Edith Cowan University
Centre for Marine Ecosystems Research

Keep Watch Seagrass Monitoring 2020 Report for GeoCatch

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Cite as:
McMahon and Dunham (2020). Keep Watch Seagrass Monitoring, 2020. Report to GeoCatch. Centre for Marine Ecosystems Research, Edith Cowan University 33 pages.

This work was funded by GeoCatch and Water Corporation and supported in-kind by Department of Biodiversity, Conservation and Attractions.

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Keep Watch Seagrass Monitoring

Annual Report 2020

Investigator: Kathryn McMahon and Natasha Dunham

A project funded by GeoCatch and Water Corporation with in-kind support from the Department of Biodiversity, Conservation and Attractions.

August 2020

1 Executive Summary

1.1 Introduction

This report summarises nine years of data (Feb 2012 - Feb 2020) from the Keep Watch Seagrass Monitoring Program in Geographe Bay. The program was developed in collaboration with GeoCatch, Edith Cowan University (ECU), Department of Water and Environmental Regulation, Department of Biodiversity, Conservation and Attractions, and the South West Catchment Council. Since 2016 annual seagrass monitoring has been carried out by ECU with in-kind support from the Department of Biodiversity, Conservation and Attractions and funding from the Water Corporation.

The Keep Watch seagrass monitoring program was initiated due to concerns for the health of seagrass meadows in Geographe Bay from predicted increases in catchment nutrients. The aim of the program is monitor near shore seagrass meadows annually to detect any change in seagrass health. Seagrass shoot density of the dominant seagrass species *Posidonia sinuosa* is monitored at seven sites across Geographe Bay as an indicator of seagrass health. Observations of algal epiphyte cover and seagrass leaf nutrient content and nitrogen isotope signals are also measured to help interpret any changes.

Three management triggers have been established for Geographe Bay to detect changes in shoot density outside normal annual variation. Comparison of shoot densities with temperate seagrass meadows in other areas in Western Australia are also used as a comparison to assess inter-annual and site variations.

1.2 Key findings 2012-2020

Key finding 1

The condition of nearshore seagrass in Geographe Bay is good and there are no major concerns regarding seagrass health. Over the last nine years seagrass shoot density has had small fluctuations with no significant trends of decline, and no management triggers breached. In fact all sites have higher shoot densities or similar shoot densities to what was observed at the start of the program. These shoot densities in Geographe Bay are also higher or above the minimum density recorded in other temperate seagrass meadows in Western Australia highightling the value of this ecosystem.

Key finding 2

Epiphyte cover has fluctuated over time, generally sites in the centre of the bay have the highest epiphyte cover. This year most sites had an increase in algal cover compared to last year, but the most common types of algae present are not those associated with nutrient enrichment. However, filamentous algae which is often associated with nutrient enrichment was observed for the first time, although it was not dominant. As no significant seagrass declines were observed, this is not a major concern at this time, unless the algal cover continues to increase into next year.

Key finding 3

Nutrient content of seagrasses in Geographe Bay is relatively low. There was a slight increase in nitrogen content across all sites this year, indicating potentially more exposure of the seagrass meadows to nitrogen. The observed increase in algal cover could also be stimulated by these nutrients, supporting the value of actions to reduce nutrient loads in the catchment. Nutrient concentration varies slightly across years and sites, and the main difference is two times higher nitrogen content at Capel compared to all other sites, indicating higher loads of nutrients reaching seagrasses at Capel.

Key finding 4

The main sources of nitrogen for seagrass at most sites is likely to be from fixation of atmospheric nitrogen or agricultural fertilisers. A higher nitrogen isotope signal at Capel suggests that nitrogen derived from animal wastes, septic tanks or from natural vegetation is also a main source. There is no evidence that nitrogen derived from treated sewerage is a major source of nitrogen for Geographe Bay seagrasses.

1.3 Recommendations

These recommendations are based on the last eight years of Keep Watch monitoring and consider GeoCatch's needs into the future.

Recommendation 1

Continue monitoring seagrass health based on the Keep Watch Monitoring protocol, including monitoring of *Posidonia sinuosa* meadows at seven sites, and nutrient monitoring of *A. antarctica* at three sites. Considering the threat of nutrient enrichment is on-going in the Geographe Bay catchment, monitoring of seagrass health provides an early warning indicator of impacts in Geographe Bay. This program is the only approach in place at present assessing potential impacts in the marine environment, linking the land to the sea.

Recommendation 2

Continue the collaborative arrangement with ECU, Department of Biodiversity, Conservation and Attractions, GeoCatch and the Water Corporation to coordinate, fund and undertake seagrass monitoring. This is a very effective and beneficial arrangement.

Recommendation 3

In 2021, the funding for this program will cease and there will be ten years of data. Long-term information on the health of our ecosystems is highly valuable, enabling managers to assess the effects of management actions as well as local (e.g. anchoring) and global scale (e.g. temperature increases from climate change) pressures. However, this needs to be balanced with other constraints (e.g. funds, time, logistics) and priorities. Therefore, a reassessment of the program is warranted with the key stakeholders to identify the needs and priorities of this program and develop a plan for the future, beyond the current funding.

Recommendation 4

It has been 13 years since seagrass extent mapping was undertaken in Geographe Bay. This is important and complimentary information for this program and it has been recommended to undertake it on a five yearly basis (McMahon 2012). Clearly this has not occurred and should be considered as a priority and included in discussions regarding the plan for this program into the future.

2 Introduction

This document is produced for GeoCatch by Kathryn McMahon and Natasha Dunham from Edith Cowan University. It reports on the Keep Watch seagrass monitoring survey that was undertaken in February 2020 and compares to data from the 2012-2019 surveys.

The objective for the Keep Watch program is to undertake long-term, cost-effective seagrass monitoring for Geographe Bay to monitor the effects of water quality, particularly catchment nutrients on seagrass distribution and health.

This year the program was funded through collaborative sponsorship from the Water Corporation and in-kind support from the Department of Biodiversity, Conservation and Attractions (DBCA).

The aim of this program is to assess seagrass health by examining changes over time. There are three triggers that have been developed to assess change and all were assessed this year (see 3.1.3 for summary of triggers). This report includes data on two seagrass species (*Posidonia sinuosa* and *Amphibolis antactica*) but the program mostly focuses on *P. sinuosa* shoot density and leaf tissue nutrients (C, N, P and N isotopes) from seven sites with leaf tissue nutrient data for *A. antarctica* seagrass from three sites. All raw data is included in the appendix to this report, and has been submitted to GeoCatch as a digital file.

3 Methods for Keep Watch – Seagrass health monitoring program

3.1 Seagrass monitoring

3.1.1 Field program

The "Keep Watch" annual seagrass monitoring program is based on the methods recommended by McMahon (2012) and agreed to by GeoCatch.

Eight seagrass sites were monitored, seven for *P. sinuosa* health (Dunsborough to Forrest Beach) and three for *A. antarctica* nutrient content (Table 1, Figure 1). These were chosen to cover the spatial range of *P. sinuosa* meadows in Geographe Bay, and areas associated with a variety of catchments with different known surface water nutrient inputs. They range from 4-5 m depth. All sites, except for Capel have *P. sinuosa* meadows. Sampling occurred from 3rd to the 6th February 2020. At Capel (8) there are high relief rocky reefs surrounded by bare sand. On the reef there are patches of *A. antarctica* seagrass that were collected for nutrient analysis in 2m depth. *A. antarctica* was also collected at Busselton Jetty (4) and Forrest Beach (7) sites as a comparison. The *Amphibolis* sampling at three sites has now been undertaken for 8 years.

Table 1: Details for eight Keep Watch sites, seven in *Posidonia sinuosa* meadows (1-7) and one in rocky reef with *Amphibolis antarctica* patches (8) in Geographe Bay. Coordinates are decimal degrees based on the WGS84 grid system.

Site Name & #	Coordinates	Depth (m)	Date	Species assessed
1. Dunsborough	S 33.61654°, E 115.12865°	4	5/2/2019	Ps
2. Buayanup	S 33.65233°, E 115.24840°	4	5/2/2019	Ps
3. Vasse Diversion Drain	S 33.64746°, E 115.32379°	4.5	5/2/2019	Ps
4. Busselton Jetty	S 33.63896°, E 115.34315°	4.5	5/2/2019	Ps, Aa
5. Port Geographe	S 33.62846°, E 115.38240°	4.5	5/2/2019	Ps
6. Vasse-Wonnerup	S 33.60188°, E 115.42345°	5	4/2/2019	Ps
7. Forrest Beach	S 33.57295°, E 115.44908°	5	4/2/2019	Ps, Aa
8. Capel	S 33.51394°, E 115.51508°	2	6/2/2019	Aa

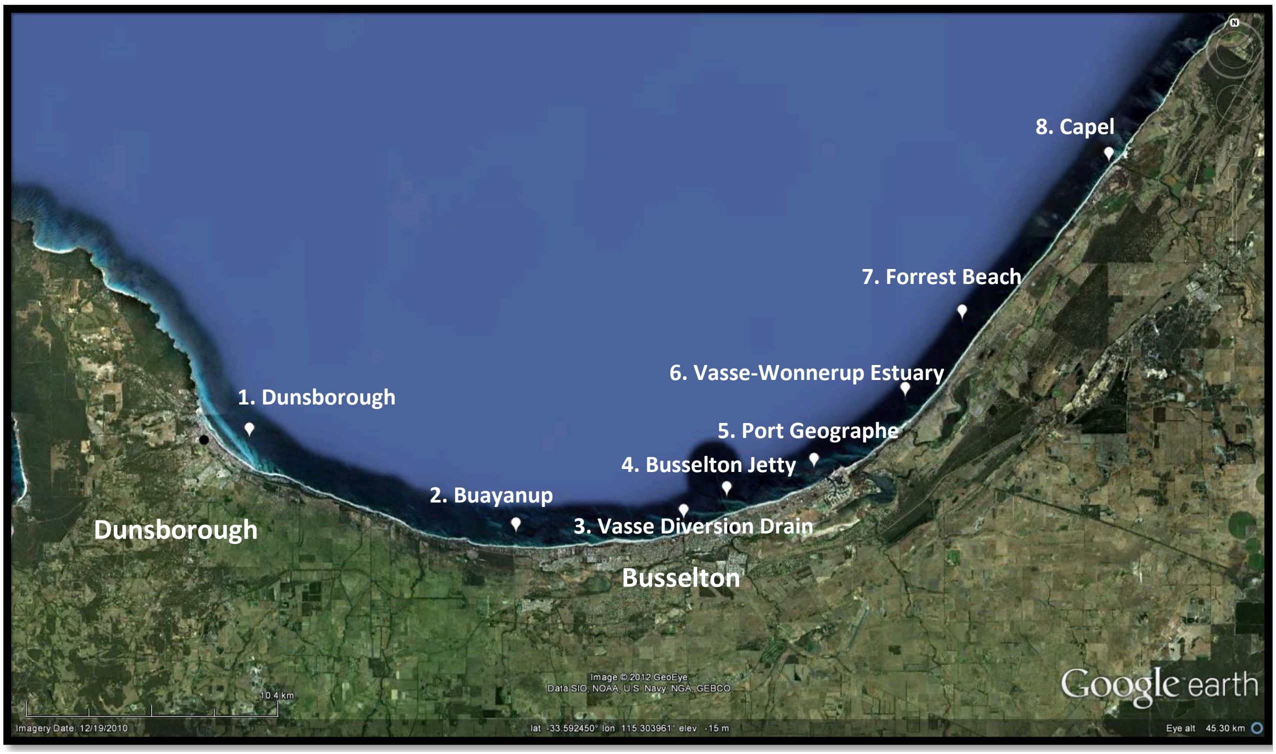


Figure 1: *Map of Geographe Bay, showing the location of the 8 seagrass sampling sites (1. Dunsborough, 2. Buayanup, 3. Vasse Diversion Drain, 4. Busselton Jetty, 5. Port Geographe, 6. Vasse-Wonnerup Estuary, 7. Forrest Beach and 8. Capel).*

Each seagrass site was located at least 30 m from the edge of the meadow and the center of the 50 m diameter site marked with a permanent star picket with a plastic cap (Figure 2). A site label was attached to the star picket. The exact locations were determined with a differential GPS (using the WSG 84 grid system), on the water surface, directly above the permanent marker.

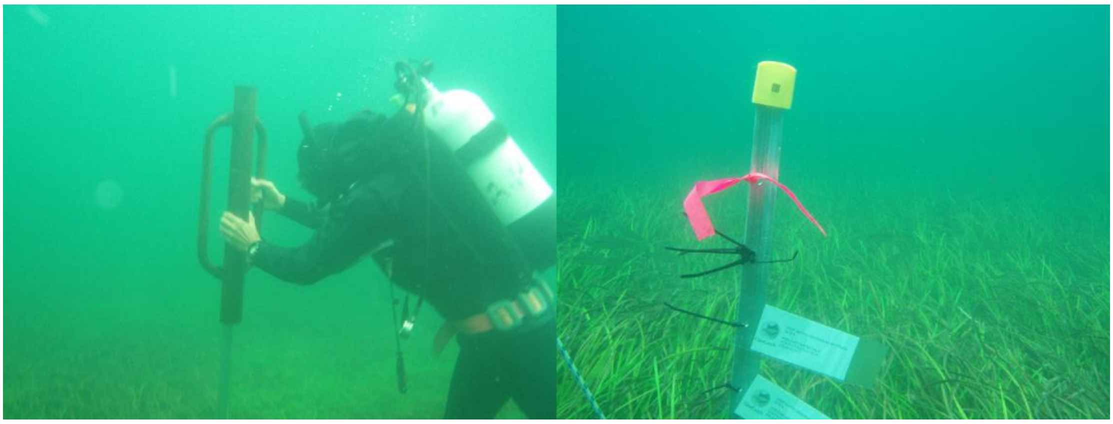


Figure 2: *Left: Banging in permanent marker with pole driver. Right: Star picket with cap and plastic coated site label, indicating center of 50 m diameter Keep Watch seagrass site.*

At each site *P. sinuosa* shoot density was counted in 30 0.2 x 0.2 m quadrats. Only shoots that originated in the quadrat were counted. Seedlings of *P. sinuosa* were also counted; these were identified by the small size of the leaves and the seed that was still attached to the seedling. As it is predicted that there can be high mortality of seedlings, these counts were not included in the shoot density assessment. The position of each quadrat was located randomly using a transect tape swum out on a pre-determined bearing using a compass and the quadrat placed at the pre-determined distance along the transect (Figure 3, See Appendix 1 for the bearing and distance along each transect that the quadrats were positioned). If there was a patch of a different species of seagrass such as *Amphibolis antarctica* or *A. griffithii*, or a blow-out without seagrass, then the quadrat was moved to the next closest point along the transect in the *P. sinuosa* meadow. The quadrats were stabilised by securing to the sediment with tent pegs, to ensure they did not move during counting.

Figure 3: *Left: Determining bearing of transect with compass. Right: Counting* P. sinuosa *shoots in a quadrat.*

A quality assurance check was carried with all divers before official counts began. Each counter counted a quadrat twice, and this was done with four different quadrats. This was repeated until there was less than a 5% error with counting, i.e. a maximum difference of 1-3 shoots. Then official counting began.

In addition, a photograph of the seagrass meadow and a video in a circle around the star-picket, 5 m distance away from the star-picket was also taken at each site. As well as the cover of algal epiphytes recorded as Very Low, Low, Moderate, High, Very High (See photo-guide for visual representation of these classifications, Figure 4), and the dominant or co-dominant type of algal epiphytes at each site were recorded from observations of the seagrass leaves, based on the following categories: Filamentous algae; Encrusting algae; Microalgal accumulations; and Other epiphytic algae (any type of algae that is not as above such as erect, branched, foliose, leathery or jointed calcareous). A photograph of the dominant epiphytic algae was also taken.

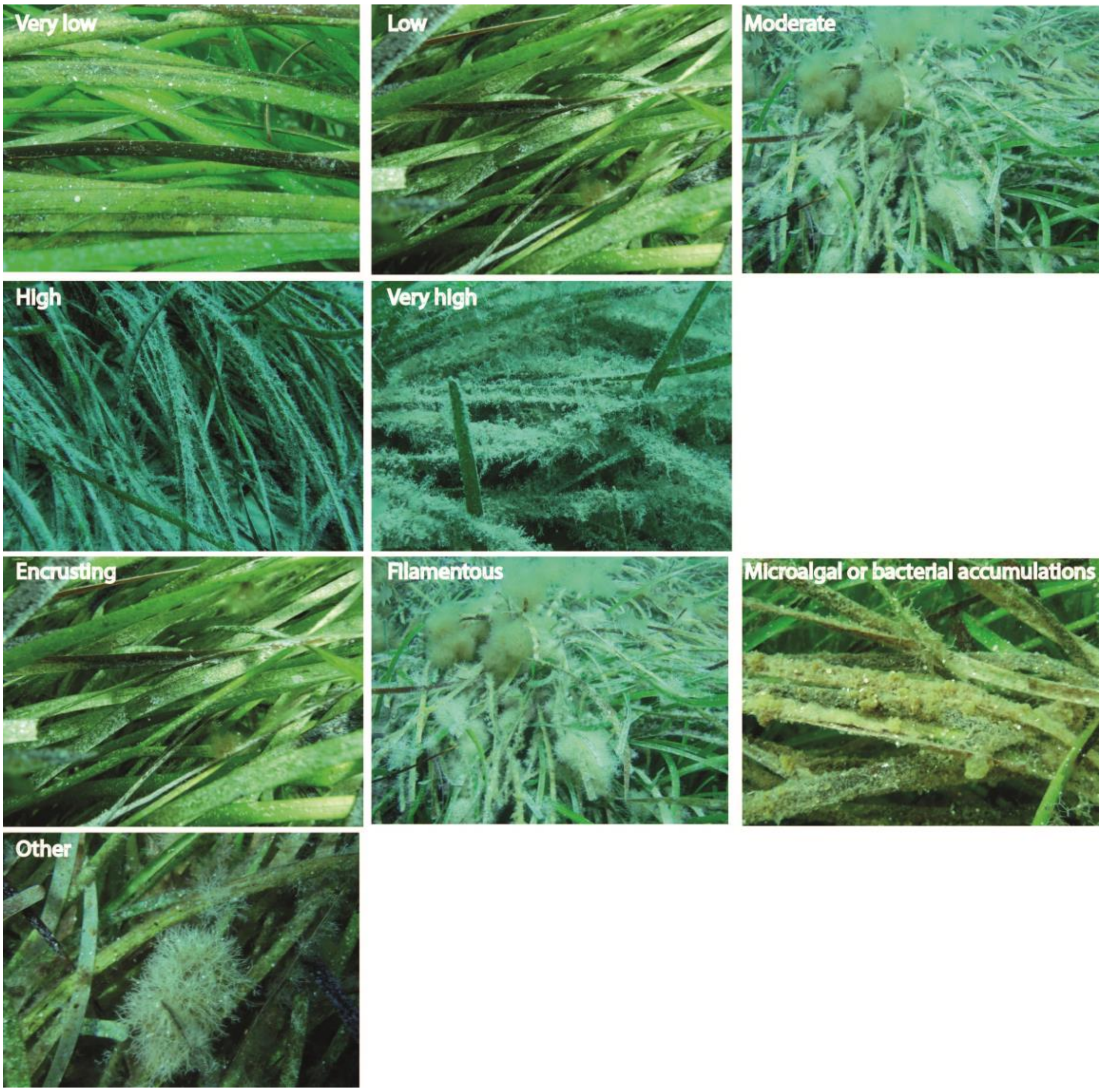


Figure 4: *Classification of epiphytic algal cover and type.*

Finally, the following points were noted: if other seagrass species were present at the site; if there were any bare patches of sand within the meadow, and if there was rhizome in the sand, indicating a loss of shoots from the area. Movement of sand bars through the seagrass meadow is common in this area, so it is likely that these will be noted; and any signs of anchor damage in the meadow.

Also three samples of *P. sinuosa* seagrass shoots were collected for TN, TP and TC as well as nitrogen stable isotope analysis after the counting was completed. Each sample was collected randomly in the meadow, just outside the 50 m diameter of the site and consisted of 5 shoots. These were placed in separate plastic bags and frozen until processed. Three samples of *A. antarctica* stems and leaves were collected at Capel, Busselton Jetty and Forrest Beach sites for the same type of nutrient analysis.

At each site the Secchi disk depth (m) and temperature were recorded from the boat.

Field work was carried out by Kathryn McMahon (KM) from ECU with David Lierich (DL), Ian Anderson (IA), Eden Baxter (EB), Chanelle Webster (CW) and Natalie Travaglione (NT) from Department of Biodiversity, Conservation and Attractions. Samples were processed and data analysed by Natasha Dunham. The boat and tank fills were provided by Department of Biodiversity, Conservation and Attractions. The monitoring program was funded through sponsorship by Water Corporation.

3.1.2 Laboratory processing

In the laboratory the three seagrass shoot samples were measured for total length and width, just above the sheath. Then all algal epiphytes were removed by gently scraping, and the leaves placed in the oven at 50°C for 24 hours or until dry, then ground into a fine powder with a Ball Mill grinder. This material was then analysed for total C, N and $\delta^{15}N$ (external error of analysis 1 standard deviation) at UWA using a continuous flow system consisting of a Delta V Plus mass spectrometer connected with a Thermo Flush 1112 via Conflo IV (Thermo-Finnigan/Germany). Total phosphorus (<0.05 mg.P.g^{-1}) was analysed at ECU by acid digest followed by ICP-OES, the same method that has previously been used.

3.1.3 Trigger assessment

To assess change over time, and to keep watch on the health of the seagrass, three triggers were proposed by McMahon (2012) and agreed upon by GeoCatch. If these thresholds are triggered it indicates a potential issue with seagrass health at a particular site that warrants further investigation. These trigger values are for shoot density. All other information collected i.e. seagrass nutrient concentration, water quality and algal cover are complimentary information to help interpret any changes observed in the seagrass shoot density. The trigger value will be triggered as follows:

Trigger 1:

If there is a > 50% reduction in shoot density at a particular site compared to the previous year (Need 2 years of data to assess this, always compare the current year with the previous year).

Trigger 2:

If there is > 20% reduction in shoot density at a particular site compared to the previous year, two years in a row (Need 3 years of data to assess this).

Trigger 3:

If there is a significant trend of a reduction in shoot density at a particular site over all time periods (when there is 5 or more years of data), as determined by trend analysis (Makesens Mann-Kendall trend statistic, need at least 5 years of data to assess this).

4 Results

4.1 Shoot density

Shoot density varied from a site average of 1204-1521 shoots m^{-2} across the seven sites (Figure 5). This year, Dunsborough, Buayanup and Forrest Beach had the highest shoot density (> 1400 shoots m^{-2}) and the remaining sites were similar, around 1200 shoots m^{-2}. All raw data is in Appendix 2.

Last year all sites increased in shoot density, or had minimal change (<5%) but this year three sites declined: Port Geographe (-19%); Buayanup (-11%); and Busselton Jetty (-6%), three sites increased: Vasse Diversion (17%); Forrest Beach (11%) and Dunsborough (8%) with little change at Vasse Wonnerup (Table 2). The decline at Port Geographe is approaching the 20% trigger value and is consistent with previous years where there have been relatively high increases and declines, however, compared to the first year of monitoring there has been a 29% increase in shoot density at this site. Vasse Diversion has always had the lowest shoot density over the last nine years, but with the increase this year is more similar to other sites and is the first time it has recorded above the maximum site average shoot density from similar monitoring programs in the the Shoalwater Bay and Jurien Bay Marine Parks (Data Courtesy of DBCA).

Compared to the start of the monitoring program in 2012, most sites (Vasse Diversion to Forrest Beach) have shown an increase in shoot density, particularly the most central sites, Vasse Diversion (40%), Busselton Jetty (30%) and Vasse Wonnerup (35%). Dunsborough (-1%) and Buayanup (-5%) have had minimal change (Table 2). Interestingly the variations over time are generally site specific, with little consistency among sites (Appendix 4).

The shoot density at all sites in Geographe Bay are above the maximum range (1 180 m^2) of site averages from references sites where similar monitoring is carried out in Shoalwater Bay and Jurien Bay Marine Park (Figure 5, data courtesy of DBCA). This is the first time all sites have been above the maximum site average.

P. sinuosa average shoot length ranged from a minimum of 46 cm at Busselton Jetty to a maximum of 73 cm at Vasse Wonnerup and a range in width of 5.3-5.9 mm (Appendix 3).

Table 2: Change assessment based on Trigger 1 and 2. There is a concern with seagrass health when there is a 50% decline in shoot density from one year to the next (Trigger 1) or when there is more than a 20% decline two years in a row. A negative number indicates a decline in shoot density and orange shading is a decline of more than 20%.

	% change in shoot density								
Site Name & #	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**	**17-18**	**18-19**	**19-20**	**12-20**
1. Dunsborough	3	-18	7	9	-3	-10	5	8	-1
2. Buayanup	11	-24	20	-7	2	-5	15	-11	-5
3. Vasse Diversion	6	-8	0	-15	19	12	8	17	40
4. Busselton Jetty	0	22	-4	1	-1	-5	23	-6	30
5. Port Geographe	17	-7	12	-6	-23	41	28	-19	29
6. Vasse-Wonnerup	19	13	-4	-3	4	-5	13	-3	35
7. Forrest Beach	16	-23	2	5	-3	8	0	11	12

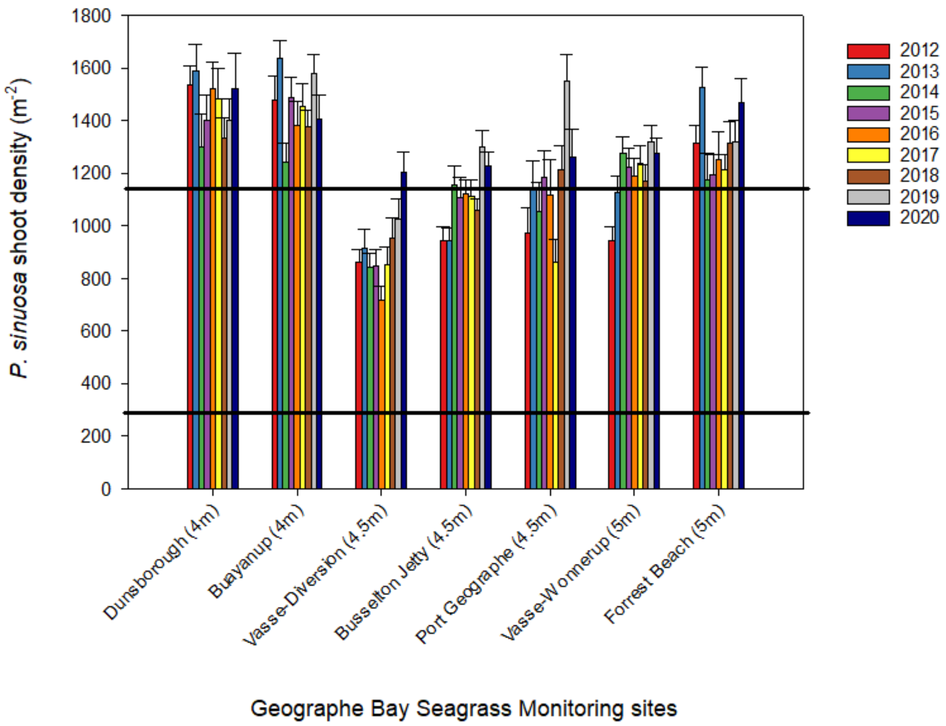


Figure 5: *Shoot density (average* m^{-2} *± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in January or February 2012-2020. Dotted lines indicate the minimum and maximum site averages from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2012-2020 (data courtesy of DBCA, 2020).*

4.2 Trigger assessment

4.2.1 Trigger 1

As a decline of 50% was not detected at any of the seven sites, this threshold was not triggered (Table 2, % change 2019-2020).

4.2.2 Trigger 2

As there were no declines of 20% or more over two consecutive years this threshold was not triggered (Table 2, % change 2018-2019 & 2019-2020). In fact, over the entire monitoring program (2012-2020) declines of 20% or more have only occurred in two years, 2013-14 (two sites) and 2016-17 (one site).

4.2.3 Trigger 3

No sites showed a significant linear trend over the nine years, either increasing or decreasing in shoot density (Table 3). When the plots of individual sites are examined (Appendix 4), linear increases in shoot density are obvious at a few sites but only over a subset of the years. For example Vasse Diversion has a linear increase in shoot density from 2016 to 2020 and Port Geographe from 2017-2019.

Table 3: Mann-Kendall Trend statistic to assess if there has been a significant decline over time in shoot density from 2012-2020.

Site Name & #	Significance ($p<0.05$)	Overall slope	R^2
1. Dunsborough	ns	+ve	5%
2. Buayanup	ns	+ve	0%
3. Vasse Diversion	ns	+ve	41%
4. Busselton Jetty	ns	+ve	62%
5. Port Geographe	ns	+ve	31%
6. Vasse-Wonnerup	ns	+ve	50%
7. Forrest Beach	ns	+ve	1%

4.3 Epiphytes

This year there was an increase in epiphyte cover at all sites, but once again with the exception of Dunsborough which has maintained a moderate cover for the last three years (Table 4). At Port Geographe, Vasse Wonnerup and Forrest Beach the epiphyte cover increased one category either from Very Low to Low or Low to Moderate, however at Buayanup, Vasse Diversion Drain and Busselton Jetty the cover increased two or three categories up to High (Figure 6, Table 4). The type of epiphyte cover varied among sites, either microalgae was dominant (Buayanup, Vasse Diversion, Port Geographe) or other forms of algae such as the brown algae, *Dictyota* at Dunsborough, Busselton Jetty and Vasse Wonnerup. Other epiphytes observed included the red algae *Laurencia,* forams and small, branching calcified red algae (Figure 6, Table 4). Filamentous algae was observed for the first time at Vasse Diversion Drain and Busselton Jetty but in low amounts (Figure 7).

Table 4: Algal cover at the Keep Watch seagrass monitoring sites, 2012-2020. Algal cover categories were Very low, Low, Moderate, High and Very High. Algal types were F=filamentous, E= encrusting, M=microalgal aggregations and O=other. If the category is capitalised it means it is dominant, lowercase indicates present but not dominant.

Site	Algal cover								
	-12	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**	**-19**	**-20**
1. Dunsborough	M	L	M	M	L	L	M	M	M
2. Buayanup	M	L	M	M	H	H	M	VL	H
3. Vasse Diversion Drain	L	M	H	H	H	H	H	L	H
4. Busselton Jetty	L	L	H	H	M	M	M	L	H
5. Port Geographe	L	VL	L	L	M	M	M	L	M
6. Vasse-Wonnerup	L	VL	L	M	L	L	L	VL	L
7. Forrest Beach	L	VL	L	L	L	VL	L	VL	L
	Algal Type								
	-12	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**	**-19**	**-20**
1. Dunsborough	O,f,m	F,O	O	O,m	O	O,e,m	O,m	O,m	O,m
2. Buayanup	M,o	E,O	M,o	M,o	M , o	M,e,o	M,o	O,m	M,o,e
3. Vasse Diversion Drain	M,o	E,O	M,o	M,o	M , o	M,o	M,o	O,m	M,o,e,f
4. Busselton Jetty	M,o	O	M	M,f	O,e,m	M,o,e	O,M	O,m	O,m,e,f
5. Port Geographe	E, o	E,M	M,e	M,f	O, f	M,o,e	O,M	M	M,o
6. Vasse-Wonnerup	E, o, m	E,O	M,f	O	E,o,m	E,m	O,M	O	O,e
7. Forrest Beach	E, M,o	F,E	M,f	O,e	E,o	E,o	O,e	O	E,m,o

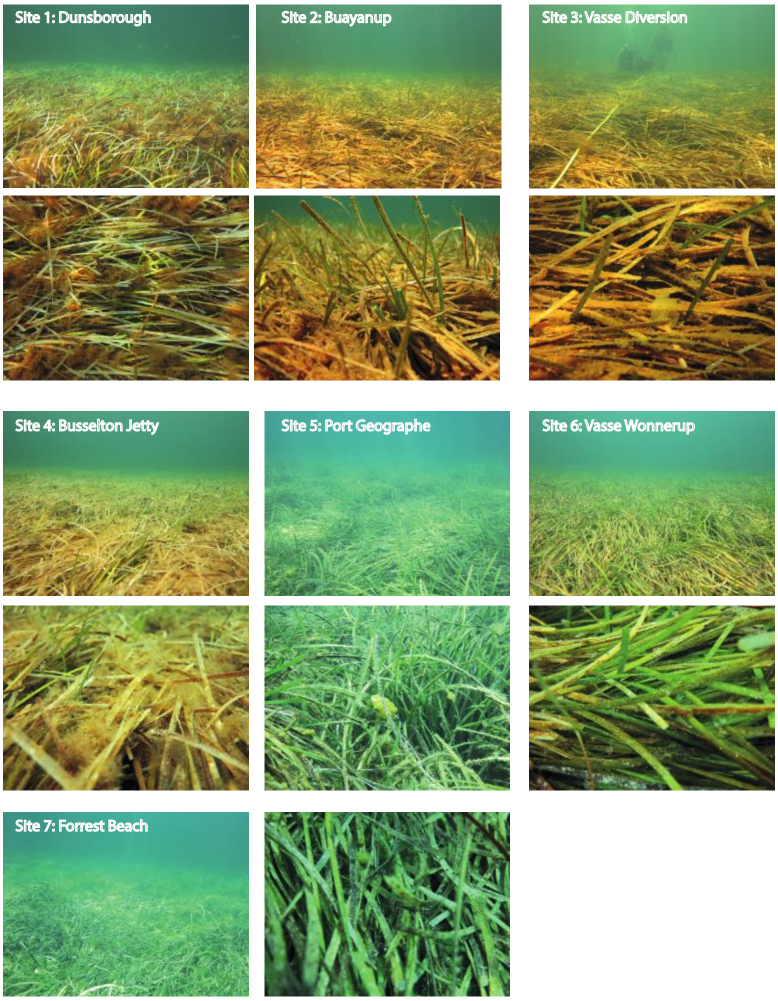


Figure 6: Pictures of seagrass meadow and the dominant algal epiphytes at each *P. sinuosa* site. (1. Dunsborough, 2. Buayanup, 3. Vasse Diversion Drain, 4. Busselton Jetty, 5. Port Geographe, 6. Vasse-Wonnerup Estuary, 7. Forrest Beach)

4.4 Other observations

A. antarctica was observed at all sites except Buayanup and Vasse Wonnerup and *A. griffithii* was also noted at Forrest Beach and Capel. The remains of flowering shoots were observed only at Vasse-Diversion Drain and no seedlings were observed.

No anchor damage was observed at any site, blowouts remain at the Dunsborough site, most likely from water movement, and a few small bare or sparse patches were noted at Dunsborough and Buayanup, indicating some small scale recent shoot loss. The bare patches at Port Geographe are still present, and the patches of dieback that were observed at Busselton Jetty three years ago appear smaller indicating recovery into the patches, but they are still discernable.

Most sites had accumulations of wrack either under the canopy (Dunsborough, Port Geographe, Forrest Beach), on top of the seagrass canopy (Buayanup, Vasse Diversion) or in sand patches on the edge of the meandows (Vasse Diversion, Dunsborough). The white tips on the long leaves at Dunsborough remain, most likely from sun damage due to the shallow and very clear water.

Figure 7: Filamentous epiphytic algae at Busselton Jetty.

4.5 Nutrient content

The nitrogen content of *P. sinuosa* leaves ranged from 0.9-1.5 % N dry weight (DW), the highest concentrations observed to date, but this is still considered low (Figure 8, Table 5). The increase compared to last year was up to 0.8% (Figure 8). The nitrogen content of *A. antarctica* leaves was higher, ranging from 1.1-2.2% N DW, and like *P. sinuosa* there was an increase at all sites compared to last year (Figure 9). The nitrogen content of the *A. antarctica* leaves is still greater at Capel, up to 1.9x greater than the other two sites.

The phosphorus content of *P. sinuosa* leaves in 2020 ranged from 0.14-0.19% P DW (Figure 8). Three sites, Dunsborough, Port Geographe and Vasse Wonnerup increased slightly compared to last year (~0.04 % DW) and there was more variability between samples than has been observed previously at some sites. For *A. antarctica* leaves, the phosphorus content was similar, all within 0.12% DW and there was minimal change from last year (Figure 9). The phosphorus content at Capel is clearly similar to other locations in Geographe Bay. All raw data is in Appendix 5.

The nitrogen and phosphorus concentrations continue to be in the range that has been observed in Geographe Bay in the past and these levels are not considered high (Table 5).

Table 5: Comparison of shoot tissue nutrient concentrations and $\delta^{15}N$ values of *P. sinuosa* and *A. antarctica* leaves in Geographe Bay. Data are expressed as averages of all sites from the study with the range of observations in brackets, min-max.

Date collected	Study	***P. sinuosa***			***A. antarctica***		
		TN (% DW)	**TP (% DW)**	$\delta^{15}N$	**TN (% DW)**	**TP (% DW)**	$\delta^{15}N$
1994/95 Apr, Jan	(McMahon & Walker 2008) Geographe Bay	0.8 Jan 1.032 Apr	0.13	-	-	-	-
1994 Apr, Jul, Sep	(McMahon 1994) Geographe Bay	1.26 (0.06-1.66)	0.18 (0.9-0.28)	3.30 (2.61-5.24)	0.95 (0.79-1.14)	0.10 (0.07-0.14)	2.52 (0.8-4.18)
2008 Aug	(Oldham et al. 2010) Geographe Bay	1.43 (1.30-1.56)	-	3.66 (3.30-4.36)	0.97 (0.9-1.16)	-	4.51 (4.01-4.8)
Autumn	(Paling & McComb 2000) Shoalwater Bay	1.8	-	-	0.6	-	-
Summer 2003	(Collier et al. 2008) Cockburn Sound	1.2-1.4	-	-			
Autumn 2008	(Hyndes et al. 2012) Warnbro Sound	-	-	4			

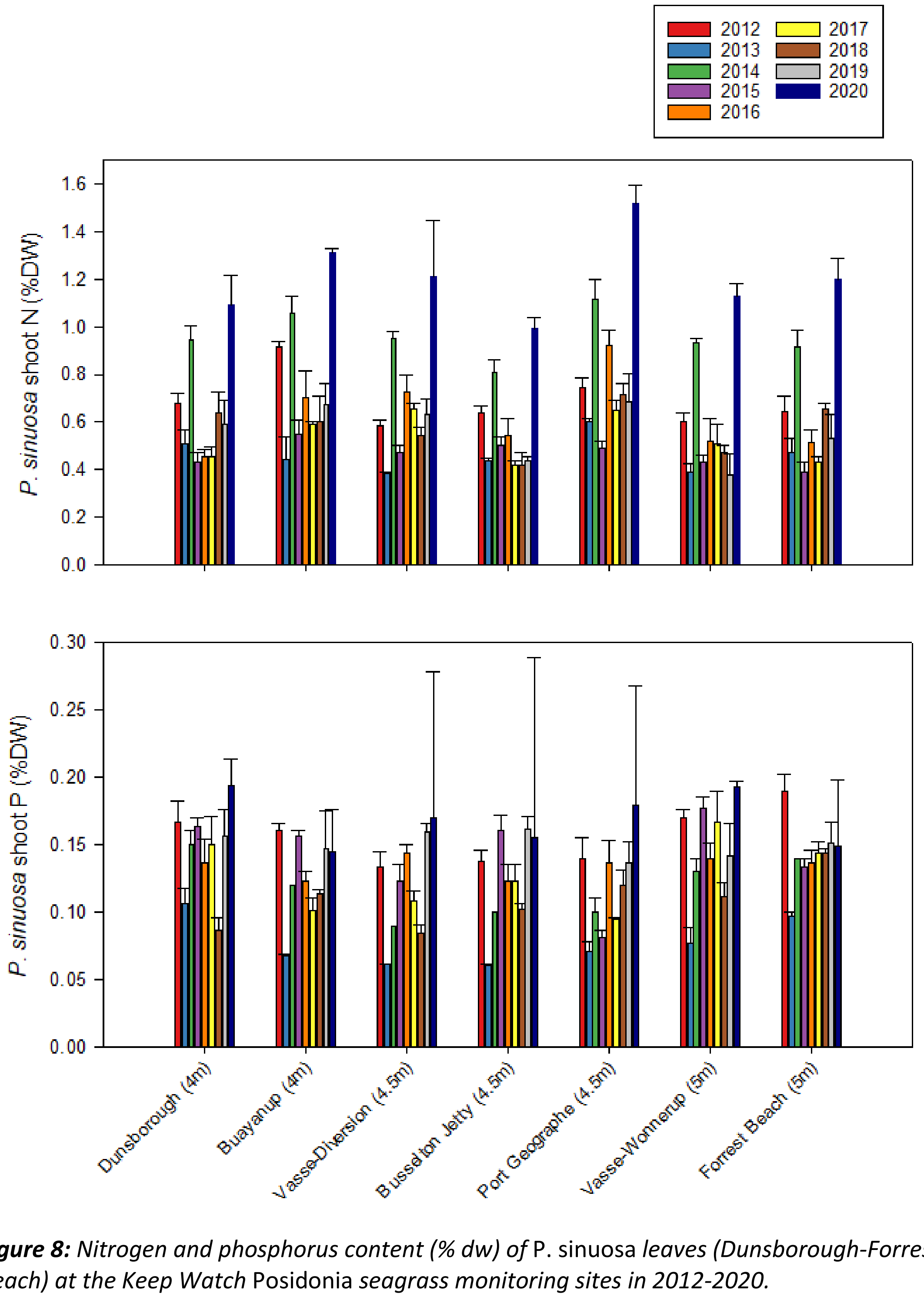
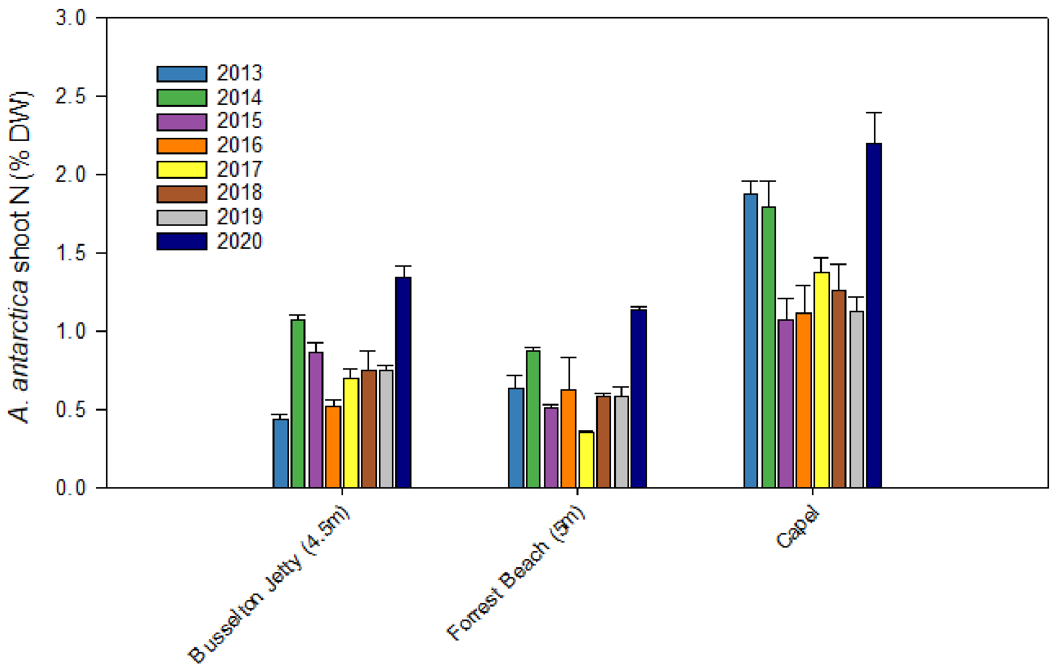


Figure 8: *Nitrogen and phosphorus content (% dw) of* P. sinuosa *leaves (Dunsborough-Forrest Beach) at the Keep Watch* Posidonia *seagrass monitoring sites in 2012-2020.*



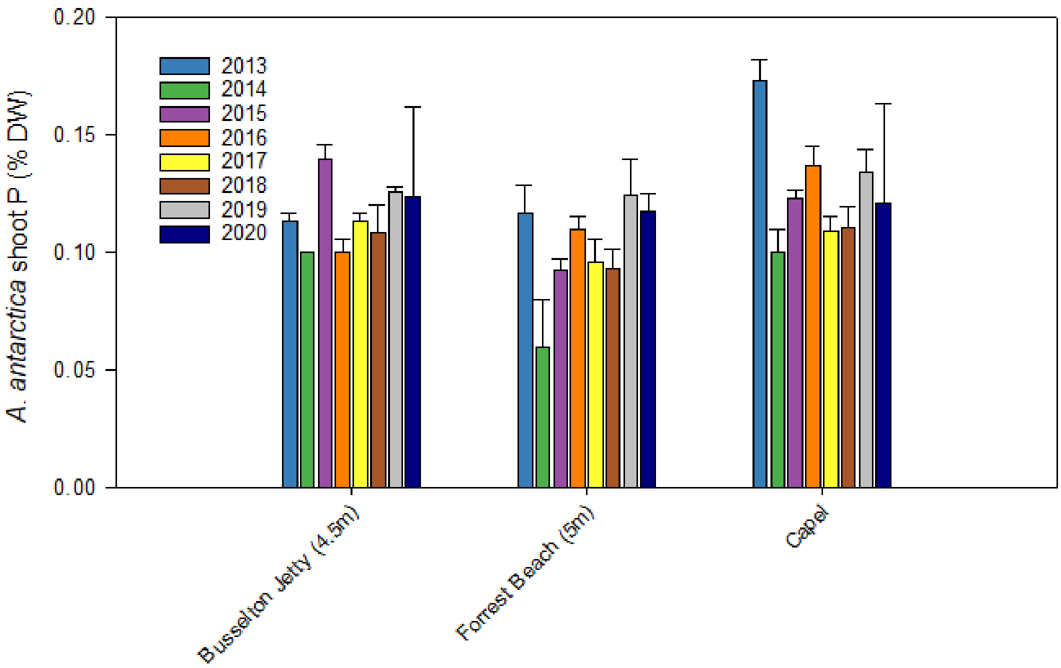


Figure 9: *Nitrogen and phosphorus content (% dw) of* A. antarctica *leaves (average ± se) at the Keep Watch* Amphibolis *seagrass monitoring sites in 2013-2020.*

Nitrogen isotope signals can indicate the main sources of nitrogen seagrasses are accessing. Nitrogen derived from the fixation of atmospheric nitrogen or agricultural fertilisers has a signature close to 0‰. Nitrogen derived from native bushland has a signal between 2-5 ‰, whereas nitrogen derived from animal waste or septic tanks is usually in the order of 5-6 ‰ and nitrogen from treated sewerage is usually around 9 ‰ (Jones & Saxby 2003). In Geographe Bay, nitrogen isotope signals measured in seagrass leaves indicate that the meadows are accessing different sources of nitrogen, and these sources vary among sites.

The $\delta^{15}N$ of *P. sinuosa* leaves ranged from 1.25 to 2.5 ‰. $\delta^{15}N$ signals remained similar to last year at Dunsborough, Vasse Diversion, Port Geographe and Forrest Beach and increased slightly at Buayanup, Busselton Jetty and Vasse Wonnerup but remained within the range observed over the last nine years (Figure 10). The nitrogen isotope signals in the seagrass leaves indicate that this year seagrasses are mostly receiving a mix of sources, but the main sources could be either from fixation of atmospheric nitrogen or agricultural fertilisers, as the signal is close to 0‰ with other sources contributing a small amount. There is no evidence that nitrogen derived from treated sewerage is the main source for seagrasses, if this was the case, we would expect the signal to be much higher, around 9 ‰.

The $\delta^{15}N$ signal of *Amphibolis* leaves ranged from 1.5-3.6‰, remaining stable at Busselton Jetty but increasing slightly at Forrest Beach and Capel compared to last year (Figure 10). Once again the highest values were observed at Capel indicating a different source of nitrogen at this site. All raw data is in Appendix 5.

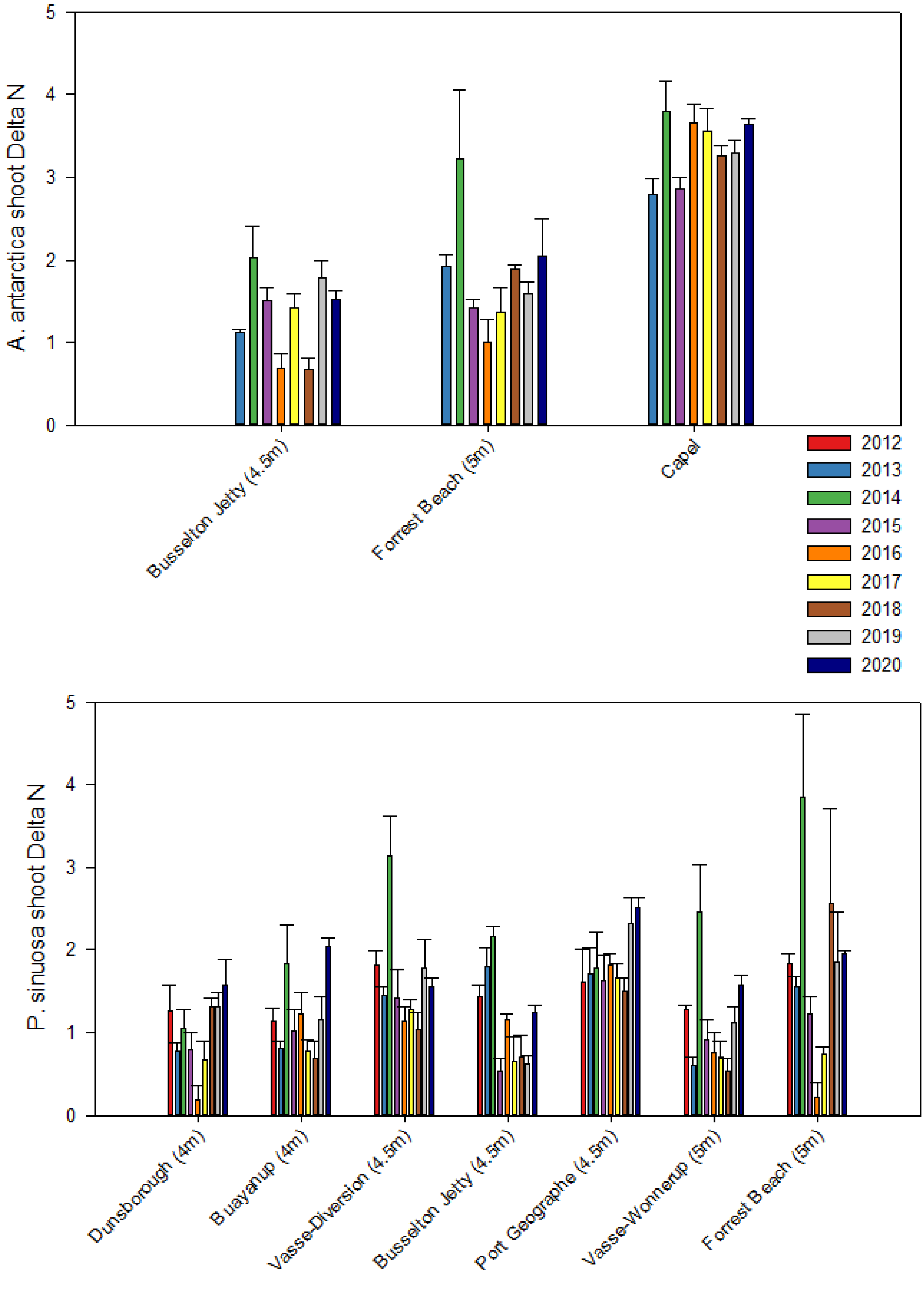


Figure 10: *δ^{15}N of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4, 7 & 8 average ± se) at the Keep Watch seagrass monitoring sites in 2012-2020. Note that only Capel was measured in 2012, and is not included in these graphs.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 23.5-24.7°C. Water clarity is higher than 2019 observations, the Secchi disk was observed on the bottom at all sites (Table 6).

Table 6: Water quality measures at the Keep Watch seagrass monitoring sites from 2012-2020, *=Secchi disk depth on bottom.

Site	Secchi disk depth (m)								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Dunsborough	4.2*	3	3	3.2*	3*	3.5*	2.7	2.7	4.0*
2. Buayanup	3.5	2.5	3*	3.2*	3.5*	2.5*	3*	2.8	3.5*
3. Vasse Diversion Drain	4	3.25	3.5*	3.6*	3.5*	5*	3.3	3	3.5*
4. Busselton Jetty	4.2	2.5	3.5	3.6*	3.5*	2.5*	4*	2.9	3.5*
5. Port Geographe	3.75	2.5	4	4.1*	3.5	4.5*	3.5*	3.2	3.0*
6. Vasse-Wonnerup	4	2	4.5	4.6*	4.5*	4*	4.5*	4	4.5*
7. Forrest Beach	5*	2	4	4.2*	4.5*	4*	3.5	3.8	4.5*
	Temperature (°C)								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Dunsborough	22	22.5	23.1	23.3	22.9	22.5	21.2	20.6	23.5
2. Buayanup	22.8	22.6	23.5	25.2	23.7	22.8	21.7	21.7	24.4
3. Vasse Diversion Drain	23.4	23.8	23.5	24.5	23.9	22	22.1	21.7	24.7
4. Busselton Jetty	23.4	27.3	23.3	26.3	22.6	22.5	22.6	22.8	23.6
5. Port Geographe	23.4	25.5	23.3	24.3	23	22.5	22.3	22.8	23.7
6. Vasse-Wonnerup	23.1	28.4	22.2	26.1	22.3	22.3	21.9	21.6	23.6
7. Forrest Beach	22.5	23.5	22.1	25.1	23.3	22.5	21.5	21.7	24.0

5 General conclusions

5.1 No significant declines in shoot density

No management criteria were triggered in 2020 for all three triggers. Some sites declined, some increased and one showed little change compared to last year. Overall, sites have increased in shoot density or had no major changes since the start of the monitoring program, although there have been small fluctuations up and down over the years. Shoot density of the seagrass *P. sinuosa* continues to be higher than most other locations in south-west WA where similar monitoring programs are carried out by the Department of Biodiversity, Conservation and Attractions. Based on this set of information, there continues to be no major concerns for seagrass health in Geographe Bay. The recommendation is to continue monitoring and reassess the changes next year. As there is only one more year remaining for funding of this program which will have generated 10 years of data on seagrass health, a reassessment of the program is warranted. Long-term information on the health of our ecosystems are highly valuable, enabling managers to assess the effects of management actions as well as local (e.g. anchoring) and global scale (e.g. temperature increases from climate change) pressures. However, this needs to be balanced with other constraints (e.g. funds, time, logistics) and priorities for relevant stakeholders (Water Corporation, DWER, DBCA, Fisheries, GeoCatch).

5.2 Algal epiphyte cover increases in 2020

Epiphytes are important components of seagrass ecosystems, contributing to primary production, food and habitat for fauna. This year has seen an increase in algal epiphyte cover with the greatest number of sites (3) reaching a high category. The amount of epiphyte cover on seagrasses is promoted by nutrients, and this year a slightly higher exposure to nutrients for seagrasses was indicated based on the seagrass leaf nitrogen content, which may explain the elevated epiphyte cover. The dominant algal types are not those commonly associated with nutrient enrichment, but filamentous algae, a type of algae that does commonly respond to nutrient enrichment was also observed for the first time at two of the monitoring sites. These changes in the algal epiphyte cover have not had a significant impact on the seagrasses meadows of Geographe Bay this year, but the relationship between seagrass density, algal cover, nutrient loads and other factors that influence seagrass ecosystems such as temperature and wave energy is something to investigate further as part of the review and reassessment of this program.

5.3 Small increases in nitrogen exposure detected but no obvious change in the sources

Overall there was a slight increase in the amount of nitrogen in seagrass tissue at all sites compared to last year, indicating greater exposure this year than last year. This was not the case for phosphorus with only a few sites showing a slight increase. Despite this, the concentrations observed are very low and do not indicate exposure to excess nutrients. Still, the nitrogen content and nitrogen isotope values of seagrass leaves from Capel indicate that these meadows are receiving more and a different source of nitrogen compared to other sites. The main potential nitrogen sources based on the higher nitrogen isotope signal (3.3 ‰) indicate nitrogen derived from animal wastes or septic tanks or sources from natural vegetation. Despite the higher nitrogen content at Capel the lower phosphorus levels were maintained, indicating that there continues to be less exposure to phosphorus compared to earlier years.

5.4 Keeping Watch of seagrasses in Geographe Bay into the future

Next year is the final funded year for the Keep Watch Monitoring program, reaching 10 years of monitoring the health of seagrasses in relation to the threat of nutrient enrichment. This data is valuable for linking the extensive catchment management activities to reduce nutrient loads reaching the waterways of the Geographe catchment and it’s coastal waters and assessing the condition and trends of the valued seagrass meadows, a key assest of the Ngari Capes Marine Park. A reassessment of this program is warranted with the key stakeholders to identify the needs and priorities of this program and develop a plan for the future, beyond the current funding.

6 References

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Appendix 1: Randomly generated quadrat positions from 2020 survey.

Quadrat #	Bearing	Distance
1	0	1
2	0	5
3	0	11
4	0	15
5	0	21
6	80	9
7	80	12
8	80	14
9	80	23
10	80	25
11	180	2
12	180	3
13	180	6
14	180	13
15	180	17
16	220	11
17	220	13
18	220	19
19	220	20
20	220	21
21	260	2
22	260	5
23	260	13
24	260	16
25	260	24
26	340	9
27	340	11
28	340	13
29	340	18
30	340	21

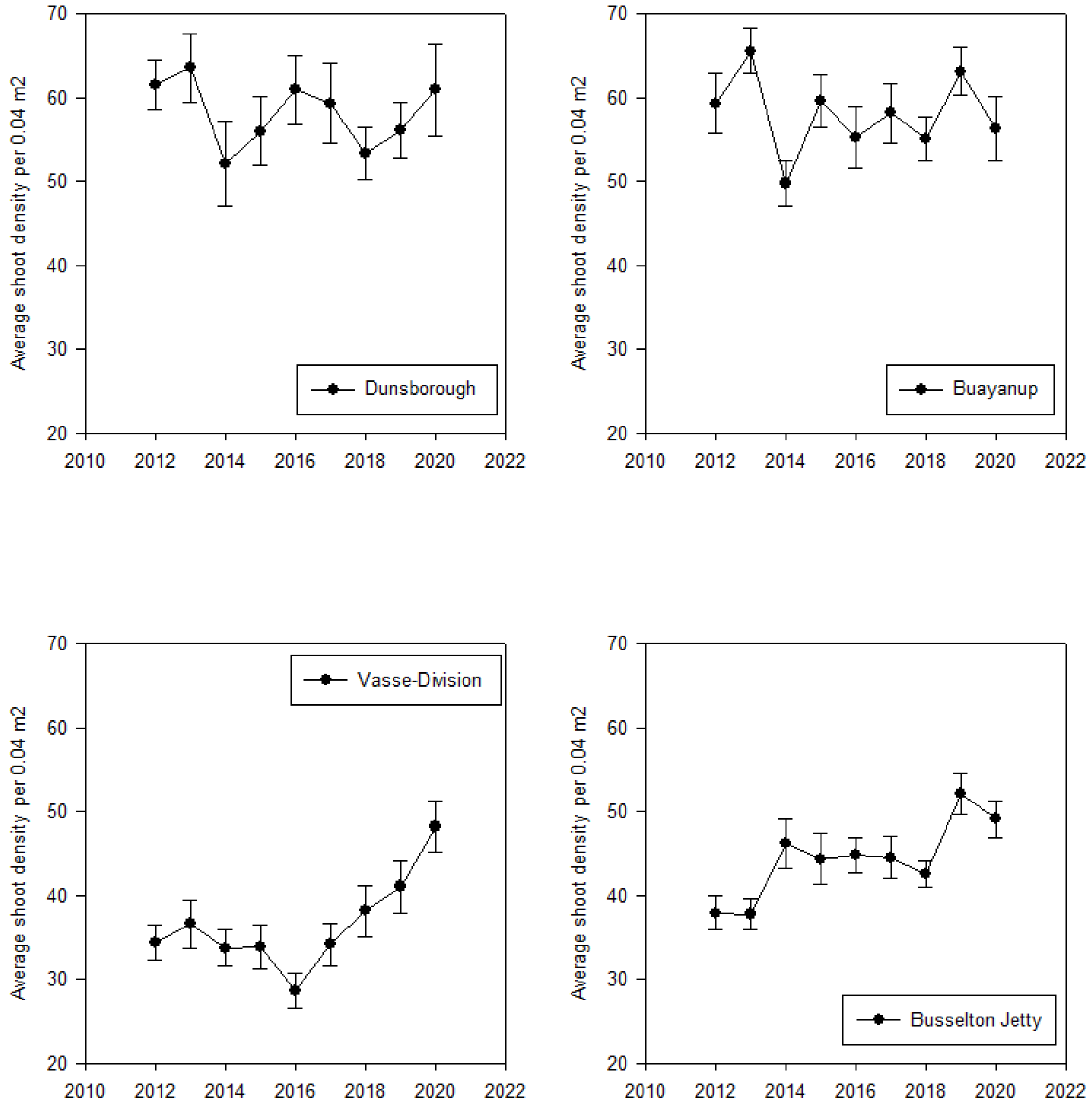
Appendix 2: Raw and summary statistics for shoot density data for the seven Keep Watch Seagrass Monitoring Sites in 2020. Seedling counts, and the person who counted each quadrat is also included.

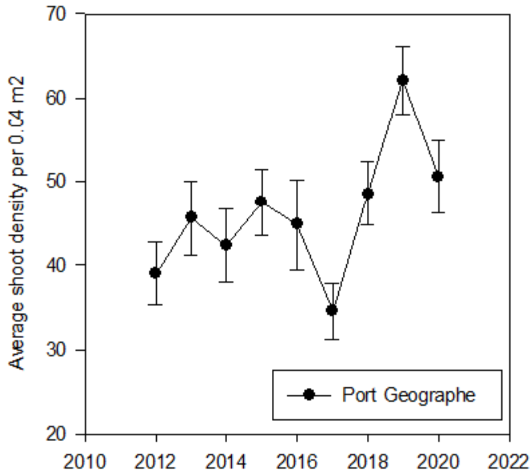
	1. Dunsborough			2. Buayanup			3. Vasse Diversion			4. Busselton Jetty			5. Port Geographe			6. Vasse-Wonnerup			7. Forrest Beach		
Quadrat	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter
1	29	0	CW	41	0	CW	37	0	CW	51	0	CW	60	0	KM	41	0	CW	69	0	EB
2	76	0	EB	58	0	EB	40	0	CW	41	0	CW	56	0	KM	44	0	CW	22	0	CW
3	51	0	CW	64	0	CW	66	0	EB	60	0	EB	46	0	KM	53	0	EB	41	0	EB
4	45	0	EB	57	0	EB	66	0	EB	46	0	EB	65	0	EB	52	0	EB	52	0	CW
5	42	0	CW	20	0	CW	55	0	CW	33	0	CW	24	0	CW	58	0	CW	53	0	EB
6	44	0	NT	74	0	IA	31	0	NT	40	0	NT	125	0	KM	61	0	KM	60	0	NT
7	72	0	IA	45	0	NT	36	0	DL	35	0	DL	50	0	CW	49	0	KM	74	0	IA
8	67	0	NT	70	0	IA	43	0	DL	64	0	NT	9	0	NT	45	0	NT	58	0	NT
9	112	0	IA	60	0	NT	43	0	NT	34	0	DL	48	0	IA	57	0	DL	60	0	IA
10	107	0	IA	64	0	IA	29	0	DL	68	0	DL	45	0	CW	45	0	DL	28	0	NT
11	46	0	CW	22	0	CW	100	0	EB	61	0	CW	35	0	CW	70	0	EB	77	0	CW
12	48	0	CW	70	0	EB	65	0	CW	59	0	EB	25	0	EB	56	0	CW	78	0	EB
13	111	0	EB	87	0	CW	49	0	CW	75	0	CW	29	0	CW	47	0	CW	44	0	CW
14	58	0	CW	75	0	EB	78	0	EB	68	0	EB	22	0	EB	41	0	EB	71	0	EB
15	38	0	EB	47	0	CW	44	0	CW	46	0	CW	62	0	CE	49	0	CW	48	0	CW
16	12	0	NT	68	0	IA	39	0	DL	51	0	DL	27	0	NT	50	0	KM	32	0	NT
17	121	0	IA	72	0	NT	43	0	NT	23	0	NT	41	0	IA	65	0	NT	76	0	IA
18	19	0	NT	62	0	IA	46	0	DL	49	0	DL	45	0	NT	22	0	DL	55	0	NT
19	65	0	NT	86	0	NT	34	0	NT	51	0	NT	91	0	IA	56	0	NT	51	0	IA
20	87	0	IA	60	0	KM	65	0	DL	42	0	DL	74	0	IA	38	0	DL	11	0	NT
21	21	0	KM	24	0	CW	60	0	KM	49	0	CW	65	0	EB	22	0	CW	84	0	KM
22	30	0	KM	77	0	KM	28	0	EB	57	0	EB	37	0	CW	61	0	CW	80	0	KM
23	57	0	KM	66	0	CW	47	0	CW	52	0	EB	21	0	EB	57	0	EB	58	0	KM
24	67	0	EB	66	0	EB	57	0	KM	55	0	CW	68	0	CW	66	0	EB	89	0	KM
25	48	0	CW	52	0	KM	59	0	EB	37	0	EB	39	0	EB	43	0	CW	86	0	KM
26	42	0	NT	50	0	EB	41	0	DL	52	0	KM	71	0	KM	57	0	KM	59	0	IA
27	88	0	KM	53	0	KM	49	0	KM	37	0	KM	54	0	KM	55	0	DL	88	0	NT
28	62	0	EB	71	0	CW	15	0	NT	58	0	NT	74	0	KM	39	0	NT	44	0	IA
29	110	0	IA	2	0	KM	39	0	DL	43	0	DL	66	0	KM	79	0	KM	50	0	KM
30	51	0	CW	26	0	EB	41	0	KM	37	0	KM	40	0	KM	54.0	0	DL	64	0	KM
Average	**60.9**	**0.0**		**56.3**	**0.0**		**48.2**	**0.0**		**49.1**	**0.0**		**50.5**	**0.0**		**51.1**	**0.0**		**58.7**	**0.0**	
Median	**54.0**	**0.0**		**61.0**	**0.0**		**43.5**	**0.0**		**50.0**	**0.0**		**47.0**	**0.0**		**52.5**	**0.0**		**58.5**	**0.0**	
SE	**5.40**	**0.00**		**3.74**	**0.00**		**3.08**	**0.00**		**2.21**	**0.00**		**4.36**	**0.00**		**2.25**	**0.00**		**3.64**	**0.00**	
Stdev	**29.59**			**20.50**			**16.86**			**12.08**			**23.90**			**12.33**			**19.92**		
CV	**0.49**			**0.36**			**0.35**			**0.25**			**0.47**			**0.24**			**0.34**		

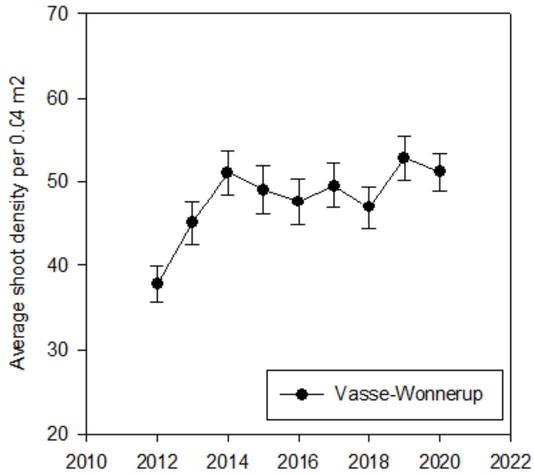
Appendix 3: Leaf morphology data for 2020

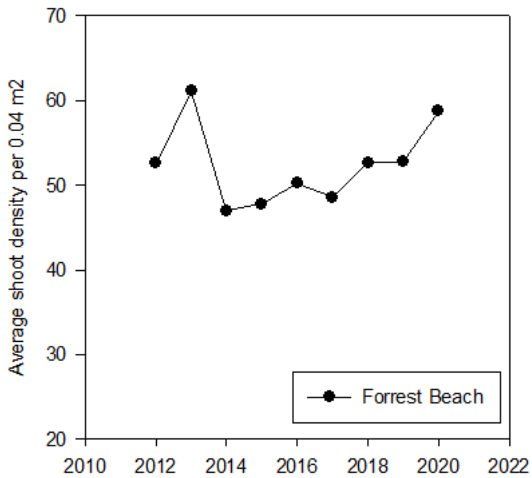
	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5	S6	S6	S7	S7
	Dun.	Dun.	Buayanup	Buayanup	Vasse Div.	Vasse Div.	Buss Jetty	Buss Jetty	Port Geo	Port Geo	Vasse Won	Vasse Won	Forrest B	Forrest B
Rep	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)
1	55.4	5.5	53.9	4.0	59.4	6.0	61.3	6.0	69.6	5.5	75.0	5.0	75.0	5.0
2	66.0	5.5	38.0	4.0	38.5	6.0	46.7	5.0	74.1	6.0	64.1	5.0	56.3	5.0
3	48.3	5.5	56.1	7.0	72.1	5.0	48.2	6.0	84.7	5.5	64.4	6.0	81.6	6.0
4	46.9	6.0	53.5	6.0	73.1	6.0	76.1	5.0	60.6	6.0	77.7	5.5	81.3	5.0
5	58.4	5.0	46.6	6.0	47.8	6.0	18.0	5.0	62.6	5.0	80.0	5.0	74.0	6.0
6	45.5	5.0	35.5	5.0	77.2	5.0	38.0	6.0	50.6	6.0	84.2	6.0	65.9	5.0
7	44.8	5.0	48.0	5.0	76.9	5.0	46.4	7.0	33.7	6.0	101.2	6.0	61.6	5.0
8	39.6	5.0	53.6	5.0	64.4	5.5	56.4	5.0	62.0	6.5	85.8	6.5	67.7	5.0
9	42.3	5.0	63.6	5.0	81.5	5.5	26.1	5.0	69.0	6.0	84.0	6.0	55.6	5.0
10	46.4	5.0	46.8	5.0	78.7	6.0	53.5	5.5	55.1	5.0	62.6	6.5	61.7	6.0
11	54.4	6.0	35.1	6.0	76.9	5.5	42.5	7.0	57.9	6.0	78.8	5.5	77.5	5.0
12	34.1	5.5	50.0	6.0	49.0	5.0	44.0	7.0	84.9	5.5	49.4	6.0	36.7	6.0
13	32.8	5.0	44.5	6.0	51.1	5.0	47.5	7.5	66.0	6.0	74.3	6.0	54.5	6.0
14	45.9	6.0	53.6	5.0	51.5	5.5	37.1	5.0	68.4	5.5	48.4	6.0	57.0	6.0
15	61.4	5.0	75.4	5.0	53.9	6.0	51.6	7.0	28.9	5.0	72.4	5.5	44.6	6.0
Average	**48.1**	**5.3**	**50.3**	**5.3**	**63.5**	**5.5**	**46.2**	**5.9**	**61.9**	**5.7**	**73.5**	**5.8**	**63.4**	**5.5**
SE	**2.4**	**0.1**	**2.7**	**0.2**	**3.6**	**0.1**	**3.6**	**0.2**	**4.0**	**0.1**	**3.6**	**0.1**	**3.4**	**0.1**

Appendix 4: Trends over time in seagrass shoot density.




Average shoot density per 0.04 m2
70
60
50
40
30
20
2010
2012
2014
2016
2018
2020
2022
Port Geographe


Average shoot density per 0.04 m2
70
60
50
40
30
20
2010
2012
2014
2016
2018
2020
2022
Vasse-Wonnerup


Average shoot density per 0.04 m2
70
60
50
40
30
20
2010
2012
2014
2016
2018
2020
2022
Forrest Beach

Appendix 5: Nutrient data for 2020

Site	Species	δ15N (‰)	N [% DW]	P (% DW)
Dunsborough	Posidonia	2.09	1.03	0.21
Dunsborough	Posidonia	1.63	1.33	0.19
Dunsborough	Posidonia	1.00	0.90	0.18
Buayanup	Posidonia	1.90	1.30	0.16
Buayanup	Posidonia	2.22	1.34	0.13
Buayanup	Posidonia	2.03	1.28	0.14
Vasse-Diversion	Posidonia	1.38	1.19	0.23
Vasse-Diversion	Posidonia	1.65	1.26	0.17
Vasse-Diversion	Posidonia	1.66	1.19	0.11
Busselton Jetty	Posidonia	1.09	1.08	0.24
Busselton Jetty	Posidonia	1.38	0.91	0.10
Busselton Jetty	Posidonia	1.27	0.99	0.12
Port Geographe	Posidonia	2.31	1.60	0.19
Port Geographe	Posidonia	2.55	1.38	0.12
Port Geographe	Posidonia	2.70	1.59	0.23
Vasse-Wonnerup	Posidonia	1.76	1.22	0.19
Vasse-Wonnerup	Posidonia	1.60	1.11	0.19
Vasse-Wonnerup	Posidonia	1.39	1.05	0.20
Forrest Beach	Posidonia	2.01	1.08	0.12
Forrest Beach	Posidonia	1.98	1.37	0.16
Forrest Beach	Posidonia	1.86	1.15	0.17
Busselton Jetty	Amphibolis	1.39	1.19	0.10
Busselton Jetty	Amphibolis	1.74	1.45	0.15
Busselton Jetty	Amphibolis	1.43	1.39	0.12
Forrest Beach	Amphibolis	2.90	1.17	0.12
Forrest Beach	Amphibolis	1.38	1.12	0.12
Forrest Beach	Amphibolis	1.86	1.12	0.11
Capel	Amphibolis	3.52	2.48	0.15
Capel	Amphibolis	3.75	1.83	0.10
Capel	Amphibolis	3.66	2.30	0.11