Edith Cowan University
Centre for Marine Ecosystems Research and,
Centre for People, Place and Planet

Keep Watch Seagrass Monitoring 2026 Report for GeoCatch

Ankje Frouws and Kathryn McMahon





No portion of this material may be reproduced or communicated without the permission of GeoCatch and ECU, unless the reproduction or communication is authorised by law. ECU 2026.

Keep Watch Seagrass Monitoring, 2026. Report to GeoCatch.

Ankje Frouws and Kathryn McMahon

Cite as:
Frouws and McMahon (2026). Keep Watch Seagrass Monitoring, 2026. Report to GeoCatch. Centre for Marine Ecosystems Research and Centre for People, Place and Planet, Edith Cowan University 35 pages.

This work was funded by GeoCatch and Water Corporation and in collaboration with Department of Biodiversity, Conservation and Attractions.

EDITH COWAN UNIVERSITY



Table of Contents

1 Executive Summary 5

2 Introduction 7

3 Methods for Keep Watch – Seagrass health monitoring program 8

3.1 Seagrass monitoring 8
3.2 Laboratory processing 12
3.3 Trigger assessment 12

4 Results 13

4.1 Shoot density 13
4.2 Trigger assessment 15
4.2.1 Trigger 1 15
4.2.2 Trigger 2 15
4.2.3 Trigger 3 15
4.3 Epiphytes 16
4.4 Other observations 18
4.5 Nutrient content 19
4.6 Water quality 25

5 General conclusions 26

5.1 Baywide declines in shoot density 26
5.2 Nitrogen exposure is low but some changes in the sources 28
5.3 Keep Watch program continuing 28

6 References 29

Appendix 1: Randomly generated quadrat positions from 2026 survey. 30

Appendix 2: Raw and summary statistics for shoot density data for the seven Keep Watch Seagrass Monitoring Sites in 2026. 31

Appendix 3: Leaf morphology data on shoot length and width of *Posidonia sinuosa* for 2026 32

Appendix 4: Trends over time in seagrass shoot density of *Posidonia sinuosa* from 2012 to 2026. 33

Appendix 5: Nutrient data for 2026 including the original (O) and modified (M). ..35

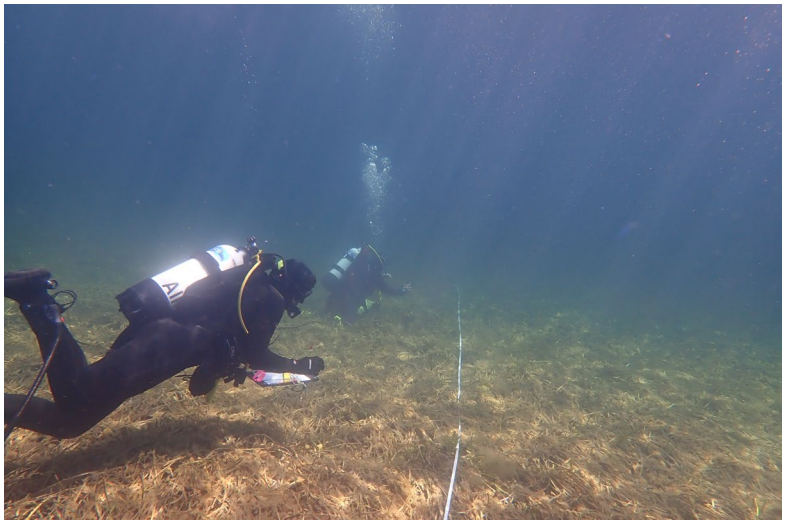
Keep Watch Seagrass Monitoring

Annual Report 2026

Investigator: Ankje Frouws and Kathryn McMahon

A project funded by GeoCatch and Water Corporation in collaboration with the Department of Biodiversity, Conservation and Attractions.

October 2026



1 Executive Summary

Researchers from Edith Cowan University and scientists and rangers from Department of Biodiversity, Conservation and Attractions and Ngari Capes Marine Park conducted the Keep Watch seagrass monitoring at seven *Posidonia sinuosa* sites and three *Amphibolis antactica* in Geographe Bay from the 10th – 12th February 2026. This has been carried out consistently for 15 years, since 2012.

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. Over time, global warming and marine heatwaves are also considered a threat to these seagrass meadows. The aim of the program is to 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 and macroalgae nutrient content and nitrogen isotope signals are also measured to help interpret any changes. Three management triggers have been established for Geographe Bay to detect changes in shoot density outside normal annual variation.

Key finding 1

This year all *Posidonia sinuosa* sites showed a decline in shoot density, the indicator used to assess seagrass condition. This is the first time that all sites have shown a decline. The greatest declines occurred at four sites in the central region, Buayanup, Vasse Diversion, Busselton Jetty and Port Geographe where shoot density declined by 30-40%. Despite these declines, the management triggers were not breached as Trigger 1 requires a >50% reduction from one year to the next, Trigger 2 requires a >20% decline two years in a row and Trigger 3 requires a significant decline over time, and none of these conditions were observed. For the two years prior to 2026, there were large increases at these sites, so the decline this year may represent natural fluctuations.

Key finding 2

Three of these sites, Buayanup, Vasse Diversion and Busselton Jetty also had an increase in epiphyte cover from Low or Moderate, up to High cover. High epiphyte cover for extended periods can lead to shoot loss, however observations of high epiphyte cover in the past in Geographe Bay have not been associated with shoot declines. The most common epiphyte cover at these sites was microalgal accumulations which are an unusual feature of seagrass meadows in Geographe Bay over the summer months.

Key finding 3

Nutrient content of seagrasses in Geographe Bay continues to be low with the main sources of nitrogen for seagrass at most sites likely to be from fixation of atmospheric nitrogen and/or agricultural fertilisers. This was confirmed by both seagrass and macroalgal tissue nutrient content and nitrogen isotope signals. There is no indication that elevated nutrients have caused the recent seagrass decline. Capel continues to

have higher nutrient exposure and different sources, potentially with loads increasing in the last two years based on the seagrass nutrient data. The higher nitrogen isotope signal at Capel suggests that nitrogen derived from animal wastes, septic tanks or from natural vegetation is also a main source. As the nitrogen isotope signal increased at Vasse Diversion Drain, seagrasses have been exposed to different sources of nitrogen this year, potentially less exposure to nutrients derived from fertiliser runoff. There is no evidence that nitrogen derived from treated sewerage is a major source of nitrogen for Geographe Bay seagrasses.

Recommendation 1

The Keep Watch annual seagrass monitoring program in Geographe Bay, a collaboration between ECU, DBCA and GeoCatch, funded in part by Water Corp will continue for another five years. All sites will be re-assessed for shoot density, epiphyte cover and nutrient content as well as nitrogen isotope ratio to indicate potential nutrient sources for the seagrass. If the four sites with >20% declines, have subsequent declines in 2027, this would be a breach of Management Trigger 2 and further investigations would be recommended.

Recommendation 2

This program assesses the condition of seagrass meadows but for a wholistic ecosystem approach should be combined with seagrass mapping every 5 years. As a range of mapping methodologies are available a mapping exercise should ensure that changes can be compared with previous data sources.

Recommendation 3

With nutrient exposure increasing at the Capel site there is value in exploring nutrient loads and catchment management practices to assess if, nutrients loads have changed and if any modifications are required.



2 Introduction

This document is produced for GeoCatch by Ankje Frouws and Kathryn McMahon from Edith Cowan University. It reports on the Keep Watch seagrass monitoring survey that was undertaken in February 2026 and compares to data from the 2012-2025 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 collaboration with 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 (see 3.1.3 for summary of triggers). This report includes data on two seagrass species (*Posidonia sinuosa* and *Amphibolis antarctica*) 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. Based on the 10-year review workshop held in Busselton on 17th November 2021 since 2022 samples of macroalgae (*Dictyota*) have also been collected for nutrient and isotope analysis. This is to explore the potential for incorporating algae into the monitoring program as there were concerns raised in the review that macroalgae cover was increasing at Capel. Macroalgae from the genus *Dictyota* were selected as most suitable to monitor as this genus is most commonly observed among sites. This year macroalgae (*Dictyota*) samples from Dunsborough, Vasse Diversion, Forrest Beach and Capel were included in the nutrient and isotope analysis. All raw data (except for technical replicates) 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

The "Keep Watch" annual seagrass monitoring program is based on the methods recommended by McMahon (2012) and reviewed and modified in 2021. 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, Figure 6). 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 on the 9th – 12th of February 2026. At Capel (8) there are high relief rocky reefs surrounded by bare sand that can be reached from the shore. On the reef there are patches of *A. antarctica* seagrass and *Dictyota* that were collected for nutrient analysis in 2m depth. *A. antarctica* was collected at Vasse Diversion Drain (3) and Forrest Beach (7) sites as a comparison to Capel (8). Since 2022, due to the reduced abundance of *Amphibolis* at Busselton Jetty (4) from the dieback of *A. antarctica* in 2017 and no subsequent recovery, no samples were collected here.

Table 1: Details for eight Keep Watch sites, seven in *Posidonia sinuosa (Ps)* meadows (1-7) and one in rocky reef with *Amphibolis antarctica (Aa)* patches (8) in Geographe Bay. One macroalgae species (*D* = *Dictyota*) was also assessed in four of these sites. Coordinates are decimal degrees based on the WGS84 grid system.

Site Name & #	Coordinates	Depth (m)	Date	Seagrass species assessed	Macroalgal species assessed
1. Dunsborough	S 33.61654°, E 115.12865°	4	11/02/2026	*Ps*	*D*
2. Buayanup	S 33.65233°, E 115.24840°	4	10/02/2026	*Ps*	
3. Vasse Diversion Drain	S 33.64746°, E 115.32379°	4.5	09/02/2026	*Ps, Aa*	*D*
4. Busselton Jetty	S 33.63896°, E 115.34315°	4.5	09/02/2026	*Ps*	
5. Port Geographe	S 33.62846°, E 115.38240°	4.5	11/02/2026	*Ps*	
6. Vasse-Wonnerup	S 33.60188°, E 115.42345°	5	10/02/2026	*Ps*	
7. Forrest Beach	S 33.57295°, E 115.44908°	5	10/02/2026	*Ps, Aa*	*D*
8. Capel	S 33.51394°, E 115.51508°	2	12/02/2026	*Aa*	*D*

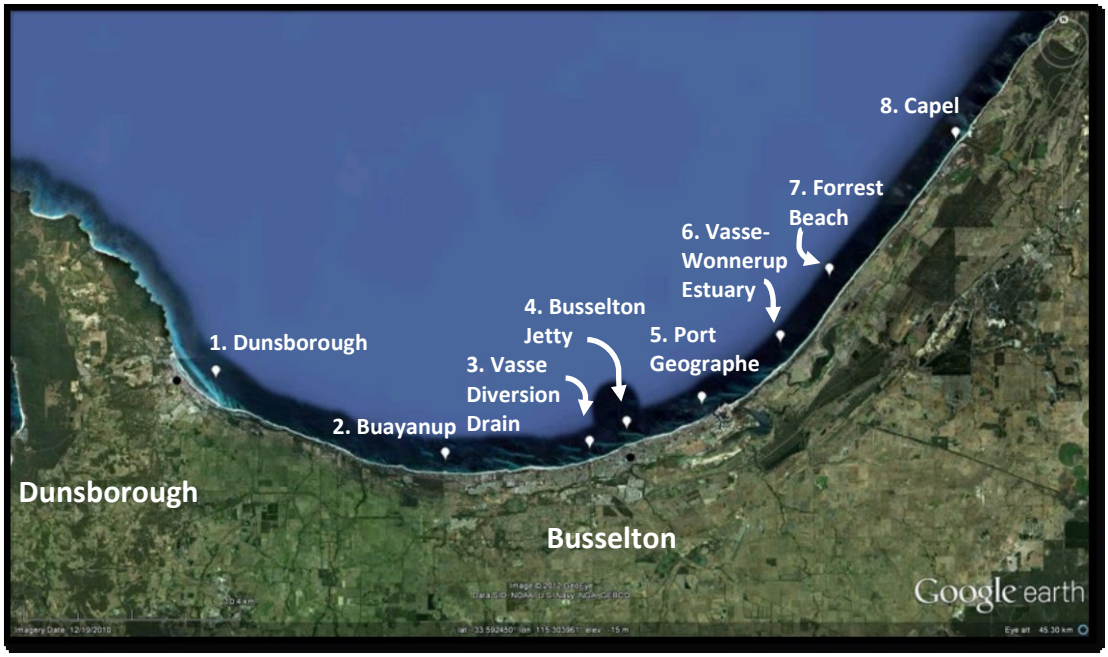


Figure 1*: Map of Geographe Bay, showing the location of the 8 seagrass sampling sites (1. Dunsborough, 2. Buayanup, 3. Vasse Diversion Drain, 4. Busselton Jetty, 5. Port Geographe, 6. Vasse-Wonnerup Estuary, 7. Forrest Beach and 8. Capel).*

Each seagrass site was located at least 30 m from the edge of the meadow and the centre 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. Middle: Star picket with cap indicating centre of 50 m diameter Keep Watch seagrass site. Right: Permanent cattle tag with site label.*

At each site *P. sinuosa* shoot density was counted in 30 0.2 x 0.2 m quadrats (0.04 m^2 area). 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 *A. antarctica* or *Amphibolis 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 them 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 three different quadrats. This was repeated until there was less than a 5% error with counting, i.e. a maximum difference of 1 shoot for a quadrat with 20 shoots and a maximum difference of 3 shoots for a quadrat with 60 shoots.

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.

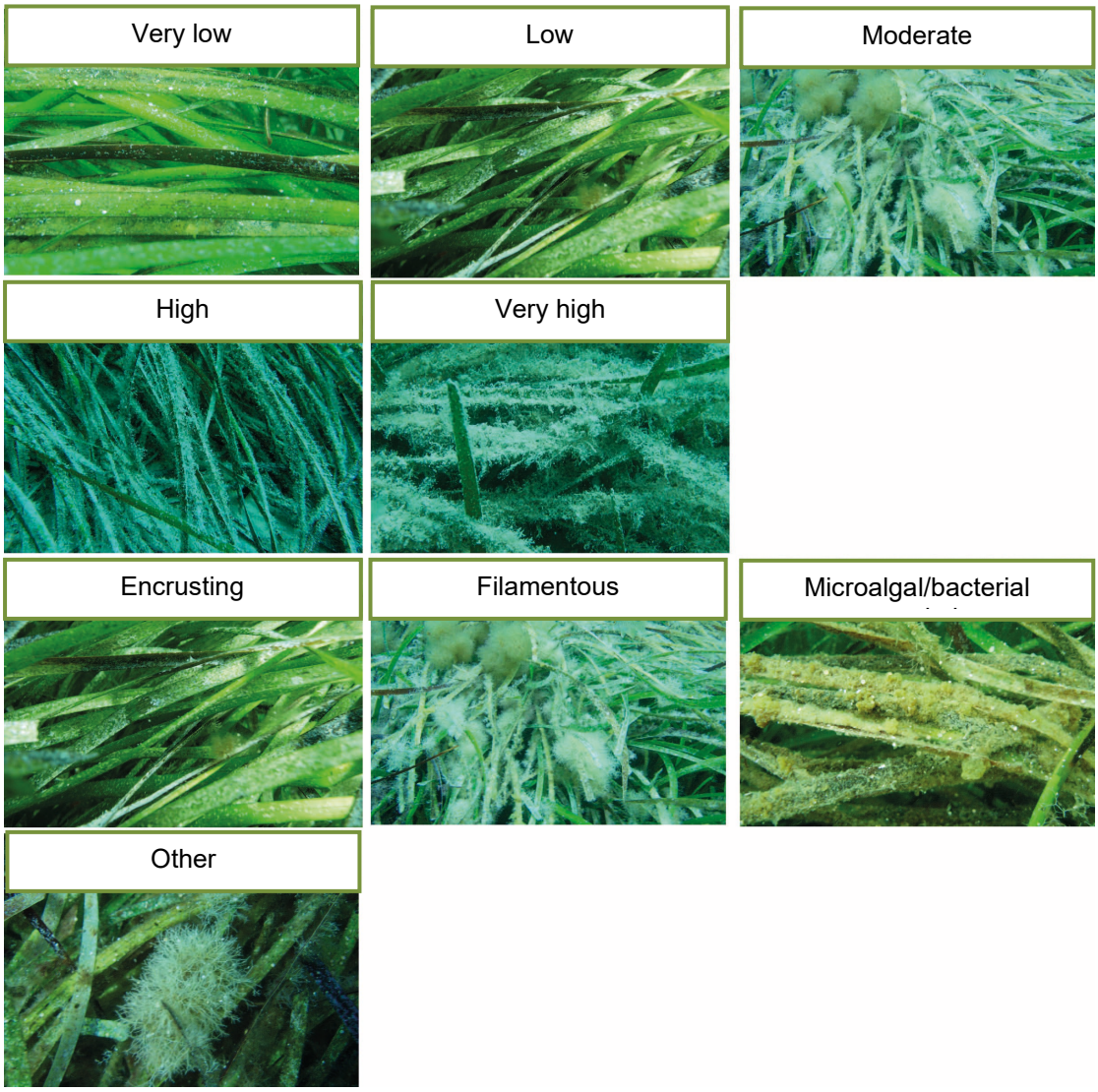


Figure 4: *Classification of epiphytic algal cover (very low-very high) and type (encrusting-other).*

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 total C, N, P as well as nitrogen stable isotope analysis ($\delta^{15}N$) 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 Vasse Diversion, Forrest Beach and Capel sites for the same type of nutrient analysis. Four algal samples (*Dictyota*) were collected at Dunsborough, Vasse Diversion, Forrest Beach and Capel for the same type of nutrient analysis as well.

At each site the Secchi disk depth (m) and temperature (°C) were recorded from the boat. Field work was carried out by Kathryn McMahon (KM) from ECU with Glen Sutton (GS), Simone Strydom (SS), Kate Livingston (KL) and Cam Bates (CB) from the Department of Biodiversity, Conservation and Attractions (DBCA). Samples were processed by Ria Heemskerk and Ankje Frouws and data analysed by Ankje Frouws. This year the DBCA research vessel "Wattern" was used for diving activities. The monitoring program was funded through sponsorship by Water Corporation and in collaboration with Department of Biodiversity, Conservation and Attractions staff.

3.2 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 from both the seagrass and algal samples were removed by gently scraping, and the leaves placed in the oven at 60°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 ECU using a continuous flow Thermo Scientific™ EA IsoLink™ IRMS system consisting of a Flash IRMS Elemental Analyzer, Delta V Advantage IRMS and Conflow IV Universal Interface. Several replicate samples were analysed for quality control and for those samples the mean of both replicate values was used for the C, N and $\delta^{15}N$ value for the sample. Total phosphorus (<0.05 $mg.P.g^{-1}$) was analysed at ECU by acid digest followed by ICP-OES, the same method that has previously been used.

As presented in 2021, the laboratory that performed the C, N and $\delta^{15}N$ analysis changed in 2020 from UWA to ECU and there was a slight offset between ECU and UWA laboratories. This offset has been applied again this year to the C and N data. In this report the 2020 to 2026 data was modified as follows N% [y=1.063x - 0.5653], δN [y=1.0725x - 0.55824], δC [y=0.9846x - 2.1902] and C% [y=0.4568x + 24.225] where x is the ECU laboratory result for each respective variable.

3.3 Trigger assessment

To assess change over time, and to keep watch on the health of the seagrass, three triggers proposed by McMahon (2012) and agreed upon by GeoCatch were used. 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, 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 1026-1560 shoots m^{-2} across the seven sites (Figure 5). Compared to the previous year, there was a reasonably sharp drop in shoot density for all sites, but this drop was especially clear in Buayanup, Vasse Diversion, Busselton Jetty and Port Geographe where there was a decline of over 30%. This year was also the lowest shoot density ever recorded at Buayanup. Dunsborough (1560 shoots m^{-2}) had the highest shoot density, followed by Forrest Beach (1316 shoots m^{-2}), whereas Port Geographe (1026 shoots m^{-2}) and Vasse Diversion (1056 shoots m^{-2}) had the lowest shoot density. The remaining sites ranged between 1199-1244 shoots m^{-2}. All raw data is in Appendix 2.

Last year all seven sites increased in shoot density, from 5- 47% with four out of the seven sites increasing >30% in shoot density. This year shoot density decreased in all sites, with 7-39% with the four sites described above declining by more than 30% (Table 2). This has resulted in shoot densities, similar or slightly lower than two years ago. Since the first year of monitoring there has been a net increase at most sites (2-31%%) except for Forrest Beach where there has been no change, and Buayanup where a 16% decline in shoot density was observed between 2012-2026.

P. sinuosa average shoot length ranged from a minimum of 20.5 cm at Port Geographe to a maximum of 99.9 cm at Vasse-Diversion and a range in average width of 4.0-7.0 mm (Appendix 3).

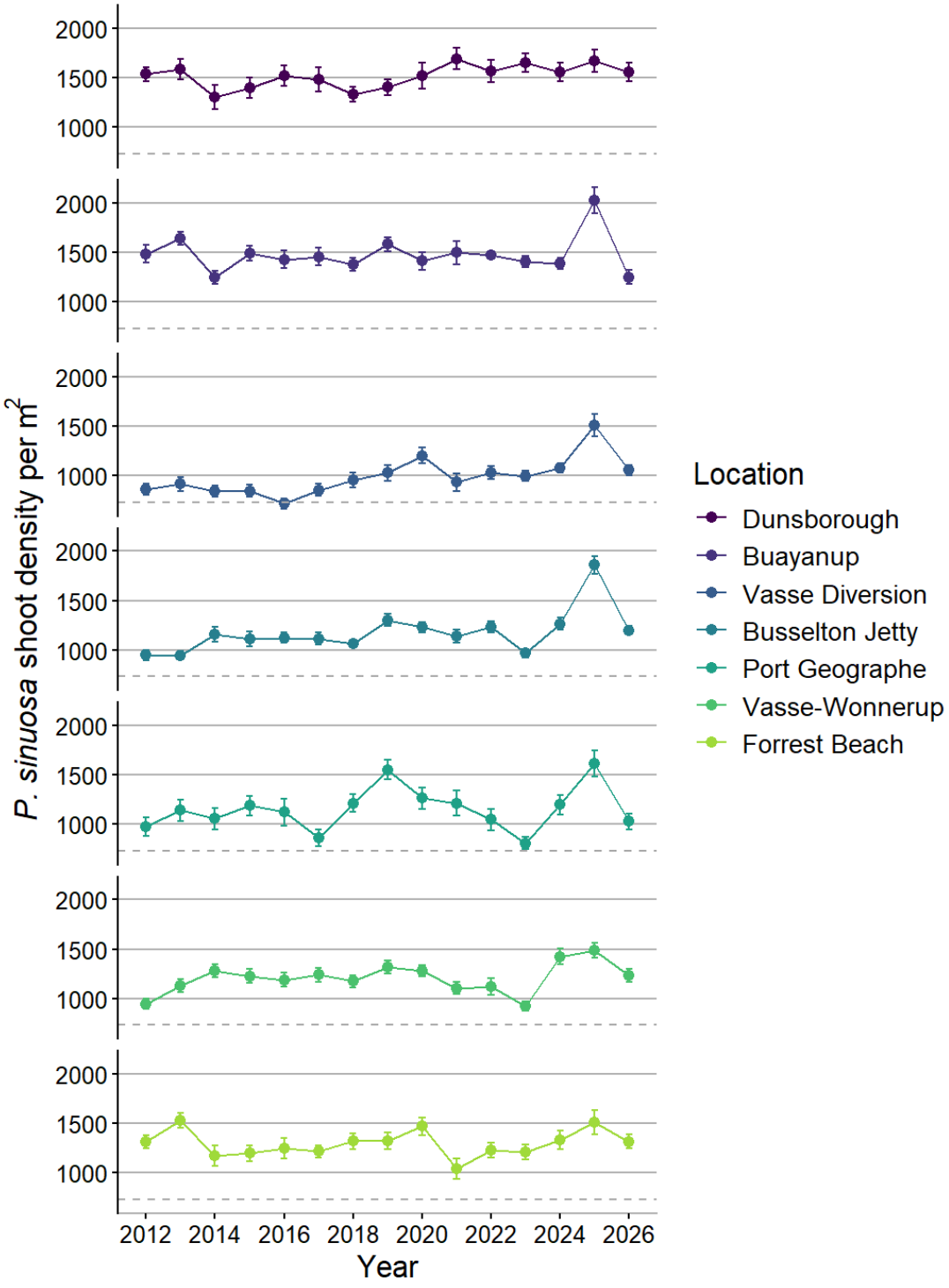


***Figure 5**: Shoot density (average m^{-2} ± se) at the seven Keep Watch seagrass monitoring sites with* P. sinuosa *meadows in January or February 2012-2026. Dark grey dotted lines indicate the maximum site average (729.17 shoots m^2) from the reference sites at 3-5 m in Shoalwater Bay and Jurien Bay Marine Parks from 2024 (data courtesy of DBCA, 2025).*

***Table 2**: Change assessment based on Trigger 1 and 2, shown as percentage change in* P. sinuosa *shoot density between years. 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%. Note that the last column shows change over the duration of the monitoring, between 2012-2026.*

Percentage change in shoot density between years								
Site	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
1. Dunsborough	3	-18	7	9	-3	-10	5	8
2. Buayanup	11	-24	20	-7	2	-5	15	-11
3. Vasse Diversion	6	-8	0	-15	19	12	8	17
4. Busselton Jetty	0	22	-4	1	-1	-5	23	-6
5. Port Geographe	17	-7	12	-6	-23	41	28	-19
6. Vasse-Wonnerup	19	13	-4	-3	4	-5	13	-3
7. Forrest Beach	16	-23	2	5	-3	8	0	11

Site	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**2024-25**	**2025-26**	**2012-26**
1. Dunsborough	11	-7	6	-6	7	-7	2
2. Buayanup	6	11	-17	9	34	-39	-16
3. Vasse Diversion	-23	11	-4	9	40	-30	23
4. Busselton Jetty	-8	9	-22	31	47	-35	28
5. Port Geographe	-8	-10	-21	48	32	-36	5
6. Vasse-Wonnerup	-14	1	-18	55	5	-17	31
7. Forrest Beach	-29	18	-1	10	14	-13	0

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 2025-2026).

4.2.2 Trigger 2

As there were no declines of 20% or more over two consecutive years this threshold was not triggered (Table 2, % change 2024-2025 & 2025-2026). However, four sites Buayanup, Vasse Diversion, Busselton Jetty and Port Geographe with >20% decline this year need to be checked again in 2027 in relation to this trigger.

4.2.3 Trigger 3

This threshold was not triggered as no sites showed a significant decline over time. Interestingly, two of the sites, Vasse Diversion and Busselton Jetty, showed a significant, positive, linear trend over the fourteen years, indicating increases in shoot density over this time period (Table 3).

***Table 3**: Mann-Kendall Trend statistic to assess if there has been a significant decline over time in shoot density from 2012-2026. The annual rate of change (increase/decline) in shoot density has been given for sites with a significant change over the monitoring period.*

Site Name & #	Significance (p<0.05)	Overall slope	Rate of change	R^2
1. Dunsborough	ns	+ve		26%
2. Buayanup	ns	+ve		4%
3. Vasse Diversion	significant	+ve	1.15	47%
4. Busselton Jetty	significant	+ve	1.12	33%
5. Port Geographe	ns	+ve		5%
6. Vasse-Wonnerup	ns	+ve		12%
7. Forrest Beach	ns	+ve		1%

4.3 Epiphytes

This year epiphyte cover increased for half of the sites (from Moderate to High at Buayanup, from Low to High at Vasse Diversion, from Low to High at Busselton Jetty), declined for two sites (from Moderate to Low for Dunsborough and Forrest Beach) and remained stable for the remaining two sites (Moderate for Port Geographe and Low for Vasse Wonnerup) (Table 4, Figure 6). There were three sites with high epiphyte cover this year, but this has been observed in some of the previous years as well (e.g. 2020, 2021, 2024). The type of epiphyte cover was consistent amongst the five Eastern sites, Vasse Diversion to Forrest Beach, with microalgae dominating for most of these sites while the two Western sites (Dunsborough and Buayanup) are dominated with Other algae types.

Table 4: Algal epiphyte cover at the Keep Watch seagrass monitoring sites, 2012-2026, Du = Dunsborough, Bu = Buayanup, VD = Vasse Diversion Drain, BJ = Busselton Jetty, PG = Port Geographe, VW = Vasse-Wonnerup, FB = Forrest Beach. Very low (VL), Low (L), Moderate (M), High (H) and Very High (VH). Algal types were filamentous (F), encrusting (E), microalgal aggregations (M) and other (O). If the category is capitalised it means it is dominant, lowercase indicates present but not dominant.

Site	Algal cover														
	2012	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**	**-19**	**-20**	**-21**	**-22**	**-23**	**-24**	**-25**	**-26**
Du	M	L	M	M	L	L	M	M	M	L	M	M	M	M	L
Bu	M	L	M	M	H	H	M	VL	H	H	H	H	H	M	H
VD	L	M	H	H	H	H	H	L	H	H	H	M	H	L	H
BJ	L	L	H	H	M	M	M	L	H	H	H	M	M	L	H
PG	L	VL	L	L	M	M	M	L	M	M	M	M	H	M	M
VW	L	VL	L	M	L	L	L	VL	L	M	L	M	L	L	L
FB	L	VL	L	L	L	VL	L	VL	L	L	VL	L	M	M	L
	Algal Type														
	2012	**-13**	**-14**	**-15**	**-16**	**-17**	**-18**	**-19**	**-20**	**-21**	**-22**	**-23**	**-24**	**-25**	**-26**
Du	O,f,m	F,O	O	O,m	O	O,e,m	O,m	O,m	O,m	O	O,m	O	M,o	E,M,o	O,m
Bu	M,o	E,O	M,o	M,o	M,o	M,e,o	M,o	O,m	M,o,e	M,o	M	M	M,o,f	E,M	M
VD	M,o	E,O	M,o	M,o	M,o	M,o	M,o	O,m	M,o,e,f	M	M,o	M	M,o	E,M,O	M
BJ	M,o	O	M	M,f	O,e,m	M,o,e	O,M	O,m	O,m,e,f	M	M,o	M	M,O	E,M,o	M,o
PG	E,o	E,M	M,e	M,f	O,f	M,o,e	O,M	M	M,o	M,o	M,o	M	M,O	M,o	M
VW	E,o,m	E,O	M,f	O	E,o,m	E,m	O,M	O	O,e	M	M	O	O	M,O	O
FB	E,M,o	F,E	M,f	O,e	E,o	E,o	O,e	O	E,m,o	O	E,m	E	O,m	E,O	O,e

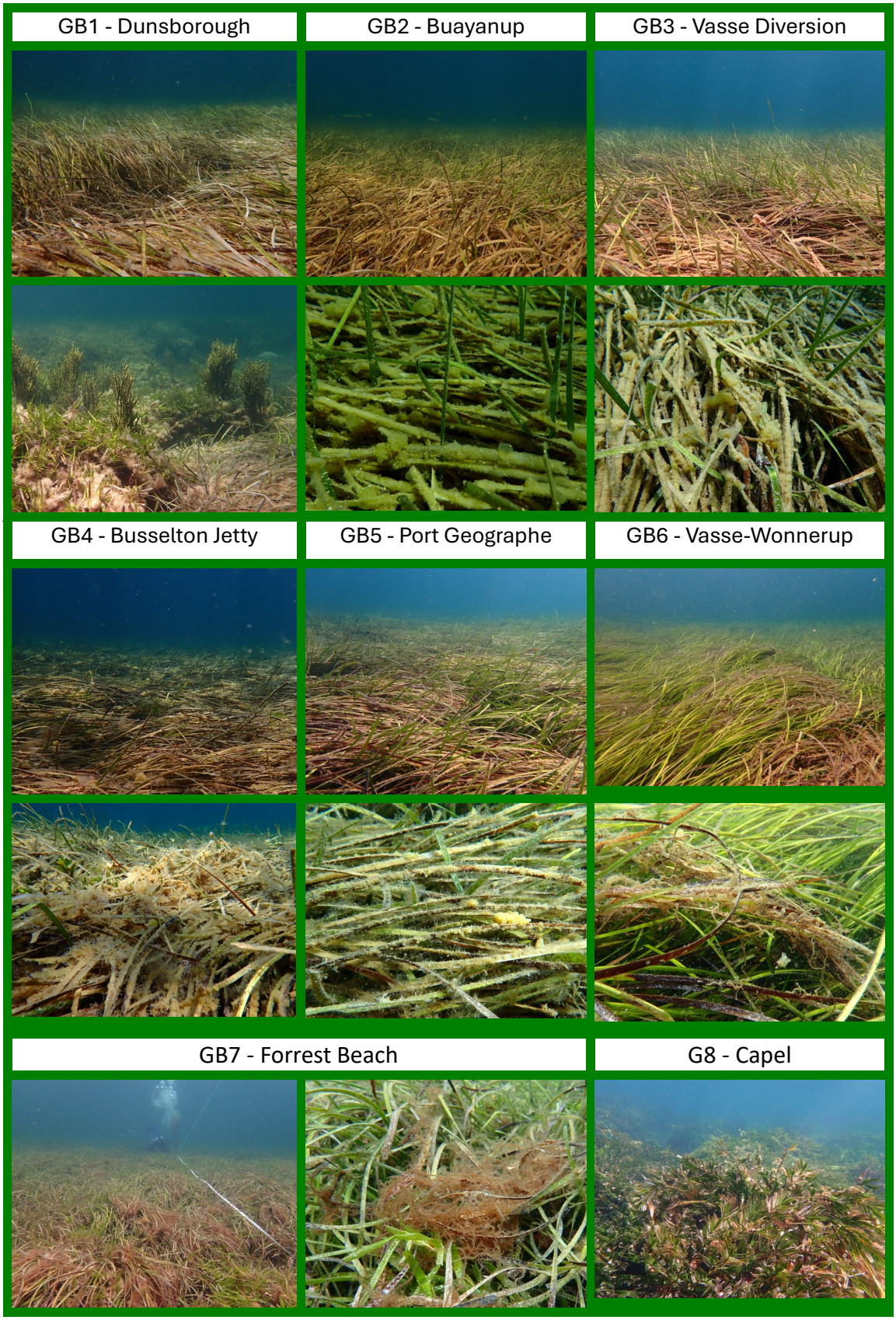


***Figure 6**: Pictures of seagrass meadow (top picture) and the dominant algal epiphytes (bottom picture) at each* P. sinuosa *site (dominant algal type is shown on the right of the seagrass meadow picture for Forrest Beach). The last picture shows the rocky substrate with macroalgae at the* A. antarctica *site (8. Capel).*

4.4 Other observations

A. antarctica was observed at all sites except Buayanup and Vasse-Wonnerup and *A. griffithii* was also growing at Dunsborough, Forrest Beach and Capel. Seedlings of *P. sinuosa* were observed at all *P. sinuosa* sites this year, except for Port Geographe and flowering shoots were observed at all sites, except for Port Geographe (Appendix 2). Note that flowering shoots are difficult to spot in the field and are more commonly seen by experienced observers. Some potential anchor damage was observed at Vasse-Wonnerup and Forrest Beach, and blowouts remain at the Dunsborough site since monitoring began, most likely from water movement (Figure 7). Small bare or sparse patches were noted at Vasse Diversion Drain, Port Geographe and Vasse-Wonnerup, indicating historical and potentially some small-scale recent shoot loss, but no obvious dead blackened leaves were observed at any of the sites. There was extensive wrack visible in Port Geographe, which could originate from near or distant meadows, and some wrack at Dunsborough where some leaf damage was also observed in the form of whitened leaf tips. This is common from high light conditions.

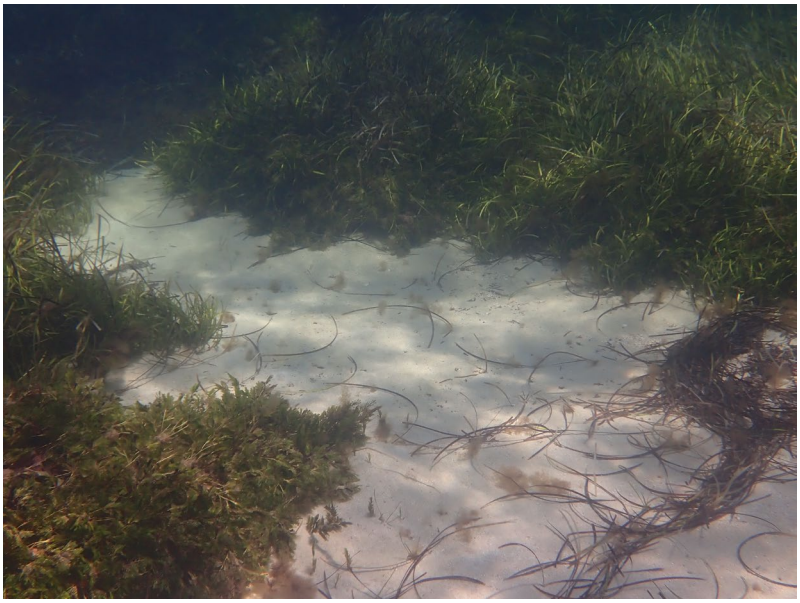


***Figure 7**: Picture of seagrass blowout observed at the Dunsborough site in 2025.*

4.5 Nutrient content

The nitrogen content of *P. sinuosa* leaves ranged from 0.50-0.78% N dry weight (DW), within the range observed over the last five years (Figure 8). Once again, the nitrogen content of *A. antarctica* leaves was slightly higher, ranging from 0.63-1.59% N DW. The highest nitrogen concentration was at Capel, with an increase in concentration for the last two years in a row, reaching the higher end of the range recorded over the life of the monitoring program.

The phosphorus content of *P. sinuosa* leaves in 2025 ranged from 0.08-0.13% P DW, similar to the range observed over the last four years (Figure 8). For *A. antarctica* leaves, the phosphorus content ranged from 0.06-0.11% DW with the concentration at Capel slightly higher than Vasse Diversion Drain and Forrest Beach (Figure 9). All raw data is in Appendix 5.

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

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

Date collected	**Study**	***P. sinuosa*** **TN (% DW)**	**TP (% DW)**	$\delta^{15}N$	***A. antarctica*** **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			

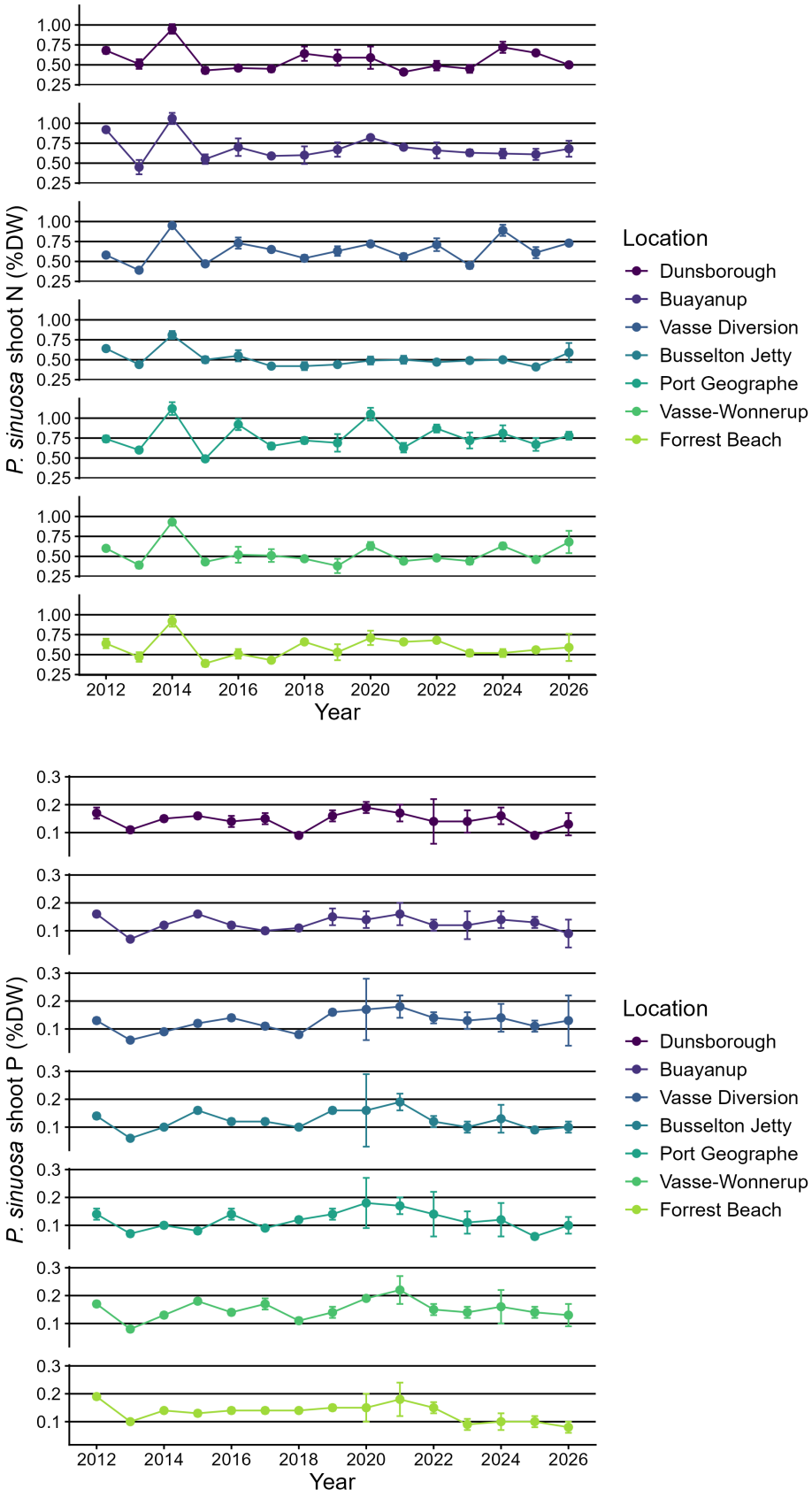


Figure 8: *Nitrogen and phosphorus content (% DW) of* P. sinuosa *leaves (average ± se) at the Keep Watch seagrass monitoring sites (Dunsborough-Forrest Beach) in 2012-2026.*

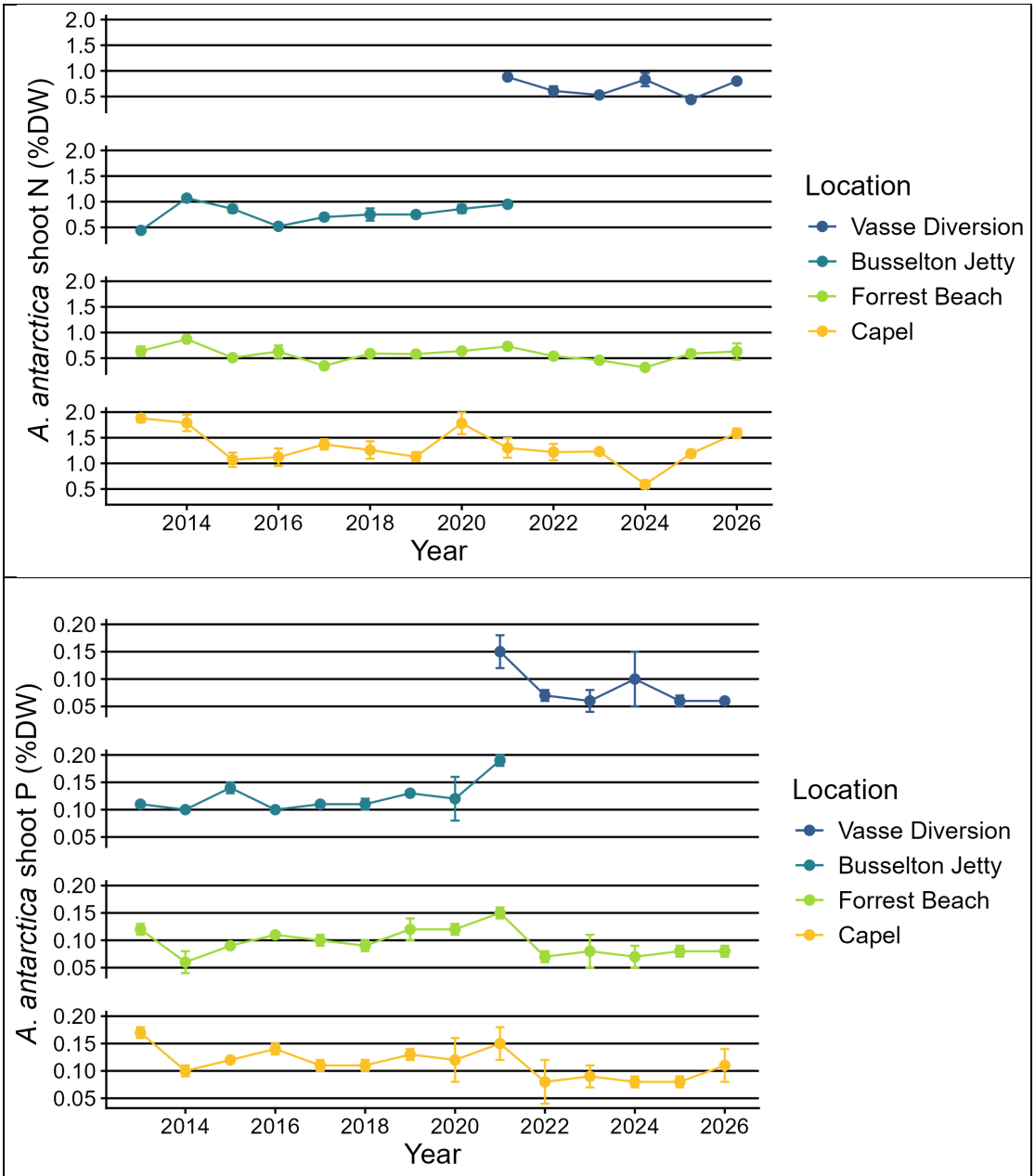


Figure 9: *Nitrogen and phosphorus content (% DW) of* A. antarctica *leaves (average ± se) at the Keep Watch seagrass monitoring sites in 2013-2026. Note that sampling at Busselton Jetty ended in 2021 and with a new site established at Vasse Diversion drain.*

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

The $\delta^{15}N$ of *P. sinuosa* leaves ranged from 0.50 to 2.23 ‰. $\delta^{15}N$ signals dropped slightly or stayed similar at most sites, with the exception of Vasse Diversion Drain and Port Geographe that increased by ~ 1‰ compared to last year. All values are in the range that has been observed over the life of the monitoring program (Figure 10). The nitrogen isotope signals in the seagrass leaves indicate that this year seagrasses are mostly receiving a mix of sources, but the main sources could be either from fixation of atmospheric nitrogen or agricultural fertilisers, as the signal is close to 0‰ with other sources contributing a small amount. There is no evidence that nitrogen derived from treated sewerage is the main source for seagrasses, if this was the case, we would expect the signal to be much higher, around 9 ‰.

The $\delta^{15}N$ signal of *A. antarctica* leaves ranged from 2.06-2.76‰, increasing at all sites. The greatest compared to last year occurred at Vasse Diversion Drain, the highest vale recorded to date at this site (Figure 10). As in previous years, the highest values were observed at Capel, and these was only a slight increase here this year. But the other sites are approaching these higher values, indicating that the sources of nitrogen that the plants receive may be more similar among sites this year. All raw data is in Appendix 5.

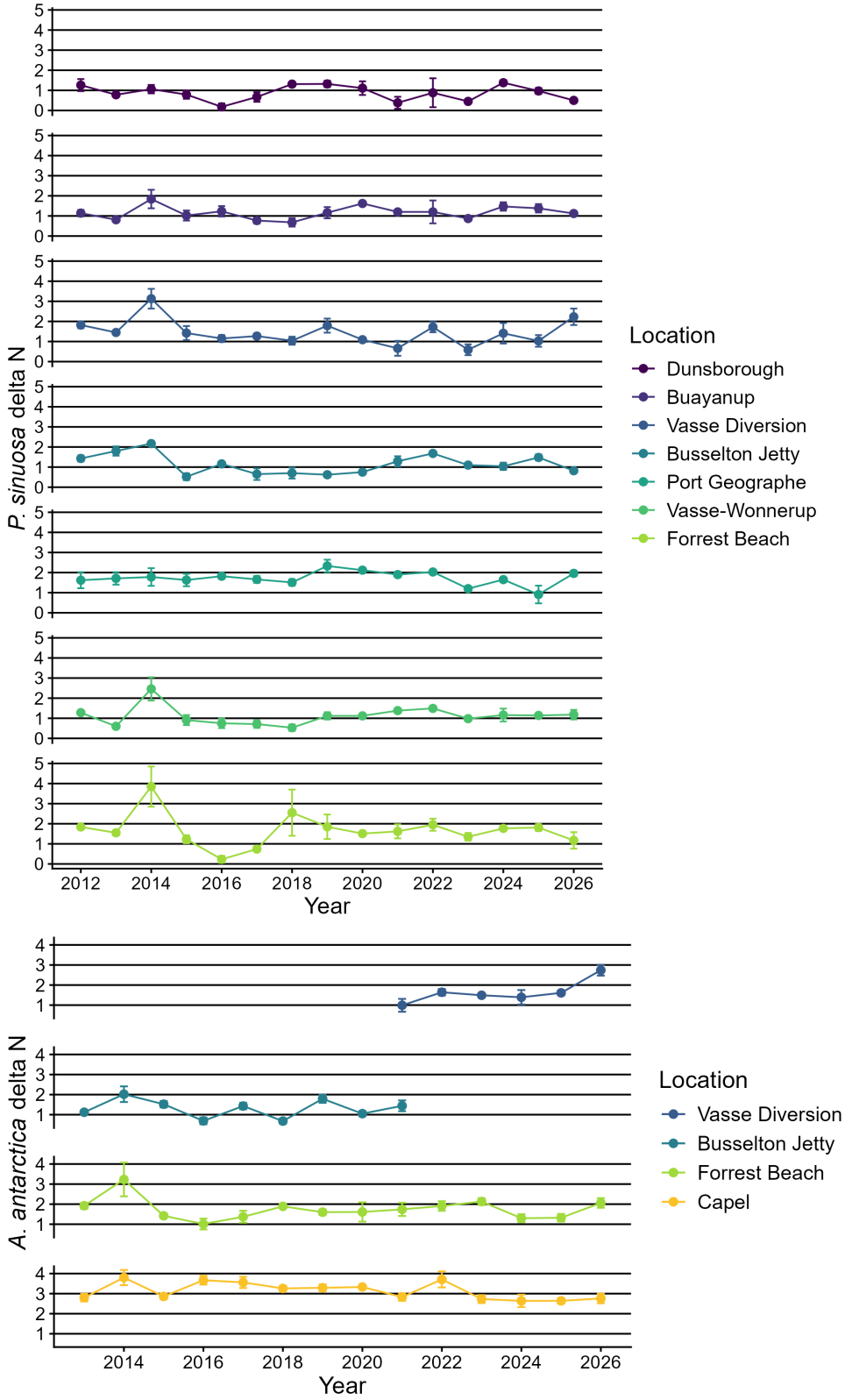
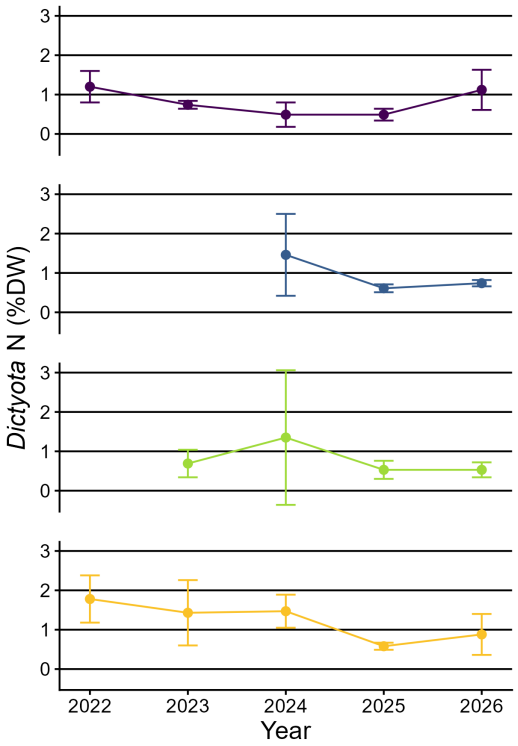


Figure 10: *$\delta^{15}N$ of* P. sinuosa *leaves (Site 1-7) and* A. antarctica *leaves (Site 4, 6, 7 & 8; average ± se) at the Keep Watch seagrass monitoring sites in 2012-2025 for* P. sinuosa *and 2013-2025 for* A. antarctica*. Note that only Capel was measured in 2012 for* A. antarctica*, and is not included in these graphs.*

The epiphytic macroalgae, *Dictyota* had higher phosphorus content (% DW) at Capel compared to the other sites (0.08% DW vs 0.03-0.04% DW), the nitrogen content was highest at both Capel and Dunsborough compared to Vasse Diversion and Forrest Beach (~1.0% vs <0.75% DW). The phosphorus and nitrogen were in the range of what has been observed in previous years, and at the lower end of the range for Capel (Figure 11). For Dictyota, the $\delta^{15}N$ signal remains highest at Capel (1.87 ‰) compared to the other sites (-1.18 to -0.69 ‰), indicating different sources of nitrogen between Capel and other sites. Across all sites, values were similar to last year (Figure 11).



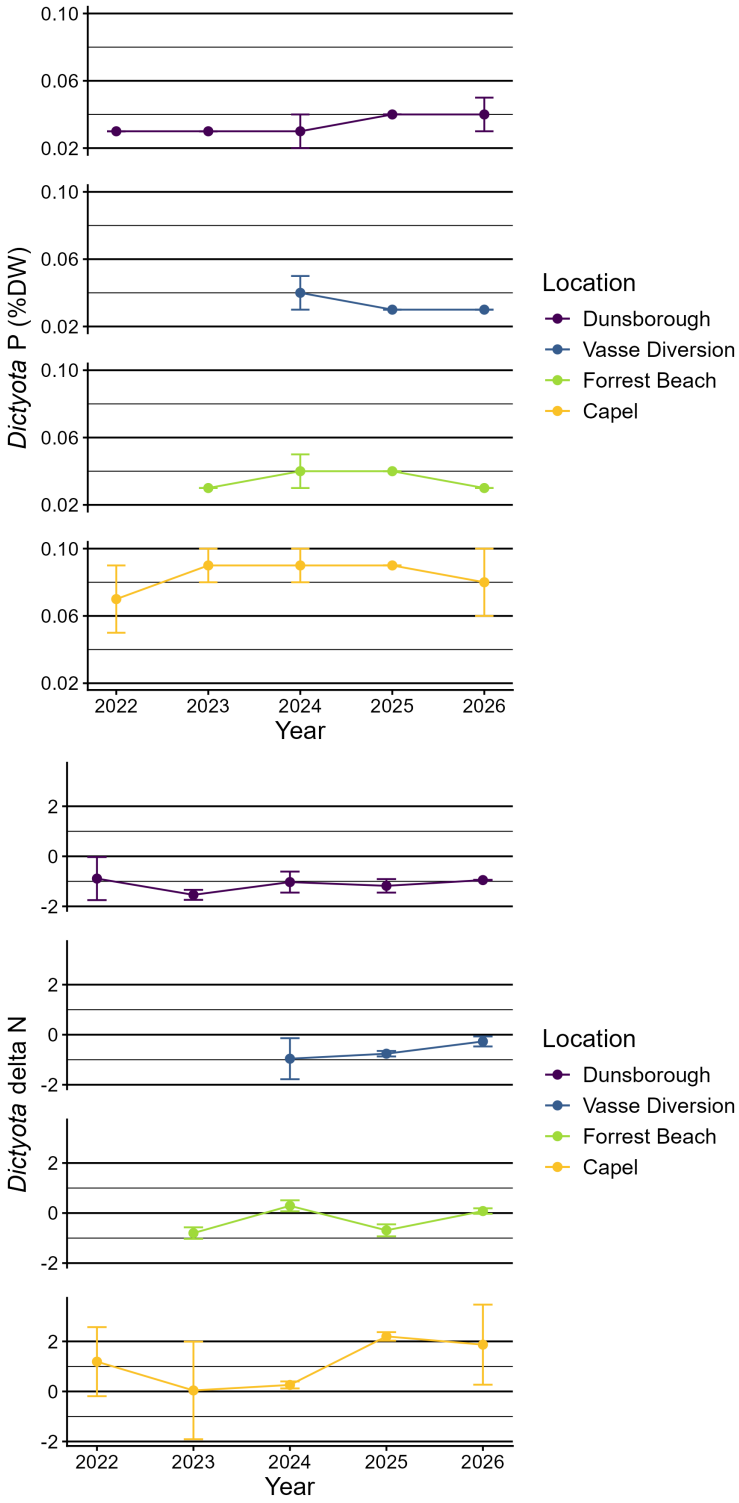


Figure 11: *Nutrient (N, P) and $\delta^{15}N$ of the epiphytic macroalgae* Dictyota *from Keep Watch Seagrass monitoring sites from 2022-2025. Note that Forrest Beach only has been sampled in 2023-2026 and Vasse Diversion only in 2024-2026.*

4.6 Water quality

Water temperature at the Keep Watch seagrass sites ranged from 21.5-23.1°C during sampling, within the range observed for previous years. Water clarity was high and

the Secchi disk was always observed on the bottom except for Vasse Wonnerup and Forrest Beach where visibility was at least 4m (Table 6).

Table 6: *Water quality measures at the Keep Watch seagrass monitoring sites from 2012-2026, Du = Dunsborough, Bu = Buayanup, VD = Vasse Diversion Drain, BJ = Busselton Jetty, PG = Port Geographe, VW = Vasse-Wonnerup, FB = Forrest Beach, *=Secchi disk depth on bottom.*

Site	Secchi disk depth (m)														
	2012	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Du	4.2*	3	3	3.2*	3*	3.5*	2.7	2.7	4.0*	3.3	4.0*	3.5*	3.4*	4.2*	4.0*
Bu	3.5	2.5	3*	3.2*	3.5*	2.5*	3*	2.8	3.5*	3.2	3.5*	3.5*	3.2*	3.8*	4.0*
VD	4	3.25	3.5*	3.6*	3.5*	5*	3.3	3	3.5*	3.4	4.0*	4.0*	3.7*	4.0*	4.5*
BJ	4.2	2.5	3.5	3.6*	3.5*	2.5*	4*	2.9	3.5*	3.1	4.5*	3.7*	3.3*	2.4*	4.4*
PG	3.75	2.5	4	4.1*	3.5	4.5*	3.5*	3.2	3.0*	4.5*	3.5*	3.6*	3.3*	2.7*	3*
VW	4	2	4.5	4.6*	4.5*	4*	4.5*	4	4.5*	5.4*	5.0*	4.6*	4.1*	5.2*	4
FB	5*	2	4	4.2*	4.5*	4*	3.5	3.8	4.5*	5*	5.0*	4.3*	4.4*	4.8*	4.5
	Temperature (°C)														
	2012	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Du	22	22.5	23.1	23.3	22.9	22.5	21.2	20.6	23.5	20.0	23.6	22.9	21.6	23.5	21.5
Bu	22.8	22.6	23.5	25.2	23.7	22.8	21.7	21.7	24.4	20.1	23.9	24.3	23.3	22.5	22.6
VD	23.4	23.8	23.5	24.5	23.9	22	22.1	21.7	24.7	20.9		24.4	23.4	22.7	23.1
BJ	23.4	27.3	23.3	26.3	22.6	22.5	22.6	22.8	23.6	20.9		23.3	22	22.8	22.3
PG	23.4	25.5	23.3	24.3	23	22.5	22.3	22.8	23.7	20.9		24.1	23.1	23.1	21.5
VW	23.1	28.4	22.2	26.1	22.3	22.3	21.9	21.6	23.6	21.2	24.4	24.3	22	23.1	22.3
FB	22.5	23.5	22.1	25.1	23.3	22.5	21.5	21.7	24.0	21.4		23.6	22.6	23.5	22.4

5 General conclusions

5.1 Baywide declines in shoot density

None of the three management criteria were triggered in 2026, indicating no serious concerns for the health of the seagrass meadows. Despite this, all sites showed a decline in shoot density, the first time there has been a consistent across all monitoring locations. It is also the biggest losses observed, with four sites reducing more than 30% compared to last year. Although this is somewhat concerning, if we place it in the context of the last three years, there were large increases at these sites where the greatest losses occurred this year (30-39%), from increases of 31-48% in 2023-2024 and 32-47% in 2024-2025 (Table 13). So, it could be considered part of the natural fluctuations that occur in meadows over the years (Webster et al., 2024). The long-term trends in Geographe Bay, as assessed by Trigger 3, show no significant declines over time from 2012, in fact two of the sites with the large losses observed this year, have significantly increased over time from the start of the monitoring program. The condition of seagrass meadows will be reassessed again in 2027, and if there is >20% loss for two years in a row at a site, then the Trigger 2 will be breached. It is recommended to continue monitoring to keep track on the condition of the

meadows, especially as the Ngari Capes have been recognised as potentially important temperate seagrass refugia (Webster et al., 2024), including being resilient to ocean warming and marine heatwaves (Said et al., 2026) and genetically diverse (Whale et al., 2026).

Declines in the shoot density of *Posidonia* can occur due to persistent light reduction from algal blooms including epiphytic algae, runoff of turbid water from the catchment, dredging or large increases in temperature such as from marine heatwaves (McMahon et al., 2022; Strydom et al., 2020). There was higher algal cover at the sites that experienced large losses this year (Table 14), which may have contributed to the declines if they had persisted over the previous year, however, in the past based on assessments from this Keep Watch Program, higher epiphyte cover has not been associated with seagrass declines. There is limited evidence that there was an increase in nutrient exposure based on the nitrogen and phosphorus content in the seagrass leaves at these sites, as only very small increases were observed at some of the sites, and they were within the range observed previously. The one major change was the source of nitrogen at the Vasse Diversion Drain site, where the nitrogen isotope signal was higher, and for *Amphibolis*, the highest that has been observed, indicating a potentially different source of nitrogen that the plants were exposed to this year. Finally Western Australia did experience an extreme marine heatwave commencing in February of 2025, although it was more extreme in the north of Australia, there were still elevated temperatures in Geographe Bay (Lester et al., 2026). This may have contributed to a decline, that was detected in 2026. Seagrass loss due to marine heatwaves has been attributed to seagrass decline in Perth waters, Jurien Bay and Shark Bay (Webster et al., 2024, Strydom et al., 2020). However, a long-term analysis did not find any links with temperature in Geographe Bay, although this was conducted prior to 2025 (Webster et al., 2024).

Site	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1. Dunsborough	61	64	52	56	61	59	53	56	61	68	63	66	62	67	62
2. Buayanup	59	66	50	60	57	58	55	63	56	60	59	56	61	81	50
3. Vasse Div.	34	37	34	34	29	34	38	41	48	37	41	40	43	60	42
4. Busselton Jet.	38	38	46	44	45	45	43	52	49	45	49	39	51	74	49
5. Port Geo.	39	46	42	47	45	35	49	62	50	48	42	32	49	65	41
6. Vasse-Wonn.	38	45	51	49	48	50	47	53	51	44	45	37	57	60	49
7. Forrest Beach	53	61	47	48	50	49	53	53	59	42	49	48	53	61	53

Figure 13: *Heatmap of average shoot density of* P. sinuosa *per quadrat (0.04m^2) over time, 2012-2026, at each Keep Watch seagrass monitoring sites.*

	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1. Dunsborough	3	2	3	3	2	2	3	3	3	2	3	3	3	3	2
2. Buayanup	3	2	3	3	4	4	3	1	4	4	4	4	4	3	4
3. Vasse Diversion	2	3	4	4	4	4	4	2	4	4	4	3	4	2	4
4. Busselton Jetty	2	2	4	4	3	3	3	2	4	4	4	3	3	2	4
5. Port Geographe	2	1	2	2	3	3	3	2	3	3	3	3	4	3	3
6. Vasse-Wonnerup	2	1	2	3	2	2	2	1	2	3	2	3	2	2	2
7. Forrest Beach	2	1	2	2	2	1	2	1	2	2	1	2	3	3	2

Figure 14: *Heatmap of changes in algal cover on* P. sinuosa *over time, 2012-2026, at each Keep Watch seagrass monitoring sites. The numbers and colours reflect the cover of epiphytic algae with 1=Very low, 2=Low, 3=Moderate, 4=High and 5=Very High*

5.2 Nitrogen exposure is low but some changes in the sources

Overall, the nutrient concentrations in seagrass continue to be very low and do not indicate exposure to excess nutrients that are impacting seagrass condition. At Capel, the higher nitrogen and phosphorus content in seagrass higher phosphorus content in algae indicates higher exposure to nutrients, most likely from runoff from the Capel River. Since 2020 to 2024, the nutrient content of seagrass has been declining at Capel, but it has increased again in the last two years, potentially reflecting higher nutrient loads over from 2024. Monitoring for algae only commenced in 2022 and over this time the nutrient concentrations of phosphorus have remained elevated compared to other sites. These findings indicate there is value in continuing catchment management practises to reduce nutrient flows into Capel River.

Since this study commenced, Capel has always had a higher nitrogen isotope signal to the other sites in Geographe Bay in *Amphibolis* seagrass and algae. It is likely that the main potential nitrogen sources are derived from animal wastes or septic tanks or sources from natural vegetation. This continues to be the case, but for the first time, Vasse Diversion Drain has a higher compared to previous years, and a similar nitrogen isotope signal to Capel. This indicates that prior to sampling in February 2026 different sources of nitrogen have been accessed by the seagrass. This could be due to changes in the catchment management impacting the Vasse Diversion Drain or through groundwater discharge into the marine environment in that area. Reduction in fertiliser derived nitrogen entering the marine environment could account for this.

5.3 Keep Watch program continuing

Funding from Water Corp has been secured to continue the Keep Watch Seagrass Monitoring Program in collaboration with GeoCatch, ECU and DBCA. This contributes to DBCA's routine monitoring of the marine park, which without this program would only occur every two years in the shallow water sites. This continuation will enable annual assessment of the condition of the ecologically valuable seagrass meadows of Geographe Bay.

6 References

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

Fraser, Martin, Kendrick, Strydom (2019). The 2019 survey of selected seagrass meadows in Cockburn Sound, Owen Anchorage and Warnbro Sound. Unpublished report for DWER on behalf of Cockburn Sound Management Council.

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

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

Lester, E., Mastrantonis, S., Hickey, SM., Lafratta, A., Benthuysen, JA., Afrifa-Yamoah, E., Chandrapavan, A., Depczynski, M., Evans, RD., Fairclough, DV., Fulton, CJ., Gagnon, MM., Jones, NL., Pinter, S., Ross, CL., Robbins, WD., Richards, ZT., Ryan, KL., Strydom, S., Tweedley, JR., Wells, F., Williams, H., Wilson, SK., McMahon, K. (2026). Understanding ecosystem responses to recurrent marine heatwaves. *Biological Conservation*, 322(2026), article number 112016. https://doi.org/10.1016/j.biocon.2026.112016

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

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

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

McMahon, K., Kilminster, K., Canto, R., Roelfsema, C., Lyons, M., Kendrick, G., Waycott, M., Udy, J. (2022). The Risk of Multiple Anthropogenic and Climate Change Threats Must Be Considered for Continental Scale Conservation and Management of Seagrass Habitat. *Frontiers in Marine Science*, 9(March 2022), Article number 837259. https://doi.org/10.3389/fmars.2022.837259.

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

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

Said, N., Webster, C., Strydom, S., Dunham, N., Adams, M.P. and McMahon, K. (2026), Seagrasses are most vulnerable to marine heatwaves in tropical zones: local-scale and broad climatic zone variation in thermal tolerances. New Phytol, 249: 2835-2851. https://doi.org/10.1111/nph.70742

Strydom, Murray, Wilson, Huntley, Rule, Heithaus, ... & Zdunic (2020). Too hot to handle: Unprecedented seagrass death driven by marine heatwave in a World Heritage Area. *Global change biology*, *26*(6), 3525-3538

Webster, McMahon, Ross, Afrifa-Yamoah, Said, Hovey, Martin & Strydom (2024). Two decades of seagrass monitoring data show drivers include ENSO, climate warming and local stressors. Prepared for the WAMSI Westport Marine Science Program. Western Australian Marine Science Institution, Perth, Western Australia.

Whale, J. Sinclair, E.A., Webster, C.L., Said, N.E., Frouws, A.M., Field, D.L., McMahon, K. (in press). Evidence for local adaptation associated with temperature despite weak latitudinal structure in a temperate seagrass. Molecular Ecology.

Appendix 1: Randomly generated quadrat positions from 2026 survey.

Quadrat #	Bearing	Distance (m)
1	20	11
2	20	12
3	20	15
4	20	17
5	20	21
6	20	24
7	60	1
8	60	3
9	60	4
10	60	9
11	60	10
12	60	11
13	140	2
14	140	4
15	140	17
16	140	18
17	140	19
18	140	20
19	180	7
20	180	10
21	180	15
22	180	16
23	180	19
24	180	20
25	320	2
26	320	3
27	320	9
28	320	14
29	320	15
30	320	18

Appendix 2: Raw and summary statistics for shoot density data for the seven Keep Watch Seagrass Monitoring Sites in 2026, with the average (Av), median (Me), standard error (Se), standard deviation (Sd) and coefficient of variation (Cv) shown in the bottom rows. Shoot counts (Sh), number of seedlings (Sl) and the number of flowering shoots (Fs) per quadrat (0.04 m^2) are given and the initials of the person who counted each quadrat is also included (C, see also legend below). Columns for Seedlings and/or Flowering shoots are excluded from sites where no seedlings or flowering shoots were observed. The table continues on the next page.

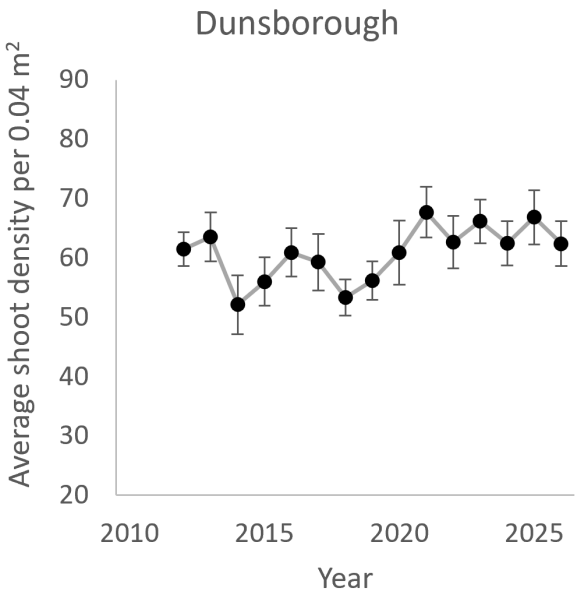
	1. Dunsborough				2. Buayanup				3. Vasse Diversion				4. Busselton Jetty				5. Port Geographe		6. Vasse-Wonnerup				7. Forrest Beach			
Rep	Sh	Sl	FSh	C	Sh	Sl	FSh	C	Sh	Sl	FSh	C	Sh	Sl	FSh	C	Sh	C	Sh	Sl	FSh	C	Sh	Sl	FSh	C
1	72	0	0	GS	46	0	0	CB	51	0	0	SS	44	0	0	SS	40	CB	36	0	1	CB	50	0	0	SS
2	57	0	0	GS	50	0	0	CB	42	0	0	SS	43	0	0	SS	35	CB	37	0	1	CB	41	1	0	SS
3	53	0	0	GS	66	0	0	CB	38	1	0	GS	49	0	0	GS	45	CB	38	2	0	CB	42	0	0	SS
4	49	2	0	SS	54	1	0	SS	26	1	0	GS	56	0	0	GS	38	SS	31	0	2	SS	77	0	0	CB
5	32	1	0	SS	53	0	0	SS	35	0	0	KM	46	0	1	KM	54	SS	23	0	1	SS	57	0	0	CB
6	46	0	1	SS	38	0	1	SS	30	0	0	KM	39	0	3	KM	33	SS	40	1	0	SS	52	0	0	CB
7	105	0	0	KL	31	0	0	KL	56	0	0	SS	52	0	0	SS	19	KL	54	1	0	KL	76	0	0	KL
8	48	2	0	KL	59	0	0	KL	37	0	0	SS	49	0	0	SS	5	KL	54	0	1	KL	43	0	0	KL
9	55	1	0	KL	29	0	0	KL	49	0	0	GS	48	0	0	GS	21	KL	45	0	0	KL	60	0	0	KL
10	64	3	1	KM	90	2	4	KM	36	1	0	GS	61	0	0	GS	52	KM	66	1	0	KM	48	0	0	KM
11	69	0	1	KM	30	1	1	KM	45	0	0	KM	57	0	2	KM	37	KM	33	2	4	KM	68	0	1	KM
12	77	2	2	KM	86	0	0	KM	32	0	0	KM	71	0	0	KM	43	KM	64	1	1	KM	36	0	0	KM
13	51	1	0	GS	44	0	0	CB	48	0	0	SS	28	0	0	SS	63	CB	36	0	0	SS	40	0	0	SS
14	40	4	0	GS	39	0	0	CB	65	0	0	SS	41	1	0	SS	57	CB	48	0	1	SS	59	0	0	SS
15	28	1	0	GS	79	0	0	CB	34	0	0	GS	43	0	0	GS	28	CB	42	0	0	SS	66	0	0	SS
16	59	0	0	SS	46	0	0	SS	30	1	0	GS	43	0	0	GS	20	SS	68	0	0	CB	35	0	0	CB
17	68	0	0	SS	39	0	1	SS	45	0	0	KM	60	0	0	KM	38	SS	70	0	0	CB	34	0	0	CB
18	66	1	0	SS	42	0	0	SS	43	0	0	KM	41	0	0	KM	19	SS	66	0	0	CB	47	0	0	CB
19	108	0	0	KL	45	0	0	KL	66	0	0	SS	34	1	0	SS	51	KL	33	0	0	KL	76	0	0	KL
20	107	1	0	KL	46	0	0	KL	41	0	0	SS	53	0	0	SS	22	KL	57	0	0	KL	38	0	0	KL
21	40	0	0	KL	35	0	0	KL	48	0	0	GS	41	0	0	GS	24	KL	55	0	0	KL	48	0	0	KL
22	75	1	0	KM	44	0	0	KM	45	0	0	GS	47	0	0	GS	51	KM	67	1	0	KM	41	0	0	KM
23	84	0	0	KM	60	0	1	KM	29	0	0	KM	75	1	2	KM	45	KM	63	0	2	KM	53	0	0	KM
24	90	0	0	KM	57	0	0	KM	24	0	0	KM	53	0	1	KM	78	KM	68	0	1	KM	91	1	0	KM
25	57	1	0	GS	58	0	1	SS	60	0	0	SS	62	2	0	SS	36	KL	51	0	0	SS	47	0	0	SS
26	69	1	0	GS	37	0	0	SS	43	0	0	SS	48	0	0	SS	62	SS	84	0	0	SS	54	0	0	CB
27	43	0	0	GS	39	0	0	SS	45	0	0	GS	44	0	0	GS	39	CB	36	0	1	SS	28	0	0	CB
28	57	0	0	SS	46	0	0	CB	33	0	0	GS	30	0	0	GS	67	CB	39	0	0	CB	48	0	0	SS
29	42	0	0	SS	69	0	0	CB	55	1	2	KM	51	1	0	KM	56	SS	37	0	0	CB	63	0	0	SS
30	61	1	1	SS	36	0	0	KL	36	0	1	KM	49	1	0	KM	53	SS	38	0	0	KL	61	0	0	CB
Average	**62.4**	**0.8**	**0.2**		**49.8**	**0.1**	**0.3**		**42.2**	**0.2**	**0.1**		**48.6**	**0.2**	**0.3**		**41.0**		**49.3**	**0.3**	**0.5**		**52.6**	**0.1**	**0.0**	
Median	**58.0**	**0.5**	**0.0**		**46.0**	**0.0**	**0.0**		**42.5**	**0.0**	**0.0**		**48.0**	**0.0**	**0.0**		**39.5**		**46.5**	**0.0**	**0.0**		**49.0**	**0.0**	**0.0**	
SE	**3.8**	**0.2**	**0.1**		**2.9**	**0.1**	**0.1**		**2.0**	**0.1**	**0.1**		**1.9**	**0.1**	**0.1**		**3.1**		**2.8**	**0.1**	**0.2**		**2.7**	**0.0**	**0.0**	
Stdev	**20.9**	**1.0**	**0.5**		**15.8**	**0.4**	**0.8**		**11.0**	**0.4**	**0.4**		**10.6**	**0.5**	**0.7**		**16.8**		**15.2**	**0.6**	**0.9**		**14.8**	**0.3**	**0.2**	
CV	**0.3**	**1.3**	**2.4**		**0.3**	**3.3**	**2.6**		**0.3**	**2.3**	**4.0**		**0.2**	**2.2**	**2.5**		**0.4**		**0.3**	**2.0**	**1.7**		**0.3**	**3.8**	**5.5**	

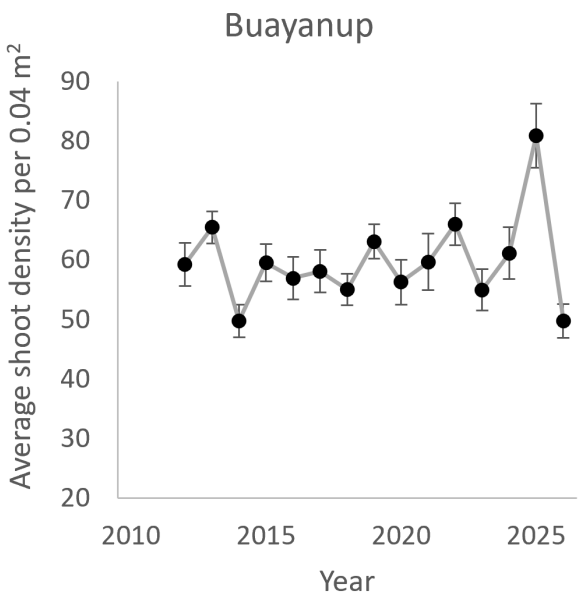
Counter (C): GS=Glen Sutton, SS-Simone Strydom, KL=Kate Livingston, KM=Kathryn McMahon, CB=Cam Bates

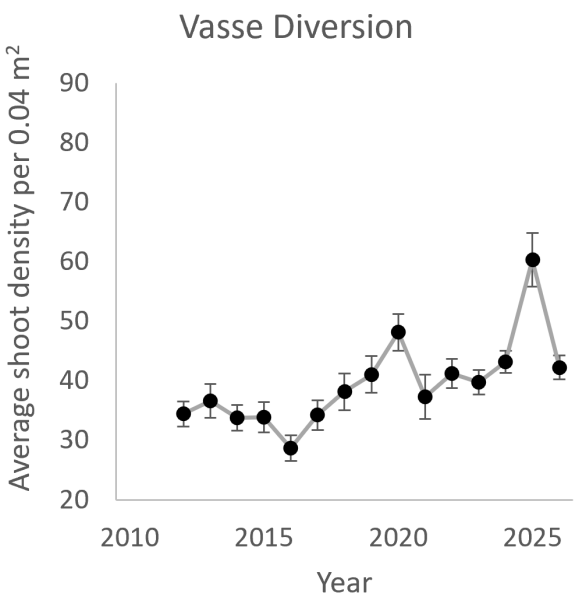
Appendix 3: Leaf morphology data on shoot length and width of *Posidonia sinuosa* for 2026 with the average (Av), standard error (Se), minimum (Min) and maximum (Max) values shown in the bottom rows.

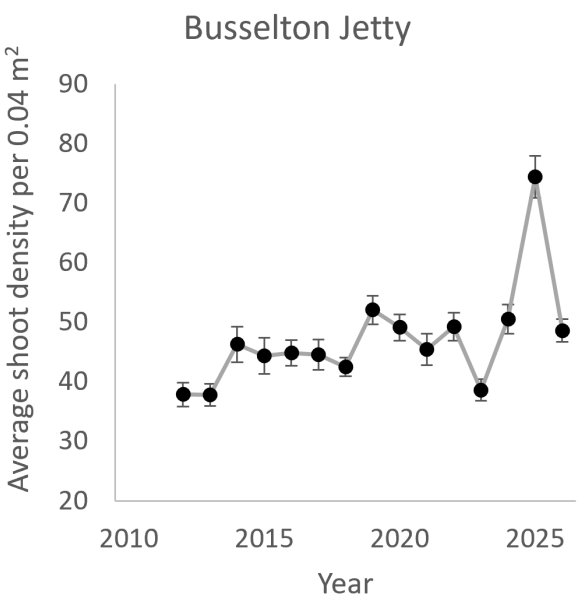
	S1. Dunsborough		S2. Buayanup		S3. Vasse Diversion		S4. Busselton Jetty		S5. Port Geographe		S6. Vasse-Wonnerup		S7. Forrest Beach	
Rep	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)	Shoot Length (cm)	Shoot Width (mm)
1	56.4	5.0	38.9	5.0	63.0	6.0	84.4	7.0	63.2	7.0	62.7	6.0	35.9	6.0
2	33.5	7.0	56.8	5.0	47.5	5.0	57.8	6.0	53.9	7.0	72.3	6.0	54.0	7.0
3	45.5	5.0	39.5	5.0	57.2	6.0	53.5	7.0	60.5	6.0	49.5	5.0	22.4	6.0
4	56.5	5.0	29.2	5.0	39.0	6.0	37.3	6.0	64.2	6.0	21.7	6.0	35.0	5.5
5	39.3	7.0	56.3	5.0	99.9	5.0	73.8	7.0	33.6	6.0	78.2	6.0	28.6	7.0
6	44.0	5.0	36.1	5.0	43.5	6.0	67.5	6.0	20.5	5.5	77.5	5.0	40.5	5.5
7	53.0	5.0	53.7	5.0	38.2	6.0	72.8	7.0	62.3	5.0	77.6	6.5	33.5	5.0
8	56.5	7.0	55.4	5.0	23.8	6.0	67.0	7.0	53.6	5.0	89.4	6.5	38.5	7.0
9	58.4	6.0	41.5	5.0	44.2	6.0	56.0	6.0	48.8	7.0	96.0	6.0	30.8	5.5
10	50.0	6.0	32.7	5.0	48.5	6.0	93.3	6.0	53.1	6.0	68.2	7.0	44.1	6.5
11	59.0	7.0	61.2	5.0	52.8	6.0	60.6	6.0	40.0	6.0	71.0	5.5	43.8	7.0
12	38.5	5.0	31.9	4.0	33.2	6.0	60.0	7.0	40.0	6.0	83.0	5.0	45.9	6.0
13	46.0	6.0	42.7	5.0	58.1	7.0	65.5	7.0	90.3	5.0	44.8	7.0	56.5	6.5
14	47.9	6.0	68.7	5.0	87.7	6.0	48.9	7.0	66.7	6.0	69.1	7.0	56.5	6.0
15	44.5	6.0	49.2	5.0	56.9	6.0	50.0	7.0	68.0	7.0	98.6	6.0	54.6	6.5
Av	**48.6**	**5.9**	**46.3**	**4.9**	**52.9**	**5.9**	**63.2**	**6.6**	**54.6**	**6.0**	**70.6**	**6.0**	**41.4**	**6.2**
Se	**2.0**	**0.2**	**3.1**	**0.1**	**5.1**	**0.1**	**3.7**	**0.1**	**4.3**	**0.2**	**5.2**	**0.2**	**2.8**	**0.2**
Min	**33.5**	**5.0**	**29.2**	**4.0**	**23.8**	**5.0**	**37.3**	**6.0**	**20.5**	**5.0**	**21.7**	**5.0**	**22.4**	**5.0**
Max	**59.0**	**7.0**	**68.7**	**5.0**	**99.9**	**7.0**	**93.3**	**7.0**	**90.3**	**7.0**	**98.6**	**7.0**	**56.5**	**7.0**

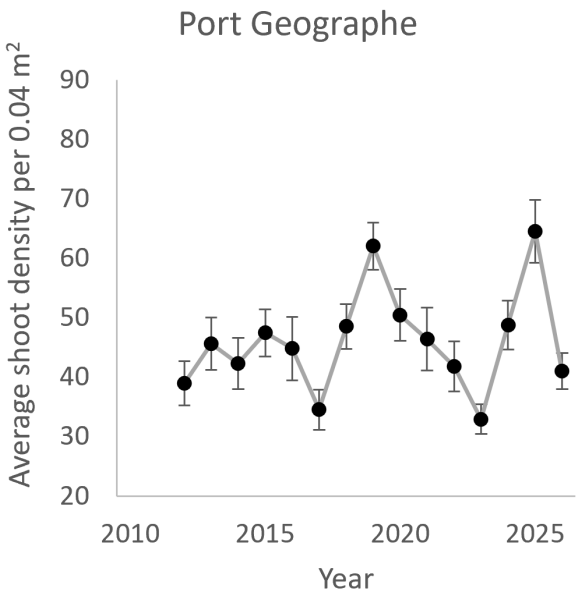
Appendix 4: Trends over time in seagrass shoot density of *Posidonia sinuosa* from 2012 to 2026.

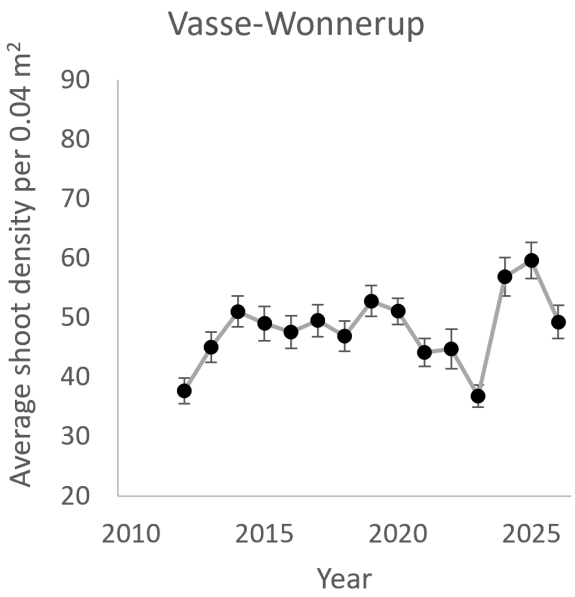


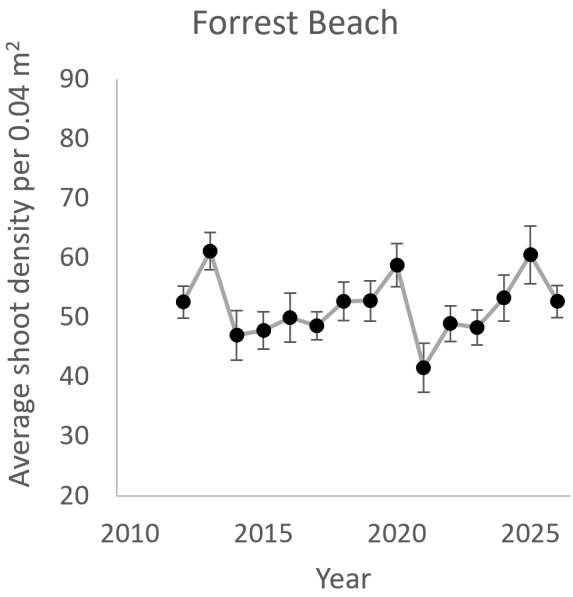







Port Geographe
Average shoot density per 0.04 m²
90
80
70
60
50
40
30
20
2010
2015
2020
2025
Year


Vasse-Wonnerup
Average shoot density per 0.04 m²
90
80
70
60
50
40
30
20
2010
2015
2020
2025
Year


Forrest Beach
Average shoot density per 0.04 m²
90
80
70
60
50
40
30
20
2010
2015
2020
2025
Year

Appendix 5: Nutrient data for 2026 including the original (O) and modified (M) calibrated values for 2020 as well as the calibrated values for 2026 for several species (Spec) of seagrasses (*Ps* = *Posidonia sinuosa*, *Aa* = *Amphibolis antarctica*) and macroalgae (*D* = *Dictyota*).

		2026		2026		2026
		Original	Modified	Original	Modified	Original
Site	Species	δ15N	δ15N	N [wt %]	N [wt %]	P (% DW)
1. Dunsborough	Posidonia	0.89	0.37	0.98	0.48	0.14
1. Dunsborough	Posidonia	1.21	0.71	1.06	0.56	0.11
1. Dunsborough	Posidonia	0.93	0.42	0.97	0.47	0.15
2. Buayanup	Posidonia	1.45	0.98	0.99	0.49	0.12
2. Buayanup	Posidonia	1.67	1.21	1.32	0.84	0.08
2. Buayanup	Posidonia	1.63	1.17	1.21	0.72	0.07
3. Vasse-Diversion	Posidonia	3.10	2.74	1.24	0.76	0.09
3. Vasse-Diversion	Posidonia	1.87	1.43	1.19	0.70	0.19
3. Vasse-Diversion	Posidonia	2.91	2.54	1.23	0.74	0.10
4. Busselton Jetty	Posidonia	1.26	0.77	1.09	0.59	0.11
4. Busselton Jetty	Posidonia	1.18	0.69	1.27	0.79	0.11
4. Busselton Jetty	Posidonia	1.48	1.01	0.89	0.38	0.09
5. Port Geographe	Posidonia	2.56	2.17	1.36	0.88	0.12
5. Port Geographe	Posidonia	2.44	2.03	1.26	0.77	0.09
5. Port Geographe	Posidonia	2.12	1.69	1.19	0.70	0.10
6. Vasse-Wonnerup	Posidonia	2.07	1.64	1.40	0.92	0.15
6. Vasse-Wonnerup	Posidonia	1.33	0.84	1.16	0.67	0.12
6. Vasse-Wonnerup	Posidonia	1.52	1.05	0.95	0.44	0.11
7. Forrest Beach	Posidonia	2.40	1.99	1.39	0.91	0.08
7. Forrest Beach	Posidonia	1.22	0.72	1.01	0.50	0.07
7. Forrest Beach	Posidonia	1.29	0.80	0.87	0.36	0.09
3. Vasse-Diversion	Amphibolis	3.11	2.75	1.29	0.81	0.07
3. Vasse-Diversion	Amphibolis	2.66	2.27	1.25	0.76	0.06
3. Vasse-Diversion	Amphibolis	3.54	3.21	1.32	0.84	0.06
7. Forrest Beach	Amphibolis	2.30	1.89	1.10	0.60	0.08
7. Forrest Beach	Amphibolis	2.91	2.54	1.40	0.93	0.08
7. Forrest Beach	Amphibolis	2.18	1.75	0.88	0.37	0.08
8. Capel	Amphibolis	3.56	3.23	2.10	1.66	0.13
8. Capel	Amphibolis	2.98	2.61	2.14	1.71	0.11
8. Capel	Amphibolis	2.81	2.43	1.86	1.41	0.09
1. Dunsborough	Dictyota	-0.35	-0.95	1.50	1.03	0.03
1. Dunsborough	Dictyota	-0.35	-0.96	1.36	0.88	0.04
1. Dunsborough	Dictyota	-0.34	-0.95	1.89	1.44	0.04
3. Vasse-Diversion	Dictyota	0.19	-0.38	1.23	0.74	0.03
3. Vasse-Diversion	Dictyota	0.30	-0.26	1.18	0.69	0.03
3. Vasse-Diversion	Dictyota	0.40	-0.15	1.27	0.79	0.03
7. Forrest Beach	Dictyota	0.59	0.05	1.10	0.60	0.03
7. Forrest Beach	Dictyota	0.68	0.15	1.08	0.59	0.04
7. Forrest Beach	Dictyota	0.57	0.03	0.91	0.40	0.03
8. Capel	Dictyota	3.02	2.65	1.26	0.77	0.08
8. Capel	Dictyota	1.34	0.85	1.68	1.22	0.07
8. Capel	Dictyota	2.51	2.11	1.14	0.65	0.09