, Scotland	Widespread Europe (> 15 countries), Nth America (6 States), Chile in Sth America, Japan, New Zealand and Australia. In Australia, recorded from NSW, VIC, TAS and SA. SA records from Cowell (1993) and West Lakes (1978)	Sliwa et al. (2006) and CSIRO (2006) reported this species to be non-native in Australia. Considered to be an introduced species in Tasmania (Lewis 1999 in Underwood 2001). An adventive species (Womersley 2003).

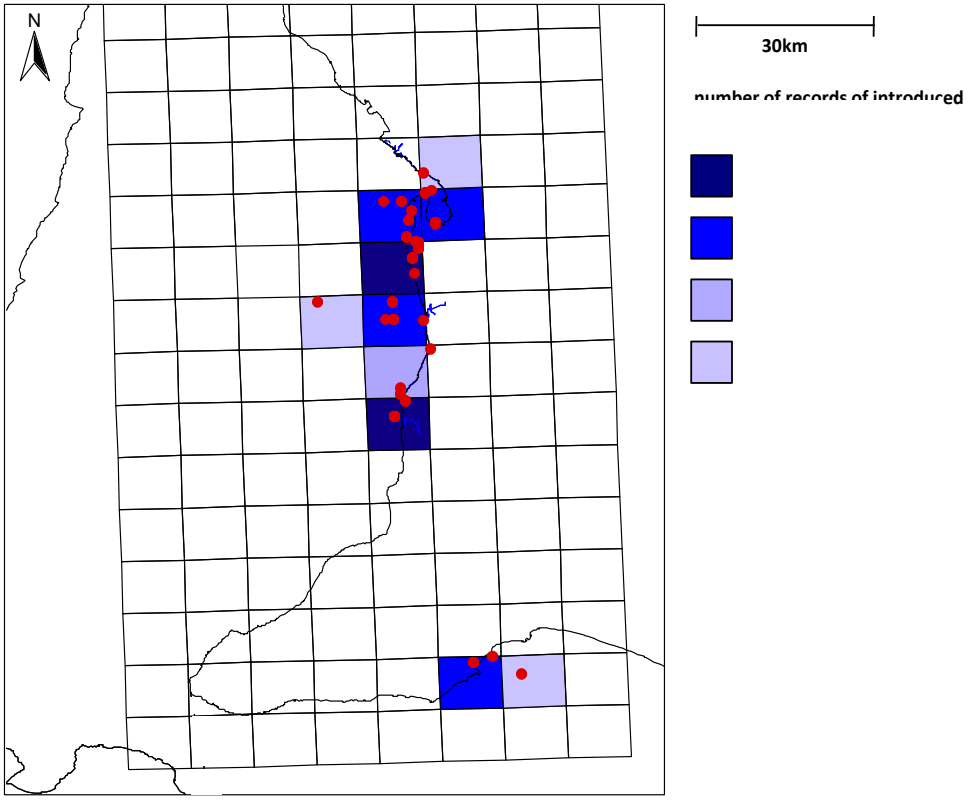
Table 12 (cont.):

Species	Type Locality	Distribution	Notes
Red Macroalgae			
Antithamnionella spirographidis **(5)**	Trieste, Italy	Thought to have originated in the North Pacific (Lindstrom and Gabrielson 1989, cited by JNCC 2010). Widespread Europe (~ 14 countries), also several Atlantic islands, Russia, several states in Nth America, China, Korea, Vietnam and Australia. In Australia, known from NSW, VIC and SA. SA records from Port Adelaide wharf and possibly other areas of Port Adelaide (1950 - 1958), and Port Stanvac (1972). It is noted that Blair et al. (2009, citing Campbell et al., 2005) reported date of first Australian record as being 1953.	Hewitt et al. (2004) and CSIRO (2006) reported this species to be non-native in Australia. Reported to be an introduced species in Victoria (Parliament of Victoria, undated). Listed in Hayes et al. (2005) report as a low priority introduced species in Australia. Introduced to Europe prior to 1911 (C.A. Maggs, Queens University of Belfast, pers. comm. in JNCC, 2010) Introduced in Britain from the Mediterranean, probably carried on the hulls and mooring ropes of ships, although it could also have been introduced with oysters. Spreads successfully due to very rapid vegetative reproduction / fragmentation and the rapid production of new thalli. It can be easily dispersed through shipping activities, aided by its ability to grow on ropes, buoys and other artificial surfaces such as plastic (JNCC, 2010).
Chondria arcuata **(1)**	Laguna Beach, Orange County, California, U.S.A.	Recorded from few countries and few States, including Nth America (California), Mexico, Africa (Morocco), Korea, French Polynesia, Hawaii, New Zealand and Australia. In Australia, known from VIC and SA. SA records from Port Noarlunga (1987)	Hewitt et al. (2004), CSIRO (2006) and Sliwa et al. (2006) reported this species to be non-native in Australia. Considered in Tasmania to be an introduced species (Tasmanian Planning Commission 2009).
Species	**Type Locality**	**Distribution**	**Notes**
Cottoniella fusiformis **(5)**	Playa de Santa Catalina [Las Palmas], Canary Islands.	Records in few areas, such as various Atlantic islands (Canary Is., Madeira Salvage Is.), Libya in Africa, Pakistan, and Australia. Australian records from SA only. SA records from locations in GSV, including Grange tyre reef (1985), Seacliff reef (1986), 1km N of Port Stanvac (1988), and Port Noarlunga (1987).	CSIRO (2006) reported this species to be non-native in Australia.

Table 12 (cont.):

Species	Type Locality	Distribution	Notes
Gymnogongrus crenulatus **(6)**	Oporto, Portugal	Recorded in ~ 8 countries in Europe, also Atlantic islands, Turkey, few parts of Africa, few parts of N^{th} and S^{th} America, Canada (LeGall and Saunders 2010), Australia and New Zealand. In Australia, records from NSW (e.g. Port Jackson), SA, VIC (e.g. Port Phillip Bay). SA records from Topgallant I. in GAB (1992), locations in GSV include Port Noarlunga (1993), Henley Beach (1992), Barcoo outlet at West Beach (2009), Robe jetty in upper SE SA (1991).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be non-native in Australia. CSIRO (2006, citing Lewis 1999) recorded the introduction date into Australia (Port Philip Bay) as 1969. Womersley (1994) considered that the species may be adventive, since most Australian specimens are from near harbours. Hewitt et al. (1999, 2004) and Parliament of Victoria (undated) recorded it as an introduced species in Victoria. Listed in Hayes et al. (2005) report as a low priority introduced species in Australia.
Schottera nicaeensis **(1)**	Marseilles, France	Widespread Europe (~ 14 countries, mostly in Mediterranean), several countries in Africa, few countries in SW Asia, few locations in Sth America and Atlantic islands, and Australia. In Australia, records from NSW, VIC (especially Pt Phillip Bay), TAS and SA. SA records from Stony Point in upper Spencer Gulf (2006) on a *Trichomya* mussel, and Glenelg (1970).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be non-native in Australia. Listed in Hayes et al. (2005) report as a low priority introduced species in Australia. Lewis and Kraft (1979) hypothesised that the species was introduced from Europe into Port Phillip Bay in Vic during the 1970s, and suggested shipping as a possible means of importation. Considered in Tasmania to be an introduced species (Anonymous, 2009).

Figures 24, **25**, **26**, and **27** show the distribution of all, green, red and brown introduced species of macroalgae in the AMLR NRM region, respectively. The majority of the green species have been recorded in the north-east region, around Port Adelaide and West Lakes, North Haven, Outer Harbour and St Kilda. One species has also been recorded off Glenelg, and a couple further south at Port Stanvac and O'Sullivans Beach. Introduced red species have been recorded from Port Adelaide wharf, West Lakes, and Glenelg, and further south around Port Stanvac and Port Noarlunga area. Other than the small epiphyte *Elachista nigra,* introduced species of brown macroalgae are known mainly from West Lakes, and off Glenelg and Port Stanvac. *E. nigra* has been recorded in the Noarlunga and Aldinga areas (17 specimens and 12 specimens respectively in ADHerb 2010), and in the Encounter Bay and Port Elliot areas. The large number of records of introduced species from the Noarlunga area **(Figure 24**) reflects the abundance of *E. nigra* collections (from *Ecklonia radiata* plants).



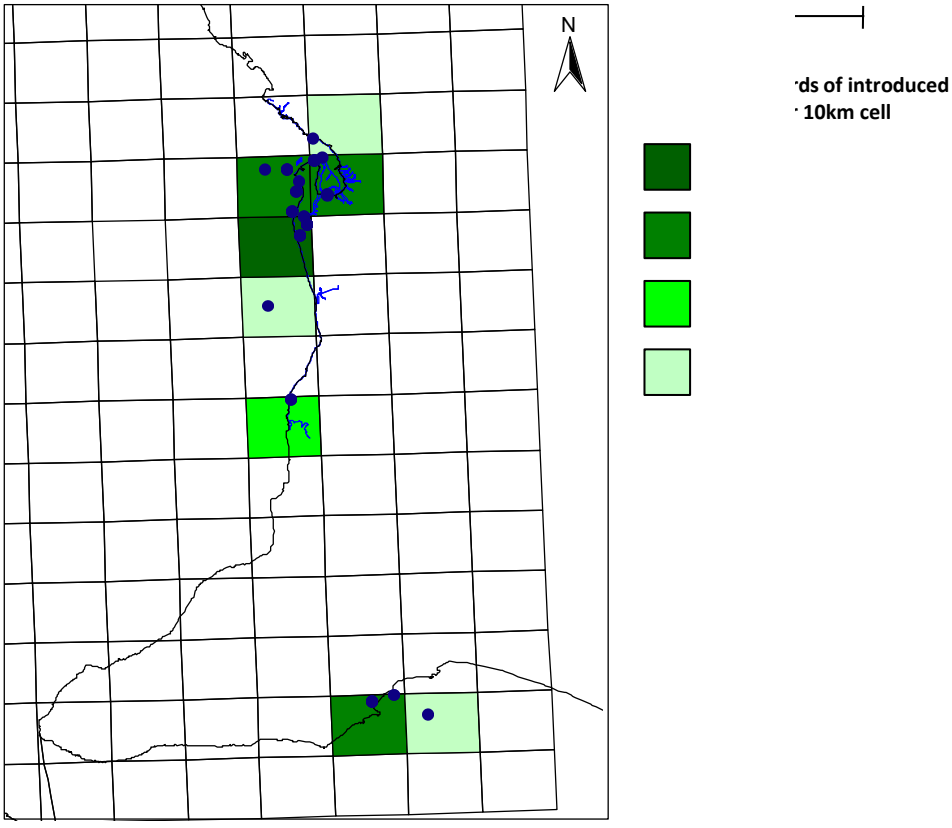


Figure 25: Distribution of introduced marine macroalgal species of Chlorophyta in the AMLR NRM coast region, according to SA State Herbarium records.

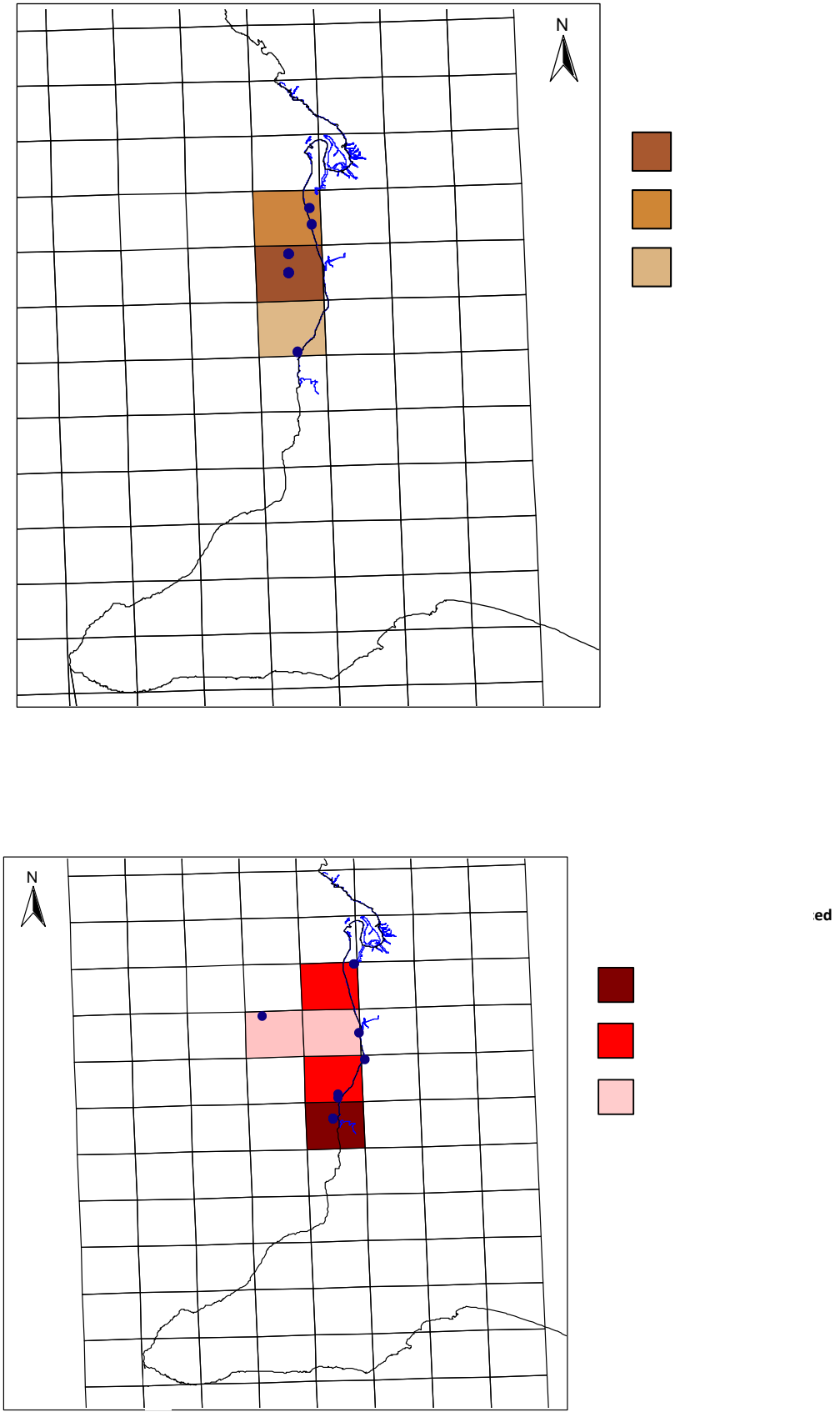


Figure 27: Distribution of introduced marine macroalgal species of Rhodophyta in the AMLR NRM coast region, according to SA State Herbarium records.

Table 13 details the 38 species likely to be cryptogenic in AMLR NRM region, according to information from CRIMP / NIMPIS 2002, Hewitt et al. 2004, Hayes et al. 2005, Sliwa et al. 2006, Womersley 1984, 1987, 1994, 1996, 2003, 2004 and 2005, CSIRO 2006, Cowan 2006, Wiltshire et al. 2010, Baldock 2010, Guiry and Guiry 2010, record distributions and dates data based in ADHerb 2010, and references cited in **Table 13**. Of these possible cryptogenic species, 17 are species of green macroalgae. A number of these, such as various species of *Cladophora, Chaetomorpha* and *Ulva* (the latter including *Enteromorpha*) have the potential to bloom in eutrophic conditions, such as those present in ports / boat harbours and estuaries. *Ulva* blooms have been recently observed in Lake Butler, Robe in the upper south east of SA in November 2007 (C.F.D. Gurgel, pers. observation). Some species, such as *Chaetomorpha ligustica*, have a very wide temperature tolerance, which can assist global spread. Some of these species (e.g. *Chaetomorpha indica*, *Chaetomorpha linum*, *Cladophora dalmatica*, *Cladophora sericea,* and *Ulva prolifera*) have been responsible for the formation of ~~–~~green tides" in other countries (Taylor et al. 2001, Silva et al. 2008, CSIRO 2009. See also note section in **Table 13**).

One of the *Ulva* species of uncertain origin, *Ulva rigida*, has been recorded in South Australia (46 records), with known locations in AMLR NRM region including West Lakes (1980), Port Stanvac (1982), also Victor Harbor / Rosetta Head area (1980, 1982). This species has the potential to bloom in abundance in eutrophic conditions, as has been shown in the Mediterranean (e.g. Sfriso 2010). Another *Ulva* species, *U. fasciata*, for which Egypt is the type locality, is considered to be a possible introduction into Australia (CRIMP / NIMPIS 2002, Parliament of Victoria undated, CSIRO 2006). This species is also often associated with high-nutrient areas (e.g. mangroves, bird roosting islands), polluted areas near freshwater sources or in the vicinity of ports. Although there are no major impacts of *U. fasciata* in Australian waters, it is considered probable that it could become a fouling nuisance in industries that utilise shallow water areas (CRIMP / NIMPIS 2002). Hayes et al. (2005) reported that *U. fasciata* dominates and out-compete native species.

Several species that have been listed in other reports as cryptogenic in Australia (e.g. Hewitt et al. 2004, CSIRO 2006) are not included in **Table 13**, because of their presence in South Australia in areas remote from ports or other source areas for introduction, and/or presence in South Australia dating back to at least the 1940s or 1950s, when specimens were first recorded during general collecting by H.B.S. Womersley for taxonomic work. Examples include: *Centroceras clavulatum*, *Ceramium rubrum*, *Chaetomorpha aerea*, *Cladostephus spongiosus*, *Colpomenia peregrina* and *C. sinuosa*, *Dictyota dichotoma*, *Ectocarpus fasciculatus* and *E. siliculosus*, *Enteromorpha compressa*, *Feldmannia globifera*, *Gelidium pusillum, Hincksia granulosa* and *H. mitchelliae, Nemalion helminthoides, Pterocladiella capillacea, Scytosiphon lomentaria,* and *Ulva lactuca.* The introduced status of some of these species is uncertain, and there are also taxonomic issues regarding specific specimens, particularly older records (e.g. of *Ulva lactuca*). A number of globally distributed *Audouinella* species have also been excluded from **Table 13** below, because these are known from very few Australian records, and status in southern Australia is hard to determine.

Of 8 species of brown macroalgae in AMLR NRM likely to be of cryptogenic origin, most are small epiphytes that are widespread in Europe. One of these, *Hincksia sandriana* is a member of a genus that commonly forms seasonal algal blooms in eutrophic conditions. In AMLR NRM region, this species has been recorded at St Kilda, north of Barker Inlet.

Most of the 11 species of non-coralline red algae possibly cryptogenic in AMLR NRM are small epiphytes. One of these, *Caloglossa leprieurii*, grows on the trunks and pneumatophores of the mangrove *Avicennia marina*, and also on rocks and jetty piles (**Table 13**). A number of the small red epiphytes are probably not cryptogenic because they are naturally very abundant and widespread globally, often on rocky shores (e.g. *Hildenbrandia rubra*), and characterised by rapid, opportunistic and frequently ephemeral growth (e.g. *Bangia atropurpurea*). One of the cosmopolitan species, *Erythrotrichia carnea*, is epiphytic on various macroalgae (e.g. *Porphyra*, *Polysiphonia*, *Dictyota*, *Padina*, *Cladosiphon*) and on eelgrass *Zostera*, often in intertidal and shallow subtidal, but deeper in some areas (Brodie and Irvine 2003; SA State Herbarium data). Another, an unnamed species of *Grateloupia* formerly known as *G. filicina*, which is most likely the invasive *G. turuturu*, is found mainly in harbours. Another species, *Cryptopleura ramosa*, a frond-

like red alga found on intertidal and shallow subtidal rocks, is not included in **Table 13** due to its absence on more formal lists of cryptogenic species (e.g. CSIRO 2006). However, this widespread species from Europe, Africa, China and some warmer parts of the Americas, may also be introduced to South Australia. There is a single record known in SA (from the AMLR NRM region), but information is lacking (e.g. Cowan 2006, State Herbarium of South Australia 2010).

Of interest in AMLR NRM region is the presence of two coralline epiphytes, *Pneophyllum confervicola*, and *Pneophyllum limitatum*, both of cryptogenic origin. The latter is known from few places in northern Europe, and 27 records have been recorded in South Australia (1 from St Kilda near Barker Inlet, and 26 from Sellicks Beach). The other, *P. confervicola* is more widespread in Europe than is *P. limitatum* (see **Table 13**), and Australian records apparently are limited to Queensland and South Australia. It is noted that both of these species have been recorded in the same locality (Sellicks Beach) in AMLRN NRM as another species of *Pneophyllum* (*P. fragile*), which is also widespread in Europe and found in several other countries, including Russia, Canada, Mexico and Australia (WA, SA, Victoria and Tasmania) (see Womersley 1996, and AVH 2010). The validity of the named specimens in South Australia should be determined, and the relationship between possibly introduced species and other species in Australia should be ascertained.

Table 13: Macroalgal species in AMLR NRM that are likely to be cryptogenic in origin. Species status determined according to the literature on: type locality; distribution at global, national and State scales; number, location and date of records in South Australia; plant habitat, habit and mode of reproduction, plus literature on their status in Australia (see literature list in Table 12). Numbers in parentheses in the SPECIES column refer to the number of records in the SA State Herbarium database. State abbreviations are listed in the caption for Table 9.

Species	Type Locality	Distribution	Notes
Green Macroalgae			
Bryopsis plumosa **(13)**	Devon, England	Global distribution (especially Europe and Africa, but also the Americas and Asia). Australian records from 1934 onwards (Rottnest I., 1934 is the single WA record in SA State Herbarium database). Records in all southern Australian States. SA records from Eyre Peninsula, Spencer Gulf, Gulf St Vincent, Kangaroo Island and the South East (see map in Wiltshire et al., 2010).	Most records in SE Australia come from bays where boats reside, but some from remote areas e.g. Cape Bridgewater in VIC. Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Hewitt et al. (2004, citing Womersley 1966) reported this species to be cryptogenic in Australia, possibly from the NE Atlantic. Plants currently known as *B. plumosa* may comprise a complex of species (B. Baldock, pers. comm., cited by Wiltshire et al., 2010).
Chaetomorpha indica **(2)**	Tanque, India	Found in SW Asia (India, Kuwait, Pakistan, Sri Lanka) and SE Asia, several Pacific islands, 2 countries in Africa, and all over Australia (including TAS and Lord Howe I.) except NT, NSW and TAS. SA records from Coffin Bay (1959), North Arm area of GSV and Robe Lake (1983).	Considered to be a ~~-~~green tide" alga that spreads prolifically, and has a wide salinity tolerance range (Silva et al. 2008)

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Chaetomorpha ligustica **(1)**	Golfo di Genova, Italy	Widespread Europe (> 15 countries), Russia, several Atlantic islands, few countries in Africa, very few parts of SE and SW Asia, few States of Nth America (including California and Hawaii), Alaska, and few parts of Australia (NT and QLD). Single record in SA State Herbarium database (none in on-line resource: ADHerb 2010). According to Guiry and Guiry (2010), Australian records are listed as *Chaetomorpha capillaris*. Under that name, records from Popes Eye in VIC (1981), Lake Butler in SA (1983), and 2 sites in American River, Kangaroo I. (1963 and 1987).	If same species globally, would have very wide temperature tolerance. Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia (NB as *Chaetomorpha capillaris* in Hewitt et al. 2004).
Chaetomorpha linum **(8)**	Lolland, Denmark	Widely distributed Europe and Africa (many countries in both continents), also Nth America, Caribbean, SE and SW Asia, China, Japan, Korea, Indian Ocean islands, Australia, Papua New Guinea, New Zealand. SA records from Bay of Shoals on Kangaroo I. (1947), Coffin and Kellidie bays (1967), Port Adelaide area (1951, 1984) and Garden I. (1999), Onkaparinga River (1983), Port MacDonnell (1982).	Most Australian records from ports, harbours and estuaries. Common in eutrophic estuaries e.g. Peel Inlet in WA (Lavery and McComb 1991). Littler et al (1983) considered it to be an opportunistic species. Forms —green tides" (Taylor et al. 2001). CSIRO (2006) reported this species to be cryptogenic in Australia. There is a large literature on the physiology of this species.
Cladophora dalmatica **(1)**	Split, Croatia	Widespread Europe (~ 18 countries, including Mediterranean) and Africa, also records from southern part of Nth America, Sth America, Japan, Philippines. In Australia, records from QLD, SA and WA. Records in SA from Baird Bay (1954), Barker Rocks on Yorke Peninsula (1967 and 1981), American River on Kangaroo I. (1946) and in a rock pool at West I., near Encounter Bay (1985).	Forms —green tides" during summer in eutrophic estuaries and inlets (e.g. Taylor et al. 2001).
Cladophora montagneana **(1)**	Cuba	Widespread Africa (8 countries), also found Nth, Sth and Central America. In Australia, known from Peel Inlet (Mandurah) in WA, and Outer Harbour in GSV, on wharf piles.	The Australian isolate is of uncertain identity (e.g. compared with examples from central America), has been the subject of extensive ecological and physiological studies concerning its role in nuisance algal blooms (Gordon et al. 1980, 1981, Hodgkin et al. 1980, Birch et al. 1981, cited by Cambridge 1991).

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Cladophora sericea **(1)**	Kent, England	Widespread Europe (> 20 countries), also in Africa, Nth America and Asia (including SE and SW), and some Pacific islands, Papua New Guinea, Australia and New Zealand. In Australia, known from QLD, SA, VIC (various sites in Pt Phillip and Western Port bays) and TAS (all sides, particularly SE). Considered in Tasmania to be an introduced species (Anonymous 2009) In SA, records from Coffin Bay, Yatala Harbour (N^{th} Spencer Gulf) and Pt Stanvac.	An opportunistic species, that forms episodic and nuisance blooms in some countries, such as Hawaii (e.g. Smith et al. 2005).
Derbesia marina **(5)**	Type locality = Kvivig, Strømø, Faeroes	Known from more than 12 countries in Europe, also Nth America (mostly the colder States, including Alaska), few parts of Central America, Caribbean and S^{th} America, several Pacific islands, few parts of Asia (including Japan and Korea), Australia and New Zealand. In Australia, recorded from SA, VIC, TAS, NSW Lord Howe I. and Norfolk I. SA records from Scott Bay 6km W of Fowler Bay in GAB (1951), Port Pirie (1984), Vivonne Bay, Kangaroo I. (1950), locations in GSV such as Grange artificial reef (1985), Port Stanvac jetty pylons (1972) and Aldinga Bay (1967), Nora Creina bay in upper SE SA (1981). Near the SA / VIC border, record from Cape Bridgewater (1953).	Widely distributed in cold temperate waters (Cowan 2006). CSIRO (2006) reported this species to be cryptogenic in Australia. Considered by Parliament of Victoria (undated) to be cryptogenic and possibly introduced in Australia.
Derbesia tenuissima **(3)**	Caprara, Italy	Recorded in at least 11 countries in Europe, 5 countries in Africa, several islands in Atlantic, several islands in Indian and Pacific oceans, India, Japan, Korea. In Australia, recorded from WA, SA, VIC and TAS. In SA, recorded from Nora Creina in upper SE (1983), also on pontoons at Pt Adelaide and North Arm in GSV (1983, 1984), Vivonne Bay at Kangaroo I. (on *Spyridia opposita*) (1957) and Scotts Bay 6km W of Fowlers Bay in GAB (1951).	Often found in reef pools and on marina pylons (Baldock 2010).
Prasiola stipitata **(1)**	Ireland	Known mainly from cold temperate North Atlantic, on European and N^{th} American coasts. Also from Chile in S^{th} America. Previously known in Australia from 3 locations (now 4), collectively in TAS and VIC, and all were coastal bird colonies (Womersley 1984). Also, one record from Victor Harbour in SA (1988).	
Rhizoclonium curvatum **(7)**	Manakau Harbour, New Zealand	Guiry and Guiry (2010) listed only New Zealand and South Australia in distribution. Cowan (2006) also included Tasmania. Australian Virtual Herbarium lists 9 records for South Australia, including several with no locality. In SA State Herbarium database, 7 records from Outer Harbour and Port Adelaide – Barker Inlet system, including 2 records collected 1981 and 1982 from mangrove stems at Garden Island. No other Australian records found.	

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Ulva flexuosa (previously *Enteromorpha flexuosa*) **(5)**	Duino (near Trieste), Adriatic Sea	Very widespread Europe (~ 20 countries) and Africa (~20 countries), also SW Asia / Middle East, SE Asia, Atlantic islands, Pacific islands, the Americas, Australia and New Zealand. Aust Virtual Herbarium lists records from at least 18 locations in QLD, 2 locations in each of WA and VIC, and 3 locations in SA. SA State Herbarium on-line database lists 4 localities (as *Enteromorpha flexuosa*): Mexican Hat (eastern Great Australian Bight) (2008), BHP Whyalla Tailings Dam (1999), and locations in GSV, including Port Adelaide (1984), and 4km off Seacliff (1988). Unpublished SA records in working data set from St Kilda and North Arm, and Seacliff area.	
Ulva intestinalis (previously *Enteromorpha intestinalis*) **(1)**	Possibly Woolwich, London, England	Cosmopolitan distribution. Widespread Europe (~ 20 countries) and Africa (~9 countries), 6 Atlantic islands, also SW Asia (5 countries), China, Japan, Korea, Taiwan, SE Asia, various Indian Ocean islands, a few Pacific islands, Canada, the Americas (widespread), Australia, New Zealand and Antarctica. In Australia, records from WA, SA, TAS, VIC, NSW, QLD, Lord Howe I. and Macquarie I. SA records from Althorpe I. (2001) and locations in GSV including Delfin I. (West Lakes) (1979) and Christies Beach (1981).	CSIRO (2006) reported this species to be cryptogenic in Australia.
Ulva linza (previously *Enteromorpha linza*) **(5)**	Probably Kent, England, possibly Europe	Widespread Europe (~ 20 countries) and Africa (~11 countries), islands off Africa, also SW Asia, China, Japan, Korea, SE Asia, Atlantic islands, a few Pacific islands, the Americas, Australia, New Zealand and Antarctica. In Australia, records from WA, SA, VIC, TAS (unconfirmed) and QLD. SA records, as *Enteromorpha linza*, from Cummins on Eyre Peninsula (1976), Port Pirie (1973), locations in GSV including St Kilda (1972) and Port Stanvac (1981), also Rosetta Head (1982) (Encounter Bay).	Usually found on seagrass *Posidonia*.
Ulva prolifera (previously *Enteromorpha prolifera*) **(12)**	Lolland, Denmark	Widespread Europe (~ 20 countries) and Africa (~10 countries), also SW Asia, China, Japan, Korea, Taiwan, SE Asia, Atlantic islands, Pacific islands, the Americas, New Zealand, Australia (QLD, VIC, TAS, SA, and Aust Virtual Herbarium includes WA) . SA records from Pt Gawler area, Pt Adelaide fishing marina (1984), Pt Stanvac (1981), Onkaparinga River, 100m from the mouth (1973). One unconfirmed SA State Herbarium record from northern SA desert (Mt Poondinna, in fresh water rock hole), collected 1978.	Forms —green tides" in Asia, in locations where excess nutrients from aquaculture exist (CSIRO 2009).

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Ulva ralfsii (previously *Enteromorpha ralfsii*) **(4)**	Bangor, North Wales	Recorded in Europe (9 countries), Africa (2 countries) and few islands in Indo-Pacific, New Zealand and Australia Australian records from Lord Howe I., QLD, SA and VIC. SA records from GSV: St Kilda (1984), Garden I. (1981) and Penrice ICI salt works (1982).	Found amongst mangroves and samphires.
Ulva rigida **(46)**	Cádiz, Spain	Cosmopolitan distribution. Widespread Europe and Africa (> 15 countries each), also Atlantic islands, Nth, Central and South America, SW Asia, Philippines, Australia, New Zealand and Antarctica. In Australia, known from WA, SA, VIC, TAS, Macquarie I., NSW, Lord Howe I. and QLD. SA records from Hardwicke Bay in lower Spencer Gulf (1980), and locations in GSV such as Coobowie (1981), Port Wakefield (1950), West Lakes (1980), and Port Stanvac (1982), also Victor Harbor / Rosetta Head area (1980, 1982).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Has the potential to bloom in abundance in eutrophic conditions (e.g. Sfriso 2010).
Brown Macroalgae			
Acinetospora crinita **(2)**	Appin, Scotland	Widespread Europe (~ 15 countries), few countries in Africa, few States in Nth America, few countries in Sth America, few Atlantic islands, few countries in SW Asia, Japan, Korea and Australia. In Australia, known from SA, TAS, VIC and NSW. SA records from O'Sullivans Beach in GSV, Granite I. in Encounter Bay (1974), the Granites, Kingston (1985) and Nora Creina Bay (1974).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia.
Cutleria multifida **(6)**	Yarmouth, Norfolk, England	Widespread Europe (> 15 countries), also Atlantic islands, few countries in Africa, few countries in South America, Japan, Samoa, Australia and New Zealand. In Australia, known from WA, SA, VIC, TAS, NSW and QLD. SA records from West I. (in eastern GAB) (2006), Port Lincoln (1975), Wedge I. (1992), locations in Spencer Gulf, such as Port Victoria (1973) and Point Turton (1973), locations in GSV, such as Edithburgh (1988), Torrens I. (1887), Glenelg tyre reef (1987) and Port Noarlunga (1996), American River on Kangaroo I. (1966 and 1972), Port Elliot (Encounter Bay) (1960), and Lake Butler at Robe (1985).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Reported in Tasmania to be an introduced species (Anonymous 2009) or a cryptogenic species (Tasmania Planning Commission 2009). Listed by Parliament of Victoria (undated) as cryptogenic and possibly introduced into Port Phillip Bay in VIC.

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Feldmannia irregularis **(15)**	Adriatic Sea	Widespread Europe (~ 15 countries), also ~ 5 Atlantic island groups, Africa (~ 12 countries), SW Asia / middle East (~ 11 countries), few areas of Nth, Central and Sth America, Hawaii, China, Japan, Korea, SE Asia, Pacific islands (~ 5 countries), Australia. In Australia, recorded from WA, SA, VIC, NSW, QLD, Norfolk I., Lord Howe I. SA records from Venus Bay (1954), fishery Bay near Pt Lincoln (1984), Port Hughes (1983), and locations in GSV including Black Point (1986), St Kilda Beach (1973), Port Noarlunga (1974), Aldinga Reef (1978), Normanville (1974), Cape Jervis (1974), American River on Kangaroo I. (1966), Encounter Bay (1974, 1980) and Port Elliot (1974), and Nora Creina (1985).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Considered to be cryptogenic and possibly introduced to Lord Howe I. (Aquenal 2006) and Victoria (Parliament of Victoria, undated).
Hincksia sandriana **(1)**	Zadar, Croatia	Widespread Europe (~ 13 countries), also several Atlantic islands, Africa (~ 4 countries), India, Turkey, few areas of Nth, Central and Sth America, China, Japan, Korea, Australia. In Australia, recorded from SA, VIC, TAS, NSW and Lord Howe I. SA records from St Kilda in GSV (1972), American River on Kangaroo I. (1963), and Robe (1965).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Considered cryptogenic and possibly introduced into Port Phillip Bay in VIC (Parliament of Victoria, undated) and Tasmania (Anonymous 2009).
Myrionema strangulans **(17)**	Appin, Argyll, Scotland	Widespread Europe (~ 20 countries), also several Atlantic islands, Africa (~ 5 countries), Canada, Nth America (~ 9 States), Chile in Sth America, India, Turkey, Levant states, Vietnam, Korea, Australia, New Zealand and Antarctica. In Australia, known from SA, VIC, TAS, NSW and Lord Howe I. SA records from Wedge I. (1963), American River on Kangaroo I., (1950), and locations in GSV such as Hallett Cove (1977), Aldinga (1977) and Normanville (1977), Encounter Bay (1976, 1986), Robe (1976), Nora Creina (1976) and Beachport (1978).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Listed by Parliament of Victoria (undated) as cryptogenic and possibly introduced into Port Phillip Bay in VIC. Specimens often recorded on green alga *Ulva*.
Petalonia fascia **(13)**	near Kristiansand, Norway	Widespread Europe (> 15 countries), also several Atlantic islands, Africa (~ 6 countries), Nth America (> 10 States), Mexico, few countries in Sth America, SW Asia, China, Japan, Korea, Australia, New Zealand and Antarctica. In Australia, known from WA, SA, VIC, TAS, Macquarie I., NSW and QLD. SA records from locations in GSV, such as Outer Harbour (1950), West Beach (1967), Port Stanvac (1972), Patawalonga River at Glenelg (1950), Port Stanvac (1972), Port Noarlunga (1975) and Aldinga Reef (1977), also Port Elliot (Encounter Bay) (1967), Cape Lannes (1982), Nora Creina (1984) and Port MacDonnell (1982).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Listed by Parliament of Victoria (undated) as cryptogenic and possibly introduced into Port Phillip Bay in VIC.

Table 13 (cont.):

Pylaiella littoralis **(2)**	Europe	Widespread Europe (> 20 countries), also Canadian Arctic, N^{th} America (> 10 States), few countries in S^{th} America, SW Asia, Japan, Korea, Vietnam, Australia, New Zealand and Antarctica. In Australia, recorded from NSW, VIC, TAS and SA. SA records from Billy Light's Point near Port Lincoln (1975) and St Kilda in GSV (1972).	Hewitt et al. (2004) reported this species to be cryptogenic in Australia.
Punctaria latifolia **(4)**	Sidmouth, England	Widespread Europe (~20 countries), Turkey, several countries in Africa, N^{th} America (5 States), Canada, China, Japan, Korea, New Zealand and Australia. In Australia, recorded from VIC, TAS and SA. SA records from Aldinga in GSV (1972).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Listed by Parliament of Victoria (undated) as cryptogenic and possibly introduced into Port Phillip Bay in VIC.
Red Macroalgae			
Antithamnionella ternifolia **(17)**	St Martin's Cove, Cape Horn, Chile	Known from Europe (~ 7 countries), S^{th} Africa, S^{th} America (3 countries), China, New Zealand, Australia and Antarctic / Subantarctic islands (Fuegia, Macquarie I.) In Australia, known from WA, SA, VIC, NSW, Lord Howe I. and TAS. SA records from locations in GSV including as Port Adelaide (1984), North Arm (1981), Port Stanvac (1977), and Port Noarlunga (1970), also locations on Kangaroo I., including Kingscote (1968) and Ballast Head (1997).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Considered cryptogenic in Tasmania (Aquenal 2001).
Bangia atropurpurea **(12)**	Weser River, Bremen	Cosmopolitan distribution. Widespread in Europe (~ 18 countries) and Africa (~ 9 countries), also Atlantic islands, SW Asia (including India and several countries in the Middle East), Russia, China, Japan, Korea, Taiwan, Vietnam, Hawaii, Easter I., N^{th} and S^{th} America, Australia, New Zealand, Antarctica. In Australia, known from WA, SA, VIC, TAS, NSW and QLD. SA records from locations in GSV such as ICI salt fields, Dry Creek (1967), West Lakes (1976), Brighton jetty (1957) and Port Stanvac (1981), also Granite I. in Encounter Bay (1946), locations on Kangaroo Island, such as Cape Willoughby (1948) and American River (1954), and Robe in upper SE SA (1985).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Typically grows in the upper littoral zone on marine rocky shores (Lüning 1990), as well in freshwater habitats just above the waterline (Sheath 1984, cited by Karsten and West 2000). Ecologically characterised as opportunistic due to rapid growth and high reproductive output, allowing quick colonisation (Müller et al. 1988, cited by Karsten and West 2000).

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Caloglossa leprieurii **(7)**	Sinnamary, NW of Cayenne, French Guiana	Widespread in tropical or cool temperate oceans. Recorded in Africa (20 countries), Nth America (8 States), Caribbean (13 states and island groups), Sth America (7 countries), India, China, Japan, Korea, SE Asia, Australian, New Zealand. In Australia, recorded from all States except NT. SA records from Arno Bay (1999), Cowell (1999), Wallaroo, Blanche Harbour (1999), locations in GSV such as Pt Clinton (2000), Price (2000), Port Wakefield (2000), and Garden I. at Pt Adelaide (several records, 1993, 1999), also Muston at American River on Kangaroo I. and Goolwa Barrage (several records, 1993).	In Australia, found on *Avicennia* trunks and pneumatophores, and on rock and jetty piles, in calm localities, extending upstream in fresh-water in some localities (Womersley 2003). Common on *Avicennia* trunks in Spencer Gulf and Gulf St Vincent (West et al. 2001).
Caloglossa ogasawaraensis **(5)**	Ogasawara-gunto (Bonin Islands), Japan.	Recorded in Africa (~ 5 countries), India and Sri Lanka, Japan, China, Indonesia, Malaysia, Singapore, Vietnam, Philippines, Fiji, Australia and New Zealand. In Australia, known from SA, NSW, QLD, NT and northern WA (Millar and Kraft 1993, Australian Virtual Herbarium 2010) In SA, several records from Port Adelaide (1982) and Garden I. (1982, 1993, 1999).	
Colaconema garbaryi (formerly *Audouinella simplex* or *Rhodochorton simplex*) **(4)**	Santa Monica, California, U.S.A. (as *Audouinella simplex*)	Known from South Africa, 3 States in Nth America, Fiji, and Australia. In Australia, known from QLD, VIC and SA. SA record, as *Audouinella simplex*, from Port Elliot (1968)	CSIRO (2006) reported this species to be cryptogenic in Australia. Listed as a cryptogenic and possibly introduced species in Victoria (Parliament of Victoria, undated). *Colaconema garbaryi* is a recent name change (Gabrielson et al. 2004)
Erythrotrichia carnea **(1)**	Glamorgan, Wales	Cosmopolitan distribution. Widespread in Europe (~ 21 countries) and Africa (~ 15 countries), 7 groups of Atlantic islands, also Russia, Nth America (> 12 States), Central America / Caribbean and South America (~ 6 countries), SW Asia (~11 countries), Japan, Korea, SE Asia, Pacific islands, Papua New Guinea, Australia and Antarctica. In Australia, known from WA (Huisman and Borowitzka 2003), SA, VIC, TAS, NSW, Lord Howe I. and QLD. SA records from Venus Bay (1951), Coffin Bay (1951), Port Augusta power station aquaculture ponds (1987), Port Stanvac in GSV (1979) and Robe (1967).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Epiphytic on various algae (e.g. *Porphyra*, *Polysiphonia*, *Dictyota*, *Padina*, *Cladosiphon*) and on eelgrass *Zostera*, often in intertidal and shallow subtidal, but deeper in some areas (ADHerb 2010, Brodie and Irvine 2003, Guiry and Guiry 2010).

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Grateloupia "filicina" **(7)**	Trieste, Italy	Species previously referred to as *G. filicina* are widespread in Europe (~ 14 countries) and Africa (~ 18 countries), also Nth, Central and Sth America, Asia, Pacific Islands. In Australia, species formerly known as *G. filicina* known from WA (e.g. Fremantle, Cottesloe beach and Point Peron), SA, VIC (especially Pt Philip Bay), NSW and TAS. SA specimens from Outer Harbour (1959) and on jetty piles at Pt Stanvac (1972) in GSV, and Carpenter Rocks (SE SA) (1993).	An rbcL-based molecular phylogeny, encompassing samples covering the entire geographic distribution of the species, revealed a plethora of _cryptic" species, and presence of genuine *G. filicina* is limited to the Mediterranean basin (de Clerck et al. 2005). Found mainly in harbours.
Hildenbrandia rubra **(1)**	Nordland, Norway	Cosmopolitan distribution. Widespread Europe (~ 19 countries), Africa (~ 11 countries), also Russia, Alaska, Nth America and Canada, Central America / Caribbean, few countries in Sth America, India, Japan, Commander Is., Korea, Indonesia, several Pacific islands, Australia. In Australia, known from QLD, SA, VIC and TAS. SA records from Lipson Cove or Tumby Bay (1990), Outer Harbour breakwater in GSV (1950), Vivonne Bay on Kangaroo I. (1950), and locations in SE SA including Cape Buffon (1992) and Carpenter Rocks (1991).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia. Listed as a cryptogenic and possibly introduced species in Victoria (Parliament of Victoria, undated) Very abundant and widespread species globally, on rocks and stones at all tidal levels.
Hypnea valentiae **(5)**	Red Sea	Widespread in Africa (12 countries), also SW Asia / Middle East (10 countries), Atlantic Ocean islands, Indian Ocean islands, Nth America, Caribbean, Sth America, SE Asia, Australia, New Zealand and Papua New Guinea. In Australia, known from WA, SA, VIC, NSW, QLD and NT. Many records from along QLD coast. SA records from Coffin Bay (1975), Port Bonython loading facility (northern Spencer Gulf) (2009), Althorpe I. (2004), locations in GSV including Port Adelaide (1984), Port Stanvac (1987) and Hallett Cove (1978) (GSV), American River / Muston on Kangaroo I. (1956, 1977).	

Table 13 (cont.):

Species	Type Locality	Distribution	Notes
Polysiphonia subtilissima **(3)**	Cayenne, French Guiana	Recorded Europe (~ 5 countries), Africa (~ 12 countries), also several Atlantic islands, Nth America (7 States plus Hawaii), Central America / Caribbean (~ 11 island groups), 5 countries in Sth America, India and Levant states, Korea, Philippines, Vietnam, Indonesia, several Pacific islands, several Indian Ocean islands, Australia and New Zealand. In Australia, known from WA, SA, VIC, TAS, NSW, QLD and Australian Antarctic territories. SA records from Kellidie Bay (Coffin Bay) (1967), Port Lincoln jetty (1968), Stony Point in Nth Spencer Gulf (2004), locations in GSV including St Kilda beach (1972), Port Stanvac (1982) and Port Noarlunga (1996), also Ballast Head (1996) and American River (1997) on Kangaroo I, boat harbour at Robe (1973), and Port MacDonnell (1996).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be cryptogenic in Australia.
Stylonema alsidii **(2)**		Known from Europe (> 15 countries), Africa, India and SW Asia, Nth America, Caribbean, Sth America, various Indian Ocean islands and Atlantic Ocean islands, Japan, Korea, Pacific island, SE Asia and Australia. Known in Australia from QLD, TAS and SA. SA records from Torrens I. (Angas Inlet) near Port Adelaide (2003) and Port Noarlunga (1988), the latter being an epiphyte on *Caulerpa scalpelliformis* in the intertidal.	Hewitt et al. (2004) reported this species to be cryptogenic in Australia.
Coralline Red Macroalgae			
Pneophyllum confervicola **(35)**	Trieste, Italy	Known from Europe (15 countries), north Africa, India, various Indian Ocean islands and Atlantic Ocean islands, Japan, and Australia (QLD, and unpublished records from SA). Aust Virtual Herbarium only lists a single Australian record (from QLD). No listings in SA State Herbarium on-line database (ADHerb 2010). In working data set, SA records from St Kilda (north-eastern GSV) and Sellicks Beach area. Collectively, 35 records from SA, and same 2 localities as *P. fragile* and *P. limitatum.*	
Pneophyllum limitatum **(27)**	Jylland, Denmark	Few global records (from Ireland, France, Sweden, Norway, Scandinavia and Baltic Sea. No listings in Aust Virtual Herbarium. No listings in on-line database (ADHerb 2010). In working data set, 1 SA record from St Kilda (north-eastern GSV) and 26 records from Sellicks Beach area. Records from same 2 localities as *P. fragile* and *P. confervicola*	

3.7 Macroalgae in the Aquatic Reserves of the AMLR NRM Region

Table 14 shows the number of species and records per species that occur in each of the Aquatic Reserves present in the AMLR NRM region (based on ADHerb 2010 database): Barker Inlet-St Kilda and St Kilda-Chapman Creek, Port Noarlunga Reef and Onkaparinga Estuary, Aldinga Reef, and the West Island Aquatic Reserve. The table also indicates the endemic species and introduced species recorded in each of the Reserves. Locations of the Aquatic Reserves in the AMLR NRM region are shown in **Figure 28**. A list with all species recorded in each of the reserves is given in **Appendix 2**. The Aquatic Reserves in the AMLR NRM region are as follows (from Jones 1984, Ivanovici 1984, 1993, Johnson 1988a, 1988b, PIRSA 2009), with numbers corresponding to those shown in **Figure 28**:

1 and 2: Barker Inlet-St Kilda and St Kilda-Chapman Creek: Barker Inlet, designated 1973 and amended in 1976 and 1980, was designated primarily for the conservation of species and associated habitats for commercial and/or recreational fisheries. Specifically, the reserve aims to protect the mangrove and seagrass communities which provide nursery areas for King George whiting (*Sillaginodes punctata*), yellow-fin whiting (*Sillago schomburgkii*), western king prawn (*Melicertus latisulcatus*), and the blue swimmer crab (*Portunus pelagicus*). The St Kilda – Chapman Creek Aquatic Reserve, which adjoins the Barker Inlet Reserve, was designated in 1980 to provide a buffer between commercial fishing exploitation and the Barker Inlet Aquatic Reserve, and also to provide further protection to the mangrove and seagrass communities and nursery areas for several commercially and recreationally significant fish species. Line fishing, and collecting bloodworms by hand are permitted in Barker Inlet and St Kilda reserve. Crab fishing by hand methods is permitted in St Kilda and Chapman Creek. Both reserves are used extensively for marine education and recreation.

There are 78 known macroalgal species in the Barker Inlet and St Kilda Reserve, based on 171 records from the SA State Herbarium. Some species are known from multiple records, including *Caloglossa leprieurii*, *Champia zostericola*, *Hydrolithon farinosum*, *Pneophyllum confervicola* and *P. fragile*. Three introduced species of macroalgae have been recorded in this reserve (**Table 14**), including one of the most significant introductions (*Caulerpa taxifolia*) recorded in South Australia.

3 and **4:** Port Noarlunga Reef and Onkaparinga Estuary: The reef was designated in 1971 primarily to protect the nearshore reef fishes from spear fishing pressure, and due to the significance of the reef for diving and associated recreation. The Onkaparinga Estuary and associated swamps, which adjoin the Port Noarlunga reserve, were designated due to their conservation significance. The estuary includes important spawning habitat for some estuarine fishes, and the estuary is one of the most significant in South Australia, in terms of its size and functions. Both conservation areas are used extensively for recreation and education. Of the Aquatic Reserves in the AMLR NRM region, the largest number of species of macroalgae (but not the largest number of records) comes from the Port Noarlunga - Onkaparinga River Aquatic Reserve. For some species, there are multiple records from that reserve (e.g. 10 or more records each of *Elachista nigra* – a possibly introduced epiphyte, *Cystophora subfarcinata*, and *Ecklonia radiata*, and 8 or 9 records each of *Sargassum lacerifolium*, *Ceramium filiculum*, *Chondria angustissima*, *Pterosiphonia pennata*). The large number of species (218) recorded in this reserve reflects not only the reef flora, but the presence of numerous species of small brown epiphytes and red epiphytes. For more than 100 species (i.e. almost half of all species recorded), there is only a single record. Four probably endemic species of macroalgae have been recorded in the Port Noarlunga – Onkaparinga Aquatic Reserve (NB a fifth is known in addition to the SA records from a single Tasmanian record, not included in the published distribution: Womersley 1998), as well as three introduced species (**Table 14**).

5: Aldinga Reef: Designated in 1971 primarily to protect from exploitation the organisms associated with the reef, intertidal platform and the surrounding sandy substrate. It has also served an important purpose in marine education (particularly for intertidal platform and rock pool studies) and recreation (e.g. the Aldinga ~~d~~rop-off" and pinnacles further offshore are used for diving). Apparently, according to SA State Herbarium data, no South Australian endemic or introduced species have been recorded in the Aldinga Aquatic Reserve.

6: West Island Aquatic Reserve: Designated primarily as a scientific research site, to protect the marine benthic organisms around the island for long term ecological studies. The island has spawned many dozens of scientific studies (of most note the research on abalone over two decades, by Dr S.A. Shepherd), and has resulted in internationally significant knowledge in abalone population dynamics, fish behaviour, predator-prey interactions, food web studies, benthic ecology, and macroalgal physiology, among other studies. West Island has also demonstrated the importance of small, fully protected areas for conservation of otherwise highly exploited species such as abalone (e.g. Shepherd 1991). A large number of records (705) have been recorded from this Aquatic Reserve. This was largely due to the intense and thorough collecting effort that occurred during the late 1960s as part of a project to document the macroalgal ecology of the island (Shepherd and Womersley, 1970; Shepherd and Watson, 1970), and further collecting of macroalgae was undertaken at West Island by staff and students of the University of Adelaide during the 1990s and early 2000s. As is the case with the Noarlunga – Onkaparinga River Aquatic reserve, multiple records of some species from West Island have raised the record tally to a high number for a single location (e.g. 10 or more records each of *Asparagopsis armata*, *Ballia callitricha*, *Cheilosporum sagittatum*, *Haliptilon roseum*, *Inkyuleea mariana*, *Lobospira bicuspidata*, *Nizymenia australis*, *Peyssonnelia capensis*, *Phacelocarpus peperocarpos*, *Plocamium angustum*, *P. cartilagineum*, *P. patagiatum*, *P. preissianum*, *Pterocladia lucida*, *Rhodophyllis membranacea*, *R. multipartita*, and *Rhodymenia sonderi*). Two species that are apparently endemic within South Australia have been recorded from the West Island Aquatic Reserve (**Table 6**).

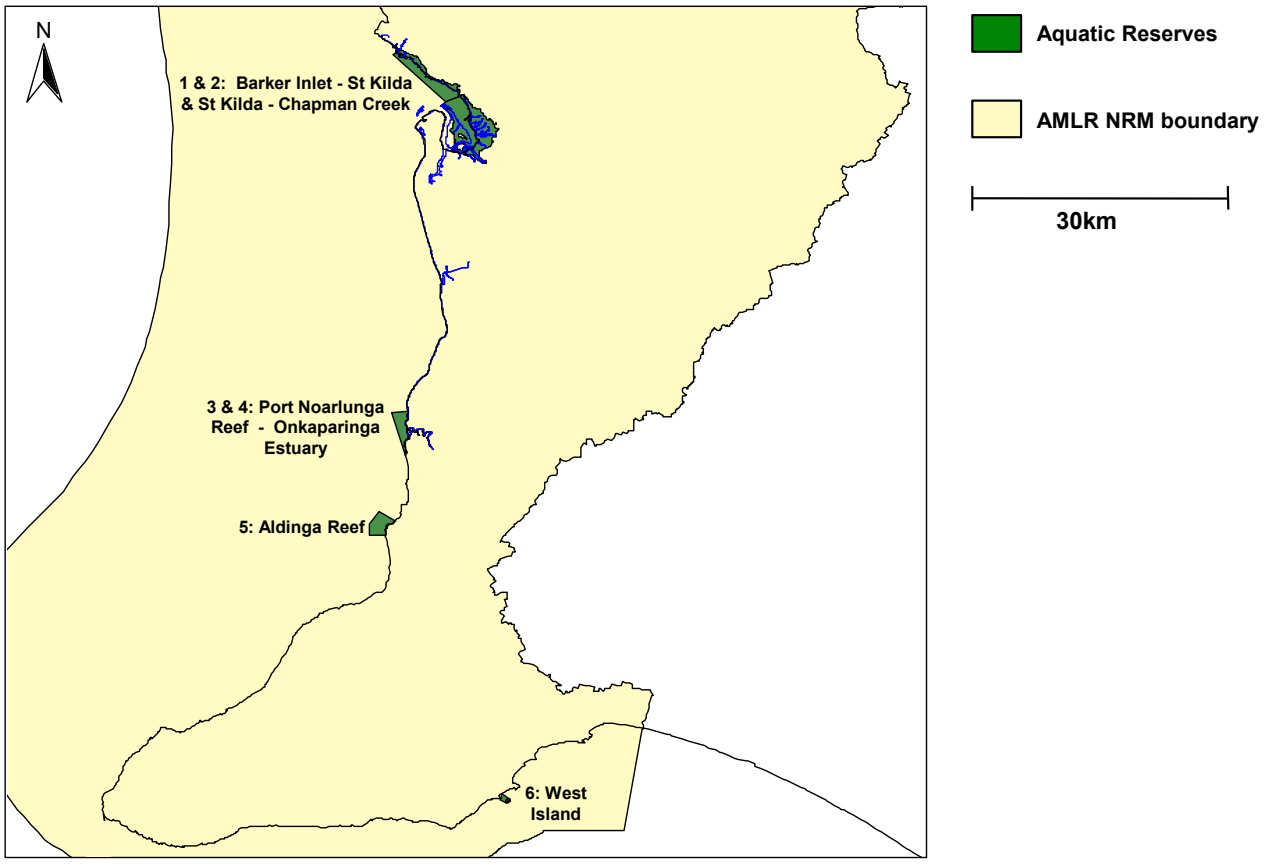


Figure 28: Location of Aquatic Reserves in the AMLR NRM region.

Table 14: Numbers of records, species, South Australian endemic species, and introduced species in the Aquatic Reserves situated within the AMLR NRM region, based on ADHerb 2010 database. Species records within 200m of reserve boundaries are included.

Aquatic Reserve	Number of Species	Number of Records	Endemic Species	Introduced Species
Barker Inlet – Chapman Creek	78	171	0	• *Caulerpa racemosa* var. *cylindracea* • *Caulerpa taxifolia* • *Cladophora prolifera*
Port Noarlunga – Onkaparinga River	218	475	• *Flabellonema codii* • *Myrionema latipilosum* • *Callithamnion circinnatum* • *Callithamnion shepherdii* • *Medeiothamnion repens*	• *Chondria arcuata* • *Cottoniella fusiformis* • *Elachista nigra* • *Gymnogongrus crenulatus*
Aldinga	51	86	0	• *Elachista nigra*
West Island	177	705	• *Antithamnionella multiramosa* • *Haraldia australica*	0

3.8 Macroalgae in the Encounter Marine Park

Figure 29 shows the location and zoning of the proposed, multi-zone Encounter Marine Park. Of the 8,532 geo-referenced records of marine macroalgae in the AMLR NRM region, exactly 50% (= 4,286) of those records occur inside the perimeter of this park. Of those, 2,849 records (33%) occur in or directly adjacent to Sanctuary Zones, or at the boundary of those zones (**Table 15**). There are 747 species in the geo-referenced data set of AMLR NRM macroalgae records, and of those, 463 species (62%) have been recorded in Sanctuary Zones of the Encounter Marine Park.

Approximately 25% of the number of geo-referenced herbarium records of Chlorophyta in AMLR NRM region has been recorded in Sanctuary Zones of the Encounter Marine Park, equating to 35 of the 85 species recorded (i.e. 41% of species).

For the Rhodophyta (excluding coralline algae), about 43% of the number of records and 63% of the number of species recorded in the AMLR NRM region , occur inside or directly adjacent to the Sanctuary Zones of the Encounter Marine Park.

For the Corallinaceae, 31% of records and almost 68% of species recorded in AMLR NRM region occur in the Sanctuary Zones of the Encounter Marine Park. The low number of records reflects multiple samples of some species (including probable cryptogenic species) collected in other parts of the AMLR region.

About 27% of the number of records and 72% of the number of species of brown macroalgae (Phaeophyceae) recorded in the AMLR NRM region, occur inside or directly adjacent to the Sanctuary Zones of the Encounter Marine Park. Therefore, the diversity of Phaeophyceae known from the region is quite well represented in protected areas, compared with the reds and greens.

Table 15: Comparison between the numbers of geo-referenced herbarium records of macroalgae in AMLR NRM region, with numbers recorded within Sanctuary Zones of Encounter Marine Park.

	Number of Records (and Species) of Macroalgae in AMLR NRM	Number of Records (and Species) of Macroalgae in Encounter MPA Sanctuary Zones
All species	8,532 (747)	2, 849 (463)
Chlorophyta	677 (85)	173 (35)
Phaeophyceae	2,242 (156)	605 (113)
Rhodophyta (excluding Corallinales)	4,533 (478)	1,944 (301)
Rhodophyta (Corallinales)	399 (28)	126 (19)

There are 18 SA endemic species recorded in the AMLR NRM region (**Figure 19,** based on 50 records). Of these, 10 species occur within the boundaries of the Encounter Marine Park (**Figure 30,** 26 records). Within this marine park, 6 species occur in the two largest proposed Sanctuary Zones in Encounter Bay (S7 and S9, based on 17 records) (**Figure 30**). Those species are: *Antithamnionella multiramosa, Euptilocladia villosa*, *Flabellonema codii*, *Haraldia australica*, *Strepsithalia leathesiae*, and *Tylocolax microcarpus*. An additional species (*Acrotrichium amphibolis*) occurs adjacent to the S8 sanctuary zone in Encounter Bay (west of Granite Island), and is known in that area from a single record. Five records of *Flabellonema codii* occur adjacent to the S1 sanctuary zone on the Fleurieu Peninsula, in the Rapid Head to Yankalilla Bay area.

Possibly endemic species not included in Sanctuary Zones include the brown species *Acrotrichium amphibolis*, *Corynophlaea cristata*, *Myriactula filiformis*, *Myrionema latipilosum*, and *Spatoglossum australasicum*, and the red species *Bonnemaisonia spinescens*, *Callithamnion circinnatum* (endemism uncertain), *Callithamnion shepherdii*, *Crouania destriana*, *Heterothamnion sessile*, *Medeiothamnion repens* and *Pterothamnion flexile*.

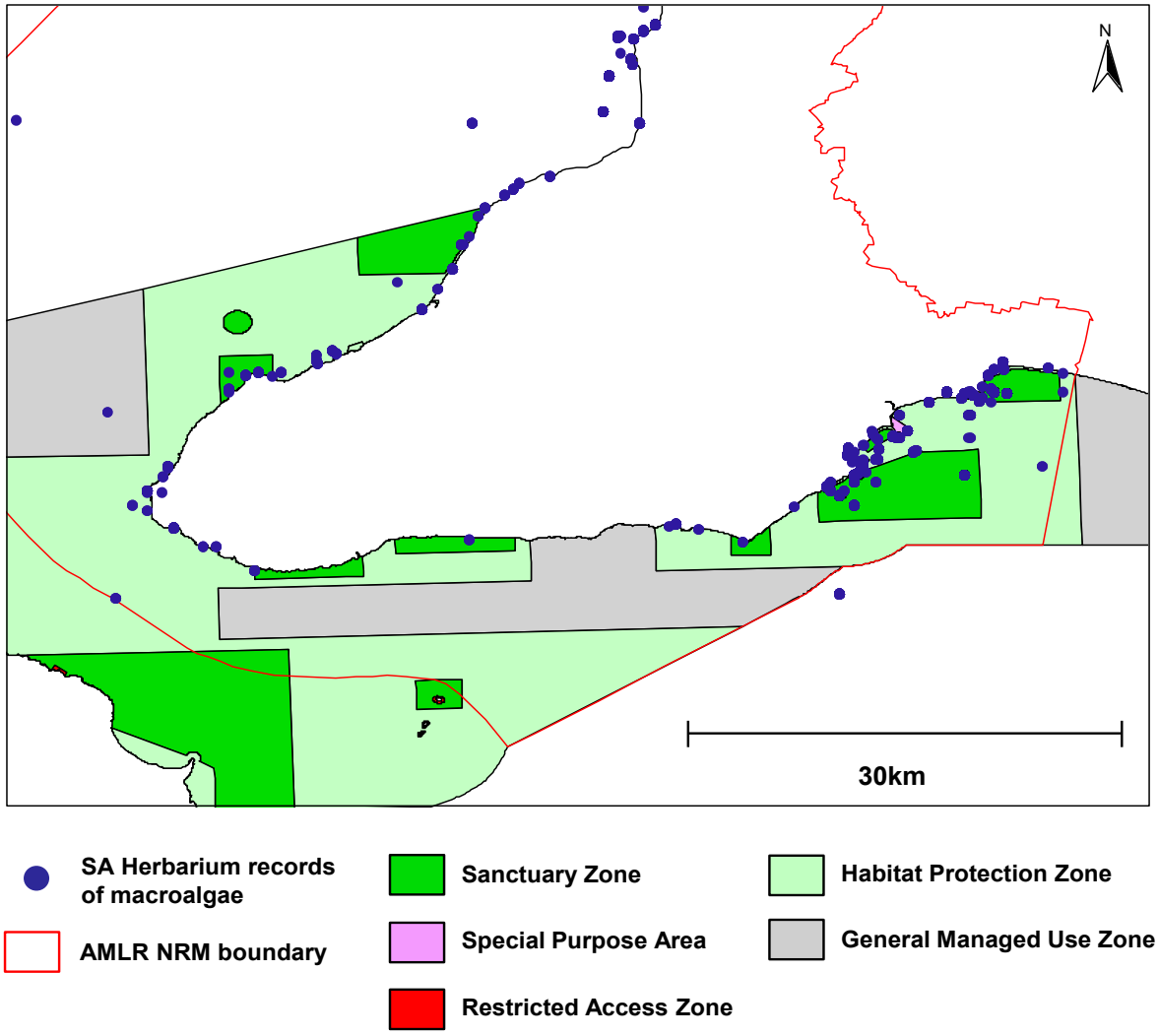


Figure 29: The Encounter Marine Park boundaries, and distribution of historical geo-referenced records of macroalgae from the South Australian State Herbarium database.

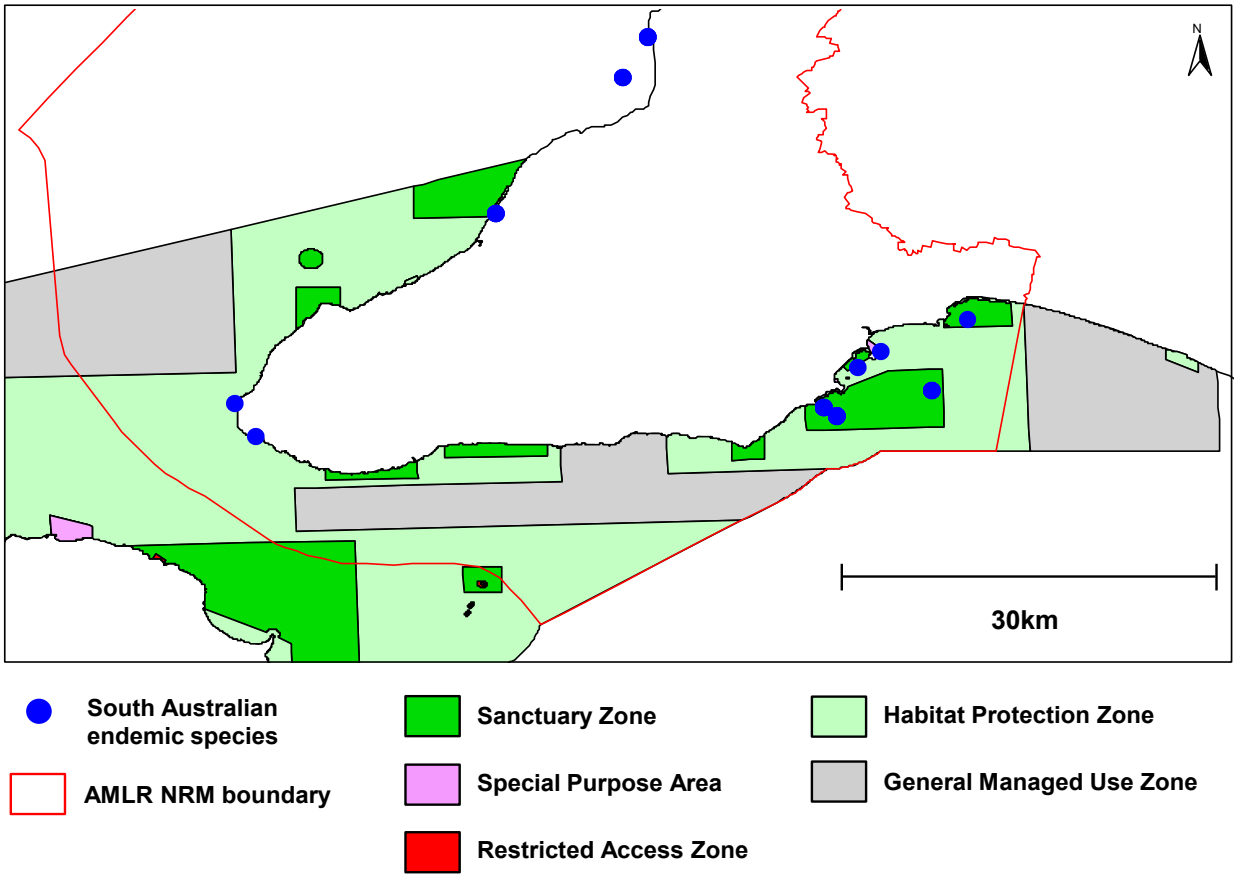


Figure 30: The Encounter Marine Park boundaries, and the plotted distribution of records of South Australian endemic species, according to data in ADHerb 2010.

Conclusions and Recommendations

Endemic, Rare / Uncommon and Potentially Threatened Species

The distribution and status of South Australian endemic species, species with limited range, rare or uncommonly recorded species and other potentially threatened species remains poorly determined. Records are very sparse and highly variable in space, time and effort. So far, records of species currently considered endemic and / or rare are concentrated in the best sampled areas, such as Port Noarlunga area, Aldinga and Encounter Bay, and it is notable that there are Aquatic Reserves in all of these locations. Several of these locations (Port Noarlunga, Aldinga, and Encounter Bay) were also previously highlighted by Cheshire et al. (2000) as important sites for limited range species, and all limited range species were considered as ~~t~~hreatened species" in that report. Cheshire et al. (2000) also listed the Cape Jervis area as being important for such species, and it is noted that two South Australian endemic species have been recorded there up til now (**Figure 19**).

Several potentially rare species or species with limited known range have been recorded from the Outer Harbour area, which is a highly modified and industrialised region next to a major port facility. One of the records of an endemic species dates back to 1852, collected by Mueller. The ~~A~~delaide area" was highlighted by Cheshire et al. (2000) as one of the sites in Gulf St Vincent (which includes AMLR NRM) that are important for limited range (~~t~~hreatened") species, and the number of endemic and other limited range species of conservation concern recorded in the area support that assumption (**Figures 19** and **21**).

A number of the records of potentially rare / limited range species in the AMLR NRM area are old (e.g. from the middle of the 20th century, and some from the 19th century), and it is not known in some cases whether those species still exist in the areas where they were originally collected, because targeted searches have not been made, and some of the areas where such species were previously recorded have been subject to numerous impacts, as discussed below.

As shown in **Figure 19** and **21**, areas around Aldinga (e.g. Maslins and Port Willunga) as well as Silver Sands – Sellicks Beach further south, appear to be important for endemic, rare and limited range species, where collectively 6 endemic macroalgae have been recorded. The entire region of Encounter Bay may also be significant, in which at least 8 endemic species have been recorded, and are spread throughout the bay.

Many of the South Australian endemic species described so far are small, inconspicuous epiphytes. Such species are likely to be more widespread but have not yet been surveyed.

Calcareous Macroalgae

Of particular concern is the lack of knowledge about the true abundance, distribution and biodiversity of crustose calcified red macroalgae in the AMLR NRM region. There is similar lack of knowledge of calcareous macroalgae at national and international levels. Calcified macroalgae (i.e. calcareous macroalgae with $CaCO_3$-impregnated cell walls) play a major role in the establishment and maintenance of reef super-structure. They are one of the principal cementing agents of the world's reefs. Calcareous macroalgae become the primary reef builders where there is continual washing by strong wave action and currents, or in regions too deep or too cold for zooxanthellae-associated coral to grow, such as reef crests, temperate reefs, and deepwater continental shelf rhodolith beds. The importance of calcareous macroalgae in coral reef growth cannot be overstated; without calcareous macroalgae, most reefs could not exist (Harney and Fletcher 2003, Birrell et al. 2008). Yet, despite their importance in reef accretion and ecology, knowledge of calcareous macroalgae diversity and biogeography remains extremely poor. Therefore, it is of primary importance that calcareous macroalgae are better understood, to maximise the potential for conservation of this important group, as well as the conservation of reefs as a whole, and management of processes and activities that impact upon them. Minor reductions in oceanic pH (from 8.1 to 7.8) can reduce calcification by as much as 21% for coral reef communities that include calcareous macroalgae (Leclerq et al. 2000). In experiments using aquaria enriched with CO_2, calcareous macroalgae - the dominant contributors to calcium carbonate mass on seagrass blades - disappears at pH = 7.7 (Martin et al. 2008). Indeed, calcareous red macroalgae are more sensitive to climate change, in terms of ocean acidification and warming, than corals (Anthony et al. 2008). Their recruitment rates and growth are also severely inhibited in elevated CO_2 conditions (Kuffner et al. 2008). These results demonstrate that calcareous macroalgae are the most sensitive and threatened reef-building organism in the world when it comes to processes associated with climate change (i.e. ocean acidification, higher CO_2 concentrations and warmer temperatures). The obvious susceptibility of calcareous macroalgae to ocean acidification, and their importance in reef building and maintenance, argues strongly that their conservation is of critical importance for maintaining reefs into the future, and should be afforded the highest priority. Efforts are required to protect calcareous reef flora that currently exists, from additional anthropogenic stresses such as physical damage (e.g. from boats, anchors, dredging etc), sediment smothering, and nutrient enrichment. Such protection may help calcareous reefs to persist longer in the face of ongoing stresses which are harder to control, such as ocean acidification from climate change.

Introduced Species

Of the 14 species of macroalgae introduced in the AMLR NRM region and discussed in this report, two of the most significant (*Caulerpa taxifolia* and *Caulerpa racemosa* var. *cylindracea*) are part of a regular monitoring program by Primary Industries and Resources South Australia and SARDI Aquatic Sciences (e.g. Rowling 2008, 2009, Wiltshire and Rowling 2009). *Caulerpa taxifolia* has attracted a large research and management effort in South Australia since the early 2000s when it was discovered in the Port Adelaide River and West Lakes. The current monitoring program could be considered an important step in controlling the spread of this invasive species, which has resisted eradication attempts.

A third species, *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*), appears to have received little attention in comparison. This species has been recorded in SA from American River on Kangaroo Island, and from North Haven and West Lakes in AMLR NRM. It was considered common in the latter area when it was discovered there in 2002 (Womersley 2003). *Codium fragile* is now a pest species in south-eastern Australia (Campbell and Hewitt 1999, Trowbridge 1999, CRIMP / NIMPIS 2002), and is considered number one in a list of invasive marine macroalgae in Europe (Nyberg and Wallentinus 2005). Impacts in Australia were discussed in Trowbridge (1999) and Bridgwood (2010). This species can alter benthic community structure and species composition by competing for space with native marine organisms, and taking over large areas of the available substrate. It can also settle on native algae and shellfish, foul fishing nets and, in some areas, large wracks of this species rot on beaches after storms. Given that this species is now established in SA (Womersley 2003, Wiltshire et al. 2010; ADHerb 2010), the potential for this form of *Codium* to spread further in the State should be considered, and measures to control such an occurrence should be undertaken where possible. However, it is noted that a recent summary of this species in Western Australia (Bridgwood 2010) concluded that all current potential means of control (chemical treatment, mechanical removal, manual removal, and biological control) may be either ineffective, or highly damaging to other marine flora in the infested areas (Trowbridge 1999). Therefore control options are currently limited, and more research is required to determine effective, non-destructive methods of management or eradication.

The various species of *Ulva* and *Cladophora* highlighted in this report as being introduced or cryptogenic should be monitored in nutrient-rich locations (such as port areas, and estuaries), for their potential to bloom. A number of these species have been responsible for ~~"g~~reen tides" in other countries. It is noted that one of the potentially invasive *Cladophora* species (*C. prolifera*) has been the subject of genetic work (Leliaert et al., 2007, cited by Blair et al. 2009), as has *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*) (Lam and Zechman 2006, Provanet al. 2008). Molecular research can assist studies of origin, detection, and potential spread of invasive species. *Cladophora prolifera* has been commonly reported along the eastern side of Gulf St Vincent (ADHerb 2010; SARDI data, cited by Wiltshire et al. 2010). Possibly cryptogenic species with capacity to form seasonal algal blooms in eutrophic conditions (e.g. species in *Hincksia*), should also be surveyed and possibly monitored. Some of these species occur in the AMLR NRM area (e.g. *H. sandriana* has been found in the St Kilda area, north of Barker Inlet). It is important to increase public awareness about potential vectors that may aid the spread of introduced macroalgae, such as algal fragments on boat propellers, ropes or other marine equipment. Public awareness may help decrease the probability at which introduced species spread in SA.

Impacts on Macroalgae, and Impact Assessment

Concern about the degradation of macroalgae-rich reefs in the AMLR NRM area has prompted much research and reporting during the past decade, both in universities and government research organisations. For example, a theoretical "~~r~~econstruction" of the condition of metropolitan reefs has been undertaken, utilising data from several time periods (Connell et al. 2008). The data employed were: (i) percentage cover of canopy macroalgae at Port Noarlunga (1968), and at Horseshoe Reef, Christies Beach (October 1969 and 1973: data by S.A. Shepherd), (ii) data from the 1990s on visual estimates of canopy cover and/or counts of canopy-forming macroalgae per m^2 (from the reef environmental impact studies of Turner, Miller and Kildea), and (iii) data from 1999 and 2005, collected as part of SARDI's Reef Health Program (see below) using a line intercept method to estimate percentage cover within 4 replicate 20m transects at Horseshoe Reef and Port Noarlunga reef. An analysis of these data indicated that historically, metropolitan sites in AMLR NRM region were indistinguishable from current reference sites across 70km of GSV, which have healthy cover of canopy-forming macroalgae. However, the metropolitan sites now have much sparser canopies compared with equivalent locations and times in the gulf. According to the reef cover reconstruction study, there is evidence of loss of up to 70% of the canopy-forming macroalgae on parts of the Adelaide metropolitan coast since major urbanisation (Connell et al. 2008). There has also been some impact on reefs in the increasingly urbanised area of Victor Harbor, possibly due to increased runoff and nutrient and sediment loads from the Hindmarsh and Inman Rivers (Turner et al. 2007, cited by Gaylard 2009). Estuary action plans have recently been written for both of these rivers (Sinclair Knight Merz 2010a,b).

There is strong evidence to indicate that increased nutrients and sedimentation in the AMLR NRM region has led to the declines in canopy-forming kelp and other large brown macroalgae, and an increase in the cover of sediment-trapping, turf-forming algae (Turner 2005, Turner and Kildea 2006, Turner et al. 2007, Gorman 2009). On naturally nutrient-poor coasts, sudden increases in nutrient concentrations from coastal run-off can have a disproportionately large impact (Russell et al. 2005, cited by Connell et al 2008, Gorman 2009), and the metropolitan coast in AMLR NRM region is a prime example. Recent experimental work has shown that in areas with substantial effluent-induced increases in dissolved organic nitrogen (compared with ambient levels in non-polluted areas), the cover and patch size of turf-forming algae are greater, and the loss of kelp cover is proportional to the size of the nitrogen increase (Gorman 2009). Once turfs become established in the place of canopy flora, they can trap sediment and further inhibit the re-establishment of canopy-forming species such as *Ecklonia* kelp and fucoid algae (e.g. species of *Sargassum* and *Cystophora*) (Gorman 2009).

In addition to (and synergistic with) nutrient-induced impacts, sedimentation from coastal discharges, and also from dredging works, can also have a detrimental effect on recruitment of canopy-forming macroalgae. There are pertinent point-source examples in the AMLR NRM region, from previous dredging operations at specific locations during the 1990s, including Port Stanvac (e.g. Turner and Cheshire 2002, Turner 2005). More recently, a wider-scale Reef Health program in the AMLR NRM region has highlighted the decline in health of a number of Adelaide metropolitan reefs, as measured by the loss of canopy-forming macroalgae (particularly *Ecklonia* kelp) and other indicators. No detailed investigation of reef sedimentation levels was undertaken in the Reef Health studies. These studies used a subjective ~~"~~sedimentation index" based on divers' observations whilst undertaking the reef surveys (Turner and Kildea 2006; Turner et al. 2007, cited by AMLR NRM 2009b).

A significant, ongoing source of sedimentation to coastal reefs is from coastal rivers, creeks and stormwater drains. A reef sediment study is being undertaken by the AMLR NRM Board in conjunction with SARDI Aquatic Sciences to determine where sediments on metropolitan reefs originate (Fernandes et al. 2008, AMLR NRM 2009b). Some of the most heavily impacted reefs in terms of sediment load include Noarlunga and Aldinga, due to the sediment from the Onkaparinga River and adjacent eroding cliffs. Agricultural runoff and sedimentation onto seagrass and reef in the Aldinga area has long been an ongoing issue (Environment Protection Council of South Australia 1992). Storm activity may re-suspend and transport sediments previously deposited by the Onkaparinga River during winter (Fernandes et al. 2008, AMLR NRM 2009b). As shown in this report, Noarlunga is apparently one of the historically more species-rich areas of the metropolitan coast in terms of composition of macroalgae, and a number of endemic species have also been recorded there.

Initial results of the aforementioned sediment study indicate that most of the sampled reefs in the area are subject to sedimentation, including the area between Port Noarlunga North and Hallett Cove (the Field River and Christies Creek are considered to be major contributors of sediments to these reefs), and Semaphore and Broken Bottom (off Glenelg), where sediments in the area are also high in nitrogen. The higher nitrogen loads on the northern reefs may be due to a combination of long-term discharges of domestic and industrial wastewaters, the Bolivar and Glenelg wastewater treatment plants, and the Penrice soda factory which discharges to the Port River (AMLR NRM 2009b). Some of the main threats identified to water quality (and thus nearshore marine habitats) in eastern Gulf St Vincent include nutrients from the SA Water wastewater treatment plants (WWTPs) and turbidity from urban stormwater; ammonia from Penrice soda factory, and elevated temperature from the Torrens Island power station (Gaylard 2009).

Apart from reefs, seagrass beds also contribute significantly to the diversity of macroalgae in the AMLR NRM region, because most seagrasses, particularly the two species of *Amphibolis*, can support numerous epiphytic macroalgae. The well-publicised degradation of seagrass beds in the

AMLR NRM region since the 1950s will not be discussed here, other than to note that the issue was known about at least as early as the 1960s (Shepherd 1970), and has been the subject of numerous investigations over the ensuing decades, including mapping of metropolitan and southern beaches seagrass decline since the 1950s (e.g. Hart 1996, 1997), and many investigatory and confirmation projects as part of the multi-project, multi-agency Adelaide Coastal Waters Study during the early 2000s. Baker (2004) provided reviews of impacts resulting in seagrass loss in the north-eastern GSV area, and Westphalen et al. (2004), and Fox et al. (2007) reviewed seagrass loss over the entire metropolitan area of GSV. Furthermore, Tanner's (2003, 2005) benthic survey work has dramatically illustrated the significant changes that have occurred to the benthos of Gulf St Vincent and Investigator Strait since the 1960s, including hard bottoms as well as seagrass beds, and particularly due to the effects of prawn trawling. Although changes to macroalgae cover and composition in the deeper waters of AMLR NRM (off the metropolitan area and Fleurieu Peninsula) have not been fully investigated, it is likely that significant changes have occurred due to substantial habitat modification.

Other benthic habitat types, such as shells beds and other combined hard/soft substrates, support epilithic macroalgae. Tanner (2003, 2005) provided examples of locations in AMLR NRM region where such beds have been significantly degraded over time.

Coastal developments and marina / boat harbour construction and maintenance can also impact coastal reefs and seagrass beds in the AMLR NRM (see below), and therefore adversely affect the cover of macroalgae. A pertinent recent example is 15,000 cubic metres of boat harbour dredge spoil that was dumped in the intertidal reef and beach area at O'Sullivans Beach in early 2009, which quickly smothered the shallow subtidal reef to a depth of at least 3m. Opportunistic visual assessment (before and after) by divers indicated that the load significantly altered the species composition of macroalgae in the days, weeks and months following the event, including destruction of *Ecklonia* kelp cover and also the understorey flora. The longer term impacts have not yet been investigated, and no formal monitoring program is yet in place. Increased turbidity and increased sedimentation may also occur due to periodic dredging of the ferry harbour at Cape Jervis, and also due to the regular operation of the Kangaroo Island ferry in that area (Bryars 2003).

In addition to the metropolitan area, coastal discharges and sedimentation are also an issue along many parts of the Fleurieu Peninsula. Baker (2004) provided a summary of community concerns during the past two decades, including the following:

- Agricultural runoff (fertilisers, farm chemicals as well as sediments) onto reef and seagrass beds in a number of areas in the Southern Fleurieu region
- Nutrients and other pollutants (e.g. agricultural chemicals, sediments etc) flowing from the Yankalilla, Bungala and Myponga Rivers and from Waitpinga Creek, into the near-shore area (DEH 1996, unpublished data; Bryars 2003). An increased level of nutrients has been listed as a perceived threat to the estuarine habitats in these areas (Bryars 2003), and Yankalilla and Bungala rivers are classified as being in moderate to poor condition based on their elevated concentrations of nutrients (Elsdon et al. 2009 and unpublished data, cited by Irving 2009). The point source pollution from the Bungala River was the subject of a community-based impact monitoring program during the mid 1990s, and more recently, an estuary action plan has been prepared for the Bungala estuary (AECOM Australia Pty Ltd 2010).

- Community submissions received by government during 1991, described land-based impacts in the southern Fleurieu area (e.g. Lady Bay - Carrickalinga - Normanville - Second Valley), such as: declining quality of the near-shore reef and seagrass ecosystems due to land clearing and coastal development, farming and grazing (causing pollution of local estuaries from agricultural runoff including sediments, herbicides and pesticides, cattle wastes, dairy runoff at Second Valley), and effluent overflow from septic tanks at Carrickalinga, Second Valley and Rapid Bay) (Schiansky pers. comm. to S.A. Department of Fisheries 1991; Bryars 2003). One report suggested that pollutants from river outlets in the area has resulted in reduced variety of macroalgae in the shallow waters near river outlets, and siltation of near-shore reefs resulting in reduced diversity of reef biota (Christie, pers. comm. to S.A. Department of Fisheries 1991).
- Decreased freshwater flows cased by abstraction from the Waitpinga Creek catchment has been listed as a potential threat to near-shore habitat in that area (Bryars 2003).
- Land clearing and coastal soil disturbance associated with coastal development (e.g. housing sub-divisions) contributes to sedimentation in the near-shore Southern Fleurieu marine environment (e.g. Carrickalinga / Lady Bay / Rapid Bay / Normanville area and other coastal areas of increasing sub-division) (CCSA 2000). When stormwater runoff occurs from urbanised and rural areas, particularly areas undergoing building site clearance, a large amount of sediment from coastal developments ends up in coastal waters (Caton 1997, cited by Brook 2000), which reduces light availability for healthy macroalgal growth, and also smothers marine plants. Community submissions received by government during 1991 described impacts in the southern Fleurieu area (e.g. Lady Bay - Carrickalinga - Normanville - Second Valley) as including impacts upon near-shore environment due to coastal subdivisions and marina development (e.g. Wells pers. comm. to S.A. Department of Fisheries 1991).

There are also potential impacts upon near-shore reefs and seagrass beds from marinas in the AMLR NRM area (e.g. Wirinna area - Emmett 1997). General impacts of marinas include hydrocarbon pollution, metal contamination of sediments and biota from anti-foulants, physical damage to benthos such as seagrass destruction and increased sedimentation from channel dredging and maintenance, anchor damage, boat hull scouring, and exotic species introductions (Harvey 1993). Marinas and waterfront housing / canal estates are some of the most destructive agents for nearshore marine habitats, and during the 2000s, some have been planned for very unsuitable locations (e.g. Port Wakefield).

The aforementioned issues in the metropolitan area and Fleurieu Peninsula also apply to Encounter Bay, an increasingly urbanised area at the edge of the AMLR NRM region. During the early 2000s, this area attracted around 1.1 million visitors per annum (Tourism Victor Harbor 2010). Between 1990 and 2000, the base population reportedly increased nearly 50%, a growth rate 10 times that of the State as a whole. Victor Harbor has continued to grow at around 3% per annum for the past 10 years to 2008. In 2009, the base population of the Victor Harbor Council area was 13,600 (Australian Bureau of Statistics data, 2010). The base population increases to about 30,000 in summer due to temporary holiday residency (City of Victor Harbor 2008). Baker (2004) provided a summary of impacts in the Encounter Bay area that may affect near-shore reef and seagrass habitats.

Long-term Monitoring

In the AMLR NRM region, the community-based monitoring program run by Reef Watch, uses the line intercept transect method (LIT), to survey the sessile macro-benthos (bottom-dwelling species) that forms the major structural components of reef systems. The LIT method is described in Miller et al. (1998) and Turner (2005). In the Reef Watch monitoring program, macroalgae are not usually identified to species level, but are coded as ~~"l~~life forms" based on the appearance / morphology of the plant. Plants are divided into basic groups according to the shape and texture, such as foliaceous, lobed, leathery, lumpy, robust, branched etc. For example, a brown, branching plant would be coded ~~"B~~BRANCH", where ~~"B~~" is for ~~"b~~rown", and ~~"B~~RANCH" for ~~"b~~ranching" (Reef Watch 2004). Regular monitoring sites in the AMLR NRM area include Broken Bottom (near Glenelg), Hallett Cove, the inside northern and outside southern sections of Port Noarlunga reef,

Second Valley, and –The Bluff" (Rosetta Head) in Encounter Bay (Westphalen 2008, 2009; M. Kaehne, Reef Watch, pers. comm. 2010). Of the areas within the AMLR NRM region for which a reasonable collecting effort has been made over the years, two of the locations where the greatest concentration of potentially rare, limited range species have been recorded are Noarlunga and south-western Encounter Bay (including The Bluff area). Although both of these areas are Reef Watch benthic monitoring sites, additional specialised training would need to be undertaken by volunteer divers to identify the rare taxa to species level, given that the majority of endemic and otherwise rare species known in SA are small, inconspicuous epiphytes, and also, the Reef Watch monitoring program is not species-specific in the identification of macroalgae.

In addition to Reef Watch, the AMLR NRM Board has organised and supported a number of recent monitoring studies in the Region, which can directly benefit reef health, and conservation of the abundance and diversity of macroalgae. For example, a number of the AMLR NRM Board's water monitoring stations are in coastal areas adjacent to locations where macroalgae are present, or within a distance that may influence locations where macroalgae occur to the north or south of those points. Examples include Torrens River, Field River, Christies Creek, Pedler Creek, River Bungala, Tunkalilla Creek, and the Hindmarsh and Inman rivers in Encounter Bay. At these sites, a program is being developed to monitor stormwater volume and flow rate, salinity, turbidity, suspended solids and nutrients. For some of the 18 outfall sites in AMLR NRM where flow and pollutant loads enter the sea, data are now becoming available (AMLR NRM 2009). In 2010, a community-based, AMLR NRM Board-sponsored, water monitoring program was established, whereby trained volunteers measure water clarity at as many sites as possible around the Gulf, and enter depth-related data into a centralised database for analysis.

Determining the origin of sediment loads on metropolitan reefs is an important first step in the long term monitoring and possible management of reef sedimentation. Many of the actions required to do this must commence well upstream, particularly in the case of degraded rivers.

Significant steps have been undertaken during the past several years to address the long term issue of declining water quality (including nutrient enrichment and sedimentation) in the AMLR NRM, and its impact on macroalgae-dominated reefs. Classification of reef types and extents in the AMLR NRM area (Department for Environment and Heritage 2008) may also aid long-term monitoring of reef health in the region, by providing baseline data.

Other Recommendations for Monitoring and Impact Management

In addition to the recommendations above, relating to rare and endemic species, introduced species, and sediment and water quality monitoring, other recommendations include continuing the current work of the AMLR NRM Board, to ensure the persistence of remaining healthy reefs and seagrass beds, and the restoration of these where degraded, through the 21st century. Such work includes:

- Continued assistance for watercourse improvement and land management works (e.g. through the AMLR NRM's Sustainable Landscapes Program).
- Continued restoration and management of rivers and land upstream to stop erosion and reduce the amount of sediment and nutrients that enters rivers and creeks (and thus ends up on coastal reefs), particularly during peak load times as occurs after major storms.
- Building of settlement or sediment ponds to reduce the amount of stormwater reaching the sea (Breakout Creek Wetland on the River Torrens is one example).
- Continued treatment and recycling of wastewaters on land, and reduction of effluent-rich flows to the sea.
- Where possible, particular protection of existing Aquatic Reserves and proposed Sanctuary Zones of marine parks from physical impacts, nutrient enrichment, and sedimentation, especially those which are known to provide habitat for apparently endemic / limited range

species of macroalgae. Examples include the Port Noarlunga Reef Aquatic Reserve, and proposed sanctuary zones in Encounter Bay.

- Long-term and regular water quality monitoring to improve coastal water quality and the condition of marine and coastal habitats, as is currently occurring with the AMLR NRM Board's monitoring and report card program.

It is noted here that community-based monitoring of reef recovery is also planned for the sediment-impacted O'Sullivans Beach area, utilising the University of Tasmania's Reef Life Survey methods. This may be an important area for monitoring in the AMLR NRM region, given that the native reef flora has recently been significantly degraded, and is subject to sediment load from dredging approximately every 5 to 6 years, yet no formal monitoring of the subtidal reef area has occurred. At least one introduced species (*Caulerpa racemosa* var. *cylindracea*) has been recorded at O'Sullivans Beach. Observations after the 2009 dredge spoil dumping indicated a seasonal bloom of *Ulva* over bare reef substrate where kelp and understorey flora previously existed. Impacts such as dredge spoil dumping not only degrade reef habitats, but increase the potential for opportunistic and invasive species to occupy the degraded habitats, and proliferate.

Summary of Information Gaps, and Other Recommendations

As shown in this report, little is known of the species-specific composition of macroalgae in many parts of the AMLR NRM region. Examples of areas for which more information is required include:

- the upper north-eastern part of GSV (including the northern boundary area of AMLR NRM)
- much of the Fleurieu Peninsula (particularly the area north of Cape Jervis, and Backstairs Passage and surrounds
- much of the central gulf region (particularly waters deeper than 10m), and
- much of the coastal area from Cape Jervis to Encounter Bay, including Deep Creek. (For example, in two of the 10km grid cells along that coast, there are only two records of macroalgae lodged in the SA State Herbarium).

For such areas, very little is known about the macroalgal flora and diversity, despite the intense historical sampling effort known for other parts of the AMLR NRM region. For conservation parks abutting the coast (e.g. Deep Creek), more should be known about the biodiversity, to ensure adequate environmental management, and well-informed conservation decision making.

Many species of macroalgae are also considered rare, based on the paucity of records. Many of these are likely to be more widespread but have not yet been sampled due to their small size and/or cryptic habits. Without substantial survey and collecting effort, it is not possible to determine true ~~r~~arity" over any spatial scale, or to produce reliable systematic maps of their range. Such maps and reliable assessments of abundance are required for robust diversity analyses (e.g. Whittaker 2005). The datasets here analysed were based on presence and absence only. Frequency data based on number of herbarium records is too unreliable to calculate any indices of diversity that require an accurate assessment of abundance (or evenness).

Currently, analyses of species richness hotspots, and spatially-explicit reserve planning (e.g. MARXAN: Ball and Possingham 2000, Ball et al. 2009) cannot be meaningfully employed for macroalgae using opportunistically collected records of macroalgae over space and time, considering (i) substantial gaps in collecting effort (and record numbers) for numerous localities, as occurs in many parts of the AMLR NRM area, and other regions in South Australia, (ii) lack of knowledge of the current presence and spatial extent of species known only from old records, and (iii) the inability to compare ~~li~~like with like" in herbarium data sets, because the records are an amalgamation of data using different sampling techniques, variable survey or collecting intensity per area, and different time scales (ranging from the present back to more than 150 years).

Targeted studies are also required to determine the current distribution and relative abundance of species known only from very few records (sometimes a single plant has ever been collected), or

from very old records (e.g. 1850s to early 20th century). Many of these species are small, inconspicuous epiphytes that require highly trained taxonomists for their precise taxonomic identification.

Also, the status of many species considered cryptogenic should be tested using modern techniques in molecular biology, as they most likely correspond to cryptic species and/or species complexes from which morphological characters alone are not able to resolve long standing problems about their true biogeography and diversity.

Our multivariate analysis suggests that there are substantial floristic differences along the AMLR NRM coastline, and that this difference seems to be predominantly determined by cryptic, epiphytic or rare species rather than major foundation species in the canopy. However, our data sets are not optimal for such analysis, because herbarium collections are opportunistic and reflect the historical accumulation of several (or many) distinct studies rather than a targeted design to test community spatial turnover along the SA coast. More systematic, targeted research is necessary to test small scale beta-diversity and biogeographic hypotheses along the AMLR NRM coastline.

This report has provided some indication of the species richness and composition of the marine benthic macroalgal flora of the AMLR NRM region, based on historical herbarium records. We have also provided an assessment, including maps, of the gaps in knowledge and poorly studied regions along the AMLR coastline. This clearly shows where further studies should focus if we are to produce a comprehensive description of the true biodiversity and biogeography of the benthic macroalgal flora in the AMLR NRM region and wider Gulf St Vincent area, one of the richest in the world.

Summary of Recommendations

- Continued assistance for watercourse improvement and land management.
- Continued restoration and management of rivers and land upstream to stop erosion and reduce the amount of sediment and nutrients that enters rivers and creeks (and thus ends up on coastal reefs), particularly during peak load times as occurs after major storms.
- Building of settlement or sediment ponds to reduce the amount of stormwater reaching the sea.
- Continued treatment and recycling of wastewaters on land, and reduction of effluent-rich flows to the sea.
- Where possible, particular protection of existing Aquatic Reserves and proposed Sanctuary Zones of marine parks from physical impacts, nutrient enrichment, and sedimentation, especially those which are known to provide habitat for apparently endemic / limited range species of macroalgae. Examples include the Port Noarlunga Reef Aquatic Reserve, and proposed sanctuary zones in Encounter Bay.
- Long-term and regular water quality monitoring to improve coastal water quality and the condition of marine and coastal habitats, as is currently occurring with the AMLR NRM Board‘s monitoring and report card program.
- Perform new surveys to better determine the distribution, composition and abundance of South Australian rare and endemic species of macroalgae, particularly in Aquatic Reserves and MPA sanctuary zones, and also in port areas (and other highly modified areas where threatening processes exist).
- Specialised training of NRM coastal and marine scientific officers, and volunteer divers, to identify a range of ecologically important taxa (e.g. rare, cryptogenic, invasive, and foundation

species) in key areas, such as Noarlunga and south-western Encounter Bay (including The Bluff area). Training should also include improved sample preparation techniques so that, once collected, specimens are properly preserved for posterior expert taxonomic analysis.

- More information on the macroalgal species composition / biodiversity of data-poor areas such as upper north-eastern part of Gulf St Vincent; much of the Fleurieu Peninsula; much of the central gulf region (particularly waters deeper than 10m), and much of the coastal area from Cape Jervis to Encounter Bay, including conservation parks abutting the coast.

- Target studies to determine the current distribution and relative abundance of species known only from very few records.

- Protect calcareous reef flora that currently exists in and around AMLR NRM, from additional anthropogenic stresses such as physical damage (e.g. from boats, anchors, dredging etc), sediment smothering, and nutrient enrichment. Such protection may help calcareous reefs to persist longer in the face of ongoing stresses which are harder to control, such as ocean acidification from climate change.

- Establishment of a reliable and sensitive monitoring program for Aquatic Reserves, ports and harbour areas and other coastal waters not only for marine pest species, but also to generate baseline data to detect a plethora of marine impacts caused by either local or global stressors. Continuation of the SA Government‘s current monitoring program for *Caulerpa taxifolia* is recommended

- Continue the SA Government‘s current monitoring program for *Caulerpa taxifolia.*

- Consider the invasive possibilities of *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*), and develop measures to control such an occurrence.

- Survey and monitoring of various species of *Ulva*, *Cladophora* and *Hincksia* that may be introduced or cryptogenic, in nutrient-rich locations (such as port areas, and estuaries), as these species have the potential to bloom.

- Increase public awareness about potential vectors that may aid the spread of introduced macroalgae.

- Test the status of macroalgae that are considered to be cryptogenic, using modern techniques in molecular biology.

References

Adelaide Mount Lofty Ranges Natural Resource Management Board (AMLR NRM) (2009a) *2009 Regional Summary of Outflows for the Adelaide and Metropolitan Region.* http://www.amlrnrm.sa.gov.au/Portals/1/Monitoring/Regional_Summary_Surface_Water_Outflows_Adelaide_Metro_Region_2009.pdf

Adelaide Mount Lofty Ranges Natural Resource Management Board (AMLR NRM) (2009b) *Reef Sediment Study.* http://www.amlrnrm.sa.gov.au/CoastandMarineServices/ThreatstoMarineEnvirons/Reefsedimentstudy.aspx

ADHerb (2010) State Herbarium of South Australia data base, March 2010 version.

AECOM Australia Pty Ltd (2010) *Bungala Estuary Action Plan.* Draft report for the Adelaide and Mount Lofty Ranges Natural Resource Management Board, South Australia.

Anonymous (2009) *State of the Derwent Estuary 2009.* http://www.derwentestuary.org.au/file.php?id=386

Anthony, K.R.N., Kline, D.I., Diaz-Pulido, G., Dove, S., and Hoegh-Guldberg, O. (2008) Ocean acidification causes bleaching and productivity loss in coral reef builders. *PNAS* **105**: 17442-17446.

Aquenal Pty Ltd (2001) *Final Report: Exotic Marine Pests Survey - Port of Launceston, Tasmania.* Report by Aquenal Pty Ltd Aquatic Environment Analysts, for Port of Launceston Pty Ltd to meet the requirements of the AQIS Decision Support System (DSS) for Ballast Water Management. November 2001.

Aquenal Pty Ltd (2004) *Final Report: Exotic Marine Pests Survey - Port of Burnie, Tasmania.* Report by Aquenal Pty Ltd Aquatic Environment Analysts, for Burnie Port Corporation Pty Ltdto meet the requirements of the AQIS Decision Support System (DSS) for Ballast Water Management. June 2004

Aquenal (2006) *Exotic marine pests survey, Lord Howe Island, New South Wales.* Report by Aquenal Pty Ltd Aquatic Environment Analysts for the New South Wales Marine Parks Authority.

Australian Virtual Herbarium (AVH) (2010) Australia‘s Virtual Herbarium. Web site by Council of Heads of Australasian Herbaria Inc. http://www.ersa.edu.au/avh/index.jsp

Aziz, A., Nurul Islam, A.K.M, and Jahan, A. (2008) Marine algae of the St Martin‘s Island, Bangladesh. VI. New records of species of the genus *Kallymenia* J. Ag. (Rhodophyta).*Bangladesh J. Bot.* **37**(2): 173-178.

Baker, J.L. (2000) *Guide to Marine Protected Areas*. Report prepared for Coast and Marine Section, Department for Environment and Heritage, South Australia.http://www.environment.sa.gov.au/coasts/pdfs/mpa1.pdf

Baker, J.L. (2004) *Towards a System of Ecologically Representative Marine Protected Areas in South Australian Marine Bioregions - Technical Report*. Report for Coast and Marine Conservation Branch, Department for Environment and Heritage, South Australia. 1250p. http://www.environment.sa.gov.au/marineparks/pdfs/part_1.pdf

Baker, J.L. and Edyvane, K.E. (1996) *Marine Biogeography, Conservation Values and Potential Environmental Impacts in the Victor Harbor Region, South Australia*. Consultancy Report for the South Australian Department of Housing and Urban Development.

Baldock, R.N. (2003) *Dictyopteris gracilis* Womersley. http://www.flora.sa.gov.au/efsa/algae_revealed/pdf/Dictyopteris_gracilis.pdf

Baldock, R.N. (2005) *Caulerpa racemosa* (Forsskal) J. Agardh var. *cylindracea* (Sonder) Verlaque, Huisman & Boudouresque. http://www.flora.sa.gov.au/efsa/algae_revealed/pdf/Caulerpa_racemosa_var._cylindracea.pdf

Baldock, R.N. and Ricci, C. (2005) Revision of ~~–A~~ list of marine benthic algal species known from single or very few records or from restricted habitats in southern Australia", by H.B.S.Womersley, State Herbarium, Plant Biodiversity Centre, Adelaide, June, 2004. Unpublished report by R. Baldock and C. Ricci, October 2005.

Baldock, R.N. (2010) *Identification Fact Sheets of the Marine Benthic Flora (Algae) of Southern Australia.*State Herbarium of South Australia.

Bégin, C. and Scheibling, R.E. (2003) Growth and survival of the invasive green alga *Codium fragile* ssp. *tomentosoides* in tide pools on a rocky shore in Nova Scotia. *Botanica Marina* **46**: 404-412.

Ball, I.R., and Possingham, H.P. (2000) MARXAN (V1.8.2): Marine Reserve Design Using Spatially Explicit Annealing, a Manual. A Manual prepared for The Great Barrier Reef Marine Park Authority, Queensland.

Ball, I.R., H.P. Possingham, and M. Watts (2009) Marxan and relatives: Software for spatial conservation prioritisation. Chapter 14 in: Moilanen, A., Wilson, K.A. and Possingham, H.P. (Eds) *Spatial conservation prioritisation: Quantitative methods and computational tools*. Oxford University Press, Oxford, UK.

Birch, P.B., Gordon, D.G. and McComb, A.J. (1981) Nitrogen and phosphorus nutrition of *Cladophora* in the Peel-Harvey Estuarine System, Western Australia. *Botanica Marina* **24**: 381-387.

Birrell, C.L., McCook, L.J., Willis, B.L., and Diaz-Pulido, G. (2008) Effects of benthic algae on the replenishment of corals and the implications for the resilience of coral reefs. *Oceanogr. Mar. Biol. Ann. Rev.* **46**: 25-64.

Blair, D., Momigliano, P., Garrard, S. and Heimann, K. (2009) *Review of genetic probe development for invasive marine species, with a focus on choice of target gene and on DNA amplification technology*. March Interim Report (Part 2) to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns. 33p.

Bridgwood, S. (2010) *Codium fragile* ssp. *fragile* (Suringar) Hariot: summary document. Fisheries Research Report No. 202. Department of Fisheries, Western Australia. 12p.

Brodie, J. and Irvine, L.M. (2003) *Seaweeds of the British Isles*. Volume 1. Rhodophyta. Part 3B. Bangiophycidae. 167p.

Brodie, J., Maggs, C.A. and John, D.M. (2007) *Green Seaweeds of Britain and Ireland.*British Phycological Society, London. 242p.

Brook, J. (2000) Issues Relating to the Establishment of Marine Protected Areas in the Southern Fleurieu coast. Report prepared for the Southern Fleurieu Coastal Reference Group, South Australia.

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

Byrne, K., Zuccarello, G.C., West, J., Liao, M.-L. and Kraft, G.T. (2002) *Gracilaria* species (Gracilariaceae, Rhodophyta) from south-eastern Australia, including a new species, *Gracilaria perplexa* sp. nov.: Morphology, molecular relationships and agar content. *Phycological Research* **50**(4): 295-312.

Cambridge, M.L., Breeman, A.M. and van den Hoek, C. (1991) Temperature responses and distribution of Australian species of *Cladophora* (Cladophorales: Chlorophyta). *Aquatic Botany* **40** (1): 73-90.

Campbell, M.L. and Hewitt, C.L. (1999) A bay-wide survey for introduced species in Port Phillip Bay 1995-1996, In: Hewitt, C.L., Campbell, M.L., Thresher, R.E., and Martin, R.B. (Eds*) Marine Biological Invasions of Port Phillip Bay, Victoria*. CRIMP Technical Report No. 20, CSIRO Marine Research, Hobart, Australia.

Caton, B. (1997). Southern Fleurieu Coastal Action Plan, Report prepared for Coastal Working Group, Southern Hills Local Government Component, Mount Lofty Ranges Catchment Program.

CCSA (2000) Senate Inquiry into Gulf St Vincent. Submission by the Conservation Council of South Australia Inc. Report collated by M. Grady and J. Brook, 3rd February, 2000.

Cheshire, A.C. and Collings, G.J. (1998) Composition of subtidal macroalgal communities of the lower gulf waters of South Australia, with reference to water movement and geographical separation. *Australian Journal of Botany* **46**(6): 657 – 669.

Cheshire, A.C. and Westphalen, G. (2000) *Assessing the status of temperate reefs in Gulf St Vincent IV. Results of the 1999 surveys.* Report to DEH South Australia, by Botany Department, University of Adelaide, South Australia.

Cheshire, A.C., Collings, G.J., Edyvane, K.S. and Westphalen G. (2000) *Overview of the Conservation Status of Australian Marine Macroalgae*. A report to Environment Australia. Department of Environmental Biology, University of Adelaide, July 2000.

Cheshire, A.C., Westphalen, G., Wenden, A., Scriven, L.J. and Rowland, B.C. (1996) Photosynthesis and respiration of phaeophycean-dominated macroalgal communities in summer and winter. *Aquatic Botany* **55**(3): 159-170.

Cheshire, A.C., Havenhand, J., Hall, S.J., Matsumoto, G. and Butler, A.J. (1997a) *Assessing the status of temperate reefs in Gulf St Vincent I: Background and methodology for assessments.* Report for Environment Protection Authority, South Australia.Botany Department, University of Adelaide, South Australia.

Cheshire, A., Hall, S., Havenhand, J. and Miller, D. (1997b) *Assessing the status of temperate reefs in Gulf St Vincent II: survey results.* Report for Environmental Protection Authority, South Australia. Botany Department, University of Adelaide, South Australia.

Cheshire, A., Westphalen, G., Boxall, V., Marsh, R., Gilliland, J., Collings, G., Seddon, S. and Loo, M. (2002) *Caulerpa taxifolia* in West Lakes and the Port River, South Australia: distribution, eradication options and consequences. (South Australian Research and Development Institute, Aquatic Sciences and PIRSA Fisheries, Marine Habitat Program, Adelaide, South Australia. 53p.

City of Victor Harbor (2008) Council Profile. http://www.victor.sa.gov.au/site/page.cfm?u=150

Clarke, K.R. and Gorley, R.N. (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, UK.

Collings, G.J. (1998) *Spatio-temporal variation of macroalgae communities of southern Fleurieu Peninsula, South Australia.*PhD thesis, department of Botany, University of Adelaide, South Australia.

Cohen, B.F., McArthur, M.A. and Parry, G.D. (2001) *Exotic Marine Pests in the Port of Melbourne, Victoria.*Marine and Freshwater Resources Institute Report No. 25. February 2001.

Connell, S.D. and Irving, A.D. (2008) Integrating ecology with biogeography using landscape characteristics: a case study of subtidal habitat across southern Australia. *Journal ofBiogeography* **35**(9): 1608 – 1621.

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

Cowan, R. (2006) *Australian Marine Algal Name Index*. Database by R. Cowan, Murdoch University, Western Australia, for the Australian Biological Resources Study, Canberra.

CRIMP / NIMPIS (2002) *Codium fragile* ssp.*tomentosoides* species summary.In: Hewitt, C.L., Martin, R.B., Sliwa, C., McEnnulty, F.R., Murphy, N.E., Jones, T. and Cooper, S. (Eds) *Centre for Research on Introduced Marine Pests: National Introduced Marine Pest Information System*. http://crimp.marine.csiro.au/nimpis.

CRIMP / NIMPIS (2002) *Ulva fasciata* species summary.In: Hewitt, C.L., Martin, R.B., Sliwa, C., McEnnulty, F.R., Murphy, N.E., Jones, T. and Cooper, S. (Eds) *Centre for Research on Introduced Marine Pests: National Introduced Marine Pest Information System*. http://crimp.marine.csiro.au/nimpis.

CSIRO (2006) *Algae - marine incursions*.(Spreadsheet from CSIRO Marine and Atmospheric Research, Hobart).

CSIRO (2009) Turning the ‗green tide' in the Yellow Sea. CSIRO media release. Tuesday, 18th August 2009. http://www.intecol10.org/media/CSIRO_Green%20Tide_JKeesing.doc.

D'Amours, O. and Scheibling, R.E. (2007) Effect of wave exposure on morphology, attachment strength and survival of the invasive green alga *Codium fragile* ssp. *tomentosoides*. *Journal of Experimental Marine Biology and Ecology* **351**: 129-142.

De Clerk, O., Gavio, B., Fredericq, S., Ba´rbara, I. and Coppejans, E. (2005) Systematics of *Grateloupiafilicina* (Halymeniaceae, Rhodophyta), based on rbcL sequence analyses and morphological evidence, including the reinstatement of *G. minima* and the description of *G. capensis* sp. *Journal of Phycology* **41**: 391-410.

Department for Environment and Heritage (DEH)(2008) *Marine Habitats in the Adelaide and Mount Lofty Ranges NRM Region.* Final Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board for the program: Facilitate Coast, Marine and Estuarine Planning and Management by Establishing Regional Baselines. Prepared by the Coast and Marine Conservation Branch, Departmentfor Environment and Heritage, South Australia.

Department for Environment and Heritage (DEH) (2009) *Facilitate Coast, Marine and Estuarine Planning and Management by Establishing Regional Baselines*. DRAFT Final Report to the

Adelaide and Mount Lofty Ranges Natural Resources Management Board. Prepared by the Department for Environment and Heritage, Coast and Marine Conservation Branch.

Department of Environment and Conservation (DEC), and Western Australian Herbarium (2010) *FloraBase: the Western Australian Flora.* http://florabase.calm.wa.gov.au

Deveney, M., Rowling, K., Wiltshire, K., Manning, C., Fernandes, M., Collings, G. and Tanner, J. (2008) *Caulerpa taxifolia* (M. Vahl) C. Agardh: Environmental risk assessment. A report prepared for PIRSA Marine Biosecurity. SARDI Publication No. F2008/000854-1. SARDI Research Report Series No. 307.

Dutton, A. and Benkendorff, K., (2008) *Biodiversity Assessment and Monitoring of the Port Stanvac Intertidal Reef.* A Report to the Adelaide and Mt Lofty Natural Resource Management Board, School of Biological Sciences, Flinders University, June 2008.

Edyvane, K. (1999) *Conserving Marine Biodiversity in South Australia.Part 2 – identification of areas of high conservation value in South Australia*. SARDI Report Number 39, SARDI Aquatic Sciences, South Australia.

Edyvane, K. (2008) Macroalgal biogeography and assemblages of Gulf St Vincent. Chaper in: Shepherd, S.A., Bryars, S., Kirkegaard, I.R., Harbison, P. and Jennings, J. (2008) *The Natural History of Gulf St Vincent.* Royal Society of South Australia.

Elsdon, T. S., de Bruin, M.B.N.A., Diepen, N.J. and Gillanders, B.M. (2009) Extensive drought negates human influence on nutrients and water quality in estuaries. *Science of the Total Environment* **407**(8): 3033-3043.

Emmett, J. (1997) Divers report damage at Wirrina. Reef Watcher, Volume 1, Issue 1.

Environment Protection Council of South Australia (1992). *The State of the Environment Report for South Australia.* Department of Environment and Natural Resources, Adelaide.

Fairhead, V.A. and Cheshire, A.C. (2004a) Rates of primary productivity and growth in *Ecklonia*radiata measured at different depths, over an annual cycle, at West Island, South Australia. *Marine Biology* **145**(1): 41-50.

Fairhead, V.A. and Cheshire, A.C. (2004b) Seasonal and depth related variation in the photosynthesis–irradiance response of *Ecklonia*radiata (Phaeophyta,Laminariales) at West Island, South Australia. *Marine Biology* **145**(2): 415-426.

Falkenberg, P. (1901) Die Rhodomelaceen des Golfes von Neapel und der angrenzenden Meeres-Abschnitte.*Fauna und Flora des Golfes von Neapel, Monographie* **26**. Berlin. 754p.

Fernandes, M., Theil, M. and Bryars, S. (2008) *Sedimentation surveys of Adelaide's coastal reefs. Part 1: winter and summer.* Report for the Adelaide and Mt Lofty Rages NRM Board. SARDI Aquatic Sciences Publication No. F2008/000103-1. South Australian Research and Development Institute (Aquatic Sciences), South Australia.

Fox, D.R., Batley, G.E., Blackburn, D., Bone, Y., Bryars, S., Cheshire, A., Collings, G., Ellis, D., Fairweather, P., Fallowfield, H., Harris, G., Henderson, B., Kämpf, J., Nayar, S., Pattiaratchi, C., Petrusevics, P., Townsend, M., Westphalen, G., and Wilkinson, J. (2007) *The Adelaide Coastal Waters Study. Final Report, Volume 1: Summary of Study Findings.* Report for South Australian Environment Protection Authority. CSIRO Environmental Project Office.

Fuhrer, B., Christianson, I.G., Clayton, M.N., and Allender, B.M. (1988) *Seaweeds of Australia.* Reed Books, Sydney, Australia.

Gabrielson, P.W., Widdowson, T.B. and Lindstrom, S.C. (2004) Keys to the seaweeds and seagrasses of Oregon and California. *Phycological Contribution* **6**: 1-181.

Gärdenfors, U., Hilton-Taylor, C., Mace, G.M. and Rodríguez, J.P. (2001) The application of IUCN Red List Criteria at regional levels. *Conservation Biology* **15**(5): 1206-1212.

Gaylard, S. (2009) *A risk assessment of threats to water quality in Gulf St Vincent*. Environmental Protection Authority, South Australia.

Gordon, D.G., Birch, P.B. and McComb, A.J. (1980) The effect of light, temperature and salinity on photosynthetic rates of an estuarine *Cladophora*. *Botanica Marina* **23**: 749-755.

Gordon, D.G., Birch, P.B. and McComb, A.J. (1981) Effects of inorganic nitrogen and phosphate on the growth of an estuarine *Cladophora* in culture. *Botanica Marina* **24**: 93-106.

Gorman, D. (2009) Declining water quality as a driver for changes in subtidal communities. Ph.D thesis, School of Earth and Environmental Sciences, University of Adelaide, South Australia.

Gurgel, C.F.D. (2010) The Status of the genus *Sargassum* in the Great Australian Bight (AW NRM).DEH Report.17 pp.

Gurgel, C.F.D., Fredericq, S. and Norris, J.N. (2004) Phylogeography of *Gracilaria tikvahiae* (Gracilariaceae, Rhodophyta): a study of genetic discontinuity in a continuously distributed species. *Journal of Phycology* **40**: 748-758.

Guiry, M.D. and Guiry, G.M. (2010) *AlgaeBase*. World-wide electronic publication.National University of Ireland, Galway.http://www.algaebase.org.

Harney, J.N. and Fletcher, C.H. (2003) A budget of carbonate framework and sediment production, Kailua Bay, Oahu, Hawaii. *J. Sedim. Res.* **73**: 856-868.

Hart, D. (1996) Near-shore seagrass change between 1949 and 1995 – mapped using digital aerial ortho-photography – Northern Metropolitan Adelaide area: Largs Bay – Glenelg. Image Data Services, Resource Information Group, DENR, Netley SA.

Hart, D. (1997) Near-shore seagrass change between 1949 and 1996 – mapped using digital aerial ortho-photography – Metropolitan Adelaide area: Largs Bay – Aldinga, South Australia. Image Data Services, Resource Information Group, DENR, Netley SA.

Harvey, N. (1993) Sensitivity of South Australian Environments to Marina Construction. In: Allison, R., and Thomas, D. (Eds) *Landscape Sensitivity*. John Wiley and Sons Ltd.

Hayes, K., Sliwa, C., Migus, S., McEnnulty, F. and Dunstan, P. (2005) *National priority pests: part II. Ranking of Australian marine pests.* An independent report undertaken for the Department of the Environment and Heritage by CSIRO Marine Research, Hobart.

Hewitt, C.L., Campbell, M.L., Thresher, R.E. and Martin, R.B. (1999)*Marine Biological Invasions of Port Phillip Bay, Victoria.* Centre for Research on Introduced Marine Pests.Technical Report No. 20. CSIRO Marine Research, Hobart, 344pp.

Hewitt, C.L., Campbell, M.L., Thresher, R.E., Martin, R.B. and 15 co-authors (2004) Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Marine Biology* **144** (1): 183-202.

Hiscock, K. and Pizzolla, P. (2007) *Ceramium virgatum*. A red seaweed. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine

Biological Association of the United Kingdom.
http://www.marlin.ac.uk/speciesinformation.php?speciesID=2922

Hodgkin, E.P., Birch, P.B., Black, R.E. and Humphries, R.B. (1980) *The Peel-Harvey Estuarine System Study 1976-1980.*Western Australian Department of Conservation and Environment, Report No. 9, 103p.

Huisman, J.M. and Borowitzka, M.A. (2003) Marine benthic flora of the Dampier Archipelago, Western Australia. In: Wells, F.E., Walker, D.I. and Jones, D.S. (Eds) *The Marine Flora and Fauna of Dampier, Western Australia*. Western Australian Museum, Perth, WA.

Huisman, J.M. and Walker, D.I. (1990) A catalogue of the marine plants of Rottnest Island, Western Australia, with notes on their distribution and biogeography. *Kingia* **1**: 349-459.

Irving, A. D., (2009) *Reproduction, recruitment, and growth of the seagrass Amphibolis antarctica near the Bungala and Yankalilla rivers, South Australia*. Final report prepared for the Coastal Management Branch of the Department for Environment and Heritage SA and the Adelaide and Mount Lofty Ranges Natural Resources management Board. South Autralian Research and Development Institute (Aquatic Sciences), Adelaide. 1pp. SARDI Publication Number F2009/000468-1

IUCN (2001) *2001 IUCN Red List Categories and Criteria - Version 3.*
http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria

IUCN Shark Specialist Group (2007) *Summary of IUCN Red List Categories and Criteria* .http://www.iucnssg.org/tl_files/Assets/pdf/RL2001Cats&Crit_Summary_1page.pdf

Ivanovici, A. (1984, 1993) *Inventory of Declared Marine and Estuarine Protected Areas in Australian Waters.* Special Publication Number 12. Volumes 1 and 2.Australian National Parks and Wildlife Service. Commonwealth Publishers, Canberra, Australia.

Jaccard, P. (1901) Etude comparative de la distribution florale dans une portion des Alpes et des Jura. *Bull. Soc. Vaudoise Sci. Nat*. **37**: 547-579.

Johnson, J. (1988a) A brief history of South Australia‘s aquatic reserves. *SAFISH* **13**: 4-7.

Johnson, J. (1988b) Marine reserves: recent research and a future approach. *SAFISH* **13** (2): 8-10.

Jones G.K. (1984) The importance of Barker Inlet as an aquatic reserve, with special reference to fish species.*SAFIC* **8**(6): 8-13.

JNCC (Joint Nature Conservation Committee) (2010) *Antithamnionella spirographidis*.
http://www.jncc.gov.uk/page-1672

Kamiya, M., Zuccarello, G.C. and West, J.A. (2004) Phylogeography of *Caloglossa leprieurii* and related species (Delesseriaceae, Rhodophyta) based on the rbcL gene sequences. *The Japanese Journal of Phycology* **52** (Supplement): 147-151.

Karsten, U. and West, J.A. (2000) Living in the intertidal zone — seasonal effects onheterosides and sun-screen compounds in the red alga *Bangia atropurpurea* (Bangiales). *Journal of Experimental Marine Biology and Ecology* **254**: 221–234

Kershwell, A.P. (2006) Global Biodiversity Patterns of Benthic Marine Algae. *Ecology* **87**: 2479-2488

King, R.J., Hope Black, J., and Ducker, S.C. (1971) Intertidal ecology of Port Phillip Bay with systematic lists of plants and animals.*Mem. Nat. Mus. Vic.* **32**: 93–128.

Kitayama, T., Miller, K.A. and Silva, P.C. (2005) First record of *Elachista nigra* (Chordariales, Phaeophyceae) from California, North America. *Bulletin of the National Science Museum, Tokyo, Ser. B* **31**: 57-61.

Klein, J. (2007) Impact of *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) on macrophyte assemblages of the north-western Mediterranean Sea. Ph.D. Thesis. University of Aix-Marseilles II, France.

Klein, J. and Verlaque, M. (2008) The *Caulerpa racemosa* invasion: A critical review. *Marine Pollution Bulletin* **56**: 205–225.

Kristiansen, A. and Pedersen, P.M. (2003) *Giraudia sphacelarioides* (Phaeophyceae) at the Canary Islands and in Danish waters: a study in ecotypic differentiation and its biogeographical implications. *Nordic Journal of Botany* **23**(6): 735-742.

Kuffner, I.B., Andersson, A.J., Jokiel, P.L., Rodgers, K.S. and Mackenzie, F.T. (2008) Decreased abundance of crustose coralline algae due to ocean acidification. *Nat. Geosci*. **1**: 114–117.

Kusakina, J., Synder, M., Kristie, D.N. and Dadswell, M.J. (2006) Morphological and molecular evidence for multiple invasions of *Codium fragile* in Atlantic Canada. *Botanica Marina* **49**: 1-9.

Lam, D.W. and Zechman, F.W. (2006). Phylogenetic analyses of the Bryopsidales (Ulvophyceae, Chlorophyta) based on rubisco large subunit gene sequences. *Journal of Phycology* **42**: 669-678.

Lavery, P.S.and McComb, A. J. (1991) Macroalgal-sediment nutrient interactions and their importance to macroalgal nutrition in a eutrophic estuary. *Estuarine, Coastal and Shelf Science* **32**(3): 281-295.

Lee, Y. (2008) *Marine algae of Jeju*.Academy Publication, Seoul. 177p.

Leclercq, N., Gattuosa, J.P. and Jaubert, J. (2000) CO_2 partial pressure controls the calcification rate of a coral community. *Glob. Change Biol*. **6**: 329–334.

Le Gall, L. and Saunders, G.W. (2010) DNA barcoding is a powerful tool to uncover algal diversity: a case study of the Phyllophoraceae (Gigartinales, Rhodophyta) in the Canadian flora. *Journal of Phycology* **46**(2): 374-389.

Lewis, J.A. (1999) A review of the occurrence of exotic macroalgae in Southern Australia, withemphasis on Port Phillip Bay, Victoria, In: Hewitt, C.L., Campbell, M.L.,Thresher, R.E., Martin, R.B. (Eds) Marine biological invasions of Port Phillip Bay,Victoria. Centre for Research on Introduced Marine Pests. CRIMP Technical Report 20, CSIRO Marine Research, Hobart, Australia pp. 61-87.

Lewis, J.A. and Kraft, G.T. (1979) Occurrence of a European red alga (*Schotteranicaeensis*) in southern Australian waters. Journal of Phycology **15**: 226-230.

Leliaert, F., De Clerck, O., Verbruggen, H., Boedeker, C. and Coppejans, E. (2007) Molecular phylogeny of the Siphonocladales (Chlorophyta: Cladophorophyceae).*Molecular Phylogenetics and Evolution* **44**: 1237-1256.

Lindstrom, S.C., and Gabrielson, P.W. (1989) Taxonomic and distributional notes on northeast Pacific Antithamnionaceae (Ceramiales: Rhodophyta).*Japanese Journal of Phycology* **37**: 221-235.

Littler, M.M., Martz, D.R. and Littler, D.S. (1983) Effects of recurrent sand deposition on rocky intertidal organisms: importance of substrate heterogeneity in a fluctuating environment. *Marine Ecology Progress Series* **11**: 129-139.

Lüning, K. (1990) *Seaweeds: Their Environment, Biogeography, and Ecophysiology*. Wiley, New York.

MarLIN (undated) Green sea fingers: *Codium fragile* spp. *tomentosoides*. http://www.marlin.ac.uk/marine_aliens/species.asp?SpID=28

Martin, S., Rodolfo-Metalpa, R., Ransome, E., Rowley, S., Buia, M.C., Gattuso, J.P., and Hall-Spencer, J. (2008) Effects of naturally acidified seawater on seagrass calcareous epibionts. *Biological Letters* **4**: 689-692.

Miller, D.J., Cheshire, A.C., Hall, S.J. and Havenhand, J. (1998) *Assessing the status of temperate reefs in Gulf St Vincent III: Evaluation and description of methodologies for assessing the status of reefs.* Report for the Environment Protection Authority of South Australia.Botany department, University of Adelaide, South Australia.

Müller, K.M., Sheath, R.G., Vis, M.L., Crease, T.J., Cole, K.M. (1998) Biogeography and systematics of *Bangia* (Bangiales, Rhodophyta) based on the Rubisco spacer, rbcL gene and 18S rRNA gene sequences and morphometric analyses. 1. North America. *Phycologia* **37**: 195–207.

Neto, A.I. (1994) Checklist of the benthic marine macroalgae of the Azores Arquipélago. *Ciências Biológicas e Marinhas* **12A**: 15-34.

NIMPIS (2010) *Caulerpa taxifolia* reproduction and habitat. National Introduced Marine Pest Information System.http://www.marinepests.gov.au/nimpis

Parliament of Victoria (undated) *Report on Ballast Water and Hull Fouling In Victoria.* http://www.parliament.vic.gov.au/enrc/inquiries/old/enrc/ballast/default.htm#TopOfPage
(Includes Appendix D: List of introduced exotic marine organisms in Port Phillip Bay)
http://www.parliament.vic.gov.au/enrc/inquiries/old/enrc/ballast/Ballast-76.htm#P4827_419788

PIRSA (2006) *Caulerpa taxifolia*. Update- March 2006.http://www.pir.sa.gov.au/__data/assets/pdf_file/0010/13114/caulerpa_taxifolia_update_0206.pdf

PIRSA (2009a) *Barker Inlet - St Kilda Aquatic Reserve*. Information page. Primary Industries and Resources, South Australia. http://www.pir.sa.gov.au/fisheries/pdf_equivalents/barker_inlet_-_st_kilda_aquatic_reserve

PIRSA (2009b) *St Kilda - Chapman Creek Aquatic Reserve.* Information page. Primary Industries and Resources, South Australia. http://www.pir.sa.gov.au/fisheries/pdf_equivalents/st.kilda_-_chapman_creek_aquatic_reserve

PIRSA (2009c) *Caulerpa taxifolia.*
http://www.pir.sa.gov.au/fisheries/pdf_equivalents/1345km_inland_fmc_annual_report_2001_2002

Provan, J., Booth, D., Todd, N.P., Beatty, G.E. and Maggs, C.A. (2008) Tracking biological invasions in space and time: elucidating the invasive history of the green alga *Codium fragile* using old DNA. *Diversity and Distributions: A Journal of Conservation Biogeography* **14**: 343-354.

Reef Watch (2004) *Reef Watch Benthic Identification Manual.* Version 4 (October, 2004).Reef Watch Community Monitoring Program, Conservation Council of South Australia Inc., Adelaide, South Australia.

Romesburg, C. (1984) *Cluster Analysis for Researchers.* Wadsworth Inc. USA.

Rowling, K (2008) Re-assessment of the presence or absence of *Caulerpa taxifolia* and *Caulerpa racemosa* var. *cylindracea* at the dredge spoil dump site for the Outer Harbor dredging. Prepared for the KBR and Flinders Ports. SARDI Aquatic Sciences Publication No.F2008/000187-1, SARDI Research Report Series No 279.

Rowling, K (2009) *Caulerpa taxifolia* – 2008 survey of the upper Port River. Prepared for PIRSA Marine Biosecurity. SARDI Aquatic Sciences Publication No.F2009/000049-1, SARDI Research Report Series No 331.

Russell, B.D., Elsdon, T.S., Gillanders, B.M., Connell, S.D. (2005) Nutrients increase epiphyte loads: broad-scale observationsand an experimental assessment. *Marine Biology* **147**: 551–558.

Sanderson, J.C. (1987) *Subtidal Macroalgal Assemblages in Temperate Australian Coastal Waters.* Consultancy report for Environment Australia.Australia: State of the EnvironmentTechnical Paper Series (Estuaries and the Sea). Environment Australia, Department of the Environment, Canberra.

Schramm, W. And Booth, W. (1981) Mass bloom of the alga *Cladophora prolifera* in Bermuda: productivity and phosphorus accumulation. *Botanica Marina* **24** (8): 419–426.

Secilla, A., Santolaria, A., Díez, I., Berecibar, E., Díaz, P., Bárbara, I. and Gorostiaga, J.M. (2008). *Scageliopsis patens* (Ceramiales, Rhodophyta), a new introduced species along the European coast. *Cryptogamie, Algologie* **29**: 191-199.

Sfriso, A. (2010) Coexistence of *Ulva rigida* and *Ulva laetevirens* (Ulvales, Chlorophyta) in Venice Lagoon and other Italian transitional and marineenvironments. *Botanica Marina* **53**: 9-18.

Sheath, R.G. (1984) The biology of the freshwater red algae. *Prog. Phycol. Res*. **3**: 89-157.

Shepherd, S.A. (1970) Preliminary report upon degradation of seagrass beds at North Glenelg. Unpublished report. South Australian Department of Fisheries. 29p.

Shepherd, S.A. (1991) Marine reserves can be used to conserve abalone stocks. *SAFISH* **15**: 7-9.

Shepherd, S.A. and Sprigg, R. (1976) Substrate, sediments and subtidal ecology of Gulf St Vincent and Investigator Strait. In: Twidale, C., Tyler, M., and Webb, B. (Eds) (1976) *Natural History of the Adelaide Region.* Royal Society of South Australia, Adelaide, South Australia.

Shepherd, S.A. and Watson, J. (1970) The sublittoral ecology of West Island, South Australia. 2. The association between hydroids and algal substrate. *Transactions of the Royal Society of South Australia* **94**: 140-146.

Shepherd, S.A. and Womersley, H.B.S. (1970).The sublittoral ecology of West Island, South Australia. I. Environmental features and algal ecology. *Transactions of the Royal Society of South Australia* **94**: 105-138.

Silva, P.H., McBride, S., de Nys, R. and Paul, N.A. (2008) Integrating filamentous 'green tide' algae into tropical pond-based aquaculture. *Aquaculture* **284** (1-4): 74-80.

Sinclair Knight Merz (2010a) Hindmarsh River – Estuary Action Plan. Report for Adelaide and Mount Lofty Ranges Natural Resources Management Board, South Australia.

Sinclair Knight Merz (2010b) Inman River – Estuary Action Plan. Report for Adelaide and Mount Lofty Ranges Natural Resources Management Board, South Australia.

Skinnner, S and Womersley, H.B.S. (1983) New records (possibly introductions) of *Striaria*, *Stictyosiphon* and *Anthrocladia* (Phaeophyta) for southern Australia. *Transactions of the Royal Society of South Australia* **107**(1): 59-68.

Sliwa, C., Migus, S., Hayes, K., and McEnnulty, F. (2006) Marine bio-invasions in Australia. CSIRO Marine Research report. CSIRO, Hobart.

Smith, J.E., Runcie, J.W. and Smith, C.M. (2005) Characterization of a large-scale ephemeral bloom of the green alga *Cladophora sericea* on the coral reefs of West Maui, Hawai'i. *Marine Ecology Progress Series* **302**: 77-91.

State Herbarium of South Australia (2007, 2010) *eFlora SA: The Electronic Flora of South Australia*. Plant Distribution Mapper.

Stegenga, H., Bolton J.J. and Anderson, R.J. (1997) Seaweeds of the South African West Coast. *Contributions from the Bolus Herbarium* **18**: 1 - 655.

Summerson, R., Darbyshire, R. andLawrence, E. (2007) *Invasive Marine Species Range Mapping.*Bureau of Rural Sciences, Canberra.

Tanner, J. (2003) The influence of prawn trawling on sessile benthic assemblages in Gulf St. Vincent, South Australia. *Canadian Journal of Fisheries and Aquatic Sciences* **60**(5): 517-526.

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

Tasmanian Planning Commission (2009) *State of the Environment Tasmania 2009.* Table: Status of cryptogenic marine pests and where they have been identified. Government of Tasmania.

Taylor, R., Fletcher, R.L., and Raven, J.A. (2001) Preliminary studies on the growth of selected 'green tide' algae in laboratory culture: effects of irradiance, temperature, salinity and nutrients on growth rate. *Botanica Marina* **44** (4): 327–336.

Theil, M.J and Tanner J.E. (2009) Marine characterisation study for a possible seawater desalination plant to supply Adelaide. Final report prepared for South Australian Water Corporation. SARDI Publication Number F2008/001128-1. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 66p.

Tittley, I. and Neto, A.I. (1994) "Expedition Azores 1989": Benthic marine algae (seaweeds) recorded from Faial and Pico. Vol. 12A pp. 1-13.: Separata.

Tourism Victor Harbor (2001) *Stay and Play: Victor Harbor*. Visitors' Guide.

Tourism Victor Harbor (2010) *Tourism in Victor Harbor.* http://www.victor.sa.gov.au/site/page.cfm?u=656

Trowbridge, C. (1995) Establishment of the green alga *Codium fragile* ssp. *tomentosoides* on New Zealand rocky shores: current distribution and invertebrate grazers. *Journal of Ecology* **83**: 949-965.

Trowbridge, C. (1999) An assessment of the potential spread and options for control of the introduced green macroalga *Codium fragile* ssp. *tomentosoides* on Australian shores. CRIMP Consultancy Report. CSIRO, Tasmania.

Tulloss, R.E. (1997) Assessment of similarity indices forundesirable properties anda new tripartite similarity indexbased on cost functions. In: Palm, M. E. and I. H. Chapela, (Eds) *Mycology in Sustainable Development: Expanding Concepts, Vanishing Borders.* Parkway Publishers, Boone, North Carolina.

Turner, D.J. (1995) A comparative study of destructive and non-destructive survey techniques for use in macroalgal systems. Honours thesis, Department of Botany, University of Adelaide, Adelaide, South Australia.

Turner, D.J. (2005) Effects of sedimentation on the structure of a phaeophycean dominated macroalgal community. PhD Thesis, Department of Environmental Biology, University of Adelaide, Adelaide, Australia.

Turner, D.J., and Cheshire, A.C. (2002) Effect of dispersed sediment plumes from beach sand replenishment dredging on recruitment of phaeophycean algae to rocky reefs in Gulf St. Vincent, South Australia. Final report: incorporating surveys from 1998-2001. Department of Botany, University of Adelaide, South Australia.

Turner, D.J. and Kildea, T.N. (2006) Examining the health of subtidal reef environments in South Australia, Part 2: Status of selected South Australian reefs based on the results of surveys undertaken in 2005. Project RD03/0252-6. South Australian Research and Development Institute (SARDI) Aquatic Sciences, Adelaide, South Australia.

Turner, D.J., Kildea, T.N. and Westphalen, G. (2007) Examining the health of subtidal reef environments in South Australia, Part 2: Status of selected South Australian reefs based on the results of the 2005 surveys. South Australian Research and Development Institute (Aquatic Sciences), South Australia. SARDI Publication Number RD03/0252-6.

Underwood, S. (2001) Introduced Non-Vascular Plants/ Lower Plants in Tasmania - 2001. In: government of Tasmania (2003) *State of the Environment Report 2003*. http://www.soer.justice.tas.gov.au/2003/file/8/Non-vascular.pdf

Uwai, S., Kogame, K. and Masuda, M. (2002) Conspecificity of *Elachista nigra* and *Elachista orbicularis* (Elachistaceae, Phaeophyceae). *Phycological Research* **50**(3): 217-226.

van den Hoek, C. and Chihara, M. (2000) A taxonomic revision of the species of *Cladophora* (Chlorophyta) along the coasts of Japan and the Russian Far-East. *Natural Science Museum [Tokyo] Monographs* **19**: 1-242.

Vié, J.-C., Hilton-Taylor, C., Pollock, C., Ragle, J., Smart, J., Stuart, S.N. and Tong, R. (2008) The IUCN Red List: akey conservation tool. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (Eds) *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland.

Waters, J.M., Wernberg, T., Connell, S.D., Thomsen, M.S., Zuccarello, G.C., Kraft, G.T., Sanderson, J.C., West, J.A. and Gurgel, C.F.D. (2010) Australia's marine biogeography revisited: Back to the future? *Austral Ecology* (in press).

West, J.A., Zuccarello, G.C. and Kamiya, M. (2001) Reproductive patterns of *Caloglossa* species (Delesseriaceae, Rhodophyta) from Australia and New Zealand: multiple origins of asexuality in *C. leprieurii*. *Phycological Research* **49**: 183–200.

Westphalen, G. (2008) *Analysis of the Reef Watch subtidal data*. A report to the Conservation Council of South Australia.

Westphalen, G. (2009) *Surveys across six reefs in the Adelaide and Mt Lofty Ranges Natural Resource Management Region 2008 – 2009.* Reef Watch South Australia. Report to the Conservation Council of South Australia Inc.

Westphalen, G., Collings, G., Wear, R., Fernandes, M., Bryars, S. and Cheshire, A. (2004) *A review of seagrass loss on the Adelaide metropolitan coastline.* ACWS Technical Report No. 2 prepared for the Adelaide Coastal Waters Study Steering Committee. South Australian Research and Development Institute (Aquatic Sciences) Publication No. RD04/0073, Adelaide, South Australia.

Whittaker, R.J., Araújo, M.B., Jepson, P., Ladle, R.J. Watson, J.E.M. and Willis, K.J. (2005) Conservation biogeography: assessment and prospect. *Diversity and Distributions* **11**: 3–23.

Wiltshire, K. (2010) *Caulerpa taxifolia*– 2010 survey of current distribution and high risk areas, and summary of distribution patterns 2003-2010. SARDI Aquatic Sciences Publication No. F2010/000612-1. SARDI Aquatic Sciences, South Australia.

Wiltshire, K.H. and Rowling, K (2009) *Caulerpa taxifolia* – 2009 surveys of current distribution and high risk areas. SARDI Aquatic Sciences Publication No. F2009/000347-1. SARDI Aquatic Sciences, South Australia.

Wiltshire, K., Rowling, K. and Deveney, M. (2010) *Introduced marine species in South Australia: a review of records and distribution mapping.*SARDI Aquatic Sciences Publication No. F2010/000305-1. SARDI Research Report Series No. 468.

Womersley, H.B.S. (1966) Port Phillip Bay survey 1957–1963. Algae. *Mem. Nat. Mus. Vic*. **27**: 133–156.

Womersley, H.B.S. (1984) The Marine Benthic Flora of Southern Australia. Part I. (South Australian Government Printing Division, Adelaide, South Australia). 329 pp.

Womersley, H.B.S. (1987) The Marine Benthic Flora of Southern Australia. Part II. South Australian Government Printing Division, Adelaide, South Australia. 484 pp.

Womersley, H.B.S. (1990) Biogeography of Australasian marine macroalgae. In: Clayton, M. and King, R. (Eds) *Biology of Marine Plants*. Longman Cheshire, Melbourne, Australia.

Womersley, H.B.S. (1994) The Marine Benthic Flora of Southern Australia. Part IIIA. Australian Biological Resources Study, Canberra. 508 pp.

Womersley, H.B.S. (1996) The Marine Benthic Flora of Southern Australia. Part IIIB. Australian Biological Resources Study, Canberra, Australia. 392 pp.

Womersley, H.B.S. (1998) The Marine Benthic Flora of Southern Australia. Part IIIC. State Herbarium of South Australia. 535 pp.

Womersley, H.B.S. (2003) The Marine Benthic Flora of Southern Australia - Part IIID Ceramiales - Delesseriaceae, Sarcomeniaceae, Rhodomelaceae. Australian Biological Resources Study Canberra and State Herbarium of South Australia.

Womersley, H.B.S. (2004, 2005) Comments on marine benthic algal species known from single or very few records or from restricted habitats in southern Australia. State Herbarium, Plant Biodiversity Centre, Adelaide. Unpublished report. June, 2004 and October, 2005.

Zuccarello, G.C., West, J.A. and King, R.J. (1999) Evolutionary divergence in the *Bostrychiamoritziana*/*B. radicans* complex (Rhodomelaceae, Rhodophyta): molecular and hybridisation data. *Phycologia* **38**: 234-244.

Zuccarello, G.C., West, J.A. and Kikuchi, N. (2008) Phylogenetic relationships within the Stylonematales (Stylonematophyceae, Rhodophyta): biogeographic patterns oo not apply to *Stylonema alsidii*. *Journal of Phycolgy* **44**: 384–393.

4. Appendices

Appendix 1: List of all benthic macroalgal species known for the AMLR NRM region (Source: ADHerb 2010 and AVH 2010 databases)

Chlorophyta		
Acetabularia calyculus	*Chaetomorpha ligustica*	*Codium mamillosum*
Acetabularia peniculus	*Chaetomorpha coliformis*	*Codium muelleri*
Acrochaete viridis	*Chaetomorpha indica*	*Codium perriniae*
Apjohnia laetevirens	*Chaetomorpha ligustica*	*Codium pomoides*
Avrainvillea clavatiramea	*Chaetomorpha linum*	*Codium spinescens*
Blidingia marginata	*Cladophora bainesii*	*Codium spongiosum*
Blidingia minima	*Cladophora coelothrix*	*Derbesia marina*
Bryopsis gemellipara	*Cladophora dalmatica*	*Derbesia tenuissima*
Bryopsis plumosa	*Cladophora feredayi*	*Dictyosphaeria sericea*
Callipsygma wilsonii	*Cladophora fracta*	*Gayralia oxysperma*
Caulerpa alternans	*Cladophora glomerata*	*Microdictyon umbilicatum*
Caulerpa annulata	*Cladophora herpestica*	*Prasiola stipitata*
Caulerpa brownii	*Cladophora hutchinsioides*	*Rhizoclonium curvatum*
Caulerpa cactoides	*Cladophora laetevirens*	*Rhizoclonium riparium*
Caulerpa cliftonii	*Cladophora lehmanniana*	*Rosenvingiella polyrhiza*
Caulerpa flexilis	*Cladophora montagneana*	*Struvea plumosa*
Caulerpa flexilis var. *muelleri*	*Cladophora prolifera*	*Ulva clathrata*
Caulerpa longifolia	*Cladophora rhizoclonioidea*	*Ulva compressa*
Caulerpa longifolia f.*crispata*	*Cladophora sericea*	*Ulva fasciata*
Caulerpa obscura	*Cladophora* sp. aff. *glomerata*	*Ulva flexuosa*
Caulerpa papillose	*Cladophora vagabunda*	*Ulva intestinalis*
Caulerpa racemosa var. *cylindracea*	*Cladophora valonioides*	*Ulva lactuca*
Caulerpa remotifolia	*Codium australicum*	*Ulva linza*
Caulerpa scalpelliformis	*Codium capitulatum*	*Ulva prolifera*
Caulerpa sedoides	*Codium duthieae*	*Ulva ralfsii*
Caulerpa sedoides f.*geminata*	*Codium fragile* ssp. *tasmanicum*	*Ulva rigida*
Caulerpa simpliciuscula	*Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*)	*Ulva taeniata*
Caulerpa taxifolia	*Codium galeatum*	*Ulvella lens*
Caulerpa trifaria	*Codium harveyi*	*Valonia sp.*
Chaetomorpha aerea	*Codium lucasii*	*Wittrockiella salina*

Appendix 1 (cont.)

Phaeophyceae		
Acinetospora crinita	*Dictyopteris gracilis*	*Hincksia sordida*
Acrocarpia paniculata	*Dictyopteris muelleri*	*Homoeostrichus sinclairii*
Acrotrichium amphibolis	*Dictyopteris nigricans*	*Hormosira banksii*
Arthrocladia villosa	*Dictyota alternifida*	*Hydroclathrus clathratus*
Asperococcus bullosus	*Dictyota bifurca*	*Leathesia marina*
Austronereia australis	*Dictyota dichotoma*	*Lobophora variegata*
Bachelotia antillarum	*Dictyota diemensis*	*Lobospira bicuspidata*
Bellotia eriophorum	*Dictyota fastigiata*	*Macrocystis pyrifera*
Carpoglossum confluens	*Dictyota fenestrata*	*Myriactula arabica*
Carpomitra costata	*Dictyota furcellata*	*Myriactula filiformis*
Caulocystis cephalornithos	*Dictyota gunniana*	*Myriactula haydenii*
Caulocystis uvifera	*Dictyota naevosa*	*Myriodesma integrifolium*
Cladosiphon filum	*Dictyota polyclada*	*Myriodesma leptophyllum*
Cladosiphon vermicularis	*Dictyota robusta*	*Myriodesma quercifolium*
Cladostephus spongiosus	*Discosporangium mesarthrocarpum*	*Myriodesma tuberosum*
Colpomenia peregrina	*Distromium flabellatum*	*Myrionema latipilosum*
Colpomenia sinuosa	*Distromium multifidum*	*Myrionema ramulans*
Corynophlaea cristata	*Ecklonia radiata*	*Myrionema strangulans*
Corynophlaea cystophorae	*Ectocarpus fasciculatus*	*Myriotrichia clavaeformis*
Cutleria multifida	*Ectocarpus siliculosus*	*Notheia anomala*
Cystophora botryocystis	*Elachista nigra*	*Pachydictyon paniculatum* (or*Dictyota paniculata*)
Cystophora brownii	*Encyothalia cliftonii*	*Perithalia caudata*
Cystophora congesta	*Feldmannia globifera*	*Petalonia fascia*
Cystophora cuspidata	*Feldmannia irregularis*	*Phloiocaulon spectabile*
Cystophora expansa	*Flabellonema codii*	*Phyllospora comosa*
Cystophora intermedia	*Giraudia robusta*	*Pilinia novae-zelandiae*
Cystophora monilifera	*Giraudia sphacelarioides*	*Polycerea nigrescens*
Cystophora moniliformis	*Glossophora nigricans* (or *Dictyota nigricans*)	*Pseudolithoderma australe*
Cystophora pectinata	*Halopteris funicularis*	*Punctaria latifolia*
Cystophora platylobium	*Halopteris paniculata*	*Pylaiella littoralis*
Cystophora polycystidea	*Halopteris platycena*	*Ralfsia verrucosa*
Cystophora racemosa	*Halopteris pseudospicata*	*Rugulopteryx okamurae*
Cystophora retorta	*Halopteris ramulosa*	*Rugulopteryx radicans*
Cystophora retroflexa	*Halothrix ephemeralis*	*Sargassum decipiens*
Cystophora siliquosa	*Hecatonema terminale*	*Sargassum decurrens*
Cystophora subfarcinata	*Hincksia granulosa*	*Sargassum distichum*
Cystoseira trinodis	*Hincksia mitchelliae*	*Sargassum fallax*
Dictyopteris australis	*Hincksia sandriana*	*Sargassum heteromorphum*

Appendix 1 (cont.)

Phaeophyceae (cont.)
Sargassum lacerifolium
Sargassum linearifolium
Sargassum paradoxum
Sargassum podacanthum
Sargassum sonderi
Sargassum spinuligerum
Sargassum tristichum
Sargassum varians
Sargassum verruculosum
Sargassum vestitum
Scaberia agardhii
Scytosiphon lomentaria
Scytothalia dorycarpa
Seirococcus axillaris
Spatoglossum australasicum
Sphacelaria biradiata
Sphacelaria brachygonia
Sphacelaria bracteata
Sphacelaria carpoglossi
Sphacelaria cirrosa
Sphacelaria implicata
Sphacelaria reinkei
Sphacelaria rigidula
Sphacelaria tribuloides
Splachnidium rugosum
Sporochnus apodus
Sporochnus comosus
Sporochnus radiciformis
Stilophora tenella
Stilopsis harveyana
Strepsithalia leathesiae
Striaria attenuata
Suringariella harveyana
Taonia australasica
Tinocladia australis
Xiphophora chondrophylla
Zonaria angustata
Zonaria crenata
Zonaria spiralis
Zonaria turneriana

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales)	
Acrosorium ciliolatum	*Dasya baldockii*
Acrothamnion preissii	*Dasya ceramioides*
Acrotylus australis	*Dasya clavigera*
Adelophycus corneus	*Dasya comata*
Aglaothamnion tenuissimum	*Dasya crescens*
Alleynea bicornis	*Dasya divergens*
Amansia pinnatifida	*Dasya extensa*
Amansia serrata	*Dasya haffiae*
Amoenothamnion planktonicum	*Dasya hookeri*
Anotrichium crinitum	*Dasya quadrispora*
Anotrichium elongatum	*Dasya villosa*
Anotrichium secundum	*Dasyclonium flaccidum*
Anotrichium subtile	*Dasyclonium incisum*
Anotrichium tenue	*Dasyphila preissii*
Antithamnion delicatulum	*Dasyphloea insignis*
Antithamnion gracilentum	*Dasythamniella dasyura*
Antithamnion hanovioides	*Dasythamniella latissima*
Antithamnion pinnafolium	*Dasythamniella plumigera*
Antithamnionella glandifera	*Dasythamniella wollastoniana*
Antithamnionella multiramosa	*Delisea elegans*
Antithamnionella spirographidis	*Delisea hypneoides*
Antithamnionella ternifolia	*Delisea pulchra*
Antrocentrum nigrescens	*Dichotomaria australis*
Apoglossum spathulatum	*Dichotomaria “marginata”*
Areschougia congesta	*Dicranema cincinnalis*
Areschougia stuartii	*Dicranema revolutum*
Asparagopsis armata	*Dictyomenia angusta*
Asparagopsis taxiformis	*Dictyomenia harveyana*
Audouinella barbadense	*Dictyomenia sonderi*
Audouinella dictyotae	*Dictyomenia tridens*
Audouinella floridula	*Diplocladia patersonis*
Audouinella humilis	*Ditria expleta*
Audouinella liagorae	*Doxodasya bolbochaete*
Audouinella microscopica	*Doxodasya hirta*
Audouinella plumosa	*Doxodasya lanuginosa*
Audouinella polyidis	*Drewiana nitella*
Audouinella repens	*Echinosporangium semipennatum*
Audouinella spongicola	*Echinothamnion hookeri*
Audouinella unifila	*Echinothamnion hystrix*
Austroclonium charoides	*Elisiella arbuscula*
Austrophyllis alcicornis	*Epiglossum proliferum*

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales) (cont.)	
Ballia callitricha	*Epiglossum smithiae*
Bangia atropurpurea	*Erythroclonium angustatum*
Bonnemaisonia australis	*Erythroclonium muelleri*
Bonnemaisonia spinescens	*Erythroclonium sonderi*
Bornetia tenuis	*Erythronaema ceramioides*
Bostrychia intricata	*Erythrostachys strobilifera*
Bostrychia moritziana	*Erythrotrichia carnea*
Bostrychia simpliciuscula	*Euptilocladia spongiosa*
Botryocladia sonderi	*Euptilocladia villosa*
Brongniartella australis	*Euptilota articulata*
Callithamnion circinnatum	*Ganonema farinosum*
Callithamnion confertum	*Gattya pinnella*
Callithamnion obstipum	*Gayliella flaccida*
Callithamnion shepherdii	*Gelidium asperum*
Callithamnion violaceum	*Gelidium australe*
Callophycus harveyanus	*Gelidium crinale*
Callophycus laxus	*Gelidium pusillum*
Callophyllis cervicornis	*Gelinaria ulvoidea*
Callophyllis lambertii	*Gibsmithia womersleyi*
Callophyllis rangiferina	*Gigartina brachiata*
Caloglossa leprieurii	*Gigartina disticha*
Caloglossa ogasawaraensis	*Gigartina pinnata*
Camontagnea hirsuta	*Gigartina sonderi*
Capreolia implexa	*Gigartina wehliae*
Carpopeltis phyllophora	*Gloiocladia fruticulosa*
Carpopeltis spongeaplexus	*Gloiocladia halymenioides*
Carpothamnion gunnianum	*Gloiophloea scinaioides*
Centroceras clavulatum	*Gloiophyllis barkeriae*
Cephalocystis furcellata	*Gloiosaccion brownii*
Ceramium australe	*Gonatogenia subulata*
Ceramium cliftonianum	*Gracilaria chilensis*
Ceramium excellens	*Gracilaria cliftonii*
Ceramium filiculum	*Gracilaria ramulosa*
Ceramium isogonum	*Grateloupia filicina*
Ceramium macilentum	*Griffithsia elegans*
Ceramium monacanthum	*Griffithsia gunniana*
Ceramium puberulum	*Griffithsia monilis*
Ceramium pusillum	*Griffithsia pulvinata*
Ceramium rubrum	*Griffithsia teges*
Ceramium shepherdii	*Guiryella repens*
Chamaethamnion schizandra	*Gulsonia annulata*

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales) (cont.)	
Champia affinis	*Gymnogongrus crenulatus*
Champia viridis	*Halicnide similans*
Champia zostericola	*Haloplegma preissii*
Chauviniella coriifolia	*Halydictyon arachnoideum*
Chiracanthia arborea	*Halymenia floresia* subsp. *harveyana*
Chondria angustissima	*Halymenia muelleri*
Chondria arcuata	*Halymenia plana*
Chondria bulbosa	*Haplodasya urceolata*
Chondria curdieana	*Haraldia australica*
Chondria foliifera	*Haraldiophyllum erosum*
Chondria harveyana	*Helminthocladia australis*
Chondria incrassata	*Helminthocladia densa*
Chondria incurva	*Helminthora australis*
Chondria succulenta	*Hemineura frondosa*
Chondrophycus brandenii	*Herpopteros fallax*
Chondrophycus thuyoides	*Herposiphonia calothrix*
Chondrophycus tumidus	*Herposiphonia filipendula*
Cirrulicarpus nanus	*Herposiphonia rostrata*
Cladurus elatus	*Herposiphonia versicolor*
Cliftonaea pectinata	*Heterocladia australis*
Coelarthrum opuntia	*Heterocladia caudata*
Coeloclonium tasmanicum	*Heterocladia umbellifera*
Coeloclonium umbellula	*Heterodoxia denticulata*
Colacodasya australica	*Heterosiphonia australis*
Colaconema bonnemaisoniae	*Heterosiphonia callithamnium*
Colaconema caespitosum	*Heterosiphonia curdieana*
Colaconema daviesii	*Heterosiphonia gunniana*
Colaconema garbaryi	*Heterosiphonia lawrenciana*
Cottoniella fusiformis	*Heterosiphonia microcladioides*
Craspedocarpus blepharicarpus	*Heterosiphonia muelleri*
Craspedocarpus ramentaceus	*Heterosiphonia wrangelioides*
Craspedocarpus tenuifolius	*Heterothamnion sessile*
Craspedocarpus venosus	*Hildenbrandia rubra*
Crassilingua marginifera	*Hirsutithallia angustata*
Crouania destriana	*Hirsutithallia formosa*
Crouania robbii	*Hirsutithallia laricina*
Crouania shepleyana	*Hirsutithallia mucronata*
Cryptonemia digitata	*Holotrichia comosa*
Cryptonemia kallymenioides	*Husseya rubra*
Cryptonemia undulata	*Hymenena affinis*
Cryptopleura ramosa	*Hymenena curdieana*
Curdiea angustata	*Hymenena endiviaefolia*

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales) (cont.)	
Curdiea obesa	*Hymenena multipartita*
Inkyuleea ballioides	*Hymenocladia chondricola*
Inkyuleea mariana	*Hymenocladia divaricata*
Interthamnion attenuatum	*Hymenocladia usnea*
Involucrana crassa	*Hypnea charoides*
Involucrana meredithiana	*Hypnea filiformis*
Janczewskia tasmanica	*Hypnea ramentacea*
Kallymenia rubra	*Hypnea valentiae*
Kallymenia tasmanica	*Hypneocolax stellaris* subsp. *orientalis*
Kraftia dichotoma	*Hypoglossum armatum*
Lasiothalia hirsuta	*Hypoglossum protendens*
Laurencia aldingensis	*Naccaria naccarioides*
Laurencia arbuscula	*Nemalion helminthoides*
Laurencia brongniartii	*Nitophyllum crispum*
Laurencia clavata	*Nitospinosa pristoidea*
Laurencia elata	*Nizymenia australis*
Laurencia filiformis	*Nizymenia conferta*
Laurencia forsteri	*Nizymenia furcata*
Laurencia heteroclada	*Ochmapexus minimus*
Laurencia majuscula	*Ophidocladus simpliciusculus*
Laurencia shepherdii	*Osmundaria spiralis*
Laurencia tasmanica	*Pachymenia orbicularis*
Lejolisia aegagropila	*Palisada cruciata*
Lenormandia latifolia	*Parviphycus antipai*
Lenormandia marginata	*Peltasta australis*
Lenormandia muelleri	*Perischelia glomulifera*
Lenormandia pardalis	*Perithamnion muelleri*
Lenormandia spectabilis	*Peyssonnelia capensis*
Leptophyllis conferta	*Peyssonnelia dubyi*
Liagora harveyana	*Peyssonnelia inamoena*
Liagora wilsoniana	*Peyssonnelia novae-hollandiae*
Lomathamnion epicodii	*Phacelocarpus alatus*
Lomentaria australis	*Phacelocarpus apodus*
Lomentaria monochlamydea	*Phacelocarpus complanatus*
Lomentaria pyramidalis	*Phacelocarpus peperocarpos*
Lophosiphonia prostrata	*Phacelocarpus sessilis*
Lophothalia hormoclados	*Phitymophora amansioides*
Lophothalia verticillata	*Phycodrys australasica*
Lophothamnion hirtum	*Platyclinia stipitata*
Lophurella periclados	*Platysiphonia delicata*
Macrothamnion pellucidum	*Platysiphonia victoriae*
Macrothamnion secundum	*Plocamium angustum*

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales) (cont.)	
Malaconema roeanum	*Plocamium cartilagineum*
Martensia australis	*Plocamium costatum*
Mazoyerella arachnoidea	*Plocamium dilatatum*
Mazoyerella australis	*Plocamium leptophyllum*
Medeiothamnion halurus	*Plocamium mertensii*
Medeiothamnion protensum	*Plocamium patagiatum*
Medeiothamnion repens	*Plocamium preissianum*
Melanamansia serrata	*Pollexfenia crispata*
Melanema dumosum	*Pollexfenia lobata*
Melanthalia abscissa	*Pollexfenia pedicellata*
Melanthalia fastigiata	*Polyopes constrictus*
Melanthalia obtusata	*Polyopes tenuis*
Micropeuce feredayae	*Polysiphonia amphibolis*
Micropeuce glomerulifera	*Polysiphonia atricapilla*
Muellerena wattsii	*Polysiphonia blandii*
Mychodea aciculare	*Polysiphonia constricta*
Mychodea australis	*Polysiphonia crassiuscula*
Mychodea carnosa	*Polysiphonia decipiens*
Mychodea disticha	*Polysiphonia infestans*
Mychodea gracilaria	*Polysiphonia isogona*
Mychodea hamata	*Polysiphonia mollis*
Mychodea marginifera	*Polysiphonia scopulorum*
Mychodea pusilla	*Polysiphonia sertularioides*
Mychodea ramulosa	*Polysiphonia subtilissima*
Myriogramme gunniana	*Porphyra columbina*
Radiathamnion speleotis	*Porphyra lucasii*
Rhabdonia clavigera	*Porphyra woolhouseae*
Rhabdonia coccinea	*Porphyridium purpureum*
Rhabdonia verticillata	*Porphyropsis minuta*
Rhipidothamnion secundum	*Protokuetzingia australasica*
Rhodopeltis australis	*Pterocladia lucida*
Rhodophyllis membranacea	*Pterocladiella capillacea*
Rhodophyllis multipartita	*Pterosiphonia pennata*
Rhodophyllis volans	*Pterothamnion flexile*
Rhodymenia leptophylla	*Pterothamnion ramulentum*
Rhodymenia obtusa	*Ptilocladia australis*
Rhodymenia sonderi	*Ptilocladia crouanioides*
Rhodymenia verrucosa	*Ptilocladia pulchra*
Rhodymeniocolax austrina	*Ptilocladia vestita*
Sahlingia subintegra	*Ptilonia australasica*
Sarcodia marginata	*Ptilonia subulifera*
Sarcomenia delesserioides	*Ptilota? hannafordii*

Appendix 1 (cont.)

Rhodophyta (excluding Corallinales) (cont.)	
Sarcothalia crassifolia	*Ptilothamnion schmitzii*
Sarcothalia insidiosa	*Taenioma perpusillum*
Sarcotrichia tenera	*Tetrathamnion lineatum*
Scageliopsis patens	*Thamnoclonium dichotomum*
Schottera nicaeensis	*Thamnoclonium lemannianum*
Scinaia aborealis	*Thuretia australasica*
Scinaia acuta	*Thuretia quercifolia*
Scinaia tsinglanensis	*Tikvahiella candida*
Shepleya australis	*Trematocarpus affinis*
Shepleya wattsii	*Trithamnion aculeatum*
Solieria robusta	*Trithamnion eubryanii*
Sonderopelta coriacea	*Trithamnion gracilissimum*
Spongoclonium australicum	*Trithamnion vulgare*
Spongoclonium brownianum	*Tsengia comosa*
Spongoclonium conspicuum	*Tsengia feredayae*
Spongoclonium fasciculatum	*Tylocolax microcarpus*
Spyridia dasyoides	*Tylotus obtusatus*
Spyridia filamentosa	*Veleroa adunca*
Spyridia squalida	*Vidalia spiralis*
Spyridia tasmanica	*Warrenia comosa*
Stenogramme interrupta	*Webervanbossea tasmanensis*
Stenogramme leptophylla	*Wetherbeella australica*
Stylonema alsidii	*Wetherbeella foliosa*
Stylonema cornu-cervi	*Wilsonaea dictyuroides*
	Wollastoniella myriophylloides
	Womersleya monanthos
	Wrangelia abietina
	Wrangelia australis
	Wrangelia nobilis
	Wrangelia plumosa
	Wrangelia velutina
	Zymurgia chondriopsidea

Appendix 1 (cont.)

Corallinales
Amphiroa anceps
Arthrocardia flabellata
Cheilosporum sagittatum
Choreonema thuretii
Corallina officinalis
Haliptilon roseum
Hydrolithon farinosum
Jania adhaerens
Jania affinis
Jania micrarthrodia
Jania minuta
Jania pusilla
Jania verrucosa
Lithophyllum prototypum
Melobesia membranacea
Mesophyllum engelhartii
Mesophyllum macroblastum
Metagoniolithon chara
Metagoniolithon radiatum
Metagoniolithon stelliferum
Metamastophora flabellate
Neogoniolithon brassica-florida
Phymatolithon repandum
Pneophyllum confervicola
Pneophyllum coronatum
Pneophyllum fragile
Pneophyllum limitatum
Sporolithon durum
Synarthrophyton patena

<u>Appendix 2</u>: List of all benthic macroalgal species present in each Aquatic Reserve present in the AMLR NRM region. 1 & 2 = Barker Inlet – St Kilda and St Kilda – Chapman Creek Aquatic Reserve, 3 & 4 = Port Noarlunga Reef and Onkaparinga Estuary Aquatic Reserve, 5 = Aldinga Reef Aquatic Reserve, and 6 = West Island Aquatic Reserve. (source: ADHerb 2010)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Acrocarpia paniculata		■		■
Acrosorium ciliolatum	■			
Acrothamnion preissii		■		■
Acrotylus australis				■
Aglaothamnion tenuissimum		■		
Amoenothamnion planktonicum				■
Amphiroa anceps		■	■	■
Anotrichium crinitum				■
Anotrichium elongatum				■
Anotrichium secundum	■		■	
Anotrichium tenue	■			
Antithamnion delicatulum		■	■	■
Antithamnion gracilentum		■		
Antithamnion hanovioides		■		■
Antithamnion pinnafolium				■
Antithamnionella multiramosa				■
Antithamnionella ternifolia	■	■		
Antrocentrum nigrescens				■
Apjohnia laetevirens	■		■	
Apoglossum spathulatum				■
Areschougia congesta		■	■	■
Arthrocardia flabellata				■
Asparagopsis armata		■	■	■
Asparagopsis taxiformis		■	■	
Asperococcus bullosus	■			
Audouinella daviesii	■			
Audouinella dictyotae		■		
Audouinella floridula		■		
Audouinella polyidis		■		
Austroclonium charoides				■
Austronereia australis		■		
Austrophyllis alcicornis				■
Ballia callitricha				■
Bostrychia moritziana	■			
Bostrychia simpliciuscula	■			
Botryocladia sonderi		■		
Bryopsis plumosa	■	■		
Callithamnion circinnatum		■		
Callithamnion confertum				■
Callithamnion shepherdii		■		
Callithamnion violaceum		■		
Callophycus laxus				■

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Callophyllis lambertii				■
Caloglossa leprieurii	■			
Caloglossa ogasawaraensis	■			
Camontagnea hirsuta				■
Carpoglossum confluens		■		
Carpomitra costata		■		■
Carpopeltis phyllophora				■
Carpothamnion gunnianum		■		
Caulerpa brownii		■		■
Caulerpa cactoides		■	■	
Caulerpa flexilis		■		■
Caulerpa obscura				■
Caulerpa papillosa	■			
Caulerpa racemosa var. *cylindracea*	■			
Caulerpa scalpelliformis		■		
Caulerpa sedoides			■	
Caulerpa simpliciuscula		■		
Caulerpa taxifolia	■			
Caulerpa trifaria		■		
Caulocystis cephalornithos		■		
Caulocystis uvifera		■	■	
Centroceras clavulatum		■		
Cephalocystis furcellata				■
Ceramium cliftonianum	■	■		■
Ceramium filiculum		■		
Ceramium macilentum		■		
Ceramium puberulum	■	■	■	
Ceramium pusillum		■		■
Ceramium rubrum		■		
Chaetomorpha aerea		■		
Chaetomorpha capillaris	■			
Chaetomorphalinum	■			
Champia affinis		■		
Champia viridis				■
Champia zostericola	■	■		
Cheilosporum sagittatum		■	■	■
Chondria angustissima		■		
Chondria arcuata		■		
Chondria foliifera				■
Chondria succulenta		■		
Chondrophycus paniculatus			■	
Chondrophycus tumidus		■		
Choreonema thuretii				■
Cladophora coelothrix		■		
Cladophora dalmatica				■
Cladophora prolifera	■			
Cladophora rhizoclonioidea				■

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Cladophora vagabunda	■			
Cladophora valonioides		■		
Cladostephus spongiosus		■		
Codium capitulatum			■	
Codium duthieae		■		
Codium galeatum				■
Codium lucasii		■		
Codium mamillosum		■		
Codium muelleri		■		
Codium perriniae		■		
Codium pomoides				■
Coelarthrum opuntia		■		
Coeloclonium tasmanicum		■		
Colaconema caespitosum		■		
Colpomenia peregrina	■	■		
Colpomenia sinuosa		■		
Corallina officinalis		■		■
Cottoniella fusiformis		■		
Craspedocarpus ramentaceus		■		■
Craspedocarpus venosus				■
Crassilingua marginifera				■
Crouania robbii		■		
Crouania shepleyana		■	■	
Cutleria multifida	■	■		
Cryptonemia undulata		■		
Cystophora brownii		■		
Cystophora cuspidata		■		
Cystophora intermedia				■
Cystophora monilifera		■		■
Cystophora moniliformis		■		■
Cystophora platylobium				■
Cystophora racemosa		■		
Cystophora retorta		■	■	
Cystophora subfarcinata		■	■	■
Cystoseira trinodis			■	
Dasya baldockii				■
Dasya ceramioides				■
Dasya comata		■		
Dasya extensa		■		
Dasyahookeri	■			
Dasya villosa		■		
Dasyclonium incisum				■
Dasyphloea insignis		■		
Dasythamniella plumigera				■
Dasythamniella wollastoniana				■
Delisea elegans				■
Delisea hypneoides			■	■

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Delisea pulchra				
Derbesia tenuissima				
Desmodium hannii				
Dictyomenia harveyana				
Dictyomenia tridens				
Dictyopteris australis				
Dictyopteris muelleri				
Dictyopteris nigricans				
Dictyosphaeria sericea				
Dictyota alternifida				
Dictyota dichotoma				
Dictyota diemensis				
Dictyota fastigiata				
Dictyota fenestrata				
Dictyota gunniana				
Dictyota robusta				
Dilophus fastigiatus				
Dilophus marginatus				
Distromium flabellatum				
Distromium multifidum				
Ditria expleta				
Doxodasya bolbochaete				
Doxodasya hirta				
Drewiana nitella				
Echinothamnion hookeri				
Echinothamnion hystrix				
Ecklonia radiata				
Epiglossum smithiae				
Ectocarpus fasciculatus				
Ectocarpus siliculosus				
Elachista nigra				
Elisiella arbuscula				
Encyothalia cliftonii				
Erythroclonium muelleri				
Erythronaema ceramioides				
Euptilota articulata				
Feldmannia globifera				
Feldmannia irregularis				
Flabellonema codii				
Ganonema farinosum				
Gattya pinnella				
Gayliella flaccida				
Gayralia oxysperma				
Gelidium asperum				
Gelidium australe				
Gelidium pusillum				
Gelinaria ulvoidea				

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Gibsmithia womersleyi		■		
Gigartina brachiata	■	■	■	
Giraudia robusta	■			■
Giraudia sphacelarioides	■			
Gloiocladia fruticulosa		■		
Gloiocladia halymenioides		■		
Gloiosaccion brownii		■		
Glossophora nigricans (Dictyota nigricans)				■
Gracilaria chilensis		■		
Gracilaria cliftonii	■	■		
Griffithsia elegans				■
Griffithsia gunniana				■
Griffithsia teges		■		■
Guiryella repens		■		
Gulsonia annulata		■		
Gymnogongrus crenulatus		■		
Halicnide similans				■
Haliptilon roseum		■	■	■
Haloplegma preissii		■		■
Halopteris funicularis				■
Halopteris paniculata				■
Halopteris pseudospicata			■	■
Halopteris ramulosa				■
Halymenia plana				■
Haraldia australica				■
Haraldiophyllum erosum				■
Hemineura frondosa				■
Herposiphonia filipendula				■
Heterodoxia denticulata		■		
Heterosiphonia australis				■
Heterosiphonia microcladioides				■
Heterosiphonia muelleri		■		
Hincksia granulosa		■		
Hincksia mitchelliae		■		
Hincksia sandriana	■			
Hirsutithallia mucronata				■
Homoeostrichus sinclairii				■
Hormosira banksii			■	
Hydrolithonfarinosum	■			
Hymenena affinis	■			■
Hymenena curdieana		■		
Hymenena multipartita		■		■
Hypnea filiformis	■	■		
Hypnea ramentacea		■		■
Hypoglossum protendens				■
Inkyuleea mariana				■

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Jania micrarthrodia				
Jania verrucosa				
Laurencia brongniartii				
Laurencia clavata				
Laurencia elata				
Laurencia filiformis				
Laurencia forsteri				
Laurencia heteroclada				
Laurencia majuscula				
Laurencia shepherdii				
Lenormandia latifolia				
Leptophyllis conferta				
Liagora harveyana				
Liagora wilsoniana				
Lobophora variegata				
Lobospira bicuspidata				
Lomentaria australis				
Lophosiphonia prostrata				
Lophothalia hormoclados				
Lophothamnion hirtum				
Macrothamnion pellucidum				
Malaconemaroeanum				
Martensia australis				
Mazoyerella arachnoidea				
Mazoyerella australis				
Medeiothamnion halurus				
Medeiothamnion repens				
Melanema dumosum				
Melanthalia abscissa				
Melanthalia fastigiata				
Melanthalia obtusata				
Melobesia membranacea				
Metagoniolithon radiatum				
Metagoniolithon stelliferum				
Metamastophora flabellata				
Micropeuce feredayae				
Muellerena wattsii				
Mychodea australis				
Mychodea hamata				
Myrionema latipilosum				
Myrionema strangulans				
Nizymenia australis				
Ochmapexus minimus				
Ophidocladus simpliciusculus				
Osmundaria prolifera				
Pachydictyon paniculatum (*Dictyota paniculata*)				

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Peltasta australis				■
Perithalia caudate				■
Petalonia fascia		■		
Peyssonnelia capensis		■	■	■
Peyssonnelia novae-hollandiae				■
Phacelocarpus apodus				■
Phacelocarpus peperocarpos				■
Phitymophora amansioides				■
Phycodrys australasica		■		
Phloiocaulon spectabile		■		
Platysiphonia victoriae		■		
Plinthanthesis rodwayi				■
Plocamium angustum		■	■	■
Plocamium cartilagineum	■	■	■	■
Plocamium costatum				■
Plocamium leptophyllum				■
Plocamium mertensii		■		■
Plocamium patagiatum				■
Plocamium preissianum		■	■	■
Pneophyllum confervicola	■			
Pneophyllum fragile	■			
Pneophyllum limitatum	■			
Pollexfenia pedicellata	■			
Polycerea nigrescens		■		
Polyopes constrictus				■
Polysiphonia amphibolis	■			
Polysiphonia blandii		■		
Polysiphonia decipiens	■	■		■
Polysiphonia infestans		■		
Polysiphonia isogona	■	■		
Polysiphonia mollis	■			
Polysiphonia scopulorum		■		
Polysiphonia sertularioides	■	■		
Polysiphonia subtilissima	■	■		
Porphyra lucasii	■	■		
Porphyra woolhouseae	■	■		
Porphyridium purpureum				■
Porphyropsis minuta				■
Pseudolithoderma australe				■
Pterocladia lucida	■		■	■
Pterocladiella capillacea				■
Pterosiphonia pennata		■		■
Pterothamnion ramulentum				■
Ptilocladia crouanioides				■
Ptilocladia vestita		■		
Ptilonia australasica				■
Ptilothamnion schmitzii		■		■

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Pylaiella littoralis	■			
Ralfsia verrucosa		■		■
Rhizoclonium curvatum	■			
Rhizoclonium riparium	■			
Rhodophyllis membranacea				■
Rhodophyllis multipartita				■
Rhodymenia leptophylla	■			■
Rhodymenia sonderi	■	■		■
Rhodymenia verrucosa				■
Rugulopteryx okamurae		■		
Sahlingia subintegra		■		
Sargassum decipiens		■	■	
Sargassum distichum		■		■
Sargassum fallax		■	■	■
Sargassum lacerifolium		■	■	
Sargassum linearifolium		■	■	
Sargassum paradoxum			■	
Sargassum podacanthum		■		
Sargassum spinuligerum		■		
Sargassum tristichum		■		
Sargassum varians		■		
Sargassum verruculosum		■		■
Scaberia agardhii		■		
Scageliopsis patens		■		
Scytosiphon lomentaria		■		■
Scytothalia dorycarpa		■		■
Seirococcus axillaris				■
Shepleya australis				■
Solieria robusta	■	■		
Sonderopelta coriacea				■
Sphacelaria bracteata		■		
Sphacelaria cirrosa		■		
Sphacelaria rigidula				■
Sphacelariatribuloides		■	■	
Spongoclonium australicum	■			
Spongoclonium brownianum				■
Spongoclonium conspicuum	■	■		■
Spongoclonium fasciculatum		■		■
Sporochnus comosus		■		
Sporochnus radiciformis		■		
Sporolithon durum				■
Spyridia dasyoides				■
Spyridia filamentosa	■			
Spyridia squalida		■		
Stenogramme interrupta				■
Struvea plumosa		■		
Stylonemaalsidii	■	■		

Appendix 2 (cont.)

Species / Aquatic Reserve	1 & 2	3 & 4	5	6
Stylonema cornu-cervi		■		
Taonia australasica		■		
Tetrathamnion lineatum		■		
Thamnoclonium dichotomum		■		■
Trithamnion aculeatum		■		
Trithamnion eubryanii		■		
Trithamnion vulgare		■		
Ulva clathrata	■			
Ulva flexuosa	■			
Ulva intestinalis		■		
Ulva lactuca	■	■		
Ulva linza	■			
Ulva prolifera		■		
Ulva ralfsii	■			
Ulva rigida	■			
Warrenia comosa				■
Wittrockiella salina		■		
Wrangelia plumosa		■		
Zonaria angustata			■	■
Zonaria spiralis		■	■	■
Zonaria turneriana		■		

ATTACHMENT 1:
BIODIVERSITY AND CONSERVATION OF MACROALGAE IN THE GULF ST VINCENT BIOREGION

SUPPLEMENTARY REPORT TO ADELAIDE AND MT LOFTY RANGES NATURAL RESOURCES MANAGEMENT BOARD

BY J.L. BAKER[1] & C.F. GURGEL[2]

[1] Janine L. Baker, Marine Ecologist: jannebaker@adam.com.au

[2] Dr Fred Gurgel, Marine Botany Chair, School of Earth and Environmental Sciences, University of Adelaide, North Terrace, Adelaide, South Australia 5005

AUGUST 2010

5. Table of Contents

Citation

This report may be cited as:

Baker, J.L. and Gurgel, C.F.D. (2010) Assessment of Biodiversity and Distribution of Macroalgae in the Gulf St Vincent Bioregion. Supplementary report in: *Biodiversity and Conservation of Macroalgae in the Adelaide & Mt Lofty Ranges NRM Region*. Report to Adelaide & Mt Lofty Ranges Natural Resources Management Board.

Introduction

This report is a supplement to the report –Biodiversity and Conservation of Macroalgae In the Adelaide and Mt Lofty Ranges NRM Region" (Baker and Gurgel 2010), and briefly describes the composition of macroalgae in the Gulf St Vincent Bioregion, according to South Australian State Herbarium records from the late 19th century to 2009. The main report discusses species composition of macroalgae on the eastern side of the bioregion (metropolitan Gulf St Vincent and the Fleurieu Peninsula) and in Encounter Bay. This report mainly describes the macroalgae of parts of the GSV Bioregion not included within the Adelaide and Mt Lofty NRM region, such as eastern Yorke Peninsula, Investigator Strait and northern Kangaroo Island.

Appendix A1 describes the features of the Gulf St Vincent bioregion (IMCRA 1998; Baker 2004).

Materials and Methods

The data set used for this part of the project is an amalgamation of herbarium records from the late 1880s to 2009, from the South Australian State Herbarium (also known as ADHerb database, version 2010), supplemented with South Australian records from other herbaria from the Australian Virtual Herbarium database (AVH, version 2010). The geo-referenced data set of records of macroalgae within the Gulf St Vincent bioregion comprised approximately 9,000 records after cleaning (i.e. removal of irrelevant taxa, and erroneous records).

The taxonomy for each species was checked, and updated where necessary, using the current literature, in addition to databases such as Algaebase (Guiry and Guiry 2010), and the Australian Marine Algal Names Index (Cowan 2006). A referenced list of updated names for various taxa which were known in the South Australian herbarium databases under their previous names (now junior synonyms), is available from the first author.

Species recorded as genus only were removed from the data set for this analysis. Intra-specific ranks such as subspecies, varieties, forms and ecads were not considered distinct taxa, hence were collapsed into a single species. The only non-specific records which were retained, were those for which no other member of the genus was present in the data sets.

From the main data set, supplementary data sets were created, for the main groups of macroalgae (Chlorophyta, Phaeophyceae, Rhodophyta, and Corallinales in Rhodophyta). Databases were also created for endemic species, introduced species, and cryptogenic species, according to literature discussed in other sections of this report.

Software used to summarise the contents include ESRI's ARCView and Spatial Analyst, Microsoft Excel and Microsoft Access.

Results and Discussion

Overview of Macroalgae in GSV Bioregion

Within the GSV Bioregion, examples of locations where numerous herbarium samples have been taken include the metropolitan area; Encounter Bay; the bays of north-eastern Kangaroo Island, the foot of Yorke Peninsula, and several locations in Investigator Strait (**Figure A1**). Sites along the eastern side of the gulf and in Encounter Bay are discussed in the main report accompanying this supplement.

Professor H.B.S. Womersley of the South Australian State Herbarium collected numerous specimens of macroalgae from around Gulf St Vincent and Kangaroo Island, over several decades. Within the GSV Bioregion, notable and extensive collections include those from American River (Womersley, 1956), and the southern metropolitan coast and upper Fleurieu beaches (e.g. Port Noarlunga, Aldinga, Willunga, Sellicks). Kinloch (2005) provided a summary of sites on Kangaroo Island surveyed by H.B.S. Womersley from 1944 to 1949. During the late 1990s, collections of macroalgae were made at various sites along the Dudley Peninsula (including the Hog Bay region) on north-eastern Kangaroo Island, by J. Lavers and colleagues, as part of a collaborative government and community-based program for monitoring reef health in the north-eastern Kangaroo Island area (e.g. KI-AMCS, 2000).

Various collections have also been made along the foot of Yorke Peninsula over several decades, including those by Womersley (e.g. 1950, 1963, amongst other years), Woelkerling (1968), Kraft (1973), Davey (undated), and in 1993 by staff at SARDI Aquatic Sciences, during a benthic survey program (Edyvane and Baker, 1998). Collections at the Althorpe Islands were made in 1993 (Baker et al., 2005) and in 2004 (Baldock and Womersley, 2005). Collections were made by S.A. Shepherd during the late 1960s in various locations in Gulf St Vincent and along the Yorke Peninsula coast, most notably in a species-rich community of red macroalgae on a reef at 10m depth east of Troubridge Island.

In deeper waters of Investigator Strait, collections were made in 1971 by J. Watson along a transect between southern Yorke Peninsula (Foul Bay area) and northern Kangaroo Island, and some of the depths from which collections were made (31m, 35m and 41m deep), represent the deepest known to date for a number of species of macroalgae in South Australia. This reflects the paucity of collecting effort in other areas of the State, in waters over 20m, due to the limitations of general diving, such as the reduced bottom time available at depths greater than 20m.

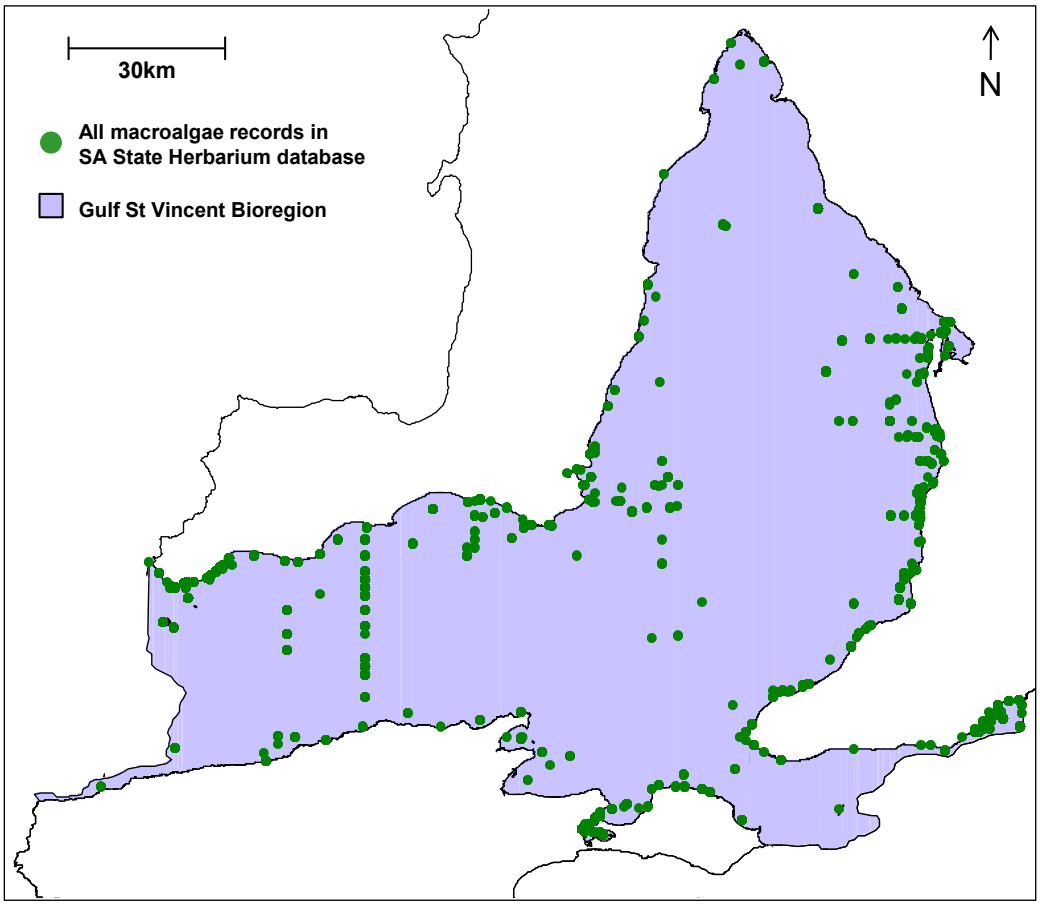


Figure A1: Distribution of records of macroalgae from the SA State Herbarium database, within the Gulf St Vincent Bioregion (IMCRA 1998).

Within the GSV Bioregion, the distribution of records in each of the major groups (Chlorophyta, Phaeophyceae, Rhodophyta, and Corallinales in Rhodophyta – **Figures A2**, **A3**, **A4** and **A5** respectively) closely resembles that of all groups combined (**Figure A1**).

Abundant records of macroalgae in Chlorophyta come from American River on Kangaroo Island (at least 30 species of green macroalgae have been recorded in the river); also from sites in the metropolitan area (such as Outer Harbour to Semaphore; South Brighton - Marino - Hallett Cove - Port Stanvac area, and Port Noarlunga); and the reefs and mixed reef/sand/seagrass habitats in the Encounter Bay area. The records in Chlorophyta from some of these areas are discussed in the main body of the report.

Records in Phaeophyceae and Rhodophyta are particularly abundant along the metropolitan coast; also along the ~~f~~oot" of Yorke Peninsula, and along a deeper water transect in Investigator Strait (survey in 1971 by J. Watson); north-east Kangaroo Island, and the Encounter Bay area (including Victor Harbor and Port Elliot) (**Figures A3** and **A4**). Other than Investigator Strait (which is a deeper water, relatively inaccessible area), this reflects a strong historical bias in collecting effort along areas with convenient access to researchers rather than a true higher local biodiversity in these areas.

Records in Corallinales are particularly abundant from the ~~f~~oot" of Yorke Peninsula (**Figure A5**). In this area, calcareous macroalgae in the articulated genera *Amphiroa*, *Haliptilon*, *Cheilosporum* and *Metagoniolithon*, and crustose corallines such as *Lithothamnion* (among others) form a significant component of the understorey on subtidal reefs at 5m – 10m (J. Baker, pers. obs. 1993; Edyvane and Baker 1998) and possibly deeper.

To date, inadequately sampled areas in GSV Bioregion include the far northern waters of the gulf; most of the central waters between Yorke Peninsula and the metropolitan area / Fleurieu Peninsula; also much of the north coast of Kangaroo Island and the Dudley Peninsula (particular the eastern edge of Kangaroo Island); most of Investigator Strait, and the area between the foot of Fleurieu Peninsula and Newland Head. The deeper depths and/or strong currents in some of these areas, such as the central gulf and Investigator Strait, have limited collecting opportunities by SCUBA.

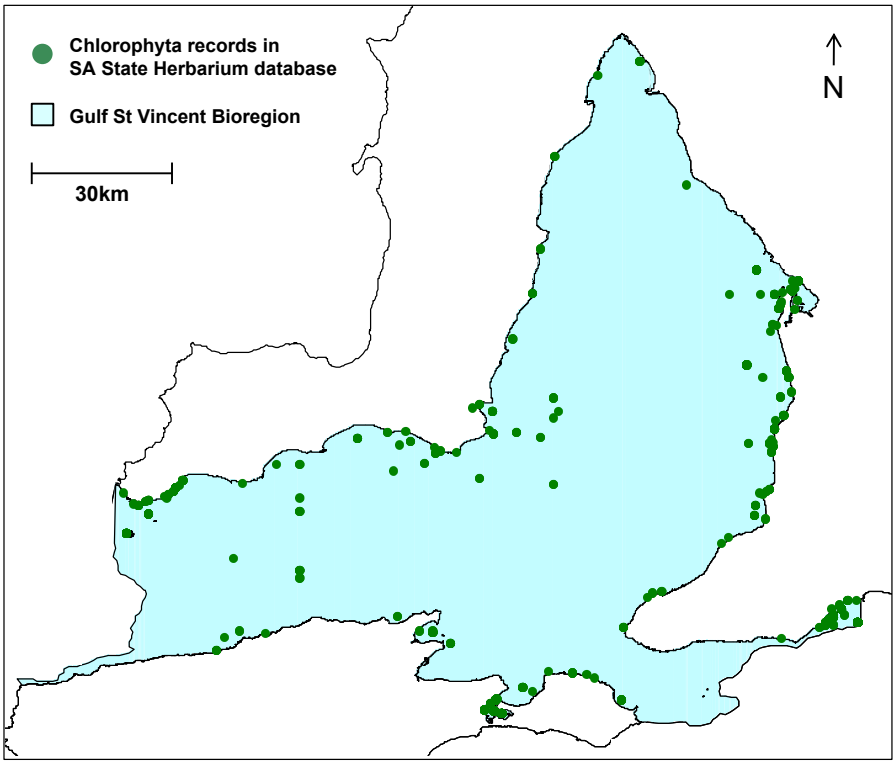


Figure A2: Distribution of records of macroalgae in Chlorophyta, in SA State Herbarium database, within the Gulf St Vincent Bioregion.

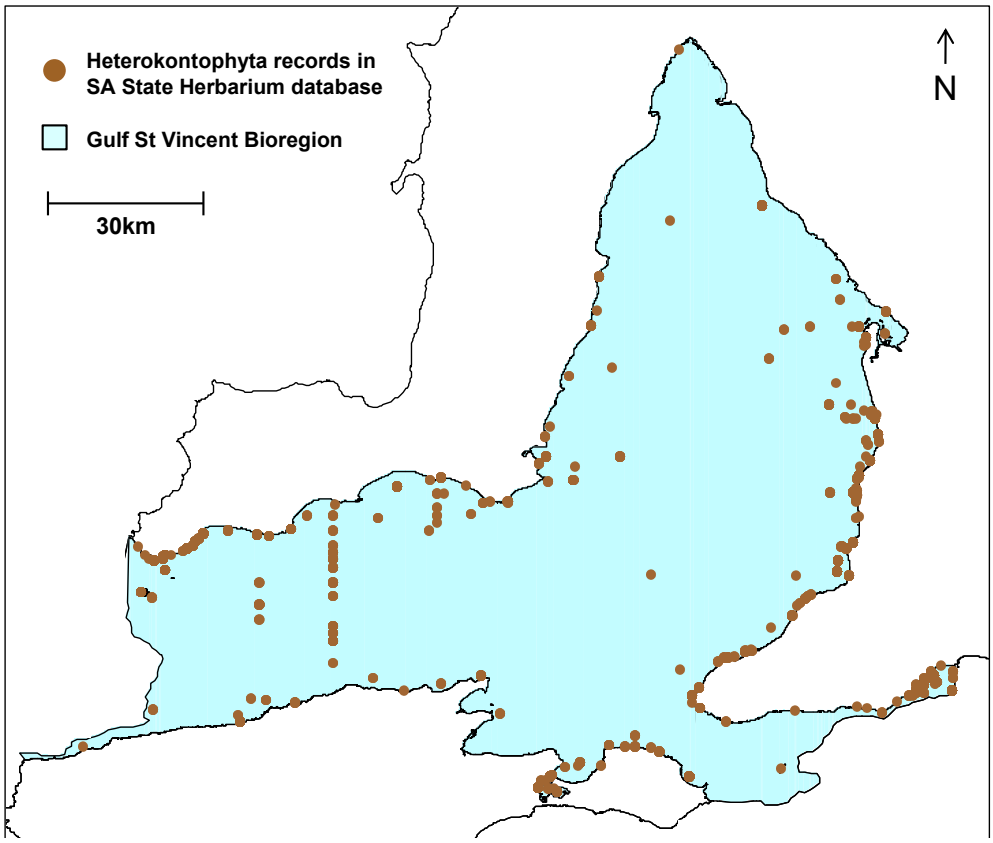


Figure A3: Distribution of records of macroalgae in Phaeophyceae in SA State Herbarium database, within the Gulf St Vincent Bioregion.

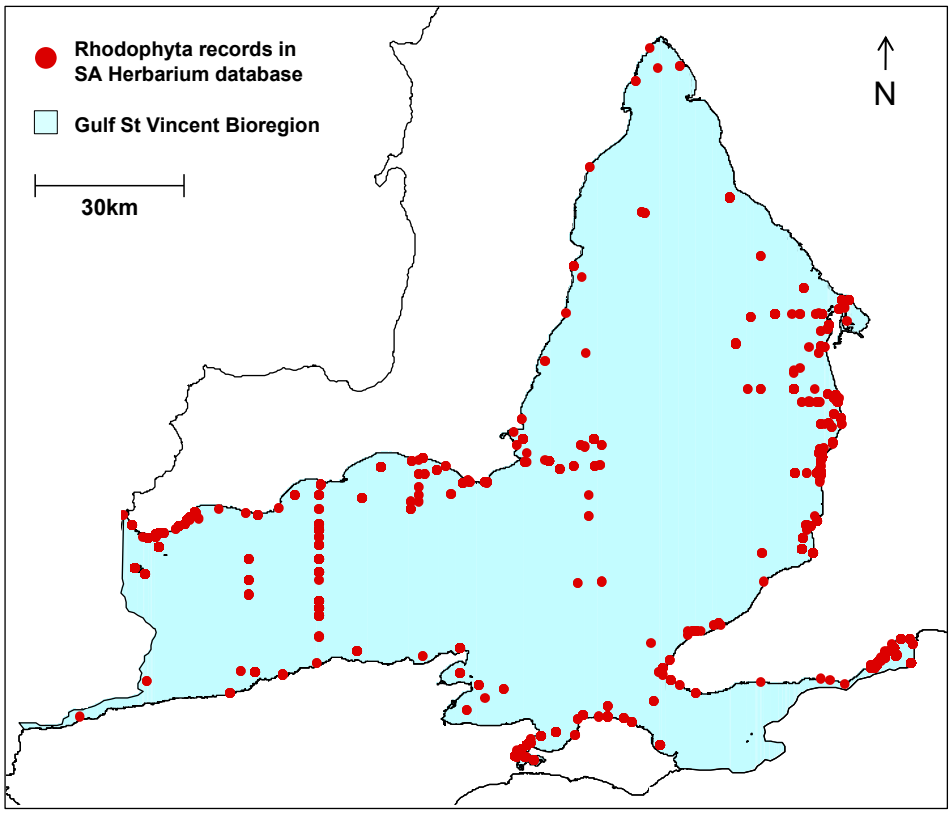


Figure A4: Distribution of records of macroalgae in Rhodophyta (excluding Corallinaceae) in SA State Herbarium database, within the Gulf St Vincent Bioregion.

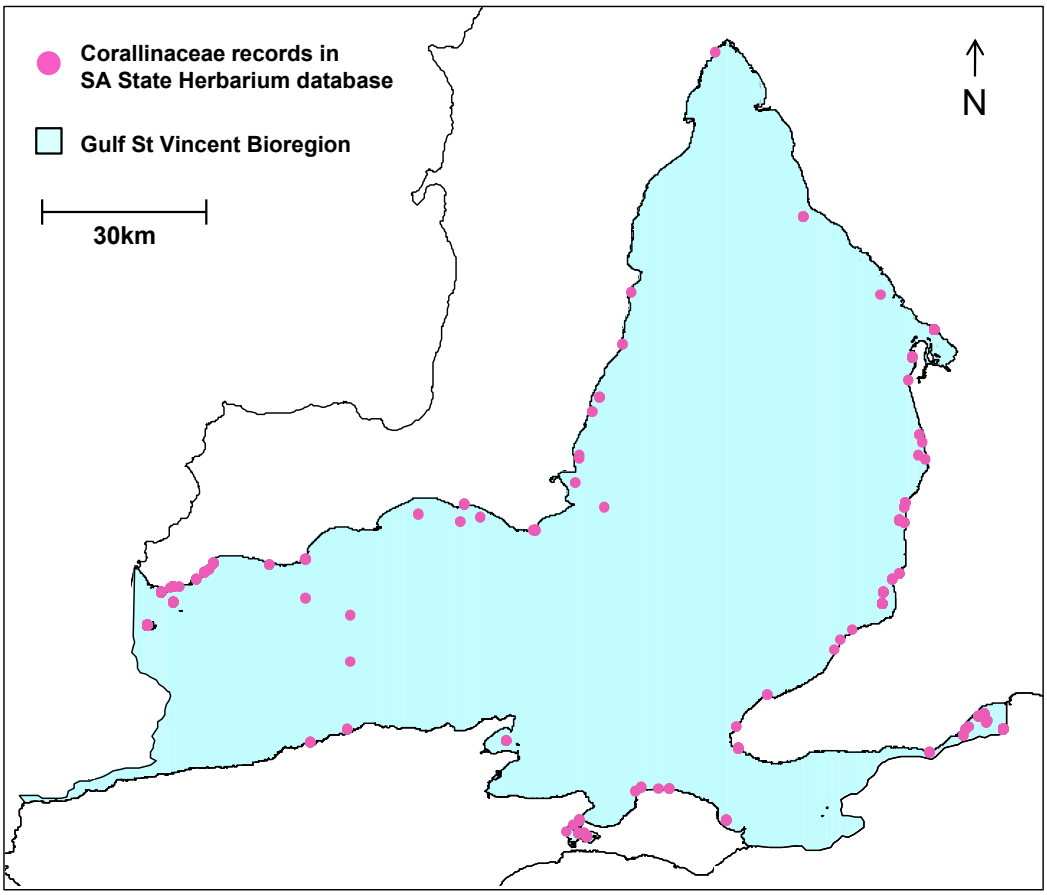


Figure A5: Distribution of records of macroalgae in Corallinaceae (Corallinales) in SA State Herbarium database, within the Gulf St Vincent Bioregion.

Endemic Species of Macroalgae in GSV Bioregion

So far, 18 species in Rhodophyta, 8 species in Phaeophyceae, and 2 species on Chlorophyta present in the GSV Bioregion, are currently considered endemic within South Australia, according to the South Australian State Herbarium database (listed in **Table A1**). The distribution of herbarium records of endemic species listed in **Table A1** is shown in **Figure A6**. Off the ~~h~~eel" of Yorke Peninsula, there are 10 records of endemic Rhodophyta, including *Bonnemaisonia spinescens*, *Callithamnion shepherdii*, *Chylocladia grandis*, *Polysiphonia propagulifera* and *P. shepherdii.* Along the deeper water transect between in Investigator Strait, between southern Yorke Peninsula and northern Kangaroo Island, a total of 9 records comprising 4 endemic species have been collected, including the reds *Bonnemaisonia spinescens*, *Callithamnion shepherdii*, *Chylocladia grandis*, *Polysiphonia propagulifera* and the small brown epiphyte *Zosterocarpus australica.* Two of these, *B. spinescens* and *Z. australica*, have also been recorded in western Investigator Strait, towards the Althorpe Islands group. The endemic species *Peyssonnelia foliosa* and *Sympodophyllum reinboldii* have been recorded at the Althorpe islands.

Three species (the greens *Cladophora aegagropiloidea*, *Cladophoropsis magna* and the coralline *Jania parva*) have been recorded in the Bay of Shoals area on Kangaroo Island, and the reds *Callithamnion shepherdii* and *Haraldia australica* have been recorded in American River.
On the Dudley Peninsula, eastern Kangaroo Island, records of endemic species include the small red alga *Audouinella blumii*, and the prostrate species *Peyssonnelia foliosa.* Other endemic species, namely *Crouania destriana* and *Bonnemaisonia spinescens*, have also been recorded in the area, (J. Lavers, cited by T. Flaherty, pers. comm. 2001). Other species of interest in the area include:

- *Dasya hapalathrix* (known mainly from Victoria and Tasmania, with only two herbarium specimens in the SA State Herbarium);

- *Dasya wilsonis*: known from Victoria and South Australia, with the single SA record known to date from 2km east of Penneshaw, collected in 1997, from waters 19 – 22m deep (Womersley 1998; ADHerb 2010).

A number of uncommonly recorded species, not endemic within South Australia, are also known from the Kangaroo Island area. One example is the western Australian species *Erythroclonium sedoides*, for which only two records are known in South Australia thus far, one of these from Stokes Bay (ADHerb 2010).

In western Gulf St Vincent (eastern Yorke Peninsula), the brown *Spatoglossum australasicum* has been recorded at Port Julia, and the coralline *Jania parva* has been recorded at Stansbury. In eastern Gulf St Vincent, three endemic species have been recorded in the now industrialised and modified Outer Harbour area, namely the brown *Spatoglossum australasicum* (old record, from 1852), the small fluffy red *Callithamnion shepherdii*, and the delicate, multi-branched *Bonnemaisonia spinescens* (the latter being a dredge record from 7 – 9 km west of Outer Harbour, in 1963).Approximately 20km west-south-west of that area, in deeper waters off Semaphore, the multi-branched red alga *Pterothamnion flexile* was recorded in 1975.

Other metropolitan records include *Spatoglossum australasicum* collected from Brighton beach in 1943; *Bonnemaisonia spinescens* from Port Stanvac (2008); the small brown epiphyte *Myrionema latipilosum* from the Onkaparinga Estuary (**Table A1**); the small red epiphyte *Medeiothamnion repens* and two species in *Callithamnion*, recorded from Port Noarlunga Aquatic Reserve during the 1980s and 1990s. In the Aldinga area, endemic species recorded to date include the brown epiphytes *Corynophlaea cristata*, *Flabellonema codii* (also recorded at Seaford beach) and *Myriactula filiformis*, and the densely-tufted, multi-branched red alga *Callithamnion circinnatum*.

Due to lack of collecting along the Fleurieu Peninsula, records of endemic species are sparse, other than the small red epiphyte *Crouania destriana* recorded in 2006 on the coralline *Metagoniolithon stelliferum*, at Fishery Beach near Cape Jervis; and *Bonnemaisonia spinescens* at Cape Jervis (collected in 1983).

The largest number of records of endemic species up till now comes from the well-surveyed Encounter Bay area, from where detailed collections have been made in some areas (e.g. Rosetta Head, and West Island). There are 18 records in the South Australian State Herbarium of endemic species in the Encounter Bay and Port Elliot area combined, including multiple records (i.e. about 11 specimens) of the red epiphyte *Antithamnionella multiramosa*, and also specimens of the brown epiphytes *Acrotrichium amphibolis*, *Flabellonema codii* and *Strepsithalia leathesiae*; the red epiphytes *Heterothamnion sessile* and *Tylocolax microcarpus*, and the spongy, multi-branched alga *Euptilocladia villosa*.

Table A1: South Australian endemic species recorded to date in GSV Bioregion. Species marked in gray shading have been recorded so far only in GSV region. # = possibly endemic, but also known from a single Tasmania record which is not included in the published distribution.

Species Name	Description	No. Records in GSV Bioregion
Green Macroalgae		
Cladophora aegagropiloidea	Known from several drift specimens collected at Bay of Shoals, Kangaroo Island in 1950, and from Wanna, near Port Lincoln (1990 record).	2
Cladophoropsis magna	A green alga for which Smoky Bay in the eastern Great Australian Bight (GAB) is the type locality. Also known from Denial Bay area (near Smoky Bay), and Bay of Shoals on Kangaroo Island (1987 record).	1
Brown Macroalgae		
Acrotrichium amphibolis	A brown epiphyte, the single member of a genus resembling *Myriactula*, and recorded on *Amphibolis antarctica* seagrass in Encounter Bay in 1981 (Womersley 1987).	1
Corynophlaea cristata	A soft, mucoid brown epiphyte, found on *Cystophora* species, and recorded to date from Point Westall in the eastern GAB; several islands in the Sir Joseph Banks Group in Spencer Gulf, and Aldinga Reef in Gulf St Vincent (ADHerb 2010).	1
Flabellonema codii	A small brown epiphyte, which is found on the utricle ends of the green ball-like alga *Codium mamillosum*, and has been recorded at various locations in S.A., from Eyre Peninsula to Encounter Bay (Womersley 1987; ADHerb 2010).	2
Myriactula filiformis	A small epiphyte found on *Cystophora*, and apparently known only from South Australia (Cowan 2006; Guiry and Guiry 2010), from a drift specimen collected in 1977 at Aldinga Beach (Womersley 1987; ADHerb 2010; Australian Virtual Herbarium 2010).	1
Myrionema latipilosum	A small brown epiphyte, apparently known to date only from type collection taken in 1977 from the Onkaparinga Estuary, on *Zostera* seagrass (Womersley 1987; ADHerb 2010; Australian Virtual Herbarium 2010)	2
Spatoglossum australasicum	A dichotomously-branched brown plant, which grows to about 16cm tall (Womersley 1987), and has been recorded from Port Julia on Yorke Peninsula; Brighton jetty and LeFevre Peninsula in Gulf St Vincent (the latter specimens collected by Mueller in 1852); Port Bonython loading terminal in Spencer Gulf (2009), and Nobby Island on southern Kangaroo Island (1994) (ADHerb 2010).	5
Strepsithalia leathesiae	A small brown epiphyte, which forms patches on the surface of the brown alga *Leathesia difformis*, and has been recorded on a rock platform at Aldinga, and in Encounter Bay (Womersley 1987; ADHerb 2010).	1
Zosterocarpus australica	A small brown filamentous species known from Investigator Strait in deeper water (e.g. specimens from 31m, 35m and 41m deep).	3

Table A1 (continued):

Red Macroalgae		
Antithamnionella multiramosa	A small epiphyte, that occurs on coralline algae such as *Corallina officinalis*, and *Haliptilon roseum*. This species is known from at least 14 records in SA, ranging from Greenly Beach on Eyre Peninsula to West Island out of Encounter Bay, where the majority of specimens have been collected (Womersley 1998; ADHerb 2010; Australian Virtual Herbarium 2010).	11
Audouinella blumii	A small alga, known from samples collected in *Helminthocladia australis* and *H. densa*, on jetty piles at Antechamber Bay on Kangaroo Island (1967 record)	1
Bonnemaisonia spinescens	A delicate, multi-branched alga which grows to about 8cm long, and has been found in various locations in Gulf St Vincent, Investigator Strait and Backstairs Passage, in waters from about 10m to 41m deep (Womersley 1996; ADHerb 2010).	8
Callithamnion circinnatum #	A densely tufted, multi-branched alga, which grows up to 12cm high, and has been recorded from Elliston and Crinoline Point on Eyre Peninsula; also 15m deep off Crag Point in northern Spencer Gulf, and Noarlunga tyre reef and Aldinga reef in GSV. It is noted that there is an unverified record in the SA State Herbarium database of a specimen from Tasmania, collected in 1948 and more recently identified as *Callithamnion circinnatum*; however, Tasmania is not included as part of the distribution in published references (e.g. Womersley 1998).	3
Callithamnion shepherdii	A small fluffy alga, recorded from various locations in S.A., ranging from Waldegrave I. in the eastern GAB, through to American River on Kangaroo Island, and several locations in Gulf St Vincent.	5
Chylocladia grandis	Known from approximately 18 records, ranging from St Francis Island in the eastern GAB, through to Cape Coutts, and Cable Hut Reef (west of Cape Coutts) on eastern Kangaroo Island. Several records come from deeper waters in Investigator Strait: e.g. 10km, 15km and 25km south of Foul Bay, between Yorke Peninsula and northern Kangaroo Island (1971 records). The type was collected at Tapley Shoal, east of Edithburgh at 15m deep, in 1969.	5
Crouania destriana	A small epiphyte, which occurs on the surface of coralline macroalgae such as *Metagoniolithon*, *Amphiroa* and *Sporolithon*. Known from approximately 14 specimens, ranging from Point Lowly in northern Spencer Gulf to Cape Northumberland near the Victorian border (Womersley 1998; ADHerb 2010; Australian Virtual Herbarium 2010). AMLR NRM specimen is from Fishery Beach near Cape Jervis.	1
Euptilocladia villosa	A spongy, multi-branched alga, about 5cm – 15cm long, recorded from various locations in South Australia that range from Topgallant I. in the eastern GAB, through to Cape Northumberland in the South East.	1
Haraldia australica	Apparently known only from several old records in South Australia, including Rocky Point (1950) and Muston / American River (1950) on Kangaroo Island, and West Island out of Encounter Bay (1966) (Womersley 2003; ADHerb 2010).	2
Heterothamnion sessile	A small red epiphyte, closely related to *Heterothamnnion muelleri*, and known from old records from Victor Harbor (1963), and Seal Bay on Kangaroo Island (1966), growing on drift specimens of *Cystophora platylobium* (Womersley 1998; ADHerb 2010)	1
Jania parva	Known from approximately 10 specimens, ranging from Whyalla in Spencer Gulf, through to Port MacDonnell in the lower south east of SA. Records from GSV Bioregion include Stansbury on Yorke Peninsula (type locality), and Bay of Shoals, Pelican Lagoon and Eastern Cove on Kangaroo Island.	6
Medeiothamnion repens	A small red epiphyte, found growing on *Cystophora* species (Womersley, 1998), and recorded from a number of South Australian locations, ranging from Elliston in the eastern GAB, through to Port MacDonnell in the South East (ADHerb 2010).	1

Table A1 (continued):

Red Macroalgae		
Peyssonnelia foliosa	Known from at least 92 specimens, ranging from St Francis Island in the eastern GAB, through to eastern Kangaroo Island (e.g. Kangaroo Head and Cape Hart) and Coorong. Many of the specimens are from offshore islands. Type was collected at —The Hotspot", west of Flinders Island in the eastern GAB, at 32m deep.	6
Polysiphonia propagulifera	Known from specimens collected at Troubridge Island at 23m deep, and from two sites in Investigator strait at 33m and 34m, and from Penneshaw Reef on Kangaroo Island at 11m deep. Specimens from east of Lakes Entrance in Victoria and from D'Entrecasteaux Channel in Tasmania may or may not be the same species (Womersley 2003), and further collections are necessary to determine if *P. propagulifera* is not limited to South Australia.	4
Polysiphonia shepherdii	Known from approximately 5 specimens, collectively from Waldegrave Island in the eastern GAB, and two locations in GSV (edge of Tapley Shoal 15 km east of Edithburgh, and ~3.5 km east of Troubridge Island)	4
Pterothamnion flexile	A multi-branched alga, about 4cm to 8cm long, which is known from off Outer Harbour (found growing on old shells, at 20m – 25m deep, in 1975) and Point Lowly in Spencer Gulf (record from artificial reef at 14m deep, collected 1987) (Womersley 1998; ADHerb 2010).	1
Sympodophyllum reinboldii	A rare species, epiphytic on *Dictyota*, and apparently known from only two specimens, collected in Investigator Strait in 1899, and from the type, at Pondalowie Bay off Yorke Peninsula (1955) (Womersley 2003; ADHerb 2010; Australian Virtual Herbarium 2010).	1
Tylocolax microcarpus	A small epiphyte found on *Lenormandia spectabilis* (Womersley 2003) and recorded from Point Avoid and Wanna on the Eyre Peninsula; Vivonne Bay and Pennington Bay on southern Kangaroo Island; and Encounter Bay (ADHerb 2010).	2

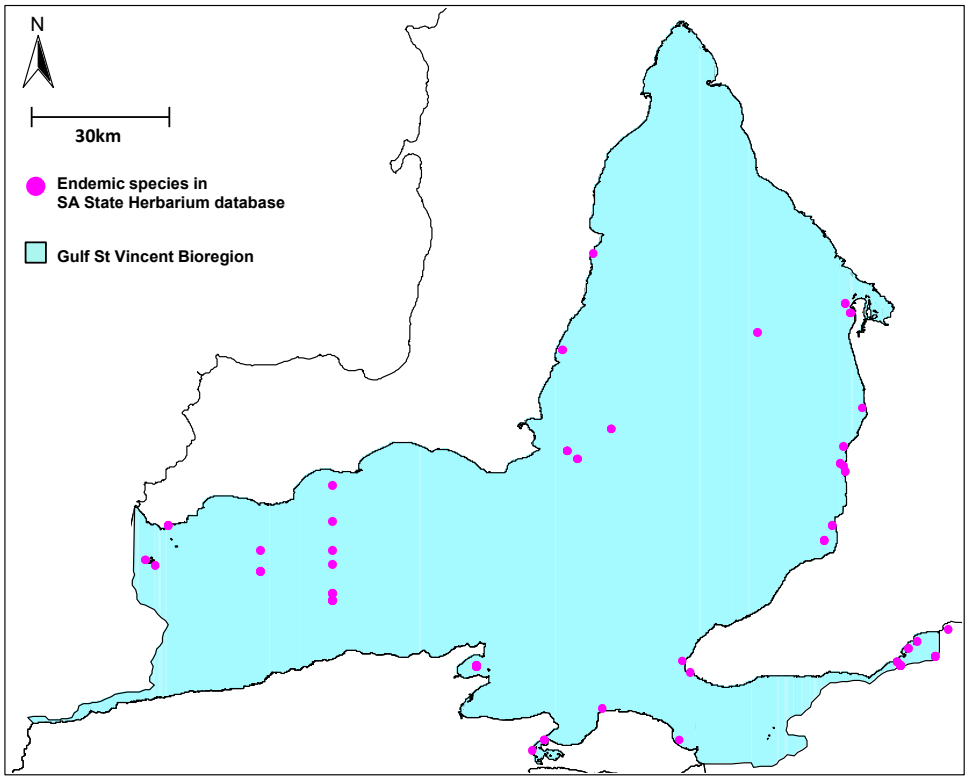


Figure A6: Distribution of records of South Australian endemic species of macroalgae, within the Gulf St Vincent Bioregion, according to SA State Herbarium database records.

Introduced and Cryptogenic Species of Macroalgae in GSV Bioregion

Introduced species recorded in GSV Bioregion, known from location-specific records in SA State Herbarium database as of 2010, are listed in **Table A2**. These include 6 species in Chlorophyta, 4 species in Phaeophyceae, and 5 species in Rhodophyta. Additionally, at least 36 species of probable cryptogenic origin in South Australia occur in the GSV Bioregion. The distribution of SA State Herbarium records of these species is shown in **Figure A7**, and cryptogenic species are detailed in Table 13 of the main report.

The three introduced species of most concern, *Caulerpa taxifolia* (number one priority), *Codium fragile* ssp. *fragile* (= *C. fragile* ssp. *tomentosoides*), and *Caulerpa racemosa* var. *cylindracea*, are discussed in the main report. In addition to metropolitan records of the three aforementioned species, there is one record of *Codium fragile* ssp. *fragile* from the American River. According to ADHerb and AVH databases, Yorke Peninsula is free from these three invasive species. As discussed in the main report, *Codium fragile* ssp. *fragile* is now considered to potentially be one of the 10 most damaging marine pest introductions in Australia (Hayes et al. 2005). This *Codium*, which can reproduce both sexually and vegetatively, may settle on native algae and shellfish, wharf pilings and jetties. In some areas, large wracks of this alga rot on beaches after storms (Trowbridge 1999; CRIMP / NIMPIS 2002). *Codium fragile* ssp. *fragile* tolerates large variations in salinity and temperature, which enables it to colonise a wide range of environments (Bégin and Scheibling 2003). Potential impacts are considered to include smothering of mussels and scallops (which can affect feeding ability, and also impede harvesting in aquaculture facilities); fouling of nets and ropes (which also aid dispersion of the alga); fouling of pylons, jetties and beaches; and also ecological impacts due to habitat degradation, and reduction in diversity of native species in heavily infested areas (Bridgwood 2010).Trowbridge (1999, cited by Bridgwood 2010) identified the potential of interbreeding as being a possible risk with native Australian con-specific *Codium* species. Impacts in southern Australia have been considerably less than those associated with *Caulerpa taxifolia*.

As shown in **Figure A7**, records of most introduced species are concentrated in the metropolitan area, other than records of the brown epiphyte *Elachista nigra*.

As mentioned above, the most significant introduced species of macroalgae in South Australia (all of which are green algae), have not yet been recorded in western GSV and Investigator Strait, including eastern and southern Yorke Peninsula, and northern Kangaroo Island. However, in these regions, a number of possibly cryptogenic species have been recorded, including:

- *Cutleria multifida* and *Ulva rigida* in the Edithburgh area (the latter has also been recorded in intertidal pools south of Edithburgh, at Goldsmiths Beach on the ~~h~~eel" of Yorke Peninsula)
- *Bryopsis plumosa* near Sturt Bay, on southern Yorke Peninsula
- *Sphacella subtilissima*, recorded in Investigator Strait in 1971
- *Hypnea valentiae* and *Ulva rigida* from the Althorpe islands
- *Hypnea valentiae*, *Chaetomorpha linum*, and *Ulva flexuosa* from the Bay of Shoals area on Kangaroo Island
- multiple records from American River in Kangaroo Island, including the following species (with number of specimens recorded to date in brackets: *Cutleria multifida* (13), *Ulva flexuosa* (10), *Hypnea valentiae* (5), *Polysiphonia brodiei* (4), *Myrionema strangulans* (3), *Bryopsis plumosa* (3), *Cladophora dalmatica* (2), *Feldmannia irregularis* (1), *Hincksia sandriana* (1), *Cladophora prolifera* (1), *Chaetomorpha ligustica* (1), and *Polysiphonia subtilissima* (1).

Table A2: Introduced species of macroalgae in the GSV Bioregion (main source: herbarium records in ADHerb 2010, the SA State Herbarium database). Species status determined according to information from CRIMP / NIMPIS 2002; Hewitt et al. 2004; Hayes et al. 2005; Sliwa et al. 2006; Cowan 2006; Womersley 1984, 1987, 1994, 1996, 2003, 2004, 2005; CSIRO, 2006; Guiry and Guiry, 2010; Baldock 2010, and record dates in ADHerb, 2010). Note: a number of globally distributed *Audouinella* species have been excluded from the table below because these are known from very few Australian records, and status in southern Australia is hard to determine. Numbers in parentheses in the Species column refer to the number of records of each species in the SA State Herbarium at the time this report was written.

Species	Type Locality	Distribution	Notes
Green Macroalgae			
Caulerpa racemosa var. *cylindracea* **(13)**	Western Australia	Australian records from WA (where it is endemic), NT, QLD and SA. South Australian records from St Kilda boat ramp and Bolivar (Wiltshire and Rowling 2009), Garden I., Port River, Outer Harbour / North Haven area and O'Sullivans Beach boat ramp and marina.	Endemic to WA, but invasive and now globally widespread (Klein and Verlaque 2008). Has aggressively spread through the Mediterranean Sea since the early 1990s (and now in 9 European countries).
Caulerpa taxifolia **(13)**	St. Croix, Virgin Islands	Recorded in Europe (4 Mediterranean countries); 11 countries in Africa; several Atlantic Islands; 6 countries in SW Asia; Mexico; Hawaii; Central America and Caribbean (11 countries); several countries in Sth America; 6 Indian Ocean islands; China; Japan; 6 countries in SE Asia; at least 4 groups of Pacific islands; Papua New Guinea; New Zealand; Australia. In Australia, known from WA, SA, NSW, Norfolk I. and Lord Howe I. SA records from locations in GSV, including Bolivar (Wiltshire and Rowling 2009), Outer Harbour / North Haven, Port River – Barker Inlet system and West Lakes.	This species is considered to be non-native in Australia (CSIRO 2006). One of the most significant invasive marine plant species ever known in southern Australia.
Cladophora prolifera **(7)**	Mediterranean	Widespread warm temperate Europe and Africa; numerous Atlantic islands; few countries in SA and SE Asia; few states in Nth America, Central America and Caribbean and Sth America; few islands in Indian and Pacific oceans; Australia & New Zealand. In Australia, recorded from all States except NT and TAS. SA records from Fowlers Bay in GAB (1994); Muston (American River on Kangaroo Island) (1996); Granite I. (1981); and locations in GSV such as The Dredge wreck off Glenelg (2005); Semaphore (2005) and St Kilda (1972). This species is common in Gulf St Vincent / AMLR NRM region (see map in Wiltshire et al. 2010).	Forms blooms in some countries (e.g. Schramm and Booth 1981). Hewitt et al. (2004), Hayes et al. (2005) & CSIRO (2006) reported this species to be non-native in Australia. Listed in Hayes et al. (2005) report on introduced pests as a low priority introduced species in Australia. There is a very large literature on this species. The occurrence in Australia has been linked with that of the introduced opisthobranch *Aplysiopsis formosa* considered to be an introduction from the North Atlantic/Mediterranean (Fuhrer et al. 1988). Has colonised and is locally abundant on exposed coastal rock platforms and deep water. However, these locations are close to international shipping lanes. Shipping must be considered a potential vector for the introduction of this species (Lewis 1999).

Table A2 (continued):

Species	Type Locality	Distribution	Notes
***Green Macroalgae* (cont.)**			
Codium fragile ssp. *fragile* (= ssp. *tomentosoides*) **(5)** (N.B. Maggs, in Brodie et al. 2007, and Provan et al. 2008), considered *Codium fragile* ssp. *tomentosoides* to be a junior synonym of *Codium fragile* ssp. *fragile*)	Japan (as *Codium fragile* ssp. *fragile*)	Widespread in Europe (~ 11 countries). Also recorded at a few Atlantic islands; few parts of Nth Africa; Turkey; Nth America (11 states); Japan; Australia, and New Zealand. In Australia, known from SA, VIC and TAS. SA records from American River on Kangaroo I. (2008); locations in GSV including North Haven (2008) and West Lakes (2002).	Hayes et al. (2005) and CSIRO (2006) reported this species to be non-native in Australia. An introduced pest species in south-eastern Australia (CRIMP / NIMPIS (2002) citing Campbell and Hewitt 1999; Trowbridge 1999), which settles on native algae and shellfish, fouls fishing nets, and in some areas large wracks of this species rot on beaches after storms.
Ulva fasciata **(1)**	Alexandria, Egypt	Widespread Africa (~ 21 countries); also Europe (~ 6 countries); various Indian Ocean islands; 5 Atlantic islands; also SW Asia (9 countries); Nth America (6 States); Hawaii; Central America / Caribbean (13 locations); and South America (~ 5 countries); China; Japan; Korea; Taiwan; SE Asia (4 countries); Papua New Guinea, Australia and New Zealand In Australia, records from WA, SA, VIC, NSW, QLD, and Norfolk Island. SA State Herbarium records from Wanna near Pt Lincoln (1959), and West Lakes in GSV (1980). An *Ulva* reported to be this species has also been found in the Glenelg area (Wiltshire et al. 2010).	Considered to be a possible introduction into Australia (CRIMP / NIMPIS 2002; Parliament of Victoria, undated; CSIRO 2006). Hewitt et al. (2004) reported this species to be introduced in Australia from the Mediterranean. Plants are often associated with high-nutrient areas (e.g. mangroves, bird roosting islands), polluted areas, near freshwater sources or in the vicinity of ports. Although there are no major impacts of this species in Australian waters to date, it is considered probable that it could become a fouling nuisance in industries that utilise shallow water areas (CRIMP / NIMPIS 2002). Hayes et al (2005) reported that *U. fasciata* can dominate/out compete and limit resources of native species.
Ulva taeniata **(5)**	Monterey, California, USA.	Recorded in few locations in Nth America, Central America and Sth America; India; Turkey; Pakistan; Korea; Australia and New Zealand. Originally from west coast USA, now considered to be naturalised in New Zealand and Australia (Baldock 2010). In Australia, known from WA, SA, VIC and TAS. SA records from eastern GAB, such as Elliston (1970), Sheringa (1981); Wanna (1959); Pennington Bay (1948) and Vivonne Bay (1950) on Kangaroo I.; Victor Harbor (1980); Robe (1960) and Beachport (1960). Recent unverified record from Pt Stanvac in GSV (Dutton and Benkendorff 2008).	CSIRO (2006) reported this species to be cryptogenic in Australia. Baldock (2010) reported this species to be introduced or adventive.

Table A2 (continued):

Species	Type Locality	Distribution	Notes
Brown Macroalgae			
Arthrocladia villosa **(1)**	Cornwall, England	Widespread Europe (> 15 countries, particularly Mediterranean); 2 countries in Africa; Nth America (6 States); few Atlantic islands; and Australia. In Australia, known from SA (Port Stanvac). No records in ADHerb 2010.	CSIRO (2006) reported this species to be non-native in Australia. Skinner and Womersley (1983) recorded unattached plants from 4-5m deep at Port Stanvac (1981) in GSV, where international ships berth, and at the time, it was not known whether the species was established (or would establish) in South Australia.
Discosporangium mesarthrocarpum **(9)**	Dalmatia (Adriatic Sea), Mediterranean	Recorded in Europe (7 countries, mainly Mediterranean); Turkey; Atlantic islands; Morocco in Africa; Hawaii. In Australia, known from SA. Records from Grange and Glenelg, on artificial tyre reefs (1987)	Reported by Aquenal (2001) to be an introduced species in Australia. CSIRO (2006) reported this species to be cryptogenic in Australia.
Elachista nigra **(40)**		Recorded in Japan and Korea, California and Australia (Guiry and Guiry 2010). Introduced to California (Kitayama et al. 2005) and possibly introduced in Australia (Womersley, 1987). In Australia, known from NSW, SA and WA, and may have been first identified as present in 1976 (Womersley 1987; Hayes et al. 2005). In AMLR NRM region, 39 records to date, on *Ecklonia radiata*. Examples include Port Stanvac, Seaford, Aldinga Reef in GSV, and Rosetta Head and Frenchmans Rock near Pullen Island in Encounter Bay.	A small epiphyte, which is found on kelps such as *Ecklonia* and *Undaria*. (NB the invasive species *Undaria* has not yet been recorded in SA, as at 2010). Formerly known as *Elachista orbicularis*.
Striaria attenuata **(1)**	Isle of Bute, Scotland	Widespread Europe (> 15 countries); Nth America (6 States); Chile in Sth America; Japan; New Zealand and Australia. In Australia, recorded from NSW, VIC, TAS and SA. SA records from Cowell (1993) and West Lakes (1978)	Sliwa et al. (2006) and CSIRO (2006) reported this species to be non-native in Australia. Considered to be an introduced species in Tasmania (Underwood 2001). An adventive species (Womersley 2003).

Table A2 (continued):

Species	Type Locality	Distribution	Notes
Red Macroalgae			
Antithamnionella spirographidis **(5)**	Trieste, Italy	Thought to have originated in the North Pacific (Lindstrom and Gabrielson 1989, cited by JNCC, 2010). Widespread Europe (~ 14 countries); also several Atlantic islands; Russia; several states in Nth America; China, Korea, Vietnam and Australia. In Australia, known from NSW, VIC and SA. SA records from Port Adelaide wharf and possibly other areas of Port Adelaide (1950 - 1958), and Port Stanvac (1972). It is noted that Blair et al. (2009, citing Campbell et al., 2005) reported date of first Australian record as being 1953.	Hewitt et al. (2004), CSIRO (2006) reported this species to be non-native in Australia. Listed in Hayes et al. (2005) report as a low priority introduced species in Australia. Reported to be an introduced species in Victoria (Parliament of Victoria, undated). Introduced to Europe prior to 1911 (JNCC 2010) and was introduced to Britain from the Mediterranean, probably carried on the hulls and mooring ropes of ships, although it could also have been introduced with oysters. Spreads successfully due to very rapid vegetative reproduction / fragmentation and the rapid production of new thalli. It can be easily dispersed through shipping activities, aided by its ability to grow on ropes, buoys and other artificial surfaces such as plastic (JNCC 2010).
Chondria arcuata **(1)**	Laguna Beach, Orange County, California, U.S.A.	Recorded from few countries and few States, including Nth America (California); Mexico; Africa (Morocco); Korea; French Polynesia; Hawaii; New Zealand and Australia. In Australia, known from VIC and SA. SA records from Port Noarlunga (1987)	Hewitt et al. (2004), CSIRO (2006) and Sliwa et al. (2006) reported this species to be non-native in Australia. Considered in Tasmania to be an introduced species (Tasmanian Planning Commission, 2009).
Cottoniella fusiformis **(5)**	Playa de Santa Catalina [Las Palmas], Canary Islands.	Records in few areas, such as various Atlantic islands (Canary Is.; Madeira Salvage Is.); Libya in Africa; Pakistan; and Australia. Australian records from SA. SA records from locations in GSV, including Grange tyre reef (1985), Seacliff reef (1986, 1km N of Port Stanvac (1988) and Port Noarlunga (1987).	CSIRO (2006) reported this species to be non-native in Australia.

Table A2 (continued):

Species	Type Locality	Distribution	Notes
***Red Macroalgae* (cont.)**			
Gymnogongrus crenulatus **(6)**	Oporto, Portugal	Recorded to date in ~ 8 countries in Europe; also Atlantic islands; Turkey; few parts of Africa; few parts of Nth and Sth America; Canada (LeGall and Saunders, 2010), Australia and New Zealand. In Australia, records from NSW (e.g. Port Jackson), SA, VIC (e.g. Port Phillip Bay). SA records from Topgallant I. in GAB (1992); locations in GSV such as Port Noarlunga (1993), Henley Beach (1992), and Barcoo outlet at West Beach (2009); and Robe jetty in upper SE SA (1991).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be non-native in Australia. CSIRO (2006) recorded the introduction date into Australia (Port Philip Bay) as 1969. Womersley (1994) considered that the species may be adventive, since most Australian specimens are from near harbours. Hewitt et al. (1999, 2004) and Parliament of Victoria (undated) recorded it as an introduced species in Victoria. Listed in Hayes et al. (2005) report as a low priority introduced species in Australia.
Schottera nicaeensis **(1)**	Marseilles, France	Widespread Europe (~ 14 countries, mostly in Mediterranean); several countries in Africa; few countries in SW Asia; few locations in Sth America and Atlantic islands; and Australia. In Australia, records from NSW, VIC (especially Pt Phillip Bay), TAS and SA. SA records from Stony Point in upper Spencer Gulf (2006) on a *Trichomya* mussel, and Glenelg (1970).	Hewitt et al. (2004) and CSIRO (2006) reported this species to be non-native in Australia. Listed in Hayes et al. (2005) report as a low priority introduced species in Australia. Lewis and Kraft (1979) hypothesised that the species was introduced from Europe into Port Phillip Bay in Vic during the 1970s, and suggested shipping as a possible means of importation. Considered in Tasmania to be an introduced species (Anonymous 2009).

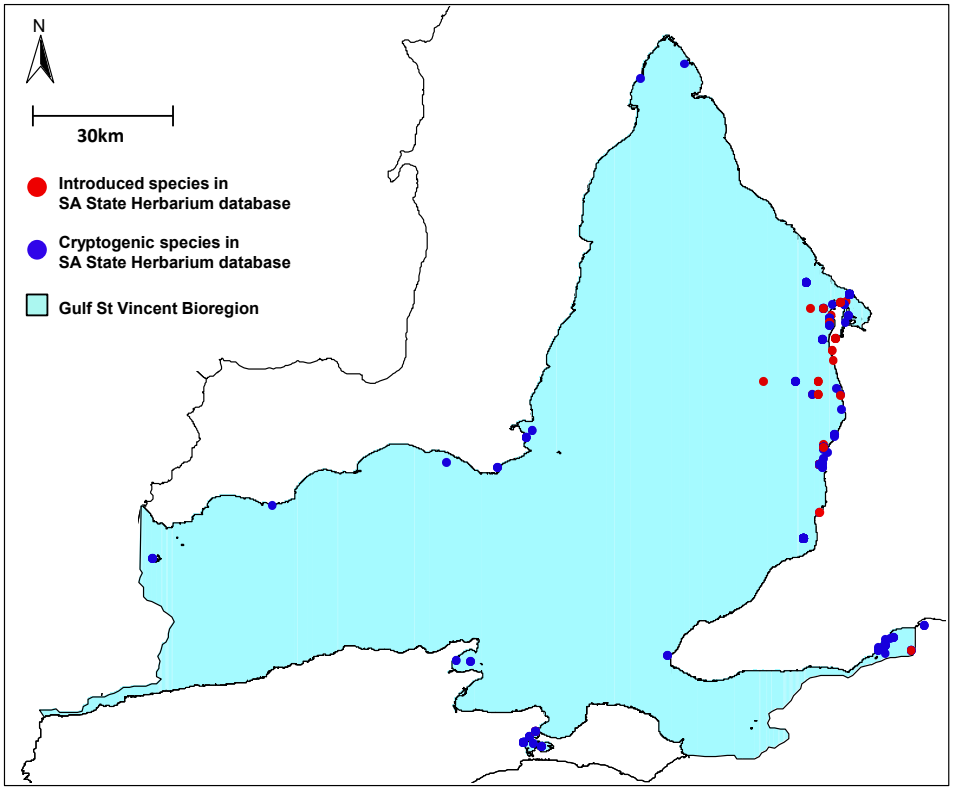


Figure A7: Distribution of SA State Herbarium records of introduced species in the GSV Bioregion.

Macroalgae in Aquatic Reserves - western GSV Bioregion

In the main report, Table 14, Figure 28 and Appendix 2 collectively describe and discuss species records from ADHerb (2010) that occur in each of the Aquatic Reserves in the AMLR NRM region, including introduced species and endemic species. The AMLR NRM region forms the eastern section of the GSV Bioregion, and composition of macroalgae in those reserves will not be reiterated here. Of the several reserves the western part of the GSV Bioregion, details of significant species recorded to date are discussed below in **Table A3**. The Aquatic Reserves of the GSV Bioregion are shown in **Figure A8**. Note that the number of species of macroalgae recorded in the Aquatic Reserves is significantly underestimated by records in the South Australian Herbarium. A complete inventory of species has not been made in these reserves, and the true numbers of species present is significantly higher than those presented here. It is therefore likely that the number of endemic species, and possibly also invasive species, has been similarly underestimated by the limited number of records in ADHerb to date from the Aquatic Reserves.

Table A3: Numbers of records, species, South Australian endemic species, and introduced species in the Aquatic Reserves situated within the western part of the GSV Bioregion, according to SA State Herbarium data sets (ADHerb 2010). Species records within 200m of reserve boundaries are included.

Aquatic Reserve	No. Species	No. Records	Endemic Species	Introduced Species
Coobowie	3	5	-	-
Troubridge Hill	61	143	-	-
American River	97	304	*Callithamnion shepherdii* (records of this species also adjacent to northern boundary of reserve) *Haraldia australica*	*Codium fragile* ssp. *fragile* (+ 5 cryptogenic species in the reserve, and another 6 cryptogenic species adjacent to the northern boundary of the reserve)

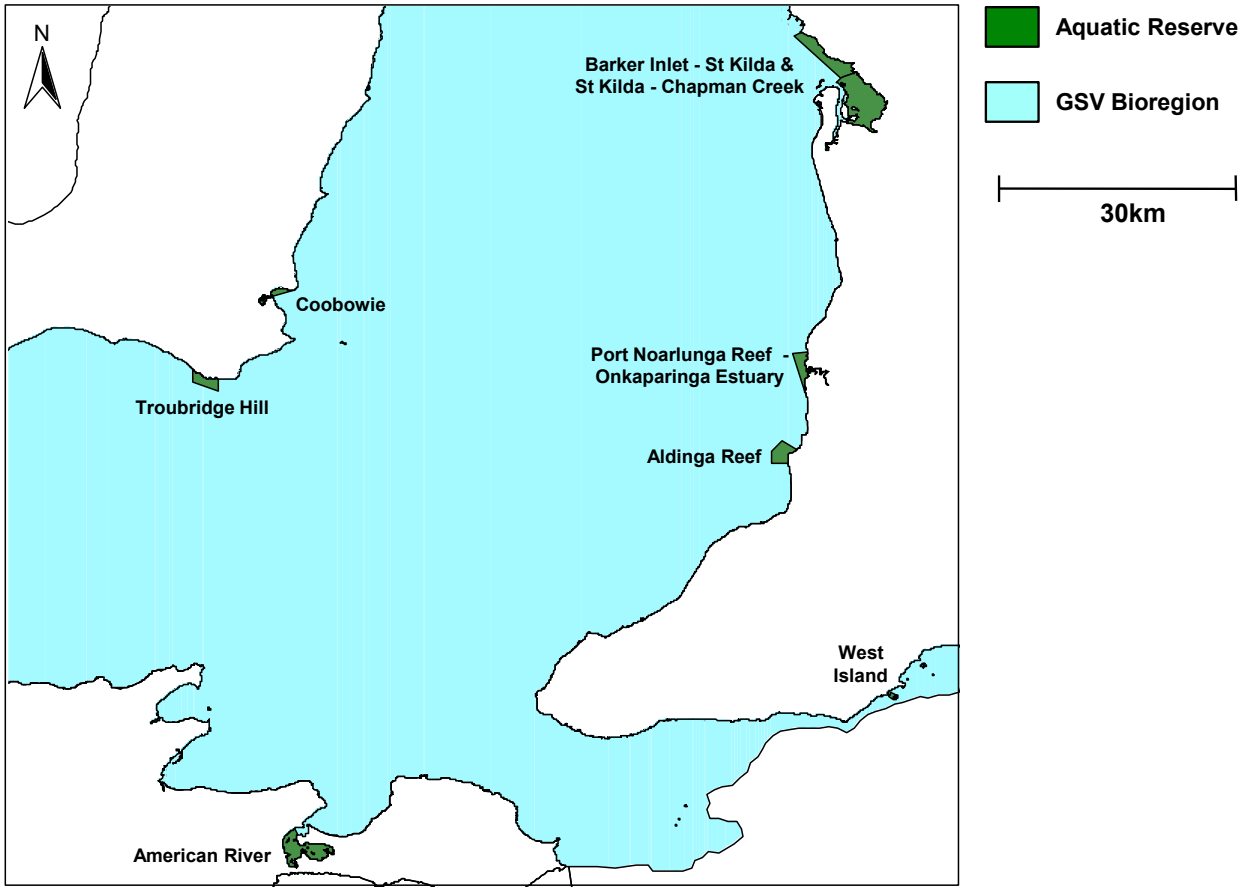


Figure A8: Location of Aquatic Reserves in GSV Bioregion

Conclusions and Recommendations

Endemic Species
Endemic species and other potentially threatened, rare or uncommonly recorded species, including species with limited known geographical range, are discussed in detail in the main report. As is the case for the AMLR NRM region, records in much of the GSV Bioregion are sparse, and span many decades. Within the bioregion, such records are concentrated in the best sampled areas, such as Port Noarlunga area, Aldinga, Encounter Bay, and a well surveyed ~~"s~~trip transect" in Investigator Strait, between southern Yorke Peninsula and northern Kangaroo Island (surveyed by J. Watson in 1971).

For all of these areas, it is not known whether previously recorded endemic species still exist in the areas where they were originally collected, because targeted searches have not been made, and some of the areas where such species were previously recorded have been subject to numerous impacts, as discussed below. For example, Tanner (2003, 2005) discussed the significant changes to the benthos that have occurred in Investigator Strait, particularly in relation to prawn trawling.

Many of the South Australian endemic species are small, inconspicuous epiphytes. Such species are likely to be more widespread but have not yet been sampled.

Introduced Species
One of the three most significant species of introduced macroalgae known from SA State Herbarium records, *Codium fragile* ssp. *fragile* (= ssp. *tomentosoides*), has apparently been recorded in American River in 2008 (South Australian Herbarium record, collected by M. Kinloch, 2008), yet not recorded in a recent assessment of introduced species on Kangaroo Island (Kinloch et al. 2010), nor in the list of introduced species in the KI NRM Board's (2009) *Kangaroo Island Natural Resources Management Plan.* Given the fact that this species has spread in other countries where it has been introduced, and is also considered to be a pest in south-eastern Australia (see main report for examples), the potential for spreading in Gulf St Vincent and on Kangaroo Island should be investigated. Measures to control such an occurrence should be undertaken where possible (see main report for information about the apparent ineffectiveness of control methods to date).

Two other invasive species, *Caulerpa taxifolia* and *C. racemosa* var. *cylindracea*, apparently have not yet been recorded in the waters of Yorke Peninsula or Kangaroo Island (Kinloch et al. 2009; SA State Herbarium data; Wiltshire et al. 2010). Both species are part of a regular monitoring program by Primary Industries and Resources South Australia and SARDI Aquatic Sciences (e.g. Rowling 2008, 2009; Wiltshire and Rowling 2009).

The various species of *Ulva* and *Cladophora* highlighted in the main report and in this supplement as being introduced or cryptogenic should be monitored in nutrient-rich locations (such as port areas, and estuaries), for their potential to bloom. A number of these species have been responsible for "~~g~~reen tides" in other countries. One of the potential "~~b~~loom" species of *Cladophora*, *C. prolifera*, has been recorded in American River, and is commonly reported along the eastern side of Gulf St Vincent (Wiltshire et al. 2010). Possibly cryptogenic species with the capacity to form seasonal algal blooms in eutrophic conditions (e.g. species in *Hincksia*), should also be monitored, and some of these species occur in the GSV Bioregion.

Calcareous Macroalgae
The main report discusses the crucial role that calcareous macroalgae play in building and maintaining temperate reefs, and the lack of knowledge about the true abundance, distribution and biodiversity of crustose calcified red macroalgae in the GSV region is a concern (**Figure A5**). Calcareous macroalgae are threatened by climate change, particularly ocean acidification (see summary in main report), and efforts are required to protect the calcareous reef flora that currently exists, from additional anthropogenic stresses such as physical damage (e.g. from boats, anchors, dredging etc), sediment smothering, and nutrient enrichment. Such protection may help calcareous reefs to persist longer in the face of ongoing stresses which are harder to control, such as ocean acidification from climate change.

Summary of Impacts in Part of the Western GSV Bioregion
The main report discusses the degradation of habitats that support macroalgae in the AMLR NRM area, and much of that discussion is pertinent to other parts of the GSV bioregion, including (i) macroalgae-dominated reefs; (ii) seagrass beds which support abundant epiphytic macroalgae (i.e. naturally occurring epiphytes, not opportunistic blooming species that replace the original flora in conditions of nutrient-enrichment), and (iii) hard substrates such as shells beds, which support epilithic macroalgae.

Although the western part of the GSV bioregion, with low population levels and no major urban developments, has apparently not lost the significant amount of canopy cover that has occurred in the metropolitan area (e.g. Connell et al. 2008), some benthic habitats (including reefs) are still at risk from coastal developments, such as boat harbour construction and maintenance, and holiday or retirement housing developments and other coastal building works. Examples include north-eastern Kangaroo Island, and southern and south-eastern Yorke Peninsula.

As is the case with the metropolitan area, increased nutrients and sedimentation also impact marine habitats in other parts of the GSV bioregion. Physical disturbance, sedimentation and increased nutrient and chemical run-off from such works can impact on nearshore reefs and seagrass beds, and therefore on the cover of macroalgae. A significant, ongoing source of sedimentation to coastal reefs in GSV Bioregion is from coastal rivers, creeks, stormwater drains and artificial channels.

On the western side of Gulf St Vincent and on north-eastern Kangaroo Island, examples of developments and activities which may adversely affect macroalgae on reefs, and also seagrass beds which support macroalgae, include the following:

Coastal developments: in western GSV, building activity reportedly increased between 10 and 25 per cent in coastal towns during the decade to 2000 (Senate Inquiry into GSV, evidence presented to Parliament of South Australia 2000, Baker 2004). During the 2000s, there was further development in a number of coastal towns, such as Marion Bay and other locations that have become increasingly popular for holiday and/or retirement housing, and where new waterfront housing developments are occurring.

Additionally, there are many tourists that visit Yorke Peninsula, and use caravans and campsites. During the past decades, few regional towns have had a common effluent drainage scheme and they generally use septic systems. Shacks, houses and other buildings may be situated on the edge of rivers and creeks, and the coast. This proximity to the water can result in polluted runoff from septic systems flowing untreated into waterways, and causing environmental impacts, particularly due to increased nutrients and sediments. Coastal towns such as Edithburgh, Coobowie, Stansbury, and Port Vincent have previously been highlighted in this regard (Senate Inquiry into GSV, evidence presented to Parliament of South Australia 2000; Bryars 2003).

Land reclamation, as part of coastal developments, may also result in physical destruction of habitat, sedimentation, and increased turbidity from suspended sediments. Land reclamation occurs as part of port upgrades (e.g. Port Giles), or for marina construction (Port Vincent) or waterfront housing developments (e.g. Ardrossan and Marion Bay).

Boating activity: There is reported loss of seagrass adjacent to townships in the western part of the GSV bioregion, possibly due to boats mooring in the region, which may cause benthic damage, for example, due to scouring by hulls and anchors. This activity combined with effect of effluent discharge may be contributing factors in the depletion of seagrass adjacent to townships (Baker 2004);

Introduced species: These may be introduced from shipping and ballast water exchange, and there is potential at such locations as Port Giles, and other shipping ports in the western part of the GSV Bioregion. Some introduced species of macroalgae may be introduced and spread by boating activity and fishing equipment, and vigilance is required to prevent such spread.

Nutrient enrichment: Perhaps the greatest potential impact on benthic environments in the GSV bioregion is increased nutrients. On naturally nutrient-poor coasts, sudden increases in nutrient concentrations from coastal run-off can have a disproportionately large impact (Connell et al. 2008; Gormon 2009). One pertinent example is the Nepean Bay area on Kangaroo Island. There has been considerable loss of seagrass in the Nepean Bay catchment (around 2,700 hectares, according to Hale 1997 and Gray 2000), including Western Cove. During the late 1990s, there was concern about opportunistic epiphytic algae smothering remaining seagrass in parts of the Western Cove area (Gray, 2000). Possible causes for the decline were reported by Edyvane (1997), Flaherty (1997), Gray (2000), Bryars (2003), and Southgate (2004). High nutrient loads and sediments, particularly from the Cygnet River and surface runoff, as well as saline seepage from land clearing have been identified as potential causes of current elevated nutrient levels and seagrass loss in Western Cove area of Nepean Bay. Turbidity and/or sedimentation caused by agricultural run-off from the Cygnet River may also have contributed to the seagrass loss. Diffuse agricultural runoff in the Western Cove area of Nepean Bay may also be a threat to habitats. Richards (2001) reported that causes being investigated include ~~-n~~utrient-loaded groundwater discharging into the town storm water and effluent water and into the bay". The discharge of agricultural runoff from Cygnet River, with observed impact due to nutrient enrichment in seagrass beds in Western Cove of Nepean Bay, is considered by the Environment Protection Authority a significant threat in the area (Gaylard 2009). There has been some loss of seagrass from the eastern part of the Nepean Bay area (e.g. Eastern Cove and American River), but less pronounced than in the Western Cove area (J. Baker, pers. obs. 1994, 2008).

Hale (1997) and Flaherty (1997) discussed concerns about the existing and more recent developments (i.e. STED scheme) for sewage treatment facilities in the Kingscote area, and their relation to the Cygnet River / Nepean Bay system. Previously, Gilliland (1996) reported that there is potential marine pollution associated with townships such as Kingscote, and that several other pollution sources in the Western Cove area have included the effluent ponds associated with the Kingscote common effluent disposal system, and a disused rubbish dump site. There are effluent ponds at Brownlow, and the increased nutrient levels caused by effluent leakage from the ponds, and also from septic tank overflows in the Nepean Bay settlement, and at Emu Bay, American River, Island Beach, Baudin Beach and Penneshaw, are considered to be a potential threat to habitats in those areas (Bryars 2003; Kinloch 2005). The increased level of nutrients caused by stormwater in the Kingscote area (e.g. there is an outfall near the Kingscote yacht club) is considered to be a localised habitat threat (Edwards 1987, cited by Edyvane 1999; Bryars 2003). A fish processing plant at Kingscote may cause an increased level of nutrients in the area (Bryars 2003).

There is sewage and other effluent pollution in Eastern Cove and American River, from sewage outfall pipes and runoff (e.g. sewage outlets along the foreshore north of Pelican Point, and at American River, from hotels, motels and residential development). Concern about effluent disposal in the area has been documented since at least the 1980s (see Edwards 1987). Two licensed sewage outfalls at American River are used for stormwater runoff, rather than sewage, according to Gilliland (1996). In 1998, the State Government's Environment, Resources and Development Committee recommended that the effluent outfall problem at American River be resolved as a matter of urgency.

There have been impacts resulting from the proliferation of subdivisions that have occurred on the banks of Eastern Cove during the past decade (e.g. untreated effluent disposal). Benthic sampling in 1994 showed that 50% of the seagrass was dead at Newland Bay and Rocky Point (near Island Beach), and covered with filamentous epiphytes. There is anecdotal evidence to suggest contamination of local molluscs in the American River area, due to effluent impacts (Flaherty 1998; M. McKelvey, pers. comm. 1999).

On the eastern edge of Kangaroo Island, according to the Kangaroo Island Coastal Protection District Study Report (Edwards 1987, cited by Edyvane 1999), the golf course, effluent ponds, and rubbish dump located north of Cygnet River have caused ~~-e~~xtensive modification of the catchment area", however details were not provided.

Other impacts: During the past decade, other marine environmental issues in the north-eastern Kangaroo Island area have included the following (from Kinloch 2005):

- physical disturbance, and increased turbidity and sedimentation from channel dredging operations at Christmas Cove and Penneshaw, and proposed wharf redevelopment and marina construction at Kingscote;
- alterations to current flows and depositional patterns from permanent breakwaters at Penneshaw;
- physical disturbance caused by boat moorings and boating activities, mainly at Kingscote, Island Beach, American River and Pelican Lagoon;
- hydrocarbon pollution from boating activity at Kingscote and Island Beach, and in American River and Pelican Lagoon;
- increased turbidity and sedimentation caused by KI ferry operations at Penneshaw and grain barge activities at Kingscote (Kinloch 2005).

Many of the processes described in the preceding paragraphs can adversely impact (i) macroalgae-dominated reefs (resulting, for example, in displacement of canopy-forming species with turfing species), and (ii) seagrass beds, in which the natural load of epiphytic macroalgae can be replaced by opportunistic species, including cryptogenic species, in conditions of nutrient increase from effluent discharge.

Impact Assessment and Monitoring

Programs to monitor and mitigate impacts in the eastern part of the GSV Bioregion (AMLR NRM region) are discussed in the main report accompanying this supplement. A number of government, industry and community-based monitoring programs have been occurring since the mid 1990s in the western part of the GSV Bioregion. For example, during the late 1990s and early 2000s, monitoring projects studied the effects of seagrass loss in the Nepean Bay area (e.g. Edyvane 1997; Gray 2000; Southgate 2004). Also, during that time, there was a collaborative government and community-based program for monitoring reef health in the Dudley Peninsula / Hog Bay region (e.g. KI-AMCS 2000). There was community and school involvement with the Coastcare Hog Bay Monitoring Project, for monitoring of impacts on reefs, and sand movement in the area (KI-AMCS 2000). The Hog Bay program also included a facts and resources register, which included heritage information and marine scientific information (McKelvey 1997).

At Pelican Lagoon in inner American River, a research centre that previously was concerned mainly with terrestrial flora and fauna studies has also been involved with marine habitat studies (for example, as part of a Coastcare project monitoring the seagrass ecosystem at Pelican Lagoon, and documenting long term changes in the seagrass beds since the 1940s - e.g. McKelvey, 1997 and Pelican Lagoon Research Centre promotion materials, 2001-2003). More recently, the Kangaroo Island Natural Resources Management Plan (KI NRM Board 2009) has provided guidelines for ~~"m~~monitoring, evaluating, reporting, learning and improving" (MERLIN) with regard to the management of natural resources in the region. Two of the numerous goals of this management plan are improved water quality, and maintaining ~~"fu~~nctioning, resilient ecosystems". The threat to marine habitats and biodiversity from coastal discharges and other contaminating processes has also been recognised in the Northern and Yorke NRM's Integrated Natural Resources Management Pan (2003). One of the stated targets of that Plan was maintaining coastal and marine ~~"ha~~bitat integrity". Two of the Plan's ~~"re~~source condition targets" were:

- ~~"p~~rogressive reduction in average and peak nutrient loads and turbidity levels in point source and diffuse discharges to the marine environment, with clear targets determined" (by 2004) and

- ~~"in~~vestigate impact of point source and diffuse contamination from urban and industrial areas upon watercourses and marine waters" (by 2006)

(Northern and Yorke Agricultural District Integrated Natural Resource Management Committee Inc, 2003, p. 71 and p. 132).

Two of the management targets / recommended actions were

- ~~"e~~stablish register or database of pollution incidents, sources and their impact on the marine environment" (by 2004), and

- ~~"e~~stablish representative monitoring program for terrestrial, coastal and marine biodiversity focussing on areas subject to water contamination and other threatening processes" (by 2004).

(Northern and Yorke Agricultural District Integrated Natural Resource Management Committee Inc. 2003, p. 103).

By the end of 2004, a summary target was:

- the ~~"p~~rogressive improvement in the quality of marine waters that are subject to diffuse and point source land based discharges, through reduction of contamination loads in those discharges; clear water quality targets for discharges and receiving waters to be established"

(Northern and Yorke Agricultural District Integrated Natural Resource Management Committee Inc. 2003, p. 134).

The degree to which these targets have now been achieved should be investigated, given the date of the Plan, and the importance of ongoing impact assessment and monitoring in the nearshore marine environment. This is especially pertinent in areas of Yorke Peninsula that are subject to increasing urbanisation through marina construction and housing developments.

Significant steps have been undertaken during the past decade to address the long term issue of declining water quality (including nutrient enrichment and sedimentation) in the western GSV bioregion, which has an impact on macroalgae-dominated reefs and seagrass beds and other substrates that support macroalgae.

Recommendations for Monitoring and Impact Management
Recommendations for continued management actions that may help to ensure the persistence of remaining healthy reefs and seagrass beds, and the restoration of degraded reefs and seagrasses through the 21st century, include the following:

- continued assistance for watercourse improvement and land management works;
- continued restoration and management of rivers and land upstream to stop erosion and reduce the amount of sediment that enters rivers and creeks (and thus ends up on coastal reefs), particularly during peak load times as occurs after major storms
- building of settlement or sediment ponds to reduce the amount of stormwater reaching the sea
- continued treatment and recycling of wastewaters on land, and reduction of effluent-rich flows to the sea
- where possible, particular protection of existing Aquatic Reserves and proposed Sanctuary Zones of marine parks from physical impacts, nutrient enrichment, and sedimentation, particularly those which are known to provide habitat for apparently endemic / limited range species of macroalgae
- prohibition of dredge spoil dumping in intertidal and subtidal areas, which not only degrades reef habitats, but increases the potential for opportunistic and invasive species to occupy the degraded habitats, and proliferate
- continued monitoring of Aquatic Reserves, ports and harbour areas for marine pest species, given the potential for some of the introduced species of macroalgae to spread to Yorke Peninsula and Kangaroo Island (e.g. there is a commercial vessel that moves between Kingscote and Port Adelaide, and many recreational and commercial vessels cross Backstairs Passage between Cape Jervis and Kangaroo Island)
- protection of reefs on which calcareous flora are a dominant feature (e.g. parts of southern Yorke Peninsula), from anthropogenic stresses such as physical damage (e.g. from boats, anchors, dredging etc), sediment smothering, and nutrient enrichment. Such protection may help calcareous reefs to persist longer in the face of ongoing stresses which are harder to control, such as ocean acidification from climate change;
- long-term and regular assessment of progress to improve coastal water quality and the condition of marine and coastal habitats
- monitoring data must be recorded in databases and adequately warehoused, to serve as the baseline data necessary to detect long term changes in the marine environment.

Summary of Information Gaps, and Recommendations
As shown in the main report on AMLR NRM region accompanying this supplement, little is known of the species-specific composition of macroalgae in many parts of the GSV Bioregion. Examples of areas for which more information is required include:

- the upper north-eastern part of GSV (including the northern boundary area of AMLR NRM)
- much of the lower Fleurieu Peninsula (particular the area north of Cape Jervis, and Backstairs Passage and surrounds)
- Investigator Strait
- northern Kangaroo Island
- much of the central gulf region (particularly waters deeper than 10m)
- further east along the coast from Cape Jervis to Encounter Bay, and
- the Aquatic Reserves, particularly those along Yorke Peninsula. .

Targeted searches are required to determine the current distribution and relative abundance of species known from few records, and for many species, this is a large undertaking. Targeted searches are also required to better determine the distribution of many of the small, inconspicuous epiphytes considered endemic within South Australia. Most of the latter are currently considered rare, based on the paucity of records. Many of endemic epiphytes are likely to be more widespread, but have not yet been sampled due to their small size, and/or cryptic habits.

The main report on macroalgae of the AMLR NRM area discusses the difficulties in determining the true status of species that appear rare, but for which no systematic searches have been made, and for which records are old and opportunistic. Without targeted surveys, true assessment of the biodiversity is not possible, including reliable information regarding presence or absence of rare, endemic, invasive and cryptogenic species over the range.

This report has provided some indication of the species composition of marine flora in various parts of the GSV Bioregion. The extent of the knowledge here provided is based on historical herbarium record databases (ADHerb 2010, and AVH 2010). Even in the absence of future research effort to learn more about the diversity, distribution, relative abundance and conservation status of macroalgae in the region, biodiversity conservation efforts should include protection of representative habitats that support macroalgae throughout the region.

References

Anonymous (2009) *State of the Derwent Estuary 2009* http://www.derwentestuary.org.au/file.php?id=386

Aquenal Pty Ltd (2001) *Final Report: Exotic Marine Pests Survey - Port of Launceston, Tasmania.* Report by Aquenal Pty Ltd Aquatic Environment Analysts, for Port of Launceston Pty Ltd to meet the requirements of the AQIS Decision Support System (DSS)for Ballast Water Management. November 2001.

Aquenal Pty Ltd (2004) *Final Report: Exotic Marine Pests Survey - Port of Burnie, Tasmania.* Report by Aquenal Pty Ltd Aquatic Environment Analysts, for Burnie Port Corporation Pty Ltd to meet the requirements of the AQIS Decision Support System (DSS) for Ballast Water Management. June 2004

Aquenal (2006) *Exotic marine pests survey, Lord Howe Island, New South Wales.* Report by Aquenal Pty Ltd Aquatic Environment Analysts for the New South Wales Marine Parks Authority.

Australian Virtual Herbarium (2010) *Australia's Virtual Herbarium*. Web site by Council of Heads of Australasian Herbaria Inc. http://www.ersa.edu.au/avh/index.jsp

Baker, J.L. (2004) *Towards a System of Ecologically Representative Marine Protected Areas in South Australian Marine Bioregions - Technical Report*. Report for Coast and Marine Conservation Branch, Department for Environment and Heritage, South Australia. 1250p. http://www.environment.sa.gov.au/marineparks/pdfs/part_1.pdf

Baker, J.L., Edgar, G.J. and Barrett, N.S. (2005) Subtidal macroflora of the Althorpe Islands, South Australia. *Transactions of the Royal Society of South Australia* **129**(2): 128-144.

Baldock, R.N. (2010) *Identification Factsheets of the Marine Benthic Flora (Algae) of Southern Australia.* State Herbarium of South Australia.

Baldock, R. N. and Womersley, H.B.S. (2005) Marine benthic algae of the Althorpe Islands, South Australia. *Transactions of the Royal Society of South Australia* **129**: 116-127.

Bégin, C. and Scheibling, R.E. (2003) Growth and survival of the invasive green alga *Codium fragile* ssp. *tomentosoides* in tide pools on a rocky shore in Nova Scotia. *Botanica Marina* **46**: 404-412.

Blair, D., Momigliano, P., Garrard, S. and Heimann, K. (2009) *Review of genetic probe development for invasive marine species, with a focus on choice of target gene and on DNA amplification technology.* March Interim Report (Part 2) to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns. 33p.

Bridgwood, S. (2010) *Codium fragile* ssp. *fragile* (Suringar) Hariot: summary document. Fisheries Research Report No. 202. Department of Fisheries, Western Australia. 12p.

Brodie, J., Maggs, C.A. and John, D.M. (2007) *Green Seaweeds of Britain and Ireland.* British Phycological Society, London. 242p.

Campbell, M.L. and Hewitt, C.L. (1999) A bay-wide survey for introduced species in Port Phillip Bay 1995-1996, In: Hewitt, C.L., Campbell, M.L., Thresher, R.E., and Martin, R.B. (Eds*) Marine Biological Invasions of Port Phillip Bay, Victoria*. CRIMP Technical Report No. 20, CSIRO Marine Research, Hobart, Australia.

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

Cowan, R. (2006) *Australian Marine Algal Name Index*. Database by R. Cowan, Murdoch University, Western Australia, for the Australian Biological Resources Study, Canberra.

CRIMP / NIMPIS (2002) *Codium fragile* ssp. *tomentosoides* species summary. In: Hewitt, C.L., Martin, R.B., Sliwa, C., McEnnulty, F.R., Murphy, N.E., Jones, T. and Cooper, S. (Eds) *Centre for Research on Introduced Marine Pests: National Introduced Marine Pest Information System*. http://crimp.marine.csiro.au/nimpis.

CRIMP / NIMPIS (2002) *Ulva fasciata* species summary. In: Hewitt, C.L., Martin, R.B., Sliwa, C., McEnnulty, F.R., Murphy, N.E., Jones, T. and Cooper, S. (Eds) *Centre for Research on Introduced Marine Pests: National Introduced Marine Pest Information System*. http://crimp.marine.csiro.au/nimpis.

CSIRO (2006) *Algae - marine incursions*. (Spreadsheet from CSIRO Marine and Atmospheric Research, Hobart).

CSIRO (2009) Turning the ‗green tide' in the Yellow Sea. CSIRO media release. Tuesday, 18th August 2009. http://www.intecol10.org/media/CSIRO_Green%20Tide_JKeesing.doc.

Dutton, A. and Benkendorff, K., (2008) Biodiversity Assessment and Monitoring of the Port Stanvac Intertidal Reef, A Report to the Adelaide and Mt Lofty Natural Resource Management Board, School of Biological Sciences, Flinders University, June 2008.

Edwards, G. (1987)*Kangaroo Island Coast Protection District Study Report.* Coastal Protection Board of South Australia, Department of Environment and Planning, Adelaide, S.A.

Edyvane, K. (1997) Seagrass Loss in Nepean Bay: The Need for Integrated Catchment Management. Report prepared for Primary industries Kangaroo Island (PIKI) and the Kangaroo Island Integrated Catchment Management Committee (KIIMCMC) SARDI Aquatic Sciences Report.

Edyvane, K. (1999b)*Conserving Marine Biodiversity in South Australia – Part 2 – Identification of Areas of High Conservation Value in South Australia.* SARDI Report Number 39, Primary Industries and Resources, South Australia.

Edyvane, K.S. and Baker, J.L. (1998a) Marine Benthic Survey of the Investigator Strait – Gambier Isles, South Australia. Report prepared for Environment Australia (Marine Protected Areas Program): Project D801 (Stage 4). SARDI Aquatic Sciences, South Australia.

Flaherty, T. (1997) (i) Kingscote sewage farm upgrade. *Southern Regional Ripples:* Newsletter of the Marine and Coastal Community Network **4**(3): 5. (ii) Tuna proposals for Kangaroo Island. *Southern Regional Ripples:* Newsletter of the Marine and Coastal Community Network **4**(2): 5.

Flaherty, T. (1998) Effluent problems still unresolved at American River. *South Australian Regional Ripples:* Newsletter of the Marine and Coastal Community Network **5**(2):2.

Fuhrer, B., Christianson, I.G., Clayton, M.N., and Allender, B.M. (1988) *Seaweeds of Australia.* Reed Books, Sydney, Australia.

Gaylard, S. (2009) *A risk assessment of threats to water quality in Gulf St Vincent*. Environmental Protection Authority, South Australia.

Gilliland, J. (1996) Kangaroo Island Aquaculture Management Plan. Primary Industries South Australia (Aquaculture), Adelaide.

Gorman, D. (2009) Declining water quality as a driver for changes in subtidal communities. Ph.D thesis, School of Earth and Environmental Sciences, University of Adelaide, South Australia.

Gray, L. (2000) Island community rallies for seagrass survival. *Southern Fisheries* **7**(1): 27.

Guiry, M.D. and Guiry, G.M. (2010) *AlgaeBase*. World-wide electronic publication. National University of Ireland, Galway. http://www.algaebase.org.

Hale, A. (1997) Kingscote sewage treatment effluent pond update. *South Australian Regional Ripples:* Newsletter of the Marine and Coastal Community Network **4**(4): 8.

Hayes, K., Sliwa, C., Migus, S., McEnnulty, F. and Dunstan, P. (2005) *National priority pests: part II. Ranking of Australian marine pests.* An independent report undertaken for the Department of the Environment and Heritage by CSIRO Marine Research, Hobart.

Hewitt, C.L., Campbell, M.L., Thresher, R.E. and Martin, R.B. (1999) *Marine Biological Invasions of Port Phillip Bay, Victoria.* Centre for Research on Introduced Marine Pests. Technical Report No. 20.CSIRO Marine Research, Hobart, 344pp.

Hewitt, C.L., Campbell, M.L., Thresher, R.E., Martin, R.B. and 15 co-authors (2004) Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Marine Biology* **144** (1): 183-202.

IMCRA Technical Group (1998) *Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments*. Version 3.3. Environment Australia, Canberra.

JNCC (Joint Nature Conservation Committee) (2010) *Antithamnionella spirographidis*. http://www.jncc.gov.uk/page-1672

KI-AMCS (2000) (Untitled draft) Submission to government, proposing a marine park for north-eastern Kangaroo Island. Draft prepared by Australian Marine Conservation Society, Kangaroo Island Branch, and Marine and Coastal Community Network, South Australia.

Kangaroo Island Natural Resources Management Board (KI NRM Board) (2009) *Kangaroo Island Natural Resources Management Plan 2009.*Volume 1: State of the Region 2009. Volume 5 – Monitoring, Evaluating, Reporting, Learning and Improving NRM (MERLIN). KI NRM Board, South Australia.

Kinloch, M. A. (2005) *Review of Kangaroo Island Marine, Coastal and Estuarine Biodiversity Monitoring and Research Programs*. Kangaroo Island Natural Resources Board, Kingscote.

Kinloch, M.A., Brock, D.J. and Lashmar, K.G. (2009) *Kangaroo Island Marine Pest Surveys 2008–2009.*KI NRM Board Coast and Marine Program Report No.CMP09/008.

Kitayama, T., Miller, K.A. and Silva, P.C. (2005) First record of *Elachista nigra* (Chordariales, Phaeophyceae) from California, North America. *Bulletin of the National Science Museum, Tokyo, Ser. B* **31**: 57-61.

Klein, J. and Verlaque, M. (2008) The *Caulerpa racemosa* invasion: A critical review. *Marine Pollution Bulletin* **56**: 205–225.

Le Gall, L. and Saunders, G.W. (2010) DNA barcoding is a powerful tool to uncover algal diversity: a case study of the Phyllophoraceae (Gigartinales, Rhodophyta) in the Canadian flora. *Journal of Phycology* **46**(2): 374-389.

Lewis, J.A. (1999) A review of the occurrence of exotic macroalgae in Southern Australia, with emphasis on Port Phillip Bay, Victoria, In: Hewitt, C.L., Campbell, M.L., Thresher, R.E., Martin, R.B. (Eds) *Marine biological invasions of Port Phillip Bay, Victoria.* Centre for Research on Introduced Marine Pests. CRIMP Technical Report 20, CSIRO Marine Research, Hobart, Australia pp. 61-87.

Lewis, J.A. and Kraft, G.T. (1979) Occurrence of a European red alga (*Schottera nicaeensis*) in southern Australian waters. *Journal of Phycology* **15**: 226-230.

Lindstrom, S.C., and Gabrielson, P.W. (1989) Taxonomic and distributional notes on northeast Pacific Antithamnionaceae (Ceramiales: Rhodophyta). *Japanese Journal of Phycology* **37**: 221-235.

McKelvey, M. (1997) Dudley Peninsula Coastcare projects. *South Australian Regional Ripples*. Newsletter of the Marine and Coastal Community Network **4**(2):4.

Northern and Yorke Agricultural District Integrated Natural Resource Management Committee Inc. (2003) *Integrated Natural Resources Management Plan, for the Northern and Yorke Agricultural District*. Northern & Yorke Agricultural District INRM Committee, Clare, South Australia.

Nyberg, C.D. and Wallentinus, I. (2005) Can species traits be used to predict marine macroalgal introductions? *Biological Invasions* **7**: 265-279

Parliament of Victoria (undated) *Report on Ballast Water and Hull Fouling In Victoria.* http://www.parliament.vic.gov.au/enrc/inquiries/old/enrc/ballast/default.htm#TopOfPage (includes Appendix D: List of introduced exotic marine organisms in Port Phillip Bay) http://www.parliament.vic.gov.au/enrc/inquiries/old/enrc/ballast/Ballast-76.htm#P4827_419788

Petrusevics, P., Noye, J., Harbison, P. and Petrusevics, A. (1998) *Key Sites for Off-Shore Aquaculture Development in South Australia*. Prepared for Primary Industries South Australia, Technical Appendices.

Provan, J., Booth, D., Todd, N.P., Beatty, G.E. and Maggs, C.A. (2008) Tracking biological invasions in space and time: elucidating the invasive history of the green alga *Codium fragile* using old DNA. *Diversity and Distributions: A Journal of Conservation Biogeography* **14**: 343-354.

Richards, H. (2001) Funding disappointment for local seagrass committee. *South Australian Regional Ripples:* Newsletter of the Marine and Coastal Community Network **8**(3): 6.

Rowling, K. (2008) Re-assessment of the presence or absence of *Caulerpa taxifolia* and *Caulerpa racemosa* var. *cylindracea* at the dredge spoil dump site for the Outer Harbor dredging. Prepared for the KBR and Flinders Ports. SARDI Aquatic Sciences Publication No. F2008/000187-1; SARDI Research Report Series No 279.

Rowling, K. (2009) *Caulerpa taxifolia* – 2008 survey of the upper Port River. Prepared for PIRSA Marine Biosecurity. SARDI Aquatic Sciences Publication No. F2009/000049-1; SARDI Research Report Series No 331.

Russell, B.D., Elsdon, T.S., Gillanders, B.M., Connell, S.D. (2005) Nutrients increase epiphyte loads: broad-scale observations and an experimental assessment. *Marine Biology* **147**: 551–558.

Schramm, W. and Booth, W. (1981) Mass bloom of the alga *Cladophora prolifera* in Bermuda: productivity and phosphorus accumulation. *Botanica Marina* **24**(8):419–426.

Shepherd, S. and Sprigg, R. (1976) Substrate, sediments and subtidal ecology of Gulf St Vincent and Investigator Strait. In: Twidale, C., Tyler, M., and Webb, B. (Eds) (1976) *Natural History of the Adelaide Region.* Royal Society of South Australia, Adelaide, South Australia.

Silva, P.H., McBride, S., de Nys, R. and Paul, N.A. (2008) Integrating filamentous 'green tide' algae into tropical pond-based aquaculture. *Aquaculture* **284** (1-4): 74-80.

Skinnner, S. and Womersley, H.B.S. (1983) New records (possibly introductions) of *Striaria*, *Stictyosiphon* and *Anthrocladia* (Phaeophyta) for southern Australia. *Transactions of the Royal Society of South Australia* **107**(1): 59-68.

Sliwa, C., Migus, S., Hayes, K., and McEnnulty, F. (2006) Marine bio-invasions in Australia. CSIRO Marine Research report. CSIRO, Hobart.

Southgate, R. I. (2004) *Water quality and seagrass loss on Kangaroo Island*. Kangaroo Island Integrated Catchment Management Committee, Kingscote. 94 pp.

State Herbarium of South Australia (2007, 2010) *eFlora SA: The Electronic Flora of South Australia*. Plant Distribution Mapper.

Tasmanian Planning Commission (2009) *State of the Environment Tasmania 2009.* Table: Status of cryptogenic marine pests and where they have been identified. Government of Tasmania.

Trowbridge, C. (1995) Establishment of the green alga *Codium fragile* ssp. *tomentosoides* on New Zealand rocky shores: current distribution and invertebrate grazers. *Journal of Ecology* **83**: 949-965.

Trowbridge, C. (1999) An assessment of the potential spread and options for control of the introduced green macroalga *Codium fragile* ssp. *tomentosoides* on Australian shores. CRIMP Consultancy Report. CSIRO, Tasmania.

Underwood, S. (2001) Introduced Non-Vascular Plants/ Lower Plants in Tasmania - 2001. In: government of Tasmania (2003) *State of the Environment Report 2003*. http://www.soer.justice.tas.gov.au/2003/file/8/Non-vascular.pdf

Wiltshire, K.H. and Rowling, K. (2009) *Caulerpa taxifolia*– 2009 surveys of current distribution and high risk areas. SARDI Aquatic Sciences Publication No. F2009/000347-1. SARDI Aquatic Sciences, South Australia.

Wiltshire, K., Rowling, K. and Deveney, M. (2010) *Introduced marine species in South Australia: a review of records and distribution mapping.* SARDI Aquatic Sciences Publication No. F2010/000305-1. SARDI Research Report Series No. 468.

Womersley, H.B.S. (1956) The marine algae of Kangaroo Island IV. The algal ecology of American River inlet. *Australian Journal of Marine and Freshwater Research* **7**: 64-87.

Womersley, H.B.S. (1984) The Marine Benthic Flora of Southern Australia. Part I. (South Australian Government Printing Division, Adelaide, South Australia). 329 pp.

Womersley, H.B.S. (1987) The Marine Benthic Flora of Southern Australia. Part II. South Australian Government Printing Division, Adelaide, South Australia. 484 pp.

Womersley, H.B.S. (1990) Biogeography of Australasian marine macroalgae. In: Clayton, M. and King, R. (Eds) *Biology of Marine Plants*. Longman Cheshire, Melbourne, Australia.

Womersley, H.B.S. (1994) The Marine Benthic Flora of Southern Australia. Part IIIA. Australian Biological Resources Study, Canberra. 508 pp.

Womersley, H.B.S. (1996) The Marine Benthic Flora of Southern Australia. Part IIIB. Australian Biological Resources Study, Canberra, Australia. 392 pp.

Womersley, H.B.S. (1998) The Marine Benthic Flora of Southern Australia. Part IIIC. State Herbarium of South Australia. 535 pp.

Womersley, H.B.S. (2003) The Marine Benthic Flora of Southern Australia - Part IIID Ceramiales - Delesseriaceae, Sarcomeniaceae, Rhodomelaceae. Australian Biological Resources Study Canberra and State Herbarium of South Australia.

6. Appendix: Description of Gulf St Vincent Bioregion

"St Vincent Gulf"[1] *(= Gulf St Vincent)*	**Description**
Climate	Semi-arid or "Mediterranean" climate, with hot, dry summers and cool, moist winters.
Oceanography	Confined inverse estuary, with higher salinities and temperatures in the upper reaches of the Gulf. Waters are transitional warm to cold temperate, with mean sea surface temperatures varying from 12°C in winter to 25.9°C in summer and mean salinities varying from 35.5-42.0%. Low to moderate wave energy coastline. Tidal range, microtidal to mesotidal ~ 1.2 to 3.3 metre range in the upper Gulf areas. Tides are typified by a regular period of minimal tidal movement or "dodge tide".
Coastal Geology and Geomorphology	Tidal plain coast with a shallow offshore gradient, extensive supratidal and intertidal areas, and few embayments. Coastal geology comprises headlands of Precambrian meta-sediment and Tertiary cliffs and Holocene beaches, sandflats, dunes, beach ridges, and estuarine deposits.
Biota	Marine flora and fauna typically cool temperate (i.e. Flindersian Province). In sheltered areas, extensive intertidal flats are dominated by the grey mangrove, *Avicennia marina*, the brown alga, *Hormosira banksii*, and the seagrasses, *Zostera muelleri* and *Zostera* (= *Heterozostera*) *tasmanica*. Extensive subtidal seagrass communities occur down to 17 metres water depth (becoming sparsely vegetated at greater depths). Subtidal areas characterised by extensive seagrass meadows, dominated by *Posidonia australis* in shallow areas (and northern gulf), *P. sinuosa*, *P. angustifolia* and *Amphibolis antarctica* in deeper waters (and mid-gulf and sheltered parts of the lower gulf), and small shore fringing macro-algal communities. Seagrasses in the *P. ostenfeldii* group form small communities along exposed parts of the lower gulf. Isolated reefs and rocky shore algal communities are dominated by *Scaberia agardhii* and species of *Sargassum* in sheltered areas, and *Ecklonia radiata*, *Seirococcus axillaris* and species of *Cystophora* in moderately exposed areas. Plant species diversity generally low. SA endemic element (e.g. *Vanacampus vercoi*) in the fish fauna. Coastal wetlands of national importance in the region include Clinton, Barker Inlet estuary, Wills Creek, Davenport Creek, Port Gawler, and on Kangaroo Island, American River and Cygnet River.
Estuaries	A few true rivers (e.g. Onkaparinga, Port Adelaide, Wakefield, Gawler Rivers), and several intermittent streams and tidal mangrove creeks (e.g. American River, Clinton, Wills Creek, Port Gawler).

Additional Information, for Backstairs Passage

Oceanography: High tidal flow environment, fast current speeds (125 - 150cm/sec according to Petrusevics *et al.* 1998, and 250 cm/sec in the centre, according to Shepherd and Sprigg 1976). Temperature and salinity (35.5 - 36ppt?) much less variable than upper gulf waters, and not subject to seasonal extremes. Wave energy "moderate to high", with strong swell (e.g. to at least 4m in some areas).Steep bathymetry gradients (e.g. up to 55m near-shore off Fishery Beach, according to *SA Coast and Marine Atlas*); and relatively deep centre (70 - 75m, according to Shepherd and Sprigg 1976).

[1] (see additional information below table, for Backstairs Passage area, an area which is distinctive physically and ecologically, but was not included by IMCRA Technical Group 1998, in the GSV description).

Geology and Geomorphology: In Backstairs Passage, benthic geology comprises mainly outcrops and scarps of metamorphic reefs (Kanmantoo Group meta-sediments and Permian shales, according to Shepherd and Sprigg 1976), overlain with coarse sands and pebbles. Edges of Passage (Dudley Peninsula and bottom of Fleurieu) characterised mainly by steep Kanmantoo metamorphic cliffs and associated reefs. Also present are patches of calcareous platform reef.

Biota: Assemblages in the central tidal race area characterised by large sponges (more than 1m high) and erect bryozoa (*Adeona*) and high densities of a drifting brachiopod (*Anakinetica*). Edges of Passage (Dudley Peninsula and bottom of Fleurieu) characterised mainly by steep Kanmantoo metamorphic cliffs and associated reefs (but also present are patches of calcareous platform reef and small seagrass beds (e.g. Antechamber Bay). Benthos at edges of Passage dominated at shallower depths (<15m) by mixed brown canopy-forming macroalgae, mixed red macroalgae (including articulated corallines) and sessile invertebrates (sponges, bryozoa, ascidians). At deeper depths (15+m - 50+m), biota characterised by abundant soft corals and gorgonians, large erect sponge species (such as basket sponges), large erect bryozoa, sea pens, echinoderms (crinoids, basket stars, brittle stars) and gastropod molluscs (i.e. fauna characteristic of deeper water, strong current flow conditions, which is uncommon in the near-shore State waters of S.A., making the invertebrate assemblages of biogeographic significance). Specific groups of biogeographic significance include the globally significant numbers of Australian sea lions (at the Pages), and abundance and diversity of stalked crinoids and brachiopods in Backstairs Passage. There are small areas of seagrass (e.g. Antechamber Bay).

Additional Information, for Investigator Strait

Oceanography: Moderate to fast current speeds/strong tidal flow in places (approx. 100cm / sec at western entrance, and max. approx. 160cm/sec east of Troubridge Shoals, where the Strait meets the gulf, and up to 200cm/sec in some central areas). Depths in middle of strait range from around 65m at the western entrance to around 30m at the eastern (GSV) entrance, with shallow depths and gradients towards the northern Strait (i.e. southern foot of Yorke Peninsula), where waters less than 20m occur up to 10km from shore. Strong influence of wind waves in some areas (e.g. southern heel of Yorke Peninsula). Temperature and salinity less variable than gulf waters, and not subject to seasonal extremes.Subject to sea surface temperature fronts in summer, that influence the Strait as far east as Sturt Bay (causing temperature differences of up to 3 degrees C, compared with average summer temps in the western Strait).

Geology, Geomorphology, and Biota: Variety of benthic types: intertidal and benthic platform reefs (both limestone and granite, at eastern foot of Yorke Peninsula), with mixed seagrass / patch reef / sand bays; metamorphic near-shore reefs (e.g. north-western Kangaroo Island); extensive seagrass beds on broad shallow banks which stretch at least 8km seaward from the coast; (e.g. Sturt Bay - Foul Bay area); broad patches of calcreted shell bed reef (beds of 30km long and up to 30km wide) in waters (20m - 30+m deep) off northern Kangaroo Island and south of the Foul Bay seagrass beds off Yorke Peninsula). Centre of Strait (25m - 30m) dominated mainly by sparse *Zostera* (= *Heterozostera*) seagrass on sediment beds, with patches of consolidated sand reef and rugose limestone reef. The Investigator Strait portion of the southern heel of Yorke Peninsula dominated by calcareous reef, consolidated sand reefs, and sand beds. North-eastern Kangaroo Island (where the Strait meets Backstairs Passage) contains sessile invertebrate-dominated assemblages in deeper waters, and broad, low energy, seagrass-lined bays in the shallower waters (0m - 20m). Small bays with seagrass (usually seaward of fringing cliff reefs) also occur along the northern coast of KI.

Adelaide and Mount Lofty Ranges
Natural Resources Management Board
205 Greenhill Road
Eastwood SA 5063
Phone 08 8273 9100
www.amlrnrm.sa.gov.au

Government of South Australia
Adelaide and Mount Lofty Ranges
Natural Resources Management Board