

18 SEAGRASS COMMUNITY OF SOUTH AUSTRALIA

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CLASSIFICATION

International: Den Hartog (2003) proposed a global classification of seagrass communities, of which this assemblage is a local expression of an alliance dominated by Posidonia. IUCN Habitats Classification Scheme (Version 3.0): 9. Marine Neritic / 9.9 Seagrass (Submerged)

ECOSYSTEM DESCRIPTION

Characteristic native biota

In Australia, 30 different species of seagrass from 12 genera are known to exist (Kirkman, 1997). Thirteen species are found in South Australia (SA) belonging to seven genera (Wear et al. 2006; Westphalen et al. 2004) with an estimated area of 9,620 km² (Edyvean 1999). The main seagrass species occurring in SA are Posidonia angustifolia, Posidonia australis, Posidonia coriaceae, Posidonia sinuosa, Amphibolis antarctica, Amphibolis griffithii, Heterozostera tasmanica, Halophila australis and Zostera muelleri (Larkum & den Hartog 1989).

The majority of seagrasses inhabit the semi-enclosed bays of Gulf St. Vincent and Spencer Gulf, which form the most extensive seagrass meadows (5,000 km²) in South Australia (Shepherd and Robertson 1989), but they are also found in embayments in the western part of the State, Kangaroo Island (Kinloch et al. 2007) and the South East. The seagrass communities in South Australia are considered as amongst the most diverse in the world (Shepherd et al. 1989). The ecological community assessed here (Figure 1) is the meadow forming seagrass species, which is usually dominated by ribbon weed or tape weed (Posidonia spp) and wire weed (Amphibolis spp) (Bryars et al. 2011; EPA 2008; EPA 2009; Miles and Peters 2011).

Figure S18. 1. Seagrass community of South Australia dominated by: a) Posidonia sinuosa;, and b) a mixture of Posidonia australis and Amphibolis antarctica with macro-alga Caulerpa obscura. Photos: Kym Lasmur.

Tubeworms, ascidians, seastars, sea urchins, crabs and razorfish (Pinna spp.) were found to be components of seagrass meadows in Gulf St Vincent (Shepherd and Sprigg 1976). At Kangaroo Island, seagrass meadows are dominated by “small shrimps (decapods), slaters (amphipods), sea lice (isopods)
and snails, crabs and syngnathid fish (pipefish and seahorses), weedy whitings, scorpionfish and clingfish, plus the odd seastar, polychaete worm and sea cucumber” (Kinloch et al. 2007, p 21).

Abiotic environment
Seagrasses are generally found on sandy or muddy areas in estuaries, coastal lagoons, gulfs and sheltered bays (EPA 2009). Seagrasses, particularly those found in South Australia, are confined to naturally low nutrient environments and as such they are sensitive to any increases in nutrient levels. They are also sensitive to increases in water turbidity as they require sunlight for growth.

Distribution
The majority of seagrass (82.7%) is found in the waters of Gulf St. Vincent (Adelaide metropolitan area) and Spencer Gulf (Eyre Peninsula) (Figure 2). They are also found in Streaky Bay and Smoky Bay (west of Spencer Gulf) with Fowlers Bay as the western most site containing extensive seagrass meadows (Kirkman 1997). In the South East, the seagrass community is found in shallow sheltered bays of Lacepede Bay, Guichen Bay, Nora Creina, Stinky Bay, Rivoli Bay, Bucks Bay, Bungalooy Bay and in waters adjacent to the township of Port MacDonnell. The seagrass habitat in South Australia is estimated to be over 9,620 km² (Edyvane 1999). However, the most current analysis using 1:100,000 benthic habitat mapping covering SA’s coastal waters (to 20 m depth) indicates that the area of seagrass is 8,532 km². It is not certain whether this discrepancy is due to difference in methodology or actual loss since the earlier estimate or whether seagrass species occurring in deeper waters were not captured by the latest analysis.

Figure S18. 2. The distribution of the Seagrass Community in South Australia
Key processes and interactions

Generally, seagrasses grow on sandy or muddy substrates and are dependent upon their rhizomes or underground stems for anchorage (Kirkman 1997). Seagrass meadows are not capable of withstanding great energy from swell and waves and thus are usually found in sheltered bays. The critical factors for seagrass growth and survival are light, temperature, dissolved carbon dioxide, nutrients and a suitable substrate for anchoring (Figure 3). The extensive root systems of seagrass meadows stabilise the underlying sediments (Fox et al. 2007). In South Australia, the largest seagrass meadows are found in Spencer Gulf and Gulf St Vincent. A conceptual model regarding the effect of light and nutrient to seagrasses is shown in Figure 3.

Effect of nutrient loading on primary producers

Figure S18. 3. Effect of substrate, light and nutrients on environmental suitability for seagrasses.

Seagrass ecosystems have been reported to contribute up to 15% of global ocean annual net carbon production (Duarte and Chiscano 1999). Seagrass ecosystems have been ranked closely with coral reefs and mangrove habitats in terms of productivity (Short and Wyllie-Echeverria, 1996). This highly productive ecosystem provides habitats and nursery areas to a variety of marine invertebrates and vertebrates (see above).

The Science Resource Centre of the Department of Environment and Natural Resources conducted an expert panel workshop (March 2012) to create a conceptual model of the seagrass community in South Australia (Figure 4). The conceptual model provides an illustration of the drivers of change operating within this marine ecological community.

Threatening processes

Urbanisation of coastal areas and near shore development has resulted in decline in water quality affecting seagrasses (Shepherd et al. 1989; Seddon, 2000). Changes in water properties such as increases in temperature, pollutant levels and turbidity, as well as nutrient enrichment and altered salinity may negatively affect seagrasses. The secondary effect of increased epiphytic load as a result of high levels of nutrients in water is also detrimental to seagrasses (Bryars et al. 2011). Sources of nutrients and pollutants in South Australia’s marine environment are urban and rural runoff, sewage treatment plants, and some industrial sources.
Ecosystem collapse

For assessment of criteria A and B, the seagrass community was assumed to collapse if its mapped distribution declined to zero. For assessing environmental degradation under criterion C, experimental work by Bryars et al. (2011) was used to set thresholds of collapse for seagrass due to high levels of ammoniacal and oxidized nitrogen concentration in the water column that result in high or total mortality of seagrass. It was assumed that the ecosystem would collapse when either inorganic form of nitrogen is maintained above the threshold levels 100% of the time throughout the distribution of the ecosystem (i.e. at all sample sites).
ASSESSMENT

Summary

<table>
<thead>
<tr>
<th>Criterion</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>sub-criterion 1</td>
<td>EN(VU-CR)</td>
<td>LC</td>
<td>EN(VU-EN)</td>
<td>DD</td>
<td>DD</td>
<td>EN(VU-CR)</td>
</tr>
<tr>
<td>sub-criterion 2</td>
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<td>LC</td>
<td>DD</td>
<td>DD</td>
<td></td>
<td></td>
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<tr>
<td>sub-criterion 3</td>
<td>VU(NT-CR)</td>
<td>LC</td>
<td>DD</td>
<td>DD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criterion A

Current decline. An estimate of decline for the entire distribution of seagrass meadows in South Australia has never been done. However, separate site-specific studies have been conducted in the past. For example, the loss of seagrass meadows in the coastal waters of metropolitan Adelaide (Largs Bay to Aldinga) was estimated to be 40.86 km$^2$ (32.8%) from 1949 to 1996 (Hart 1997). This change was inferred from the estimated increase of sand substrate from 26.26 to 67.12 km$^2$ during that time period. Extrapolated (slightly) to a full 50-year period, the estimated decline in distribution in this area was 33.3% (Table 1). Causes of decline were attributed by the Environmental Protection Agency to increased development within Metropolitan Adelaide, which in turn resulted in increased discharges in the Gulf St. Vincent (Figure 5).

![Graph showing rate of seagrass loss from 1949 to 1995](image)

Figure S18. 5. Rate of seagrass loss 1949-1995 between Largs Bay and Glenelg (source: EPA 2008).

In a separate analysis, a particular site within this area (between Glenelg North and West Beach) was reported to have lost 50% of the seagrass meadow during the period 1949 to 1995 (Fox et al. 2007). Outside of Gulf St. Vincent in Rivoli Bay, South East, seagrass extent in 1951 was estimated to be 0.364 km$^2$ (36.4 ha), but declined to just 0.077 km$^2$ (7.7 ha) by 1997 (Seddon et al. 2003). This is a total loss of 0.287 km$^2$ (28.7 ha) or 78.85% of seagrass area at northern Rivoli Bay in 46 years. Extrapolating to 50 years gives an estimated decline of 81.5% (Table 1). The seagrass meadow in Rivoli Bay constitutes a small proportion of the total area of seagrasses in SA but is of major importance since this is the only location in the South East of SA where a seagrass meadow is found.
These studies are the only analyses conducted on changes of seagrass cover in South Australia that cover a span of more than 45 years.

There are other studies on other sites, albeit more recent ones. For example, Seddon (2000) documented the loss of approximately 60% (from 159.3 to 64 km²) of near-shore seagrasses from a 95 km stretch of coast in Spencer Gulf from 1987 to 1994 due to heat stress. This short-term study may have failed to capture increased environmental degradation and significant losses in seagrass meadows that occurred before and during the 1970’s, about 8 years after the maximum rate of population growth in the metropolitan region (EPA 2008; Fox et al. 2007). The estimated decline over 50 years depends on whether a similar rate of decline was maintained over the past 50 years (99.9%) or whether a decline only took place between 1987 and 1994 (68.0%) (Table 1).

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Proportional annual rate of decline (r)</th>
<th>% decline over past 50 yrs</th>
<th>Calculation (r)</th>
<th>Calculation (% decline)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Range-wide proportional rate of decline over past 50 yrs is same as annual rate at Largs Bay - Aldinga during 1949 - 1998 (Hart 1997)</td>
<td>-0.008</td>
<td>33.3</td>
<td>ln(83.7/124.6)/(1998-1949)</td>
<td>100x(1-e^{-0.008})^{50}</td>
</tr>
<tr>
<td>2 Range-wide proportional rate of decline over past 50 yrs is same as annual rate at Rivoli Bay during 1951 - 1997 (Seddon et al. 2003)</td>
<td>-0.034</td>
<td>81.5</td>
<td>ln(0.077/0.364)/(1997-1951)</td>
<td>100x(1-e^{-0.034})^{50}</td>
</tr>
<tr>
<td>3 Range-wide proportional rate of decline over past 50 yrs is same as annual rate in 95 km stretch of Spencer Gulf during 1987-1994 (Seddon 2000)</td>
<td>-0.13</td>
<td>99.9</td>
<td>ln(64.0/159.3)/(1994-1987)</td>
<td>100x(1-e^{-0.13})^{50}</td>
</tr>
<tr>
<td>4 Range-wide proportional rate of decline over past 50 yrs is same as area lost in 95 km stretch of Spencer Gulf during 1987-1994, averaged over a 50 yr period (Seddon 2000)</td>
<td>-0.023</td>
<td>68</td>
<td>ln(64.0/159.3)/(1994-1954)</td>
<td>100x(1-e^{-0.023})^{50}</td>
</tr>
<tr>
<td>5 Area-weighted average based on 1, 2 &amp; 3</td>
<td>-0.077</td>
<td>97.8</td>
<td>(-0.008x124.6-0.034x0.364-0.13x159.3)/(124.6+0.034+159.3)</td>
<td>100x(1-e^{-0.077})^{50}</td>
</tr>
<tr>
<td>6 Area-weighted average based on 1, 2 &amp; 4</td>
<td>-0.016</td>
<td>55.9</td>
<td>(-0.008x124.6-0.034x0.364-0.023x159.3)/(124.6+0.034+159.3)</td>
<td>100x(1-e^{-0.016})^{50}</td>
</tr>
</tbody>
</table>

The status of the community can be based on the analyses of more than 45 years in two sites (Largs Bay to Aldinga and Rivoli Bay), assuming that these sites are representative of the overall pressures and decline on seagrass community in SA. This produces an estimated decline of 33 - 82% (Table 1). Alternatively, weighted average declines across all three sites produce an estimate of 56 - 98% decline, depending on whether a lower or upper bound is used for the third site (Table 1). The threat status therefore of this ecosystem is Endangered (plausible range Vulnerable - Critically Endangered (VU-CR) under criterion A1.

Future decline. It is well recognised that factors critical for seagrass growth (light, temperature, CO₂, nutrients and suitable substrate) are affected by climate change (Conolly, 2009). The loss of 127.17 km² of near-shore seagrasses in Spencer Gulf from 1987 to 1994 (Seddon et al. 2000) may represent the potential impact of climate change to seagrasses due to increased ambient temperature. However,
there are no studies nor modelling conducted for possible decline in seagrass meadows in South Australia using factors associated with climate change as independent variables. Also, there is no predictive modelling of seagrass extent based on current rate of decline. The status of the community is therefore Data Deficient (DD) under criterion A2.

**Historic decline.** There is anecdotal evidence of historical loss in the area of the seagrass community in the southern part of Rivoli Bay in the South East. The following account was cited by Wear et al (2006): “Firstly, an early nautical survey of Rivoli Bay in 1871 reported at Southend weeds or grass showing in places during fine weather similar to those observed in the northern end of the bay (Howard 1871). Secondly, a 1956 Marine and Harbours Board survey line shows what appears to be a remnant seagrass bank. This feature was no longer evident when resurveyed by the Coast Protection Board in 1987 and 2005” If the above historical account is true, the loss in seagrass in the southern part of Rivoli Bay is 100% since 1871. There was also a record of seagrass dredging conducted near Port Broughton (Spencer Gulf) to harvest Posidonia fibre before the First World War (Winterbottom 1917). However, estimation of the extent of loss is not possible (Kirkman 1997).

Given the paucity of data in historical decline of seagrass meadows in South Australia, the estimated 29% decline in global seagrass meadow area between 1879 and 2006 (Waycott et al. 2009) is recommended to be used as surrogate measure representing the lower bound of estimated historic decline, with the upper bound the same as the upper bound of current decline (98%, Table 1). The use of this estimate is warranted since it is an average global estimate and there is evidence of continuing decline in South Australia’s seagrass community (EPA 2008). The status of the ecosystem under criterion A3 therefore is likely to be at least Vulnerable (plausible range Near Threatened - Critically Endangered).

**Criterion B**

The Extent of Occurrence (EOO) and Area of occupancy (AOO) were determined using 1:100,000 benthic habitat mapping covering SA’s coastal waters (to 20 m depth). Benthic habitat mapping was undertaken by the CSIRO and SARDI in 2001 as part of the National CSIRO Marine Habitat mapping program. Using this polygon information, seagrass communities were extracted and combined with the generated grid to determine the AOO and further differentiate the unique cells where seagrass areas are both below and above the 1% level of cell area occupied. The Extent of Occurrence (EOO) was determined by generating a minimum convex polygon that bound and encompassed the entire seagrass community polygon on the distribution map (Figure 6). The Area of Occupancy (AOO) of the seagrass community was estimated by overlaying the entire seagrass community polygon with a 10 km x 10 km and counting the number of occupied grids.

**Extent of occurrence.** The extent of occurrence of the seagrass meadow of South Australia is estimated to be 167,913 km² (see Figure 4). The decline in the extent of seagrass community is continuous (EPA 2008) and threats such as nutrient enrichment and other types of pollution still exist. The status of the EC therefore is Least Concern (LC) under criterion B1.

**Area of occupancy.** Superimposing a 10 x 10 km grid over the mapped polygons of seagrass meadow (Figure 6) indicates that they are present within 326 grid cells. Of these, 48 grid cells contains less than 1 km² of the community (i.e. <1% of the area of a grid cell). Excluding these small occurrences, the ecosystem is therefore estimated to occupy 278 grid cells. The assessment of B2 sub-criterion is similar to those for the subcriterion B1, which place the community under Least Concern (LC) for criterion B2.

**Number of locations.** Based on the distribution map and the community’s Area of Occurrence (AOO), the seagrass meadow of South Australia occurs in 278 10 x 10 km grid cells, which could be interpreted as independent locations. If larger clusters of contiguous cells were interpreted as independent locations, there would be no fewer than ten. The status of the community is therefore Least Concern (LC) under criterion B3.
Figure S18. 6. Map polygon of the Seagrass Community of South Australia (SCSA) showing EOO and AOO. Green - all occupied cells. Yellow - with more than 1% of cells area occupied.

Criterion C

The principal mechanism of environmental degradation is through decline in water quality caused by agricultural runoff, land-based pollution and changes in the optimal conditions for seagrasses due to natural events. Data are available for nutrient levels, physico-chemical properties of water and other pollutants but are limited to specific sites and short periods of time (less than 15 years). In the assessment under Criterion C, the experimental work of Bryars et al. (2011) was used to set the threshold of collapse for seagrass community due to increased levels of ammoniacal and oxidised nitrogen concentration in the water column. In that study, an annual mean concentration of 0.026 mg/L of ammoniacal nitrogen and 0.025 mg/L of oxidised nitrogen were shown to decrease seagrass biomass and density by 70-80% and 50-55%, respectively. The inorganic forms of nitrogen (such as ammoniacal nitrogen and oxidised nitrogen) were used as the proxy measure for environmental degradation since they are biologically available (Fox et al. 2007). It was assumed that the ecosystem would collapse when either inorganic form of nitrogen is maintained above the threshold levels 100% of the time throughout the distribution of the ecosystem (i.e. at all sample sites).

Current decline. Ten to eleven years of water quality data from the Environmental Protection Authority (EPA) were used to determine the extent and relative severity of environmental degradation that negatively affects seagrasses in South Australia. These data were collected from specific sites (n = 9) in the coastal waters of the State, covering the Spencer Gulf, Gulf St. Vincent and Kangaroo Island. However, the water quality data are highly fluctuating and exhibit a lack of trend through time (Figure 7).

It can be surmised that the concentration of nutrients in the coastal waters of the South Australia fluctuate as opposed to being present at a continuous chronic level. This can be attributed to high rainfall events that flush nutrients and other pollutants from land base sources. In addition, data from some sites showed decreasing trends through time when the annual mean was computed, plotted against time and a polynomial trendline fitted (Fig. 8). The decrease in the level of nutrients may have been the result of efforts by the government regulating agencies to reduce the amount of pollutants entering the coastal waters through more efficient treatment facilities.

![Graph showing Ammoniacal nitrogen concentration from 1998 to 2008](image)

Figure S18. 7. Ammoniacal nitrogen concentration near Brighton Jetty, Gulf St. Vincent, SA showing highly fluctuating levels from 1998 to 2008 (data points fitted with moving average trendline).
Figure S18. 8. Ammoniacal nitrogen concentration offshore of Nepean Bay, Kangaroo Island, SA showing relative decrease in levels from 1999 to 2008 (data points fitted with a 6th order polynomial, $R^2 = 0.9613$).

Given the above scenario, the severity of environmental degradation was computed for each component of inorganic nitrogen using the following formula:

$$\text{Severity of abiotic degradation} = \left( \frac{b}{n} \right) \times 100$$

Where: 
- $b =$ number of observed values (annual mean) that is greater than $a$
- $a =$ the value inferred as the threshold of collapse
- $n =$ the total number of observations

The inferred thresholds of collapse ($a$) were derived from the work of Bryars et al. (2011) (see above). The estimates of relative severity were averaged across all sites, with the resulting mean taken as representing the severity of declines across 100% of the ecosystem extent.

This approach to assessing environmental degradation under criterion C means that the ecosystem will be assessed at increasing levels of risk as nitrogen levels are more frequently maintained above threshold levels during the past 10 years at more of the sites (for purposes of assessment, we assume the past 10 years represent the past 50 years). If nitrogen levels become less frequently above the thresholds in future, then the risk status of the ecosystem will improve.

The use of frequency data in relation to a collapse threshold for assessing relative severity was justified due to the following reasons: i) the method is less sensitive to fluctuations, which may obscure environmental degradation which may be undetectable as trends nutrient enrichment in the water column with 10 to 11 years of the available data; ii) the data are highly fluctuating suggesting that increased nutrient levels in the water column comes in fluxes; and iii) many of the observed nutrient level values were above the inferred threshold of collapse values. These values were assumed to have a negative effect on seagrasses even without a clear linear or polynomial trend particularly when yearly averaged was used since the threshold of collapse values were also annual means.

Applying the above formula, the relative severity of degradation (using nutrients as the surrogate measure) are shown for different sites in Table 2. Sample computations are given in Appendix A.
Table S17. 2. The relative severity and extent of environmental degradation that negatively affects seagrass community in South Australia (values are derived from annual means and expressed as percentage above threshold collapse values.

<table>
<thead>
<tr>
<th>General location</th>
<th>Sites</th>
<th>Relative severity based on Ammoniacal N (mg/L)</th>
<th>Relative severity based on Oxidised N (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf St. Vincent</td>
<td>Brighton Jetty</td>
<td>45.45</td>
<td>18.18</td>
</tr>
<tr>
<td></td>
<td>Glenelg Jetty</td>
<td>81.82</td>
<td>27.27</td>
</tr>
<tr>
<td></td>
<td>Grange Jetty</td>
<td>72.73</td>
<td>45.45</td>
</tr>
<tr>
<td></td>
<td>Henley Beach</td>
<td>72.73</td>
<td>36.36</td>
</tr>
<tr>
<td></td>
<td>Semaphore Jetty</td>
<td>45.45</td>
<td>9.09</td>
</tr>
<tr>
<td></td>
<td>Largs Bay Jetty</td>
<td>45.45</td>
<td>9.09</td>
</tr>
<tr>
<td>Spencer Gulf</td>
<td>Port Hughes Jetty</td>
<td>69.23</td>
<td>23.08</td>
</tr>
<tr>
<td>Kangaroo Island</td>
<td>Nepean Bay</td>
<td>20.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Port Morrison</td>
<td>20.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Mean (se) over 100% extent</strong></td>
<td>53 (8)</td>
<td></td>
<td>19 (5)</td>
</tr>
</tbody>
</table>

Using values for ammoniacal nitrogen, the average extent of environmental degradation across 100% of the ecosystem extent is 53±8% (plausible bounds 45-61%). The status of the community is therefore Endangered (plausible range Vulnerable - Endangered) under criterion C1. However, this could be a conservative estimate since data were available extend back to 1998 only and environmental conditions would have been worse in earlier years (Fox et al. 2007; EPA 2008).

**Future decline.** There are no available data to estimate the parameter under this criterion. The status of the community is therefore Data Deficient (DD) under criterion C2.

**Historic decline.** There are no available data to estimate the parameter under this criterion. The status of the community is therefore Data Deficient (DD) under criterion C3.

**Criterion D**

Changes in the biotic component of seagrass communities have been observed. For example, seagrass communities of the Adelaide Coastal Waters are generally dominated by a mix of Posidonia and Amphibolis but a noticeable trend away from this distinctive composition has been observed by Fox et al. (2007). In another example, the loss of seagrass cover and eventual removal of sediment (due to wave action) exposes clay or calcere base material that increases the risk of colonisation by exotic pests (Fox et al. 2007). These two examples provide qualitative evidence that disruption of biotic processes and interactions may have been occurring among the seagrass community of South Australia due to anthropogenic and natural perturbations. However, such changes in the biotic component of this ecological community have never been quantified.

**Current decline.** In the same study of Bryars et al. (2011), elevated levels of ammoniacal and oxidised nitrogen (see above Criterion C) resulted in the increase in epiphytic load and changes in epiphytic composition. The increase in epiphytic load and shift in composition may have been factors contributing to the decline of seagrass biomass and density due to decreased light availability. As these have not been quantified, the status of the community is Data Deficient (DD) under criterion D1.

**Future decline.** There are no available data to estimate the parameter under this criterion. The status of the community is therefore Data Deficient (DD) under criterion D2

**Historic decline.** There are no available data to estimate the parameter under this criterion. The status of the community is therefore Data Deficient (DD) under criterion D3
Criterion E
No quantitative analysis has been carried out to assess the risk of EC collapse for Seagrass Community of South Australia. The status of the ecosystem is therefore Data Deficient (DD) under criterion E.

REFERENCES
EPA (Environmental Protection Agency) 2008. Changes in seagrass coverage and links to water quality off the Adelaide Metropolitan coastline. Government of South Australia, Adelaide.
Howard, F. (1871) Nautical description of Rivoli Bay. No. 23.

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Winterbottom, D.C. 1917. Marine fibre, Bulletin No. 4, Department of Chemistry, South Australia.

Appendix A. Sample computation for the extent and relative severity of environmental degradation for seagrass community.

Threshold of collapse (a): 0.026 mg/L of ammoniacal nitrogen (from Bryars et al. 2001)

Relative severity of degradation = \( \frac{b}{n} \times 100 \)

Where:  
\( b \) = number of observed values (annual mean) that is greater than \( a \)  
\( a \) = the value inferred as the threshold of collapse  
\( n \) = the total number of observation
Dataset for Brighton Bay, Gulf St. Vincent, South Australia:

<table>
<thead>
<tr>
<th>Year</th>
<th>Ammoniacal Nitrogen (mg/L)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>0.02925</td>
</tr>
<tr>
<td>1999</td>
<td>0.032375</td>
</tr>
<tr>
<td>2000</td>
<td>0.033875</td>
</tr>
<tr>
<td>2001</td>
<td>0.023933333</td>
</tr>
<tr>
<td>2002</td>
<td>0.018411765</td>
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<tr>
<td>2003</td>
<td>0.034714286</td>
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<tr>
<td>2004</td>
<td>0.018636364</td>
</tr>
<tr>
<td>2005</td>
<td>0.02415</td>
</tr>
<tr>
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<td>0.044</td>
</tr>
<tr>
<td>2007</td>
<td>0.009333333</td>
</tr>
<tr>
<td>2008</td>
<td>0.005</td>
</tr>
</tbody>
</table>

*Annual mean

Number of observed values greater than a (0.026 mg/L) = 5, total number of observations = 11
Relative severity of environmental degradation at Brighton Bay = 45.45% (5/11 x 100)