Edith Cowan University
Centre for Marine Ecosystems Research

Keep Watch Seagrass Monitoring 2016 Report for GeoCatch

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Keep Watch Seagrass Monitoring, 2016. Report to GeoCatch

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Keep Watch Seagrass Monitoring

Annual Report 2016

Investigators: Kathryn McMahon

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April 2016

1 Executive Summary

1.1 Introduction

This report summarises data from the first five years (February 2012, Jan-Feb 2013, January 2014-2016) 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 three assessment triggers (Trigger 1-3) 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. Only one site has had a significant decline, though not at the level to activate any of the triggers, Vasse Diversion Drain. Despite this, at present, there are no major 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 2016, there has been a net increase at Busselton Jetty (19%), Port Geographe (16%) and Vasse-Wonnerup (26%), minimal change at Buayanup (+ 2%), Dunsborough (+ 2%) and Forrest Beach (- 1%) and a net decline at Vasse Diversion Drain (-16%). 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 maintained at a high level or greater than last year at three sites, Buayanup, Vasse Diversion Drain and Port Geographe. At the remaining sites there was a decline. Previously, when examining all sites the changes in shoot density were not correlated with changes in algal epiphyte cover. This year it is emerging that the site that has maintained a high algal cover for the last three years is the only site to show a significant decline this year, and a net decline over time. Also in general, sites with a higher algal cover are showing longer leaves, which may be a response to increase the leaf area so that the plants can maintain adequate rates of photosynthesis. 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 of seagrasses continues to be very low. Capel stands out as a site that is exposed to either a greater supply of nutrients or growth of the seagrass is limited by other factors leading to more nutrients accumulating in the leaves. Across all sites, with the exception of Capel, the source of nitrogen for seagrasses appears to be mostly from fixation of atmospheric nitrogen and agriculturally derived nitrogen. 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

These recommendations are based on the last five 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 Parks and Wildlife and Department of Fisheries. This is a very effective and beneficial arrangement.

Recommendation 3

Investigate the factors which 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.

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 2016 and compares data from the 2012-2015 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.

As was the case in 2014 and 2015, 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 and for the first time Trigger 3 can be assessed this year (see 3.1.3 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 2016. 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	27/1/2016 10:18	Ps
2. Buayanup	S 33.65233°, E 115.24840°	4	27/1/2016 12:30	Ps
3. Vasse Diversion Drain	S 33.64746°, E 115.32379°	4.5	27/1/2016 14:13	Ps
4. Busselton Jetty	S 33.63896°, E 115.34315°	4.5	28/1/2016 10:40	Ps, Aa
5. Port Geographe	S 33.62846°, E 115.38240°	4.5	27/1/2016 07:38	Ps
6. Vasse-Wonnerup	S 33.60188°, E 115.42345°	5	28/1/2016 08:59	Ps
7. Forrest Beach	S 33.57295°, E 115.44908°	5	28/1/2016 07:29	Ps, Aa
8. Capel	S 33.51394°, E 115.51508°	2	29/1/2016 09:00	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.

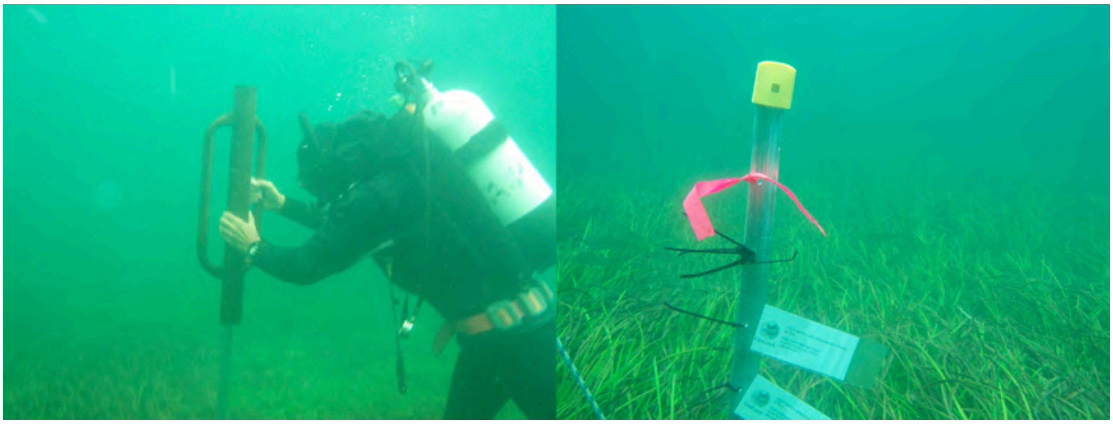

Figure 2: *Left: Banging in permanent marker with pole driver. Right: Star picket with cap and plastic coated site label, indicating center of 50 m diameter Keep Watch seagrass site.*

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.

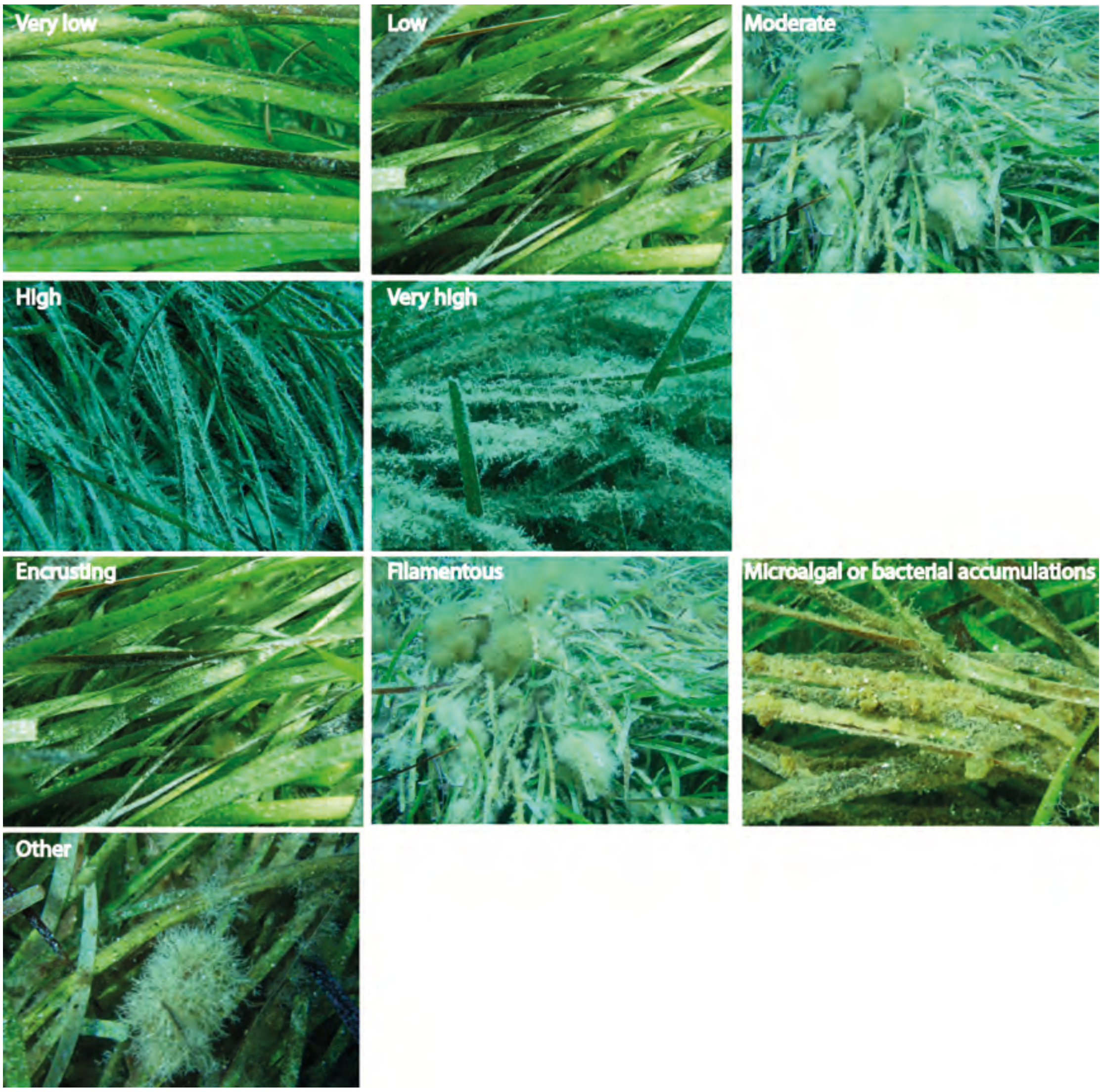

Figure 4: *Classification of epiphytic algal cover and type.*

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) and Simone Strydom (SS) from ECU with Michael Rule (MR) from Department of Parks and Wildlife and Dave Abdo 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 717-1522 shoots m^{-2} across the seven sites, this is a wider range than in 2015 (846-1489 shoots m^{-2}), 2014 (844 – 1302 shoots m^{-2}), and still 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 4 of the 7 sites, but at three of these sites, this was a minor change, with less than a 8% decline at Buayanup, Port Geographe and Vasse-Wonnerup (Table 2). Vasse Diversion Drain had the greatest decline (15%). The remaining sites had a slight increase in shoot density, with the greatest increase at Dunsborough (9% increase), Forrest Beach (5% increase) and Busselton Jetty (1% increase). Compared to 2012, when these surveys began, three sites have shown moderate increases, Vasse-Wonnerup (26%), Busselton Jetty (19%) and Port Geographe (16%) and one has shown an overall decline, Vasse Wonneryp (16%). The remaining three sites have shown little overall change.

The shoot density at most 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). However, this year for the first time, Vasse Diversion Drain has dropped below the maximum site average at the Shoalwater and Jurien Bay Marine Park sites, but it is above the minimum site average (Figure 5).

P. sinuosa average shoot length ranged from a minimum of 40 cm at Forrest Beach to a maximum of 83 cm at Vasse Diversion Drain and a range in width of 4.7-5.7 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	% change 2015-2016	Net change 2012-2016
1. Dunsborough	3	-18	7	9	2
2. Buayanup	11	-24	20	-7	-1
3. Vasse Diversion	6	-8	0	-15	-16
4. Busselton Jetty	0	22	-4	1	19
5. Port Geographe	17	-7	12	-6	16
6. Vasse-Wonnerup	19	13	-4	-3	26
7. Forrest Beach	16	-23	2	5	0

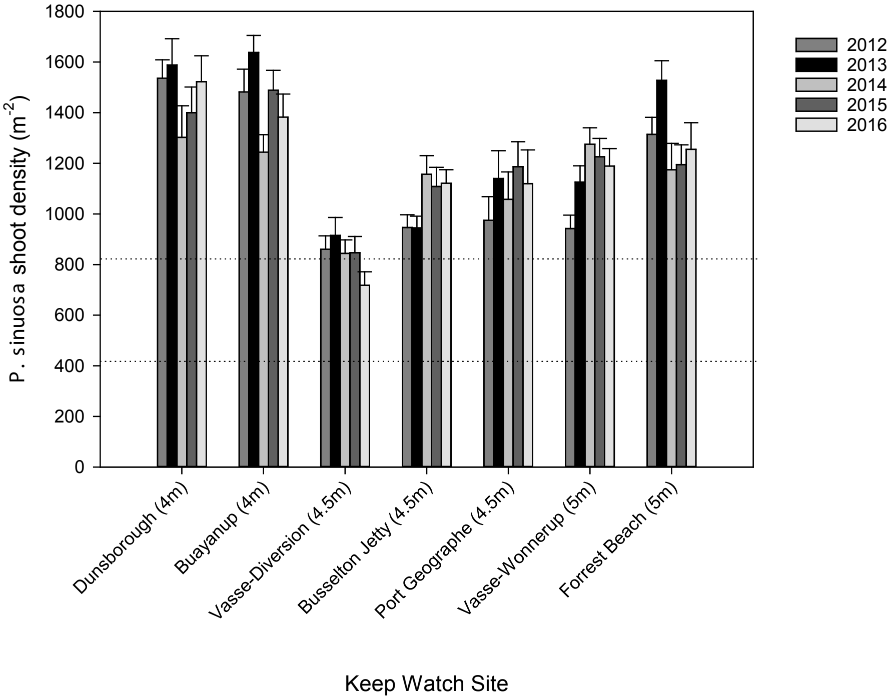

***Figure 5:** Shoot density (average m^{-2} ± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in February 2012-2016. Dotted lines indicate the minimum and maximum site averages from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2012-2015 (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 2015-2016).

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 2014-2015 & 2015-2016).

4.2.3 Trigger 3

This is the first year that Trigger 3 was assessed. No sites showed a significant trend over time, either increasing or decreasing in shoot density (Table 3). The sites which showed the greatest change was a reduction at Vasse Diversion drain and an increase at Busselton Jetty. 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.

Site Name & #	Significance ($p<0.05$)	Overall slope	R^2
1. Dunsborough	ns	-ve	6%
2. Buayanup	ns	-ve	8%
3. Vasse Diversion	ns	-ve	60%
4. Busselton Jetty	ns	+ve	63%
5. Port Geographe	ns	+ve	42%
6. Vasse-Wonnerup	ns	+ve	53%
7. Forrest Beach	ns	-ve	26%

4.3 Epiphytes

In comparison to 2015, epiphyte cover has continued to increase at some sites (Buayanup: from medium to high and Port Geographe: from low to medium), has maintained high cover at Vasse Diversion Drain and has declined at other sites (Dunsborough: from medium to low; Busselton Jetty: from high to medium; Vasse-Wonnerup: from medium to low) (Table 4). Therefore Moderate to High algal epiphyte cover was observed from Buayanup to Port Geographe, and there was Low cover either side of this area. The dominant epiphyte where there was high cover were microalgal accumulations. Whereas at most of the sites where there was low cover the epiphyte type was encrusting algae. The remainder of the sites were dominated by Other algae including the brown *Dictyota* and a brown cylindrical algae (Figure 6, Table 4).

Table 4: Algal cover at the Keep Watch seagrass monitoring sites, 2012-2016. 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	2016	2012	2013	2014	2015	2016
1. Dunsborough	M	L	M	M	L	f,O, m	F,O	O	O,m	O
2. Buayanup	M	L	M	M	H	o, M	E,O	M,o	M,o	M , o
3. Vasse Diversion Drain	L	M	H	H	H	o, M	E,O	M,o	M,o	M , o
4. Busselton Jetty	L	L	H	H	M	o, M	O	M	M,f	O, e, m
5. Port Geographe	L	VL	L	L	M	E, o	E,M	M,e	M,f	O, f
6. Vasse-Wonnerup	L	VL	L	M	L	E, o, m	E,O	M,f	O	E,o,m
7. Forrest Beach	L	VL	L	L	L	E, o, M	F,E	M,f	O,e	E,o

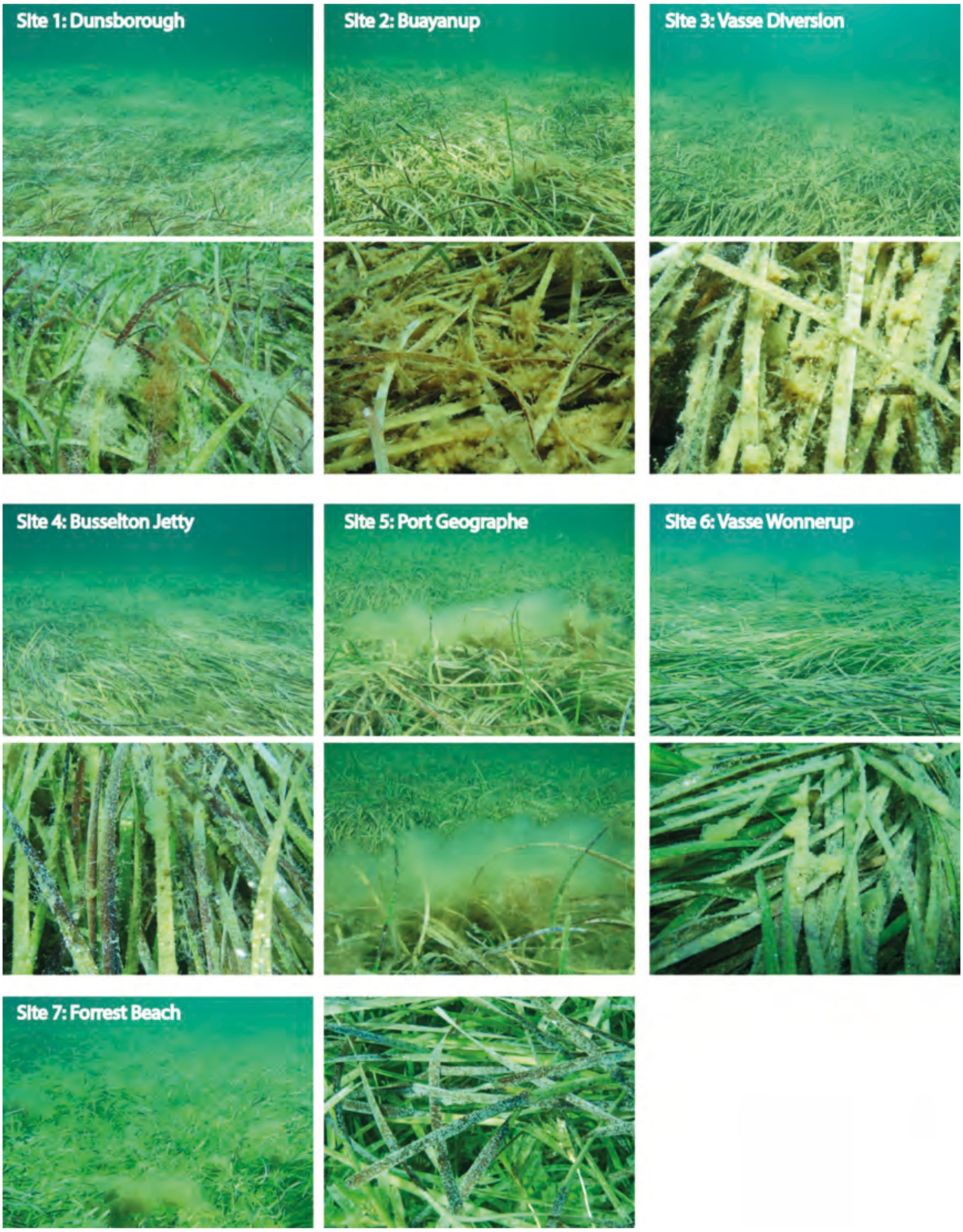

Figure 6: Pictures of seagrass meadow and the dominant algal epiphyte s at each *P. sinuosa* site. (1. Dunsborough, 2. Buayanup, 3. Vasse Diversion Drain, 4. Busselton Jetty, 5. Port Geographe, 6. Vasse-Wonnerup Estuary, 7. Forrest Beach)

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 Vasse-Diversion Drain and Port Geographe, where in both locations it was noted for the first time, and Forrest Beach and Capel. The remains of flowering shoots were observed at Dunsborough and Busselton Jetty and seedlings were observed at Dunsborough and Vasse-Wonnerup.

There were large bare patches at Port Geographe (Figure 7), indicating recent shoot loss and some blowouts at Dunsborough. Shoot density at Port Geographe declined slightly this year compared to 2015, but overall is increasing, however, 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. The section of the meadow that appears to have been colonized by *Amphibolis* is persisting. 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 and Buayanup, but none were observed at Vasse Diversion Drain this year. Once again, the brittle rhizomes were not observed at Dunsborough and Buayanup, but were at Port Geographe where some declines occurred this year.

There were noticeable accumulations of wrack in the bare patches at Port Geographe and also under the canopy at Dunsborough, Buayanup and Forrest Beach. *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.

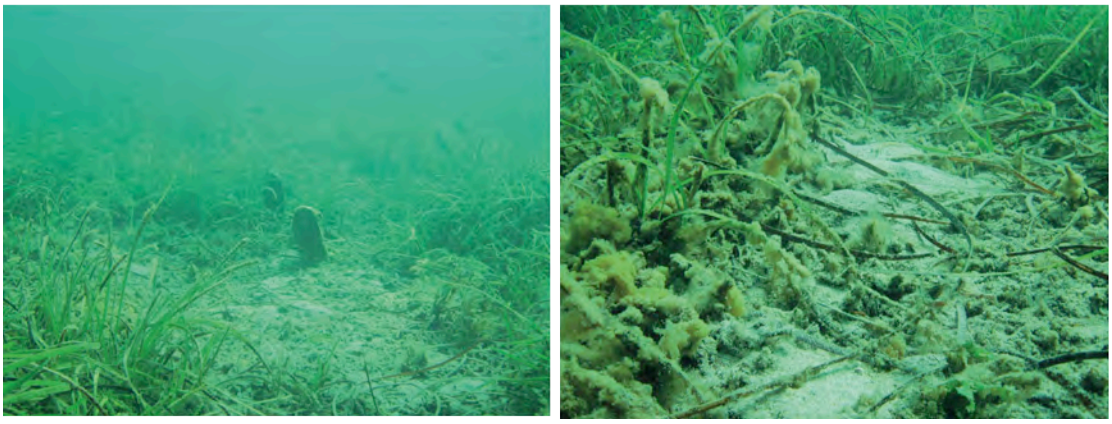

Figure 7: Bare patches within the seagrass meadow at Port Geographe, showing remains of dead shoots that have lost the leaves.

4.5 Nutrient content

The nitrogen content of *P. sinuosa* leaves ranged from 0.5-0.9 % N dry weight (DW) (Figure 8). At some sites (Dunsborough, Busselton Jetty, Vasse Wonnerup and Forrest Beach) there was little change from last year. However at the remaining sites (Buayanup, Vasse Diversion and Port Geogrpahe) there has been a slight increase compared to last year. The nitrogen content of *A. antarctica* leaves was similar compared to last year at Forrest Beach and Capel but declined slightly at Busselton Jetty (Figure 9). The nitrogen content remains greater at Capel, 1.1 % DW or 1.5-2.4x greater than the other sites, with the exception of Port Geographe which has a similar content, 0.9 % DW. This is less than previous years when Capel had up to 4x the nitrogen content than other sites (Figure 9).

The phosphorus content of *P. sinuosa* leaves in 2016 ranged from 0.12-0.14% P DW (Figure 8). Compared to last year, most sites declined (Dunsborough, Buayanup, Busselton Jetty and Vasse Wonnerup), Port Geographe increased and the remaining sites stayed the same

(Vasse Diversion and Forrest Beach). For *A. antarctica* leaves, the phosphorus content ranged from 0.10-0.14% DW. It increased compared to last year at Forrest Beach and Capel, but declined slightly at Bussleton Jetty (Figure 9). Once again, Capel had the highest P (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 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			

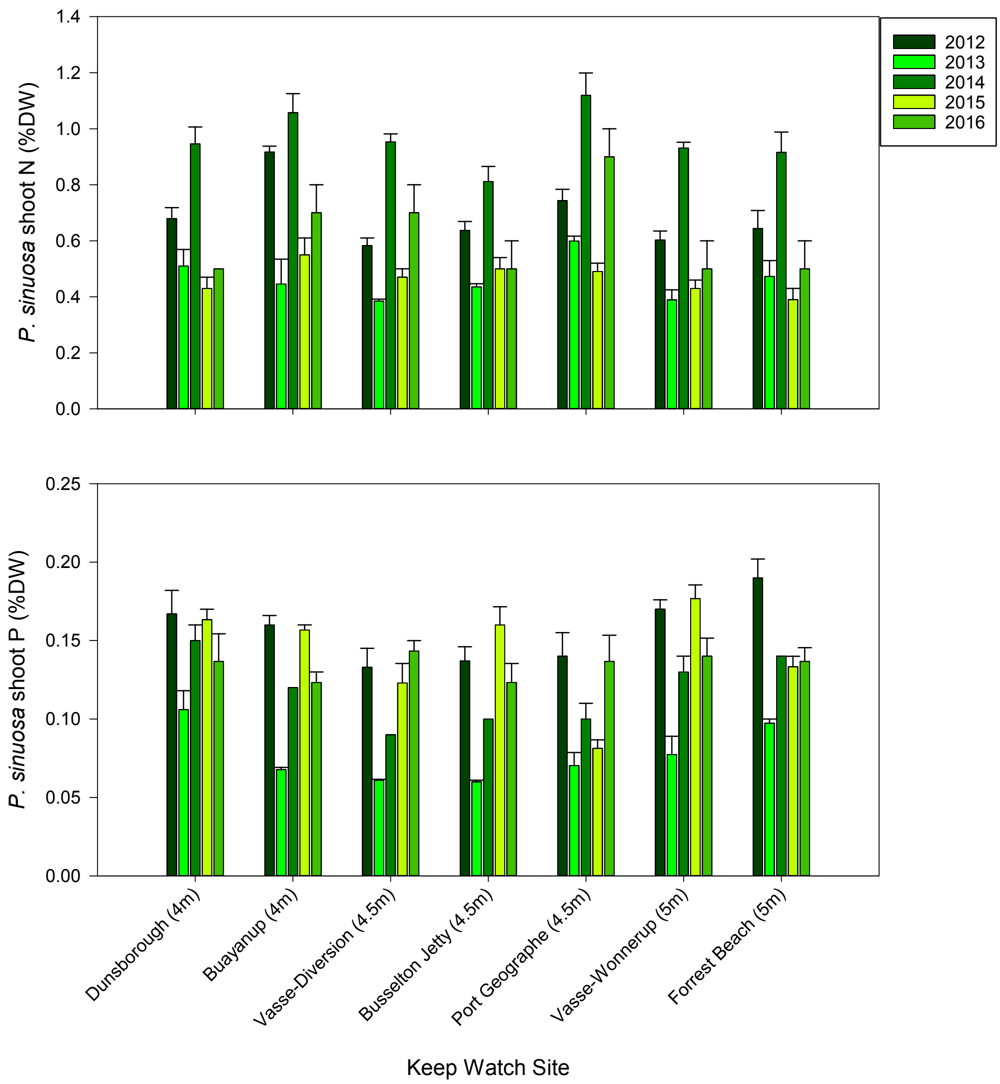

Figure 8: *Nitrogen and phosphorus content (% dw) of* P. sinuosa *leaves (Dunsborough-Forrest Beach) at the Keep Watch* Posidonia *seagrass monitoring sites in 2012-2016.*

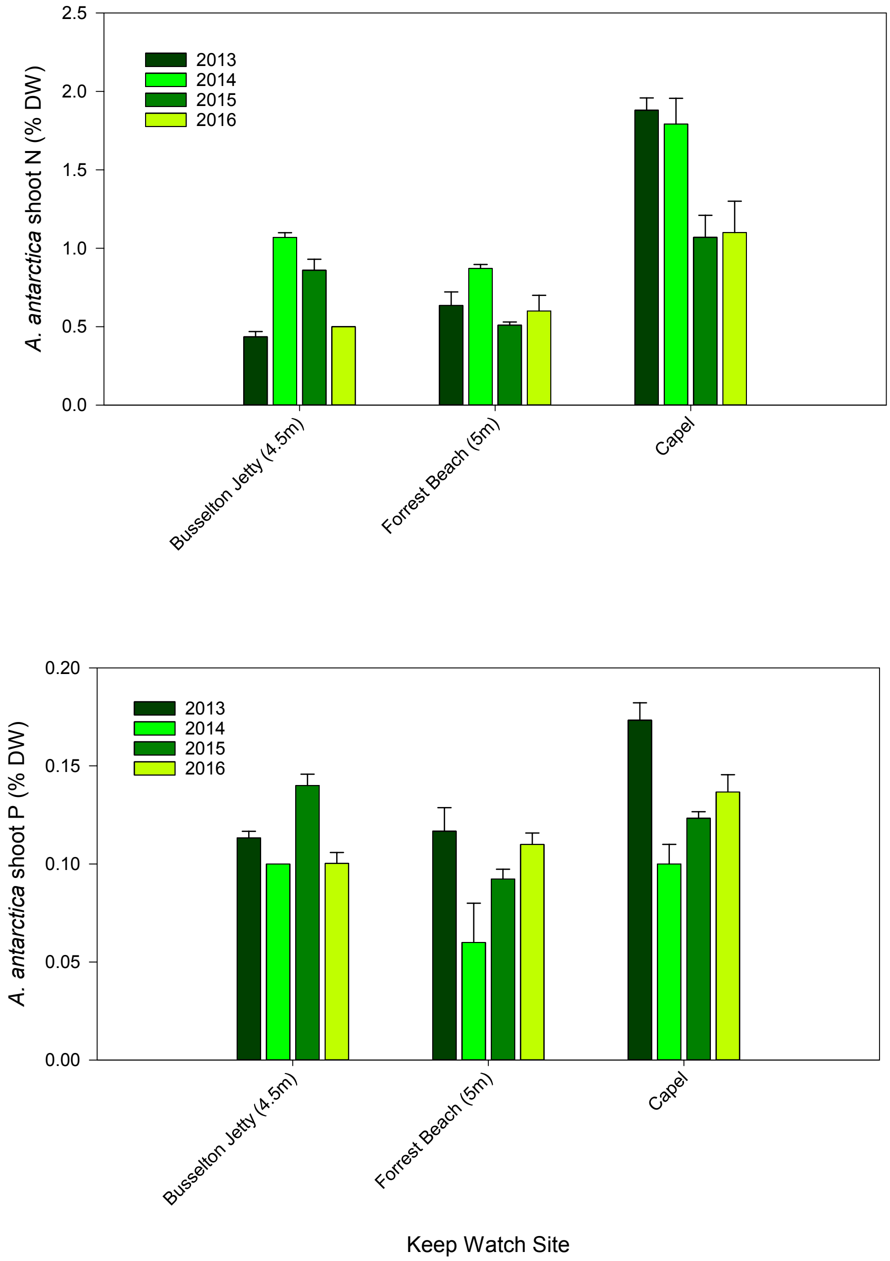

Figure 9: *Nitrogen and phosphorus content (% dw) of* A. antarctica *leaves (average ± se) at the Keep Watch* Amphibolis *seagrass monitoring sites in 2013-2016.*

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 greater than last year, from 0.2 to 1.8 ‰ (Figure 10). This was due to the lowest values recorded to date at Dunsborough and Forrest Beach (0.18 and 0.23 ‰ respectively). There was a slight increase at Busselton Jetty from 0.5 to 1.2 ‰, but all other sites were 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‰. 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 declined at 2 of the 3 *Amphibolis* monitoring sites in 2016 compared to 2014, Busselton Jetty and Forrest Beach, but it increased at Capel from 2.9 to 3.7 ‰ (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.

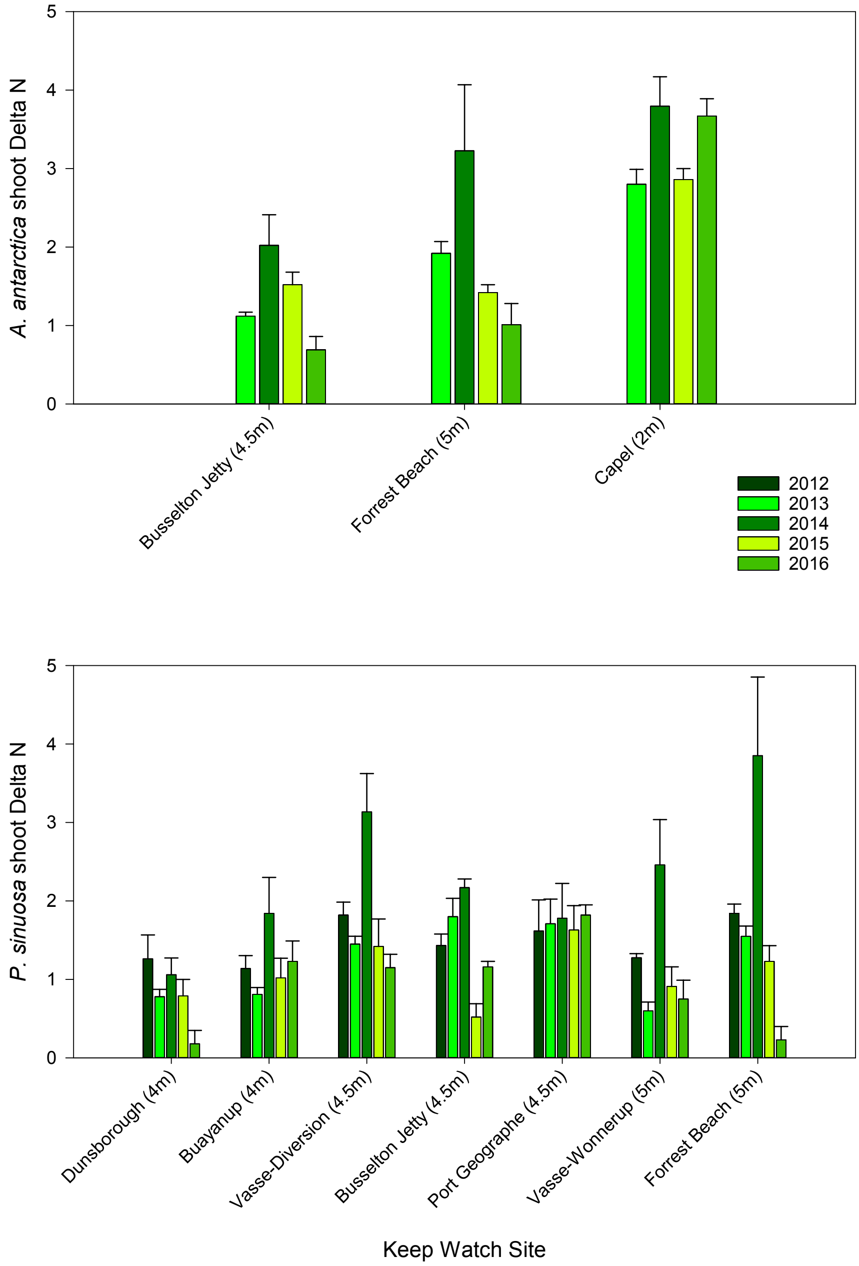

Figure 10: *δ^{15}N of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4,7 & 8 average ± se) at the Keep Watch seagrass monitoring sites in 2012-2016. Note that only Capel was measured in 2012, and is not included in these graphs.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 22.3-23.7°C. Water clarity was high and at all sites except Port Geographe, the Secchi disk was observed on the bottom (Table 6).

Table 6: 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**	**2016**	**2012**	**2013**	**2014**	**2015**	**2016**
1. Dunsborough	4.2*	3	3	3.2*	3*	22.0	22.5	23.1	23.3	22.9
2. Buayanup	3.5	2.5	3*	3.2*	3.5*	22.8	22.6	23.5	25.2	23.7
3. Vasse Diversion Drain	4.0	3.25	3.5*	3.6*	3.5*	23.4	23.8	23.5	24.5	23.9
4. Busselton Jetty	4.2	2.5	3.5	3.6*	3.5*	23.4	27.3	23.3	26.3	22.6
5. Port Geographe	3.75	2.5	4	4.1*	3.5	23.4	25.5	23.3	24.3	23.0
6. Vasse-Wonnerup	4.0	2	4.5	4.6*	4.5*	23.1	28.4	22.2	26.1	22.3
7. Forrest Beach	5*	2	4	4.2*	4.5*	22.5	23.5	22.1	25.1	23.3

5 General conclusions

5.1 No significant declines in shoot density

No management criteria were triggered in 2016 for all three triggers. Most sites were within 10% of last years shoot density. In fact, relative to 2012 data, three sites have shown an increase in shoot density: Busselton Jetty (19%), Port Geographe (16%) and Vasse Wonnerup (26%) and three have shown very little change overall (Dunsborough, Buayanup and Forrest Beach). The exception is the Vasse Diversion Drain site, which had a 15% decline this year, and an overall decline relative to 2012 of 16%. Although none of the management triggers were instigated for this site including no trend of decline overtime, it is the one site in Geographe Bay that is showing the greatest negative change and has had the greatest epiphyte cover among all sites over time. Despite this, 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 Leaf length associated with algal epiphyte cover

Since 2013, there have been declines in shoot density at Vasse Diversion Drain, an 8% decline from 2013-2014, no change from 2014-2015 and a 16% decline from 2015-2016. Over this period there has been persistent high epiphyte cover consisting of a thick microalgal accumulation (Figure 6). Persistent algal cover can reduce the light reaching the seagrass as well as reducing oxygen and nutrient exchange, which can lead to a reduction in shoot density. Interestingly, although there has been a reduction in the number of shoots, the actual length of the leaves in the shoots are the highest among all sites, 83 cm this year or an average of 67 cm over the last three years. This could be a benefit for the plant as it produces more leaf area so that photosynthesis can occur to produce energy for the plant to grow. Other sites that have experienced high algal cover over the last three years such as Busselton Jetty had a length of 62 cm this year and an average of 60 over the last three years, compared to sites with low algal cover such as Dunsborough or Forrest Beach which had lengths of 40-45 cm this year and an average of 44-51cm over the last three years. Buayanup has had greater epiphytes than Forrest Beach and Dunsborough, but less than Vasse Diversion and Busselton Jetty, and its leaf length is intermediate with 58 cm this year and an average of 54 over the least three years. Leaf length is quite variable year to year, but there is a pattern emerging of longer leaf length with greater epiphyte cover.

5.3 Microalgal accummulations dominate where epiphyte cover is high

This year, high epiphyte cover was maintained or it increased at three sites, Buayanup, Vasse Diversion Drain and Forrest Beach. At the remaining sites, epiphyte cover declined. This highlights the variation among sites from year to year in the amount of algal epiphytes, and unlike last year there was no consistent trend across all sites. The main epiphyte type where cover is moderate to high are the 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). This continues to be 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, particularly in relation to links with catchment nutrients, and the potential impacts on seagrass density and health.

5.4 Lowest recorded nitrogen isotope signals

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*. The seagrass at Capel once again has 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.

The range in nitrogen isotope signals among sites, which give an indication of nitrogen sources for seagrasses, are the greatest we have observed since the program started. This is due to the lowest values recorded at Dunsborough and Forrest Beach, <0.25 ‰ but no major changes at the other sites. The low nitrogen isotope values indicate that the most likely source of nitrogen that these seagrasses are accessing is from atmospheric nitrogen fixation or fertiliser derived nutrients. Most other sites would also be accessing these sources as the main form of nitrogen (0.7-1.8 ‰). The one outlier continues to be Capel where the nitrogen isotope signal is higher, around 3.7 ‰. 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	40	1
2	40	3
3	40	14
4	40	17
5	40	19
6	80	1
7	80	2
8	80	15
9	80	16
10	80	18
11	120	9
12	120	19
13	120	22
14	120	23
15	120	25
16	180	2
17	180	6
18	180	9
19	180	15
20	180	18
21	220	6
22	220	10
23	220	19
24	220	24
25	220	25
26	340	1
27	340	6
28	340	16
29	340	17
30	340	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.

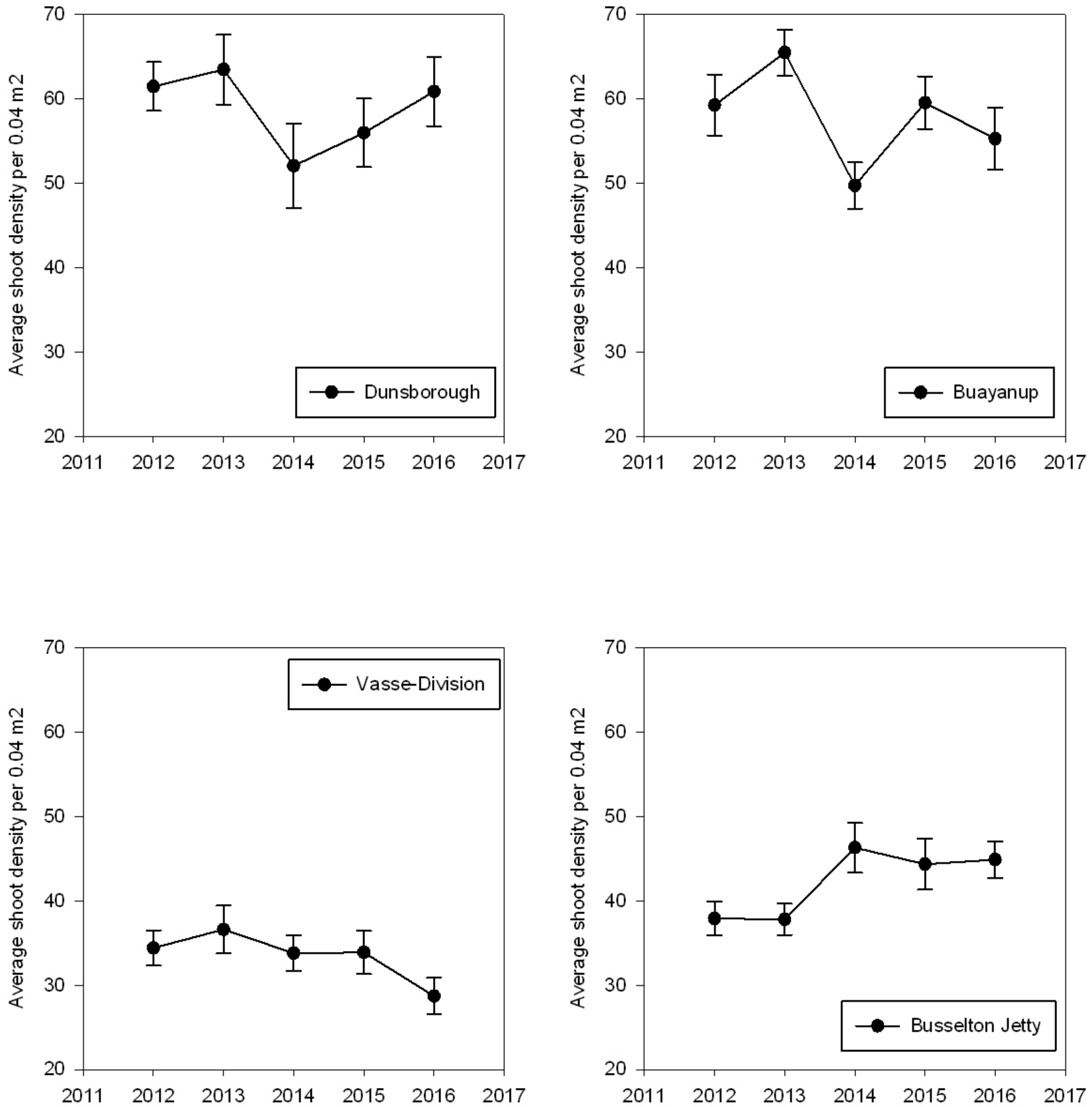
In 20 x 20 cm quadrat

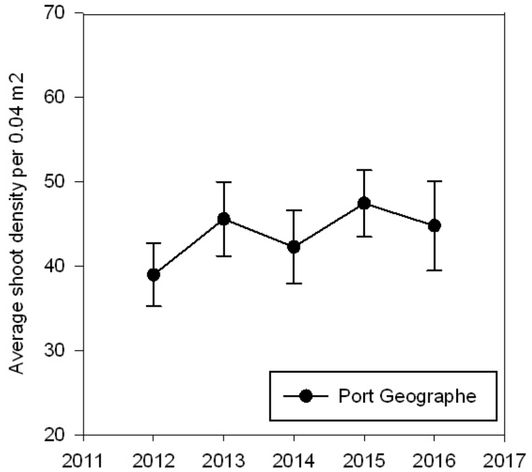
Year	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016
Date	27th January			27th January			27th January			28th January			27th January			28th January			28th January		
Rep	1. Dunsborough			2. Buayanup			3. Vasse Diversion			4. Busselton Jetty			5. Port Geographe			6. Vasse-Wonnerup			7. Forrest Beach		
0	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter	Shoots	Seedlings	Counter
1	87	0	SS	55	0	SS	37	0	SS	32	0	SS	95	0	All	40	0	SS	40	0	SS
2	26	0	SS	53	0	SS	45	0	SS	46	0	SS	94	0	All	46	0	SS	81	0	SS
3	66	0	SS	101	0	SS	28	0	SS	45	0	SS	27	0	All	62	0	SS	27	0	SS
4	52	0	SS	55	0	SS	54	0	SS	48	0	SS	82	0	SS	34	0	SS	30	0	SS
5	48	0	SS	59	0	SS	33	0	SS	53	0	SS	24	0	SS	22	0	SS	25	0	SS
6	98	0	MR	70	0	MR	28	0	SS	45	0	missing	22	0	SS	22	0	MR	58	0	MR
7	59	0	KM	62	0	KM	21	0	SS	44	0	SS	74	0	SS	49	0	SS	61	0	MR
8	63	0	SS	36	0	SS	14	0	SS	33	0	SS	22	0	SS	62	0	SS	57	0	SS
9	67	0	SS	47	0	SS	13	0	SS	38	0	SS	24	0	SS	60	0	SS	59	0	SS
10	64	0	SS	63	0	SS	27	0	SS	63	0	SS	38	0	SS	46	0	SS	25	0	SS
11	106	0	MR	35	0	MR	28	0	MR	72	0	MR	6	0	MR	62	0	MR	60	0	MR
12	57	0	MR	64	0	MR	5	0	MR	41	0	MR	7	0	MR	50	0	MR	42	0	MR
13	28	0	MR	52	0	MR	41	0	MR	48	0	MR	19	0	MR	39	0	MR	35	0	MR
14	73	0	MR	60	0	MR	18	0	MR	42	0	MR	5	0	MR	58	0	MR	38	0	MR
15	84	0	MR	75	0	MR	20	0	MR	48	0	MR	29	0	MR	34	0	MR	27	0	MR
16	53	0	MR	25	0	MR	41	0	MR	44	0	MR	38	0	MR	28	0	MR	24	0	MR
17	38	0	MR	38	0	MR	21	0	MR	35	0	MR	51	0	MR	74	0	MR	9	0	MR
18	89	0	MR	61	0	MR	17	0	MR	40	0	MR	68	0	MR	45	0	MR	44	0	MR
19	66	0	MR	28	0	MR	30	0	MR	55	0	MR	72	0	MR	48	0	MR	49	0	MR
20	14	0	MR	42	0	MR	24	0	MR	61	0	MR	13	0	MR	70	0	MR	53	0	MR
21	31	0	KM	79	0	KM	10	0	KM	22	0	MR	21	0	KM	75	0	KM	55	0	SS
22	80	0	KM	105	0	KM	22	0	KM	68	0	KM	32	0	KM	55	0	KM	77	0	KM
23	45	0	KM	56	0	KM	44	0	KM	52	0	KM	56	0	KM	61	1	KM	77	0	KM
24	50	0	KM	67	0	KM	22	0	KM	36	0	KM	28	0	KM	61	0	KM	100	0	KM
25	69	1	KM	71	0	KM	43	0	KM	46	0	KM	85	0	KM	44	0	KM	107	0	KM
26	96	0	KM	40	0	MR	29	0	MR	41	0	MR	14	0	MR	33	0	MR	63	0	MR
27	49	0	MR	19	0	MR	43	0	MR	35	0	MR	69	0	MR	35	0	MR	68	0	MR
28	68	0	MR	58	0	MR	28	0	MR	20	0	MR	71	0	MR	33	0	MR	38	0	MR

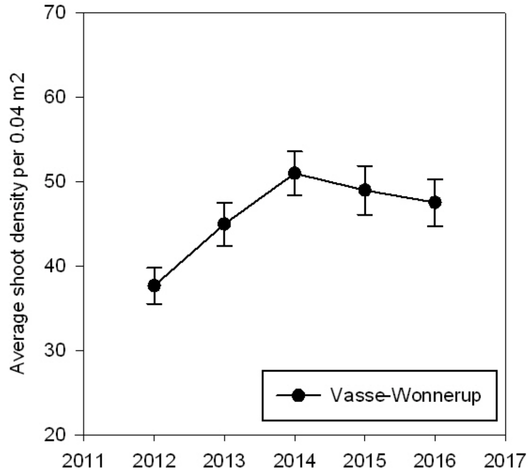
9 Appendix 3: Leaf morphology data

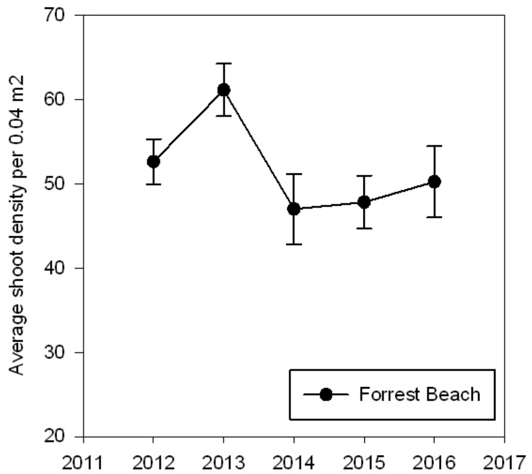
	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016	2016
	S1 Dun.	S1 Dun.	S2 Buayanup	S2 Buayanup	S3 Vasse Div.	S3 Vasse Div.	S4 Buss Jetty	S4 Buss Jetty	S5 Port Geo	S5 Port Geo	S6 Vasse Won	S6 Vasse Won	S7 Forrest B	S7 Forrest B
Rep	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot 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	44.0	5.0	70.5	5.0	87.6	6.0	78.2	6.0	54.0	5.0	69.7	4.0	35.3	5.0
2	36.8	5.0	56.9	5.0	83.4	6.0	64.5	6.0	86.5	6.0	40.9	5.0	38.2	5.0
3	43.6	5.0	63.3	4.0	85.9	6.0	75.8	6.0	51.7	5.0	48.6	6.0	37.0	5.0
4	42.2	6.0	67.4	5.0	88.1	5.0	74.6	5.0	76.2	5.0	67.0	6.0	34.9	6.0
5	32.1	5.0	62.8	5.0	101.4	5.0	61.8	5.0	69.0	6.0	42.7	5.0	45.8	5.0
6	37.3	6.0	57.3	4.0	97.0	5.0	57.2	5.0	74.2	6.0	71.2	6.0	46.3	6.0
7	51.9	6.0	40.2	4.0	77.4	6.0	27.9	6.0	54.6	6.0	32.7	5.0	35.8	5.0
8	49.8	6.0	45.6	5.0	86.3	5.0	59.1	6.0	55.2	5.0	85.7	6.0	43.7	5.0
9	19.5	5.0	68.4	5.0	91.4	5.0	62.8	6.0	48.1	6.0	85.9	5.0	49.7	5.0
10	45.6	7.0	51.6	5.0	68.3	5.0	67.2	5.0	72.4	5.0	49.8	5.0	44.3	5.0
11	47.1	6.0	73.5	5.0	74.8	6.0	58.7	6.0	67.1	5.0	82.4	5.0	45.0	5.0
12	54.5	7.0	63.4	5.0	68.3	6.0	60.8	5.0	40.3	3.0	61.3	5.0	51.5	5.0
13	66.8	5.0	51.5	5.0	96.8	6.0	72.1	6.0	62.3	4.0	58.0	5.0	27.0	4.0
14	48.7	6.0	49.7	5.0	49.3	6.0	45.7	5.0	77.7	5.0	40.6	5.0	19.5	4.0
15	60.5	6.0	61.6	4.0	88.4	6.0	68.1	5.0	41.4	5.0	70.8	5.0	52.0	4.0
Average	45.4	5.7	58.9	4.7	83.0	5.6	62.3	5.5	62.0	5.1	60.5	5.2	40.4	4.9
SE	3.0	0.2	2.5	0.1	3.5	0.1	3.3	0.1	3.6	0.2	4.5	0.1	2.4	0.2

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




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


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


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

11 Appendix 5: Nutrient data

Site number	Species	Sample name	$\delta^{15}N$ [‰ AIR]	$\delta^{13}C$ [‰ VPDB]	N [wt %]	C [wt %]	% P
1	P. sinuosa	Dun1.2016	0.40	-11.09	0.4	36.7	0.13
1	P. sinuosa	Dun2.2016	0.30	-9.56	0.4	36.6	0.11
1	P. sinuosa	Dun3.2016	-0.16	-10.79	0.5	35.1	0.17
2	P. sinuosa	Buay1.2016	1.05	-11.00	0.6	35.1	0.11
2	P. sinuosa	Buay2.2016	0.90	-12.26	0.6	36.2	0.13
2	P. sinuosa	Buay3.2016	1.73	-10.47	0.9	36.6	0.13
3	P. sinuosa	VD1.2016	1.06	-9.28	0.6	38.8	0.13
3	P. sinuosa	VD2.2016	0.91	-8.96	0.8	37.4	0.13
3	P. sinuosa	VD3.2016	1.47	-8.12	0.8	37.2	0.15
4	P. sinuosa	BJ1.2016	1.28	-9.30	0.7	37.0	0.13
4	P. sinuosa	BJ2.2016	1.16	-9.46	0.5	38.1	0.10
4	P. sinuosa	BJ3.2016	1.03	-9.24	0.5	37.3	0.14
5	P. sinuosa	PG1.2016	1.82	-10.39	0.9	34.3	0.12
5	P. sinuosa	PG2.2016	1.60	-9.55	0.8	36.8	0.12
5	P. sinuosa	PG3.2016	2.04	-11.76	1.1	37.1	0.17
6	P. sinuosa	VW1.2016	0.92	-10.06	0.6	36.1	0.14
6	P. sinuosa	VW2.2016	0.28	-9.78	0.3	35.7	0.12
6	P. sinuosa	VW3.2016	1.06	-12.00	0.7	36.5	0.16
7	P. sinuosa	FB1.2016	0.33	-9.36	0.6	38.7	0.12
7	P. sinuosa	FB2.2016	-0.10	-10.84	0.5	36.0	0.15
7	P. sinuosa	FB3.2016	0.45	-10.94	0.5	38.4	0.14
4	A. antarctica	BJ1.AM.2016	0.36	-11.24	0.6	35.1	0.10
4	A. antarctica	BJ2.AM.2016	0.91	-10.35	0.5	34.9	0.11
4	A. antarctica	BJ3.AM.2016	0.80	-11.10	0.4	35.1	0.10
7	A. antarctica	FB1.AM.2016	0.88	-11.83	0.6	34.3	0.11
7	A. antarctica	FB2.AM.2016	0.61	-12.44	0.5	31.7	0.10
7	A. antarctica	FB3.AM.2016	1.53	-13.24	0.9	35.3	0.12
8	A. antarctica	CAP1.2016	3.95	-14.12	1.0	37.1	0.15
8	A. antarctica	CAP2.2016	3.23	-11.98	1.4	36.2	0.14
8	A. antarctica	CAP3.2016	3.81	-12.39	0.9	36.7	0.12