Edith Cowan University
Centre for Marine Ecosystems Research

Keep Watch Seagrass Monitoring 2015 Report for GeoCatch

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Keep Watch Seagrass Monitoring

Annual Report 2015

Investigators: Kathryn McMahon

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April 2015

1 Executive Summary

1.1 Introduction

This report summarises data from the first four years (February 2012, Jan-Feb 2013, January 2014 and 2015) of the annual Keep Watch Seagrass Monitoring Program in Geographe Bay. The aim of the Keep Watch program is to assess the health of seagrass meadows in Geographe Bay in relation to the potential threat associated with the predicted nutrient enrichment from the catchment, and as more annual data is collected, to assess change over time at each site using a number of assessment triggers. Seagrass shoot density is the indicator of seagrass health and a number of other variables are collected to help interpret this indicator, including observations of algal epiphyte cover and seagrass leaf nutrient content. This year two assessment triggers (Trigger 1 and 2) have been used to indicate if there are any concerns.

1.2 Significant findings

This year there were no significant declines in seagrass shoot density, and no Triggers were activated. Last year there were some large declines, and these have either reversed through increases in shoot density or stabilised i.e. no further declines. At present, there are no concerns about the health of seagrasses in Geographe Bay. The recommendation is to continue monitoring.

When we examine the change over time from 2012 to 2015, there has been a net increase at Busselton Jetty (18%), Port Geographe (22%) and Vasse-Wonnerup (29%), a minimal increase at Buayanup (6%), a minimal decline at Dunsborough (-7%) and no significant change at Vasse Diversion Drain (-1%) and Forrest Beach (-5%). Port Geographe, which had shown signs of recent seagrass loss, continues to recover by increasing shoot density. Over all of Geographe Bay more sites are increasing in shoot density, particularly those sites in the centre of the bay. Changes in shoot density are common from year to year, and unless there are large declines or continual declines over time, it is not of concern.

The algal epiphyte cover was greater than last year. Vasse Diversion Drain and Busselton Jetty have the highest epiphyte cover, and all other sites had a similar cover to 2012. The changes in shoot density are not correlated with changes in algal epiphyte cover. The main types of epiphytes on the seagrass are not those generally associated with nutrient enrichment. Where epiphyte cover is high, the dominant form is microalgal accumulations. Very little is known about what stimulates these aggregations and contributes to their persistence. This is a knowledge gap that warrants further investigation.

Nutrient content decreased this year compared to last year, is very low and is not of concern. Nutrient content in seagrass leaves may change due to the supply of nutrients, nutrient recycling processes and changes in growth rates of the seagrasses. In particular, nutrient content has decreased at Capel, which consistently has had the highest levels. This may indicate that supply of nutrients at this site has decreased or there have been changes in the growth of the *Amphibolis* here. Across all sites, with the exception of Capel the source of nutrient for seagrasses appears to be mostly from fixation of atmospheric nitrogen and agriculturally derived nutrient. At Capel, there are potential additional sources due to the higher nitrogen isotope signal of signal such as nitrogen derived from animal wastes or septic tanks or sources from natural vegetation.

1.3 Recommendations

There are three main recommendations for GeoCatch following this 2015 monitoring.

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.

Recommendation 2

If possible, continue the collaborative arrangement with ECU, Department of Parks and Wildlife and Department of Fisheries. This was a very effective and beneficial arrangement.

Recommendation 3

Investigate the factors which influence the growth and formation of microalgal epiphytic aggregations on the seagrass.

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 2015 and compares data from the 2012-2014 surveys. As was the case in 2014, the program was funded through collaborative sponsorship from the Water Corporation and in-kind support from the Department of Parks and Wildlife (DPaW) and the Department of Fisheries (DoF). The aim of this program is to assess seagrass health by examining changes over time. There are a number of triggers that have been developed to assess change. Trigger 1 and 2 can be assessed this year but Trigger 3 can not be assessed until 2016 (see 3.1.1 for summary of triggers). This report includes data on *P. sinuosa* shoot density and leaf tissue nutrients (C, N, P and N isotopes), and a summary of all the other observations collected at each site, as well as leaf tissue nutrient data for *Amphibolis 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 27th to the 29th January 2015. At Capel there are high relief rocky reefs surrounded by bare sand. On the reef there are patches of *Amphibolis antarctica* seagrass that were collected for nutrient analysis in 2m depth. *Amphibolis 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 3 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 WGS80 grid system.

Site Name & #	Coordinates	Depth (m)	Date & Time	Species assessed
1. Dunsborough	S 33.61654°, E 115.12865°	4	29/1/2015 8:30	Ps
2. Buayanup	S 33.65233°, E 115.24840°	4	29/1/2015 09:50	Ps
3. Vasse Diversion Drain	S 33.64746°, E 115.32379°	4.5	29/1/2015 12:30	Ps
4. Busselton Jetty	S 33.63896°, E 115.34315°	4.5	28/1/2015 12:30	Ps, Aa
5. Port Geographe	S 33.62846°, E 115.38240°	4.5	28/1/2015 07:30	Ps
6. Vasse-Wonnerup	S 33.60188°, E 115.42345°	5	28/1/2015 11:00	Ps
7. Forrest Beach	S 33.57295°, E 115.44908°	5	28/1/2015 9:30	Ps, Aa
8. Capel	S 33.51394°, E 115.51508°	2	27/1/2015 14:30	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.

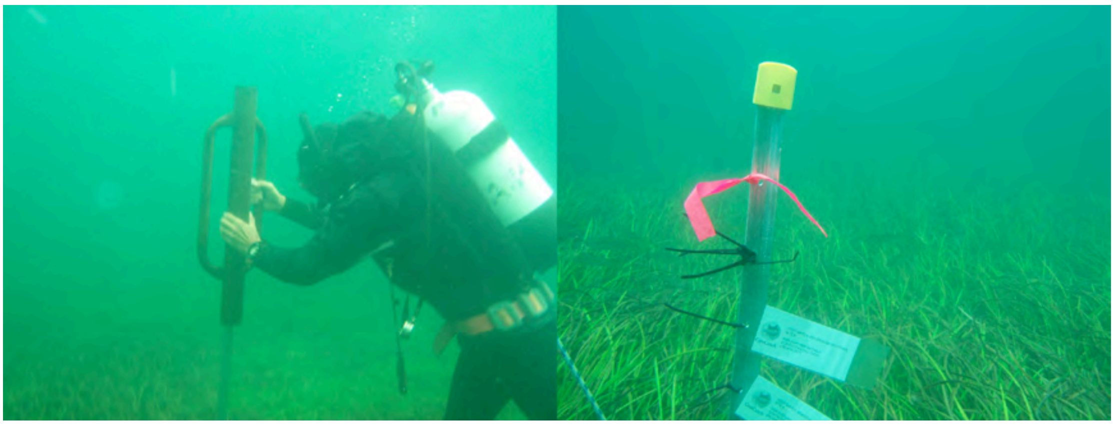


Figure 2: *Left: Banging in permanent marker with pole driver. Right: Star picket with cap and plastic coated site label, indicating center of 50 m diameter Keep Watch seagrass site.*

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.

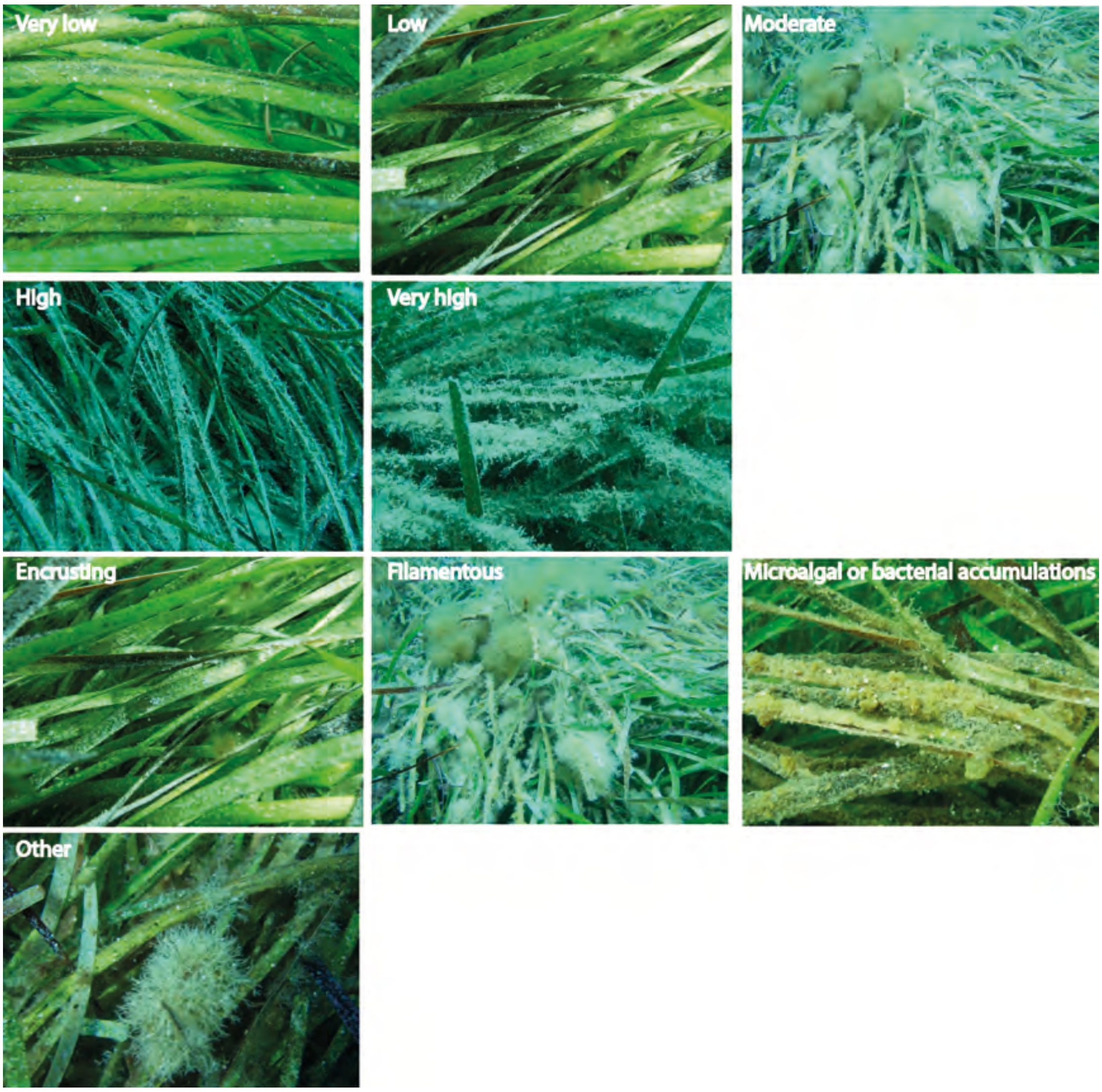


Figure 4: *Classification of epiphytic algal cover and type.*

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) and Rob Czarnik (RC) from ECU with Michael Rule (MR) from Department of Parks and Wildlife and Sam Moyle provided the boat and boat support from Department of Fisheries.

3.1.2 Laboratory processing

In the laboratory the three seagrass shoots 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 an 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 846-1489 shoots m^{-2} across the seven sites, this is slightly higher than in 2014 (844 – 1302 shoots m^{-2}), but slightly lower than was observed in 2013 (915-1637 shoots m^{-2}) and 2012 (942-1536 shoots m^{-2})(Figure 5). Once again, the shallower sites, Dunsborough and Buayanup (3.5 m) had the highest shoot density. The minimum shoot density was observed at Vasse Diversion Drain, and the remaining sites had intermediate shoot densities relative to Dunsborough, Buayanup and Vasse Diversion Drain. All raw data is in Appendix 2.

There was a reduction in shoot density at 2 of the 7 sites, but this was only a minor change, less than a 5% decline at Busselton Jetty and Vasse-Wonnerup (Table 2). All other sites had an increase in shoot density, with the greatest increase at Buayanup (19% increase), Port Geographe (12% increase) and Dunsborough (9% increase). Last year Buayanup, had large declines, and this has almost been reversed, in fact since 2012, there has been a slight increase (6%) in shoot density. In contrast, Dunsborough and Forrest Beach had slight increases this year (7% and 2% respectively), and overall have had small declines since 2012 (7% and 5% respectively). Three sites have shown a large net increase since 2012, Busselton Jetty (18%), Port Geographe (22%) and Vasse-Wonnerup (29%). There has been minimal change at Vasse Diversion Drain since 2012, although it consistently has the lowest shoot density.

Once again the shoot density at sites in Geographe Bay are above the minimum and maximum 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 DPaW).

P. sinuosa average shoot length ranged from minimum of 38 cm at Port Geographe to a maximum of 69 cm at Vasse Diversion Drain and a width of 5.6-6.4 mm (Appendix 3).

Table 2: Change assessment based on Trigger 1. There is a concern with seagrass health when there is a 50% decline in shoot density from one year to the next.

Site Name & #	% change 2012-13	% change 2013-14	% change 2014-15	Net change 2012-2015
1. Dunsborough	3	-18	7	-7
2. Buayanup	11	-24	20	6
3. Vasse Diversion Drain	6	-8	0	1
4. Busselton Jetty	0	22	-4	18
5. Port Geographe	17	-7	12	22
6. Vasse-Wonnerup	19	13	-4	29
7. Forrest Beach	16	-23	2	-5

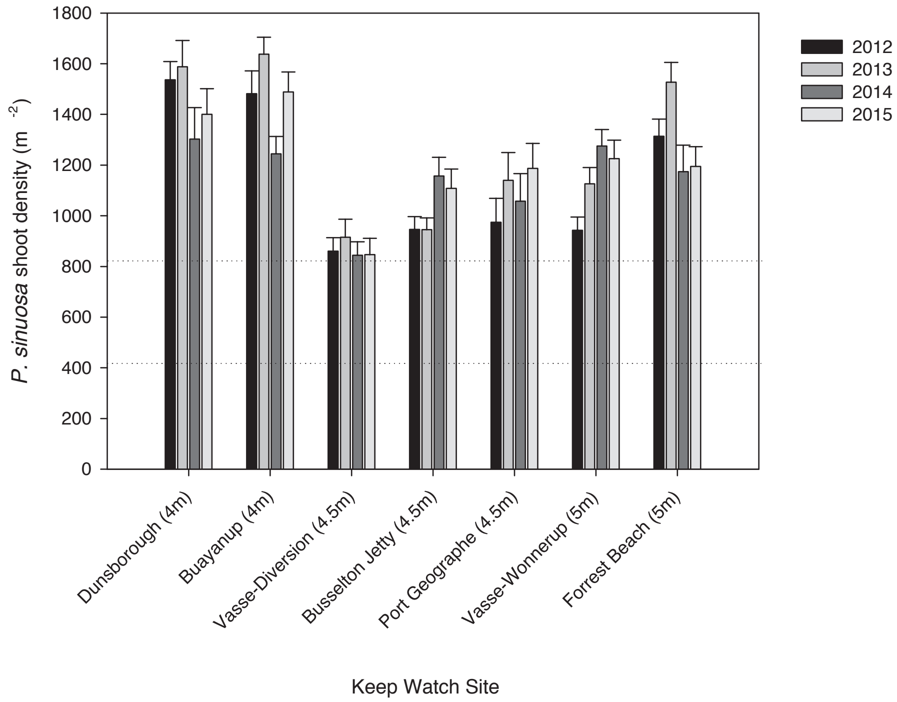


Figure 5: *Shoot density (average m^{-2} ± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in February 2012-2015. Dotted lines indicate the minimum and maximum site averages from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2012-2015 (data courtesy of DPaW, 2014).*

4.2 Trigger assessment

4.2.1 Trigger 1

As there was less than a 50% decline at each of the seven sites, this threshold was not triggered (Table 2, % change 2014-2015).

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 2013-2014 & 2014-2015).

4.2.3 Trigger 3

Trigger 3 relies on trend analysis to detect if there is a significant decline over time. Five years of data is required to be able to interpret this statistic with the amount of data that we have. This will be able to be assessed in 2016.

4.3 Epiphytes

In 2015, epiphyte cover was the same as 2014, with the exception of Vasse-Wonnerup, where cover increased from Low to Moderate. This is the highest cover that has been recorded at this site to date. High cover has been maintained at Vasse Diversion Drain and Busselton Jetty. The dominant epiphyte cover at these two sites, as well as the sites either side, Buayanup and Port Geographe was microalgal accumulations. At the remaining three sites, the dominant epiphytes were classified as others, which included the branching brown algae, *Dictyota* at Dunsborough, and a brown cylindrical algae at Vasse-Wonnerup and Forrest Beach (Figure 6, Table 3).

Table 3: Algal cover at the Keep Watch seagrass monitoring sites, 2012-2015. 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				Algal Type			
	2012	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**
1. Dunsborough	M	L	M	M	f,O, m	F,O	O	O,m
2. Buayanup	M	L	M	M	o, M	E,O	M,o	M,o
3. Vasse Diversion Drain	L	M	H	H	o, M	E,O	M,o	M,o
4. Busselton Jetty	L	L	H	H	o, M	O	M	M,f
5. Port Geographe	L	VL	L	L	E, o	E,M	M,e	M,f
6. Vasse-Wonnerup	L	VL	L	M	E, o, m	E,O	M,f	O
7. Forrest Beach	L	VL	L	L	E, o, M	F,E	M,f	O,e

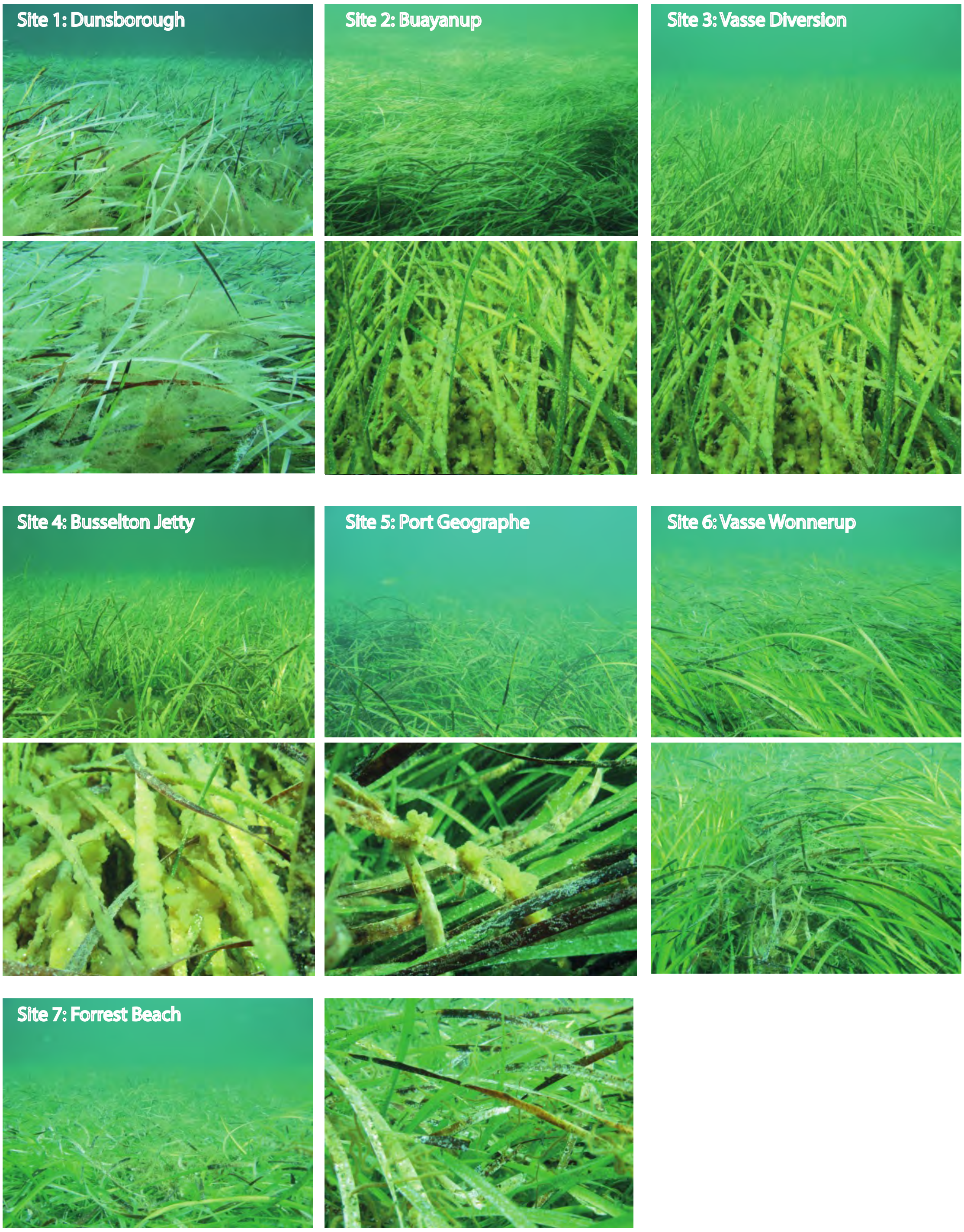


Figure 6: Pictures of seagrass meadow and the dominant algal epiphyte s at each *P. sinuosa* site. (1. Dunsborough, 2. Buayanup, 3. Vasse Diversion Drain, 4. Busselton Jetty, 5. Port Geographe, 6. Vasse-Wonnerup Estuary, 7. Forrest Beach)

4.4 Other observations

A. antarctica was present at Dunsborough, Vasse Diversion Drain, Busselton Jetty, Port Geographe and Forrest Beach. *A. griffithii* was also present at Forrest Beach and Capel. The remains of flowering shoots were observed at Dunsborough, Buayanup, Vasse Diversion Drain, Busselton Jetty and Vasse-Wonnerup. Seedlings were observed at Vasse Diversion Drain, Busselton Jetty and Vasse-Wonnerup.

There were large bare patches at Port Geographe (Figure 7), indicating recent shoot loss and some small patches near the edge of the meadow at Forrest Beach. Shoot density at Port Geographe is increasing but the signs of degradation such as bare patches and old sheaths without leaves are still present. This highlights the long timescale of recovery in this species following previous impacts. Interestingly, there was also one section of the meadow that seems to have been colonized by *Amphibolis*. This is closest to Port Geographe and may be where the greatest shoot loss has occurred in the past and hence more bare batches for the faster growing *Amphibolis* to colonise.

Dead shoots, which are the old sheaths with no leaves growing out of them were also observed at Dunsborough, Buayanup and Vasse Diversion Drain. All of these sites have had some losses in the past years, particularly Dunsborough and Buayanup in 2014. Unlike last year, the rhizomes at these sites were not noticeably brittle. This is a good sign as it indicates that they are less likely to break and reduce shoot density. This year at Dunsborough, it was noticed that the tips of the leaves where very white and the leaves a paler green colour. This could be due to the shallow nature of the meadow at this site. With shallower water, the light is higher, and the tips of leaves can bleach when exposed to high light. In addition there can be less investment in chlorophyll, which is used to harness the light, which makes the leaves a paler colour. These patterns are not of concern for the seagrass health.

There were noticeable accumulations of wrack in the bare patches at Port Geographe and also under the canopy at Dunsborough and Buayanup. *Posidonia* regularly sheds leaves, which accumulate under the canopy or within bare patches in the meadow. Most of this wrack is removed from the meadow with the first winter storms.

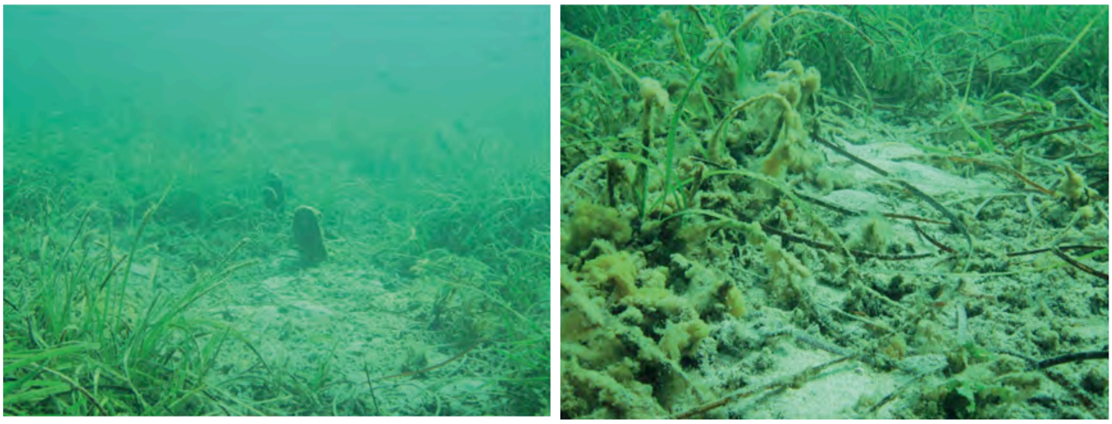


Figure 7: Bare patches within the seagrass meadow at Port Geographe, showing remains of dead shoots that have lost the leaves.

4.5 Nutrient content

The nitrogen content of *P. sinuosa* leaves ranged from 0.4-0.55 % N DW. This has declined from last year, when the highest nitrogen content was observed (Figure 8). The nitrogen content of *A. antarctica* leaves also declined at all sites. This is the first time that the nitrogen content has declined at Capel, down to 1% N DW. Previously the nitrogen content at Capel has been 1.6-4x higher than the other two sites. This year it was 1.2-2.1x higher than the other sites (Figure 9).

The phosphorus content of *P. sinuosa* leaves in 2015 ranged from 0.08-0.2% P DW (Figure 8). Compared to last year, some sites declined (Port Geographe), some sites remained the same (Dunsborough and Forrest Beach) and the remainder increased. At most sites, the P content was similar to the levels observed in 2012, with the exception of Port Geographe and Forrest Beach. For *A. antarctica* leaves, the phosphorus content ranged from 0.09-0.1% DW. At all sites the concentration increased compared to last year, and at Busselton Jetty the highest concentration to date was recorded at this site, and it is the first time that the highest concentration within a year was not observed at Capel (Figure 9).

This nitrogen and phosphorus concentrations are in the range that has been observed in Geographe Bay in the past and these levels are not considered high (Table 4). The nitrogen content and isotope ratio is slightly lower than other studies in WA for *P. sinuosa*, but few studies have reported these values (Table 4).

Table 4: Comparison of shoot tissue nutrient concentrations and δ^{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)**	δ^{15}N	**TN (% DW)**	**TP (% DW)**	δ^{15}N
1994/95 Apr, Jan	McMahon and Walker 1998 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 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			

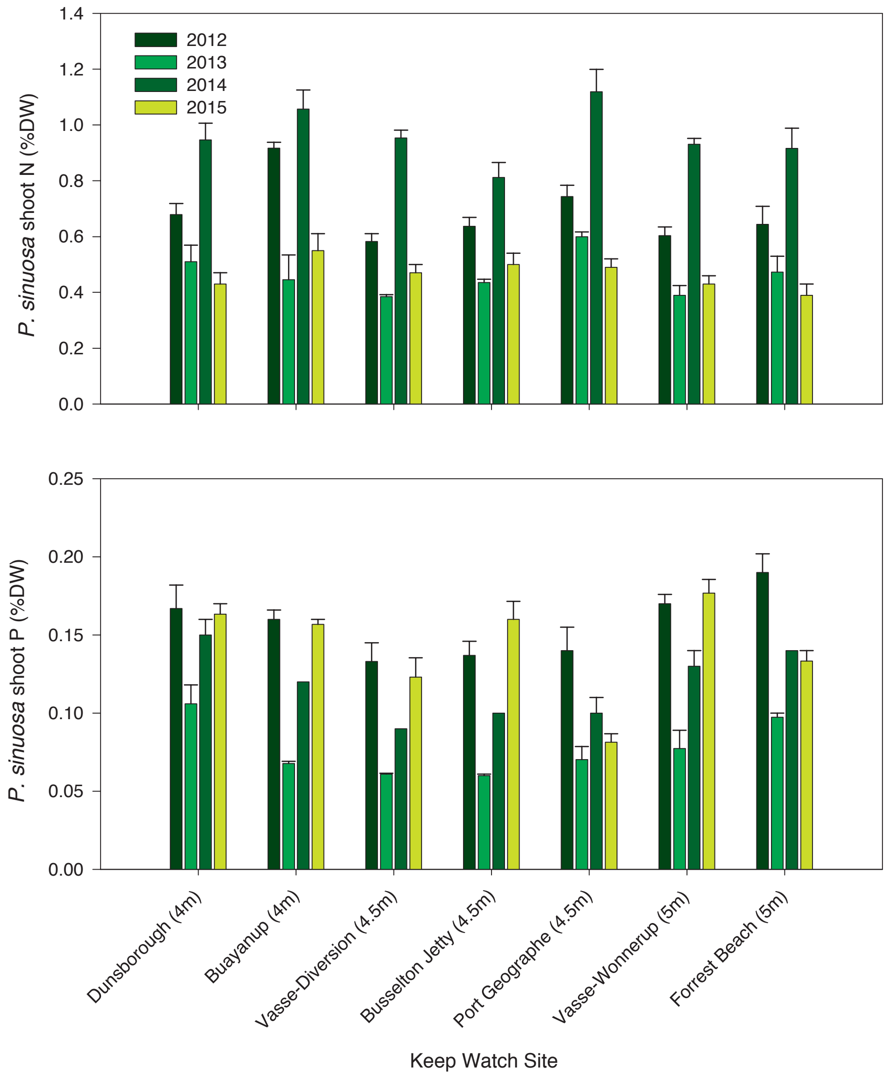
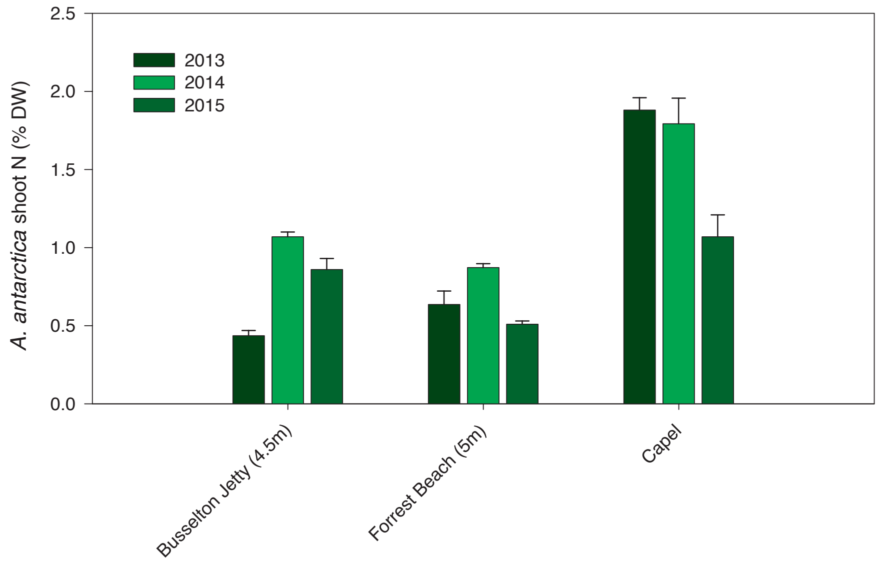


Figure 8: *Nitrogen and phosphorus content (% dw) of* P. sinuosa *leaves (Dunsborough-Forrest Beach) at the Keep Watch* Posidonia *seagrass monitoring sites in 2012-2015.*



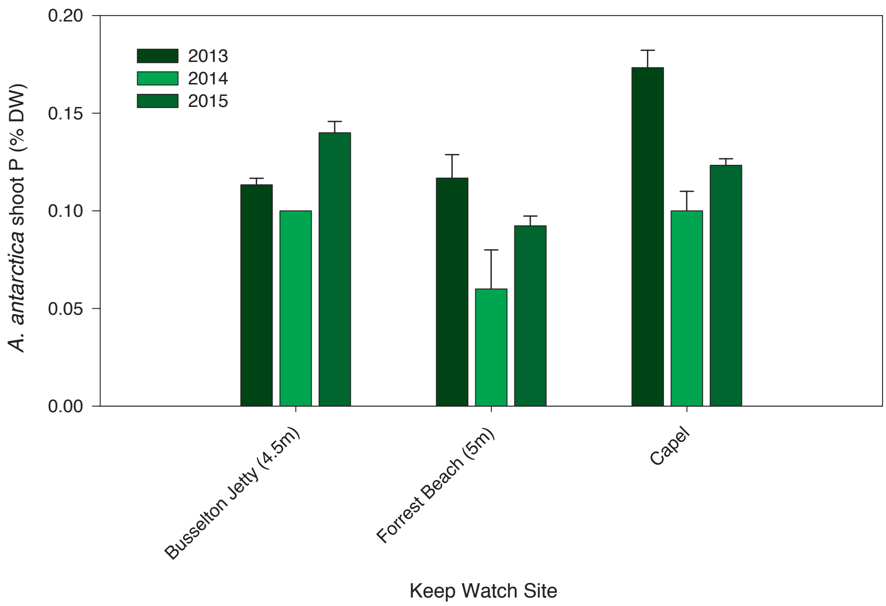


Figure 9: *Nitrogen and phosphorus content (% dw) of* A. antarctica *leaves (average ± se) at the Keep Watch* Amphibolis *seagrass monitoring sites in 2013-2015.*

Nitrogen isotope signals can indicate the main source 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 and 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 this year was lower than last year, 0.5-1.6 ‰. At five of the seven sites, there was a decline compared to last year (Figure 10). The nitrogen isotope signals in the seagrass leaves indicate that this year seagrasses are mostly receiving a mix of sources, but the main sources could be either from fixation of atmospheric nitrogen or agricultural fertilisers, as the signal is close to 0‰. 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 $\delta^{15}N$ signals also declined at all of the 3 *Amphibolis* monitoring sites in 2015 compared to 2014 (Figure 10), to ~ 1.5 ‰ at Busselton Jetty and Forrest Beach, and to 2.9 ‰ at Capel. Once again the highest values were observed at Capel, indicating a different source of nitrogen at this site (3.80 ‰).

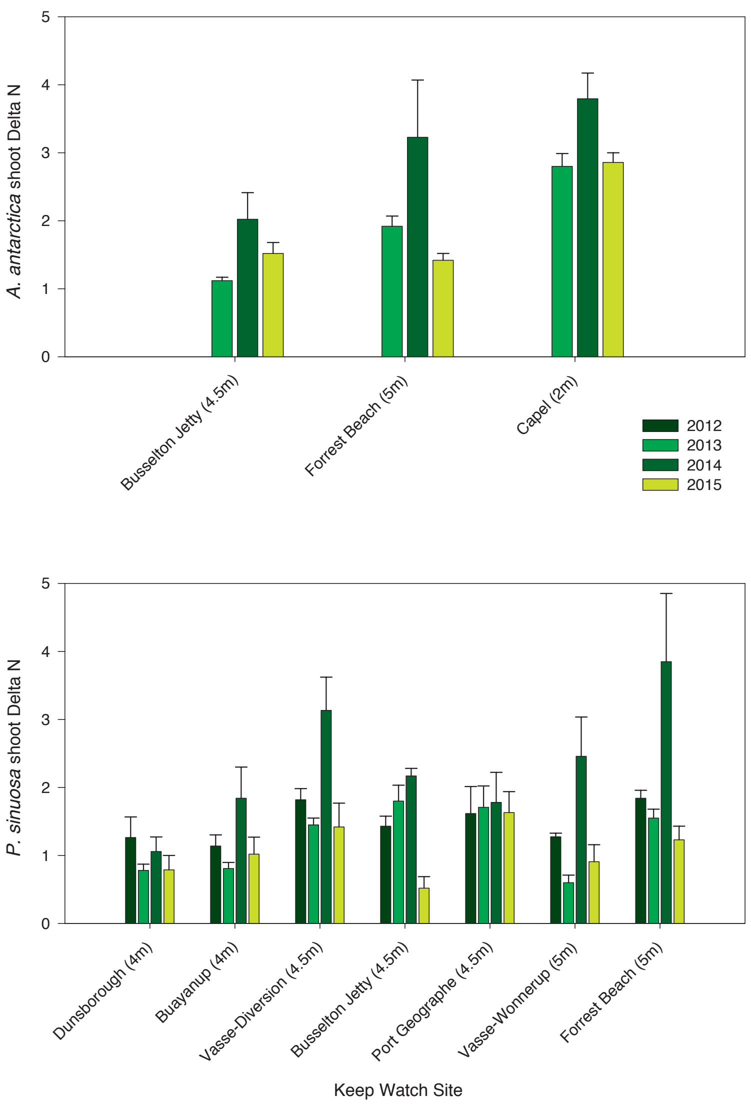


Figure 10: *$\delta^{15}N$ of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4,7 & 8 average ± se) at the Keep Watch seagrass monitoring sites in 2012-2015. Note that only Capel was measured in 2012, and is not included in these graphs.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 23.3-26.3°C. Water clarity was high and at all sites, the Secchi disk was observed on the bottom (Table 5).

Table 5: Water quality measures at the Keep Watch seagrass monitoring sites from 2012-2015, *=Secchi disk depth on bottom.

Site	Secchi disk depth (m)				Temperature (°C)			
	2012	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**
1. Dunsborough	4.2*	3	3	3.2*	22.0	22.5	23.1	23.3
2. Buayanup	3.5	2.5	3*	3.2*	22.8	22.6	23.5	25.2
3. Vasse Diversion Drain	4.0	3.25	3.5*	3.6*	23.4	23.8	23.5	24.5
4. Busselton Jetty	4.2	2.5	3.5	3.6*	23.4	27.3	23.3	26.3
5. Port Geographe	3.75	2.5	4	4.1*	23.4	25.5	23.3	24.3
6. Vasse-Wonnerup	4.0	2	4.5	4.6*	23.1	28.4	22.2	26.1
7. Forrest Beach	5*	2	4	4.2*	22.5	23.5	22.1	25.1

5 General conclusions

5.1 No significant declines in shoot density

As has occurred since the inception of this program in 2012, no management triggers were reached in 2015. Unlike last year, there were no significant declines in shoot density. In fact, three sites had increases in shoot density, Buayanup (20%), Port Geographe (12%) and Dunsborough (7%), and the remaining sites had no significant change (±5%). The increases at Buayanup counteract the declines observed last year. When observed over the life of the program (2012-2015), there has been a slight overall decline at Dunsborough (-7%) and increase at Busselton Jetty, Port Geographe and Vasse-Wonnerup, and no significant changes (±5%) at the remaining sites. These changes over years highlights the inter-annual variation in shoot density in seagrass meadows due to regional changes i.e. climate and nutrient inputs and small-scales drivers i.e. storms, variation in shoot production and mortality. At present, there are no major concerns in Geographe Bay for seagrass health. The recommendation is to continue monitoring and reassess the changes next year.

5.2 Epiphytes on seagrass increasing in cover

This year, epiphyte cover either stayed the same as last year or increased. High cover was observed at two sites (Vasse Diversion Drain, Busselton Jetty), moderate at three (Dunsborough, Buayanup, Vasse-Wonnerup) and low at the remaining two sites (Port Geographe, Forrest Beach). Over the four years there has been a trend of increasing algal cover at all sites. However, the occurrence of a high epiphyte cover does not correspond declines in shoot density. For example the three sites, which have had the greatest shoot loss have had low to moderate epiphyte cover.

It is common to see high algal cover in seagrass meadows, and is a natural component of the ecosystem. However, under certain conditions, particularly increasing nutrient loads, the growth of filamentous algal is stimulated which, if the algal blooms persist, can have a negative impact on seagrasses. In Geographe Bay, filamentous algae are not the dominant epiphyte. Where there is moderate or high epiphyte cover, the main epiphyte type is microalgal accumulations. This is a unique feature of Geographe Bay. It is not clear why these microalgal accumulations form and what maintains the aggregations. They are certainly more common in the more protected areas of the bay (i.e. Buayanup to Port Geographe). There is clearly a knowledge gap in our understanding of the ecology of these seagrass epiphytes, and further research is warranted into understanding the factors that promote its abundance.

5.3 Reductions in nutrients at Capel

Overall nutrient content in the seagrass leaves is very low; the content (% DW) is lower in *Posidonia* compared to *Amphibolis*. There are clearly variations from one year to the next but for *Posidonia* there are no sites that seem to be exposed to higher levels of nutrients. In contrast, this is not the case for *Amphibolis*. Until this year, seagrass at Capel has had higher nutrient content, indicating that it has been exposed to more nutrients or that its growth is limited and so does not use as much of the nutrient in growth compared to other sites. But, this year, the phosphorus content of seagrass at Capel was not higher than the other sites. The nitrogen content was still higher than the other sites, but only 1.2-2x higher, compared to 1.6-4x higher in other years. This could indicate that in 2014-2015 the nutrient loads entering from Capel River have reduced or that conditions for growth have improved for *Amphibolis*.

The nitrogen isotope signals, which give an indication of nitrogen sources for seagrasses have decreased at all sites this year, ranging from 0.5 to 1.6 ‰. The most likely source of nitrogen that the seagrasses are accessing is from atmospheric nitrogen fixation or agriculturally derived nutrients. The one outlier is Capel where the nitrogen isotope signal is higher, around 2.9 ‰. Here there may also be the addition of other sources, which tend to have a higher nitrogen isotope signal, such as nitrogen derived from animal wastes or septic tanks or sources from natural vegetation.

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7 Appendix 1: Randomly generated quadrat positions

Quadrat #	Bearing	Distance
1	20	5
2	20	8
3	20	18
4	20	22
5	20	25
6	40	1
7	40	10
8	40	15
9	40	20
10	40	25
11	140	10
12	140	12
13	140	15
14	140	17
15	140	21
16	200	2
17	200	6
18	200	9
19	200	15
20	200	24
21	260	6
22	260	11
23	260	18
24	260	21
25	260	24
26	320	6
27	320	8
28	320	11
29	320	18
30	320	21

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, 2015.

In 20 x 20 cm quadrat

Year	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
Date											28th January			28th January			28th January			28th January	
Rep	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
1	32	0	MR	50	0	MR	29	0	MR	44	0	MR	53	0	ALL	49	0	MR	45	0	MR
2	87	0	MR	36	0	MR	47	1	MR	31	0	MR	73	0	ALL	53	0	MR	63	0	MR
3	47	0	MR	75	0	MR	33	0	MR	45	0	MR	49	0	MR	38	0	MR	53	0	MR
4	43	0	MR	68	0	MR	37	0	MR	54	0	MR	64	0	MR	62	0	MR	39	0	MR
5	24	0	MR	43	0	MR	31	0	MR	64	0	MR	57	0	MR	46	0	MR	64	0	MR
6	41	0	RC	41	0	RC	19	0	RC	31	0	RC	85	0	ALL	49	0	RC	37	0	RC
7	42	0	RC	76	0	RC	44	0	RC	33	0	RC	58	0	RC	70	0	RC	18	0	RC
8	98	0	RC	81	0	RC	25	0	RC	28	0	RC	30	0	RC	25	0	RC	42	0	RC
9	27	0	RC	79	0	RC	33	0	RC	34	0	RC	9	0	RC	26	0	RC	53	0	RC
10	26	0	RC	64	0	RC	41	0	RC	56	0	RC	6	0	RC	47	0	RC	50	0	RC
11	101	0	KM	64	0	KM	28	0	KM	23	0	KM	39	0	KM	72	1	KM	40	0	KM
12	87	0	KM	72	0	KM	14	0	KM	42	0	KM	62	0	KM	52	0	KM	55	0	KM
13	27	0	KM	70	0	KM	45	0	KM	51	0	KM	24	0	KM	21	0	KM	38	0	KM
14	72	0	KM	39	0	KM	37	0	KM	84	1	KM	41	0	KM	51	0	KM	70	0	KM
15	38	0	KM	78	0	KM	46	0	KM	50	0	KM	49	0	KM	67	0	KM	47	0	KM
16	36	0	MR	73	0	MR	25	0	MR	24	0	MR	37	0	MR	60	0	MR	57	0	MR
17	54	0	MR	58	0	MR	21	0	MR	52	0	MR	18	0	MR	46	0	MR	59	0	MR
18	62	0	MR	63	0	MR	19	0	MR	67	0	MR	13	0	MR	68	0	MR	52	0	MR
19	43	0	MR	67	0	MR	40	0	MR	75	0	MR	47	0	MR	70	0	MR	68	0	MR
20	49	0	MR	40	0	MR	27	0	MR	39	0	MR	66	0	MR	86	0	MR	31	0	MR
21	76	0	RC	47	0	RC	33	0	RC	44	0	RC	47	0	RC	29	0	RC	66	0	RC
22	72	0	RC	45	0	RC	47	0	RC	46	0	RC	13	0	RC	59	0	RC	6	0	RC
23	59	0	RC	17	0	RC	84	0	RC	19	0	RC	44	0	RC	28	0	RC	46	0	RC
24	58	0	RC	73	0	RC	9	0	RC	21	0	RC	55	0	RC	44	0	RC	28	0	RC
25	44	0	RC	78	0	RC	40	0	RC	57	0	RC	62	0	RC	44	0	RC	45	0	RC
26	91	0	RC	59	0	RC	35	0	RC	18	0	RC	46	0	Avg	33	0	RC	28	0	RC
27	71	0	RC	44	0	KM	23	0	KM	57	0	RC	87	0	KM	53	0	KM	70	0	MR
28	49	0	MR	89	0	RC	32	0	MR	58	0	MR	49	0	MR	36	0	RC	86	0	KM
29	56	0	MR	43	0	MR	23	0	MR	39	0	MR	69	0	MR	41	0	MR	49	0	MR
30	68	0	MR	55	0	MR	49	0	MR	44	0	MR	72	0	MR	46	0	MR	29	0	MR
Average	56.00	0.00		59.57	0.00		33.87	0.03		44.33	0.03		47.47	0.00		49.03	0.03		47.80	0.00	
Median	51.50	0.00		63.50	0.00		33.00	0.00		44.00	0.00		49.00	0.00		48.00	0.00		48.00	0.00	
se	4.05	0.00		3.12	0.00		2.57	0.03		3.02	0.03		3.95	0.00		2.90	0.03		3.12	0.00	

9 Appendix 3: Leaf morphology data

	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015
	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
	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)
	37.2	6.0	57.4	6.0	62.5	5.0	59.2	6.0	59.4	5.5	35.6	7.0	38.5	6.0
	38.8	6.5	53.9	5.0	73.9	5.0	58.6	6.0	39.6	5.5	22.8	7.5	36.9	6.5
	71.6	5.5	68.8	6.0	75.3	5.5	31.3	6.0	43.4	7.0	40.8	6.0	19.4	5.0
	64.5	6.5	37.0	5.0	107.0	7.0	68.9	6.0	56.7	6.0	25.3	6.5	35.8	6.0
	54.6	6.0	46.3	5.5	65.3	5.0	56.7	6.0	54.0	7.0	70.5	6.0	14.9	5.5
	66.6	7.0	58.8	6.0	75.6	6.0	63.1	5.0	36.6	6.0	52.8	7.0	51.9	6.0
	26.8	6.0	65.1	6.0	63.5	6.0	94.4	5.5	30.5	5.0	67.7	6.0	36.5	6.5
	72.9	7.0	56.0	5.5	82.5	5.0	45.5	6.0	39.2	7.0	62.8	6.0	56.5	5.0
	45.9	6.0	44.7	5.0	52.4	6.0	64.8	6.0	30.7	5.5	62.9	6.0	50.4	6.0
	39.4	4.5	32.2	5.5	79.1	5.0	30.7	6.0	23.6	5.0	66.9	6.0	49.9	5.5
	45.3	6.5	44.7	5.0	65.1	5.0	34.0	6.0	26.7	5.0	63.5	7.0	85.1	6.5
	25.5	5.0	51.2	5.5	34.9	5.0	59.6	6.0	19.2	6.0	27.9	6.0	32.8	6.0
	32.7	5.0	35.8	5.0	86.1	6.0	71.1	5.0	22.3	7.0	83.0	5.5	75.3	6.0
	39.9	6.0	41.8	5.5	45.8	5.0	62.4	6.0	32.6	7.0	30.1	7.5	26.3	6.5
	43.8	5.5	30.9	6.0	71.8	5.0	63.2	5.5	29.1	6.0	43.7	7.0	67.6	6.0
	30.7	6.0	57.2	5.0	26.0	5.0	66.0	5.0	43.9	6.0	76.2	6.5	83.9	5.5
	35.6	5.0	55.9	5.5	66.9	5.0	67.6	6.0	34.5	6.0	81.6	7.0	63.4	6.0
	46.5	6.0	71.0	5.5	43.0	6.5	65.1	5.0	46.1	6.0	63.5	6.5	71.4	5.5
	49.8	7.0	68.9	6.5	84.8	6.0	77.9	5.0	26.6	6.0	52.9	6.0	73.4	5.5
	54.7	6.5	62.1	7.0	56.3	6.0	59.3	5.0	27.6	7.0	83.0	6.0	71.7	6.0
	57.3	7.0	69.3	5.0	84.3	6.0	39.2	5.5	42.1	5.5	45.6	6.5	36.9	6.0
	39.9	7.0	54.3	6.0	98.5	6.5	81.0	5.0	32.9	4.5	38.7	6.0	69.3	5.5
	63.3	6.0	47.9	7.0	70.2	6.0	79.2	5.5	33.6	5.0	65.4	5.5	76.6	5.5
	59.0	5.0	45.2	5.5	62.2	6.0	78.6	5.5	34.8	5.0	83.8	6.0	48.0	5.0
	51.7	7.0	49.9	5.5	77.5	6.0	91.9	6.0	54.1	5.0	83.7	6.5	37.3	5.0
	28.2	6.0	47.4	6.5	96.0	6.0	73.8	6.0	49.0	5.5	84.5	6.0	33.6	5.5
	59.4	6.5	66.1	5.5	57.2	7.5	95.8	5.5	34.5	5.5	75.6	7.0	44.2	5.0
	22.1	6.0	51.9	5.5	57.7	5.5	62.7	5.5	52.2	5.5	69.9	7.0	75.4	5.0
	27.8	5.5	35.7	5.0	97.1	6.0	83.7	5.5	47.8	5.5	82.0	6.5	52.9	5.0
	28.6	5.5	63.0	7.0	62.9	5.5	64.5	5.5	37.2	5.5	77.4	6.0	62.6	5.0
average	45.3	6.0	52.3	5.7	69.4	5.7	65.0	5.6	38.0	5.8	60.7	6.4	52.6	5.7
se	2.7	0.1	2.1	0.1	3.4	0.1	3.1	0.1	2.0	0.1	3.6	0.1	3.6	0.1

10 Appendix 4: Nutrient data

Species	Site	Sample name	δ^{15}N [‰ AIR]	δ^{13}C [‰ VPDB]	N [wt %]	C [wt %]	C/N [wt]
Amphibolis	Busselton Jetty (4.5m)	Aa4.1.1	1.41	-8.75	0.99	37.17	37.57
Amphibolis	Busselton Jetty (4.5m)	Aa4.2.1	1.83	-9.34	0.76	38.21	50.34
Amphibolis	Busselton Jetty (4.5m)	Aa4.3.1	1.32	-8.43	0.83	37.87	45.65
Amphibolis	Forrest Beach (5m)	Aa7.1.1	1.62	-9.54	0.53	37.41	70.16
Amphibolis	Forrest Beach (5m)	Aa7.2.1	1.30	-9.30	0.53	36.98	69.42
Amphibolis	Forrest Beach (5m)	Aa7.3.1	1.35	-10.29	0.46	37.13	80.68
Amphibolis	Capel	Aa8.1.1	2.79	-12.12	0.97	37.88	39.05
Amphibolis	Capel	Aa8.2.1	3.13	-11.73	1.35	38.75	28.70
Amphibolis	Capel	Aa8.3.1	2.66	-11.71	0.90	35.05	38.93
Posidonia	Dunsborough (4m)	Ps1.1.1	1.06	-10.98	0.44	37.55	84.74
Posidonia	Dunsborough (4m)	Ps1.2.1	0.94	-11.13	0.50	38.63	77.89
Posidonia	Dunsborough (4m)	Ps1.3.1	0.37	-12.10	0.36	37.92	104.49
Posidonia	Buayanup (4m)	Ps2.1.1	0.59	-9.95	0.54	37.73	70.11
Posidonia	Buayanup (4m)	Ps2.2.1	1.47	-9.93	0.66	38.54	58.08
Posidonia	Buayanup (4m)	Ps2.3.1	1.02	-9.99	0.44	36.19	82.26
Posidonia	Vasse-Diversion (4.5m)	Ps3.1.1	1.48	-7.78	0.49	37.52	76.69
Posidonia	Vasse-Diversion (4.5m)	Ps3.2.1	1.99	-9.08	0.52	37.76	72.74
Posidonia	Vasse-Diversion (4.5m)	Ps3.3.1	0.79	-7.64	0.40	36.99	91.52
Posidonia	Busselton Jetty (4.5m)	Ps4.1.1	0.44	-8.00	0.43	36.72	85.77
Posidonia	Busselton Jetty (4.5m)	Ps4.2.1	0.29	-8.54	0.50	37.36	74.19
Posidonia	Busselton Jetty (4.5m)	Ps4.3.1	0.85	-8.72	0.57	36.77	64.11
Posidonia	Port Geographe (4.5m)	Ps5.1.1	1.85	-7.30	0.45	38.81	86.41
Posidonia	Port Geographe (4.5m)	Ps5.2.1	1.02	-9.31	0.55	38.41	70.02
Posidonia	Port Geographe (4.5m)	Ps5.3.1	2.03	-8.91	0.46	39.33	85.45
Posidonia	Vasse-Wonnerup (5m)	Ps6.1.1	1.15	-9.32	0.49	38.03	78.18
Posidonia	Vasse-Wonnerup (5m)	Ps6.2.1	0.41	-9.43	0.39	37.40	97.03
Posidonia	Vasse-Wonnerup (5m)	Ps6.3.1	1.16	-10.42	0.42	37.87	89.74
Posidonia	Forrest Beach (5m)	Ps7.1.1	1.59	-8.76	0.48	38.64	81.01
Posidonia	Forrest Beach (5m)	Ps7.2.1	0.91	-7.80	0.32	37.81	116.64
Posidonia	Forrest Beach (5m)	Ps7.3.1	1.19	-9.03	0.38	36.85	96.43