

Boston Bay Marine Habitat Video Analysis



Report prepared for SA Water
by
J Diversity Pty Ltd
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Cover photo: Seagrass *Posidonia sinuosa* in Boston Bay. Source: SA Water.

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Executive Summary

Introduction and Background

SA Water proposes to construct a desalination plant on the Eyre Peninsula to relieve pressure on the Uley South Basin and provide water security to current customers while also enabling future growth. The former BHP site at Billy Lights Point (Port Lincoln) and a site near Point Boston were identified as potential sites for the plant. Accordingly, habitat mapping is required for the bays surrounding the Billy Lights Point and Point Boston sites.

A review of previous habitat surveys by CSIRO, the Environment Protection Authority (EPA) and University of Adelaide found that Proper Bay was dominated by dense seagrass with a dense cover of epiphytes, Boston Bay had dense seagrass cover to the north of the Bay, along the northern and western coastlines of the Bay and near Boston Island, with bare substrate in deeper areas, and Louth Bay had dense seagrass along the western side of the bay and west of Louth Island, with patchier areas in between, and patchiness or less certainty southwards towards Point Boston.

Habitat condition in the area had been assessed by the EPA during 2010 and 2016, finding that many sites were under stress from high levels of nutrients, resulting in epiphyte growth which can result in seagrass loss over time. Seagrass cover had reduced in southern Boston Bay, but increased in Louth Bay and northern Boston Bay between 2010 and 2016. A number of nutrient sources had been identified by the EPA, including finfish aquaculture, waste water treatment plant discharge, fish processing discharges and seasonal outflows from the Tod River, with the former likely to be 1–2 orders of magnitude higher than the other sources combined.

Twenty-eight pest species have been identified in Proper, Boston and Louth Bays (Wiltshire et al. 2010, PIRSA unpublished data), including six microalgae, a brown macroalga, two hydroids, six polychaete worms, a barnacle, two molluscs (both farmed species), five bryozoans and five ascidians.

Methods

For the current study, SA Water had collected video footage of the seabed from 150 sites throughout Louth, Boston and Proper Bays. The aim of the study was to analyse the video footage and classify each site into broad habitat groups based on predominate life forms and classify seagrass in relation to density and epiphyte cover.

Five frames separated by equal time intervals were extracted from the video and 12 point intercepts were arranged in a regular 3 x 4 grid on each frame. A percentage cover of each feature at each site was calculated from the number of point intercepts that feature divided by the total number of point classifications minus any points excluded because they could not be identified. The presence of introduced species was noted for each site from observation of the video.

Two methods were used to determine an overall habitat class for each site based on the various habitat features recorded. The first method was based on multivariate clustering, and the second was a rule-based framework that prioritised features identified by a literature review as being potentially impacted by desalination plant discharges, including seagrasses, filter feeding invertebrates and macroalgae.

Results and Discussion

Usable video durations (from when the seafloor came into focus until the camera was retrieved) ranged from 18–151 seconds (mean 68 seconds). Habitat features identified during the point intercept analysis included seagrasses *Posidonia*, *Zostera* and *Halophila*, epiphytic algae, turfs (including microphytobenthos), other macroalgal lifeforms, filter feeders and sediment.

The clustering process identified 13 habitat classes characterised by various densities of *Posidonia* and epiphytes, *Halophila*, various densities of red macroalgae and turfing algae, filter feeders and largely bare sediment. The “rule based” features that were not distinguished during the clustering process include dense *Posidonia* with no epiphytes, and *Zostera*.

Spatial patterns were evident across the Bays. *Posidonia* was the dominant habitat throughout Proper Bay, with relatively dense cover generally close to the western and southern coastlines of the Bay. There was an isolated site with dense *Zostera* in the middle of the Bay. *Posidonia* in Boston Bay was restricted to inshore sites and in the lee of northern Boston Island. *Halophila* and filter feeders were the dominant habitats to the north and west of Boston Island, respectively. Red macroalgae dominated the area directly east from Billy Lights Point to the south-east of Boston Island, and in the north of Boston Bay. Turfing macroalgae were dominant to the north-west and south-west of Boston Island, and bare substrate to the north-east. Dense *Posidonia* was the dominant habitat in Louth Bay, transitioning to sparser *Posidonia* to the south and turfing macroalgae around Point Boston. *Zostera* was recorded between Louth and Rabbit Islands and further south. These findings were generally consistent with broad-scale patterns of cover mapped by University of Adelaide, including vegetative cover throughout Proper Bay, on the north-eastern shoreline of Boston Bay and in Louth Bay.

The distribution of *Posidonia* appeared to be influenced by wave exposure and depth, but several additional factors including water quality, substrate type and species may influence seagrass distribution.

The most abundant introduced species observed during video analysis was the European fan worm *Sabella spallanzanii*, with a dense cover at three sites, a relatively sparse cover at 35 sites and possible identifications at a further four sites, with a distribution extending up to 5 km to the north and 10 km to the south and east of Port Lincoln. It is one of the pest species of most concern within South Australia and has been declared ‘noxious’ under the *Fisheries Management Act 2007*. It may compete with native or farmed filter feeders. The feather duster worm *Myxicola infundibulum* was recorded at two sites but is not considered to be a significant threat to the ecology of the region. Many of the introduced species previously recorded in the region would not be recognisable from video footage and the lack of observations of other species does not imply their absence.

Conclusion

The habitat survey found dense *Posidonia* throughout Louth Bay (west of Louth Island), along the shallow, sheltered western coastline of Boston Bay. The relatively deep waters further west in Boston Bay were dominated by *Halophila* and red macroalgae in the north, filter feeding invertebrates in the centre of the Bay, and bare sediment to the south. *Posidonia* extended throughout most of Proper Bay but was at lower densities than the western side of the Bay. *Zostera* was found at the deepest sites to the south-east and south of Louth Island, and a site near the centre of Proper Bay.

Other habitats identified as being particularly relevant to desalination discharge are macroalgae, which were relatively dense towards the north of Boston Bay and sparser south of Boston Island, and filter feeders, which were dominant in deeper water west of Boston Island.

The current survey showed that epiphyte levels remain high in Louth Bay, Proper Bay and southern Boston Bay, indicating that these areas may remain under stress from nutrient enrichment.

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1 Introduction

1.1 Background

SA Water proposes to construct a desalination plant on the Eyre Peninsula to relieve pressure on the Uley South Basin (the last remaining major productive groundwater source on the Eyre Peninsula suitable for supplying drinking water to the region) and provide water security to current customers while also enabling future growth.

The former BHP site at Billy Lights Point (Port Lincoln) and a site near Point Boston were identified as potential sites for the plant. Accordingly, habitat mapping is required for the bays surrounding the Billy Lights Point and Point Boston sites.

SA Water has collected video footage of the seabed from 150 sites throughout Louth, Boston and Proper Bays. J Diversity Pty Ltd was engaged to analyse the video footage and:

- Classify each site into broad habitat groups based on predominate life forms
- Produce broad classification relationships assessed using multivariate analysis of predominate life forms
- Classify seagrass in relation to density (e.g. sparse, medium, dense) and epiphyte cover (e.g. low, medium, high)

1.2 Existing habitat data

1.2.1 Habitat mapping

Broad scale (1:100,000) mapping by CSIRO using satellite imagery in 1998 showed seagrass throughout Proper Bay, along the western and southern coasts of Spalding Cove, around the western and northern coastline of Boston Island, along the western and northern coastlines of Boston Bay and throughout Louth Bay (Edyvane 1999, Figure 1). Finer scale mapping and video camera ground truthing undertaken elsewhere on Eyre Peninsula by Miller et al. (2009) was not undertaken in Boston, Proper and Louth Bays.

The EPA undertook video transects at 40 sites in 2012 (EPA unpublished data), with more extensive towed camera surveys undertaken by the EPA in 2010 and 2016–2018 at a number of sites (EPA 2018, Figure 1). Percentage cover of seagrass and epiphytes (Table 1) was estimated from video footage, obtained using a downward facing camera, of 10 transects each of 50 m length within a radius of 200 m of the site mark.

The University of Adelaide used Landsat image archives (Earth Explorer) from 1991, 2008, 2015 and 2021 to map vegetation cover and bare substrate in Proper, Boston and Louth Bays, using a threshold cover of 50% to distinguish these two categories (Hennekam & Clarke 2021, Figure 2).

Comparisons of satellite imagery between the four survey events showed a gain of cover (likely seagrass) in the inshore area of north-west Boston Bay, but cover loss (also likely seagrass) further offshore in north-west Boston Bay, south-western Boston Bay and south-eastern Proper Bay. Between 2015 and 2021, however, there was no loss of cover, and small gains in northern Boston Bay (Hennekam & Clarke 2021).

The three studies (CSIRO, EPA and University of Adelaide) used different methods applied at different scales. A synthesis of their findings is that:

- Proper Bay was dominated by dense seagrass (with a dense cover of epiphytes), with less certainty or reduced density towards the south-eastern extent of the Bay
- Boston Bay had dense seagrass cover to the north of the Bay, along the northern and western coastlines of the Bay and near Boston Island, with bare substrate in deeper areas
- Louth Bay had dense seagrass along the western side of the bay and west of Louth Island, with patchier areas in between, and patchiness or less certainty southwards towards Point Boston.

Table 1. Percentage cover of seagrass and epiphytes recorded during surveys by EPA in 2010 and 2016–2018
Aut = autumn, Spr = spring. Note that seagrass cover is expressed as a percentage of the seafloor, but
epiphyte cover is expressed as a percentage of seagrass cover. EPA site locations are shown in Figure 1.
Source: EPA (2018), EPA unpublished data.

EPA site code	Seagrass cover (%)					Epiphyte cover (%)				
	2010		2016	2017	2018	2010		2016	2017	2018
	Aut	Spr	Aut	Spr	Aut	Aut	Spr	Aut	Spr	Aut
m0111	39	49	71	56	40	35	52	32	40	41
m0113	3	26	34	31	19	3	50	19	30	30
m0107	5	5	13			16	27	13		
m0105	20	6	51	58	59	28	31	27	59	59
m0106	12	0	1			6	0	8		
m0103	18	4	13			18	21	20		
m0104	40	38	31	33	23	51	54	61	59	53
m0109	39	27	30	30	41	44	75	56	46	70
m0110	19	8	9	1	0	30	38	8	2	1
m0118	72	51	51	46	42	90	84	74	80	72
m0108	5	6	13	11	11	20	70	47	60	42
m0101	79	65	70			88	90	66		
m0100	66	69	64			82	89	87		
m0102	48	38	21	27	14	72	69	83	57	62



Figure 1. Broad scale (1:100,000) mapping by CSIRO and EPA monitoring sites. Source: DEW 2022a (CSIRO mapping), EPA 2018 (EPA monitoring sites).



Figure 2. Mapping of areas with vegetative cover and bare substrate undertaken by University of Adelaide (Hennekam & Clarke 2021), also showing EPA survey sites (EPA 2018).

1.2.2 Habitat condition

The EPA generates Aquatic Ecosystem Condition Reports (AECRs) on the condition of many coastal marine biounits in South Australia, based on criteria including water quality, changes in seagrass cover and seagrass epiphyte loads. The 2016 AECR report on the Jussieu Biounit, which extends from Cape Catastrophe to Tumby Bay, concluded that (EPA 2018):

- condition of sites in the south of Louth Bay had improved, with increases in seagrass cover during 2010–2016 suggesting recovery from disturbance, but widespread elevated epiphyte loads and high abundances of holothurians (sea cucumbers) were indicators of substantial nutrient enrichment.
- sites in the north of Boston Bay were in relatively good condition, with increases in seagrass cover during 2010–2016, while sites in southern Boston Bay were generally showing decreasing condition, based on reduced seagrass cover and elevated phytoplankton levels.
- condition of sites within Proper Bay was variable, with two sites maintaining dense and continuous seagrass, while another showed a 67% decline in seagrass cover during 2010–2016.
- all sites within Proper Bay showed high epiphyte load on seagrass and elevated phytoplankton levels suggesting excess nutrients.

The EPA (2018) noted that many sites were under stress from nutrient enrichment, resulting in epiphyte growth which can result in seagrass loss over time.

The EPA (2018) identified several potential sources of nutrients in Proper, Boston and Louth Bays, including finfish aquaculture, wastewater treatment plant discharge, fish processing discharges and seasonal outflows from the Tod River. Nutrient inputs from finfish aquaculture are likely to be 1–2 orders of magnitude higher than the other sources combined (Gaylard et al. 2014)¹.

A regional monitoring program for aquaculture during 2015–2019 identified that tuna and other finfish aquaculture were having a detectable impact on nutrient levels and phytoplankton communities within Boston Bay, and the potential impact of these nutrients on seagrasses in the region is being investigated during the 2019–2023 monitoring program (Tanner 2020).

Discharges of ammonia from the Port Lincoln wastewater treatment plant at Billy Lights Point have reduced in previous years as the results of reuse of treated water and improvements to the treatment process (Figure 3).

The EPA (2018) reported that two fish processing facilities discharged to the marine environment, but there was an intent to facilitate discharges to the local sewer network. The status of this initiative is unknown.

The quality of water flowing to the sea from the Tod River is likely to be poor, bringing nutrients and sediments from the agricultural land within its catchment (EPA 2018).

¹ In 2011/12, estimates of Tuna and kingfish aquaculture nutrient inputs at Port Lincoln, including offshore, were approximately 2,000 t, while the other inputs listed were < 10 t.

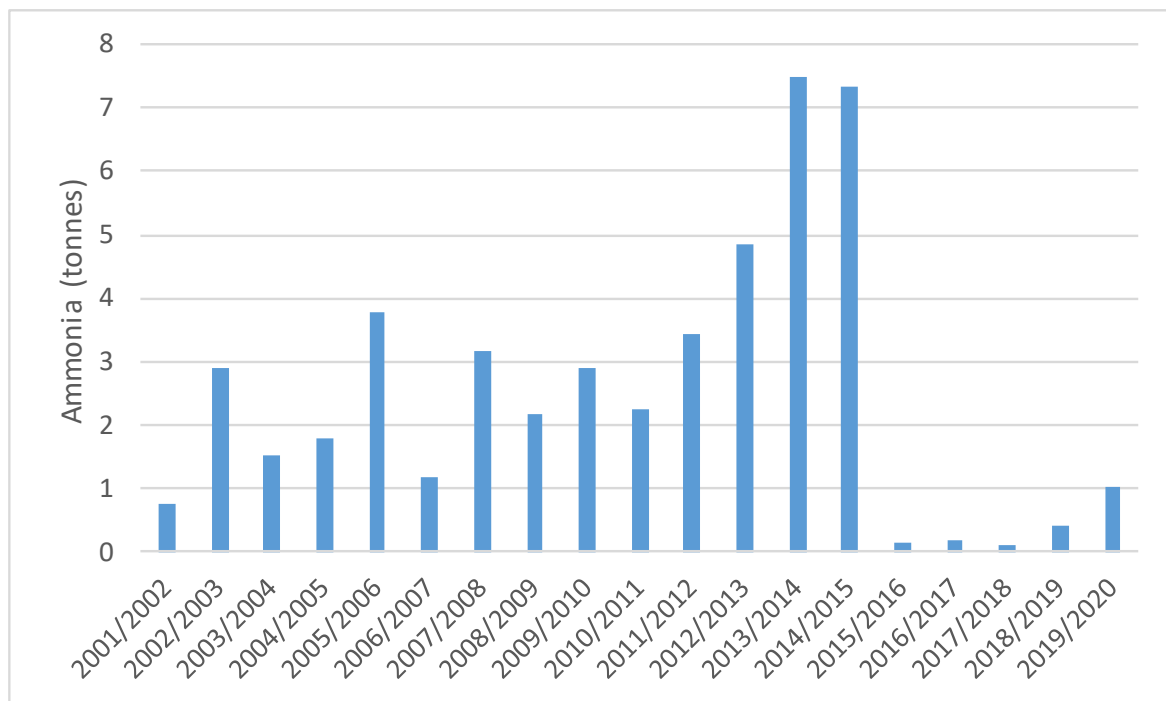


Figure 3. Discharge of ammonia from the wastewater treatment plant at Billy Lights Point. Source: DAWE (2021).

Twenty-eight pest species have been identified in Proper, Boston and Louth Bays (Wiltshire et al. 2010, PIRSA unpublished data), including six microalgae, a brown macroalga, two hydroids, six polychaete worms, a barnacle, two molluscs (both farmed species), five bryozoans and five ascidians (Table 2).

Table 2. Introduced species previously recorded in Proper, Boston and Louth Bays

Group	Species
Microalgae	<i>Alexandrium catenella</i>
	<i>Alexandrium minutum</i>
	<i>Chattonella marina</i>
	<i>Gymnodinium catenatum</i>
	<i>Heterosigma akashiwo</i>
	<i>Vicicitus globosus</i>
Macroalgae	<i>Stictyosiphon soriferus</i>
Hydroids	<i>Coryne eximia</i>
	<i>Halecium delicatulum</i>
Polychaetes	<i>Boccardia chilensis</i>
	<i>Hydroides elegans</i>
	<i>Myxicola infundibulum</i>
	<i>Polydora ciliata</i>
	<i>Pseudopolydora paucibranchiata</i>
	<i>Sabella spallanzanii</i>
Barnacles	<i>Megabalanus tintinnabulum</i>
Molluscs	<i>Crassostrea gigas</i>
	<i>Mytilus galloprovincialis</i>
Bryozoans	<i>Bugula flabellata</i>
	<i>Bugula neritina</i>
	<i>Schizoporella unicornis</i>
	<i>Watersipora arcuata</i>
	<i>Watersipora subtorquata</i>
Ascidians	<i>Ascidella aspersa</i>
	<i>Botrylloides leachi</i>
	<i>Botryllus schlosseri</i>
	<i>Ciona intestinalis</i>
	<i>Styela plicata</i>

2 Methods

2.1 Acquisition of video data

Video footage was acquired by SA Water at the sites shown in Figure 4, and provided to the author. The acquisition was spread across several periods (28 September 2021, 16 November 2021 and 26–27 May 2022), with the study area expanding during the desalination site selection process.

Each sample site was inspected by using a ‘camera-drop’ methodology, whereby a submersible Scielex video camera was lowered alongside a stationary boat, using a cable through which standard definition video was transmitted to the vessel. A GPS was linked to the camera topside system to accurately determine the position and date and time of each transect. A high resolution (GoPro) video camera was mounted above the Scielex camera to provide additional high-resolution imagery for post-field analysis. For each drop, the camera was lowered to approximately 0.5 m above the seafloor for 30 seconds for detailed observations, then to approximately 2 m above the seafloor for a further 30 seconds for an overall view. General observations and impressions of the benthic cover and exposure were denoted during field inspections using the Scielex ‘real-time’ video output, but the assessment of the benthic habitats using the high resolution video footage for the current study was completed post-field.

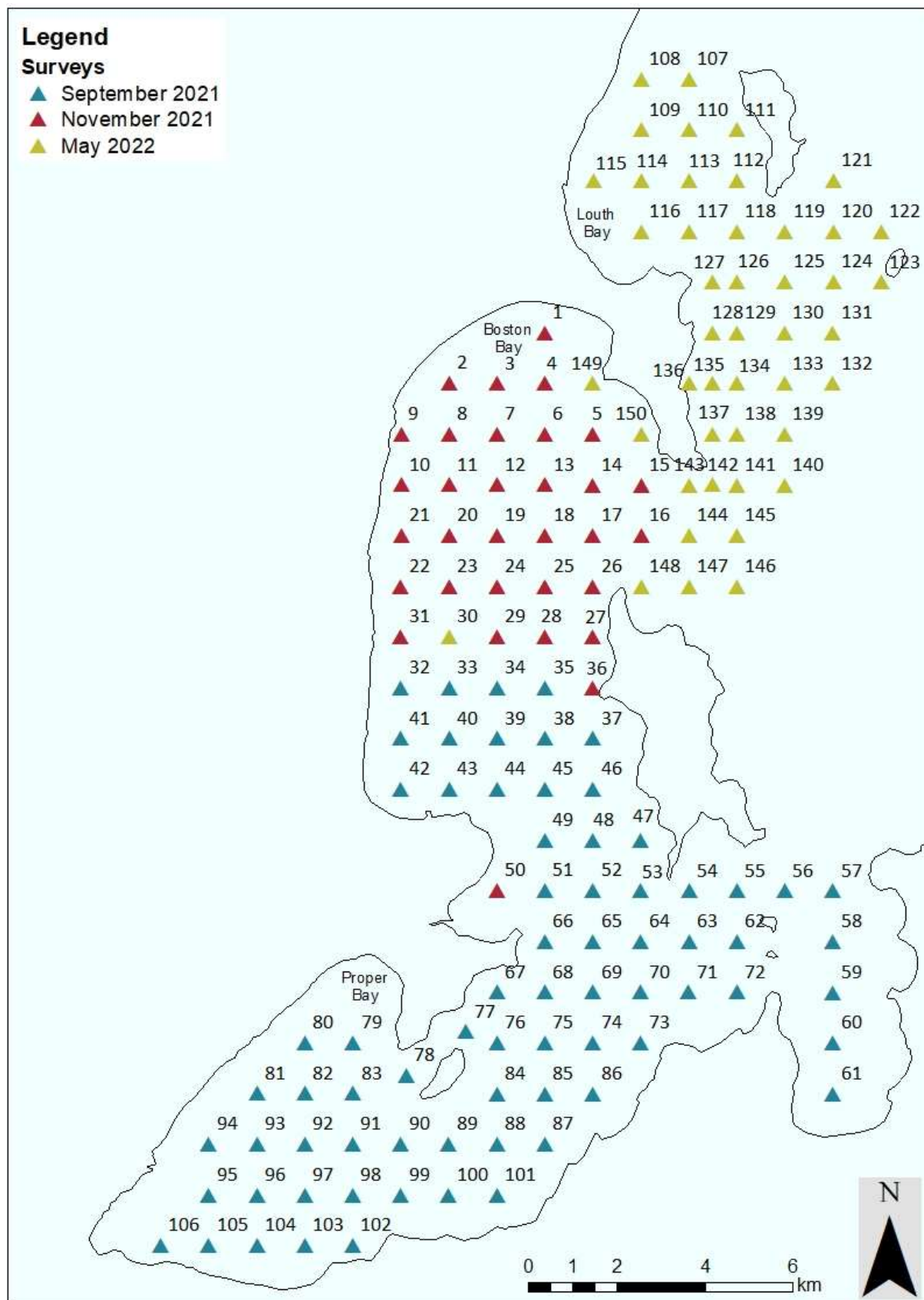


Figure 4. Towed video survey sites

2.2 Quantification of habitat features

The usable portion of video for each site was identified, which was generally from when the seabed first came into focus after camera descent to the commencement of camera ascent. Five frames separated by equal time intervals were extracted from the video using a custom R script in conjunction with the open source ffmpeg program, and point overlay files were generated for use with the Coral Point Count with extensions (CPCe) program (Kohler & Gill 2006). Twelve point intercepts were arranged in a regular 3 x 4 grid over an area of each frame image within a margin of 300 pixels at the top and 100 pixels on the other sides (Figure 5). The greater margin at the top was because the supplied video was taken at a forward-facing angle rather than straight down, and hence the seabed was not as clearly visible at the top of the image as at the bottom. A percentage cover of each feature at each site was calculated from the number of point intercepts that feature divided by the total number of point classifications (60) minus any points excluded because they could not be identified (e.g. were in shadow). For seagrass, the cover was assumed to overlap with the cover of epiphytes.

The presence of introduced species was noted for each site from observation of the video.

Two methods were used to determine an overall habitat class for each site based on the various habitat features recorded. The first method was based on multivariate analyses using the CLUSTER and SIMPROF routines of the PRIMER software, Version 6 (Clarke and Warwick 2001, Clarke and Gorley 2006) to determine habitat classes, and the SIMPER routine to determine the features that characterised each habitat class.

The second method was a rule-based framework that prioritised features identified by a literature review as being potentially impacted by desalination plant discharges (Tanner & Drabsch 2021). These features included seagrasses, filter feeding invertebrates and macroalgae, prioritised as per Table 1. The classification distinguished between turfing and other macroalgae because of functional differences and possible representation of different condition states between these groups, noting that within each of these categories there remain differences in morphology and ecology (Turner et al. 2006, Connell et al 2014).

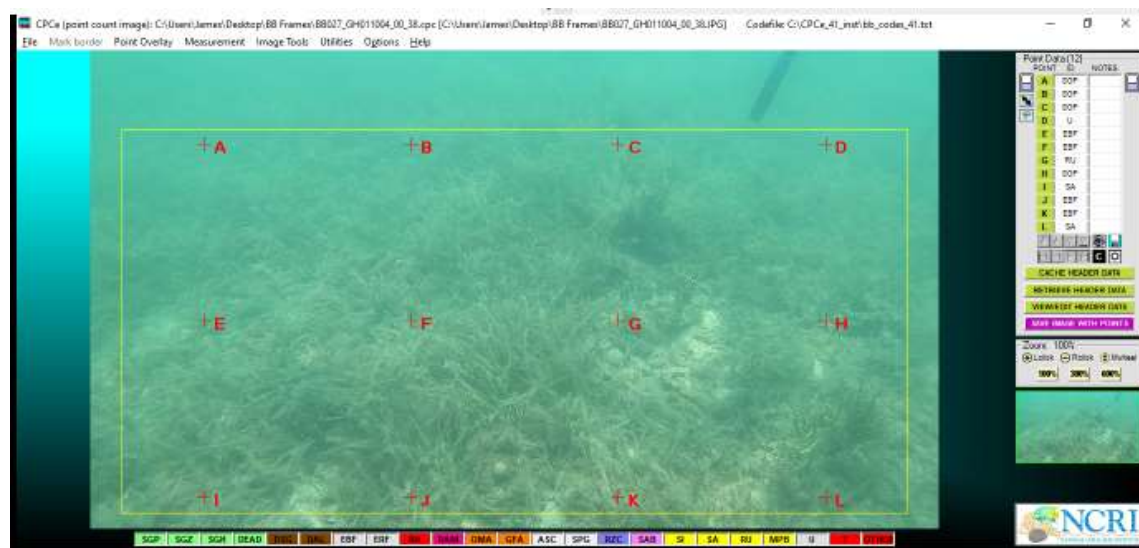


Figure 5. Sample screen from the 'Coral Point Count' program.

Table 3. Rule-based habitat classification

Rule	Habitat Class
If <i>Posidonia</i> cover > 66%	<i>Posidonia</i> dense
Else if <i>Posidonia</i> cover > 33%	<i>Posidonia</i> moderate
Else if <i>Posidonia</i> cover > 0%	<i>Posidonia</i> sparse
Else if <i>Halophila</i> cover > 10%	<i>Halophila</i>
Else if <i>Zostera</i> cover > 10%	<i>Zostera</i>
Else if filter feeder cover > 10%	Filter feeders
Else if (red/green/brown) macroalgal cover > 50%	Macroalgae dense
Else if (red/green/brown) macroalgal cover > 10%	Macroalgae sparse
Else if turf cover > 50%	Turf dense
Else if turf cover > 10%	Turf sparse
Else	Bare sediment

3 Results

Usable video durations (from when the seafloor came into focus until the camera was retrieved) ranged from 18–151 seconds (mean 68 seconds).

Habitat features identified during the point intercept analysis included seagrass, epiphytic algae, turfs (including microphytobenthos), other macroalgal lifeforms, filter feeders and sediment.

The clustering process identified the following 13 habitat classes characterised by:

- Dense *Posidonia* with epiphytes (Plate 1)
- High to moderately dense *Posidonia* with epiphytes (Plate 2)
- Moderately dense *Posidonia* with epiphytes (Plate 3)
- Sparse *Posidonia* (Plate 4)
- Sparse *Posidonia* with large brown macroalgae (Plate 5)
- *Halophila australis* and red macroalgae (Plate 6)
- Moderately dense red macroalgae (Plate 7)
- Sparse red macroalgae (Plate 8)
- Sparse red macroalgae/turf (Plate 9)
- Moderately dense turf (Plate 10)
- Sparse turf
- Filter feeders (Plate 11)
- Bare sediment (Plate 12, but see also coarser sand in Plate 8)

Details of the habitat features scored during the point intercept analysis and their corresponding habitat classes are provided in Appendix A. Details of the clustering process including the dendrogram, SIMPER analysis and multi-dimensional scaling plot are provided in Appendix A.

Habitat classes not identified by the clustering process but which were included in the rule-based classification include *Zostera* (Plate 13) and dense *Posidonia* with no/few epiphytes (Plate 14). The *Posidonia* species throughout Proper and Boston Bays was *P. sinuosa*². A number of *Posidonia* sites in Louth Bay included *P. australis*, either as monospecific stands (Plate 15) or mixed with *P. sinuosa* (Plate 16). Atypical sites included Site 81, with a distinct boundary between dense red macroalgae and seagrass (Plate 17), and Site 105 with green filamentous macroalgae prevalent amongst the *Posidonia* (Plate 18).

The results of the cluster- and rule-based habitat classifications are shown in Figure 6. A summary of the comparison of the two habitat classification methods is provided in Table 4. Classification using the rule-based scheme rather than cluster-based scheme saw the reallocation of sites classified as ‘bare sediment’ or ‘turf sparse’ to *Halophila*, *Zostera*, sparse *Posidonia*, sparse red macroalgae or sparse turf categories, while some of the ‘*Halophila*/red macroalgae’ sites were reclassified to sparse *Posidonia* or dense red macroalgae categories. It is emphasised that these habitat classes are named according to their dominant (for cluster-based classes) or important (for rule-based classes) features but may include other biota. In particular, the ‘bare sediment’ rule-based habitat class may have up to 10% seagrass, macroalgae or filter feeders and the equivalent cluster-based class may also include biota.

² It is possible that other thin-strapped *Posidonia* species, e.g. *P. angustifolia*, were present.

Seagrass and epiphyte covers are shown in Figure 7.

The most abundant introduced species observed during video analysis was the European fan worm *Sabella spallanzanii*, with a dense cover (many present in each video frame) at three sites, a relatively sparse cover at 35 sites and possible identifications at a further four sites (Figure 8). The cryptogenic species *Myxicola infundibulum* (feather-duster worm) was also observed at Sites 26 and 76.

Table 4. Number of sites assigned to each habitat class for both cluster- and rule-based classification systems.

Cluster-based habitat classes	Rule-based habitat classes										
	<i>Halophila</i>	<i>Zostera</i>	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density	<i>Posidonia</i> sparse	Red macroalgae dense	Red macroalgae sparse	Turf dense	Turf sparse	Filter feeders	Bare sediment
<i>Halophila</i> /red macroalgae	2				2	2					
<i>Posidonia</i> dense			30	5							
<i>Posidonia</i> mod. to high density				14							
<i>Posidonia</i> moderate density				5	5						
<i>Posidonia</i> sparse					5						
<i>Posidonia</i> sparse/macroalgae					1						
Red macroalgae moderate					1	1	6				
Red macroalgae sparse	1				1		3				
Red macroalgae/turf sparse					2		2			1	
Turf moderate density					2		4	6	4	1	
Turf sparse	1	2			1		3		13		
Filter feeders										4	
Bare sediment	3	2			1		1		1		12



Plate 1. Dense *Posidonia sinuosa*, with dense epiphyte cover



Plate 2. Moderate to high density *Posidonia sinuosa*, with moderate epiphyte cover



Plate 3. Moderately dense *Posidonia sinuosa*



Plate 4. Sparse *Posidonia sinuosa*



Plate 5. Sparse *Posidonia* with large brown macroalgae



Plate 6. *Halophila australis* with red macroalgae



Plate 7. Moderately dense red macroalgae



Plate 8. Sparse red macroalgae



Plate 9. Sparse red macroalgae/turf



Plate 10. Moderately dense turfing algae (including microphytobenthos)



Plate 11. Filter feeders including razor clam *Pinna bicolor* and mauve-mouthed ascidian *Polycarpa viridis*



Plate 12. Predominantly bare substrate

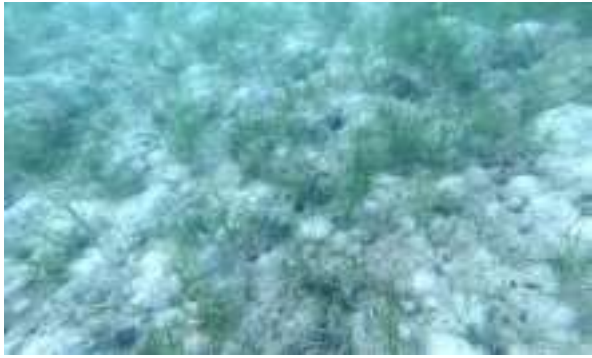


Plate 13. *Zostera*, probably *Z. nigricaulis*



Plate 14. Dense *Posidonia sinuosa*, with few epiphytes



Plate 15. *Posidonia australis*



Plate 16. *Posidonia australis* mixed with *P. sinuosa*



Plate 17. Red macroalgae/*Posidonia sinuosa* boundary



Plate 18. *Posidonia sinuosa* with green filamentous macroalgae

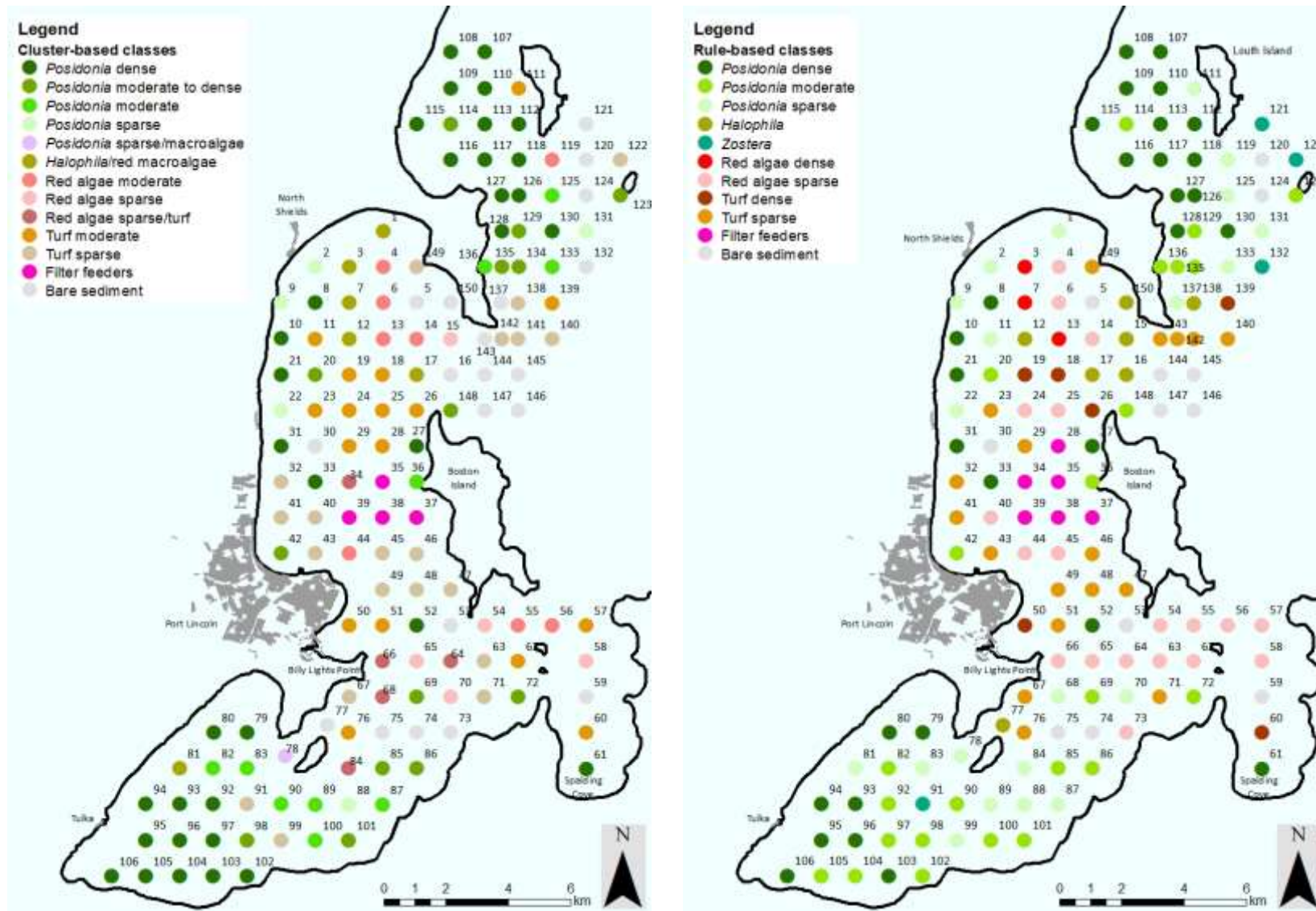


Figure 6. Habitat classifications based on clustering (left) or hierarchical rules (right).

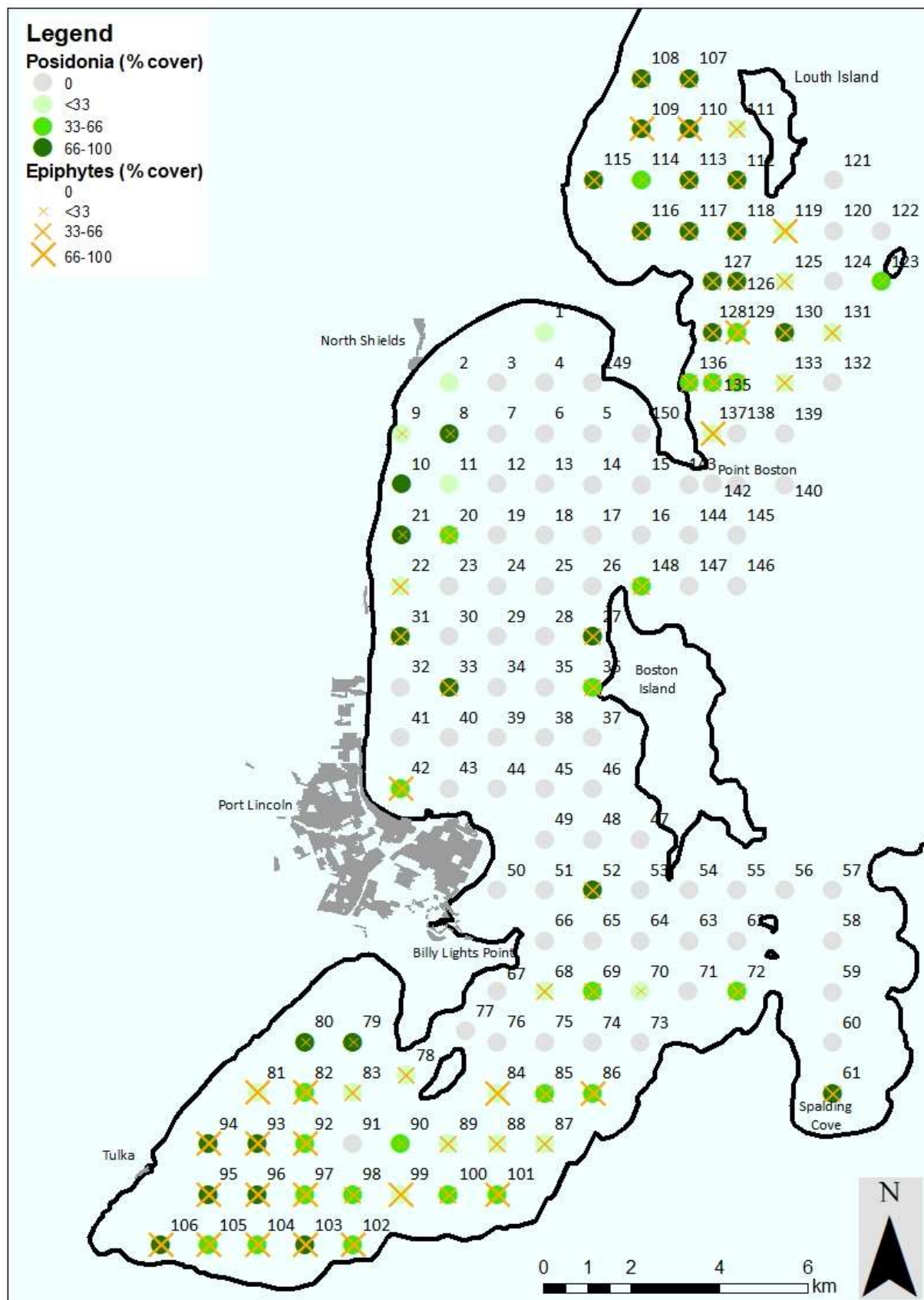


Figure 7. Percentage cover classes of *Posidonia* at each site, overlaid by percentage epiphyte cover classes. Note that *Posidonia* cover is a percentage of the seafloor, but epiphyte cover is a percentage of *Posidonia* cover.

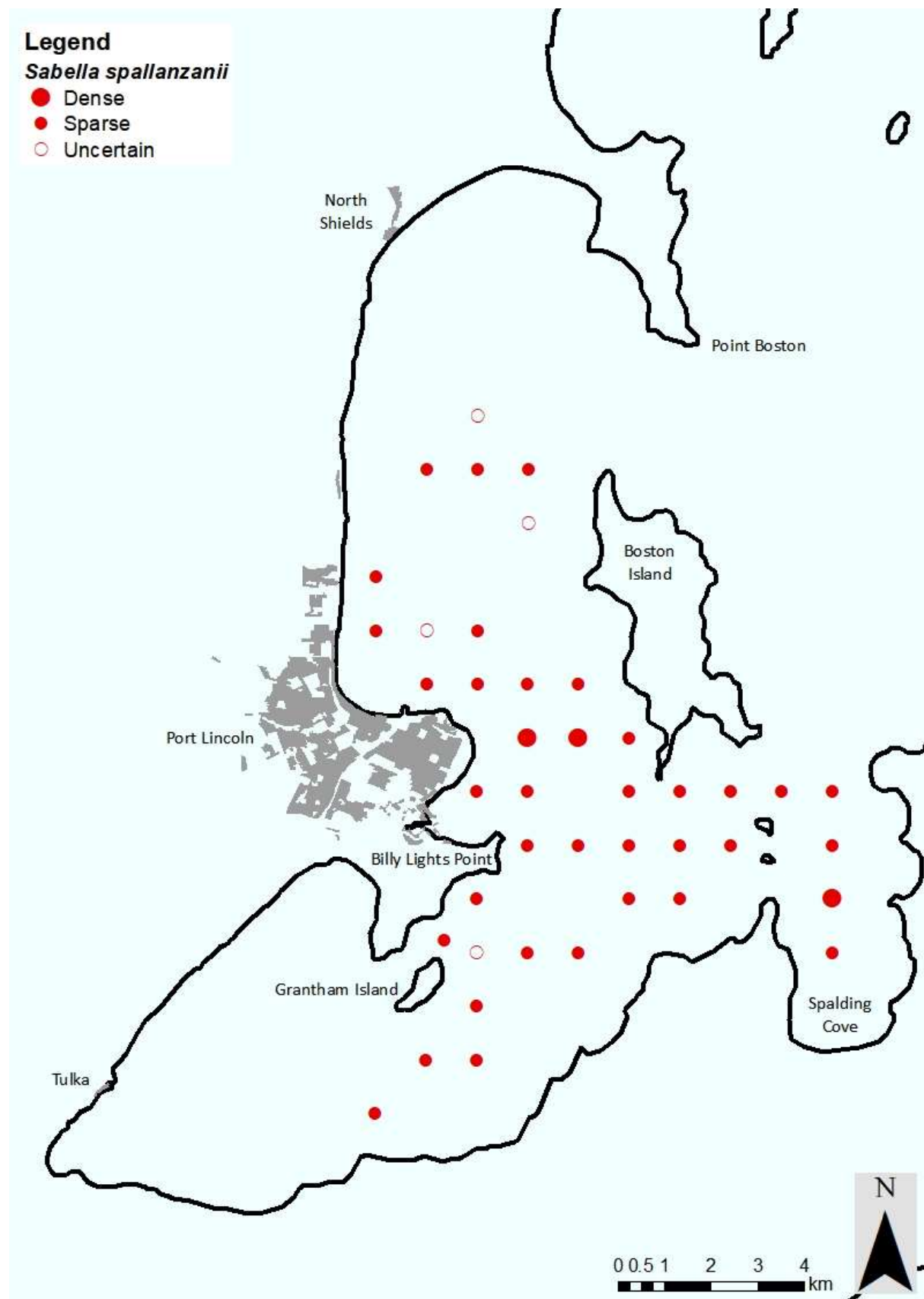


Figure 8. Distribution of the European fan worm *Sabella spallanzanii*.

4 Discussion

4.1 Spatial patterns and physical drivers

Spatial patterns were evident across the Bays (Figure 6). *Posidonia* seagrass was the dominant habitat throughout Proper Bay, with relatively dense cover generally close to the western and southern coastlines of the Bay. There was an isolated site with dense *Zostera* in the middle of the Bay.

Posidonia in Boston Bay was restricted to inshore sites and in the lee of northern Boston Island. *Halophila* and filter feeders were the dominant habitats to the north and west of Boston Island, respectively. Red macroalgae dominated the area directly east from Billy Lights Point to the south-east of Boston Island, and in the north of Boston Bay. Turfing macroalgae were dominant to the north-west and south-west of Boston Island, and bare substrate to the north-east (Figure 6).

Dense *Posidonia* was the dominant habitat in Louth Bay, transitioning to sparser *Posidonia* to the south and turfing macroalgae around Point Boston. *Zostera* was recorded between Louth and Rabbit Islands and further south (Figure 6).

These findings were generally consistent with broad-scale patterns of cover mapped by University of Adelaide, including vegetative cover throughout Proper Bay, on the north-eastern shoreline of Boston Bay and in Louth Bay (Figure 2, Figure 6).

Epiphyte levels were generally highest in Louth Bay and Proper Bay, and in the south of Boston Bay (Figure 7).

Both bays are relatively sheltered from wave exposure, with most of the mainland shoreline classified as 'low' or 'very low', the lowest of a five-level classification by DEW (2022). Relatively few areas classified as *Posidonia* were found in the areas with relatively high (i.e. 'low' rather than 'very low') wave exposure (Figure 9). Epiphytes levels were generally highest in sheltered waters, and it should be noted that the high epiphyte levels near Point Boston are on seagrass of less than 2% cover and determined from a single point overlay.

Depth is also likely to be a major influence on seagrass distribution, noting that the *Posidonia* sites were generally at shallower depths (less than 10 m) and *Halophila* and *Zostera* were in relatively deep areas (Figure 9). The maximum depth of *Posidonia* in Boston Bay is shallower than other locations in South Australia, including the Adelaide metropolitan coastline, where it is usually found to depths of 15 m (Westphalen et al. 2005).

There could be several additional factors controlling seagrass distribution including water quality, substrate type and species. It should be noted that the spatial patterns observed in this study are potentially confounded by temporal change between the three sampling events each targeting a different set of sites (Figure 4). However, the dominant species in the region was *Posidonia*, which is a perennial species. Seasonal changes in its distribution are not usually observed other than in relation to blade density (shed during autumn and winter and grow during spring and summer). These changes may have some minor impact on percentage cover estimates but seasonal differences in meadow aerial production would not be expected (Short et al. 2017).

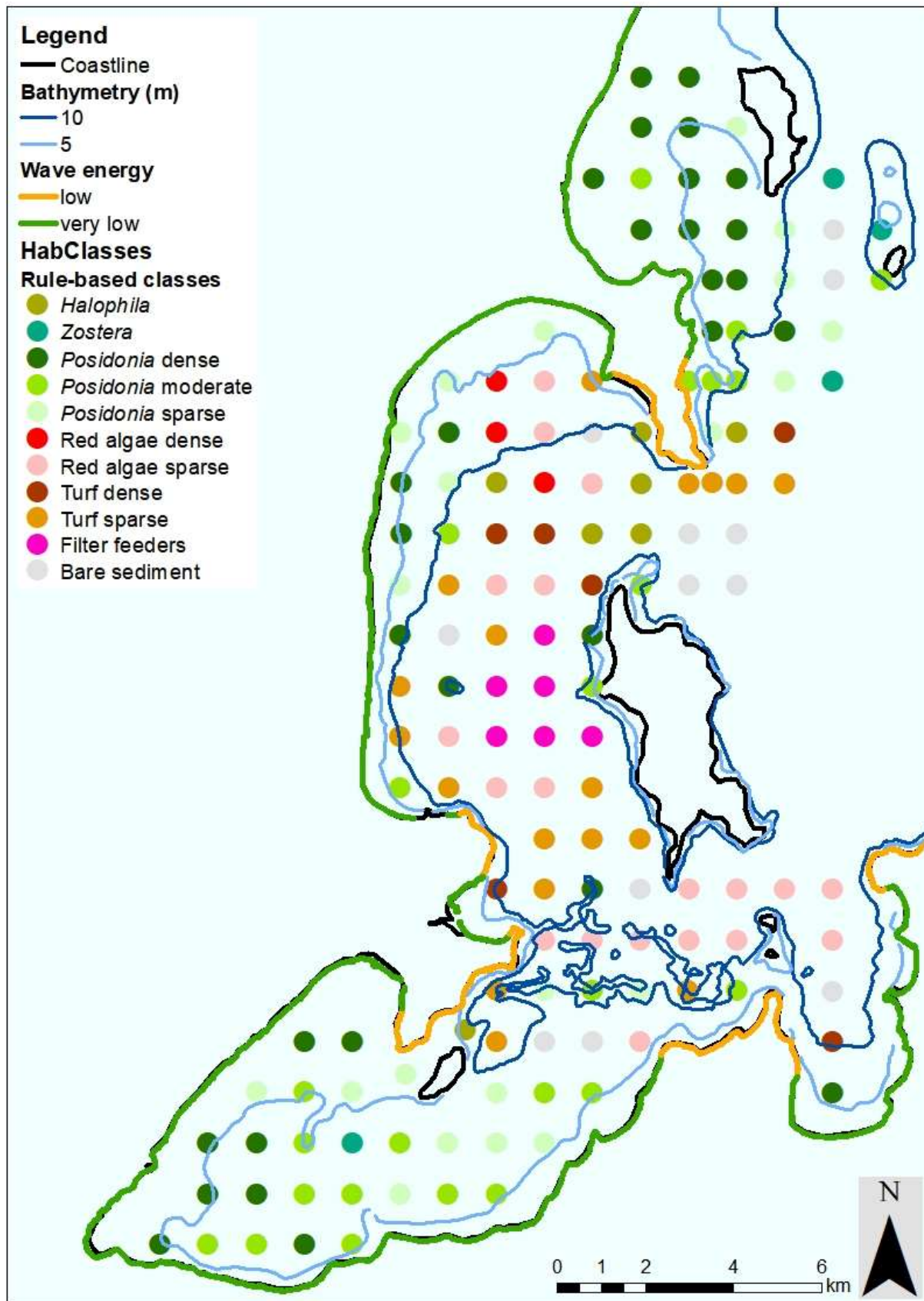


Figure 9. Wave energy at mainland shorelines in Proper Bay and Boston Bay, bathymetry contours and habitat classes derived for this study. Note that wave energy at island shorelines has not been classified. Source: DEW 2022b (wave exposure), DEW 2022c (bathymetry).

4.2 Habitat condition

The EPA noted that from their 2018 survey of Boston, Proper and Louth Bays (EPA, 2018) that many sites monitored were under stress from nutrient enrichment, resulting in epiphyte growth which could result in seagrass loss over time (Section 1.2.2). The current study showed that epiphyte levels appeared highest in Proper Bay, south of Boston Bay (near Port Lincoln) and Louth Bay (near Louth Island) and were similar to levels recorded by the EPA (2018) in these areas.

The data presented in this report are not sufficient to draw inferences on the impact of aquaculture on habitat condition in Boston, Proper or Louth Bays, with reasons including the lack of before and after data obtained using a consistent method, and inadequate spatial coverage of the 'before' data. Similarly, there is insufficient spatial coverage and resolution to draw conclusions about change in habitat condition since the reduction of nutrient discharge from the WWTP.

The European fan worm has been identified as one of the pest species of most concern within South Australia (PIRSA undated) and has been declared 'noxious' under the *Fisheries Management Act 2007* (PIRSA 2019). It may compete with native or farmed filter feeders. There were no records near Port Lincoln from a review of marine pests by Wiltshire et al. (2010), nor from a regional survey that included Port Lincoln wharf and marina (Dittmann et al. 2010), but there was a record from 2010 near the wharf (SARDI unpublished data). The current study showed a distribution extending up to 5 km to the north and 10 km to the south and east of Port Lincoln (Figure 8). The feather duster worm *Myxicola infundibulum*, a cryptogenic³ species observed at two sites, is not considered to be a significant threat to the ecology of the region. Many of the introduced species previously recorded in the region would not be recognisable from video footage and the absence of observations does not mean an absence of these species.

5 Conclusion

The habitat survey found dense *Posidonia* throughout Louth Bay (west of Louth Island), along the shallow, sheltered western coastline of Boston Bay. The relatively deep waters further west in Boston Bay were dominated by *Halophila* and red macroalgae in the north, filter feeding invertebrates in the centre of the Bay, and bare sediment to the south. *Posidonia* extended throughout most of Proper Bay but was at lower densities than the western side of the Bay. *Zostera* was found at the deepest sites to the south-east and south of Louth Island, and a site near the centre of Proper Bay.

Other habitats identified as being particularly relevant to desalination discharge are macroalgae, which were relatively dense towards the north of Boston Bay and sparser south of Boston Island, and filter feeders, which were dominant in deeper water west of Boston Island.

The current survey showed that epiphyte levels remain high in Louth Bay, Proper Bay and southern Boston Bay, indicating that these areas may remain under stress from nutrient enrichment.

³i.e. uncertain origin

6 References

- Clarke, KR & Gorley, RN (2006), *PRIMER v6: User Manual/ Tutorial*. PRIMER-E Ltd, Plymouth.
- Clarke, KR & Warwick, RM (2001), *Change in Marine Communities: An approach to Statistical Analysis and Interpretation*. Plymouth Marine Laboratory, Plymouth.
- Clarke, K, Hennessy, A & Lewis, M (2018), *Adelaide Metropolitan Coastline benthic habitat mapping from hyperspectral imagery, Product A: bare-substrate vs non-bare substrate*, University of Adelaide, report to SA Water, SA Department for Environment and Water, and SA Environmental Protection Authority.
- Connell, SD, Foster, M & Airoidi, L (2014), What are algal turfs? Towards a better description of turfs. *Marine Ecology Progress Series*, 495, 299-307.
- DAWE (2021), *National Pollutant Inventory, Australian Government*. <http://www.npi.gov.au>, Australian Government Department of Agriculture, Water and the Environment, viewed December 2021.
- DEW (2022a), EGIS data: *Marine Benthic Habitats*, viewed June 2022, http://location.sa.gov.au/lms/Reports/ReportMetadata.aspx?p_no=1224&pu=y&pa=dewnr. Department for Environment and Water, Adelaide, South Australia.
- DEW (2022b), EGIS data: *Coastal Shoreline Classification*, viewed June 2022, http://location.sa.gov.au/lms/Reports/ReportMetadata.aspx?p_no=1149&pu=y&pa=dewnr. Department for Environment and Water, Adelaide, South Australia.
- DEW (2022c), EGIS data: *Topography - Bathymetry - Navigation Chart*, viewed June 2022, http://location.sa.gov.au/lms/Reports/ReportMetadata.aspx?p_no=1121&pu=y&pa=dewnr. Department for Environment and Water, Adelaide, South Australia.
- Dittmann S, Cameron S, Conlon K (2010) Increasing knowledge on introduced species in the marine environments of the Eyre Peninsula. Draft report to the Eyre Peninsula Natural Resources Management Board. Flinders University of South Australia, Bedford Park.
- 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, PIRSA, F2007/000565-9. SARDI Research Report Series No. 816. 44pp.
- EPA (2018a), Jussieu Nearshore Marine Biounit 2010 Aquatic Ecosystem Condition Report, viewed 3 June 2022, https://www.epa.sa.gov.au/reports_water/jussieu-ecosystem-2010.
- EPA (2018b), Jussieu Nearshore Marine Biounit 2016 Aquatic Ecosystem Condition Report, viewed 3 June 2022, https://www.epa.sa.gov.au/reports_water/jussieu-ecosystem-2016.
- Gaylard, S (2014). Marine Pollution in Spencer Gulf. In Shepherd S.A., Madigan, S.M., Gillanders B.M., Murray-Jones, S., Wiltshire D.J., (eds.), *Natural History of Spencer Gulf*, Royal Society of South Australia: Adelaide.
- Hennekam, ME & Clarke, K (2021), *Addition of 2021 mapping and comparison to previous years*. Draft results addendum to Clarke, K & Lewis, M (2020). *Mapping change in seagrass cover over time (1991, 2008 and 2015): Boston and Louth Bays, South Australia*, The University of Adelaide, for The Environment Protection Authority.

Kohler, KE & Gill, SM (2006), Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32(9), pp. 1259-1269.

Miller, D, Westphalen, G, Jolley, AM & Brayford, B (2009), *Marine Habitats within the Sheltered Bays of the Eyre Peninsula NRM Region*, Final Report to the Eyre Peninsula Natural Resources Management Board for the program: Establishing Marine Baselines. Coast and Marine Conservation Branch, Department for Environment and Heritage, Adelaide, South Australia.

PIRSA (2019), *Noxious fish list*, Primary Industries and Regions South Australia, Government of South Australia, Adelaide, viewed 24 July 2020, http://pir.sa.gov.au/biosecurity/aquatics/aquatic_pests/noxious_fish_list.

PIRSA (undated), *Stop aquatic pests harming our environment*, brochure produced by Primary Industries and Regions South Australia.

Short, J, Fraser, M, McLean, D, Kendrick, G, Byrne, M, Caley, J, Clarke, D, Davis, A, Erftemeijer, P, Field, S, Gustin-Craig, S, Huisman, J, Keesing, J, Keough, M, Lavery, P, Masini, R, McMahon, K, Mergersen, K, Rasheed, M, Statton, J, Stoddart, J & Wu, P (2017), *Effects of dredging-related pressures on critical ecological processes for organisms other than fish or coral*, Report of Theme 9 – Project 9.1, prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia.

Tanner, JE & Drabsch, S (2021). *Literature review of potential impacts of desalination discharges in Boston Bay, with particular reference to Aquaculture*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2021/000299-1. SARDI Research Report Series No. 1105. 17pp.

Tanner, JE, Doubell, M, van Ruth, P, James C & Middleton, J (2020), *Aquaculture Environmental Monitoring Program: 2015-2019*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2019/000334-1. SARDI Research Report Series No. 1053. 67pp.

Turner, DJ, Kildea, TN & Murray-Jones, S (2006), *Examining the health of subtidal reef environments in South Australia, Part 1: Background review and rationale for the development of the monitoring program*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 62pp. SARDI Publication Number RD03/0252-3.

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.

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

Appendix A. Point intercept scores and habitat classes

Note that total percentages for each site may exceed 100% because of overlap between seagrass and epiphytes.

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
1	0.0	1.7	0.0	0.0	23.3	0.0	0.0	0.0	75.0	0.0	<i>Halophila</i> /red macroalgae	<i>Posidonia</i> sparse
2	0.0	18.6	0.0	0.0	81.4	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> sparse	<i>Posidonia</i> sparse
3	0.0	0.0	0.0	0.0	16.7	0.0	0.0	0.0	83.3	0.0	<i>Halophila</i> /red macroalgae	Red macroalgae dense
4	0.0	0.0	0.0	0.0	60.7	0.0	0.0	0.0	39.3	0.0	Red macroalgae moderate density	Red macroalgae sparse
5	0.0	0.0	0.0	0.0	90.0	0.0	0.0	0.0	7.3	0.0	Bare sediment	Bare sediment
6	0.0	0.0	0.0	0.0	63.3	0.0	0.0	0.0	36.7	0.0	Red macroalgae moderate density	Red macroalgae sparse
7	0.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0	86.7	0.0	<i>Halophila</i> /red macroalgae	Red macroalgae dense
8	6.7	90.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
9	1.7	13.3	0.0	0.0	86.7	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> sparse	<i>Posidonia</i> sparse
10	0.0	98.3	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
11	0.0	5.0	0.0	0.0	45.0	41.7	0.0	3.3	3.3	1.7	Turf moderate density	<i>Posidonia</i> sparse
12	0.0	0.0	43.3	0.0	15.0	25.0	0.0	0.0	16.0	0.0	<i>Halophila</i> /red macroalgae	<i>Halophila</i>
13	0.0	0.0	0.0	0.0	42.4	0.0	0.0	0.0	57.6	0.0	Red macroalgae moderate density	Red macroalgae dense
14	0.0	0.0	0.0	0.0	51.7	0.0	0.0	0.0	48.3	0.0	Red macroalgae moderate density	Red macroalgae sparse
15	0.0	0.0	20.0	0.0	66.7	0.0	0.0	0.0	12.0	0.0	Red macroalgae sparse	<i>Halophila</i>
16	0.0	0.0	13.3	0.0	81.7	0.0	0.0	0.0	5.0	0.0	Bare sediment	<i>Halophila</i>
17	0.0	0.0	58.3	0.0	28.3	0.0	0.0	0.0	13.3	0.0	<i>Halophila</i> /red macroalgae	<i>Halophila</i>
18	0.0	0.0	0.0	0.0	0.0	96.7	0.0	0.0	3.3	0.0	Turf moderate density	Turf dense
19	0.0	0.0	0.0	0.0	5.0	93.3	0.0	0.0	1.7	0.0	Turf moderate density	Turf dense

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
20	38.3	58.3	0.0	0.0	28.3	10.0	0.0	0.0	0.0	3.3	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
21	8.3	90.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
22	12.1	19.0	0.0	0.0	77.6	1.7	0.0	0.0	0.0	1.7	<i>Posidonia</i> sparse	<i>Posidonia</i> sparse
23	0.0	0.0	0.0	0.0	40.0	46.7	0.0	0.0	5.3	6.7	Turf moderate density	Turf sparse
24	0.0	0.0	0.0	0.0	41.7	40.0	0.0	0.0	15.0	3.3	Turf moderate density	Red macroalgae sparse
25	0.0	0.0	0.0	0.0	30.0	45.0	0.0	0.0	23.3	1.7	Turf moderate density	Red macroalgae sparse
26	0.0	0.0	0.0	0.0	40.7	57.6	0.0	0.0	1.7	0.0	Turf moderate density	Turf dense
27	32.7	80.0	0.0	0.0	12.7	0.0	0.0	3.6	3.6	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
28	0.0	0.0	0.0	0.0	29.3	53.4	0.0	0.0	1.7	15.5	Turf moderate density	Filter feeders
29	0.0	0.0	0.0	0.0	40.0	50.0	0.0	0.0	0.0	10.0	Turf moderate density	Turf sparse
30	0.0	0.0	0.0	0.0	90.0	8.3	0.0	1.7	0.0	0.0	Bare sediment	Bare sediment
31	44.1	72.9	0.0	0.0	25.4	0.0	0.0	0.0	0.0	1.7	<i>Posidonia</i> dense	<i>Posidonia</i> dense
32	0.0	0.0	0.0	0.0	75.9	13.8	0.0	0.0	2.7	6.9	Turf sparse	Turf sparse
33	54.2	84.7	0.0	0.0	11.9	0.0	0.0	0.0	1.7	1.7	<i>Posidonia</i> dense	<i>Posidonia</i> dense
34	0.0	0.0	0.0	0.0	51.7	15.5	0.0	0.0	19.0	13.8	Red macroalgae sparse/turf	Filter feeders
35	0.0	0.0	0.0	0.0	58.3	5.0	0.0	0.0	0.0	36.7	Filter feeders	Filter feeders
36	18.3	36.7	0.0	0.0	55.0	8.3	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> moderate density
37	0.0	0.0	0.0	0.0	50.0	16.7	0.0	0.0	1.7	31.7	Filter feeders	Filter feeders
38	0.0	0.0	0.0	0.0	58.3	3.3	0.0	0.0	13.3	25.0	Filter feeders	Filter feeders
39	0.0	0.0	0.0	0.0	53.3	15.0	0.0	1.7	2.0	26.7	Filter feeders	Filter feeders
40	0.0	0.0	0.0	0.0	63.3	18.3	0.0	0.0	11.7	6.7	Turf sparse	Red macroalgae sparse
41	0.0	0.0	0.0	0.0	66.7	20.0	0.0	0.0	3.3	10.0	Turf sparse	Turf sparse

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
42	33.9	39.0	0.0	0.0	47.5	1.7	0.0	0.0	8.5	3.4	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
43	0.0	0.0	0.0	0.0	73.3	16.7	0.0	0.0	10.0	0.0	Turf sparse	Turf sparse
44	0.0	0.0	0.0	0.0	58.3	10.0	0.0	0.0	30.0	1.7	Red macroalgae moderate density	Red macroalgae sparse
45	0.0	0.0	0.0	0.0	66.7	20.0	0.0	0.0	11.7	1.7	Turf sparse	Red macroalgae sparse
46	0.0	0.0	0.0	0.0	71.7	16.7	0.0	0.0	1.7	10.0	Turf sparse	Turf sparse
47	0.0	0.0	0.0	0.0	71.7	20.0	0.0	0.0	5.0	3.3	Turf sparse	Turf sparse
48	0.0	0.0	0.0	0.0	68.3	23.3	0.0	0.0	3.3	5.0	Turf sparse	Turf sparse
49	0.0	0.0	0.0	0.0	72.9	22.0	0.0	0.0	1.7	3.4	Turf sparse	Turf sparse
50	0.0	0.0	0.0	0.0	25.9	69.0	0.0	0.0	1.7	3.4	Turf moderate density	Turf dense
51	0.0	0.0	0.0	0.0	45.0	46.7	0.0	0.0	0.0	8.3	Turf moderate density	Turf sparse
52	51.7	86.7	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
53	0.0	0.0	0.0	0.0	80.0	5.0	0.0	0.0	6.7	8.3	Bare sediment	Bare sediment
54	0.0	0.0	0.0	0.0	66.7	13.3	0.0	0.0	16.7	3.3	Red macroalgae sparse	Red macroalgae sparse
55	0.0	0.0	0.0	0.0	58.3	6.7	0.0	0.0	31.7	3.3	Red macroalgae moderate density	Red macroalgae sparse
56	0.0	0.0	0.0	0.0	60.0	1.7	0.0	0.0	38.3	0.0	Red macroalgae moderate density	Red macroalgae sparse
57	0.0	0.0	0.0	0.0	38.3	43.3	0.0	0.0	18.3	0.0	Turf moderate density	Red macroalgae sparse
58	0.0	0.0	0.0	0.0	71.4	8.9	0.0	1.8	14.3	3.6	Red macroalgae sparse	Red macroalgae sparse
59	0.0	0.0	0.0	0.0	85.0	10.0	0.0	0.0	5.0	0.0	Bare sediment	Bare sediment
60	0.0	0.0	0.0	0.0	26.7	73.3	0.0	0.0	0.0	0.0	Turf moderate density	Turf dense
61	41.4	87.9	0.0	0.0	3.4	3.4	0.0	0.0	5.2	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
62	0.0	0.0	0.0	0.0	35.0	50.0	0.0	0.0	15.0	0.0	Turf moderate density	Red macroalgae sparse
63	0.0	0.0	0.0	0.0	66.7	18.3	0.0	0.0	15.0	0.0	Turf sparse	Red macroalgae sparse

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
64	0.0	0.0	0.0	0.0	46.7	21.7	0.0	0.0	28.3	3.3	Red macroalgae sparse/turf	Red macroalgae sparse
65	0.0	0.0	0.0	0.0	75.0	6.3	0.0	0.0	18.8	0.0	Red macroalgae sparse	Red macroalgae sparse
66	0.0	0.0	0.0	0.0	58.3	15.0	0.0	0.0	16.7	10.0	Red macroalgae sparse/turf	Red macroalgae sparse
67	0.0	0.0	0.0	0.0	70.0	28.3	0.0	0.0	0.0	1.7	Turf sparse	Turf sparse
68	6.7	13.3	0.0	0.0	58.3	15.0	0.0	0.0	13.3	0.0	Red macroalgae sparse/turf	<i>Posidonia</i> sparse
69	18.6	47.5	0.0	0.0	39.0	5.1	0.0	0.0	6.8	1.7	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
70	1.7	6.7	0.0	0.0	66.7	6.7	0.0	0.0	16.7	3.3	Red macroalgae sparse	<i>Posidonia</i> sparse
71	0.0	0.0	0.0	0.0	71.7	21.7	0.0	0.0	6.7	0.0	Turf sparse	Turf sparse
72	15.0	45.0	0.0	0.0	50.0	0.0	0.0	0.0	3.3	1.7	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
73	0.0	0.0	0.0	0.0	86.7	0.0	0.0	0.0	13.3	0.0	Bare sediment	Red macroalgae sparse
74	0.0	0.0	0.0	0.0	90.0	0.0	0.0	3.3	5.0	1.7	Bare sediment	Bare sediment
75	0.0	0.0	0.0	0.0	78.3	5.0	0.0	0.0	10.0	6.7	Bare sediment	Bare sediment
76	0.0	0.0	0.0	0.0	48.3	50.0	0.0	0.0	0.0	1.7	Turf moderate density	Turf sparse
77	0.0	0.0	10.0	0.0	78.3	6.7	0.0	0.0	5.0	0.0	Bare sediment	<i>Halophila</i>
78	3.3	6.7	0.0	0.0	68.3	0.0	0.0	11.7	6.7	6.7	<i>Posidonia</i> /macroalgae	<i>Posidonia</i> sparse
79	26.7	86.7	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
80	21.7	93.3	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
81	20.0	26.7	0.0	0.0	1.7	3.3	0.0	0.0	68.3	0.0	<i>Halophila</i> /red macroalgae	<i>Posidonia</i> sparse
82	25.0	35.0	1.7	0.0	53.3	8.3	0.0	0.0	1.7	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> moderate density
83	16.7	31.7	0.0	0.0	65.0	3.3	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> sparse
84	3.3	5.0	0.0	0.0	55.0	15.0	0.0	0.0	18.3	6.7	Red macroalgae sparse/turf	<i>Posidonia</i> sparse
85	25.0	38.3	0.0	0.0	36.7	25.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
86	41.7	58.3	0.0	0.0	38.3	3.3	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
87	10.0	28.3	0.0	0.0	56.7	5.0	0.0	0.0	10.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> sparse
88	6.7	15.0	0.0	0.0	75.0	8.3	0.0	0.0	0.0	1.7	<i>Posidonia</i> sparse	<i>Posidonia</i> sparse
89	8.3	21.7	0.0	0.0	63.3	13.3	0.0	0.0	1.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> sparse
90	5.0	40.0	0.0	0.0	53.3	6.7	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> moderate density
91	0.0	0.0	0.0	23.3	61.7	10.0	0.0	0.0	3.3	1.7	Turf sparse	<i>Zostera</i>
92	53.3	65.0	0.0	0.0	16.7	13.3	0.0	0.0	3.3	1.7	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density
93	73.3	88.3	0.0	0.0	1.7	10.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
94	60.0	76.7	0.0	0.0	8.3	15.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
95	68.3	78.3	0.0	0.0	1.7	18.3	0.0	0.0	1.7	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
96	50.0	66.7	0.0	0.0	1.7	28.3	0.0	3.3	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
97	48.3	61.7	0.0	0.0	6.7	31.7	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density
98	25.0	46.7	0.0	0.0	50.0	1.7	0.0	0.0	1.7	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
99	1.7	1.7	0.0	0.0	60.0	23.3	0.0	0.0	1.7	13.3	Turf sparse	<i>Posidonia</i> sparse
100	18.3	38.3	0.0	0.0	55.0	6.7	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> moderate density
101	36.7	45.0	0.0	0.0	40.0	13.3	0.0	1.7	0.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
102	46.7	51.7	0.0	0.0	1.7	35.0	0.0	10.0	1.7	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density
103	76.7	78.3	0.0	0.0	0.0	21.7	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
104	56.7	65.0	0.0	0.0	16.7	16.7	0.0	1.7	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density
105	45.0	48.3	0.0	0.0	0.0	0.0	48.3	0.0	3.3	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> moderate density
106	85.0	93.3	0.0	0.0	5.0	1.7	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
107	55.2	86.2	0.0	0.0	13.8	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
108	60.0	94.5	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
109	64.4	94.9	0.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
110	75.0	83.3	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
111	8.3	13.3	0.0	0.0	40.0	38.3	0.0	0.0	2.0	5.0	Turf moderate density	<i>Posidonia</i> sparse
112	45.0	76.7	0.0	0.0	23.3	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
113	57.6	93.2	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
114	19.0	65.5	0.0	0.0	31.0	3.4	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
115	43.6	98.2	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
116	28.1	84.2	0.0	0.0	15.8	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
117	50.0	91.1	0.0	0.0	8.9	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
118	30.4	71.4	0.0	0.0	23.2	3.6	0.0	0.0	1.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
119	6.7	10.0	0.0	0.0	53.3	0.0	0.0	0.0	36.7	0.0	Red macroalgae moderate density	<i>Posidonia</i> sparse
120	0.0	0.0	0.0	0.0	85.0	6.7	0.0	0.0	7.7	0.0	Bare sediment	Bare sediment
121	0.0	0.0	0.0	5.0	83.3	8.3	0.0	0.0	2.0	0.0	Bare sediment	<i>Zostera</i>
122	0.0	0.0	0.0	1.7	61.7	30.0	0.0	3.3	2.7	0.0	Turf sparse	<i>Zostera</i>
123	15.4	50.0	0.0	0.0	25.0	0.0	0.0	13.5	6.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
124	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	Bare sediment	Bare sediment
125	8.3	25.0	0.0	0.0	65.0	3.3	0.0	0.0	3.0	1.7	<i>Posidonia</i> mod	<i>Posidonia</i> sparse
126	32.8	69.0	0.0	0.0	29.3	0.0	0.0	0.0	1.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
127	39.0	76.3	0.0	0.0	20.3	1.7	0.0	0.0	0.0	1.7	<i>Posidonia</i> dense	<i>Posidonia</i> dense
128	47.5	83.1	0.0	0.0	16.9	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
129	40.0	58.3	0.0	0.0	41.7	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density

Site	Epiphytes	<i>Posidonia</i>	<i>Halophila</i>	<i>Zostera</i>	Sediment	Turf	Green macroalgae	Brown macroalgae	Red macroalgae	Filter feeders	Cluster-based class	Rule-based class
130	28.1	82.5	0.0	0.0	17.5	0.0	0.0	0.0	0.0	0.0	<i>Posidonia</i> dense	<i>Posidonia</i> dense
131	6.7	16.7	0.0	0.0	78.3	3.3	0.0	0.0	1.0	0.0	<i>Posidonia</i> sparse	<i>Posidonia</i> sparse
132	0.0	0.0	0.0	3.3	96.7	0.0	0.0	0.0	0.0	0.0	Bare sediment	<i>Zostera</i>
133	11.9	32.2	0.0	0.0	66.1	0.0	0.0	0.0	1.0	0.0	<i>Posidonia</i> mod	<i>Posidonia</i> sparse
134	25.9	55.2	0.0	0.0	39.7	0.0	0.0	0.0	2.0	1.7	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
135	19.0	46.6	0.0	0.0	25.9	5.2	0.0	12.1	4.0	3.4	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
136	15.0	35.0	0.0	0.0	55.0	1.7	0.0	0.0	4.0	1.7	<i>Posidonia</i> mod	<i>Posidonia</i> moderate density
137	1.7	1.7	0.0	5.0	83.3	8.3	0.0	0.0	1.0	0.0	Bare sediment	<i>Posidonia</i> sparse
138	0.0	0.0	1.7	0.0	66.7	30.0	0.0	0.0	1.7	0.0	Turf sparse	<i>Halophila</i>
139	0.0	0.0	0.0	0.0	41.7	53.3	0.0	0.0	2.0	1.7	Turf moderate density	Turf dense
140	0.0	0.0	0.0	0.0	70.0	23.3	0.0	3.3	0.0	3.3	Turf sparse	Turf sparse
141	0.0	0.0	0.0	0.0	76.7	18.3	0.0	0.0	0.0	5.0	Turf sparse	Turf sparse
142	0.0	0.0	0.0	0.0	60.0	38.3	0.0	0.0	0.0	1.7	Turf sparse	Turf sparse
143	0.0	0.0	0.0	0.0	85.0	13.3	0.0	0.0	0.0	1.7	Bare sediment	Turf sparse
144	0.0	0.0	0.0	0.0	91.7	1.7	0.0	1.7	2.0	1.7	Bare sediment	Bare sediment
145	0.0	0.0	0.0	0.0	96.7	1.7	0.0	0.0	1.7	0.0	Bare sediment	Bare sediment
146	0.0	0.0	0.0	0.0	93.3	1.7	0.0	0.0	3.0	0.0	Bare sediment	Bare sediment
147	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	Bare sediment	Bare sediment
148	17.2	41.4	0.0	0.0	48.3	5.2	0.0	0.0	3.0	0.0	<i>Posidonia</i> mod. to high density	<i>Posidonia</i> moderate density
149	0.0	0.0	0.0	0.0	73.3	25.0	0.0	0.0	1.0	0.0	Turf sparse	Turf sparse
150	0.0	0.0	6.7	0.0	90.0	3.3	0.0	0.0	0.0	0.0	Bare sediment	<i>Halophila</i>

Appendix B. PRIMER outputs from habitat classification process

The dendrogram from hierarchical clustering is shown in Figure 10, followed by the output from SIMPER analysis of the groups identified by clustering, and an MDS plot showing site groupings in Figure 11.

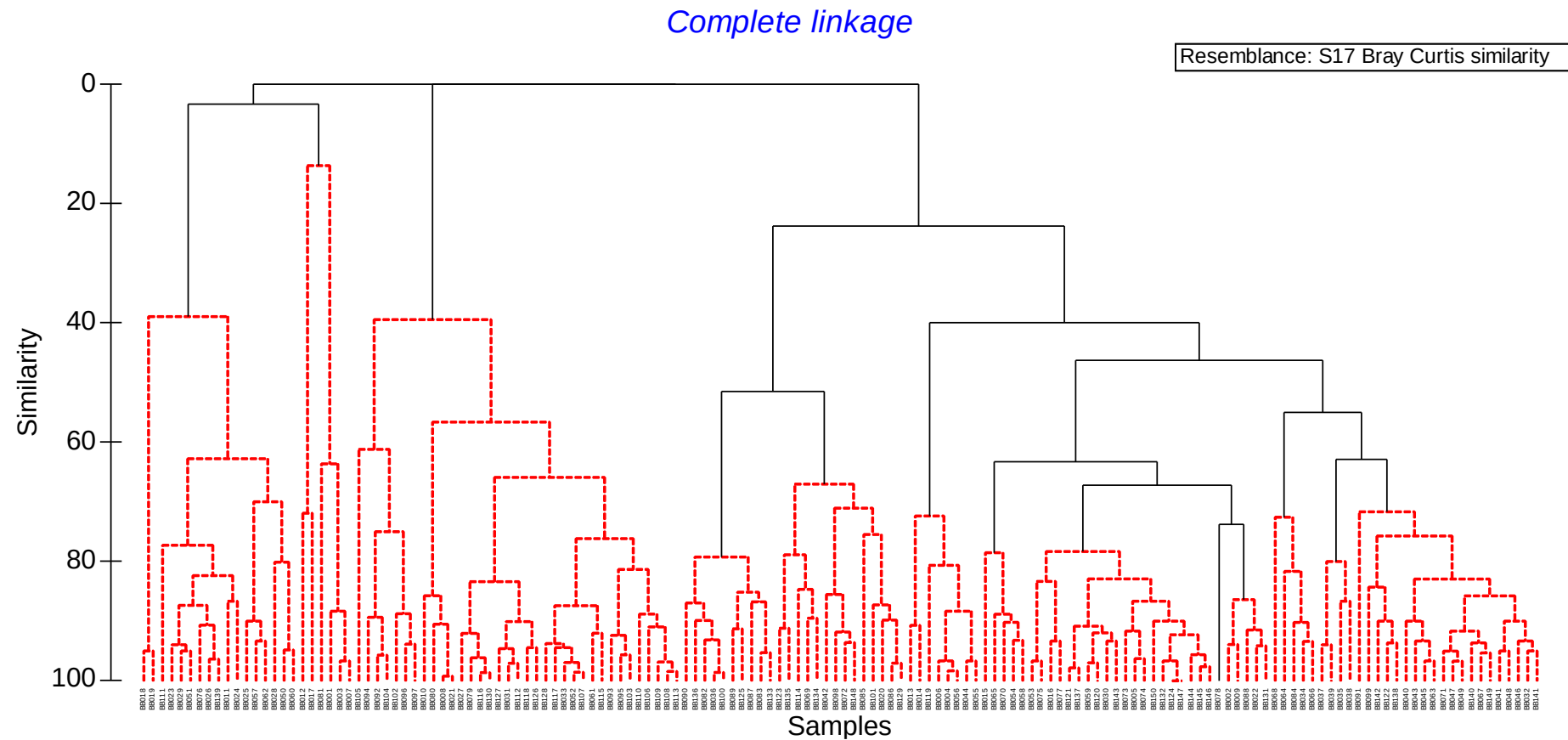


Figure 10. Dendrogram showing site clustering according to habitat features identified using Coral Point Count. Red lines show clusters with no significant structure ($P < 0.01$), resulting in 11 groups.

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet

Name: CPC_data(3)

Data type: Abundance

Sample selection: All

Variable selection: All

Parameters

Resemblance: S17 Bray Curtis similarity

Cut off for low contributions: 90.00%

Factor Groups

Sample CCF2

BB001	b
BB003	b
BB007	b
BB012	b
BB017	b
BB081	b
BB002	j
BB009	j
BB022	j
BB088	j
BB131	j
BB004	f
BB006	f
BB013	f
BB014	f
BB044	f
BB055	f
BB056	f
BB119	f
BB005	h
BB016	h
BB030	h
BB053	h
BB059	h
BB073	h
BB074	h
BB075	h
BB077	h
BB120	h
BB121	h
BB124	h
BB132	h
BB137	h
BB143	h
BB144	h
BB145	h
BB146	h
BB147	h
BB150	h
BB008	c
BB010	c
BB021	c
BB027	c
BB031	c
BB033	c
BB052	c
BB061	c
BB079	c
BB080	c

BB092	c
BB093	c
BB094	c
BB095	c
BB096	c
BB097	c
BB102	c
BB103	c
BB104	c
BB105	c
BB106	c
BB107	c
BB108	c
BB109	c
BB110	c
BB112	c
BB113	c
BB115	c
BB116	c
BB117	c
BB118	c
BB126	c
BB127	c
BB128	c
BB130	c
BB011	a
BB018	a
BB019	a
BB023	a
BB024	a
BB025	a
BB026	a
BB028	a
BB029	a
BB050	a
BB051	a
BB057	a
BB060	a
BB062	a
BB076	a
BB111	a
BB139	a
BB015	g
BB054	g
BB058	g
BB065	g
BB070	g
BB020	e
BB042	e
BB069	e
BB072	e
BB085	e
BB086	e
BB098	e
BB101	e
BB114	e
BB123	e
BB129	e
BB134	e
BB135	e
BB148	e
BB032	m
BB040	m
BB041	m
BB043	m
BB045	m
BB046	m
BB047	m
BB048	m

BB049 m
 BB063 m
 BB067 m
 BB071 m
 BB091 m
 BB099 m
 BB122 m
 BB138 m
 BB140 m
 BB141 m
 BB142 m
 BB149 m
 BB034 k
 BB064 k
 BB066 k
 BB068 k
 BB084 k
 BB035 l
 BB037 l
 BB038 l
 BB039 l
 BB036 d
 BB082 d
 BB083 d
 BB087 d
 BB089 d
 BB090 d
 BB100 d
 BB125 d
 BB133 d
 BB136 d
 BB078 i

Group b

Average similarity: 50.58

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Red algae	57.11	36.53	1.27	72.22	72.22
Sediment	16.39	10.85	1.50	21.45	93.67

Group j

Average similarity: 90.66

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	79.79	73.28	21.56	80.83	80.83
Posidonia	16.52	14.27	8.64	15.74	96.57

Group f

Average similarity: 86.66

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	56.01	51.81	7.88	59.79	59.79
Red algae	39.82	34.43	7.91	39.73	99.52

Group h

Average similarity: 88.26

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	88.25	84.64	16.97	95.90	95.90

Group c

Average similarity: 79.30

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Posidonia	80.81	51.11	4.99	64.46	64.46
Epiphytes	45.92	23.06	2.23	29.07	93.53

Group a

Average similarity: 76.26

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Turf	55.78	46.57	5.69	61.07	61.07
Sediment	33.68	26.62	1.86	34.91	95.98

Group g

Average similarity: 86.25

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	69.29	67.10	42.61	77.80	77.80
Red algae	15.67	14.07	7.12	16.31	94.11

Group e

Average similarity: 81.57

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Posidonia	49.65	35.77	8.02	43.85	43.85
Sediment	38.66	26.78	4.85	32.82	76.67
Epiphytes	26.47	16.40	3.89	20.11	96.78

Group m

Average similarity: 87.13

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	68.44	65.47	14.97	75.14	75.14
Turf	21.87	18.34	4.32	21.05	96.19

Group k

Average similarity: 84.48

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	54.01	50.00	13.14	59.19	59.19
Red algae	19.13	15.62	6.24	18.49	77.67
Turf	16.44	14.76	42.38	17.47	95.15

Group l

Average similarity: 86.18

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	55.00	52.68	16.05	61.12	61.12
Filter feeders	30.00	26.75	10.44	31.04	92.16

Group d

Average similarity: 87.25

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Sediment	58.78	49.38	12.32	56.60	56.60
Posidonia	32.39	25.52	6.08	29.25	85.84
Epiphytes	13.69	8.84	2.69	10.13	95.98

Group i

Less than 2 samples in group

[Note that this group contains only Site 78 which has 7% *Posidonia*, red macroalgae and filter feeders, and 12% large brown macroalgae]

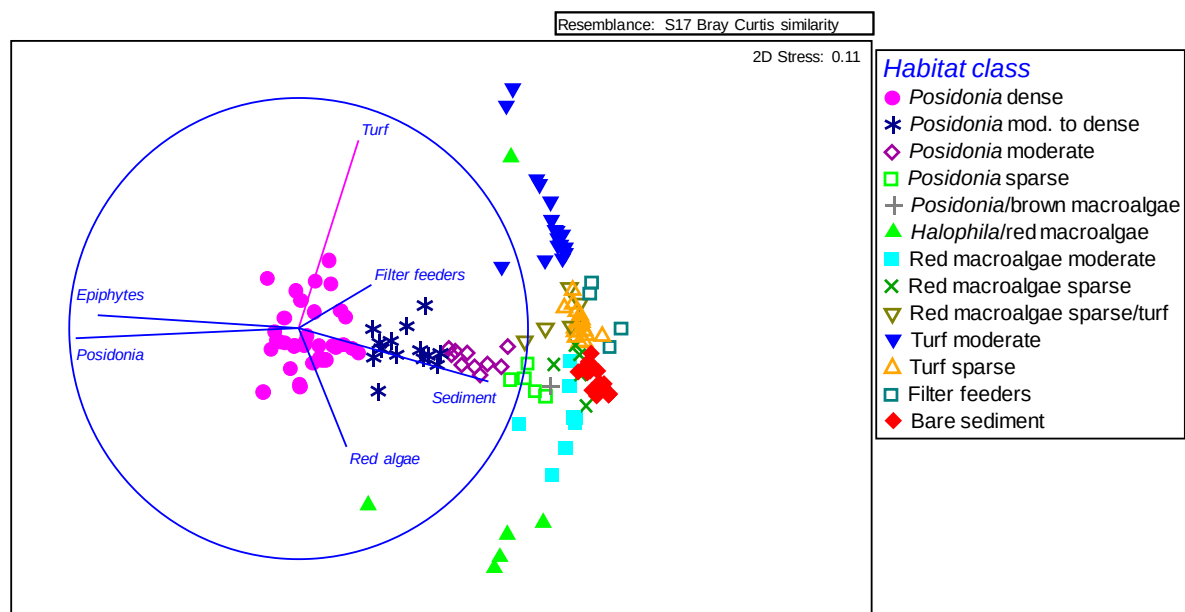


Figure 11. MDS plot showing habitat classes determined using clustering (see Figure 10). Habitat class names describe features identified using SIMPER analysis of groupings identified by CLUSTER. Vectors show correlation (> 0.2) with habitat features.