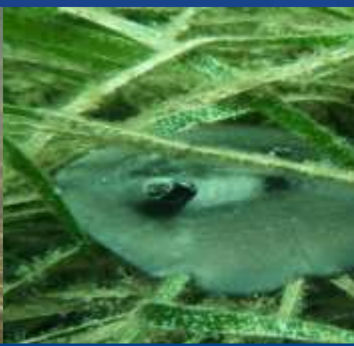
Edith Cowan University
Centre for Marine Ecosystems Research

Keep Watch Seagrass Monitoring 2019 Report for GeoCatch

Kathryn McMahon and Natasha Dunham





Keep Watch Seagrass Monitoring, 2019. Report to GeoCatch

Kathryn McMahon and Natasha Dunham

Cite as:
McMahon and Dunham (2019). Keep Watch Seagrass Monitoring, 2019. Report to GeoCatch. Centre for Marine Ecosystems Research, Edith Cowan University 36 pages.

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

Table of Contents

Keep Watch Seagrass Monitoring

Annual Report 2019

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.

September 2019

1 Executive Summary

1.1 Introduction

This report summarises data from the first eight years (Feb 2012 - Feb 2019) of 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 Catch 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 2012-2019

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 8 years seagrass shoot density has had small fluctuations with no significant trends of increase or decline, and no management triggers breached. Shoot densities in Geographe Bay are also higher or above the minimum density recorded in other temperate seagrass meadows in Western Australia.

Key finding 2

Shoot density varies across different sites, consistently the lowest shoot density was recorded at the Vasse Diversion Drain and highest shoot densities occur within the shallower sites at Dunsborough and Buayanyup. The greatest increase over time has occurred at Busselton Jetty and Port Geographe.

Key finding 3

Epiphyte cover has fluctuated over time, generally with some sites in the centre of the bay with the highest epiphyte cover. However, this year, there was a bay-wide reduction in algal epiphyte cover. As high cover of algal epiphyte can have a negative impact on seagrasses this is considered a positive result. But it is important to have some epiphytes as they provide important ecological roles.

Key finding 4

Nutrient content of seagrasses in Geographe Bay is low, and no increase in nutrient content has been observed compared to samples collected over the last two decades. Nutrient concentration varies across years and sites, and the main difference is 2 times higher nitrogen content at Capel compared to all other sites.

Key finding 5

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. This could be conducted by reviewing in light of the Ngari Capes Marine Park Management Plan and the existing monitoring that is being undertaken by Department of Biodiversity, Conservation and Attractions.

Recommendation 4

It has been 12 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.

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 2019 and compares to data from the 2012-2018 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 4th to the 5st February 2019. 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 7 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. Buayanyup	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. Buayanyup, 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.

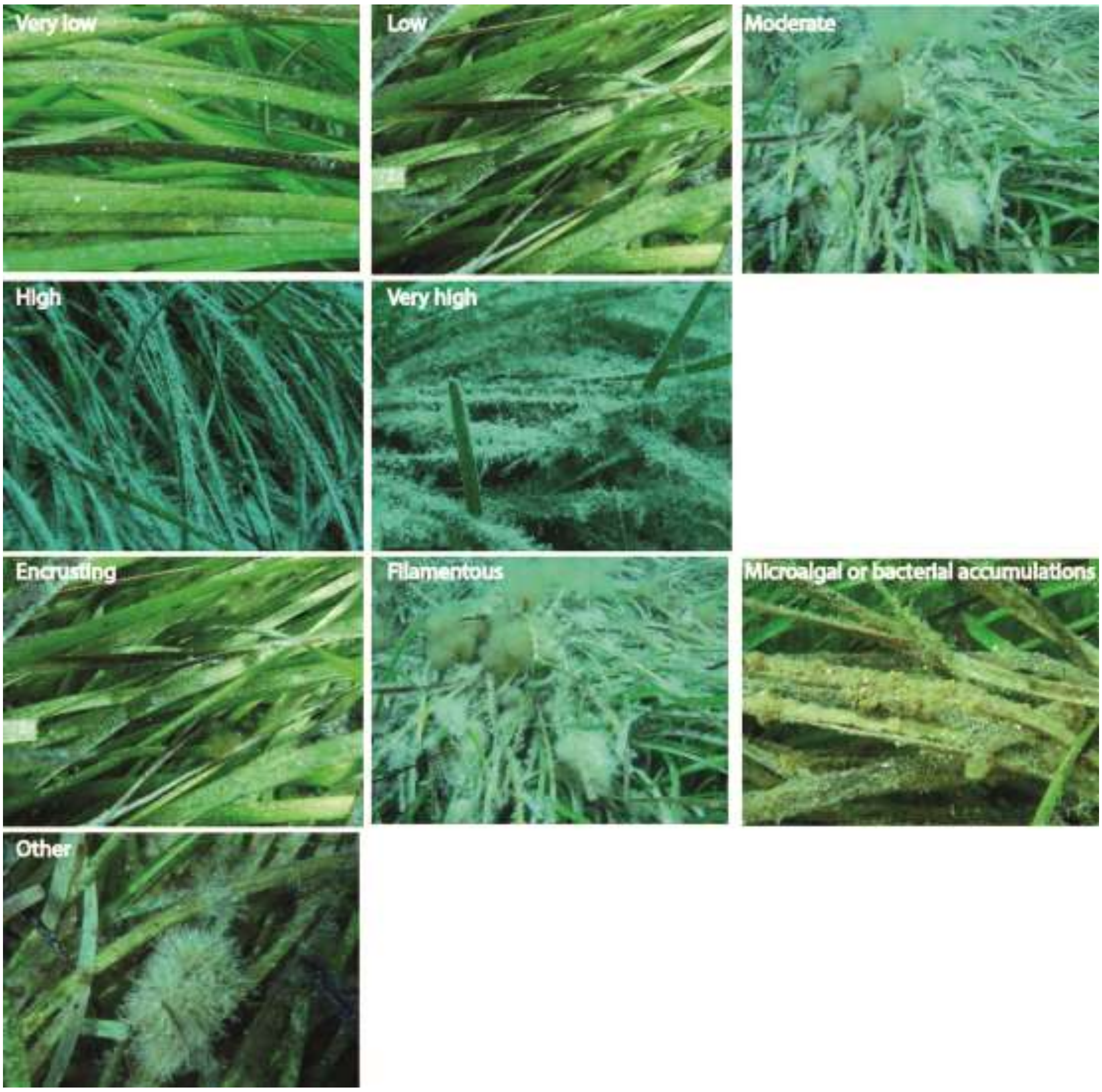


Figure 4: *Classification of epiphytic algal cover and type.*

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 Ben French (BF), David Lierich (DL), Ian Anderson (IA), Eden Baxter (EB) and Natalie Travaglione (NT) from Department of Biodiversity, Conservation and Attractions. Samples were processed and data analysed by Natasha Dunham and Sian McNamara. 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 1027-1578 shoots m^{-2} across the seven sites (Figure 5). This year, the shallower sites, Dunsborough and Buayanyup (3.5 m) maintained the highest shoot density (1404 and 1578 shoots m^{-2}) but Port Geographe increased compared to previous years and had the second highest shoot density (1552 shoots m^{-2}). All other sites had a shoot density greater than 1290 shoots m^{-2} with the exception of Vasse Diversion Drain which has maintained the minimum shoot density of 1027 shoots m^{-2}. All raw data is in Appendix 2.

Unlike last year, when there was a reduction in shoot density at 4 of the 7 sites, this year all sites increased in shoot density, or had minimal change (<5%). The greatest increases (>20%) occurred at Port Geographe and Busselton Jetty, Buayanyup and Vasse –Wonnerup increased by ~15% and Vasse Diversion Drain ~10%. The remaining sites had minimal change (<5%). (Table 2). It is positive to see the continuing upward trend in shoot density at Port Geographe from 41% last year to 23% this year. Compared to the start of the monitoring program in 2012, all central sites (Vasse Diversion to Vasse-Wonnerup) have increased in shoot density, particularly the most central sites, Port Geographe (43%) and Busselton Jetty (37%). Buayanyup has had minimal change and overall there have been declines at Dunsborough (9%) and Forrest Beach (13%).

The shoot density at all sites in Geographe Bay are above the minimum (320 m^2) and all but Vasse Diversion Drain are above the maximum (1 180 m^2) range 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 an improvement from last year when three sites in the middle of Geographe Bay, Vasse Diversion Drain, Busselton Jetty and Vasse-Wonnerup remained below the maximum site average at the Shoalwater and Jurien Bay Marine Park sites (Figure 5).

P. sinuosa average shoot length ranged from a minimum of 34 cm at Forrest Beach to a maximum of 68 cm at Vasse Diversion Drain and a range in width of 4.4-5.6 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**	**12-19**
1. Dunsborough	3	-18	7	9	-3	-10	5	-9
2. Buayanyup	11	-24	20	-7	2	-5	15	3
3. Vasse Diversion	6	-8	0	-15	19	12	8	16
4. Busselton Jetty	0	22	-4	1	-1	-5	23	37
5. Port Geographe	17	-7	12	-6	-23	41	28	45
6. Vasse-Wonnerup	19	13	-4	-3	4	-5	13	18
7. Forrest Beach	16	-23	2	5	-3	8	0	-11

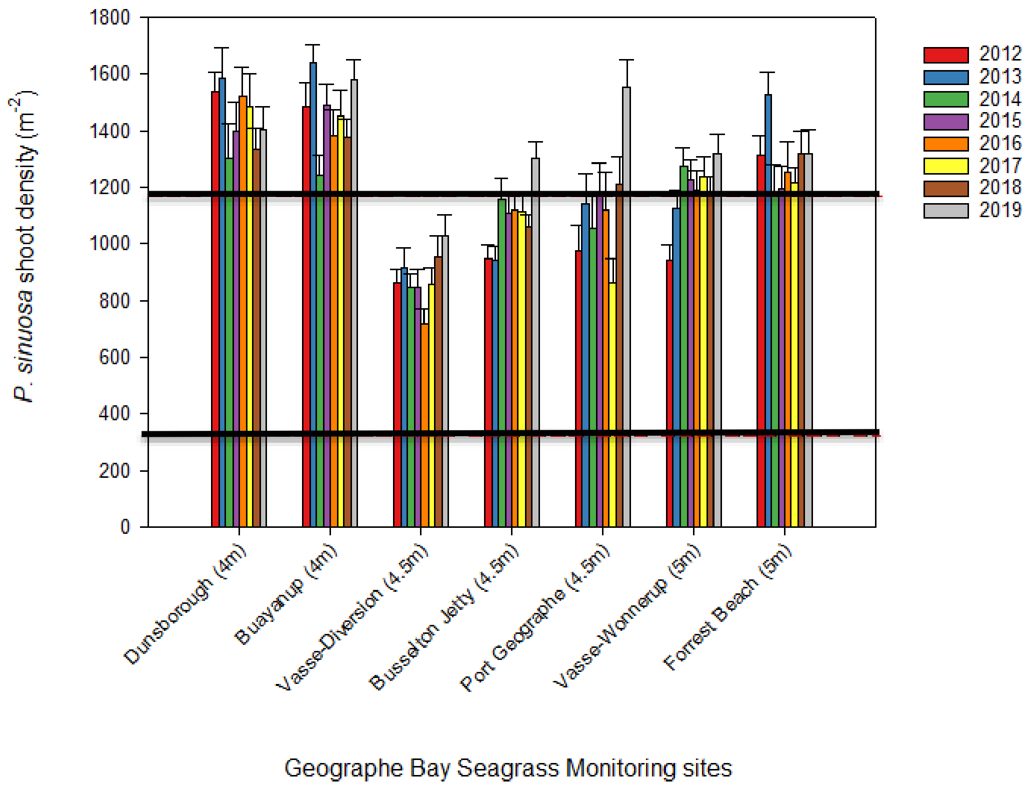


Figure 5: *Shoot density (average m^{-2} ± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in January or February 2012-2019. Dotted lines indicate the minimum and maximum site averages from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2012-2019 (data courtesy of DBCA, 2019).*

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 2018-2019).

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 2017-2018 & 2018-2019). In fact, over the last two years, there have been no declines of 20% or more.

4.2.3 Trigger 3

No sites showed a significant trend over the eight years, either increasing or decreasing in shoot density (Table 3). Plots of individual sites showing change over time are located in Appendix 4.

Table 3: Mann-Kendall Trend statistic to assess if there has been a significant decline over time in shoot density from 2012-2019.

Site Name & #	Significance ($p<0.05$)	Overall slope	R^2
1. Dunsborough	ns	+ve	19%
2. Buayanyup	ns	+ve	0%
3. Vasse Diversion	ns	+ve	16%
4. Busselton Jetty	ns	+ve	56%
5. Port Geographe	ns	+ve	29%
6. Vasse-Wonnerup	ns	+ve	48%
7. Forrest Beach	ns	+ve	5%

4.3 Epiphytes

This year there has been a reduction in epiphyte cover at all sites with the exception of Dunsborough which has maintained a moderate cover (Table 4). All other sites had a Low or Very Low cover. Such low cover has not been observed since 2012 and 2013 (Table 4). The general category 'Other epiphytes' was the most dominant form of epiphytes at most sites, and these were mostly calcified, branching red algae, forams and the brown algae, *Dictyota*. Microalgal accumulations were still present from Dunsborough to Port Geographe, and were the most dominant epiphyte at Port Geographe (Figure 6, Table 4).

Table 4: Algal cover at the Keep Watch seagrass monitoring sites, 2012-2019. 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**
1. Dunsborough	M	L	M	M	L	L	M	M
2. Buayanyup	M	L	M	M	H	H	M	VL
3. Vasse Diversion Drain	L	M	H	H	H	H	H	L
4. Busselton Jetty	L	L	H	H	M	M	M	L
5. Port Geographe	L	VL	L	L	M	M	M	L
6. Vasse-Wonnerup	L	VL	L	M	L	L	L	VL
7. Forrest Beach	L	VL	L	L	L	VL	L	VL
	Algal Type							
	-12	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**	**-19**
1. Dunsborough	O,f,m	F,O	O	O,m	O	O,e,m	O,m	O,m
2. Buayanyup	M,o	E,O	M,o	M,o	M , o	M,e,o	M,o	O,m
3. Vasse Diversion Drain	M,o	E,O	M,o	M,o	M , o	M,o	M,o	O,m
4. Busselton Jetty	M,o	O	M	M,f	O, e, m	M,o,e	O,M	O,m
5. Port Geographe	E, o	E,M	M,e	M,f	O, f	M,o,e	O,M	M
6. Vasse-Wonnerup	E, o, m	E,O	M,f	O	E,o,m	E,m	O,M	O
7. Forrest Beach	E, M,o	F,E	M,f	O,e	E,o	E,o	O, e	O

FIGURE IS IN DROPBOX, NOT INCLUDED IN THE DRAFT FORM AS IT MAKES THE DOCUMENT TOO LARGE

Figure 6: Pictures of seagrass meadow and the dominant algal epiphytes at each *P. sinuosa* site. (1. Dunsborough, 2. Buayanyup, 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 Vasse Wonnerup and *A. griffithii* was also noted at Dunsborough, Forrest Beach and Capel. The remains of flowering shoots were observed at Vasse-Diversion Drain, Busselton Jetty, Vasse-Wonnerup and Forrest Beach, three more sites than last year. Unlike last year, seedlings were observed, but only at Dunsborough.

No anchor damage was observed at any site, blowouts remain at the Dunsborough site, most likely from water movement, and a few small bare patches were noted at Vasse Wonnerup and Forrest Beach, 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 two years ago are barely discernable now, indicating recovery into the patches.

Between Buayanyup and Busselton Jetty seagrass wrack was observed on top of the seagrass canopy. The white tips on the long leaves at Dunsborough remain, and this was also observed at Busselton Jetty. Most likely from sun damage due to the shallow water and very clear water.

Figure 7: Bare patches within the seagrass meadow at Port Geographe.

4.5 Nutrient content

The nitrogen content of *P. sinuosa* leaves ranged from 0.4-0.7 % N dry weight (DW) (Figure 8). At all sites there was <0.1% change. The nitrogen content of *A. antarctica* leaves was higher, ranging from 0.6-1.3% N DW, once again with very little change from last year at each site (Figure 9). The nitrogen content of the *A. antarctica* leaves is still greater at Capel, up to 2x greater than the other two sites.

The phosphorus content of *P. sinuosa* leaves in 2019 ranged from 0.14-0.16% P DW (Figure 8). Three sites, Dunsborough, Vasse Diversion and Busselton Jetty increased slightly compared to last year (~0.07 % DW). For *A. antarctica* leaves, the phosphorus content was similar, ranging from 0.12-0.13% 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.

This 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			

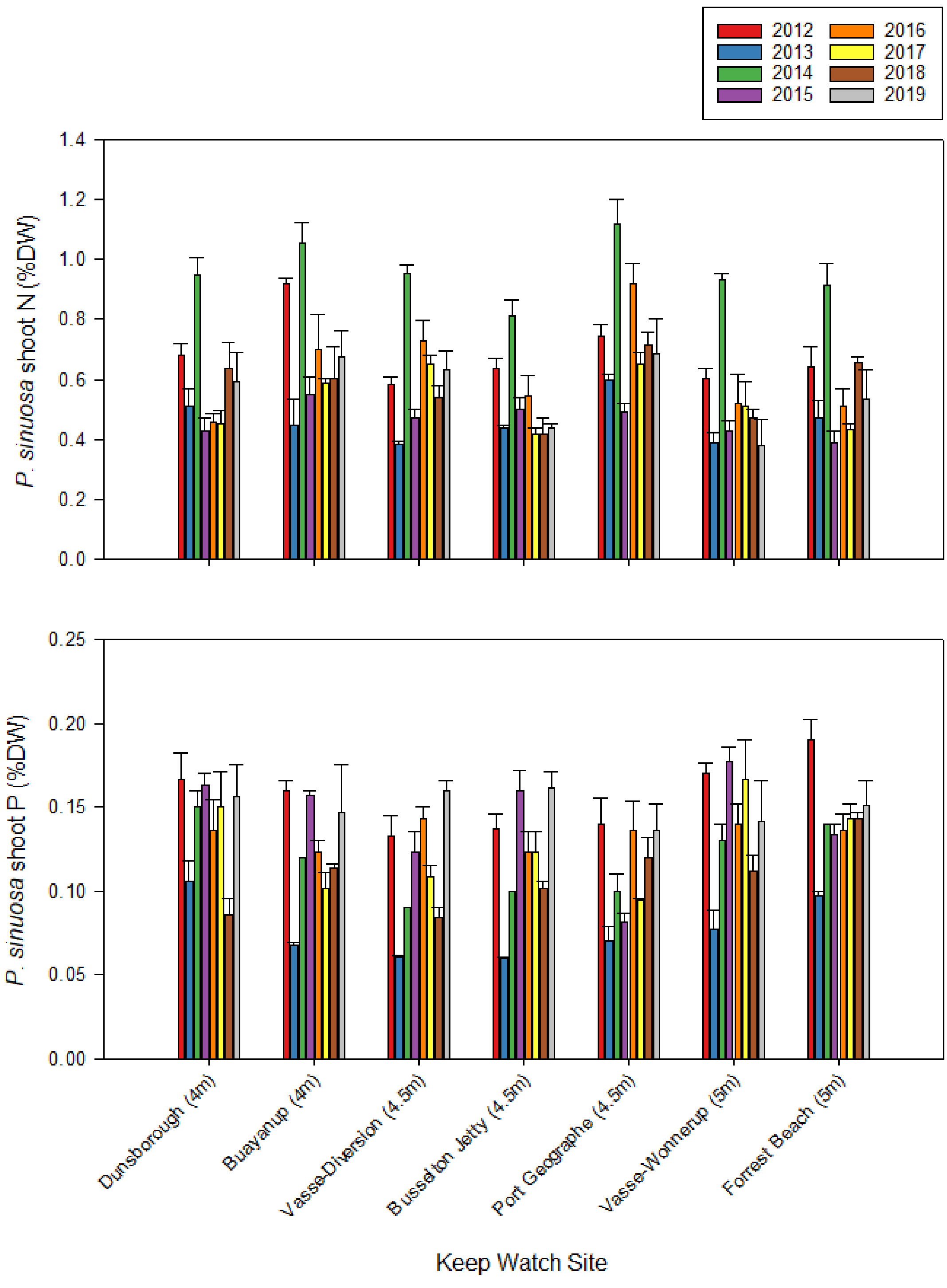


***Figure 8:** Nitrogen and phosphorus content (% dw) of* P. sinuosa *leaves (Dunsborough-Forrest Beach) at the Keep Watch* Posidonia *seagrass monitoring sites in 2012-2019.*

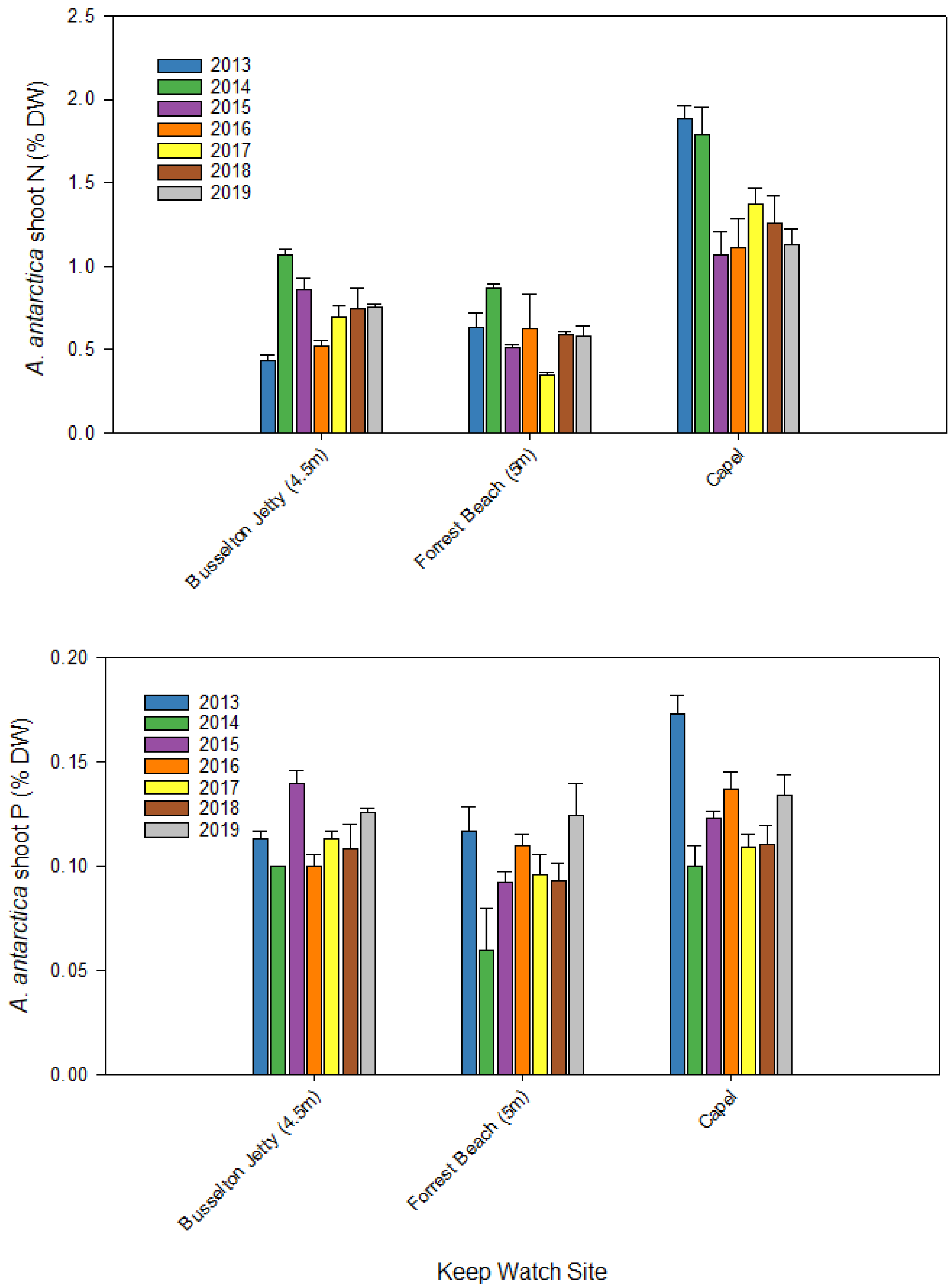


Figure 9: *Nitrogen and phosphorus content (% dw) of* A. antarctica *leaves (average ± se) at the Keep Watch* Amphibolis *seagrass monitoring sites in 2013-2019.*

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 0.6 to 2.3 ‰. $\delta^{15}N$ signals remained similar to last year at Dunsborough (1.3 ‰), Busselton Jetty (0.6 ‰) and Forrest Beach (1.8 ‰). They increased slightly at Buayanyup (1.2 ‰), Vasse Diversion (1.8 ‰) and Vasse Wonnerup (1.1 ‰) but remained within the range observed over the last eight years. However, at Port Geographe the $\delta^{15}N$ signal increased to 2.3 ‰, the highest observed at this site (Figure 10). Over the last couple of years there were consecutive increases in the $\delta^{15}N$ signal at Dunsborough and Forrest Beach, but this has not continued this year. 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 1.6-3.3‰, remaining stable at Forrest Beach (1.6 ‰) and Capel (3.3 ‰) but increasing at Busselton Jetty (1.8 ‰), 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.

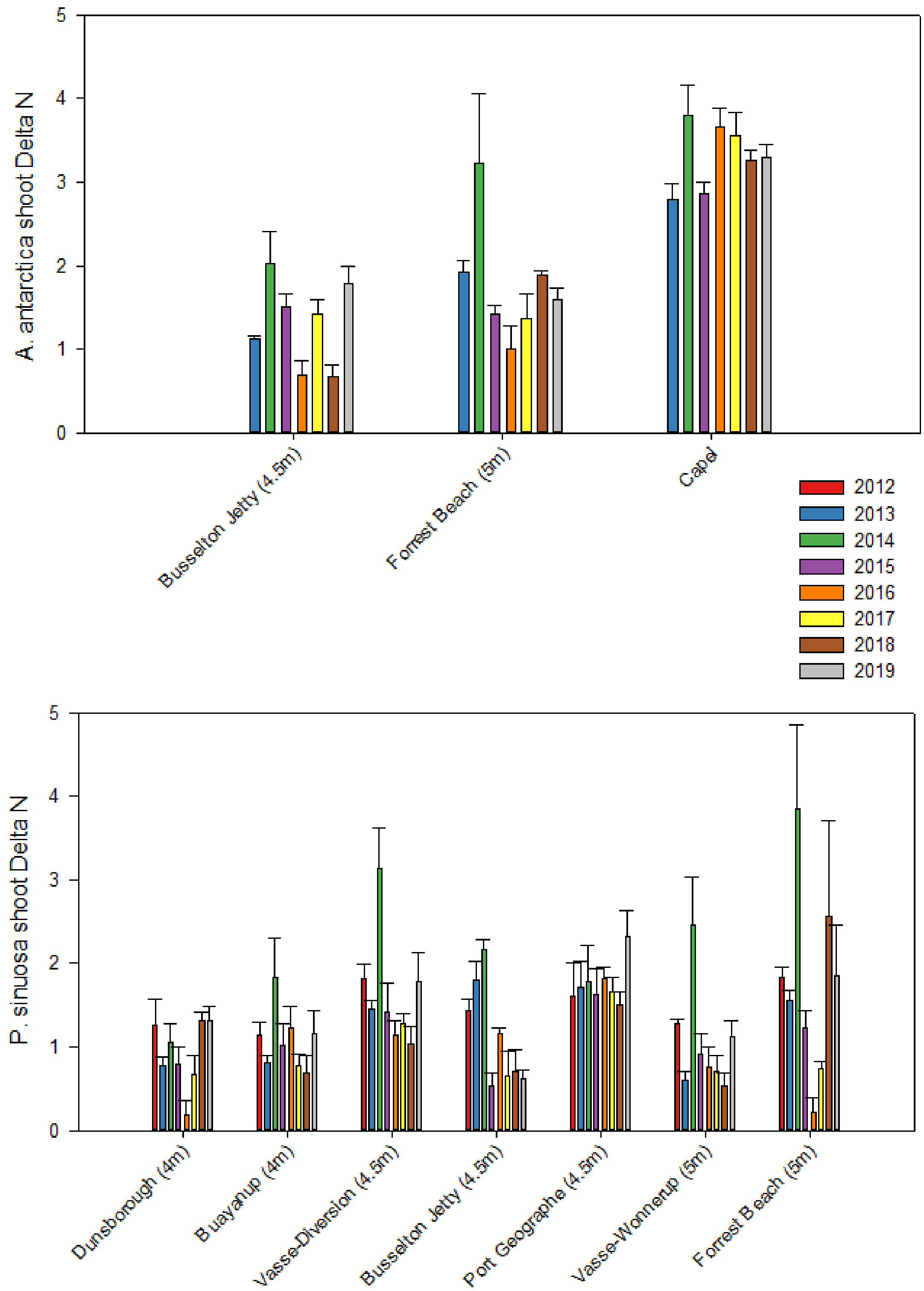


Figure 10: *δ^{15}N of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4, 7 & 8 average ± se) at the Keep Watch seagrass monitoring sites in 2012-2019. Note that only Capel was measured in 2012, and is not included in these graphs.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 20.6-22.8°C. Water clarity was not as high as 2018 observations, the Secchi disk was not observed on the bottom at any site (Table 6).

Table 6: Water quality measures at the Keep Watch seagrass monitoring sites from 2012-2019, *=Secchi disk depth on bottom.

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

5 General conclusions

5.1 No significant declines in shoot density

No management criteria were triggered in 2019 for all three triggers. Most sites showed increases compared to last year, a positive sign for seagrass health. This is also reflected in the trends across the period of this program where at most sites, seagrass shoot density is higher than when the program started. The exceptions are Dunsborough and Forrest Beach, which have experienced slight declines since the start of the program (9 and 11% respectively). 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. At this time there will be one more year remaining for funding of this program. 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. Therefore, considering that in 2021 the current funding finishes and this will have generated 10 years of data on seagrass health, a reassessment of the program is warranted.

5.2 Very low algal epiphyte cover in 2019

Epiphytes are important components of seagrass ecosystems, contributing to primary production, food and habitat for fauna. This year has seen some of the lowest algal epiphyte cover observed throughout the program, similar to 2013. The amount of epiphyte cover on seagrasses is promoted by nutrients, can be affected by temperature and controlled by grazing from fish and invertebrates as well as wave energy. The consistently lower cover of epiphytes indicates a bay-wide effect. If we examine nutrients, there was not a significant decline in the seagrass nutrient content across the bay, although this was observed at two sites, Vasse Wonnerup and Forrest Beach. There appeared to be no relationship in epiphyte cover with wind strength or the previous years rainfall. Epiphyte cover tended to be lower when water tempertures were higher (2012 and 2013). When nitrogen loads based on Department of Water and Environmental Regulation Loads increased so did epiphyte cover,, although there was variation around this at lower loads, indicating other factors are also important. This is something to investigate further as part of the review and reassessment of the program.

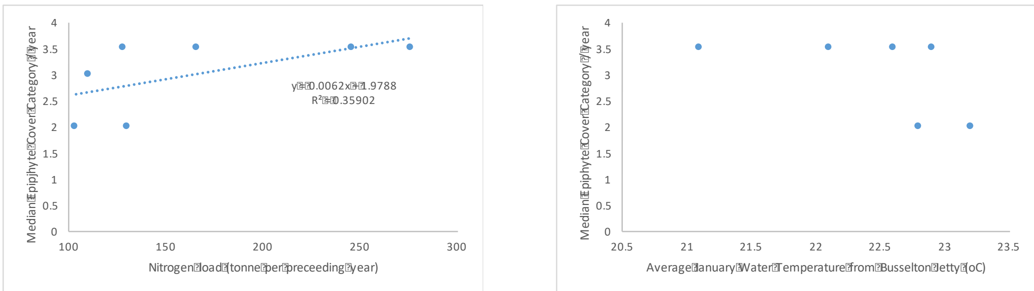


Figure 11. Relationship between median epiphyte cover category (1-5) and nitrogen loads in the preceding year based on DWER modelling (to 2017 only) and water temperature based on Busselton Jetty loggers (average from January).

5.3 No major changes in nutrient exposure or sources

Overall there was little change in the amount of nutrients, both nitrogen and phosphorus that the seagrasses had in their leaf tissue. The concentrations observed are very low and no indication of exposure to excess nutrients is evident. 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 Recovery of dieback patches is continuing in some locations

Two years ago, 2017, small patches of seagrass dieback of both *P. sinuosa* and *A. antarctica* were observed at Dunsborough and Busselton Jetty. Since then, no new patches have been observed and recovery is evident. Last year shoots and leaves were observed emerging from the rhizomes and stems left in the bare patches, and rhizome growth into the patches was observed. This year the patches were barely visible and these was clearly an increase in shoot density at Busselton Jetty, supporting the recovery. This was not as evident at Dunsborough where the shoot density remained consistent with a negligible 5% increase.

These patterns are in contrast to Port Geographe, where bare patches that were observed at the start of the monitoring program still persist but the shoot density continues to increase. In fact, this site has had the greatest increase in shoot density since the start of the program (45%). There may be something inhibiting recruitment into these patches, such as changes in the sediment chemistry which creates a barrier for new growth. This is a topic for which a small research project could be based.

6 References

Collier C, Lavery P, Ralph P, Masini R (2008) Physiological characteristics of the seagrass Posidonia sinuosa along a depth-related gradient of light availability. Marine Ecology Progress Series 353:65–79

Hyndes G, Lavery P, Doropoulos C (2012) Dual processes for cross-boundary subsidies: incorporation of nutrients from reef-derived kelp into a seagrass ecosystem. Marine Ecology Progress Series 445:97–107

Jones A, Saxby T (2003) Assessing nutrient sources. http://ian.umces.edu

McMahon K (1994) Seasonal and spatial changes in chemical and biological conditions in nearshore Geographe Bay. Honours thesis, University of Western Australia., Perth

McMahon K (2012) Proposed methodology for a seagrass health-monitoring program in Geographe Bay. Report to GeoCatch. Edith Cowan University, Joondalup

McMahon K, Walker D (2008) Fate of seasonal, terrestrial nutrient inputs to a shallow seagrass dominated embayment. Estuarine Coastal and Shelf Science 46:15-25

Oldham C, Lavery P, McMahon K, Pattiaratchi C, Chiffings TW (2010) Report to Dept. of Transport and Shire of Busselton. Seagrass Wrack Dynamics in Geographe Bay, Western Australia.

Paling E, McComb A (2000) Autumn biomass, below-ground productivity, rhizome growth at bed edge and nitrogen content in seagrasses from Western Australia. Aquatic Botany 67:207–219

van Niel K, Holmes K, Radford B (2009) Seagrass Mapping Geographe Bay 2004-2007. University of Western Australia

7 Appendix 1: Randomly generated quadrat positions from 2019 survey

Quadrat #	Bearing	Distance
1	40	2
2	40	4
3	40	11
4	40	17
5	40	24
6	100	10
7	100	14
8	100	15
9	100	20
10	100	25
11	140	8
12	140	13
13	140	16
14	140	21
15	140	23
16	200	22
17	200	12
18	200	16
19	200	19
20	200	23
21	240	1
22	240	9
23	240	14
24	240	16
25	240	20
26	280	2
27	280	7
28	280	10
29	280	13
30	280	20

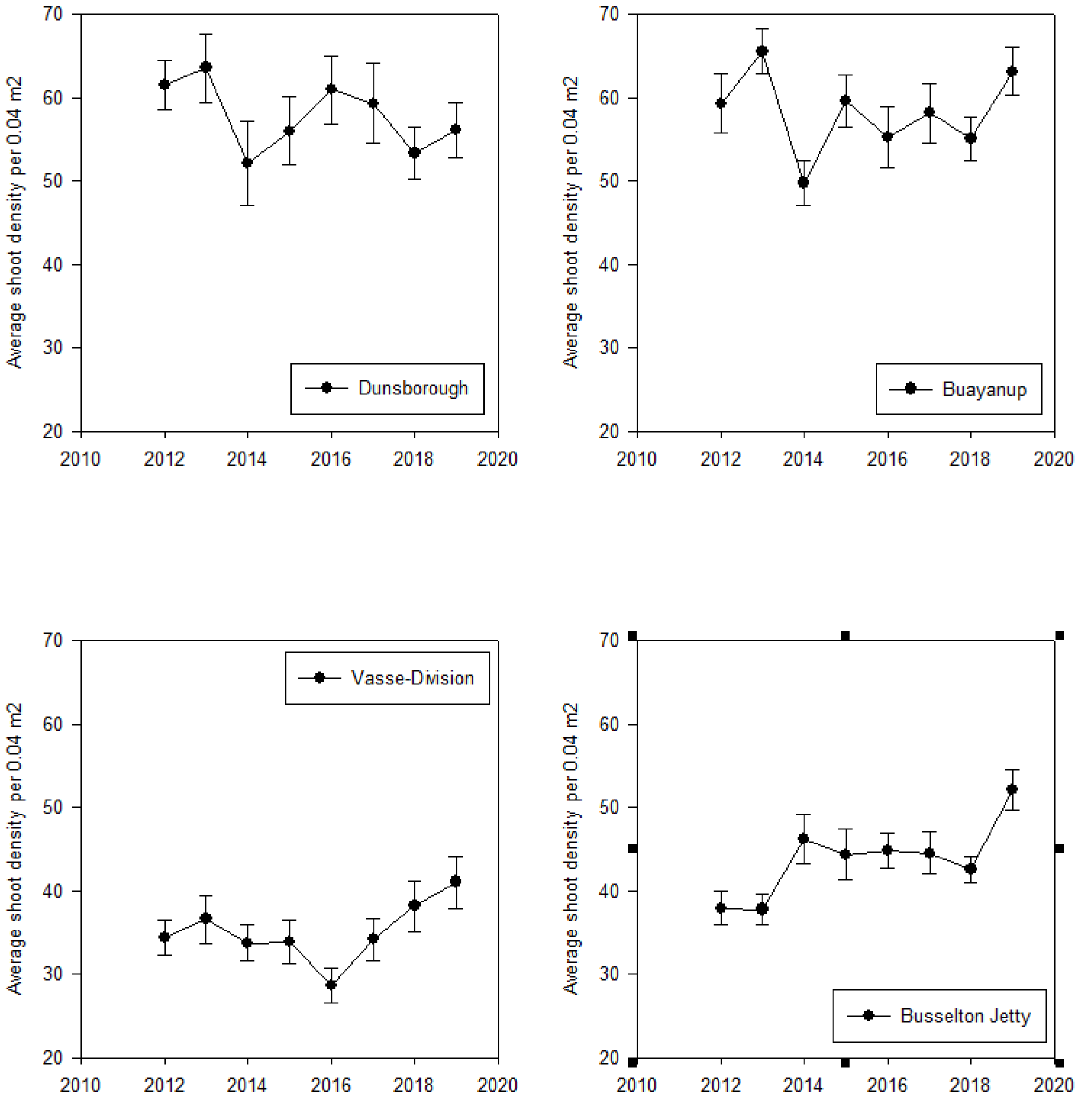
8 Appendix 2: Shoot density data for the seven Keep Watch Seagrass Monitoring Sites including the seedling counts, and the person who counted each quadrat, 2019. Numbers in orange are average, standard deviation and standard error.

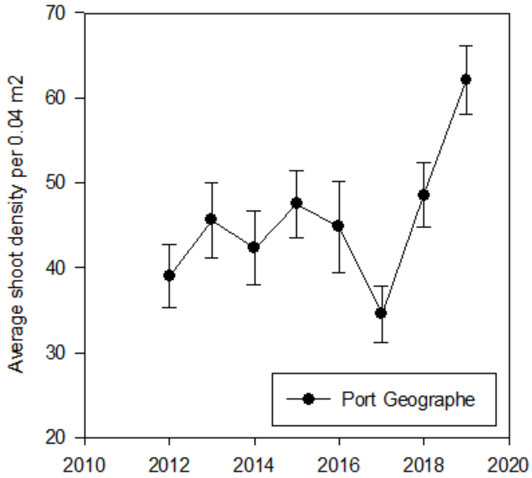
	1. Dunsborough			2. Buayanup			3. Vasse Diversion			4. Busselton Jetty			5. Port Geographe			6. Vasse-Wonnerup			7. Forrest Beach		
	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter
	29	0	EB	92	0	EB	61	0	EB	41	0		62	0	KM	29	0	E	56	0	KM
	67	0	EB	63	0	EB	48	0	EB	60	0		70	0	IA	39	0	E	98	0	KM
	77	0	EB	87	0	EB	52	0	EB	46	0		38	0	IA	53	0	E	36	0	E
	21	0	EB	47	0	EB	75	0	EB	37	0		61	0	IA	32	0	E	23	0	E
	71	0	EB	65	0	EB	6	0	EB	72	0		94	0	IA	22	0	E	75	0	E
	69	0	NT	76	0	NT	14	0	NT	58	0		53	0	KM	50	0	NT	50	0	NT
	48	0	NT	58	0	NT	42	0	NT	52	0		80	0	KM	59	0	NT	52	0	NT
	84	0	NT	60	0	NT	28	0	NT	50	0		27	0	NT	44	0	NT	44	0	NT
	54	0	NT	61	0	NT	36	0	NT	50	0		29	0	NT	37	0	NT	74	0	NT
	48	0	NT	77	0	NT	44	0	NT	26	0		63	0	NT	48	0	NT	31	0	NT
	60	0	BF	52	0	BF	28	0	BF	50	0		104	0	KM	68	0	BF	51	0	BF
	72	0	BF	54	0	BF	23	0	BF	33	0		33	0	BF	66	0	BF	35	0	BF
	61	0	BF	65	0	BF	65	0	BF	64	0		73	0	BF	62	0	BF	27	0	BF
	34	0	BF	43	0	BF	44	0	BF	40	0		71	0	BF	40	0	BF	59	0	BF
	39	0	BF	82	0	BF	33	0	BF	68	0		37	0	BF	45	0	BF	75	0	BF
	60	0	KM	55	0	KM	55	0	KM	50	0		78	0	KM	49	0	KM	39	0	KM
	81	0	KM	30	0	KM	38	0	KM	24	0		97	0	KM	43	0	KM	54	0	KM
	54	0	KM	65	0	KM	47	0	KM	73	0		55	0	KM	49	0	KM	66	0	KM
	76	0	KM	74	0	KM	36	0	KM	68	0		34	0	KM	68	0	KM	53	0	KM
	45	0	KM	51	0	KM	60	0	KM	62	0		51	0	KM	81	0	KM	21	0	KM
	36	0	BF	33	0	BF	46	0	BF	51	0		51	0	BF	57	0	BF	46	0	BF
	71	0	BF	69	0	BF	21	0	BF	53	0		79	0	BF	61	0	BF	81	0	BF
	55	0	BF	78	0	BF	23	0	BF	43	0		97	0	BF	62	0	BF	50	0	BF
	43	0	BF	34	0	BF	77	0	BF	45	0		84	0	BF	58	0	BF	36	0	BF
	27	0	BF	83	0	BF	43	0	BF	35	0		56	0	BF	63	0	BF	60	0	BF
	85	0	KM	66	0	EB	36	0	EB	56	0		48	0	IA	75	0	E	61	0	NT
	61	0	NT	62	0	KM	36	0	KM	59	0		33	0	IA	44	0	NT	33	0	NT
	32	0	EB	68	0	NT	19	0	NT	66	0		57	0	KM	42	0	NT	69	0	E
	55	0	KM	81	0	KM	40	0	KM	66	0		69	0	BF	70	0	KM	59	0	KM
	70	0	NT	63	0	KM	56	0	NT	64	0		78	0	BF	68	0	KM	68	0	KM
Average	**56.2**	**0.0**		**63.1**	**0.0**		**41.1**	**0.0**		**52.1**	**0.0**		**62.1**	**0.0**		**52.8**	**0.0**		**52.7**	**0.0**	
Median	**57.5**	**0.0**		**64.0**	**0.0**		**41.0**	**0.0**		**51.5**	**0.0**		**61.5**	**0.0**		**51.5**	**0.0**		**52.5**	**0.0**	
SE	**3.28**	**0.00**		**2.88**	**0.00**		**3.12**	**0.00**		**2.42**	**0.00**		**3.98**	**0.00**		**2.61**	**0.00**		**3.36**	**0.00**	
Stdev	**17.94**			**15.79**			**17.08**			**13.24**			**21.79**			**14.28**			**18.38**		
CV	**0.32**			**0.25**			**0.42**			**0.25**			**0.35**			**0.27**			**0.35**		

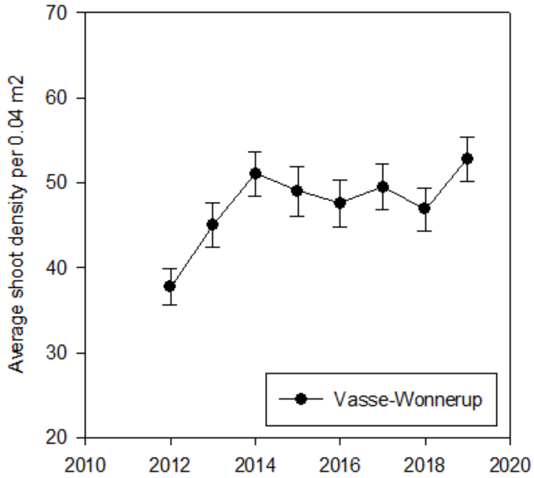
9 Appendix 3: Leaf morphology data for 2019

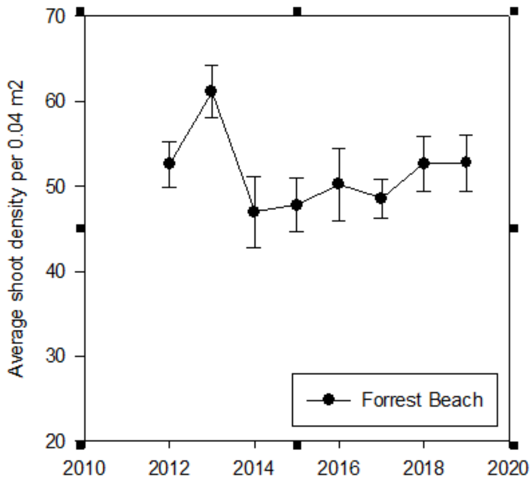
	2019	2019	2019	2019	2019	2019	2019	2019	2019	2019	2019	2019	2019	2019
	S1	S1	S2	S2	S3	S3	S4	S4	S5	S5	S6	S6	S7	S7
	Dun.	Dun.	Buayanup	Buayanup	Vasse Div.	Vasse Div.	Buss Jetty	Buss Jetty	Port Geo	Port Geo	Vasse Won	Vasse Won	Forrest B	Forrest B
Rep	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	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	28.3	6.9	53.7	4.6	54.8	5.9	50.8	5.8	48.6	5.2	43.5	5.3	46.9	4.3
2	32.7	6.3	54.7	4.6	55.3	4.8	46.6	5.5	50.2	5.2	65.5	5.6	32	5.2
3	36.1	6.6	31.4	4	84	4.7	55.2	5.8	39.3	6	58.4	6.3	36.1	5.4
4	32	6.3	62.8	3.7	67.5	4.7	70.2	5.8	34.5	7	60.1	5.9	25.1	4.1
5	36	6.1	33.1	3.7	58.1	4.1	55.2	5.7	41	5.2	41.5	6	34.2	6.2
6	38.1	5.7	50	4.1	67	3.9	33.1	5	48.7	5.4	55.6	6	36.7	4.7
7	31.4	6.9	58.9	4.3	34.2	6.4	62.9	5.5	55.7	5.5	58.1	5.3	37.2	5.1
8	13.3	6.1	30.3	4.7	57.7	5.5	50.7	5.8	60.2	5	66.1	6	52.7	5
9	29.9	5.3	45	3.7	60.1	5.3	57.4	5.5	48.6	5.1	55.5	5.3	42.6	5.1
10	12.6	5.9	27.7	3.4	81.7	5.1	42.2	5.9	49.2	5	54.7	5.4	32.9	5
11	36.9	5	27.6	4.3	72.2	5.3	42.8	5.5	33.5	5.4	75.3	5.7	9.1	5.3
12	39.7	5.4	46.6	4.4	61.6	4.7	44.5	5.4	68	5.4	83.4	5	19.2	5.7
13	31.3	5.8	56.5	4.4	79.7	4.9	59.8	6	41.6	5.9	39.5	5.3	18.6	5.8
14	35.7	5.6	24.1	4.2	64.9	5.2	13.7	6	50.3	5.8	na	na	29	5.7
15	32.7	6.2	62.2	4.1	69.8	5.9	18.1	6.1	54.3	5.6	na	na	15.2	4.2
16	46.1	5.6	51	4.1	73.7	5	40.2	5.5	26.8	5.7	78.9	5.6	49	6.1
17	30.8	5.2	41.8	4.2	92.7	5.5	35.5	5.2	39.6	5.7	66	4.9	51.8	4.8
18	29.8	5.4	43.2	5.1	50.2	6.8	24.9	5.3	43.1	5.9	76	6.4	41.1	5.1
19	45.1	5.6	63.9	4.9	50.7	5.4	19.2	5	49.5	6.1	78.5	6.6	29.5	5.1
20	35.1	4.4	52.2	4.6	84.5	4.8	21.2	5.3	47.1	6.1	52.1	5.2	40.7	5.1
21	37.1	5	52	5.3	63.3	5.5	19.5	4.4	35.7	5	77.5	5.3	42.2	5.7
22	47.1	6	31.4	4.2	61.6	4.6	54.9	5.5	39.3	5.8	71.8	6.2	39.1	3.9
23	33	6	56.7	3.8	66	5.4	44.1	5.3	39	4.7	78	5.3	39.1	5.4
24	33.1	5.4	61.4	3.7	39.3	4.7	29.4	4.8	34.5	4.6	63.5	5.6	46.2	4.7
25	42.7	6.4	63.6	4.7	55.4	4.9	32.4	5.5	31.6	4.9	67.8	6.8	52.6	4.1
26	37.7	5.1	49.3	4.2	63.4	4.9	40.1	5.7	33.6	5.4	76.6	5.8	44.7	3.4
27	45.5	5.2	67.7	4.2	47.7	5.5	61.4	4.8	40.7	4.4	69.8	5.1	37.1	3.4
28	31.7	5.3	35.4	3.3	72.6	4.7	55.1	4.8	18.7	4.3	70.5	5	28.2	4.9
29	32.4	5.6	49.3	4.6	52.5	4.8	45.1	4.7	37.5	6.2	86.6	5.4	25.1	4.5
30	47	5.4	59.2	5.2	8.2	6	na	na	40.7	5.2	78.2	6.1	30.2	3.7
31	69.5	5.8	69.2	3.8	83.8	4.9	21	4.1	32.3	4.6	59.5	5.6	48.5	4.5
32	56	4.6	57.2	4.8	78.2	4.8	48.3	4.4	24.2	4.5	73	4.7	64	5.4
33	22.3	4.9	33.5	5.4	56.5	6.2	44	6	35.3	5.2	63	5.3	30.2	5.6
34	43.8	4.8	54.2	5	48.9	6	43.4	6	42.9	5.9	64.7	5.8	35.6	5.3
35	46.7	5.4	57.2	5	40.2	5.6	52	5.9	51.4	4.1	81.4	5.7	32.9	5.8
36	26	4.9	76.3	4	83.7	4.4	60.2	5.9	36.7	4.8	89.9	6	79.6	5.4
37	48.1	5.7	61	5.5	82.1	5.1	58.1	6	38.3	5.3	24.4	4.9	51.7	5.2
38	38.1	5.7	72.5	3.7	68.5	6.2	9.7	6	26.9	3.8	51.1	6	49	5
39	29	5.8	62.7	4.9	103.5	4.9	51.6	5.8	37.7	5.4	77.3	5.7	17.6	4.7
40	29.1	5.6	78.2	4.2	103.2	5.5	53.7	5.9	39.7	4.7	72	5.4	12	4.3
41	39.7	5.6	56	5.2	82.9	4.9	20.4	6.3	52.5	4.4	36.2	4.7	2.7	5.7
42	na	na	67.2	5	135.1	5.5	na	na	36.6	5	78.6	5.4	4.2	5.6
43	na	na	65.6	4.4	101.2	5.3	na	na	48.5	4.7	71.6	5.8	3.8	5.4
44	na	na	39.1	5.2	61.2	5.3	na	na	44.4	5.2	8.1	6.1	na	na
45	na	na	54.5	4.6	85.2	4.9	na	na	25.2	4.5	34.9	7.1	na	na
AVERAGE	36.321951	5.6219512	52.157778	4.4222222	68.102222	5.2088889	42.215	5.485	41.193333	5.2177778	63.597674	5.6418605	34.788372	4.9906977
STDEV	1.5974351	0.0894776	2.0563759	0.0833569	3.177065	0.0886385	2.4626402	0.0834781	1.4667748	0.0947239	2.6341136	0.0820712	2.4596482	0.1046967

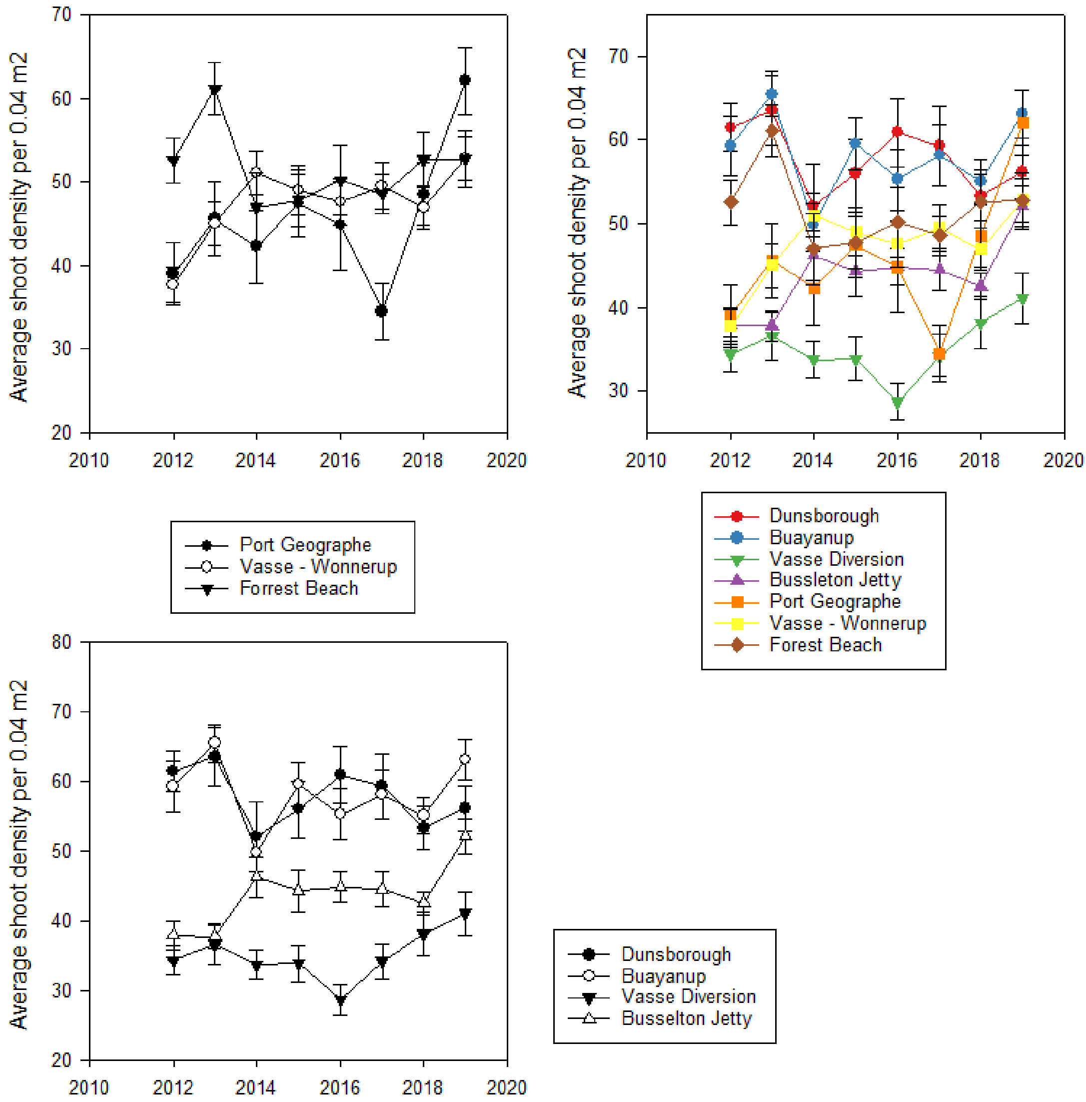
10 Appendix 4: Trends over time in seagrass shoot density.




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


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


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


Average shoot density per 0.04 m2
70
60
50
40
30
20
2010
2012
2014
2016
2018
2020
Port Geographe
Vasse - Wonnerup
Forrest Beach
Average shoot density per 0.04 m2
70
60
50
40
30
2010
2012
2014
2016
2018
2020
Dunsborough
Buayanup
Vasse Diversion
Bussleton Jetty
Port Geographe
Vasse - Wonnerup
Forest Beach
Average shoot density per 0.04 m2
80
70
60
50
40
30
20
2010
2012
2014
2016
2018
2020
Dunsborough
Buayanup
Vasse Diversion
Busselton Jetty

11 Appendix 5: Nutrient data for 2019

Site	Species	δ15N [‰ AIR]	δ13C [‰ VPDB]	N [wt %]	C [wt %]	P (% DW)
Dunsborough	Posidonia	1.47	-10.46	0.79	41.46	0.15
Dunsborough	Posidonia	1.50	-11.39	0.49	42.08	0.12
Dunsborough	Posidonia	0.99	-11.31	0.49	41.03	0.19
Buayanyup	Posidonia	1.16	-12.11	0.81	41.49	0.11
Buayanyup	Posidonia	0.68	-10.87	0.51	42.23	0.20
Buayanyup	Posidonia	1.65	-10.46	0.71	40.69	0.13
Vasse-Diversion	Posidonia	1.42	-10.64	0.56	40.97	0.15
Vasse-Diversion	Posidonia	1.46	-10.36	0.58	41.76	0.16
Vasse-Diversion	Posidonia	2.48	-10.84	0.75	41.28	0.17
Busselton Jetty	Posidonia	0.50	-10.55	0.46	41.94	0.14
Busselton Jetty	Posidonia	0.84	-12.34	0.40	42.07	0.16
Busselton Jetty	Posidonia	0.54	-10.83	0.45	41.07	0.18
Port Geographe	Posidonia	2.67	-11.90	0.80	42.16	0.16
Port Geographe	Posidonia	1.71	-9.94	0.46	41.70	0.11
Port Geographe	Posidonia	2.60	-9.63	0.80	42.62	0.15
Vasse-Wonnerup	Posidonia	0.76	-10.20	0.40	42.21	0.10
Vasse-Wonnerup	Posidonia	1.32	-11.58	0.21	41.80	0.18
Vasse-Wonnerup	Posidonia	1.29	-12.23	0.52	41.57	0.14
Forrest Beach	Posidonia	1.21	-10.50	0.45	41.97	0.16
Forrest Beach	Posidonia	1.28	-8.95	0.42	42.66	0.12
Forrest Beach	Posidonia	3.08	-11.29	0.73	40.80	0.17
Busselton Jetty	Amphibolis	1.98	-11.81	0.77	41.71	0.12
Busselton Jetty	Amphibolis	2.01	-11.70	0.78	41.79	0.12
Busselton Jetty	Amphibolis	1.38	-11.32	0.71	42.56	0.13
Forrest Beach	Amphibolis	1.88	-12.11	0.71	43.22	0.15
Forrest Beach	Amphibolis	1.50	-13.28	0.50	41.54	0.10
Forrest Beach	Amphibolis	1.43	-13.57	0.54	42.04	0.13
Capel	Amphibolis	3.05	-13.31	1.25	42.21	0.15
Capel	Amphibolis	3.61	-12.62	0.95	42.18	0.12
Capel	Amphibolis	3.21	-15.68	1.19	40.56	0.14