Edith Cowan University
Centre for Marine Ecosystems Research

Keep Watch Seagrass Monitoring 2018 Report for GeoCatch

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Keep Watch Seagrass Monitoring

Annual Report 2018

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.

December 2018

1 Executive Summary

1.1 Introduction

This report summarises data from the first seven years (Feb 2012 - Feb 2018) 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.

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 seasonal and site variations.

1.2 Key findings 2012-2018

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 7 years seagrass shoot density has had small fluctuations and increased or stayed the same at six of the seven monitoring sites, with 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 Port Geographe and highest shoot densities occur within the shallower sites at Dunsborough and Buayanup. The greatest increase over time has occurred at Port Geographe and Vasse-Wonnerup.

Key finding 3

Algal epiphyte cover has fluctuated over time, with some sites in the centre of the bay with the highest epiphyte cover, also showing some increases.The main type of epiphyte on the seagrass, with moderate to high cover is microalgal accumulations. These accumulations are not generally associated with nutrient enrichment. A Masters student from ECU is currently investigating the possible causes of these accumulations.

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 2-4 times higher nitrogen content at Capel compared to 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. This year higher signals, but not as high as Capel, were detected for the first time, The elevated signals here indicate the nitrogen could be sourced with a contribution from leaching of nutrients from natural vegetation. 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 seven 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

Investigate the factors influence the growth and formation of microalgal epiphytic aggregations on the seagrass, particularly the potential link with catchment nutrients.

Recommendation 4

Explore options to undertake seagrass extent mapping on a five yearly basis. The total area of seagrass in Geographe Bay was last mapped in 2007 (van Niel et al. 2009). The recommendation from the assessment of monitoring approaches recommended annual monitoring of seagrass health and then five year monitoring of total seagrass area to assess changes at a larger scale (McMahon 2012).

Recommendation 5

Investigate further water quality monitoring points and/or seagrass monitoring sites associated with discharge points to assess if there are increased levels of nutrients in the waters of Geographe Bay. Currently seagrass monitoring occurs at seven sites in Geographe Bay, and water quality monitoring only at one, and this is not a seagrass monitoring location. The ability to elucidate causes of change in seagrass meadows would be greatly enhanced by having linked water quality data including continuous or regular measurements of nutrients and light. Analysing seagrass samples from dieback areas in 2017 for sulphur isotope analysis could also elucidate potential mechanisms for this dieback.

Recommendation 6

Review Keep Watch seagrass monitoring methodology in line with the Ngari Capes Marine Park Management Plan.

2 Introduction

This document is produced for GeoCatch by Kathryn McMahon from Edith Cowan University. It reports on the Keep Watch seagrass monitoring survey that was undertaken in January 2018 and compares data from the 2012-2017 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 29th to the 31st January 2018. 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 6 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 & Time	Species assessed
1. Dunsborough	S 33.61654°, E 115.12865°	4	30/1/2018 10:00	Ps
2. Buayanup	S 33.65233°, E 115.24840°	4	30/1/2018 11:30	Ps
3. Vasse Diversion Drain	S 33.64746°, E 115.32379°	4.5	30/1/2018 14:00	Ps
4. Busselton Jetty	S 33.63896°, E 115.34315°	4.5	29/1/2018 13:00	Ps, Aa
5. Port Geographe	S 33.62846°, E 115.38240°	4.5	29/1/2018 15:00	Ps
6. Vasse-Wonnerup	S 33.60188°, E 115.42345°	5	31/1/2018 08:59	Ps
7. Forrest Beach	S 33.57295°, E 115.44908°	5	31/1/2018 09:15	Ps, Aa
8. Capel	S 33.51394°, E 115.51508°	2	29/1/2018 10:00	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.

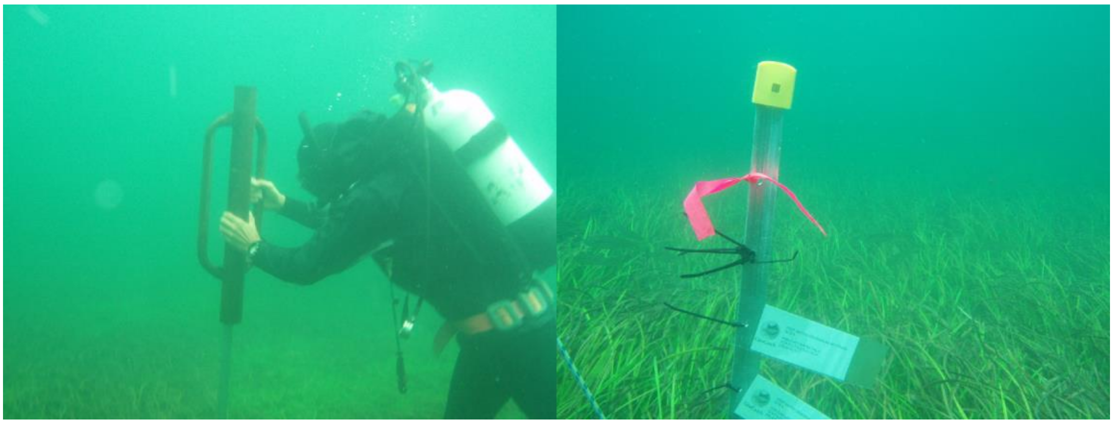

Figure 2: *Left: Banging in permanent marker with pole driver. Right: Star picket with cap and plastic coated site label, indicating center of 50 m diameter Keep Watch seagrass site.*

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.

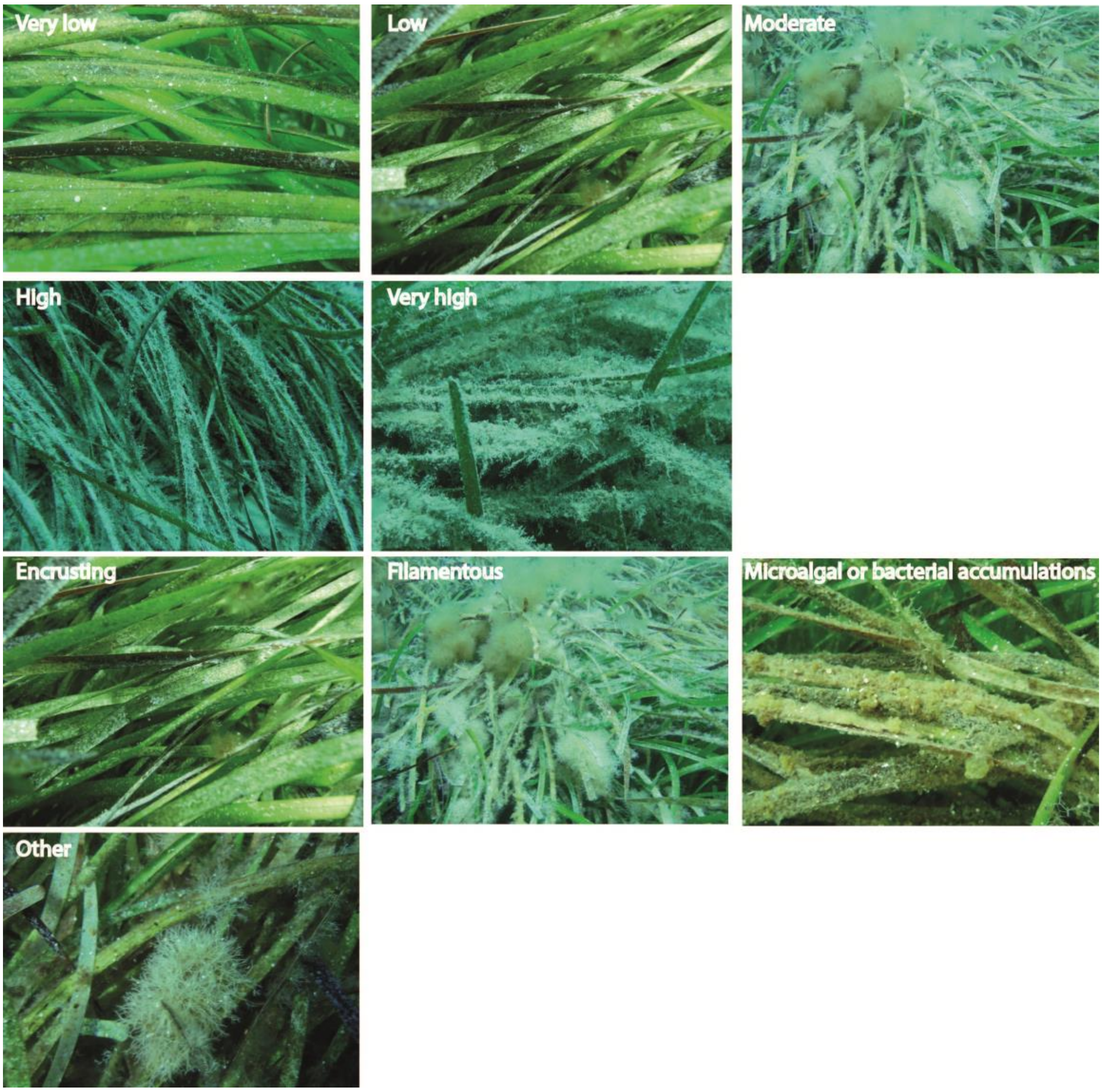

Figure 4: *Classification of epiphytic algal cover and type.*

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 Ben French (BF), Matthew Dasey (MD), David Lierich (DL) and Ian Anderson (IA) from Department of Biodiversity, Conservation and Attractions. 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 Marine and Freshwater Research Laboratory at Murdoch University using method 4500.

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 954-1377 shoots m^{-2} across the seven sites, this is the narrowest range since monitoring began (Figure 5). Once again, the shallower sites, Dunsborough and Buayanup (3.5 m) had the highest shoot density (1333 and 1377 shoots m^{-2}, respectively, closely followed by Forrest Beach (1317 shoots m^{-2}). The minimum shoot density was observed at Vasse Diversion Drain (954 shoots m^{-2}) and Busselton Jetty (1063 shoots m^{-2}), and the remaining sites had intermediate shoot densities. All raw data is in Appendix 2.

There was a reduction in shoot density at 4 of the 7 sites, but at three of these sites, this was a minor change, with a 5% decline at Buayanup, Busselton Jetty and Vasse –Wonnerup. Dunsborough had the greatest decline, 10% (Table 2). Port Geographe had a significant increase, 41% compared to last year. The remaining sites had slight increases in shoot density, Vasse Diversion (12% increase), followed by Forrest Beach (8% increase). Compared to 2012, when these surveys began, two sites have shown moderate increases, Port Geographe (34% increase) and Vasse-Wonnerup (25% increase), two sites minor increases, Vasse-Diversion and Busselton Jetty (145) one site minor declines, Dunsborough (11%) and the remaining two sites had minimal change.

The shoot density at most sites in Geographe Bay are above the minimum (320 m^2) and 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). However, this year, 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, but they are above the minimum site average (Figure 5).

P. sinuosa average shoot length ranged from a minimum of 45 cm at Buayanup to a maximum of 81 cm at Vasse Diversion Drain and a range in width of 5.5-5.8 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**	**12-18**
1. Dunsborough	3	-18	7	9	-3	-10	-11
2. Buayanup	11	-24	20	-7	2	-5	-1
3. Vasse Diversion	6	-8	0	-15	19	12	14
4. Busselton Jetty	0	22	-4	1	-1	-5	14
5. Port Geographe	17	-7	12	-6	-23	41	34
6. Vasse-Wonnerup	19	13	-4	-3	4	-5	25
7. Forrest Beach	16	-23	2	5	-3	8	5

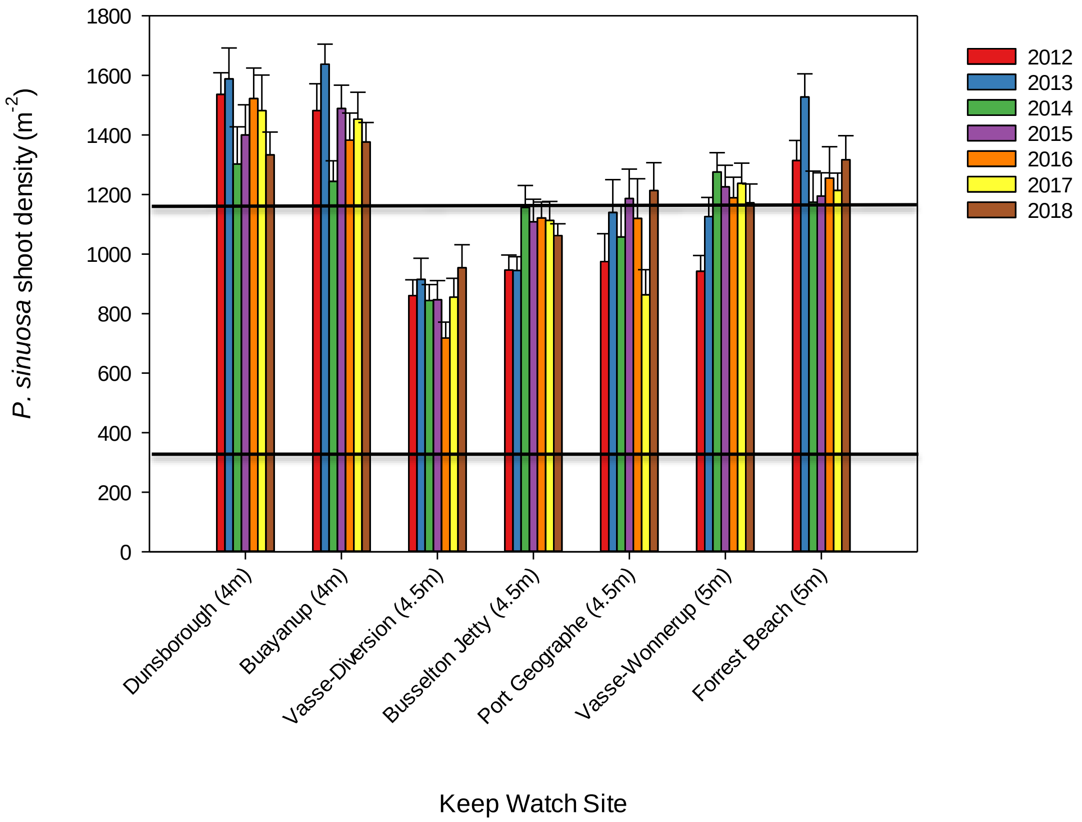

Figure 5: *Shoot density (average m^{-2} ± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in January or February 2012-2018. Dotted lines indicate the minimum and maximum site averages from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2012-2018 (data courtesy of DBCA, 2018).*

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 2017-2018).

4.2.2 Trigger 2

As there was not a 20% decline or more over two consecutive years at any site, this threshold was also not triggered (Table 2, % change 2016-2017 & 2017-2018). Port Geographe had the potential to breach this trigger if there was another 20% or more decline in 2018. As this did not occur in 2018 this threshold was not triggered.

4.2.3 Trigger 3

This is the second year that Trigger 3 was assessed. No sites showed a significant trend over the seven years, either increasing or decreasing in shoot density (Table 3). Individual plots 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 2012-2018.

Site Name & #	Significance (p<0.05)	Overall slope	R^2
1. Dunsborough	ns	-ve	18%
2. Buayanup	ns	-ve	10%
3. Vasse Diversion	ns	+ve	0%
4. Busselton Jetty	ns	+ve	34%
5. Port Geographe	ns	+ve	2%
6. Vasse-Wonnerup	ns	+ve	34%
7. Forrest Beach	ns	-ve	12%

4.3 Epiphytes

The amount of epiphyte cover is similar to 2017 at Vasse Diversion Drain, Busselton Jetty, Port Geographe and Vasse-Wonnerup. Forrest Beach and Dunsborough increased a category to Low and Moderate, respectively and cover declined at Buayanup to Moderate. High cover was maintained at Vasse Diversion Drain, Moderate cover at Busselton Jetty and Port Geographe and Low cover at Vasse-Wonnerup (Table 4). Microalgal accumulations were the dominant epiphyte at Buayanup and Vasse-Diversion but at Busselton Jetty, Port Geographe and Vasse-Wonnerup microalgal accummulations and other epiphytic algae were codominant. At Forrest Beach and Dunsborough other epiphytic algae such as *Dictyota* were dominant (Figure 6, Table 4).

Table 4: Algal cover at the Keep Watch seagrass monitoring sites, 2012-2018. 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**
1. Dunsborough	M	L	M	M	L	L	M
2. Buayanup	M	L	M	M	H	H	M
3. Vasse Diversion Drain	L	M	H	H	H	H	H
4. Busselton Jetty	L	L	H	H	M	M	M
5. Port Geographe	L	VL	L	L	M	M	M
6. Vasse-Wonnerup	L	VL	L	M	L	L	L
7. Forrest Beach	L	VL	L	L	L	VL	L
	Algal Type						
	-12	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**
1. Dunsborough	O,f,m	F,O	O	O,m	O	O,e,m	O,m
2. Buayanup	M,o	E,O	M,o	M,o	M , o	M,e,o	M,o
3. Vasse Diversion Drain	M,o	E,O	M,o	M,o	M , o	M,o	M,o
4. Busselton Jetty	M,o	O	M	M,f	O, e, m	M,o,e	O,M
5. Port Geographe	E, o	E,M	M,e	M,f	O, f	M,o,e	O,M
6. Vasse-Wonnerup	E, o, m	E,O	M,f	O	E,o,m	E,m	O,M
7. Forrest Beach	E, M,o	F,E	M,f	O,e	E,o	E,o	O, e

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. 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 present at Dunsborough, Buayanup, Vasse Diversion Drain, Busselton Jetty, Port Geographe, Forrest Beach and Capel. *A. griffithii* was also noted at Dunsborough, Forrest Beach and Capel. The remains of flowering shoots were observed at Vasse-Diversion Drain only and no seedlings were observed.

Unlike last year, no small patches of recent dieback were observed. The larger patches that were observed last year at Busselton Jetty site have not increased in size, and some of the plants within these patches have shown some signs of recovery. The bare patches at Port Geographe still remain and do not show any signs of recovery.

Some interesting variations between sites are the long leaves at Dunsborough that have white tips, mostly likely from sun damage due to the shallow water. At Port Geographe the *A. antarctica* seems to be expanding because a number of the quadrats on the eastern side of the plot had *Amphibolis* shoots.

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 two sites (Dunsborough and Forrest Beach) there was a small increase compared to last year, at one site a slight decline (Vasse-Diversion) and at the remaining sites there was little or no change. The nitrogen content of *A. antarctica* leaves was higher, ranging from 0.6-1.3% N DW with an increase at Forrest Beach compared to last year and another slight decline at Capel (Figure 9). The nitrogen content of the *A. antarctica* leaves is still greater at Capel, 1½-2x greater than the other sites.

The phosphorus content of *P. sinuosa* leaves in 2018 ranged from 0.08-0.14% P DW (Figure 8). Compared to last year, most sites showed little change, although there was a slight decrease at Dunsborough and Vasse Wonnerup. For *A. antarctica* leaves, the phosphorus content was similar, ranging from 0.09-0.11% DW. Compared to last year there was very little change and all sites were similar (Figure 9). 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			

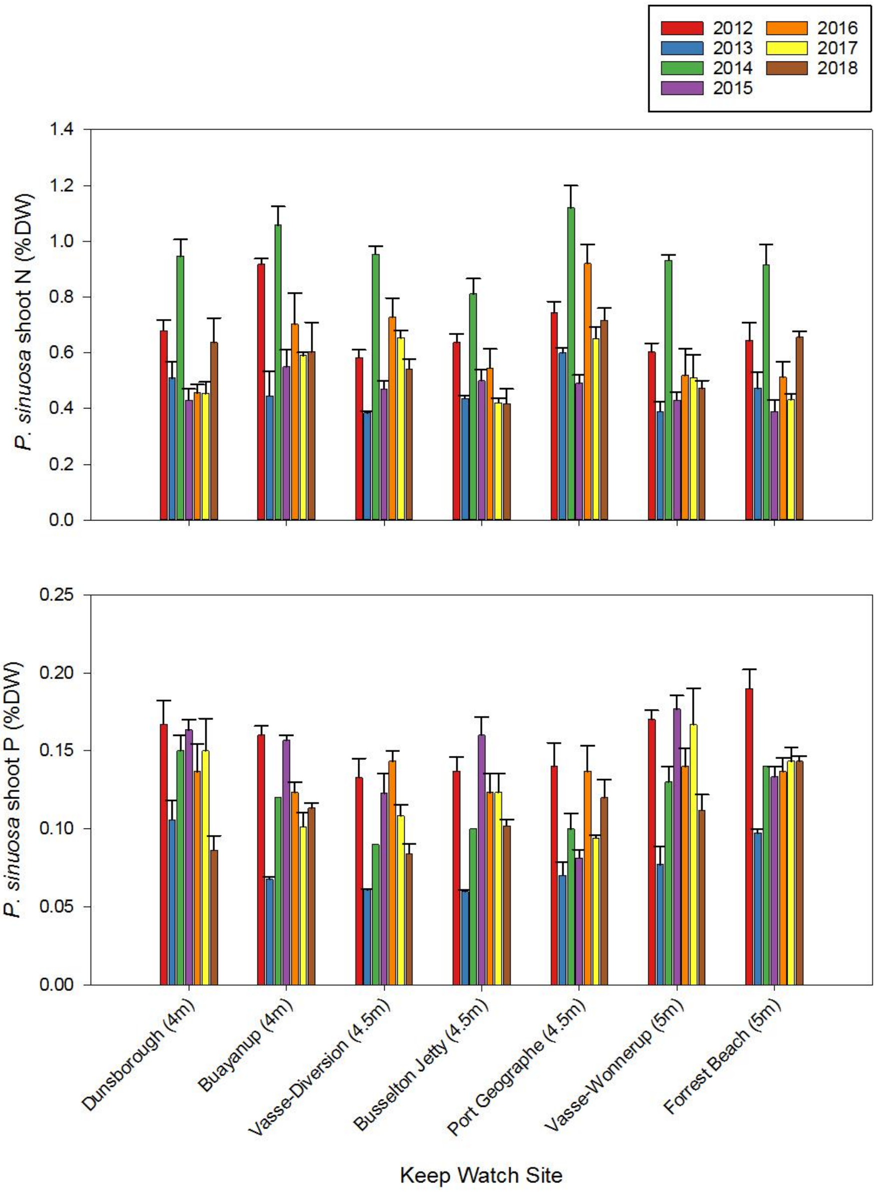

Figure 8: *Nitrogen and phosphorus content (% dw) of* P. sinuosa *leaves (Dunsborough-Forrest Beach) at the Keep Watch* Posidonia *seagrass monitoring sites in 2012-2018.*

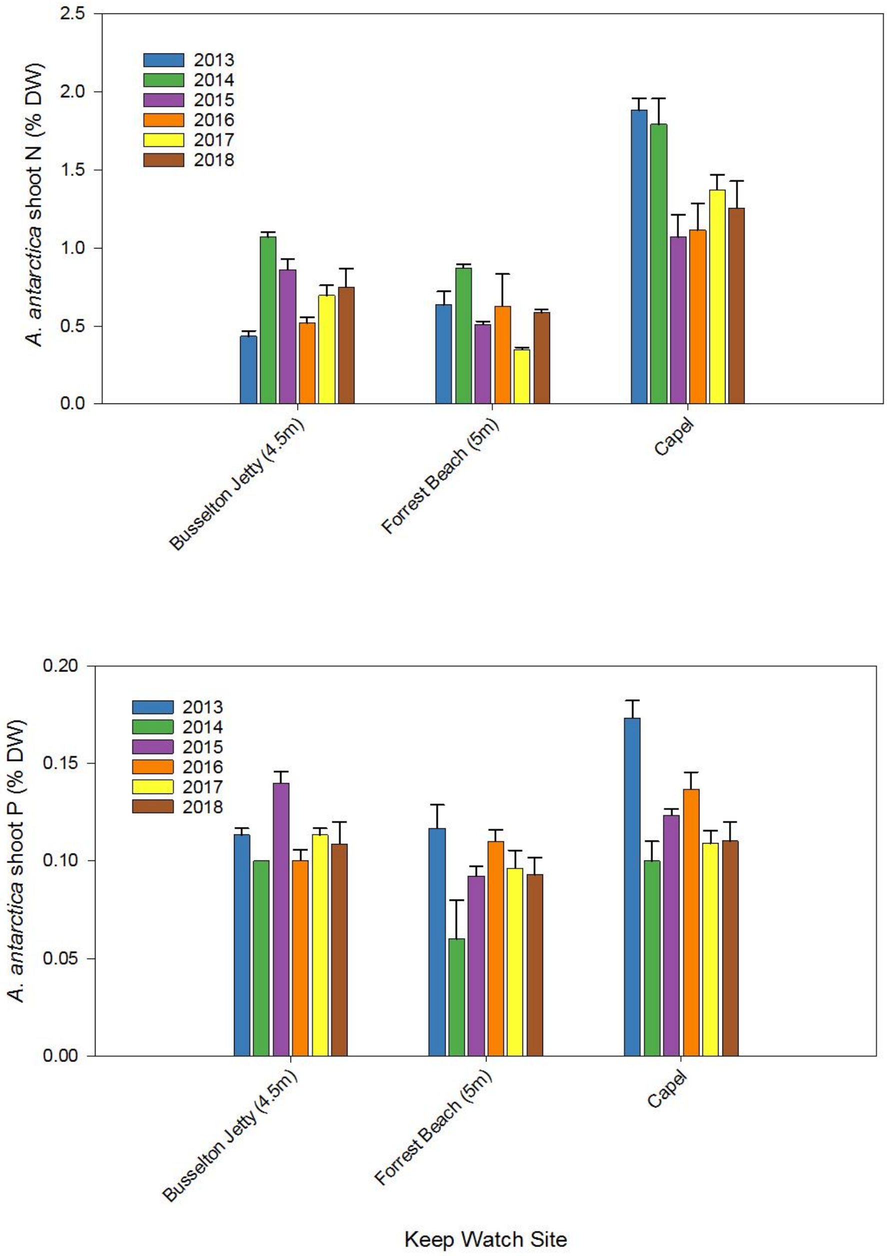

Figure 9: *Nitrogen and phosphorus content (% dw) of* A. antarctica *leaves (average ± se) at the Keep Watch* Amphibolis *seagrass monitoring sites in 2013-2018.*

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 variation in $\delta^{15}N$ of *P. sinuosa* leaves across the seven monitoring sites doubled compared to last year, from 0.5 to 2.5 ‰ (Figure 10), the values increased for a second year at Dunsborough and Forrest Beach. There was an increase at these sites of 0.6‰ and 1.8‰, respectively. Declines of 0.09 – 0.18‰ occurred at all other sites, with the exception of Busselton Jetty which was very similar to last 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. The increase in the Forrest Beach signal indicates it is likely receiving different sources, possibly from native bushland. 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*, compared to last year, increased at Forrest Beach (1.9‰), remained similar at Capel and declined to 2016 levels at Busselton Jetty (0.7‰) (Figure 10). Once again the highest values were observed at Capel (3.3 ‰), indicating a different source of nitrogen at this site. All raw data is in Appendix 5.

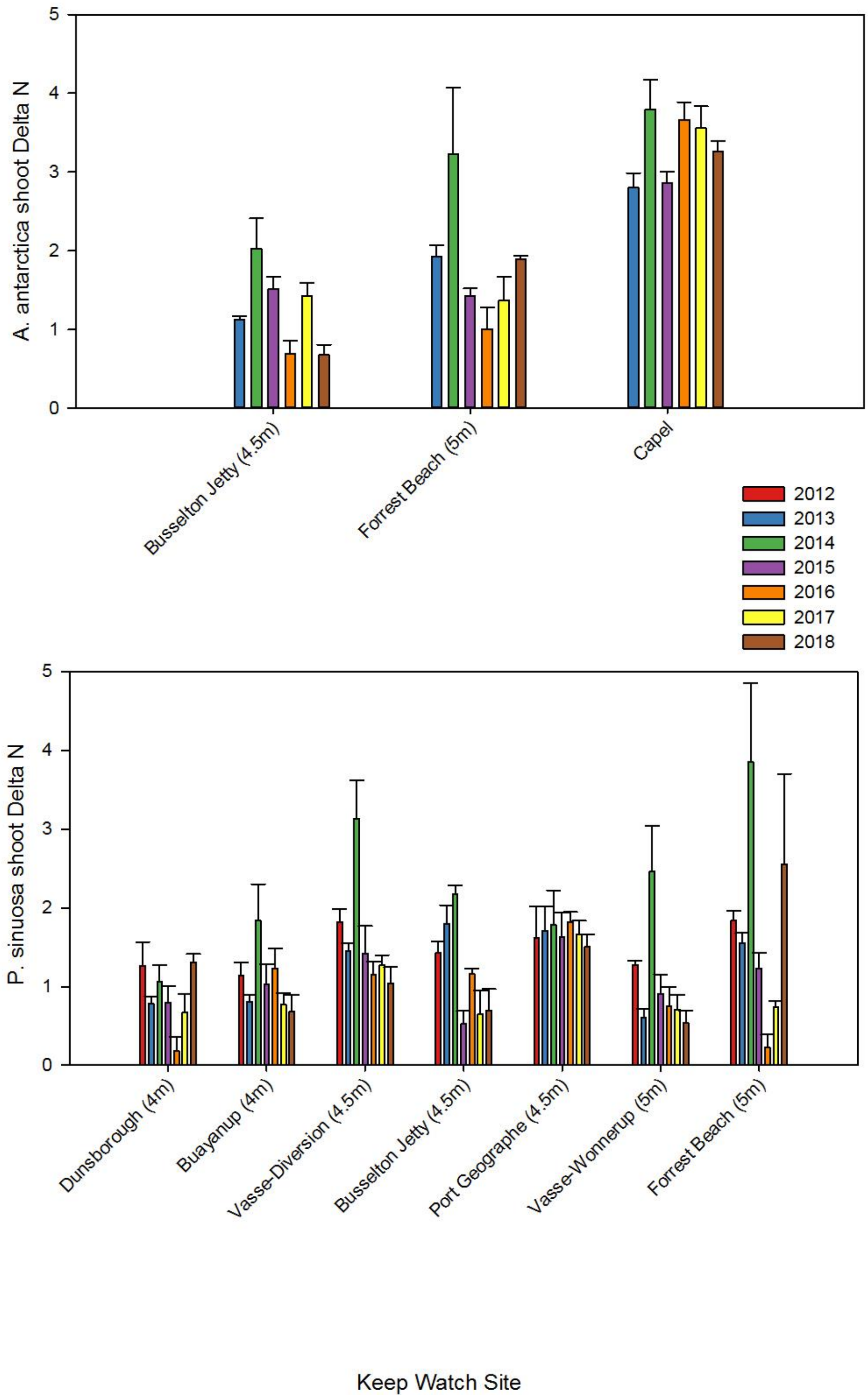

Figure 10: *δ^{15}N of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4, 7 & 8 average ± se) at the Keep Watch seagrass monitoring sites in 2012-2018. Note that only Capel was measured in 2012, and is not included in these graphs.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 22.0-22.8°C. Water clarity was high and at many sites, the Secchi disk was observed on the bottom (Table 6).

Table 6: Water quality measures at the Keep Watch seagrass monitoring sites from 2012-2018, *=Secchi disk depth on bottom.

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

5 General conclusions

5.1 No significant declines in shoot density

No management criteria were triggered in 2018 for all three triggers. Most sites showed little change (<10%) compared to last year, with the exception of Port Geographe that had a significant increase (41%) and Dunsborough that had a slight decline (10%). Port Geographe was 'On Watch' last year due to the 21% decline from 2016-2017, but the trend was reversed this year. In fact, the annual trends at this site and Dunsborough, are similar to the long-term trends where Port Georgraphe has increased by 34% compared to 2012 and Dunsborough has declined 11%. Over the seven years, four sites have increased (Vasse Diversion, Busselton Jetty, Port Geographe, Vasse-Wonnerup), two have shown little change (Buayanup, Forrest Beach) and Dunsborough has declined. Based on this information, there continue to be no major concerns in Geographe Bay for seagrass health. The recommendation is to continue monitoring and reassess the changes next year.

5.2 Variable sources of nitrogen in Geographe Bay

Since 2013, 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. This year higher nitrogen isotope signals were measured at two other sites, although not as high as Capel, most notable at Forrest Beach (2.5 ‰). This indicates that compared to last year, these two sites (Dunsborough & Forrest Beach) received a different source of nutrient, possibly more from nitrogen derived from leaching from natural vegetation. Despite changes in the sources, there were not increases in nutrient content, indicating that although the nitrogen sources available changed, the amount did not.

Lower phosphorus levels were maintained in the seagrass at Capel, indicating that there continues to be less exposure to phosphorus compared to earlier years. The nutrient content in the seagrass leaves at all other sites for both *Amphibolis* and *Posidonia* continues to be low.

5.3 Recovery is occurring in patches where dieback occurred last year

Last year, 2017, small patches of seagrass dieback of both *P. sinuosa* and *A. antarctica* were observed at Dunsborough and Busselton Jetty. This year, no new patches were observed and recovery was visible as new leaves emerging from the rhizomes of *P. sinuosa* or from the stems of *A. antarctica*. We predicted that if the dieback continued the shoot density may be reduced in 2018. Dunsborough did show a 10% decline from 2017-2018. Here, the original patches observed were smaller than at Busselton Jetty but it appeared to be a slightly more recent loss, as the dead leaves were still in the area. A 10% decline is within the natural variation we see from year to year in Geographe Bay, and within the range of change observed over the last seven years. Monitoring next year to assess the trajectory is recommended. At Busselton Jetty, although the dieback patches were larger in 2017, there has been just a 5% decline from 2017-2018, which based on our accuracy, indicates minimal change. Therefore at this site, there does not appear to be an effect of the dieback. One of the mechanisms suggested last year that may have caused the loss was not related to algal epiphyte cover or nutrient enrichment of the water column, but hydrogen sulphide intrusion. Hydrogen sulfide is toxic to seagrasses and can permeate into underground seagrass roots, and up into shoot meristems causing mortality, particularly when oxygen release from root tips is reduced or stopped. There is evidence that sediment anoxia and increased hydrogen sulphide production can directly impact the survival of adult plants (Borum et al. 2005, Raun & Borum 2013). A number of indicators have been proposed to assess exposure to sulfide and *Posidonia* species are quite sensitive to exposure (Holmer & Hasler-Sheetal 2014, Kilminster et al. 2014). The recommendation to investigate the potential causes of this dieback is to measure the sulfide indicators in seagrass. Material collected in the 2017, 2018 and previous years is in storage and could be used if desired to compare the sulfur isotope ratio to previous years.

5.4 Microalgal accummulations dominate on seagrass leaves in Geographe Bay in summer

This year microalgal accumulations were observed at six of the seven *P. sinuosa* sites and were dominant or codominant at five of these. This occurred where there was low, moderate of high algal cover and there were no major changes in the amount of algal cover observed. This continues to be a unique feature of Geographe Bay. It is not clear why these microalgal accumulations form and what maintains the aggregations. Research is underway by an ECU Masters student to understand the distribution of the microalgae in relation to drain discharge points. Observations from this program have identified that they are certainly more common in the more protected areas of the bay (i.e. Buayanup to Port Geographe). This year other algal types that are a common part of the algal community on seagrasses were also present at 6 of the seven sites, and dominant or co-dominant at five of these. These are important components of the community contributing to primary production, hood and habitat for fauna.

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7 Appendix 1: Randomly generated quadrat positions from 2018 survey

Quadrat #	Bearing	Distance
1	0	2
2	0	10
3	0	12
4	0	23
5	60	5
6	60	15
7	60	20
8	60	25
9	80	3
10	80	7
11	80	8
12	80	18
13	140	3
14	140	10
15	140	15
16	140	20
17	180	9
18	180	14
19	180	18
20	180	20
21	240	1
22	240	10
23	240	23
24	240	25
25	260	7
26	260	9
27	260	20
28	300	10
29	300	13
30	300	24

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, 2018. Numbers in orange are average, standard deviation and standard error.

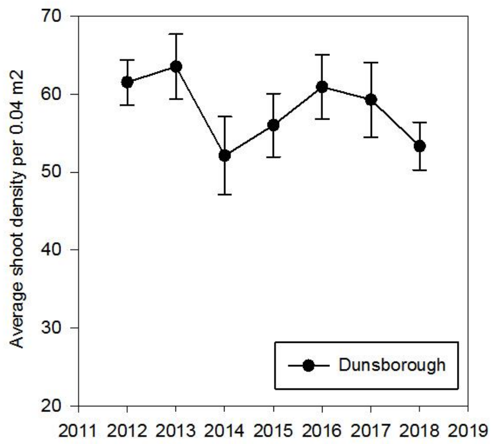
In 20 x 20 cm quad

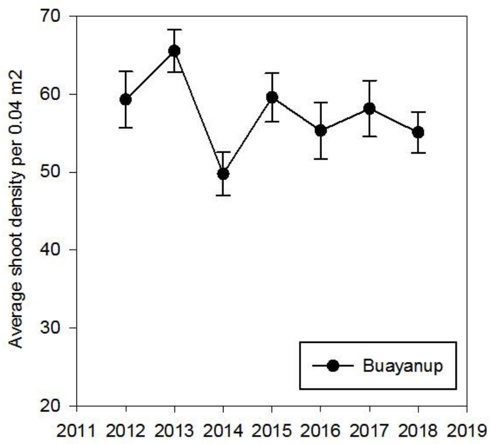
2018			2018			2018			2018			2018			2018			2018		
															31/1/2018			31/1/2018		
1. Dunsborough			2. Buayanup			3. Vasse Diversion			4. Busselton Jetty			5. Port Geographe			6. Vasse-Wonnerup			7. Forrest Beach		
Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter
79	0	BF	48	0	BF	22	0	BF	53	0	KM	75	0	avg	48	0	BF	62	0	BF
81	0	BF	45	0	BF	47	0	BF	49	0	KM	75	0	avg	57	0	BF	71	0	BF
48	0	DL	74	0	MD	35	0	DL	26	0	BF	60	0	avg	27	0	DL	47	0	DL
37	0	DL	62	0	MD	32	0	DL	45	0	DL	39	0	avg	34	0	DL	43	0	DL
57	0	BF	62	0	BF	60	0	BF	35	0	KM	101	0	BF	59	0	BF	76	0	BF
33	0	BF	82	0	BF	23	0	BF	38	0	KM	58	0	BF	79	0	BF	53	0	BF
46	0	DL	50	0	MD	49	0	DL	32	0	DL	13	0	MD	36	0	DL	39	0	DL
72	0	DL	67	0	MD	60	0	DL	46	0	BF	11	0	MD	33	0	DL	47	0	DL
45	0	BF	89	0	BF	87	0	BF	54	0	BF	53	0	BF	40	0	BF	76	0	BF
53	0	BF	49	0	BF	26	0	BF	44	0	BF	46	0	BF	41	0	BF	59	0	BF
71	0	DL	56	0	MD	42	0	DL	47	0	DL	71	0	MD	36	0	DL	31	0	DL
70	0	DL	72	0	MD	27	0	DL	28	0	DL	29	0	MF	39	0	DL	27	0	DL
76	0	BF	60	0	BF	84	0	BF	36	0	BF	43	0	KM	70	0	BF	57	0	BF
39	0	BF	72	0	BF	46	0	BF	53	0	BF	25	0	KM	64	0	BF	81	0	BF
61	0	DL	57	0	MD	20	0	DL	34	0	DL	39	0	IA	20	0	DL	47	0	DL
37	0	DL	47	0	MD	22	0	DL	43	0	DL	47	0	IA	45	0	DL	46	0	DL
59	0	KM	75	0	KM	29	0	KM	39	0	KM	69	0	KM	37	0	KM	62	0	KM
32	0	IA	38	0	IA	41	0	IA	46	0	IA	64	0	KM	42	0	IA	33	0	IA
50	0	IA	47	0	IA	30	0	IA	48	0	IA	27	0	IA	52	0	IA	47	0	IA
62	0	IA	54	0	IA	42	0	IA	58	0	IA	20	0	IA	43	0	IA	29	0	IA
65	0	KM	39	0	KM	21	0	KM	47	0	KM	31	0	KM	46	0	KM	46	0	KM
33	0	IA	60	0	KM	25	0	IA	48	0	IA	42	0	IA	52	0	IA	37	0	IA
69	0	IA	40	0	IA	24	0	IA	36	0	IA	39	0	IA	34	0	IA	36	0	IA
52	0	IA	44	0	IA	37	0	IA	45	0	IA	35	0	IA	49	0	IA	28	0	IA
35	0	KM	38	0	KM	22	0	KM	32	0	KM	72	0	KM	62	0	KM	70	0	KM
87	0	KM	31	0	KM	42	0	KM	53	0	KM	59	0	KM	67	0	KM	89	0	KM
37	0	IA	41	0	IA	35	0	IA	46	0	IA	47	0	IA	34	0	IA	40	0	IA
34	0	KM	56	0	KM	34	0	KM	45	0	KM	62	0	KM	64	0	KM	79	0	KM
36	0	KM	50	0	KM	43	0	KM	44	0	KM	45	0	KM	55	0	KM	73	0	KM
44	0	IA	47	0	IA	38	0	IA	25	0	IA	59	0	IA	42	0	IA	49	0	IA
53.33	0		**55.07**	0		**38.17**	0		**42.50**	0		**48.53**	0		**46.90**	0.00		**52.67**	0.00	
51.00	0		**52.00**	0		**35.00**	0		**45.00**	0		**46.50**	0		**44.00**	0.00		**47.00**	0.00	
3.06	0		**2.60**	0		**3.09**	0		**1.58**	0		**3.75**	0		**2.52**	0.00		**3.23**	0.00	

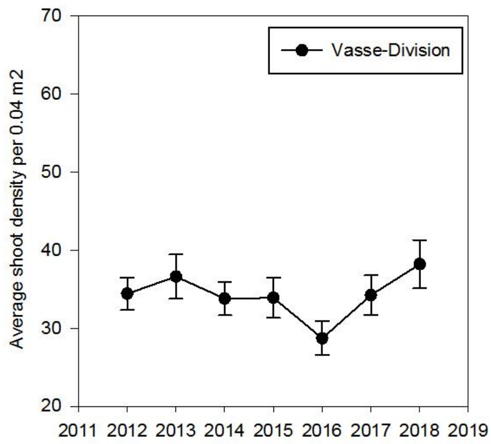
9 Appendix 3: Leaf morphology data for 2018

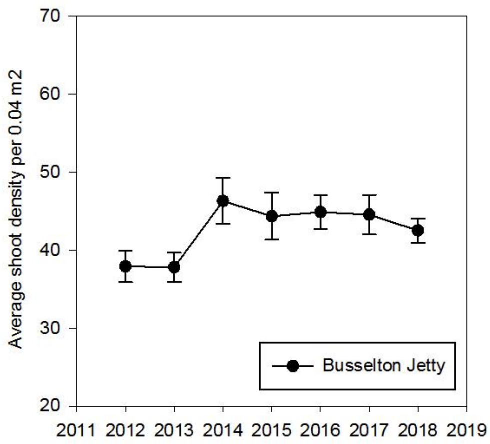
	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
	S1 Dun.	S1 Dun.	S2 Buayanup	S2 Buayanup	S3 Vasse Div.	S3 Vasse Div.	S4 Buss Jetty	S4 Buss Jetty	S5 Port Geo	S5 Port Geo	S6 Vasse Won	S6 Vasse Won	S7 Forrest B	S7 Forrest B
Rep	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot 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	60.4	5.2	48.7	5.3	80.9	5.5	57.9	5.4	35.1	6.3	103.6	5.5	54.1	6.5
2	60.4	5.7	37.4	5.4	44	5.8	50.4	4.8	25.3	5	105.5	6.4	76.9	6.6
3	63.3	4.7	60.6	5.9	61.2	5.4	57.3	6.1	71.3	6.6	81.5	5.6	55	5.9
4	43	5.9	57.4	5.5	58.8	6	52.9	5.6	19	4.9	90.6	6.5	55.2	6.2
5	46.2	5.3	54.5	5.6	85.4	5.8	66.1	5.7	40.1	5.5	86.2	5.4	70.9	6.2
6	46.1	5.2	58.1	6.5	82	5.8	57.6	6.2	46.8	5.8	78.4	6	38.6	5.3
7	55.5	5.8	54	5.3	70.5	5.9	58.3	5.9	46.2	5.7	76.4	4.9	54.5	5.8
8	46.4	6.1	60.7	5.8	54.7	5.7	49.3	5.5	34	5.7	85.9	5.6	39.4	4.9
9	38.6	5.9	53.4	5.7	56.5	5.4	49.3	4.3	32.7	5.8	68.3	5.4	44.4	5.8
10	62.5	6.1	54.7	5	62.4	5.6	64.3	5.5	50.6	5.7	59.1	6.3	42.2	5.7
11	47.4	6.5	61.1	4.9	86	6.2	58.1	5.7	26.5	5	73.9	5.7	43.9	4.6
12	48.2	4.7	44.7	4.8	66.6	5.2	49.9	5.7	67.9	4.7	72.6	6	67.7	4.4
13	43.5	6	64.2	6.3	70.1	5.7	61.7	5.5	67.6	5.5	80.5	6.3	39.2	4.9
14	44.3	6	49.7	5.3	83.1	5	43	4.8	29.6	5.7	70.4	6.3	43.9	5.7
15	35.6	5.2	28.3	5.8	101.5	5.4	55.5	5.6	77.9	4.8	80.3	5.7	49.7	5
Average	49.42667	5.62	52.5	5.54	70.91333	5.626667	55.44	5.486667	44.70667	5.513333	80.88	5.84	51.70667	5.566667
SE	2.276641	0.13877	2.495463	0.124135	3.947342	0.081338	1.623424	0.130518	4.821494	0.141039	3.205014	0.119044	3.120431	0.176923

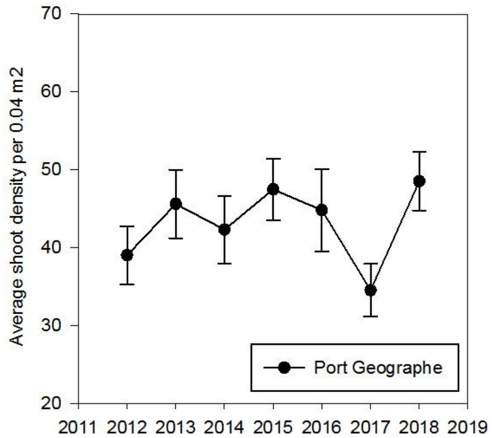
10 Appendix 4: Trends over time in seagrass shoot density.

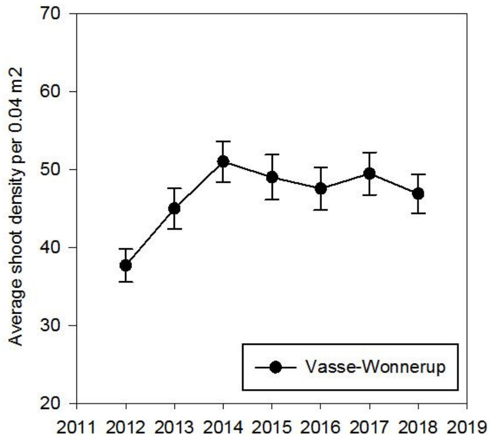


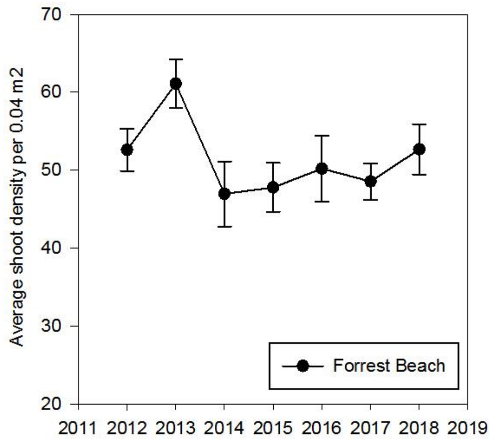







Average shoot density per 0.04 m2
70
60
50
40
30
20
2011 2012 2013 2014 2015 2016 2017 2018 2019
Port Geographe


Average shoot density per 0.04 m2
70
60
50
40
30
20
2011 2012 2013 2014 2015 2016 2017 2018 2019
Vasse-Wonnerup


Average shoot density per 0.04 m2
70
60
50
40
30
20
2011 2012 2013 2014 2015 2016 2017 2018 2019
Forrest Beach

11 Appendix 5: Nutrient data for 2018

Site	Species	δ15N [‰ AIR]	δ13C [‰ VPDB]	N [wt %]	C [wt %]	P (% DW)
Dunsborough	Posidonia	1.20	-11.41	0.80	40.74	0.10
Dunsborough	Posidonia	1.52	-10.12	0.50	41.12	0.07
Dunsborough	Posidonia	1.21	-11.33	0.61	40.70	0.10
Buayanup	Posidonia	0.46	-9.19	0.49	40.41	0.11
Buayanup	Posidonia	0.47	-9.84	0.51	40.49	0.12
Buayanup	Posidonia	1.11	-9.50	0.82	40.55	0.11
Vasse-Diversion	Posidonia	0.63	-10.27	0.47	39.88	0.08
Vasse-Diversion	Posidonia	1.18	-9.30	0.56	39.19	0.10
Vasse-Diversion	Posidonia	1.30	-9.32	0.59	40.41	0.07
Busselton Jetty	Posidonia	0.16	-10.11	0.33	39.66	0.10
Busselton Jetty	Posidonia	1.06	-10.33	0.51	39.70	0.10
Busselton Jetty	Posidonia	0.86	-10.15	0.41	40.23	0.11
Port Geographe	Posidonia	1.54	-9.38	0.74	40.44	0.10
Port Geographe	Posidonia	1.22	-9.59	0.63	40.15	0.12
Port Geographe	Posidonia	1.76	-10.04	0.78	40.53	0.14
Vasse-Wonnerup	Posidonia	0.77	-9.64	0.53	40.97	0.10
Vasse-Wonnerup	Posidonia	0.23	-10.66	0.44	40.80	0.11
Vasse-Wonnerup	Posidonia	0.60	-10.70	0.45	40.01	0.13
Forrest Beach	Posidonia	4.81	-10.40	0.65	40.15	0.15
Forrest Beach	Posidonia	1.06	-9.49	0.70	40.20	0.14
Forrest Beach	Posidonia	1.80	-10.18	0.62	40.43	0.14
Busselton Jetty	Amphibolis	0.42	-11.73	0.58	39.78	0.12
Busselton Jetty	Amphibolis	0.76	-11.72	0.68	40.01	0.12
Busselton Jetty	Amphibolis	0.85	-11.76	0.98	39.88	0.09
Forrest Beach	Amphibolis	1.90	-11.16	0.57	39.74	0.11
Forrest Beach	Amphibolis	1.97	-10.96	0.57	38.74	0.08
Forrest Beach	Amphibolis	1.80	-10.18	0.62	40.43	0.09
Capel	Amphibolis	3.51	-12.19	1.49	39.72	0.12
Capel	Amphibolis	3.21	-13.87	1.36	39.15	0.12
Capel	Amphibolis	3.05	-11.46	0.92	37.74	0.09