A Survey of Selected Seagrass Meadows in Cockburn Sound, Owen Anchorage and Warnbro Sound

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Prepared for Cockburn Sound Management Council

Data Report

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Department of Parks and Wildlife

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Contents

Appendices

Figures

Tables

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Summary

In 2014, the Department of Parks and Wildlife, Marine Science Program (MSP) undertook seagrass monitoring on behalf of the Cockburn Sound Management Council (CSMC) as part of the CSMC long-term seagrass monitoring program. A number of seagrass (*Posidonia sinuosa)* meadows in Cockburn Sound, Owen Anchorage and Warnbro Sound were surveyed over eight days between the 20th and 31st January, 2014. A total of 25 permanent sites were surveyed comprising 16 'potential impact' sites, five 'reference' sites and four 'depth transect' sites. Additional 'reference' sites inside both the Shoalwater Islands and Jurien Bay marine parks were surveyed to provide a regional context for the patterns observed in Cockburn and Warnboro sounds. At all sites seagrass shoot densities, shoot heights and epiphyte loads were surveyed following the standard operating procedure and data were assessed against CSMC guidelines for the health of seagrass meadows.

Following draft changes to the EQC guidelines which guard against declines in seagrass density in Warnboro Sound, we assessed each of the reference sites against an historical baseline termed the 'Absolute Minimum Criteria'. Shoot densities at Warnboro 2.5 and 5.5m were lower than the Baseline 5th percentile AMC, while Warnboro 2.0, 3.2 and 5.5 all had lower densities than the 1st percentile AMC. In cases where impact sites were compared against any of these sites, the AMC values were used. These results are worrying as they represent continued declines in seagrass shoot density at the Warnboro Sound reference sites.

With the exception of Garden Island Settlement and Kwinana, seagrass shoot densities at all sites achieved the Environmental Quality Criteria (EQC) for seagrass health. Both of these two sites failed against the EQC suggesting an issue may be present. Careful monitoring at these two sites is required.

The Lower Depth Limit of seagrass at depth transect sites was generally greater than in the previous years. The only exception to this was the Warnbro Sound depth transect site which was 0.4 m shallower in 2014 than 2013.

As part of the ongoing review and improvement of the seagrass monitoring program in Cockburn Sound, we recommend that the CSMC:

1. Define a process for correcting depth allocations and determining the appropriate reference depth for comparisons
2. Determine how data from the additional reference sites (Shoalwater and Jurien bay) are used to support the program in the future
3. Determine the appropriate classification of the Garden Island sites
4. Define the conditions under which damaged or empty transects are replaced

1. Introduction

Seagrass meadows are recognised for their ecological and economic importance in supporting a diverse range of flora and fauna, stabilising sediments and protecting shorelines (Heck et al., 2003). Seagrasses are also highly productive and are considered the dominant ecosystem engineers in many soft-bottom ecosystems (Connolly, 2012; Larkum et al., 1989). Physical damage, broad-scale losses, and fragmentation of seagrass meadows are evident worldwide as a result of anthropogenic pressure, such as coastal development and climate change (Orth et al., 2006; Waycott et al., 2009). Major fragmentation or loss of seagrass meadows will have major implications for food-webs, coastal geomorphology, and biogeochemical cycles (Short and Neckles, 1999). Twenty-five seagrass species occur in Western Australia, and fourteen of these species inhabit Perth's coastal waters (Walker, 1991).

In 1994, the Department of Environment and Conservation (DEC) commissioned Edith Cowan University (ECU) to assess seagrass health at locations throughout Cockburn and Warnbro Sounds in the Perth metropolitan area. The initial health assessment (Lavery, 1994) was complemented by a simultaneous assessment of changes in seagrass area in the region. Since 1998 the survey of seagrass health has been repeated annually (in summer), on behalf of the Environmental Protection Authority, DEC and Cockburn Sound Management Council (CSMC). Since 2000, the CSMC has commissioned seagrass monitoring where surveys incorporated quantitative measurements of a number of variables at each assessment site and at a series of permanently marked transects at the lower depth limit of seagrass meadows. In 2005, the program was reviewed (Environmental Protection Authority, 2005) and a standard methodology was implemented (Environmental Protection Authority, 2004). This heralded a key change in sampling technique with a shift from random quadrats to permanent or semi-permanent transects and quadrats. In 2013, CSMC contracted the then Department of Environment and Conservation's Marine Science Program (MSP) to conduct the annual seagrass monitoring program. The Department of Parks and Wildlife completed the monitoring again in 2014 as part of the Western Australian Marine Monitoring Program (WAMMP) within MSP. The Cockburn Sound monitoring now forms part of WAMMP's state-wide monitoring of seagrass, and the broader-scale understanding of seagrass communities across the state facilitates better understanding of the patterns found in Cockburn Sound.

This data report delivers results from the 2014 surveys and focuses some attention on temporal changes at each monitoring site within Cockburn Sound. Seagrass meadows are patchy in time and space and current reporting draws from only one sampling time each year. Any trends observed in the data should be treated with caution as conclusions are made about characteristics that may vary at timescales shorter than those measured. As much as possible, the sampling design attempts to reduce this source of variability by comparing data from the same time of year (January) and from exactly the same patches of seagrass habitat. The results can be used to indicate any changes in seagrass meadows over time that may warrant more intensive investigation.

1.1 Changes to the data report format

Mohring and Rule (2013a) adopted terminology that was consistent with the Environmental Quality Criteria document (Environmental Protection Authority 2005a), and thus, sites were referred to as either 'potential impact' or 'reference', and this has been continued in the 2014 report. Some issues with consistency and reporting accuracy were identified and resolved in Mohring and Rule (2013) and these changes have been continued in this report.

Current revisions of the Environmental Quality Criteria (Environmental Protection Authority, 2013) have highlighted the need for changes in reporting, particularly when identifying declines in seagrass health. Although the 2005 Environmental Quality Criteria document (Environmental Protection Authority 2005a) included measures to protect against a declining reference, this has never been implemented in any previous data report. The Office of the Environmental Protection Authority(Environmental Protection Authority, 2013) have recommended the use of Absolute Minimum Criteria in instances where reference trigger values fall below an acceptable level. The use of reference trigger values is defined in Section 5.1. According to the Draft Environmental Quality Criteria (Environmental Protection Authority, 2013) if the reference trigger values fall below the Absolute Minimum Criteria defined in Table 1, then these values should be used as a benchmark against which median seagrass density at 'potential impact' sites should be compared. Thus, in 2014 a new section in the results (Section 6.1) has been included where Absolute Minimum Criteria has been used to test the integrity of the 'reference' sites.

Table 1 Absolute minimum seagrass shoot density taken from Table 1b in the Draft 2014 Environmental Quality Criteria[1].Values are presented as number of shoots 0.04 m^{-2} to remain coinsistent with the reporting of densities in this report

Reference depth	Baseline 5th Percentile	Baseline 1st Percentile
1.5 – 2.0 m	26.64	16.48
2.0 – 3.0 m	20	11
3.0 – 4.0 m	6.84	4
5.0 – 6.0 m	16.76	12.96
6.0 – 7.0 m	2.36	1

[1] In this case the 20th Percentile trigger value calculated for seagrass at each Warnbro Sound reference site is compared to the Baseline 5th Percentile and the 5th percentile trigger value is compared to the baseline 1st percentile. The baseline percentiles are calculated from the first 4 years of sampling in Warnbro Sound.

2 Sites Surveyed

Seagrass community condition was surveyed at 16 'potential impact' sites, five 'reference' sites, and four 'depth transect' sites (Figure 1, Table 2). A description of the each of these sites is provided in Lavery and Gartner (2008). In addition, we surveyed three reference sites established in the Shoalwater Islands Marine Park during 2013, and three previously established sites in the Jurien Bay Marine Park (Table 1).

3 Methods and Metrics Measured

Methods used in the current project are consistent with the methods set out in the in the 'Manual of Standard Operating Procedures' (Environmental Protection Authority, 2004). Seagrass meadows were sampled on eight days between the 20th and the 31st January 2014, and the Jurien Bay sites were surveyed on the 25th February 2014. The standard protocols used at 'potential impact', 'reference' sites and 'depth' sites are outlined below. For a detailed description of the data collection methodology, see Environmental Protection Authority (2004).

3.1 Shoot Density

Shoots of *Posidonia sinuosa* and *Posidonia australis* were counted by SCUBA divers in 24 permanent 20 x 20 cm quadrats at each of the seagrass 'potential impact' (Table 6) and 'reference' sites (Table 7) according to the methods described by Lavery & Gartner (2008). Comparisons of seagrass shoot density at 'potential impact' and 'reference' sites are based on median seagrass shoot densities at 'potential impact' sites in 2014 compared to trigger values calculated from comparable 'reference' sites (see Section 5.1).

3.2 Shoot Height

The height of the tallest shoot was measured in each quadrat to the nearest centimetre. The average leaf length was also measured as long leaves are often necrotic for much of their length and the maximum length may be unrepresentative of the meadow. Average leaf length is defined as the 80th percentile of shoot heights (Duarte and Kirkman, 2001).

3.3 Percentage cover

At each site, ten 1 x 1m photographic quadrats were collected along each transect to obtain quantitative estimates of seagrass percentage cover. An image was taken from a standard height (~1m) every 1m along each transect (n = 40). These images were processed using a standard point-count analysis with six randomly allocated points per image.

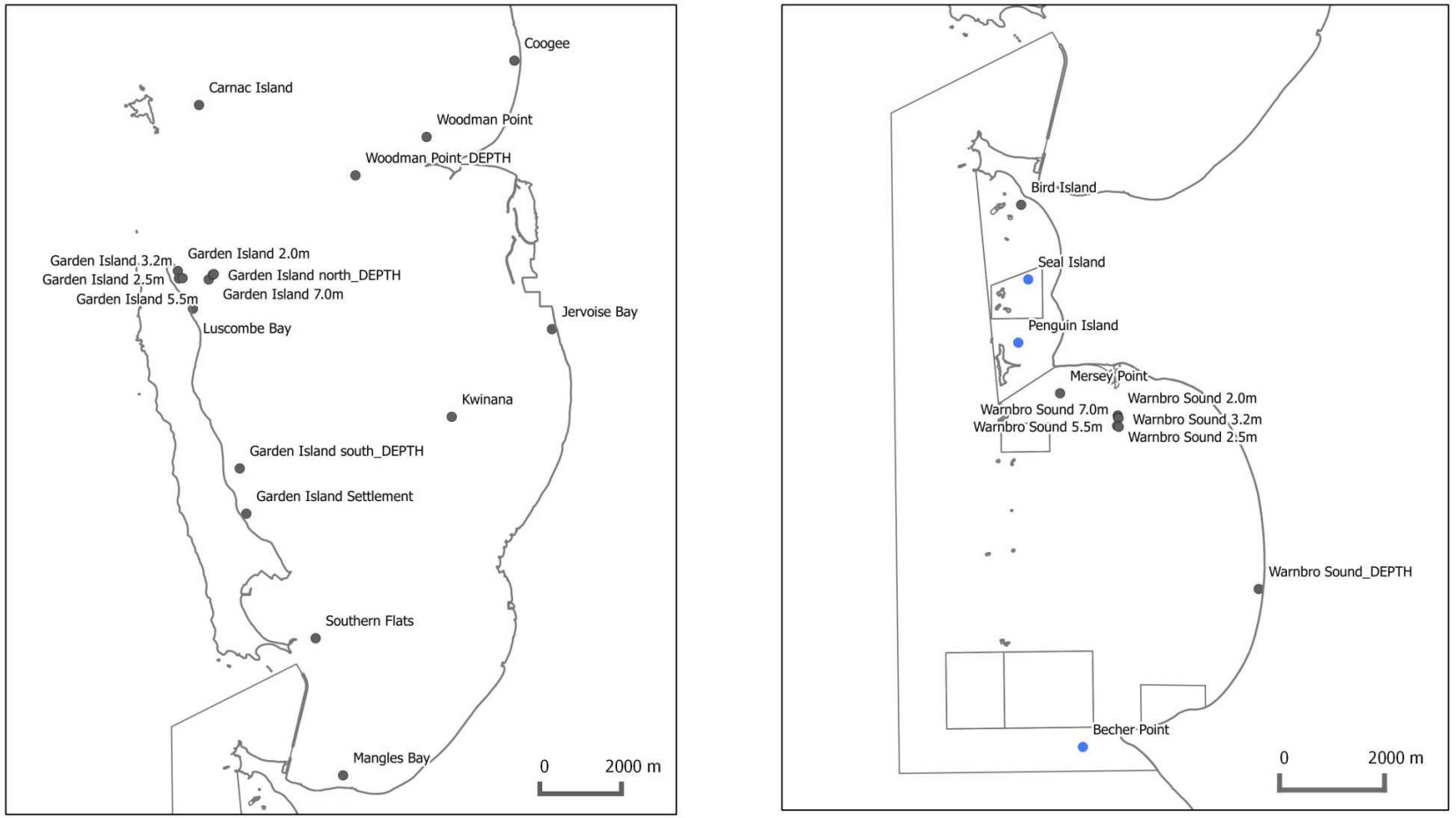

Figure 1: Map of Cockburn Sound (left) and Shoalwater Islands Marine Park (right) indicating position of 'potential impact' and 'reference' sites. Sites in blue are newly established reference sites.

Table 2: Characteristics of seagrass sites surveyed in Cockburn Sound, Owen Anchorage, the Shoalwater Islands and Jurien Bay marine parks; including site types ('potential impact' or 'reference'), years sampled and depths originally assigned and measured again in 2014.

Site name	Area	Site type	Depth	2013 Depth	Years sampled
Carnac Island	OA	Potential Impact	4.5	3.9	2005-2014
Coogee	OA	Potential Impact	5.0	5.4	2007-2014
Garden Island 7.0	CS	Potential Impact	7.0	5.9	1998-2014
Garden Is. Sett.	CS	Potential Impact	2.0	1.2	2002-2008, 2013-2014
Kwinana	CS	Potential Impact	5.2	4.5	1998-2014
Luscombe Bay	CS	Potential Impact	2.0	1.4	2002-2008, 2013-2014
Mangles Bay	CS	Potential Impact	3.2	3.2	1998-2014
Southern Flats	CS	Potential Impact	2.5	2.1	1998-2014
Woodman Point	OA	Potential Impact	2.5	4.1	2008-2014
Jervoise Bay	CS	Potential Impact	2.5	3.1	2002-2014
Bird Island	SIMP	Potential Impact	2.0	2.0	1998-2014
Mersey Point	SIMP	Potential Impact	3.0	2.7	1998-2014
Garden Island 2.0m	CS	Potential Impact	2.0	1.8	2003, 2005-2014
Garden Island 2.5m	CS	Potential Impact	2.5	3.0	2003-2014
Garden Island 3.2m	CS	Potential Impact	3.2	3.3	2003-2014
Garden Island 5.5m	CS	Potential Impact	5.2 & 5.4	5.1	2003-2014
Warnbro Sound 2.0m	SIMP	Reference	2.0	1.9	2003-2014
Warnbro sound 2.5m	SIMP	Reference	2.5	2.5	2003-2014
Warnbro Sound 3.2m	SIMP	Reference	3.2	2.8	2003-2014
Warnbro Sound 5.5m	SIMP	Reference	5.2 & 5.5	4.9	2003-2014
Warnbro Sound 7.0m	SIMP	Reference	7.0	7.3	2005-2014
Becher Point	SIMP	Reference	-	3.6	2013-2014
Penguin Island	SIMP	Reference	-	2.7	2013-2014
Seal Island	SIMP	Reference	-	4.2	2013-2014
Garden Island North	CS	Depth	-		1998-2014
Garden Island South	CS	Depth	-		1998-2014
Warnbro Sound	SIMP	Depth	-		1998-2014
Woodman point	CS	Depth	-		1998-2014
Boullanger Island 2.5m	JB	Reference	-	2.5	2003-2005, 2007-2008, 2010-2014
Boullanger Island 3.2m	JB	Reference	-	3.2	2003-2005, 2007-2008, 2010-2014
Boullanger Island 5.5m	JB	Reference	-	5.5	2003-2005, 2007-2008, 2010-2014

3.4 Qualitative Assessment

3.4.1 Epiphyte Cover

The identification of epiphytes was conducted by a single observer at each site. A qualitative rapid technique was used to estimate the cover of epiphytes on the seagrass shoots. The percentage cover of three categories of epiphytes (encrusting, filamentous and corticated) was estimated as low (<25%), medium (25-75%) or high (>75%). Encrusting refers to encrusting species of epiphytes, filamentous refers to filamentous species of epiphytes, while corticated refers to foliose species typically in the genera, *Laurencia, Hypnea* or *Gracillaria*.

3.4.2 Other qualitative information

All seagrass species present in each quadrat were identified and recorded. In addition, a general qualitative assessment of the health of seagrass meadows and observations on the presence of blow-outs or other disturbances and any other outstanding features were made at each site. Representative photographs were collected at each site to provide qualitative information about the state of the habitat.

3.5 Depth Transect Sites

All of the metrics listed above were measured along three depth transects at each of the Garden Island North, Garden Island South, Warnbro Sound and Woodman Point sites, according to the methods described in Lavery & Gartner (2008). At each transect the 'start' picket was located and a tape measure was extended down the slope to 20m. Quadrats were taken every 2 m along the transect from 0 to 20 m (11 quadrats). Two metrics were clearly defined in the 2013 data report and were consistently measured in 2014. The Leading Edge (LE) is defined as the last quadrat along a transect where shoots were recorded (Figure 2). The Lower Depth Limit (LDL) is defined as the maximum depth and distance at which seagrass shoots are observed within a 0.5m belt either side of the transect line (i.e. shoots may fall outside the quadrats; Figure 2) (Environmental Protection Authority, 2004).

4 QA/QC

4.1 Field Surveys

Prior to commencing field surveys, all observers were required to identify, count and measure seagrass shoots within several test quadrats, with results compared to ensure consistency. Identification, counts and measurements were 're-checked' periodically throughout the survey period, on different days, to ensure continued consistency between samplers and through time at the different sites.

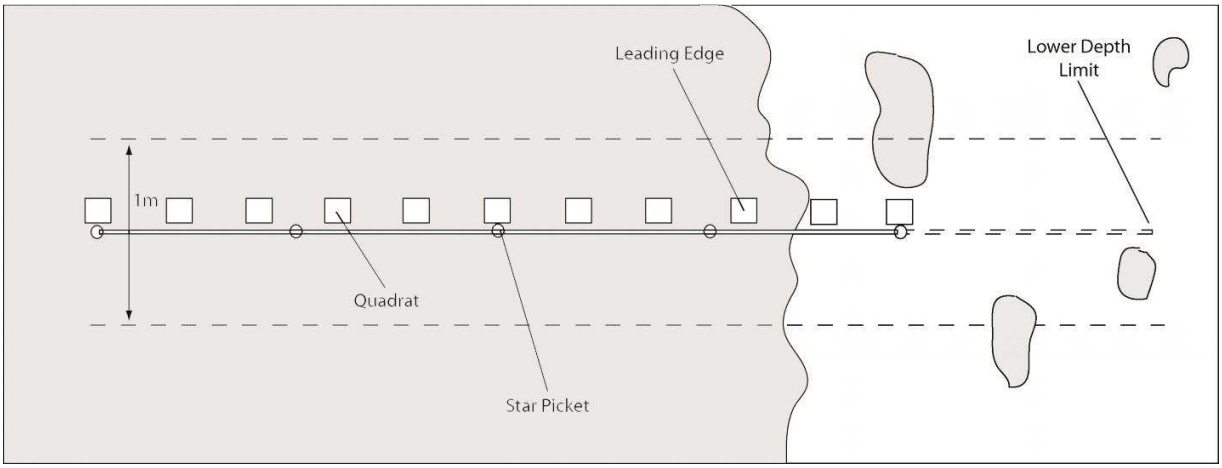

Figure 2: Diagram of the technique for surveying the depth limit of seagrass (seagrass meadow presented in grey). The Leading Edge is the last quadrat in which seagrass is present, and the Lower Depth Limit is the distance along the tape where the last shoots of seagrass fall inside a belt 0.5m on each side of the tape. In this example, the LDL is below the end of the 20m star picket.

4.2 Data management

To ensure the integrity of data and eliminate errors associated with data entry, two different analysts undertook data entry and spread sheets were cross-checked. Only when cross checks showed data in both sheets was identical did data analysis commence.

5 Seagrass Data Interpretation and Presentation

A traffic light analysis similar to the CSMC environmental report cards is presented to allow for *indicative* comparison of the 2014 seagrass monitoring year, with previous sampling years. Caution should be exercised when extrapolating these indicative results to the CSMC's annual environmental report cards. The CSMC's report cards are based on all raw data and analysed independently using the rules and criteria established in the Environmental Quality Criteria Document supporting the State Environmental (Cockburn Sound) Policy 2005.

5.1 Seagrass shoot density

Based on the rationale described in the CSMC guidelines, the median shoot densities of *P. sinuosa* at each seagrass 'potential impact' site in 2014 were compared to trigger values of shoot densities at the corresponding 'reference' site situated in Warnbro Sound. The trigger values are the 20th and 5th percentiles of a minimum of 100 quadrats previously collected at each site, i.e. data pooled from the current and previous four years (2010 – 2014). For sites that have been assigned as a 'moderate protection' area, median shoot density was compared to the 5th and 1st percentiles of shoot density at an

appropriate Warnbro Sound 'reference' site. Prior to comparison, the calculated trigger values were compared to the Absolute Minimum Criteria (Table 1) (Environmental Protection Authority, 2013, 2005) and the most conservative value was used. Seagrass shoot densities are reported at the scale of data collection (i.e. 0.04 m^2). Zero values were removed before undertaking calculations of percentiles (Environmental Protection Authority, 2005).

The condition of each 'potential impact' site was then assessed using the following guidelines (Environmental Protection Authority, 2005):

1. For two consecutive years, any site within the high protection area should have a median seagrass shoot density greater than the 20th percentile of seagrass shoot density calculated at a suitable Warnbro Sound 'reference' site whilst sites in the moderate protection area should have a density greater than the 5th percentile of seagrass shoot density calculated from the 'reference' site data;

2. In any one year, the median seagrass shoot density at any site in the high protection area of Cockburn Sound should be greater than the 5th percentile of seagrass shoot density calculated from data collected at a suitable Warnbro Sound 'reference' site while any site within the Moderate Protection area should be greater than the 1st percentile of seagrass shoot density calculated from the 'reference' site data.

Based on these criteria, we used an indicative 'traffic light system' to indicate the relative condition of each seagrass 'potential impact' site. They were given a 'green light' for passing both criteria, 'amber light' for failing one, and a 'red light' for failing both.

Any site that has not been assigned a level of protection was treated as having a 'high' level of protection, and then assessed against the applicable guidelines to assign the traffic lights (Centre for Marine Futures, 2009).

The mean shoot densities at seagrass 'potential impact' sites were also compared graphically with mean shoot densities at corresponding 'reference' sites at each of the appropriate Warnbro Sound 'reference' sites as well as the Garden Island sites.

5.2 Seagrass depth survey data

Seagrass shoot densities and shoot heights measured in quadrats along depth transects are presented in (Table 13). The leading edge (LE) distance and depth were compared to data from the previous 16 years and presented in graphical format. The lower depth limit (LDL) and distance were compared to data collected for 2008 and 2013. A two-tailed t-test (Environmental Protection Authority, 2004) was used to examine differences in the mean depths between the baseline measurement and those collected in 2014. We used the same test to examine changes in the LDL and the LE between 2014 data and previous year.

5.3 Seagrass height data

The maximal shoot height of the seagrass within the quadrats has been measured every year since 2009. The average shoot height was also measured in 2013 and 2014. The data from each 'potential impact' sites were compared to those from 'reference' sites and are summarized and presented in Appendix 1.

6 Results

6.1 Absolute Minimum Criteria

In 2014, the Office of the Environmental Protection Authority (2013) revised the Environmental Quality Criteria and incorporated several changes . One is the implementation of an absolute minimum criteria (based on historical baseline) which can be used to test the quality of the 'reference' sites (Lavery and McMahon, 2011). In the event that the quality of the 'reference' sites declines, this would result in the misrepresentation of the health of the 'potential impact' sites. The Absolute Minimum Criteria (AMC) are to be used as a replacement trigger value when the 'reference' site trigger values fall below this level. Following this recommendation, we compared the calculated 'reference' trigger values to the AMC (Table 1b; Environmental Protection Authority, 2013). In 2014, both Warnbro Sound 2.0m and Warnbro Sound 5.5m were below the AMC; (Table 3). The 5th percentile at Warnbro 3.2m was also lower than the AMC. Any comparisons against these sites will use the AMC for the specific depth when determining traffic light allocation.

Table 3 Comparisons of the current percentile trigger values (calculated from the previous 100 quadrats) and the Absolute Minimum Criteria (AMC; based on historical baseline data). Highlighted in bold are the values used for 2014.

Reference Site	Current 20th Percentile (Trigger Value)	Baseline 5th Percentile (AMC)	Current 5th Percentile (Trigger Value)	Baseline 1st Percentile (AMC)
Warnbro 2.0m	24	**26.64**	4.95	**16.48**
Warnbro 2.5m	**23.8**	20	**14.9**	11
Warnbro 3.2m	**10**	6.84	3	**4**
Warnbro 5.5m	9	**16.76**	3.95	**12.96**
Warnbro 7.0m	**4**	2.36	**2**	1

6.2 'Potential impact' sites

6.2.1 Sites in High Protection Area

Carnac Island

The median seagrass shoot densities at Carnac Island in 2014 showed an increase from 2013 and were higher than the 20th percentile recorded at the Warnbro Sound 3.2m 'reference' site (Figure 3). Thus, Carnac Island was considered healthy and assigned a green traffic light.

The mean shoot density was higher in 2014 than the previous year, and was above the mean observed at the Warnbro Sound 'reference' site (Figure 26). The percent cover of seagrass at Carnac Island was slightly higher in 2014 compared to 2013, and was higher than the cover at Warnbro Sound 3.2m (Figure 29). The mean and maximal shoot heights recorded at Carnac Island were greater than at the Warnbro Sound 'reference' site (Figure 26). Epiphytes were dominated by encrusting forms with coverage in the low range. Small patches of *Amphibolis griffithii* and *Syringodium isoetifolium* were recorded in some quadrats. Some sand inundation was also noted by the divers, and this has resulted in the burying of most pins.

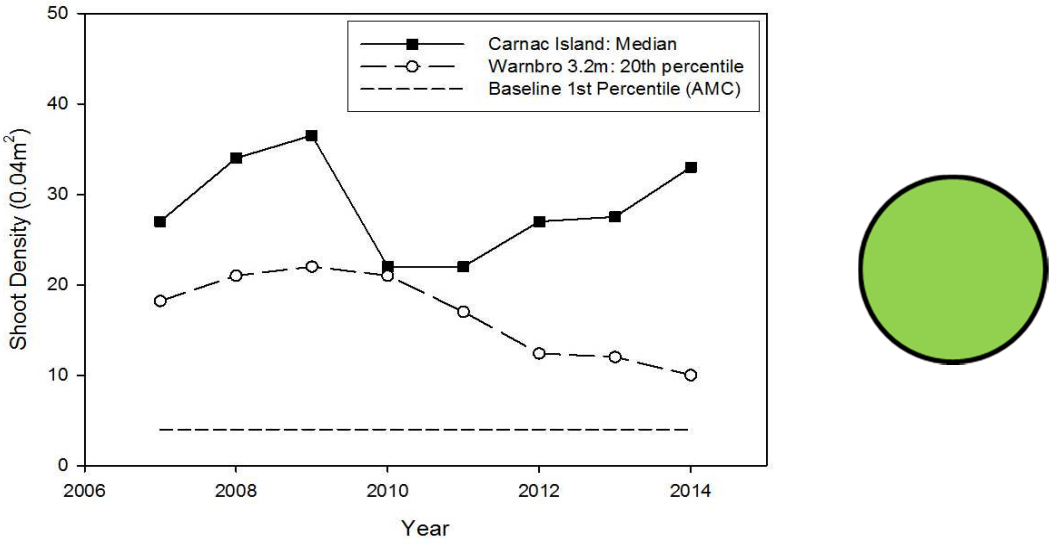

Figure 3: Median shoot densities of P. sinuosa *at Carnac Island compared to the 20th percentile and Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2 m 'reference' site.*

Coogee

The median shoot density of *P. sinuosa* at Coogee in 2014 had declined since 2013; however this is still above the Baseline 5th Percentile/Absolute Minimum Criteria for the

5.5 m ‘reference’ site (Figure 4). Therefore, Coogee has been assigned a green traffic light; however, it must be noted that the shoot density at this site is low and only just above the AMC. The median density at Coogee has fluctuated consistently at this site over time. During 2013, divers noted a second set of transects located very close to this site and raised concerns that researchers may have, on occasion, surveyed the wrong site. In 2014, a new labelling system was deployed and now the correct site at Coogee is easily distinguishable (see maintenance report).

The mean shoot density at Coogee had declined since 2013 and has fallen below the mean at Warnbro Sound (Figure 26). The percent cover of seagrass at Coogee was slightly higher in 2014 compared to 2013, but was slightly lower than the cover at Warnbro Sound 5.5 m (Figure 29). The maximal shoot height at Coogee in 2014 had increased from the previous year but was marginally lower than Warnbro Sound. The mean shoot height had also increased and was higher than Warnbro Sound (Figure 26). Epiphyte cover in all quadrats was recorded as medium level, encrusting species. No other species of seagrass were recorded at this site.

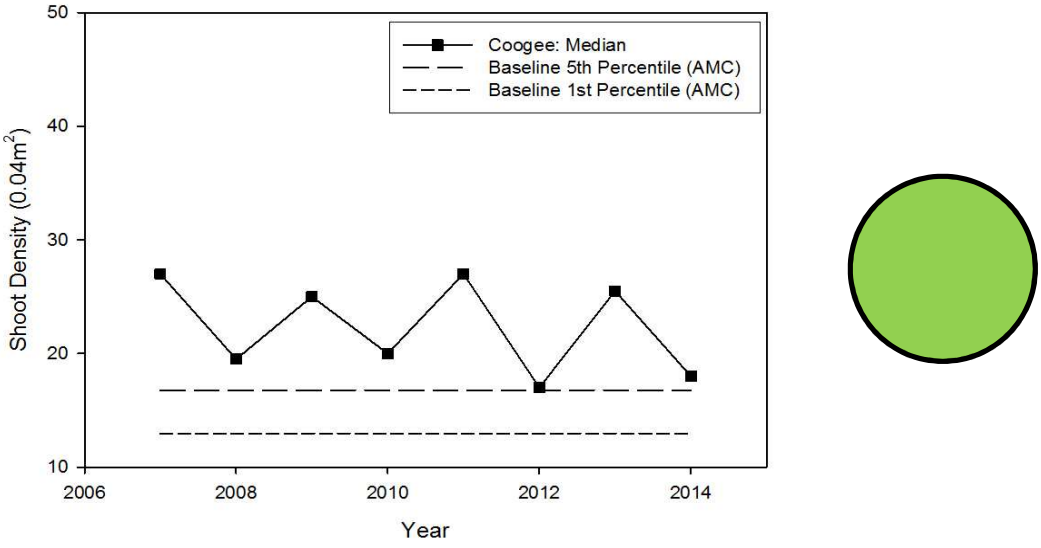

Figure 4: Median shoot densities of P. sinuosa *at Coogee compared to the Absolute Minimum Criteria of shoot densities at the Warnbro Sound 5.5 m ‘reference’ site.*

Garden Island 2.0m

The median shoot density of *P. sinuosa* at the Garden Island 2.0 m site in 2014 had increased since 2013 and is above the Baseline 5th Percentile/Absolute Minimum Criteria for the 2.0 m ‘reference’ site (Figure 5). This site has been assigned a green traffic light.

The mean shoot density at Garden Island 2.0m has increased slightly since 2013 but remains lower than the mean density recorded at the Warnbro Sound ‘reference’ site

(Figure 26). The percent cover of seagrass at Garden Island 2.0m was higher than at the Warnbro Sound 'reference' site (Figure 29), and was similar to cover in 2013. However, in 2014 no *P. australis* was recorded. The maximal shoot heights at Garden Island 2.0 m in 2014 were higher than those recorded at the Warnbro Sound 2.0 m site, but the average shoot height was lower (Figure 26). Both the mean and maximum shoot heights at this site had increased since 2013. Epiphytes were dominated by encrusting species with a medium coverage. No other seagrass species were observed.

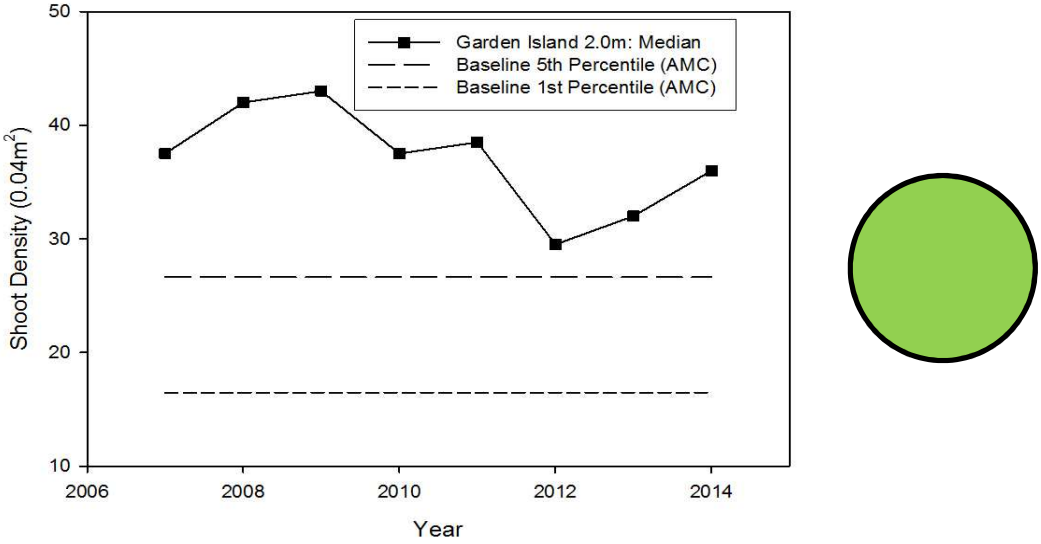

Figure 5: Median shoot densities of P. sinuosa *at Garden Island 2.0m compared to the Absolute Minimum Criteria shoot densities at the Warnbro Sound 2.0m 'reference' site.*

Garden Island 2.5 m

The median shoot density of *P. sinuosa* at Garden Island 2.5 m in 2014 was greater than in 2013 and was higher than the 20th percentile for the Warnbro Sound 2.5m 'reference' site (Figure 6). This site has been assigned a green traffic light.

The mean shoot density at Garden Island 2.5 m has increased slightly since 2013 but remains lower than the mean density recorded at the Warnbro Sound 'reference' site (Figure 26). The percent cover of seagrass at Garden Island 2.5m was lower than at Warnbro Sound 2.5m (Figure 29) and was lower than in to 2013. At this site in 2013 some *P. australis* was recorded, but not in 2014. The mean and maximal shoot heights recorded at Garden Island 2.5m were greater than at the Warnbro Sound 'reference' site (Figure 26). Both shoot height parameters had increased from 2013 to 2014. Epiphyte cover was composed of filamentous with a medium coverage. No other seagrass species were recorded at this site.

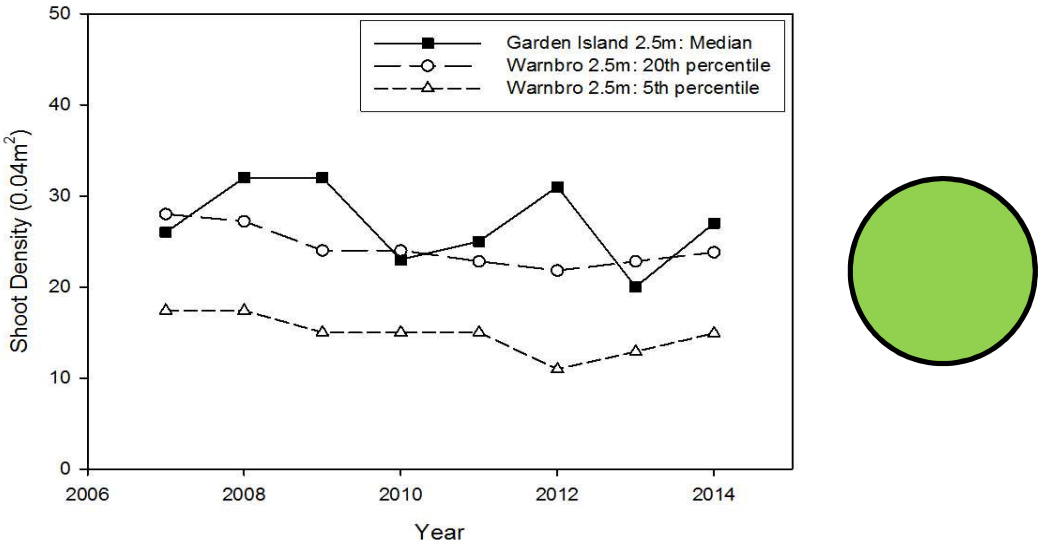

Figure 6: Median shoot densities of P. sinuosa *at Garden Island 2.5m compared to the 20th and 5th percentiles at the Warnbro Sound 2.5 m 'reference' site.*

Garden Island 3.2 m

The median seagrass shoot densities at Garden Island 3.2m in 2014 showed an increase from 2013 and were higher than the 20th percentile recorded at the Warnbro Sound 3.2m 'reference' site (Figure 7). Thus, Garden Island 3.2 m was considered healthy and assigned a green traffic light.

The mean shoot density at Garden Island 3.2m was higher in 2014 than the previous year, and was above the mean observed at the Warnbro Sound 'reference' site (Figure 26). The percent cover of seagrass at Garden Island 3.2m was similar in 2014 compared to 2013, and was higher than the cover at Warnbro Sound 3.2m (Figure 29). However, *P. australis* was recorded at this site in 2013 and was not in 2014. Both the mean and maximum shoot heights at Garden Island 3.2m had declined from 2013 to 2014, but remained above the shoot heights at Warnbro Sound (Figure 26). Epiphytes were dominated by encrusting forms with coverage in the medium range. No other seagrass species were recorded at this site.

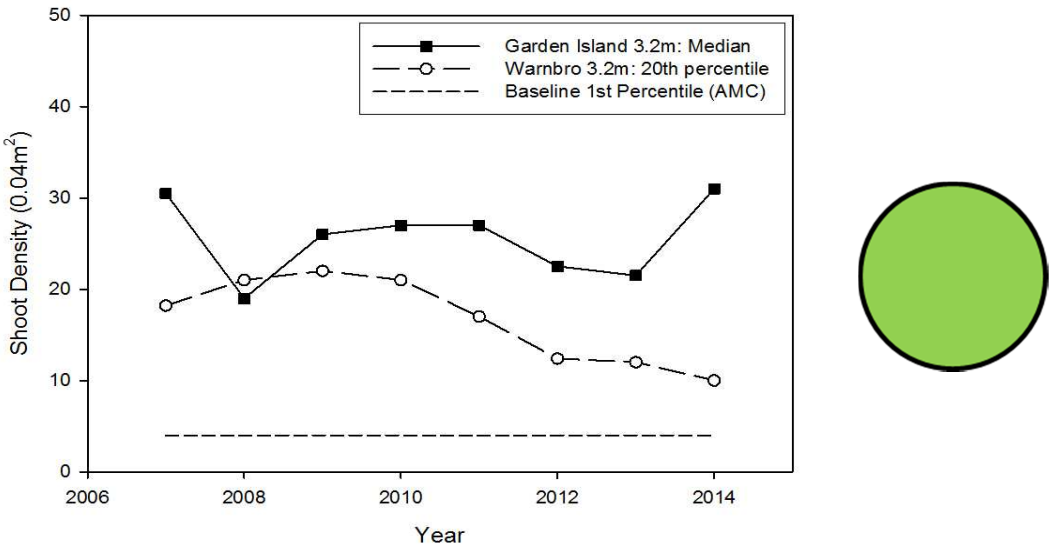

Figure 7: Median shoot densities of P. sinuosa *at Garden Island 3.2m compared to the 20th percentile and Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2 m 'reference' site.*

Garden Island 5.5m

The median shoot density of *P. sinuosa* at Garden Island 5.5m in 2014 has increased slightly since 2013 and is above the Absolute Minimum Criteria for Warnbro Sound 5.5m (Figure 8). Garden Island 5.5m has been assigned a green traffic light.

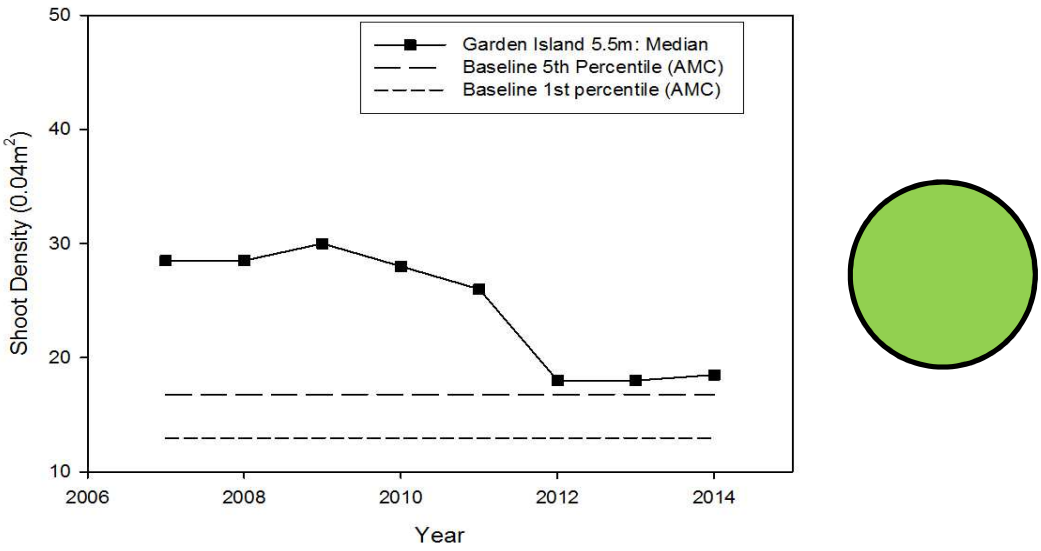

Figure 8: Median shoot densities of P. sinuosa *at Garden Island 5.5m compared to Absolute Minimum Criteria shoot densities at the Warnbro Sound 5.5m 'reference' site.*

The mean shoot density at Garden Island 5.5m has increased since 2013, but has fallen below the mean density at the Warnbro Sound 5.5 m (Figure 26). At Garden Island 5.5m, the percent cover of seagrass was lower than at Warnbro Sound but was slightly higher than last year. In 2013 there was more *P. australis* recorded here (Figure 29). The mean and maximal shoot heights at Garden Island 5.5m in 2014 were both higher than in the previous year. In 2014 the maximum shoot height at Garden Island 5.5m was lower than Warnbro Sound 5.5m but the average shoot height was higher (Figure 26). Epiphyte coverage was recorded as filamentous and medium over the whole site. *P. australis* was recorded in four quadrats, which is an increase since 2013 when none was recorded.

Garden Island 7.0m

The median shoot density of *P. sinuosa* at the Garden Island 7.0 m site in 2014 had increased since 2013 and remains greater than the 20th percentile for the Warnbro Sound 7.0 m 'reference' site (Figure 9). This site has been assigned a green traffic light.

The mean shoot density also has increased in 2014 after declining for the past 4 years and remains greater than the mean density recorded at the Warnbro Sound 'reference' site (Figure 26). The percent cover of seagrass at Garden Island 7.0m was higher than at the Warnbro Sound 'reference' site (Figure 29), and was higher than in 2013. However, the percentage of seagrass that was *P. australis* was lower. The mean and maximal shoot heights at Garden Island 7.0 m in 2014 were both higher than those recorded at the Warnbro Sound 7.0 m site (Figure 26), and this represents an increase since 2013. Epiphytes were dominated by filamentous species with a medium coverage. Two shoots of *P. australis* were recorded in one quadrat and no other species were observed.

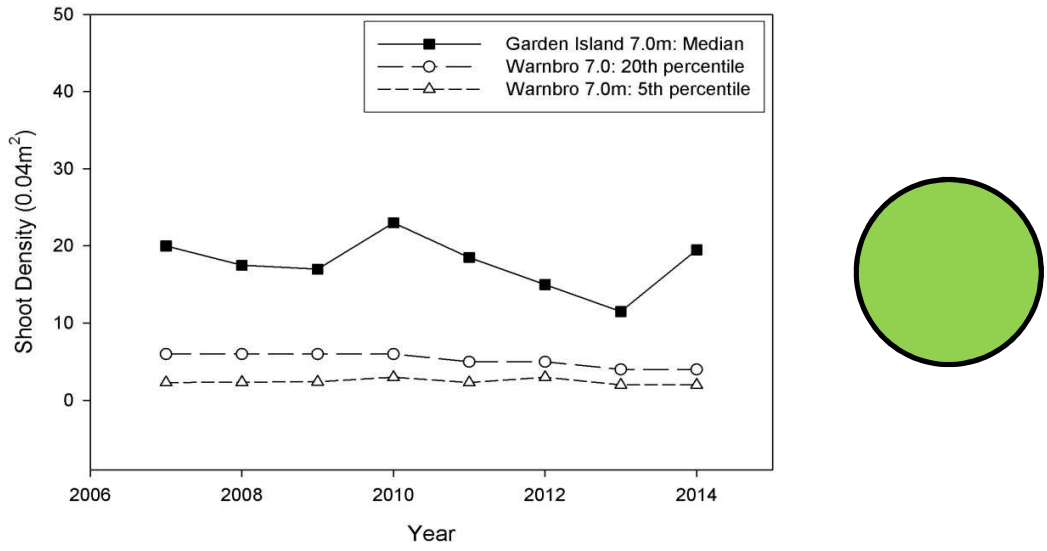

Figure 9: Median shoot densities of P. sinuosa *at Garden Island 7.0m compared to the 20th and 5th percentiles of shoot densities at the Warnbro Sound 7.0m 'reference' site.*

Garden Island Settlement

Seagrass shoot density of *P. sinuosa* at Garden Island Settlement in 2014 has declined since the previous year and has now fallen below the Baseline 5th percentile (AMC) for the 2.0m 'reference' site (Figure 10). The median density at this site remains above the Baseline 1st Percentile (AMC). This site must be assigned an amber traffic light.

In 2014, the mean shoot density at Garden Island Settlement was lower than the Warnbro Sound 'reference' site and has been since 2008. This also represents a decline since 2013 (Figure 26). At Garden Island Settlement the percent cover of seagrass was lower than at Warnbro Sound 2.0 m (Figure 29) and had declined since 2013. The percent cover of *P. australis* has increased slightly. At Garden Island Settlement the mean shoot height has increased but the maximum shoot height has declined. Both the mean and maximal shoot heights at Garden Island Settlement were below those recorded at the Warnbro Sound (Figure 26). *Posidonia australis* was recorded in four quadrats.

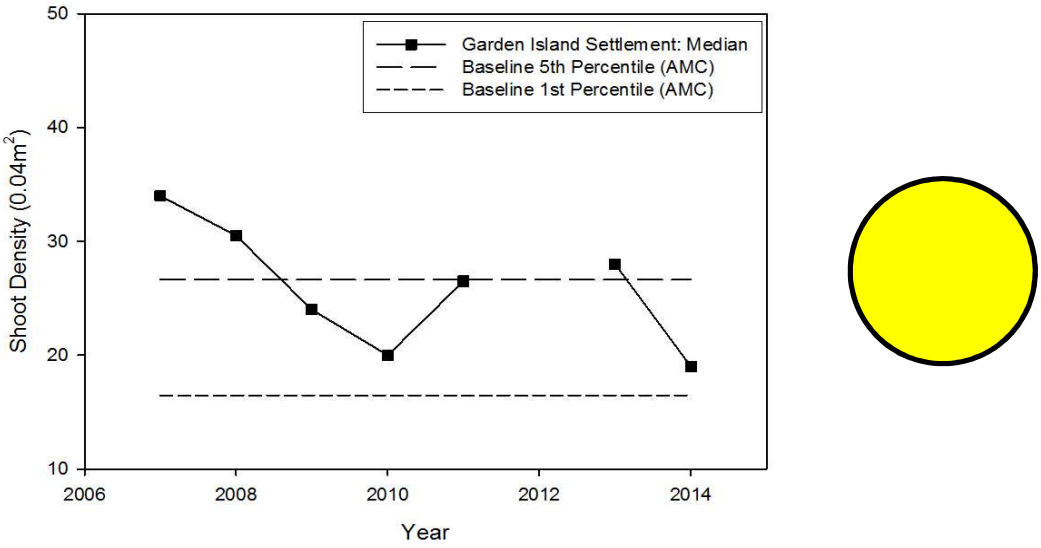

Figure 10: Median shoot densities of P. sinuosa *at Garden Island Settlement compared to the Absolute Minimum Criteria shoot densities at the Warnbro Sound 2.0 m 'reference' site.*

Kwinana

The median shoot density of *P. sinuosa* at Kwinana in 2014 has declined since 2013 and is the lowest since the beginning of sampling. This site has fallen below the Baseline 5th percentile (AMC) and has been assigned an amber traffic light (Figure 11). It is less than one shoot per 0.04m^2 away from falling below the Baseline 1st Percentile (AMC) and requires critical attention.

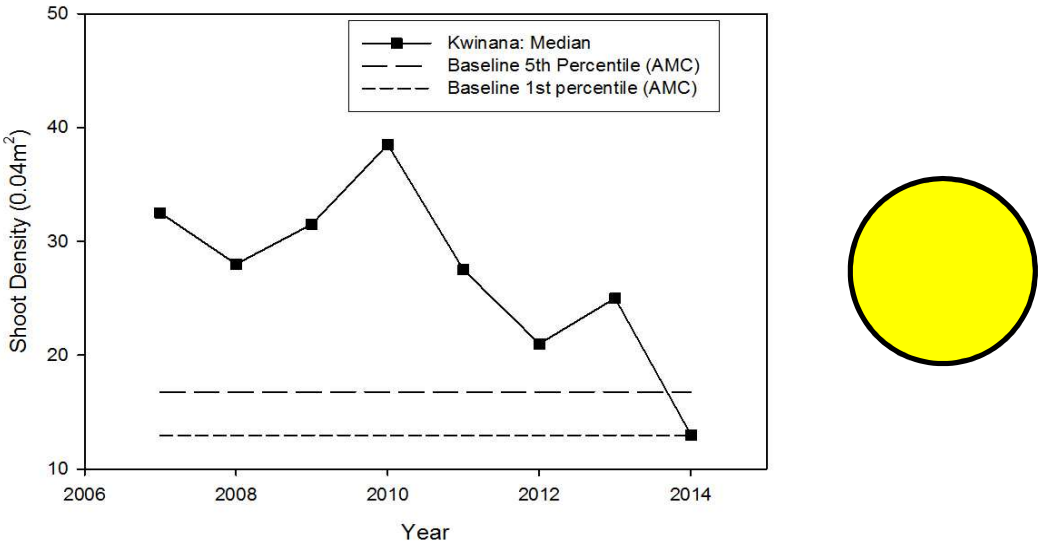

Figure 11: Median shoot densities of P. sinuosa *at Kwinana compared to Absolute Minimum Criteria shoot densities at the Warnbro Sound 5.5m 'reference' site.*

The mean shoot density at Kwinana has declined since 2013, and is lower than the mean density at the Warnbro Sound 5.5 m (Figure 26). At Kwinana, the percent cover of seagrass was higher than at Warnbro Sound and was similar to 2013; however, some *P. australis* was now recorded here (Figure 29). The mean and maximal shoot heights at Kwinana in 2014 were both higher than in the previous year but both were lower than at Warnbro Sound 5.5 m 'reference' site (Figure 26). Epiphyte coverage was recorded as filamentous and medium over the whole site. No other seagrass species were observed at this site.

Luscombe Bay

Median shoot density of *P. sinuosa* at Luscombe Bay in 2014 had declined marginally from 2013. It still remains above the Baseline 5th Percentile (AMC) for the 2.0 m 'reference' site (Figure 12). Thus, Luscombe Bay has been assigned a green traffic light. In 2013, researchers reported difficulty locating transects and confusion about the site layout. This year much effort was spent identifying transect, replacing lost star pickets and labelling everything for future clarity.

The mean shoot density at Luscombe Bay had increased since 2013 but was lower than Warnbro Sound 2.0 m (Figure 26). The percent cover of seagrass at Luscombe Bay was lower than at Warnbro Sound 2.0m; the percent cover at this site was highest of all the 'potential impact' sites (Figure 29). There was an increase in *P. australis* in 2014 compared to 2013 but a lower proportion of *P. sinuosa*. Both the mean and maximal shoot heights at Luscombe Bay in 2014 were higher than at Warnbro Sound 2.0m. The mean shoot height at Luscombe Bay had increased from 2013, but the maximum had declined (Figure 26). Epiphyte cover at Kwinana was recorded as medium level, filamentous species. No other species of seagrass were recorded in the quadrats.

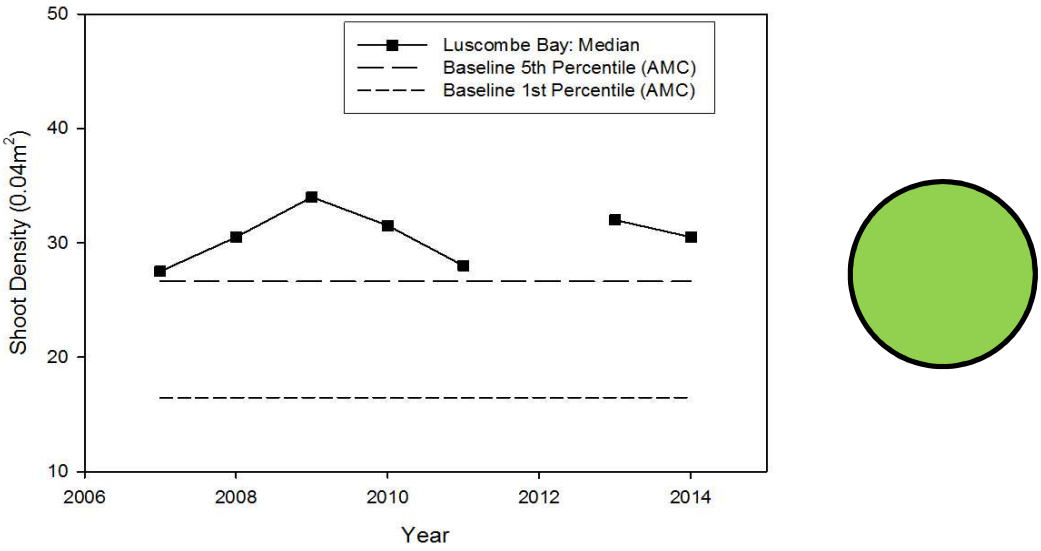

Figure 12: Median shoot densities of P. sinuosa *at Luscombe Bay compared to the Absolute Minimum Criteria shoot densities at the Warnbro Sound 2.0 m 'reference' site.*

Mangles Bay

The median shoot density of *P. sinuosa* at Mangles Bay in 2014 had declined slightly from the previous year but still remained about the 20th percentile for the Warnbro Sound 3.2m 'reference' site. Therefore Mangles Bay was assigned a green traffic light (Figure 13).

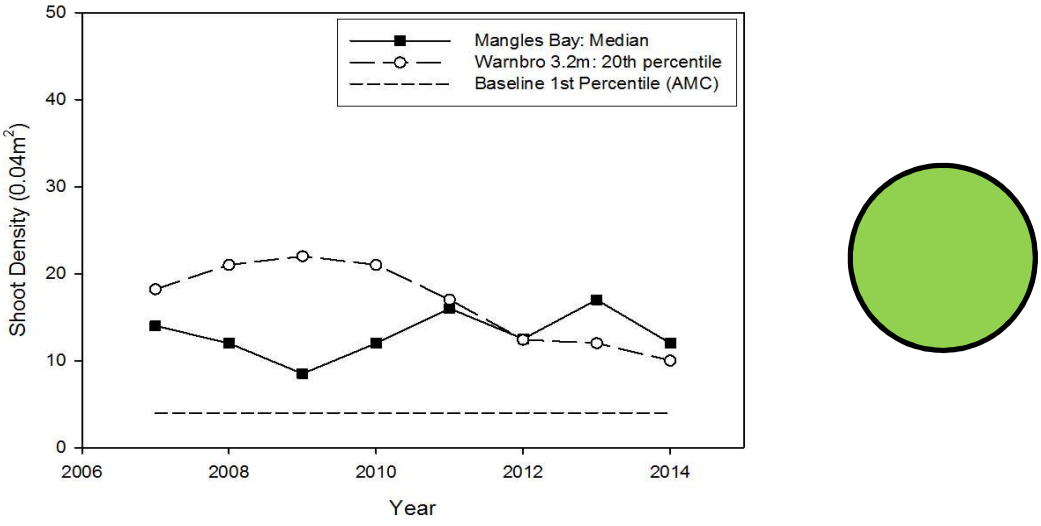

Figure 13: Median shoot densities of P. sinuosa *at Mangles Bay compared to the 20th percentile and Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2m 'reference' site.*

Mean shoot density at Mangles Bay was lower in 2014 than in 2013 and has been lower than shoot densities at Warnbro Sound 3.2 m for the past eight years (Figure 26). At Mangles Bay the percent cover of seagrass was much higher than at Warnbro Sound 3.2m and had increased from 2013 (Figure 29). Both mean and maximal shoot heights at Mangles Bay had increased in 2014 compared to the previous year. The maximum shoot height was lower than at Warnbro Sound 3.2 m; but the mean shoot height was higher (Figure 26). All epiphytes observed at Mangles Bay were documented as high and filamentous. *Posidonia australis* was observed in two quadrats at this site.

Southern Flats

Median shoot density of *P. sinuosa* at Southern Flats in 2014 has declined marginally since 2013, but remains well above the 20th percentile Warnbro Sound 2.5 m 'reference' site (Figure 14). Therefore, this site has been assigned a green traffic light. Divers noted a high level of sand inundation at this site; in fact, on transect four a large dune of sand has built up, leaving only the very tips of the shoots. It is possible that this may appear as a 'blow out' during next year's sampling.

The mean shoot density in 2014 has declined since 2013 and is now lower than Warnbro Sound 2.5 m (Figure 26). At Southern Flats the percent cover of seagrass was lower than Warnbro Sound (Figure 29) and had declined from 2013. The mean and maximal shoot heights were both lower at Southern Flats than at the comparable 'reference' sites (Figure 26), and had remained fairly consistent with the previous year. The epiphytes at this site were characterised as filamentous with a medium coverage. No other species of seagrass were recorded at this site.

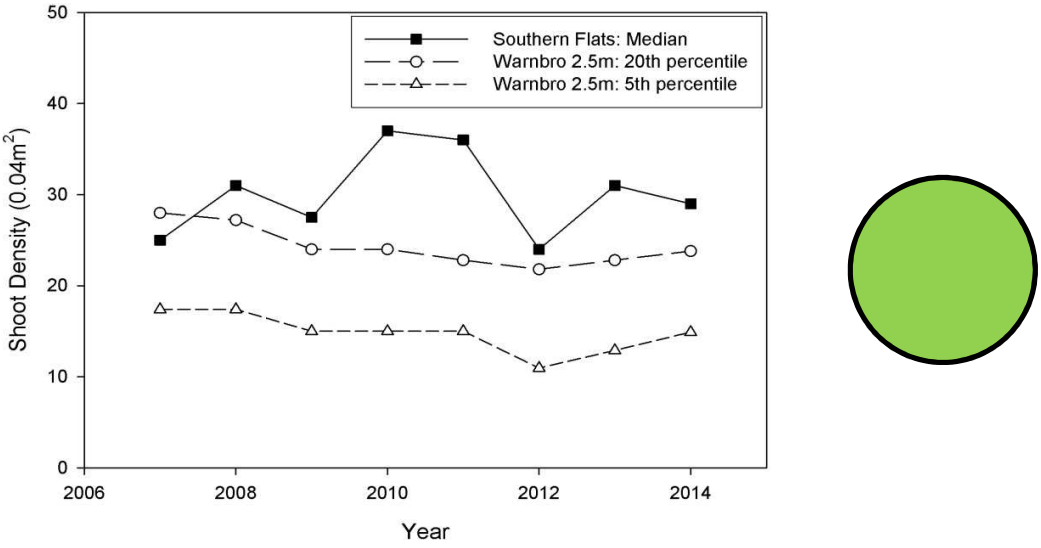

Figure 14: Median shoot densities of P. sinuosa *at Southern Flats compared to the 20th and 5th percentiles of shoot densities at the Warnbro Sound 2.5 m 'reference' site.*

Woodman Point

The median shoot density of *P. sinuosa* at Woodman Point in 2014 is similar to the previous year and is higher than the 20th percentile at the Warnbro Sound 3.2 m 'reference' site. As such, Woodman Point has been assigned a green traffic light (Figure 15). Concerns were raised in 2013 that this site appeared heavily impacted by sand movement, which had resulted in a large 'blow-out' in the middle of the site in which one transect had been lost. Therefore, in 2014 a fifth transect was established so that seagrass density at this site can still be assessed rather than continuing to 'count sand'. The lost transect will continue to be monitored for potential re-establishment of seagrass.

The mean shoot density at Woodman Point has declined in 2014 and is now lower than the mean at Warnbro Sound 3.2 m (Figure 26). At Woodman Point the percent cover of seagrass was considerably lower than at Warnbro Sound 3.2m, and was the lowest of all the sites surveyed (Figure 29). The percent cover of seagrass at Woodman Point was lower in 2014 than 2013, and less *P. australis* was recorded. The mean and maximal shoot heights at Woodman Point showed a slight increase compared to 2013 but were still lower than the reference site (Figure 26). *P. australis* was recorded in six quadrats at this site.

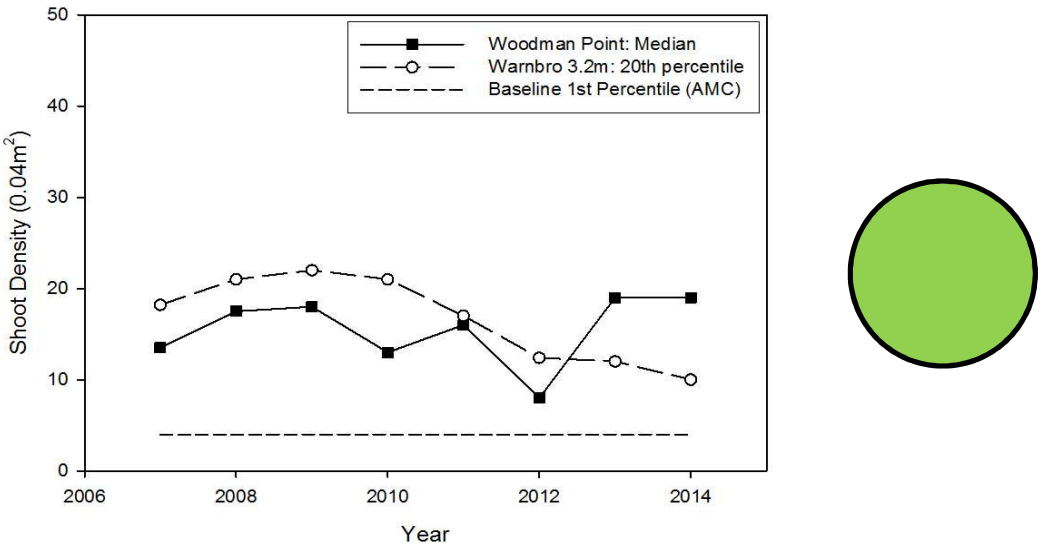

Figure 15: Median shoot densities of P. sinuosa *at Woodman Point compared to the 20th percentile and Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2 m 'reference' site.*

6.2.2 Sites in Moderate Protection Area

Jervoise Bay

Jervoise Bay is considered a 'Moderate Protection Area' and therefore, the median shoot density of *P. sinuosa* was compared to the 20th, 5th and 1st percentiles of shoot density at the Warnbro Sound 3.2m 'reference' site. Shoot densities at Jervoise Bay had declined in 2014 but remain above the 20th percentile at the Warnbro Sound 3.2 m 'reference' site (Figure 16). This site has been assigned a green traffic light. Researchers reported large *Pinna bicolor* bivalves in almost all quadrats; on some cases growing over and engulfing the quadrat pins. There was also some evidence of grazing on the seagrass at this site.

In 2014, the mean shoot density at Jervoise Bay has declined since 2013 and remains below the mean for the Warnbro Sound reference site (Figure 27). The percent cover at Jervoise Bay was lower than the Warnbro Sound 'reference' site but had increased marginally since 2013 (Figure 29). There was also more *P. australis* in 2014 than 2013. Both the mean and maximal shoot heights at Jervoise Bay had increased since 2013; however both are still lower than shoot heights at Warnbro Sound. The maximum shoot heights at Jervoise Bay is even lower than the mean shoot height at the reference site. The epiphyte cover was documented as medium encrusting species. In 2013, a large percentage of quadrats contained *P. australis*; however in 2014 no shoots were recorded at all. No other species of seagrass were observed in quadrats at this site.

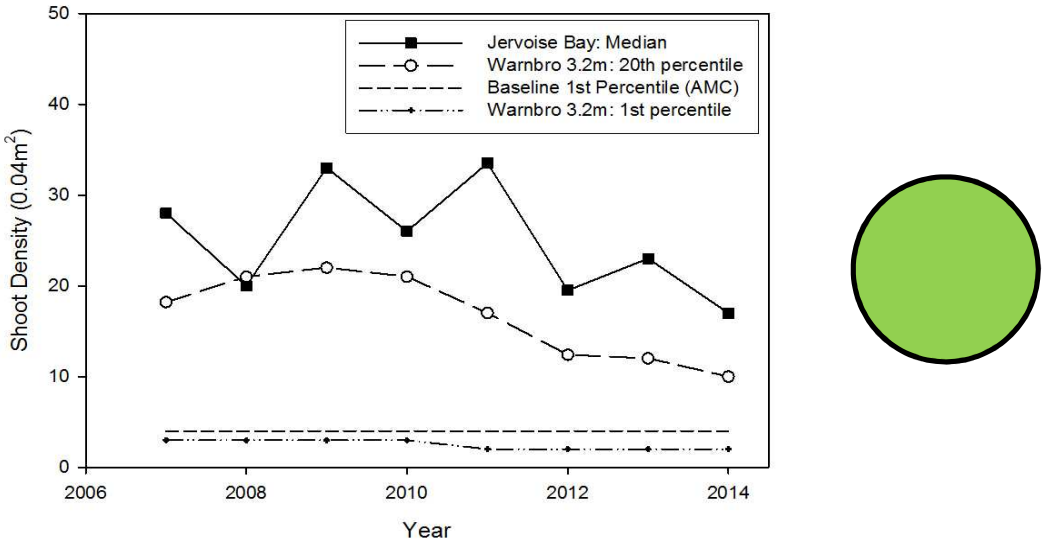

Figure 16: Median shoot densities of P. sinuosa *at Jervoise Bay compared to the 20th and 1st percentiles and Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2m 'reference' site.*

6.2.3 Sites not designated as 'High Protection' or 'Moderate Protection'

Bird Island

Bird Island has not been assigned a level of ecological protection and so is treated as 'high' (Centre for Marine Futures, 2009). The median shoot density of *P. sinuosa* at Bird Island in 2014 was greater than the previous three years and was higher than the 20th percentile for the Warnbro Sound 2.5m 'reference' site (Figure 17). Since the shoot density at Bird Island has been higher than the 'reference' site trigger values for two consecutive years it has been assigned a green traffic light. Some accumulated wrack was observed at this site.

The mean shoot density at Bird Island has increased since 2013 but remains below the shoot density at Warnbro Sound 2.5m (Figure 28). The percent cover of seagrass at Bird Island was lower than at Warnbro Sound 2.5m (Figure 29) and was similar to 2013. The maximum shoot height recorded at Bird Island increased in 2014 and was greater than at Warnbro Sound. However, the mean shoot height had declined from 2013 but was still above Warnbro Sound 2.5 m (Figure 28). Epiphyte cover was composed of filamentous with a medium coverage. *Amphibolis antarctica* was recorded in two of the quadrats.

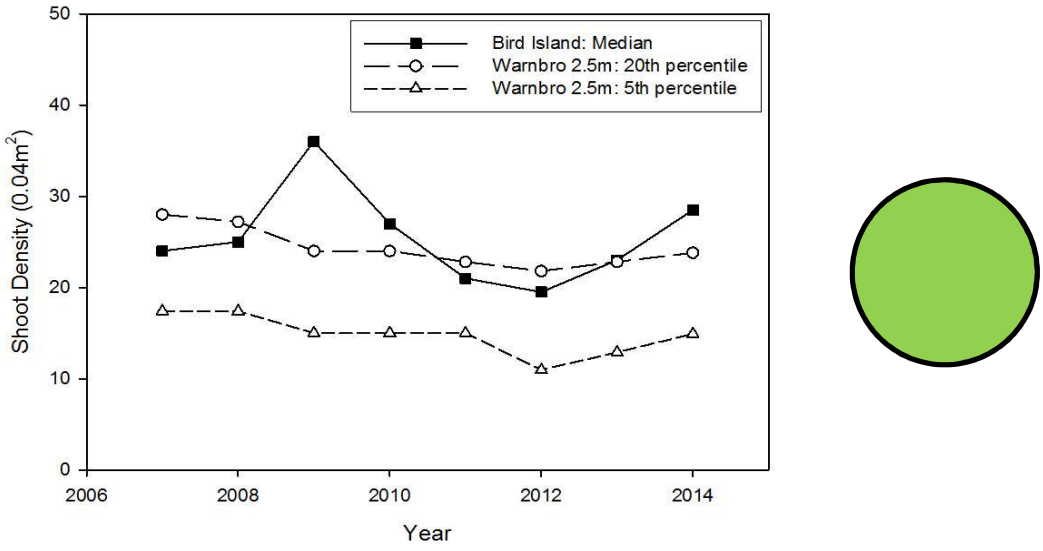

Figure 17: Median shoot densities of P. sinuosa *at Bird Island compared to the 5th and 20th percentiles of shoot densities at the Warnbro Sound 2.5 m 'reference' site.*

Mersey Point

The median shoot density at Mersey Point in 2014 has increased marginally since 2013 and is greater than the 20th percentile for the Warnbro Sound 3.2 m 'reference' site.

Thus, Mersey Point was assigned a green traffic light (Figure 18). Some wrack was recorded accumulated under the canopy.

The mean shoot density in 2014 has increased since 2013, and but remains below the mean for Warnbro Sound 3.2 m site (Figure 28). The percent cover of seagrass at Mersey Point was considerably higher than at Warnbro Sound 2.5m (Figure 29) and was similar to 2013. In 2014 the maximal shoot heights at Mersey Point had increased and the mean shoot heights had decreased compared to 2013. Both the mean and maximum shoot heights at Mersey Point were higher than those recorded at Warnbro Sound 3.2 m (Figure 28). Epiphytes were dominated by encrusting species with medium coverage. No other species of seagrass were observed at this site.

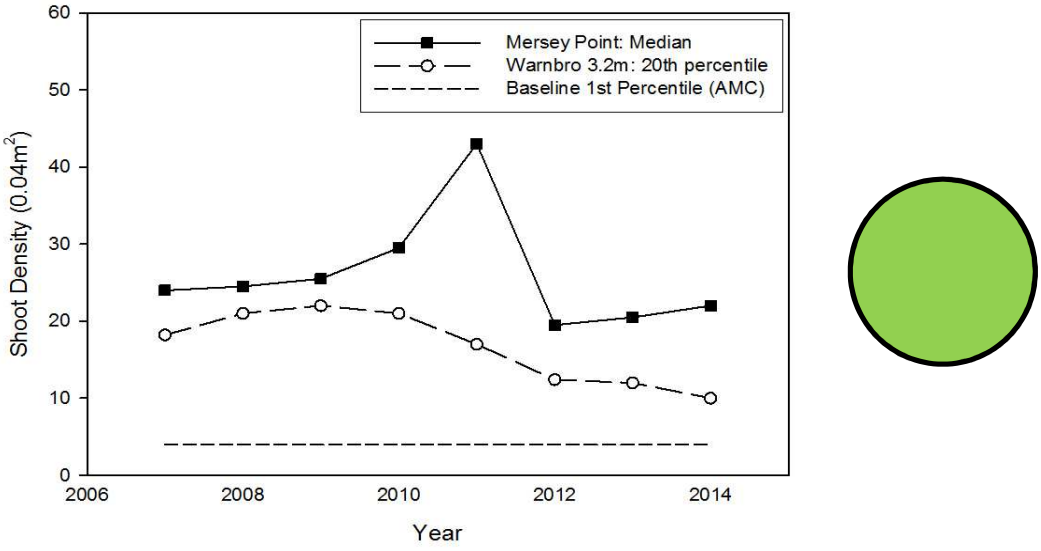

Figure 18: Median shoot densities of P. sinuosa *at Mersey Point compared to the 20th percentile and the Absolute Minimum Criteria of shoot densities at the Warnbro Sound 3.2 m 'reference' site.*

6.3 Regional Comparisons and other Reference Sites

Three new 'reference' sites (Seal Island, Penguin Island, and Becher Point), were established in the Shoalwater Islands Marine Park (SIMP) in 2013 following the protocols described by the Environmental Protection Authority (2004). Once a full 100 quadrats of data has been collected these sites may be used to protect against potential declines at the Warnbro 'reference' sites (e.g. Wave Solutions, 2012). In addition, three existing sites in the Jurien Bay Marine Park (JBMP) have been have been resampled to provide a regional perspective of the health of seagrasses in Cockburn Sound. Here we have presented the calculated percentile values for three Warnbro Sound 'reference' sites, the new Shoalwater reference sites and the Jurien Bay sites to identify any patterns of trends in seagrass density.

The three new sites in the SIMP were surveyed by WAMMP during 2012, and a total of 45 quadrats were sampled in that year. In 2013 the sites were established according to the 'Manual of Standard Operating Procedures' (Environmental Protection Authority, 2004) and data was collected from 24 quadrats. These sites were resampled in 2014 creating a total of 93 quadrats. We have used these data to calculate the 20th and 5th percentile values. These are generally calculated from a minimum of 100 quadrats, and so these values remain indicative only, and should be interpreted with caution. The three sites in the JBMP have been surveyed regularly since 2003 (2003-2005, 2007, 2008, 2010-2014), and sufficient data were available for the calculation of percentiles.

Both the new 2.5m reference sites in SIMP (Penguin Island) and JBMP (Boullanger Island 2.5m) had lower 5th and 20th percentile trigger values in 2013 than Warnbro Sound 2.5m (Figure 19). Both the maximum and average seagrass shoot heights at Penguin Island were lower than the shoot heights at Warnbro Sound 2.5m. However, the maximum shoot heights at Boullanger Island 2.5m were higher than the Warnbro Sound reference site, but the mean shoot height was lower (Table 12). The percent cover of seagrass at both new 2.5m 'reference' sites was higher than Warnbro Sound 2.5m. The Garden Island 2.5m 'test reference' site also had a lower percent cover than Penguin Island, but was higher than the percent cover at Boullanger Island 2.5m (Figure 29).

At both the new 3.2m (Becher Point and Boullanger Island 3.5m) and 5.5m (Seal Island and Boullanger 5.5) sites the trigger values were considerably higher in 2013 than the Warnboro Sound reference sites. At the 3.2m 'reference' sites, Boullanger Island 3.5m and Becher Point had similar 20th percentile, while Becher Point 3.2m (Shoalwater) had the highest 5th percentile (Figure 20). At the 5.5m reference sites, Boullanger Island 5.5m recorded the highest trigger values for both 20th and 5th percentiles (Figure 21).

At both the new 3.2m reference sites the mean and maximum shoot heights were higher than those measured at Warnbro Sound 3.2m with Becher Point having the highest maximum shoot height while Boullanger Island 3.2m had the highest mean shoot height (Table 12). At both Becher Point and Boullanger Island 3.5m the percent cover was considerably higher (almost double) than the Warnbro Sound 3.5m reference sites; however the Garden Island 3.5m 'test reference' site had a high percent cover than both new 3.5m 'reference' sites (Figure 29).

At Seal Island (new 5.5m reference site) both the maximum and average shoot heights were higher than both Warnbro Sound and Boullanger Island 5.5m. Both shoot height measurements were higher at Boullanger Island 5.5m than at the Warnbro Sound 'reference' site (Table 12). At both new 5.5m 'reference' sites the percent cover was higher than at both Warnbro Sound and Garden Island 5.5m (Figure 29).

In both 2013 and 2014, the new sites in the SIMP and JBMP provided a comparable set of trigger values compared to reference sites in Warnbro Sound. These sites need to be assessed over time as more data become available to refine the trigger values and carry out trend analysis; however, they appear to be promising and may, in the future,

provide some insurance against any potential decline of seagrass at the Warnbro Sound reference sites, and also minimize pseudo-replication (Hurlbert, 1984).

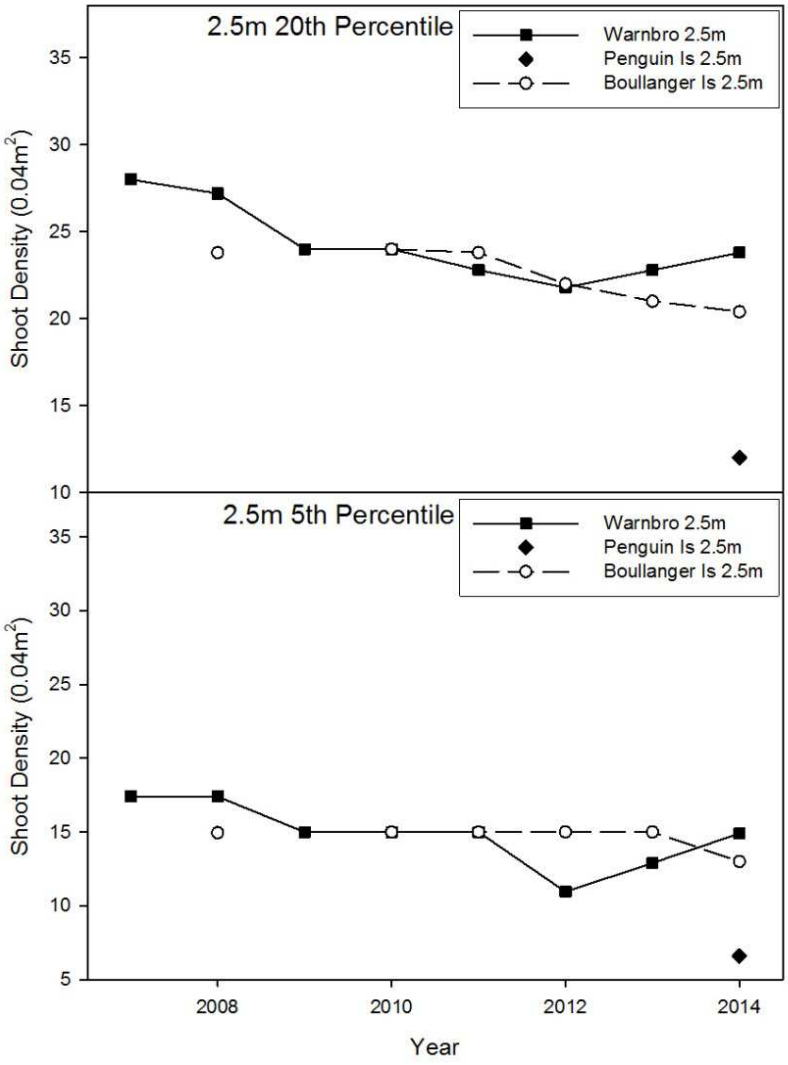

Figure 19: Comparisons of trigger values (20th percentile – upper plot, 5th percentile – lower plot) between current 2.5m 'reference' site (Warnbro Sound) to 2.5m 'reference' sites in Jurien Bay (Boullanger Island 2.5m) and Shoalwater (Penguin Island).

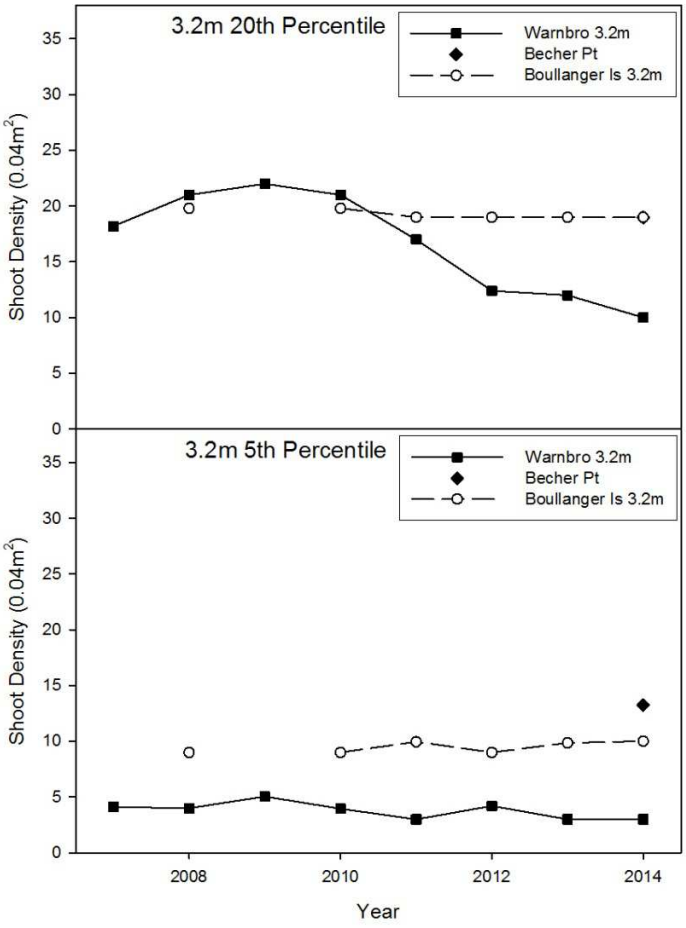

Figure 20: Comparisons of trigger values (20th percentile – upper plot, 5th percentile – lower plot) between current 3.2m 'reference' site (Warnbro Sound) to 3.2m 'reference' sites in Jurien Bay (Boullanger Island 3.5m) and Shoalwater (Becher Point).

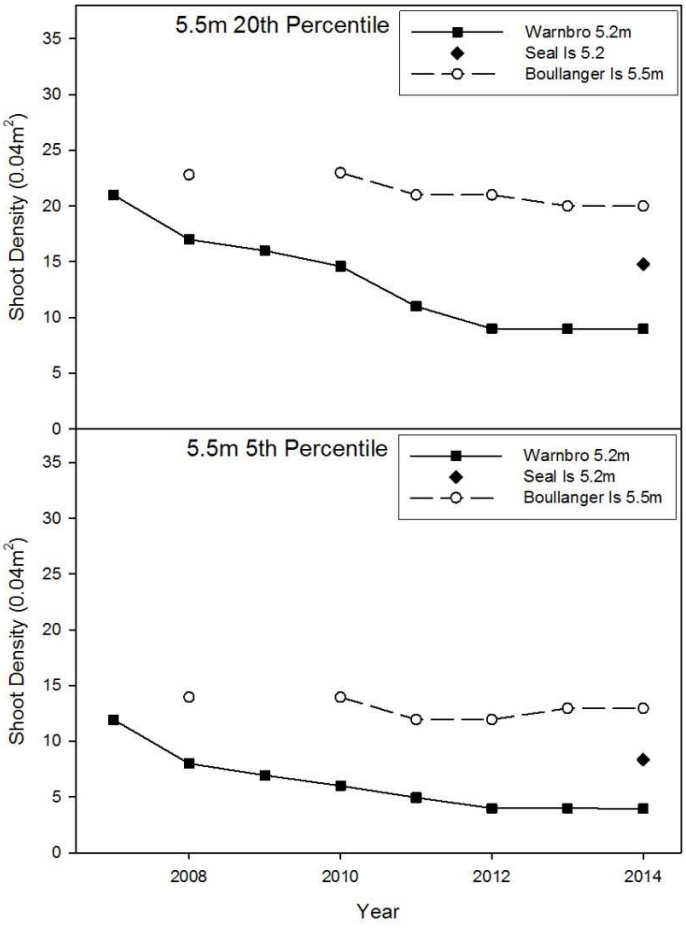

Figure 21: Comparisons of trigger values (20th percentile – upper plot, 5th percentile – lower plot) between current 5.5m 'reference' site (Warnbro Sound) to 5.5m 'reference' sites in Jurien Bay (Boullanger Island 5.5m) and Shoalwater (Seal Island).

6.4 Bathymetry

In 2013, Mohring and Rule (Mohring and Rule, 2013b)investigated the depth allocations for all the sites in this program to check that all depth comparisons were correct. This was achieved by examining a high-resolution (5 x 5 m pixel) bathymetry GIS layer that had been corrected for tidal deviations. These authors showed that the depth of several of the sites had varied from their original depths (Table 4). These were Southern Flats, Bird Island, Mersey Point, Garden Island 7.0m and Warnbro Sound 3.2 m. They recommended that future analysis of 'potential impact' sites be altered so that the correct comparisons are being carried out. There are still two points of concern. Firstly, the change in depth of the Garden Island 7.0 m means that there is now no impact site in Cockburn Sound deeper than 5.5m. Secondly, and more importantly, a correct 3.2 m reference site in Warnbro Sound must be established. There are six 'potential impact' sites at 3.2 m in Cockburn Sound which are presently being compared to a reference

site at only 2.7 m. This is likely to be resulting in a misrepresentation of the health of these sites.

Table 4 List of permanent seagrass sites, their impact designation (impact/reference), the original measured depths (from Lavery and Gartner, 2008) and their reference counterparts. Also shown are the depths calculated from the high resolution LiDAR bathymetry layer (Fugro LADS Corp, 2009) and the correct reference depths against which each impact site should be compared. Sites where the calculated comparison depth is different to the original reference comparison are shown in bold.

		Original *in situ* measured depth		Depth calculated from bathymetry	
Site name	Site type	Site depth	Assessed against	New depth	Ref. comparison
Carnac Island	Impact	4.5	3.2	3.59	3.2
Coogee	Impact	5.0	5.5	5.76	5.5
Garden Is. Settlement	Impact	2.0	2.0	1.14	2.0
Kwinana	Impact	5.2	5.5	4.68	5.5
Luscombe Bay	Impact	2.0	2.0	1.27	2.0
Mangles Bay	Impact	3.2	3.2	3.32	3.2
Southern Flats	**Impact**	**2.5**	**2.5**	**2.14**	**2.0**
Woodman Point	Impact	2.5	3.2	3.75	3.2
Jervoise Bay	Impact	2.5	3.2	3.51	3.2
Bird Island	**Impact**	**2.0**	**2.5**	**1.85**	**2.0**
Mersey Point	**Impact**	**3.0**	**3.2**	**2.33**	**2.5**
Garden Island 2.0m	Impact	2.0	2.0	1.91	2.0
Garden Island 2.5m	Impact	2.5	2.5	2.62	2.5
Garden Island 3.2m	Impact	3.2	3.2	3.11	3.2
Garden Island 5.5m	Impact	5.5	5.5	4.78	5.5
Garden Island 7.0	**Impact**	**7.0**	**7.0**	**5.79**	**5.5**
Warnbro Sound 2.0m	Reference	2.0	-	2.09	-
Warnbro sound 2.5m	Reference	2.5	-	2.38	-
Warnbro Sound 3.2m	**Reference**	**3.2**	**-**	**2.76**	**-**
Warnbro Sound 5.5m	Reference	5.5	-	5.0	-
Warnbro Sound 7.0m	Reference	7.0	-	7.0	-

6.5 Depth Transect Sites

When the original transects were established they were positioned so that the tape extended 10m either side of the seagrass meadow edge (Environmental Protection Authority 2004), allowing measurement of the expansion and contraction of the meadow's edge. In most sites, the edge has now extended beyond the lower limit of

transects, meaning that the LE is often the last quadrat along the transect and is not representative of the meadow edge.

6.5.1 Leading edge (LE)

The maximum depth at which seagrass was observed in quadrats (LE) has become shallower (receded) for three sites (Garden Island North, Warnbro Sound and Woodman Point, see Figure 22) and stayed the same for Garden Island South when compared to 2012. At the three sites where seagrass receded the mean depth of the LE has reduced by less than a meter (Garden Island North receded from 9.3 to 9.2m, Woodman Point from 7.8 to 7.3m and Warnbro Sound from 8.1 to 8.0). While there were differences in the depth of the Leading Edge at several sites, these were not statistically significant compared to last year or 1998 (Table 5).

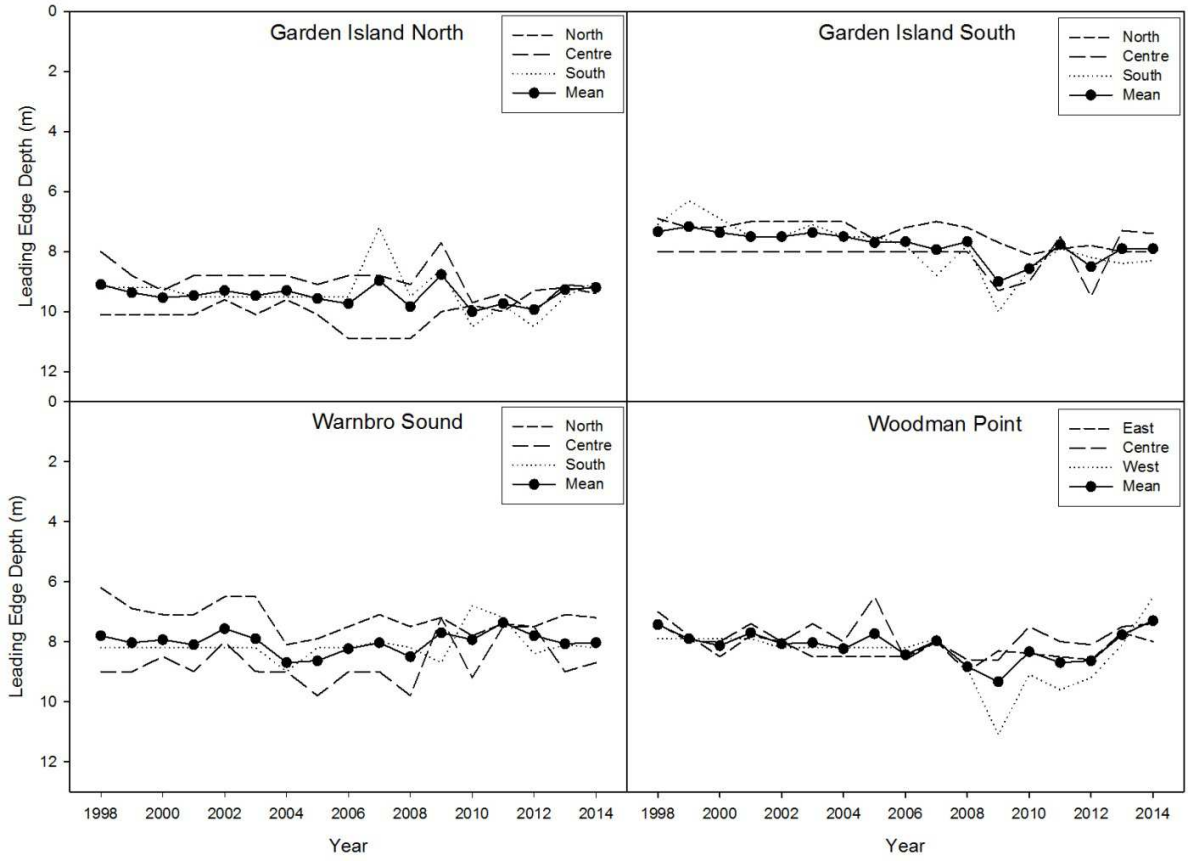

Figure 22: Leading edge depth of the seagrass meadows, i.e. the depth of the last quadrat on the transect where seagrass was recorded.

At two of the sites, Garden Island North and South the distance along the tape where the last quadrat fell remained the same between 2013 and 2014. However, at Warnbro Sound and Woodman Point the seagrass had receded, with a change from 11.3 m

(2013) to 10.7 m (2014) at Warnbro Sound and a change from 18.7 m (2013) to 12.0 m (2014). Any differences in the distance along the tape of the Leading Edge between 2014 and 2013 and historically were not statistically significant (Table 5).

Table 5: List of P-values resulting from two-tailed t-test of the Leading Edge (LE) and the Lower Depth Limit (LDL). Analysis was carried out for both depth of the seagrass and distance along the tape, and the base line year (1998 for LE and 2008 for LDL) was compared against the current year of sampling. For LE the previous year was also compared against this year, but this could not be undertaken for LDL as this was not measured. For all t-tests the df were 2.

	Depth				**Distance**			
	LE	**LE**	**LDL**	**LDL**	**LE**	**LE**	**LDL**	**LDL**
	1998 - 2014	2013 - 2014	2008 - 2014	2013 - 2014	1998 - 2014	2013 - 2014	2008 - 2013	2013 - 2014
Garden Is. North	0.880	0.710	0.844	1.000	0.219	1.000	0.129	0.905
Garden Is. South	0.257	1.000	0.314	**0.033**	0.091	1.000	0.863	0.077
Warnbro Sound	0.817	0.965	0.826	0.621	0.624	0.891	0.273	0.797
Woodman Point	0.806	0.377	**<0.001**	**0.011**	1.000	0.328	0.440	0.125

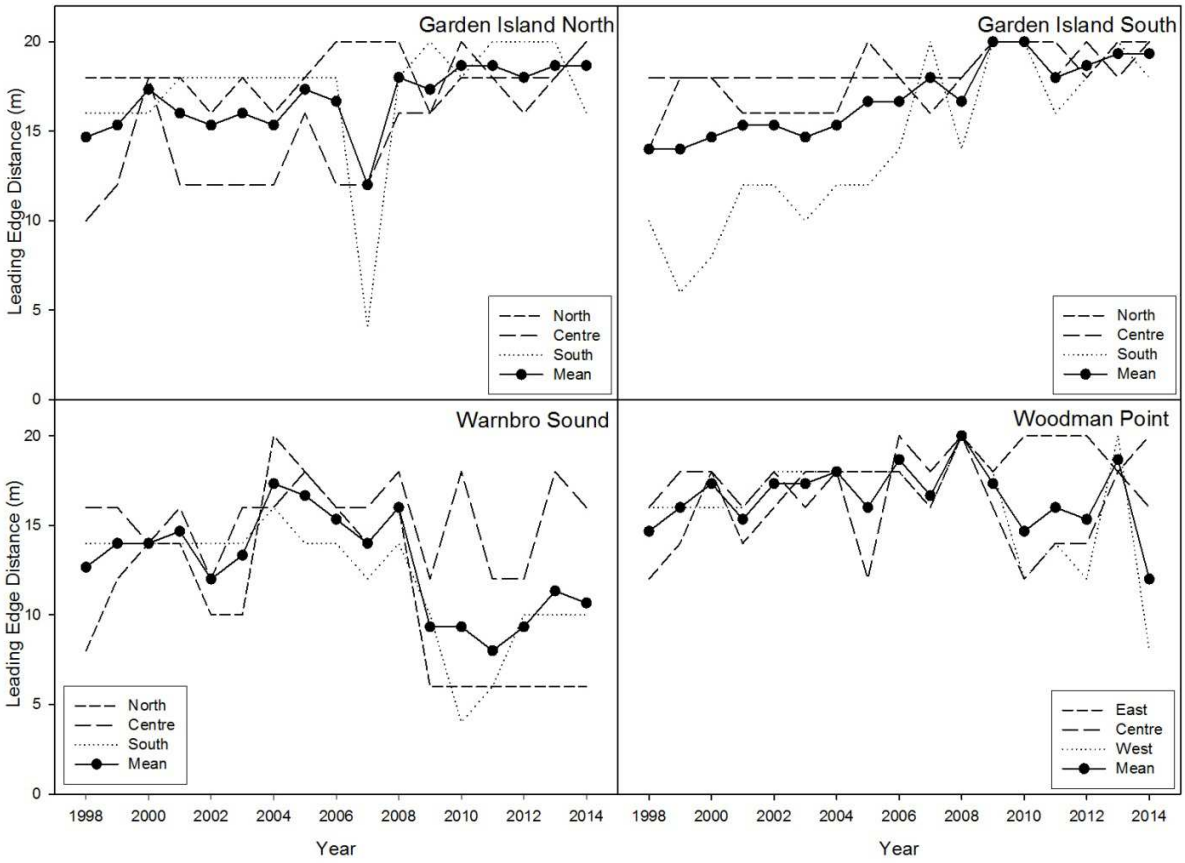

Figure 23: Leading edge distance of the seagrass meadows, i.e. the distance of the last quadrat on the transect where seagrass was recorded.

6.5.2 Lower depth limit (LDL)

In 2014, the LDL of seagrass at Woodman Point and Garden Island South was deeper than it was in 2013, and was also deeper than it was in 2008. At Garden Island North the extent remained the same in 2014 as 2013 which was deeper than it was in 2008. Finally, at Warnbro Sound the seagrass was 0.4 m shallower in 2014 than 2013, and 0.2 m shallower in 2014 than in 2008 (Table 14; Figure 24). The increase in meadow depth observed at Garden Island South was statistically significant. Both the increases at Woodman Point, between 2008 and 2014 and 2013 and 2014 were significant (Table 5).

The distance along the tape that the seagrass extended has reduced at three of the sites. At Garden Island South, and Woodman Point and Warnbro Sound the seagrass does not extend as far as it did in 2013 or even 2008. At Garden Island North the seagrass now extends further than it did in 2013 and even 2008 (Figure 25; Table 14). There were no significant differences in the distance of the LDL between the baseline year of sampling and the present year, or 2013 and 2014 (Table 5).

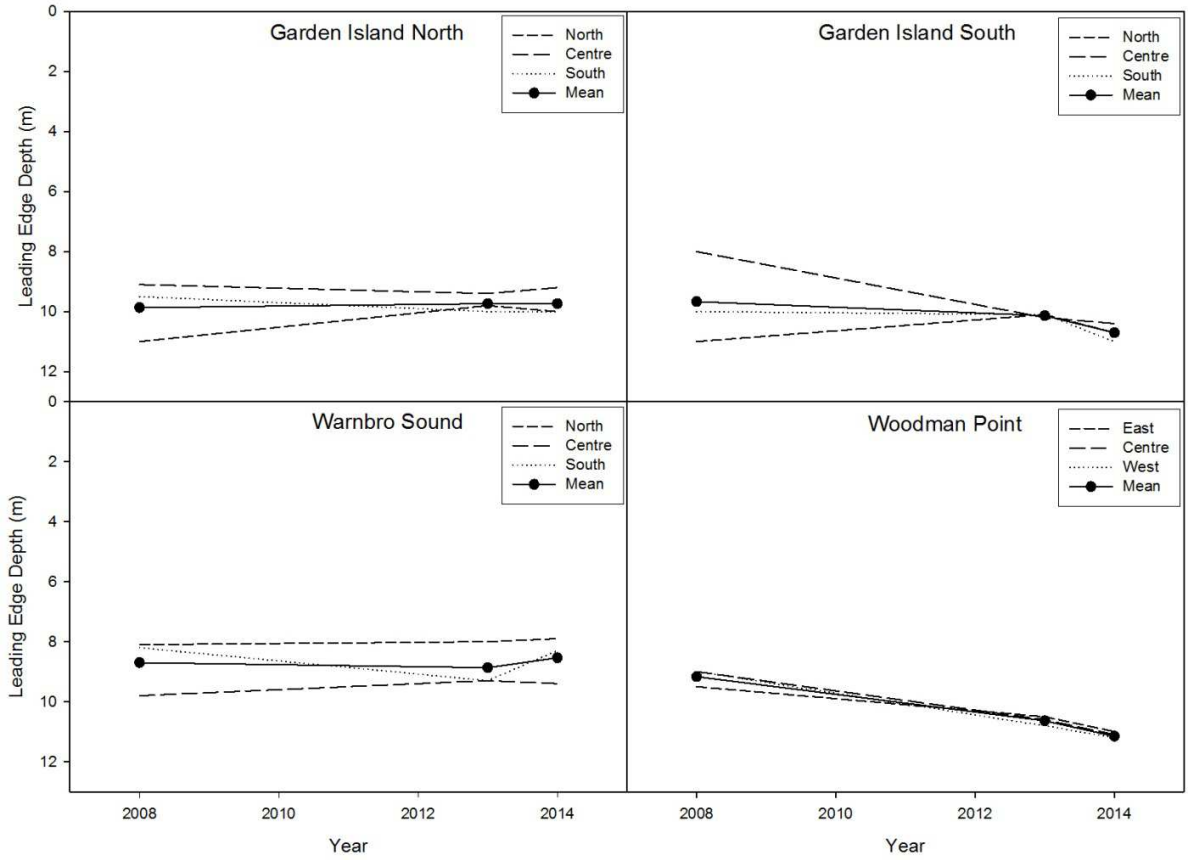

Figure 24: Difference in depth of the lower depth limit (i.e. the depth where seagrass was no longer present one meter on either side of the tape) of the seagrass meadows between 2008 and 2014.

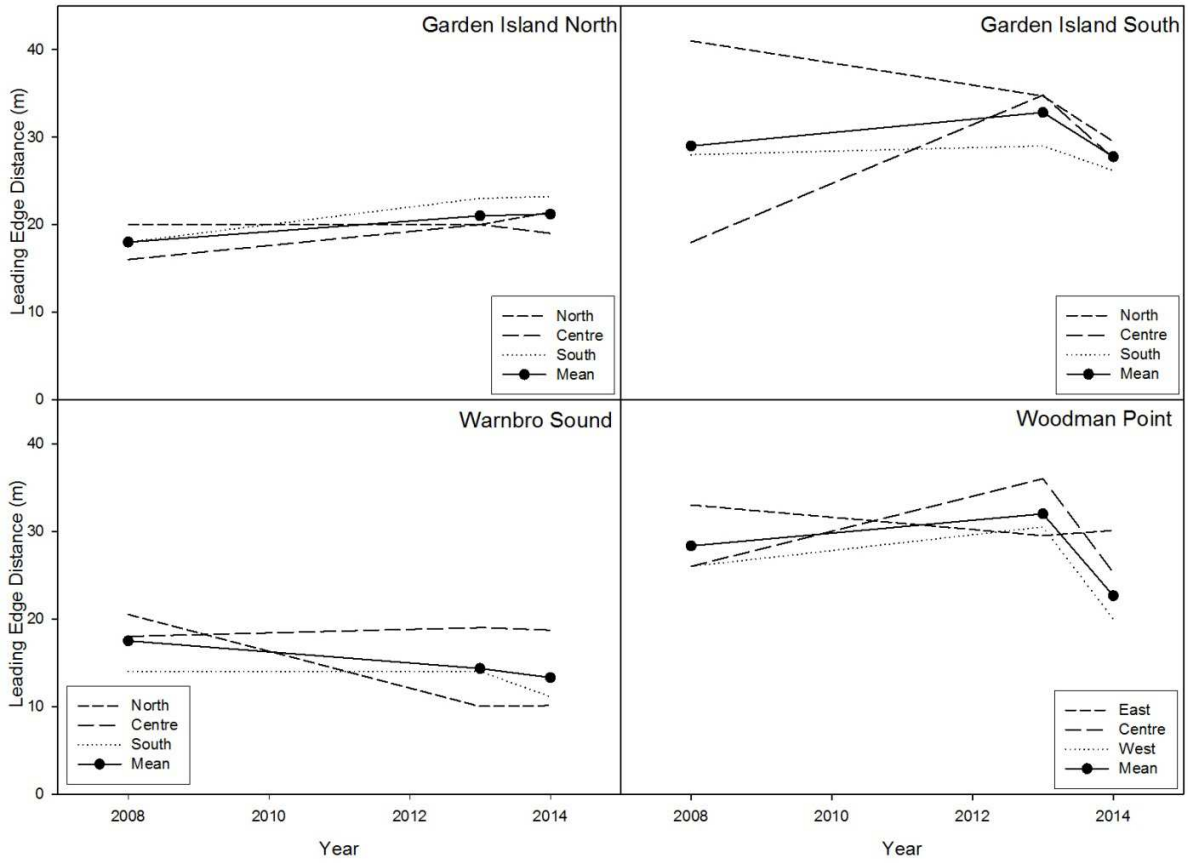

Figure 25: Difference in distance of the lower depth limit (i.e. the distance where seagrass was no longer present one meter on either side of the tape) of the seagrass meadows between 2008 and 2014.

7 Conclusions and Recommendations

Past data reports have documented declines in shoot density at several of the Warnbro Sound 'reference' sites. This continues to be the case in 2014. These declining trigger values at most of the Warnbro sites are likely to be a result of the massive clearings, or 'blow outs' observed at these sites, with whole transects located over bare sand in some cases. In 2014, the Office of the Environmental Protection Authority have reviewed the Environmental Quality Criteria (Environmental Protection Authority 2005a) and recommend the implementation of Absolute Minimum Criteria based on historical data in the event that the reference sites show significant declines.We have adopted this approach here. In 2014, two of the Warnbro Sound sites, 2.0 m and 5.5 m, had declined to the point where it was necessary to use the Absolute Minimum Criteria. It is clear that the health of the Warnbro Sound reference sites is unacceptable and the use of a combination of AMC and new reference sites is necessary.In 2015 a full set of data from the new reference sites in Shoalwater Islands Marine Park will be available (100 quadrats). At present these reference sites appear to be producing reasonable values

which could be used to supplement the Warnbro Sound reference data. The Boullanger Island sites in Jurien Bay also appear to be a good representation of seagrass density for the region. It is now a decision for the CSMC and the OEPA as to how the data from these new reference sites is used in interpreting changes at the existing Warnboro reference sites.

The majority of seagrass 'potential impact' sites were allocated green lights and were considered to be 'healthy' according to the EPA guidelines for assessing the health of seagrass meadows. However, two sites were assigned an amber traffic light. Garden Island Settlement has declined from 2013 and is now below the Absolute Minimum Criteria (AMC) Baseline 5th Percentile.. Kwinana was also assigned an amber traffic light for falling below the AMC Baseline 5th Percentile. These sites require critical attention, particularly Kwinana, as the median shoot density is less than one shoot 0.04^{-2} from falling below the AMC Baseline 1st Percentile and will be allocated a red traffic light.

Another change which requires consideration, was the decline in *Posidonia australis*. At several sites where *P. australis* was recorded, there were less shoots, and even less quadrats containing shoots, than in 2013. There was also an obvious decline in percent cover in *P. australis* compared to 2013, with six sites having lower densities or no *P. australis*. This may be cause for concern and if densities remain low in the future this may require a dedicated investigation.

There were some changes in the depth limits of seagrass in 2014, but in most cases these were positive, with seagrass extending further and deeper than previous years. In some cases the extent remained the same. However, there were some retractions. The LE distance had receded at two sites, Woodman Point and Warnbro Sound, but not significantly. There were also shallow migration in the LDL distance at three sites, Garden Island South, and Woodman Point and Warnbro Sound, and the LDL depth at Warnbro Sound. None of these reductions in seagrass were statistically significant. While the only statistically significant changes in seagrass were positive (meadow extensions), there were some non-significant declines, and this is important to monitor in the future to detect gradual changes in meadow extent that may not be detected by statistics. Of most importance are statistically significant changes from historical data, of which there were none in 2014.

7.1 Recommendations

In 2014 there were some new problems identified within the program, and some of the recommendations for 2013 still need to be addressed.

7.1.1 New recommendations

Mohring and Rule (2013b) included a comprehensive bathymetry study which found that the depths of several sites had changed from the historical measurements. In most cases approval for simple changes in comparisons is all that is required e.g. Southern Flats was orginally compared to WS 2.5 m, but would be better compared to WS 2.0 m. However, there were two sites which remain of concern. Firstly, Garden Island 7.0 m

was recorded as being at 5.79 m, meaning that unless it is re-located there is no representative 7.0 impact site in Cockburn Sound. Secondly, and more importantly, Warnbro Sound 3.2 m was recorded as being 2.76 m deep. This means that all comparisons to this reference site may be incorrect, misrepresenting the health of the meadow at these sites, and meaning that there is no 3.2 m reference site available for comparisons. To rectify this a new site would need to be established in Warnbro Sound at 3.2 m, however data for trigger values would not be available until 100 quadrats had been sampled.

Recommendation 1: Guidance from the CSMC is required regarding the process for correcting depth allocations for sites

In 2013 and 2014 new Shoalwater reference sites, as well as regional reference sites in Jurien Bay were sampled. These sites have been included in the program to assess the suitability of the current Warnbro Sound reference sites, which have been shown to be declining (Lavery and McMahon, 2011; Mohring and Rule, 2013b). In 2015, data will be available from both sites to correctly calculate the trigger values used to assess the health of impact sites. Since, these new sites will be available for use in 2015 some clarification regarding their use in the monitoring program is required. Both sets of data would greatly add to the monitoring program and supplement any changes in the Warnbro Sound reference sites. However, a decision from CSMC and the OEPA is required regarding how best to implement these data.

Recommendation 2: Guidance is required from the CSMC regarding the process for implementing additional reference data, and how these data will be used in the future

Since the commencement of this program there has been no clarification into the classification of the Garden Island sites. Initially, these sites were defined as ‘test reference’ sites. However, their suitability as reference sites is under debat as they are situated between ‘potential impact’ sites i.e. Carnac Island to the North, Luscombe Bay and Garden Island Settlement to the South and Garden Island 7.0 to the East. Thus, it would most likely be best to allocate these sites ‘potential impact’ status and use them to measure the health of Cockburn Sound, as these data are not presently used in this program.

Recommendation 3: A decision is required regarding the classification of Garden Island sites and how best to analyse this data

7.1.2 Previous recommendations

1. Field/site maintenance

While extensive maintenance was undertaken in 2014, addressing many of the recommendations for 2013, such as clearer identification of sites, replacement of lost pins and pickets etc., there are still some issues which require attention

- In 2013, transects had been lost at Woodman Point and Warnbro Sound 2.0 m. Since no guidance for this situation has been supplied, we decided to establish new transects at these sites, whilst continuing to monitor the original, empty transects. Guidelines for the conditions, under which, new transects are established are required so as to continue to adequately protect seagrass in Cockburn Sound.

- In most cases seagrass extended the full length of depth transects, meaning that the edge of the meadow could not be defined. Depth transects need to be reset or extended so that the leading edge of the seagrass bed is centred within the transect, as per the Environmental Quality Criteria (Environmental Protection Authority 2005a)

2. Data collection and storage

A number of issues around data collection and storage became apparent during 2013. These still require a solution. Given the volume of data that has been collected under this program, data storage is a critical issue for the program. The lack of an effective data storage mechanism has led to errors in calculation and interpretation of the data in previous years (Authors pers obs). To ensure the integrity of this important dataset, we recommend that all historical data be collected and compiled into a single database that can be queried. This would allow for simple QC opportunities to be installed, accurate output queries to be written that could give automated calculation of trigger values and assist the production of accurate reports.

3. Data assessment and reporting

During 2013 a number of inconsistencies in data analysis, interpretation, and reporting were observed:

- In previous years, present data were assessed against the historical data from that site using a repeated measures ANOVA or some trend analysis (e.g. Lavery and Gartner, 2008). This was undertaken by Mohring and Rule (2013b) and highlighted declines that were not detected using the present analysis technique. Here we recommend that a more detailed analysis of trends and patterns be required as part of the reporting process.

- In 2013 concerns were raised regarding the removal of ‘zero’ counts from the analyses accorded to the EQC (Environmental Protection Authority, 2005). This approach will mask losses of seagrass, and in some cases (e.g. Woodman Point) there has been a clear decline of seagrass cover which has not been detected under the current protocol. We recommend an analysis of the effect of removal of zero counts be undertaken so as to determine if this is masking seagrass losses.

- In 2013, it was recommended that a detailed analysis of the other indicators that are measured as part of the program be required as part of the reporting process. For example, clarification is required regarding the reasoning for collecting data such as

shoot height, percent cover and species present when this information is not analysed for changes and is simply described in text.

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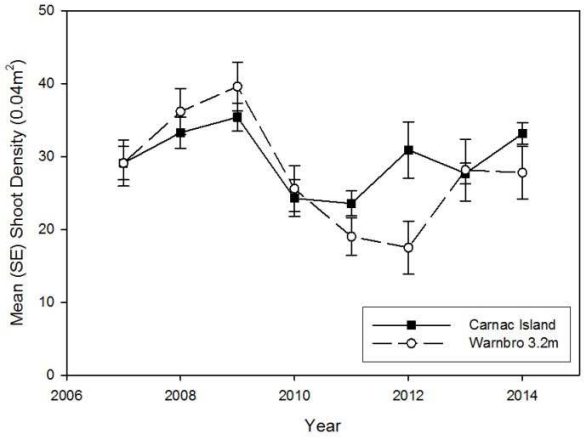
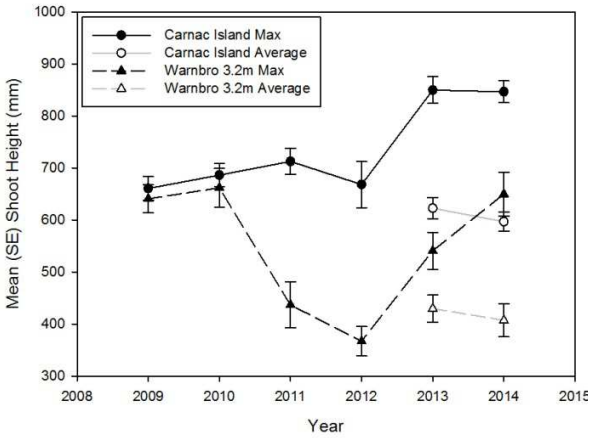
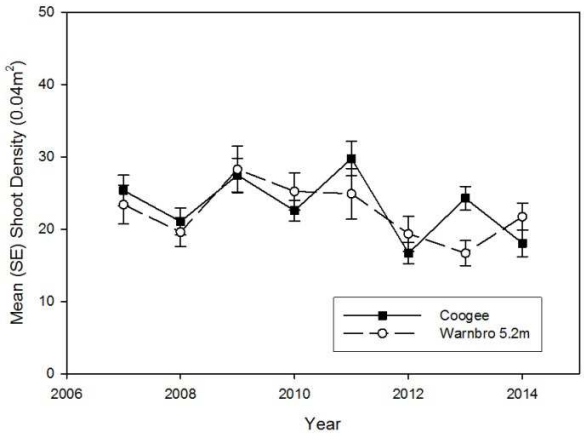
Appendix 1-Means (±SE) of shoot densities, maximum and average height and percent cover

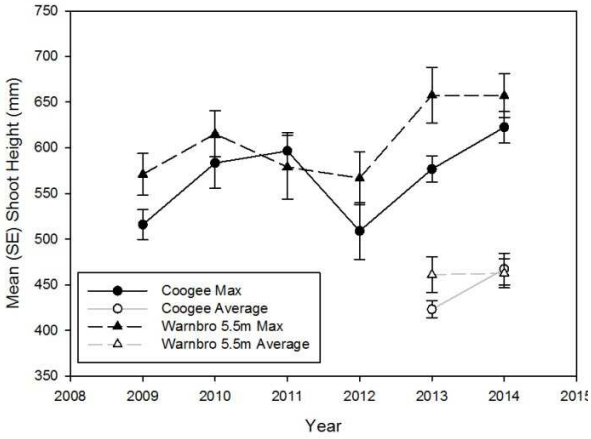
Carnac Island



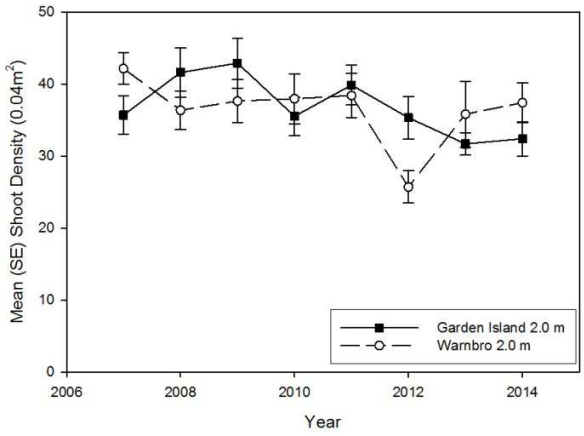


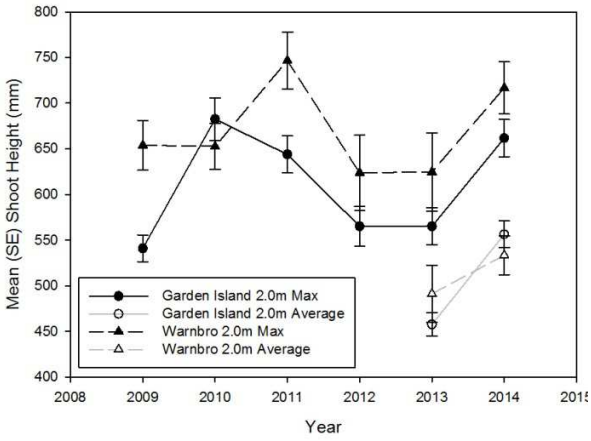
Coogee



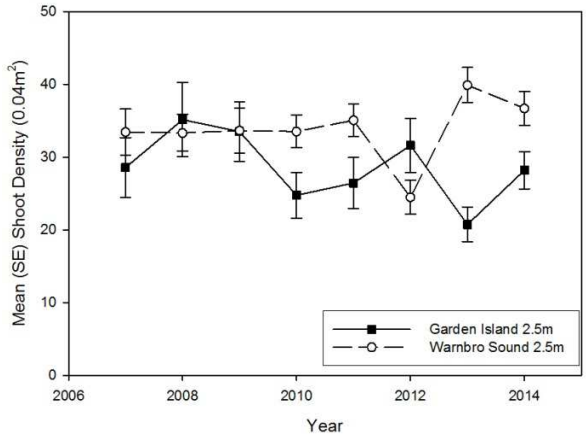


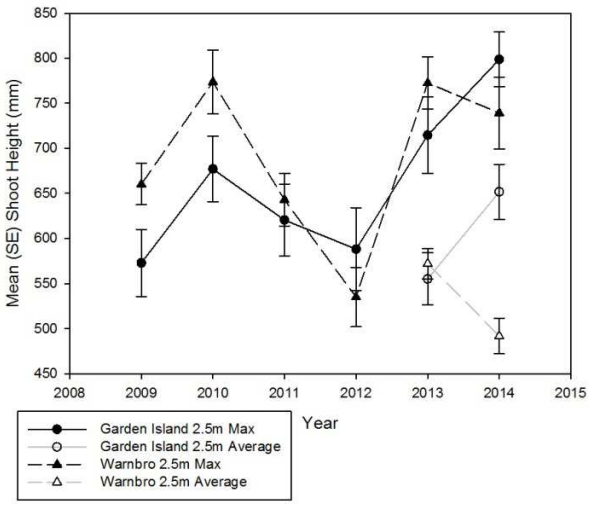
Garden Island 2.0m



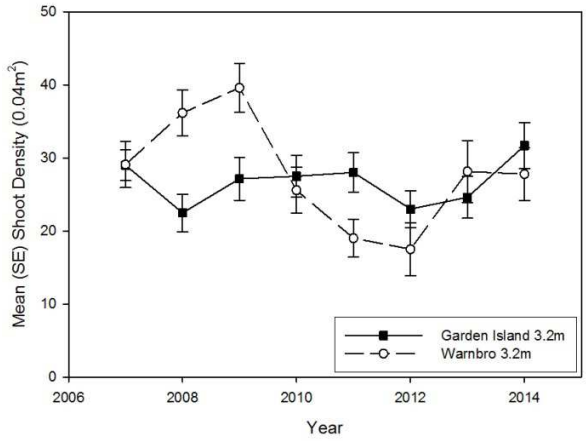


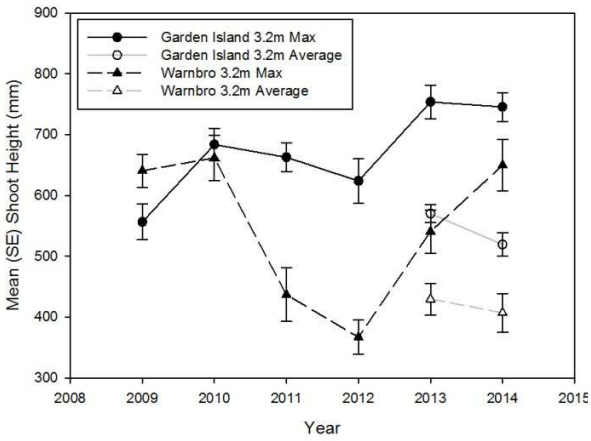
Garden Island 2.5m



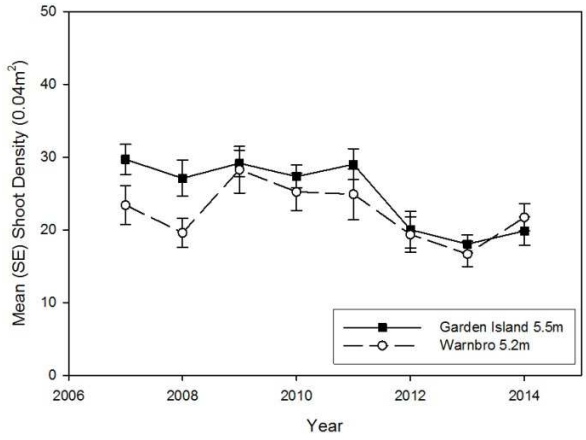


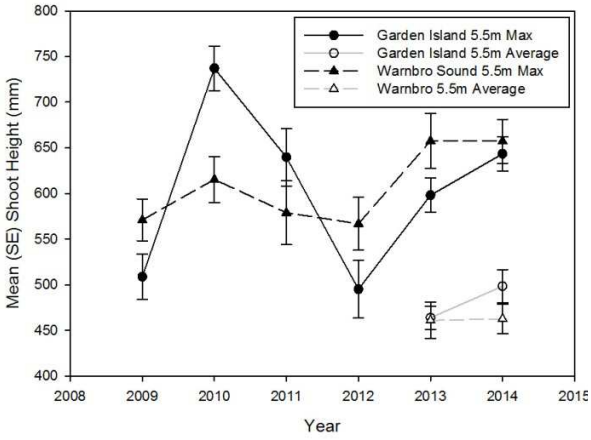
Garden Island 3.2m



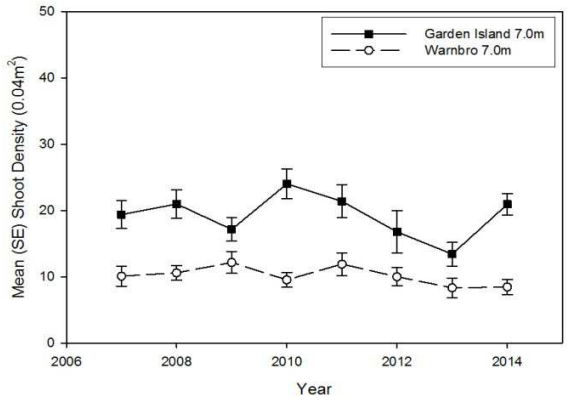


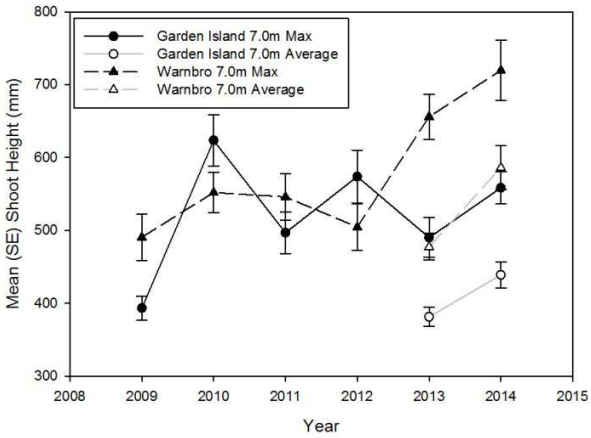
Garden Island 5.5m



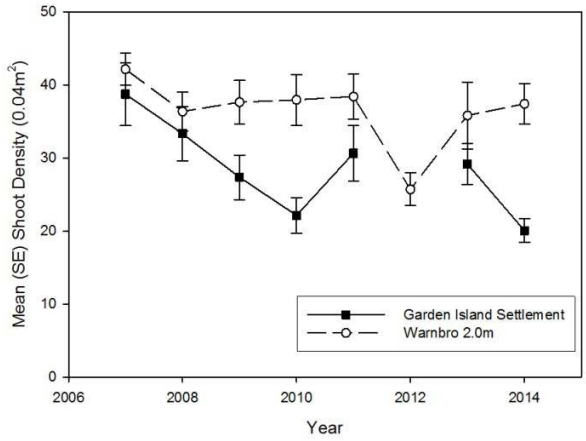


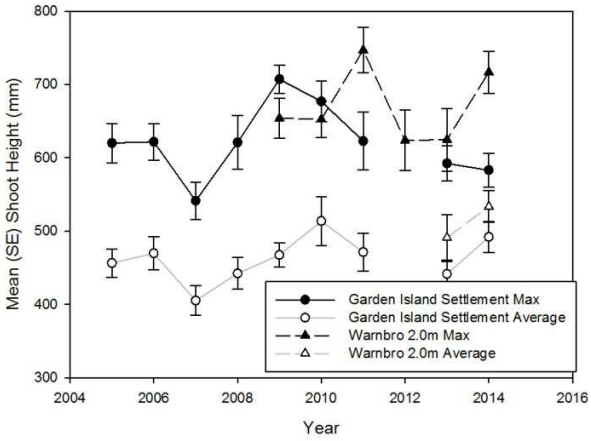
Garden Island 7.0m



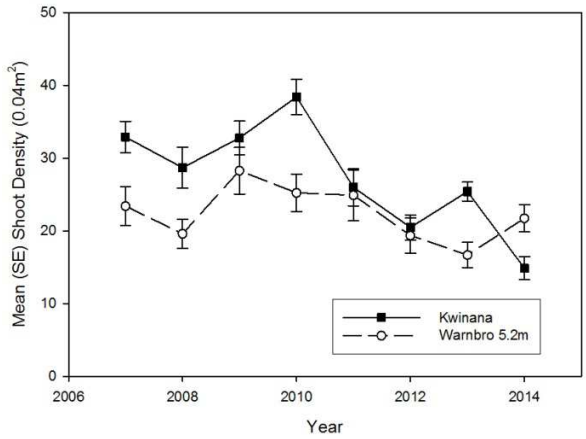


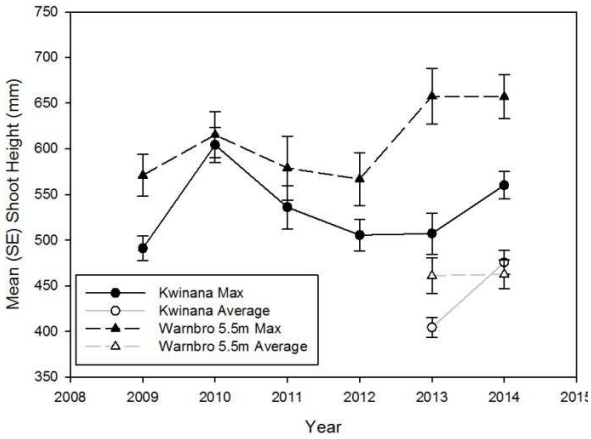
Garden Island Settlement



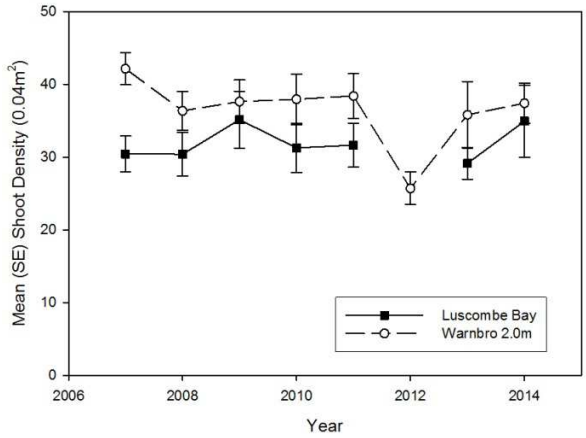


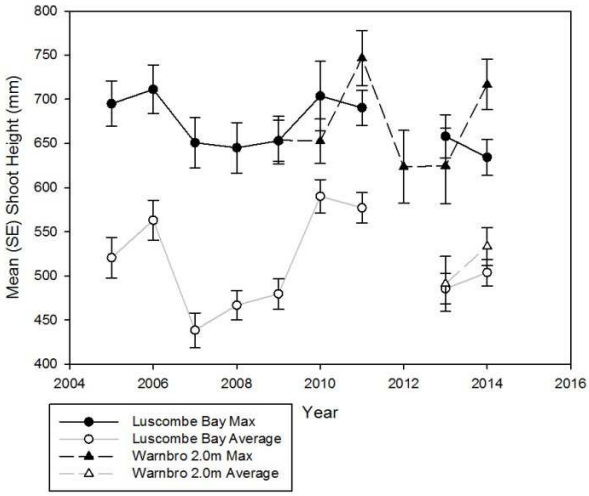
Kwinana



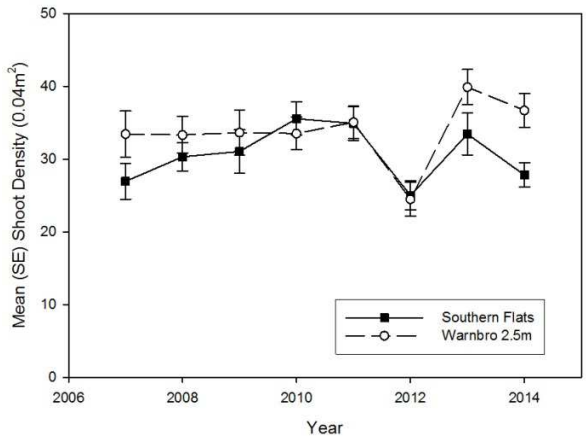


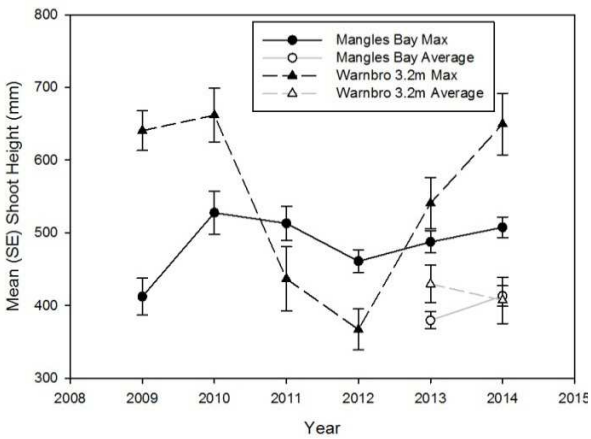
Luscombe Bay



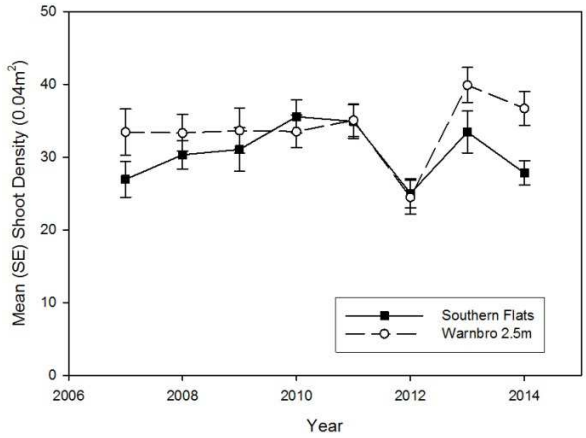


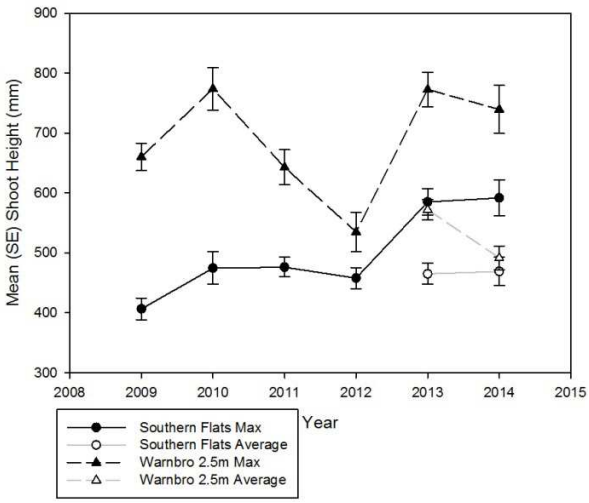
Mangles Bay





Southern Flats





Woodman Point

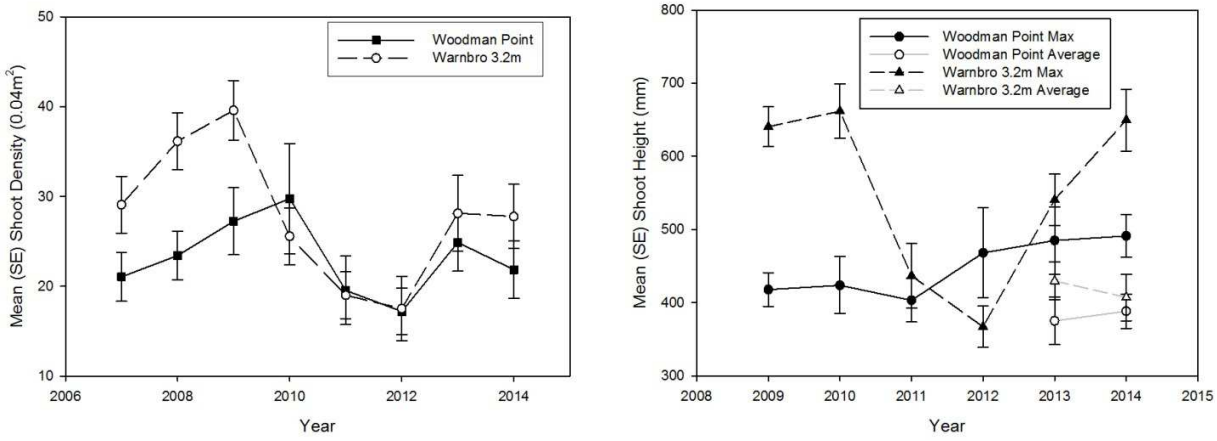


Figure 26: Thirteen 'potential impact' sites from the high protection zone. Mean shoot density on left, mean shoot heights (maximum and average) on right

Jervoise Bay

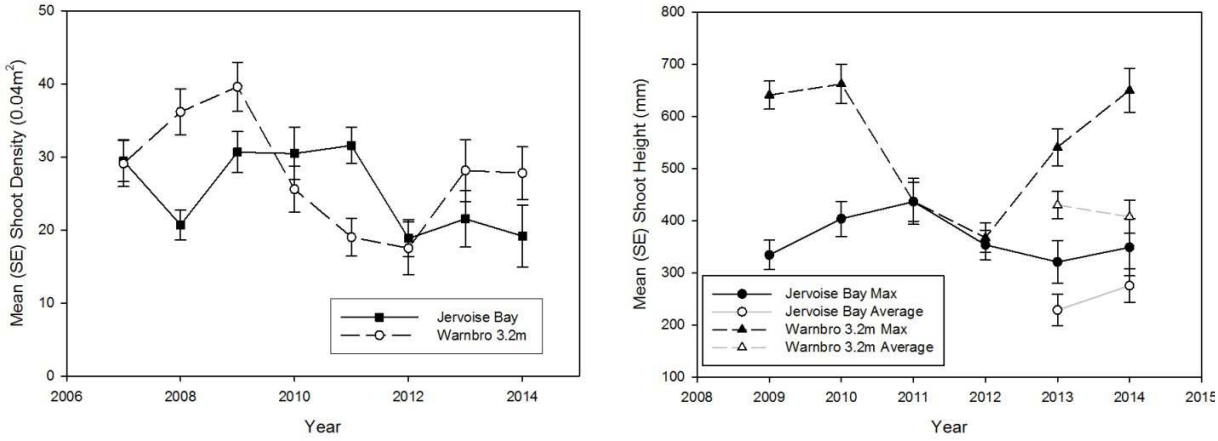
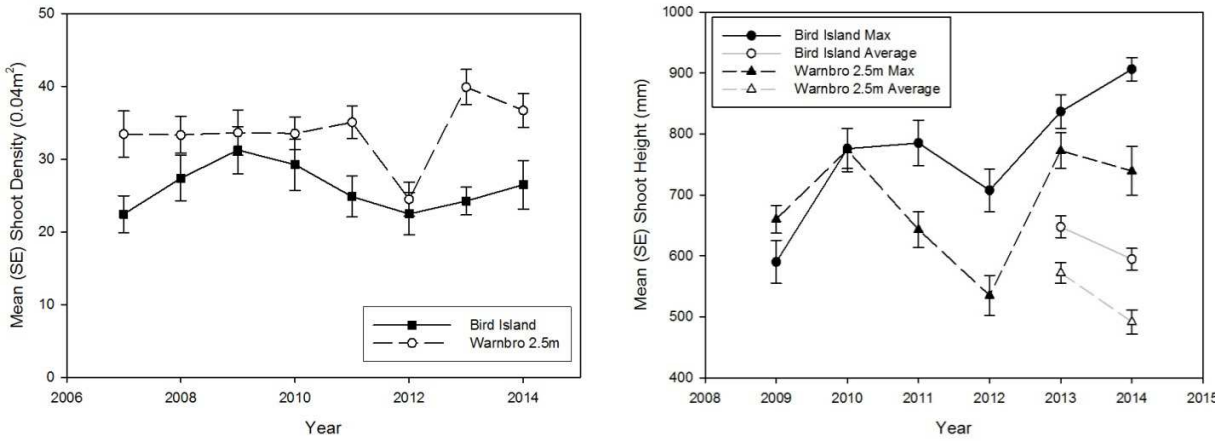


Figure 27: 'Potential impact' site from the moderate protection zone. Mean shoot density on left, mean shoot heights (maximum and average) on right

Bird Island



Mersey Point

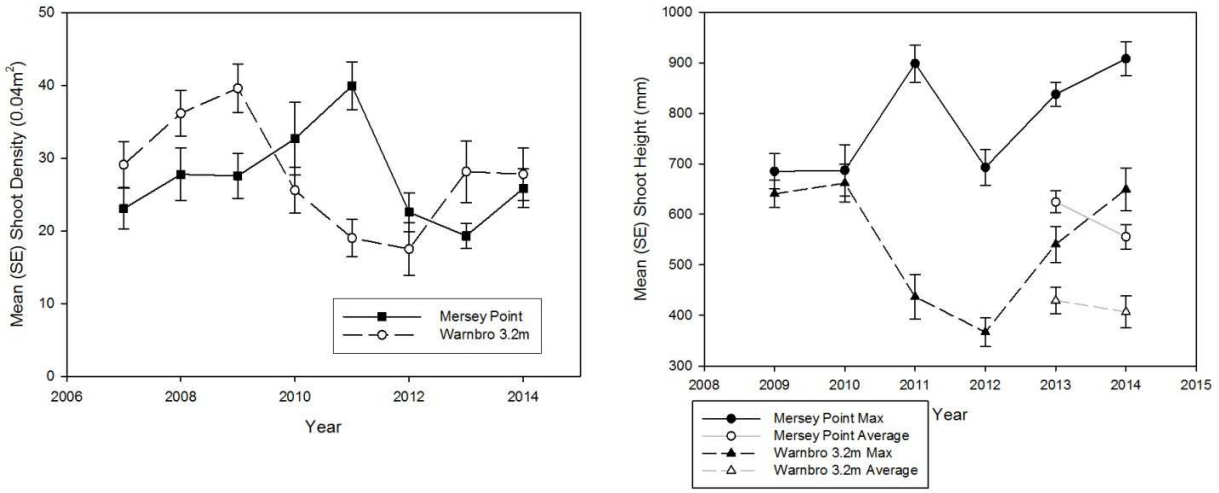


Figure 28: Two 'potential impact' sites from outside Cockburn Sound. Mean shoot density on left, mean shoot heights (maximum and average) on right

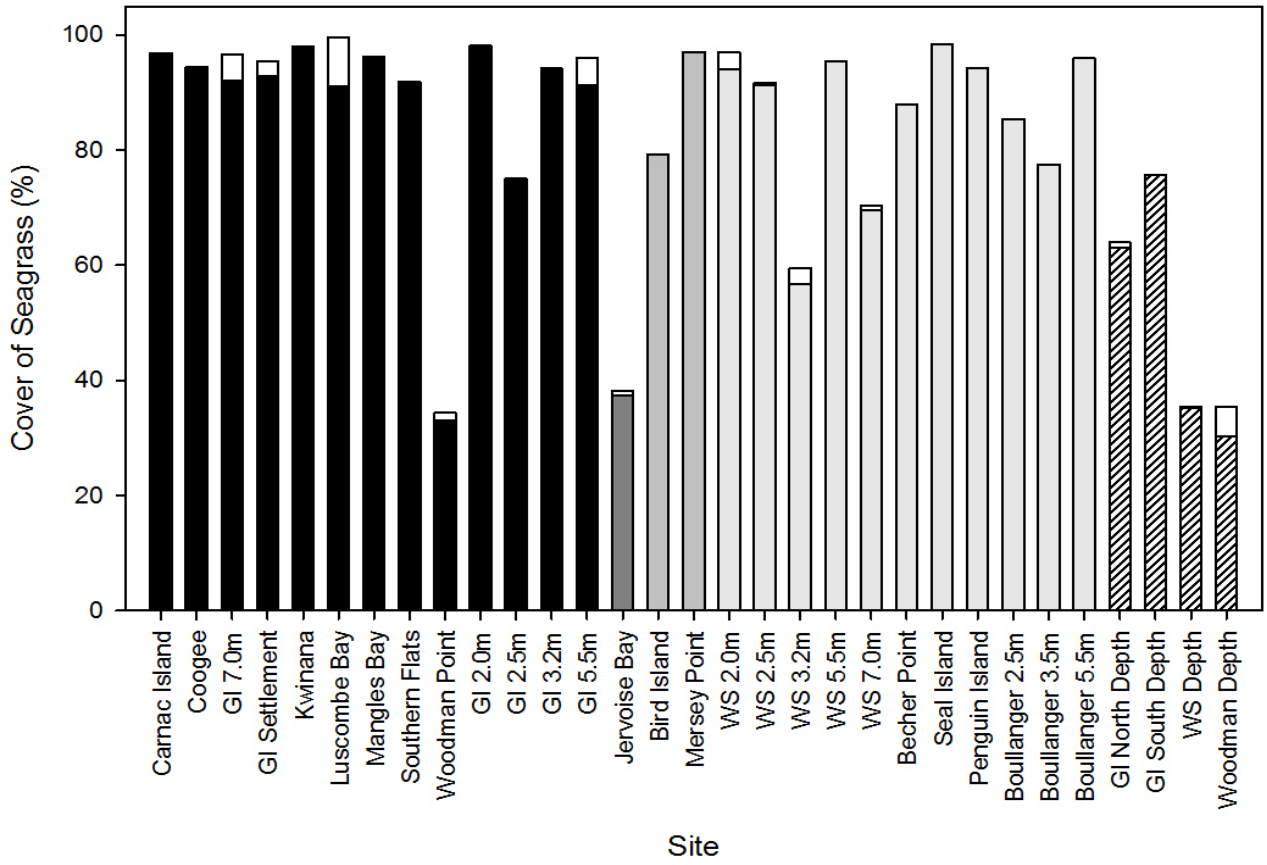


Figure 29: Percent cover of Posidonia *spp. at each site taken from photographic quadrats. Shaded portions of the bars represent cover of* P. sinuosa *and white portions are* P. australis*. From left to right; black bars - high protection areas, dark grey – moderate protection, medium grey – no protection level allocation, light grey – reference sites, hatched pattern – depth transects.*

Appendix 2 – Raw data

Table 6: Shoot densities (per 20 x 20cm quadrat) measured in seagrass 'potential impact' sites in 2014. Means, standard errors and medians are calculated. As per EPA guidelines, zero values were omitted from all calculations

Transect	Quadrat	Carnac Island	Coogee	Garden Is. 7.0	Garden Is. Settlement	Kwinana	Luscombe Bay	Mangles Bay	Southern Flats	Woodman Point	Jervoise Bay	Bird Island	Mersey Point
1	1	44	16	14	12	15	15	18	8	12		37	
	2	25	15	17	19	18	7	5	40	7		42	18
	3	39	26	29	24	19	108	12	25		1	78	10
	4	30	8	37	30	13	89	10	33			8	22
	5	33	11	7	15	23	32	14	28	10	49	17	14
	6	35	20	13	18	9	78	6	19	28	36	3	19
2	1	38	11	25	5	16	20	22	29			10	25
	2	34	14	27	5	12	37	20	23			15	13
	3	46	9	35	15	9	22	22	32			17	11
	4	27	1	14	30	13	30	18	31			35	17
	5	16	10	28	20	30	26		33			48	15
	6	26	9	23	34	41	19	12	27			32	35
3	1	41	25	16	18	14	31	12	38	31		30	17
	2	33	14	19	19	15	20	9	17			14	42
	3	28	34	11	26	6	34	12	29	37	14	38	38
	4	44	22	29	24	17	33	8	36		2	19	15
	5	23	20	8	29	13	6	7	32	10	18	29	20
	6	34	31	24	15	11	21		37		19	12	38
4	1	36	24	20	22	10	27	6	29		17	29	48
	2	32	5	28	15	16	34	29	23		40	38	35
	3	30	32	19	12	12	39	14	27		12	28	53
	4	40	22	18	16	11	36	20	10		6	17	25
	5	29	28	19	24	8	27	18	27		30	9	42
	6	32	26	22	34	5	47	10	34		5	30	22
5	1												
	2									19			
	3									12			
	4									17			
	5									38			
	6									37			
Median		33	18	19.5	19	13	30.5	12	29	19	17	28.5	22
Mean		33.13	18.04	20.92	20.04	14.83	34.92	13.82	27.80	21.85	19.15	26.46	25.83
SE		1.47	1.86	1.61	1.63	1.58	4.97	1.35	1.65	3.19	4.24	3.34	2.65

Table 7: Shoot densities (per 20 x 20cm quadrat) measured in seagrass 'reference' sites in 2014. Means, standard errors and 1st, 5th and 20th percentiles are calculated. As per EPA guidelines, zero values were omitted from all calculations

Transect	Quad	Garden Island 2.0m	Garden Island 2.5m	Garden Island 3.2m	Garden Island 5.5m	Warnbro Sound 2.0m	Warnbro Sound 2.5m	Warnbro Sound 3.2m	Warnbro Sound 5.5m	Warnbro Sound 7.0m
1	1	31	46	34	23	34	36	47	23	8
	2	17	24	32	12	34	37	10	2	1
	3	18	45	51	7	45	30	21	21	12
	4	29	27	44	17	28	18	13	23	7
	5	18	28	28	21	28	38	17	34	10
	6	13	10	36	20	35	25		28	17
2	1	49	31	54	24	44	15	2	8	2
	2	18	39	38	9	42	34	28	20	7
	3	52	42	26	23	37	36	43	10	5
	4	12	22	55	17	42	46	24	23	7
	5	24	20	10	11	45	35		34	15
	6	40	18	7	12	49	50	9	28	
3	1	36	23	26	29	48	43	45	25	
	2	45	4	41	37	41	24	26	15	8
	3	40		22	33	33	37		29	6
	4	38	27	3	20	1	39		20	2
	5	36	42	31	14	12	33		30	5
	6	27	34	29	15	32	37		32	
4	1	31	14	21	32	38	46		11	8
	2	40	39	16	35	39	52		18	12
	3	42	25	21	36	30	49	45	18	
	4	44	36	39	15	72	46		30	7
	5	39	43	65	5	52	16		33	22
	6	38	9	31	9	36	58		6	8
Median		36	27	31	18.5	37.5	37	24	24	8
1st Percentile		11.2	1	3.13	4.16	1	5.95	2	1.93	1
5th Percentile		16	4	7	7.8	4.95	14.9	3	3.95	2
20th Percentile		23.8	13.8	16	15	24	23.8	10	9	4
Mean		32.38	28.17	31.67	19.83	37.38	36.67	27.76	21.71	8.45
SE		2.38	2.55	3.14	1.97	2.74	2.31	3.58	1.89	1.15

Table 8: Shoot densities (per 20 x 20cm quadrat) measured in new seagrass 'reference' sites in 2014. Means, standard errors and 1st, 5th and 20th percentiles are calculated. As per EPA guidelines, zero values were omitted from all calculations

Transect	Quadrat	Becher Point	Penguin Island	Seal Island	Boullanger Island 2.5m	Boullanger Island 3.5m	Boullanger Island 5.5m
1	1	53	13	21	28	22	21
	2	34	17	37	29	19	24
	3	27	20	14	31	21	29
	4	26	42	8	29	51	29
	5	32	34	9	22	42	32
	6	25	27	6	25	32	36
2	1	20		17	17	16	24
	2	30	15	23	16	49	47
	3	13	10	14	34	22	28
	4	5	11	20	21	43	23
	5	24	8	10	37	32	27
	6	20	31	20	30	31	30
3	1	26	9	24	19	17	28
	2	32	24	16	25	44	30
	3	17	18	30	17	43	30
	4	35	26	17	24	57	31
	5	23	29	28	13	17	29
	6	29	29	23	35	53	26
4	1	14	18	18	23	18	18
	2	31	6	25	13	29	24
	3	26	11	33	39	32	36
	4	24	6	31	22	19	23
	5	17	41	12	43	32	10
	6		21	36	5	25	23
Median		26	18	20	28.5	32	26
1st Percentile		6.8	6	6.47	8.68	4.17	10
5th Percentile		13.25	6.6	8.35	13	10	12.95
20th Percentile		19	12	14.8	20.4	19	20
Mean		25.35	20.26	20.50	30.80	34.47	27.18
SE		1.99	2.23	1.80	1.23	1.66	0.87

Table 9: Maximum shoot heights (within 20 x 20cm quadrat) measured in seagrass 'potential impact' sites in 2014. Means of each column are calculated.

Transect	Quadrat	Carnac Island	Coogee	Garden Island 7.0	Garden Island Settlement	Kwinana	Luscombe Bay	Mangles Bay	Southern Flats	Woodman Point	Jervoise Bay	Bird Island	Mersey Point
1	1	930	640	380	430	470	640	620	430	400		800	
	2	880	600	450	710	640	640	460	700	350		920	860
	3	840	800	680	720	500	680	610	710		150	1010	690
	4	910	700	660	680	510	700	450	570			910	720
	5	800	600	470	600	600	590	580	620	430	570	870	1200
	6	670	760	510	470	510	620	430	420	650	480	990	890
2	1	800	640	520	460	520	800	490	670			910	1200
	2	880	680	520	430	590	480	400	500			1005	1100
	3	730	620	560	560	590	470	520	640			850	1200
	4	730	480	570	630	710	710	500	620			1015	900
	5	660	750	600	490	560	710		770			1005	700
	6	650	520	680	530	640	540	510	500			1020	900
3	1	830	670	540	460	650	620	460	800	600		920	920
	2	930	620	420	550	500	610	520	600			850	1110
	3	1000	640	420	480	680	780	660	630	670	470	860	900
	4	1010	650	740	570	530	740	510	760		70	860	820
	5	940	510	520	570	590	740	440	620	300	410	1030	920
	6	860	620	690	500	600	640	520	620		470	1010	890
4	1	880	620	650	800	510	530	500	580		650	900	960
	2	750	520	720	720	500	520	520	720		460	930	930
	3	920	470	360	640	580	530	560	560		250	790	730
	4	850	580	620	630	560	800	490	100	380	170	830	710
	5	960	650	610	560	400	560	380	450	450	360	690	860
	6	900	600	510	800	500	570	540	610	500	20	770	770
5	1									450			
	2									480			
	3									620			
	4									430			
	5									700			
	6									400			
Mean		846.25	622.50	558.33	582.92	560	634.17	507.39	591.67	488.13	348.46	906.04	907.83

Table 10: Average shoot heights (within 20 x 20cm quadrat) measured in seagrass 'potential impact' sites in 2014. Means of each column are calculated.

Transect	Quadrat	Carnac Island	Coogee	Garden Island 7.0	Garden Island Settlement	Kwinana	Luscombe Bay	Mangles Bay	Southern Flats	Woodman Point	Jervoise Bay	Bird Island	Mersey Point
1	1	500	480	340	300	380	450	570	400	300		480	
	2	550	430	400	570	520	500	410	550	300		460	680
	3	720	580	580	600	450	500	530	500		150	600	550
	4	480	570	610	570	470	610	350	500			670	600
	5	440	480	310	500	490	530	500	500	400	430	590	670
	6	640	620	370	440	470	520	370	380	550	360	820	600
2	1	520	540	480	440	470	620	440	500			700	760
	2	580	580	380	290	500	360	400	350			600	700
	3	570	490	440	440	520	390	480	440			630	790
	4	620	440	370	580	540	590	400	480			580	680
	5	540	600	420	380	470	600		600			570	540
	6	400	430	520	430	450	480	400	440			550	570
3	1	600	370	430	400	570	530	340	540	500		510	440
	2	700	400	380	510	450	550	450	380			520	520
	3	720	480	330	430	630	570	490	490	500	320	590	470
	4	580	450	530	510	470	540	390	670		60	530	480
	5	720	460	370	480	530	560	350	620	300	300	670	440
	6	650	470	540	450	550	540	300	500		330	680	380
4	1	660	400	490	670	410	400	420	500		420	570	480
	2	520	370	510	640	400	460	350	480		300	600	420
	3	700	250	300	520	400	430	380	500		240	560	400
	4	650	400	500	520	500	520	430	70	340	160	750	460
	5	630	450	510	440	390	420	330	370	350	230	480	550
	6	630	470	420	690	380	420	420	500	380		560	600
5	1									400			
	2									320			
	3									340			
	4									260			
	5									560			
	6									310			
Mean		596.67	467.08	438.75	491.67	475.42	503.75	413.04	469.17	381.88	275	594.58	555.65

Table 11: Maximum and average shoot heights (within 20 x 20cm quadrat) measured in seagrass 'reference' sites in 2014. Means of each column are calculated.

		Garden Island 2.0m		Garden Island 2.5m		Garden Island 3.2m		Garden Island 5.5m		Warnbro Sound 2.0m		Warnbro Sound 2.5m		Warnbro Sound 3.2m		Warnbro Sound 5.5m		Warnbro Sound 7.0m	
Transect	**Quad**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**
1	1	540	500	900	750	740	400	640	400	770	660	540	370	730	450	630	500	1100	820
	2	700	570	820	650	560	390	590	510	840	680	640	470	590	270	830	640	510	
	3	700	580	800	660	850	510	730	640	920	630	690	340	590	340	760	570	820	760
	4	520	430	750	620	790	520	620	450	710	580	570	370	710	360	750	390	560	400
	5	680	570	800	670	700	450	690	600	700	550	500	370	740	410	810	540	650	600
	6	640	530	420	310	1010	600	710	540	690	520	540	430	380	240	580	430	650	500
2	1	600	510	730	620	680	510	660	570	620	540	650	320	430	310	540	330	570	400
	2	820	550	880	660	750	470	630	580	580	460	920	500	600	330	480	410	800	650
	3	630	520	750	670	630	410	660	480	870	500	900	650	820	620	570	430	770	550
	4	760	620	900	620	860	530	650	440	780	550	710	520	820	640	750	390	640	540
	5	890	710	700	600	500	340	610	420	690	520	780	480			810	540	530	370
	6	760	680	910	800	600	390	640	400	710	520	1370	560	1000	730	580	430		
3	1	490	480	830	760	820	560	580	580	840	600	520	460	580	310	600	500		
	2	590	420	500	200	860	660	720	620	840	500	800	490	750	380	600	380	770	630
	3	550	530			830	640	610	480	670	490	770	510			690	520	690	580
	4	720	580	760	640	690	550	860	540	230	200	570	460	330	250	830	560	420	
	5	750	650	890	750	890	670	450	360	510	320	540	440			620	500	830	650
	6	530	480	780	720	730	660	510	380	720	520	650	510			640	540		
4	1	730	600	920	800	680	570	700	610	690	480	820	580			470	390	730	560
	2	700	540	1020	800	720	420	630	520	800	620	890	590			540	470	1200	800
	3	700	600	1030	810	750	560	680	540	690	540	740	650	680	470	560	420		
	4	670	580	910	730	840	550	670	430	800	650	1010	610			590	400	720	540
	5	620	600	730	580	770	600	440	330	720	550	790	480			670	400	780	640
	6	590	520	640	570	640	500	760	540	810	620	830	640			870	420	650	560
5	1													830	410				
	2													900	410				
	3													710	390				
	4													360	220				
	5													320					
	6													770	600				
Mean		661.7	556.3	798.7	651.7	745.4	519.2	643.3	498.3	716.7	533.3	739.2	491.7	649.5	407	657.1	462.5	719.5	586.1

Table 12: Maximum and average shoot heights (within 20 x 20cm quadrat) measured in seagrass 'reference' sites in 2013. Means of each column are calculated.

		Becher Point		Boullanger Island 2.5m		Boullanger Island 3.5m		Boullanger Island 5.5m		Penguin Island		Seal Island	
Transect	**Quad**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**	**Max**	**Ave.**
1	1	740	460	690	640	660	490	730	500	590	450	760	640
	2	750	500	710	600	750	510	720	490	720	650	1700	700
	3	930	690	870	670	660	500	560	430	570	440	800	600
	4	700	480	680	550	780	540	700	470	540	390	1000	650
	5	500	420	620	500	740	450	680	480	590	370	750	450
	6	570	480	650	520	880	520	720	510	960	630	1010	750
2	1	700	580	710	660	540	390	620	470			900	740
	2	800	670	730	610	700	520	700	550	600	360	1000	700
	3	760	680	660	590	690	500	720	470	500	460	700	500
	4	400	350	760	670	630	490	840	510	820	500	800	700
	5	890	730	800	630	610	530	740	500	360	290	720	500
	6	820	700	640	530	560	410	700	440	550	430	820	750
3	1	730	550	660	600	560	370	900	540	510	420	930	700
	2	810	730	770	710	700	510	860	530	740	530	700	510
	3	650	570	750	700	690	510	720	460	690	500	780	600
	4	790	690	700	620	630	490	940	510	750	500	700	630
	5	830	750	610	520	610	410	700	450	560	440	1200	680
	6	870	770	700	630	560	430	680	470	530	440	1000	700
4	1	500	420	770	720	720	550	830	580	690	500	900	620
	2	740	500	600	570	720	590	660	550	560	380	800	680
	3	800	600	500	470	620	550	800	670	740	420	900	670
	4	660	530	770	660	620	490	600	540	600	480	900	650
	5	840	700	870	760	620	530	650	590	630	510	700	580
	6	440	440	800	750	810	600	720	670	700	550	930	730
Mean		717.50	582.92	709.17	620	669.17	495	728.75	515.83	630.43	462.61	891.67	642.92

Table 13: Shoot densities, maximal and average shoot heights (mm) of Posidonia sp. (per 20 x 20cm quadrat) measured along depth transects at Garden Island North, Garden Island South, Warnbro Sound and Woodman Point.

		Garden Island North				Garden Island South				Warnbro Sound					Woodman Point			
Trans	Quad	*P. sin*	*P. aus*	Max height	Av height	*P. sin*	*P. aus*	Max height	Av height	*P. sin*	*P. aus*	Max height	Av height	Trans	*P. sin*	*P. aus*	Max height	Av height
Centre	1	13		490	440	5		560	500		17	350	300			6	360	280
	2	24		750	580	5		500	380							15	400	250
	3	10		680	600	1		370			10	460	390		25		690	530
	4	8		440	400	16		600	450		13	470	390			13	550	470
	5					8		400	350	37		650	490	Centre		3	320	200
	6	6		580	440	12		530	430		11	470	370			10	400	280
	7										7	510	430				540	400
	8					4		600	540									
	9	8		500	280					7		710	540		18		550	400
	10										3	410	330		6		500	430
	11	2		380	380	7		690	540									
North	1	11		500	470	8		450	400	5		520	380			20	330	220
	2	7		550	470	11		440	380		8	340	280			1	170	
	3	6		440	370	5		600	540		9	440	300		30		450	390
	4	4		410	370	4		710	500	4	1	520	410					
	5	7		540	400	5		610	580							11	430	300
	6	6		540	400									East		8	410	300
	7	6		680	600	1		500								6	370	310
	8					5		520	480							1	290	230
	9		1			3		540	500						5	7	460	360
	10	7		490	380		2	240	200							6	350	310
	11					7		720	570							2	510	400
South	1	9		480	400	6		650	500		2	300	220		17		600	450
	2	2		330	260	15		540	450	12	1	860	480			4	300	230
	3	10		440	330	1		440	400	26		700	500			5	370	270
	4	7		500	390	3		550	350	4	2	370	280					
	5	9		600	430	6		550	480		8	320	240			4	370	490
	6	2		440	400	1		450			1	460	320	West				
	7	4		370	310	4		500	450									
	8					5		250										
	9	8		570	440	4		570	450									
	10	11		670	440				200									
	11																	

Table 14 Depths and distances from start of permanent transect for Leading Edge (LE) and Lower Depth Limit (LDL) measurements.

Site	Transect	LE depth	LE distance	LDL depth	LDL dist.
Garden Island North	Centre	9.2	20	9.2	19.0
	North	9.4	20	10.0	21.4
	South	9.0	16	10.0	23.2
Garden Island South	Centre	7.4	20	10.4	27.6
	North	8.0	20	10.7	29.5
	South	8.3	18	11.0	26.2
Warnbro Sound	Centre	8.7	16	9.4	18.7
	North	7.2	6	7.9	10.1
	South	8.2	10	8.3	11.1
Woodman Point	Centre	7.4	16	11.1	25.3
	East	8.0	20	11.0	30.1
	West	6.5	8	11.2	20.0