REPORT NO 2007-11

SEAGRASS HEALTH REPORT FOR JURIEN BAY MARINE PARK 2007

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Report to Jurien Bay Marine Park
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Summary

In 2007, another seagrass health survey was carried out in Jurien Bay Marine Park at the six reference sites at Boullanger Island and Fishermans Island. An additional monitoring site was set-up south of Jurien Bay to monitor the effects of urban development in the region. The data in 2007 was compared against previous monitoring years, 2003-05.

Generally there were no significant differences in shoot density at sites over the years, however, there was a trend of lower shoot densities in 2007. This was also observed at the seagrass monitoring reference sites in Perth Coastal waters in 2007, indicating that the growing season was not optimal in 2006/07. The one exception was Fishermans Island 2.5m where shoot density in 2007 was significantly lower than previous years. However, as other sites in the region did not show significant declines in shoot density, this reduction is not likely due to light reduction effects, but may be due to specific conditions at that site such as water motion. High water motion has been implicated as influencing *Posidonia sinuosa* shoot density at other seagrass monitoring sites in Perth Coastal waters.

The Jurien Impact Site 1 was established and monitored in 2007. This site was compared to reference sites of a similar depth and had significantly higher shoot densities. The Environmental Quality Criteria Assessment for shoot density (Environmental Protection Authority, 2005) indicated that the Jurien Impact Site 1 passed when compared to the reference sites of a similar depth. The Jurien Impact Site 1 is most similar in location from the coast and exposure to wind and swell as the Fishermans Island reference sites. This should be taken into consideration when deciding upon the most appropriate reference site to use for this new site.

Recommendations

Continue annual monitoring of reference and impact sites in Jurien Bay following the methods already established and outlined by the Environmental Protection Authority (2005). Annual monitoring then follows the same methodology as carried out in the Perth Costal waters and also allows routine maintenance of the permanent transects and quadrats.

Introduction

In 2003 the Department of Environmental Protection (now Department of Environment and Conservation; DEC), Edith Cowan University and the Department of Conservation and Land Management (now Department of Environment and Conservation; DEC) sought funding through the SRFME (Strategic Research Fund for the Marine Environment) programme to establish seagrass health reference and monitoring sites on the central west coast of Western Australia. The project was designed to provide an essential information base for setting Environmental Quality Criteria (EQC) for ecosystem health for coastal waters off central west WA.

The Jurien Bay area was selected to conduct the study as it is within the Jurien Bay Marine Park (JBMP) and is predicted to come under increasing human-use pressure in the future through urban expansion. The main objectives of the project were to quantify the natural spatial and inter-annual variability in seagrass health indicators on the central west coast of WA for a period of three years and to broaden the geographic coverage of the environmental quality management framework currently being implemented in Perth's coastal waters. The data collected in Jurien Bay acts as a sound base-line on which to base future seagrass health monitoring. There were some differences in the trends in shoot density between reference sites in Jurien Bay compared to reference sites in Perth Coastal Waters, however, despite this these sites are still useful to monitor changes in shoot density over time (Lavery and How, 2006). This project finished in 2005 and a final report was submitted addressing the above objectives (Lavery and How, 2006).

ECU was approached by JBMP, DEC in 2006 to continue the monitoring of the seagrass health reference sites in Jurien Bay and to establish an additional monitoring site. Another seagrass health survey was conducted in February 2007 at the six reference sites, as well as the new monitoring site. This report summarises the trends in seagrass health in the Jurien Bay Marine Park from 2003 – 2007.

Methods

Site description

The six reference sites, Boullanger Island (BI) 2.5 m, 3.5 m and 5.5 m and Fishermans Island (FI) 2.5 m, 3.5 m and 5.5 m and the new impact site (JIS1) were monitored from 13-15 February 2007 (Table 1, Figure 1). Previous measures were collected between 1-3 April 2003, 27-28 February 2004 and on the 11th and 24th January 2005. Note that the FI 2.5 m site was established in 2004, and that data for the 2003 comparison was collected from a 2 m site (UTM 307408, 664795, WGS 84). It was planned for all reference sites to be within restricted activity zones in JBMP, however, the FI 3.5 m site is just outside the sanctuary zone, as a suitable site at 3.5 m could not be found within the sanctuary zone. The new site, Jurien Impact Site 1 was located south of the Jurien Bay township offshore from a new urban development site in 2.5 m of water (Figure 1).

Field crew

Field work was carried out by Kathryn McMahon, Helen Barwick and Rian Caccianga (Edith Cowan University), and Kevin Crane, Greg Inglis and Isaac Hatch from Department of Environment and Conservation, Jurien Bay.

Table 1: Location of Seagrass Health Sites in Jurien Bay.

Location	Depth	UTM Coordinates (WGS84 datum) East	North	Comment
Fishermans Is.	2.5 m	307146	6664594	New site in 2004, replacing 2.0m site
(Sanctuary Zone)	3.5 m	306940	6665428	Not inside sanctuary zone
	5.5 m	306417	6664328	
Boullanger Is.	2.5 m	307929	6644723	
(Special Purpose	3.5 m	307955	6644916	
Pucrulus Zone)	5.5 m	307971	6645019	
Jurien Impact Site 1	2.5 m	310770	6642955	Established in 2007

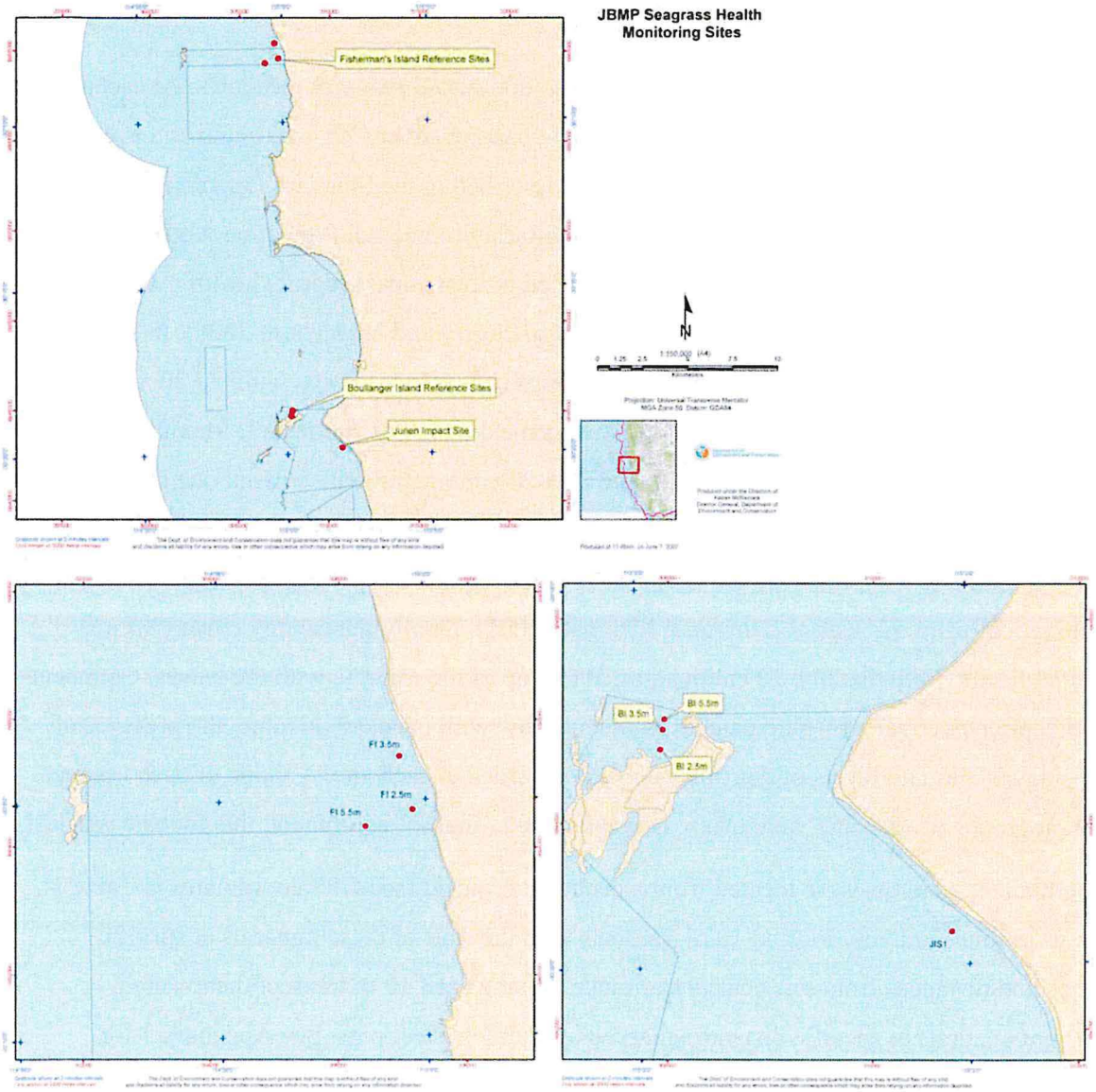

Figure 1: Map of seagrass health reference sites (Boullanger Island – BI2.5m, BI 3.5m, BI5.5m, Fisherman's Island – FI2.5m, FI3.5m, FI5.5m) and impact sites (JIS1) in Jurien Bay.

Data collection methods

All sites were located within large *Posidonia sinuosa* dominated seagrass meadows. At each site 24 permanent quadrats were measured for shoot density, canopy cover (%), maximum and average canopy height (cm). All methods were followed as described in the Standard Operating Procedures for the *State Environmental (Cockburn Sound) Policy* (Environmental Protection Authority, 2005) making the data directly comparable to those collected in the annual seagrass health monitoring programme for Perth's Southern Metropolitan waters (Lavery and McMahon, 2006). In summary, shoot density was measured by counting the number of shoots (not leaves) within a 20 x 20 cm quadrat ($0.04m^2$) by a diver on SCUBA. This was then expressed as shoots m^{-2}. Maximum canopy height was measured from tallest leaf inside the 20 x 20 cm quadrat with a metal one metre rule, from the seabed to the top of the leaf. Average canopy height was estimated by placing a metal metre rule on the seabed, ignoring the tallest 20% of leaves, and measuring the height of the tallest remaining leaf from the seabed (Duarte & Kirkman, 2001). Finally the canopy cover (%) was estimated from within the 20 x 20 cm quadrat, at the top of the canopy, with the leaves. Comments on algal epiphyte cover, any bare patches in the meadow with exposed rhizome, the presence of colonising species and levels of detritus were also recorded at each site. A video of each transect and photographs of each site were taken, however, due to theft of equipment, this footage was lost.

The permanent quadrats were located from a central star picket (see GPS coordinates in Table 1). There were four randomly located 10 m transects with the start of these transects at specific bearings and distances from this central star picket. Along each 10 m transect there were 6 permanent quadrats at specific distances marked by stainless steel pins. See Appendix 1 for locations of transects and quadrats.

Data summary and statistical analysis

Shoot density (m^{-2}), maximum canopy height, average canopy height and canopy cover were plotted for each reference site over the time period sampled, 2003-07. Statistical analysis was carried out on shoot density (raw data) and maximum canopy height. A one-way ANOVA was performed with year as the independent variable. Data was checked to ensure it conformed to the assumptions of ANOVA, normal distribution and homogeneity of variances. If not the data was transformed using an appropriate function such as natural log. If the transformation did not result in a dataset that conformed to the ANOVA assumptions, then the raw data was used in the analysis and the significance level set to 0.01. If a significant difference between years was detected by the ANOVA then an LSD post-hoc test was performed to determine what years were significantly different to each other.

The new impact site was compared to the reference sites from a similar depth, 2.5 m. Statistical analysis was performed as above but with site as the independent variable. All statistical analysis was carried out on SPSS 11.

The median, 20^{th} and 5^{th} percentile shoot density ($0.04m^2$) were also calculated for the impact site in 2007, and the reference sites including data from all years.

Results

Boullanger Island Reference Sites.

There was no significant difference in shoot density at the Boullanger Island reference sites between 2003-07 (Table 2, Figure 2). At the 2.5 m site average yearly shoot densities ranged from 860 – 950 shoots m^{-2}, at the 3.5 m site the range was 650 – 970 shoots m^{-2}, and at the 5.5 m site, 730 – 840 shoots m^{-2} (Figure 2). However, there was a trend of lower average shoot densities in 2007 at the 2.5 m and 3.5 m site, but not at the 5.5 m site (Figure 2).

There were significant differences in the maximum canopy height between 2003-07 at the 2.5 m and 5.5 m reference sites (Table 2, Figure 2). At these sites, the maximum canopy height increased from 2003-05 but declined in 2007 back to heights measured in 2003 (Figure 2). For example, the 2.5 m site increased from an average of 78 cm in 2003, up to 91 cm in 2005 and then back to 79 cm in 2007 (Figure 2). In contrast, no significant differences were measured at the 3.5 m reference site (Table 2, Figure 2). Here the maximum canopy height ranged from 60 – 65 cm, shorter canopy heights compared to the other two reference sites (Figure 2). The average canopy height followed similar patterns to the maximum canopy height at all sites (Figure 2).

Canopy cover fluctuated over the monitoring period ranging from 58 – 88 % at the 2.5 m site, 57 – 76 % at the 3.5 m site and 54 – 71 % at the 5.5 m site (Figure 2). Maximum canopy cover was observed in 2007 at both the 2.5 m and 3.5 m site (Figure 2).

The 2.5 m reference site was dominated by *P. sinuosa* but also contained patches of *P. australis*, *A.griffithii* and *A. antarctica*. The algal epiphytes consisted of mostly erect calcified forms with some filamentous and encrusting forms. Detritus was low and no dead rhizome or colonising species were observed. The 3.5 m site was dominated by *P. sinuosa* but had some patches of *A. griffithii*. The algal epiphytes were dominated by a combination of filamentous and erect calcified forms. Detritus was low and no colonising seagrass species were observed, however, there were a number of bare patches along the transect with *P. sinuosa* rhizome in them, indicating recent loss of seagrass shoots. The water clarity at both the 2.5 m and 3.5 m sites was poor, visibility was approximately 1 m and there was both dissolved and particulate organic matter in the water column. Large banks of wrack were on the shore of Boullanger Island, inshore from the site which were likely contributing to this organic matter. The discoloured water was not evident at the 5.5 m site. Here the meadow was also dominated by *P. sinuosa* with a few patches of *Syringodium isoetifolium*

and *A. griffithii.* Algal epiphytes consisted of a mix of erect calcified, encrusting and filamentous forms. There was also some cyanobacteria, *Lyngbya* growing on the star pickets and *Amphibolis*. There were a few small patches of bare sediment with *P. sinuosa* rhizome, indicating recent loss of the shoots. Detritus was low and no colonising species of seagrass were observed.

Table 2a: Results of one-way ANOVA on the dependent variables, shoot density and maximum canopy height with year as the independent variable for each Boullanger Island Reference site. n=24 for each year. Significant level set at <0.05 (*), <0.01 (**), <0.001 (***).

Parameter	BI 2.5 m		BI 3.5 m		BI 5.5 m	
	F	p	F	p	F	p
Shoot density	2.405	ns	1.142	ns	0.968	ns
Max canopy ht	7.42	***	1.439	ns	35.7	***

Table 2b: Results of LSD post-hoc tests.

	Max canopy ht							
	BI 2.5 m				BI 3.5 m			
Years	03	04	05	07	03	04	05	07
03	-	-	-	-	-	-	-	-
04	*	-	-	-	***	-	-	-
05	***	-	-	-	***		-	-
07		*	***	-		***	***	-

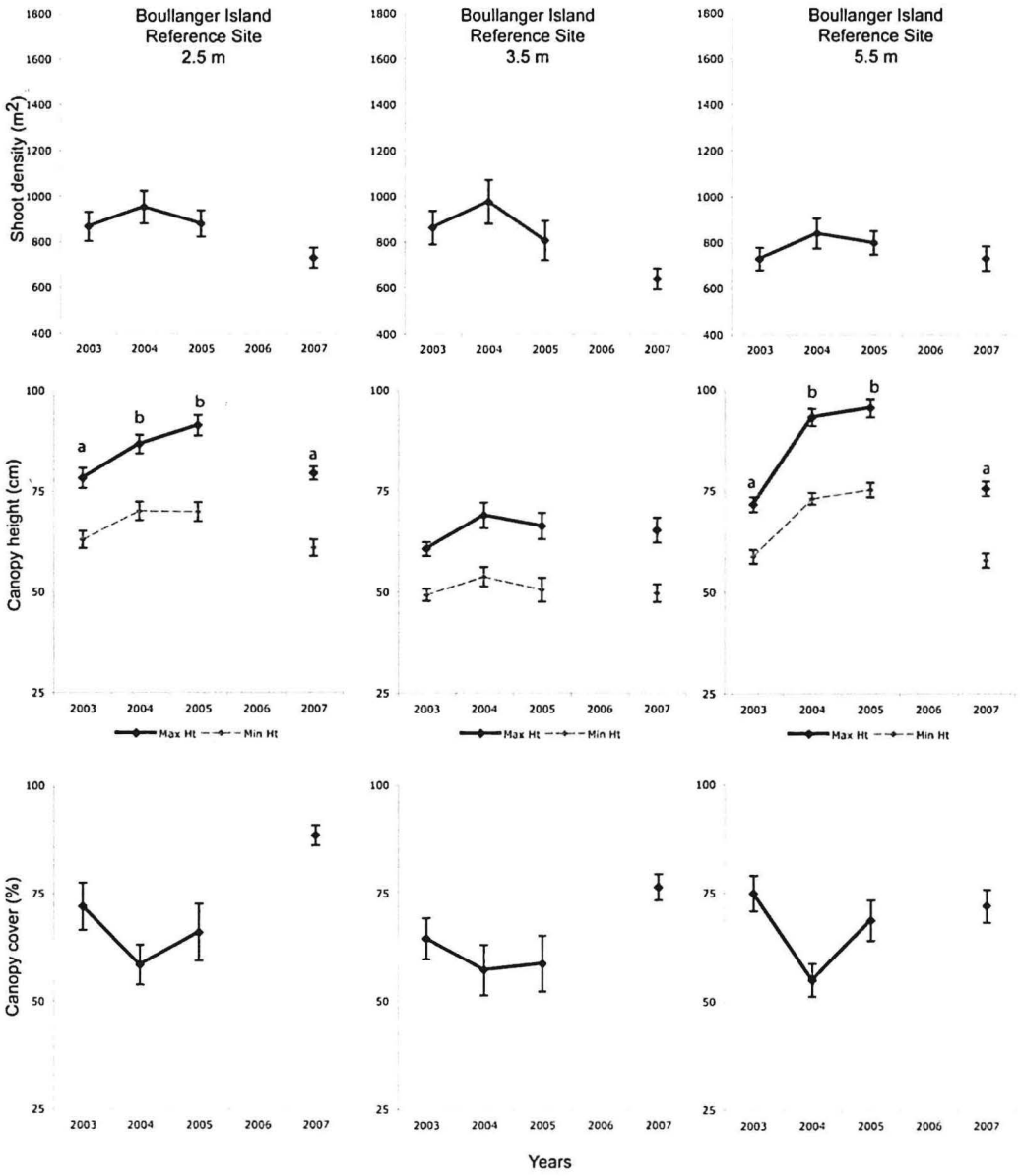

Figure 2: Shoot density (m^2), canopy height (cm) and canopy cover (%) for Boullanger Island Reference sites from 2003 – 2007. Note no measurements were collected in 2006. Letters on graphs indicate which years with a site are significantly different.

Fishermans Island

The pattern in shoot density over the monitoring period varied between the three reference sites at Fishermans Island (Figure 3). At the 2.5 m site there was a significant difference in shoot density between years with the minimum measured in 2007, 915 shoots m^{-2} and the maximum in 2004, 1511 shoots m^{-2} (Table 3, Figure 3). At the 3.5 m site there was no significant difference between years ranging from 660 – 790 shoots m^{-2}, although the lowest average was observed in 2007 (Table 3, Figure 3). At the 5.5 m site there was also no significant difference over the sampling period with a range of 880 – 1060 shoots m^{-2}, however, the minimum was also observed in 2007 (Table 3, Figure 3).

Maximum canopy height also showed different patterns between sites over the sampling period. There was a significant decline in canopy height over the sampling period at the 2.5 m site, from an average of 61 cm in 2003 to 49 cm in 2007 (Table 3, Figure 3). In contrast, at the 3.5 m site there was a significant increase in maximum canopy height from 53 cm in 2003 to 68 cm in 2007 (Table 3, Figure 3). At the 5.5 m site the canopy height in 2003 was significantly lower than the other years, 55 cm compared to 63 cm (Table 3, Figure 3).

Canopy cover followed similar patterns at all of the reference sites (Figure 3). There was a decline in canopy cover from 2003 to 2004-05, but then in 2007 canopy cover returned to 2003 levels. At the 2.5 m site canopy cover ranged from 60 – 75 %, at the 3.5 m site 45- 75 % and at the 5.5 m site 50 – 75%.

The 2.5 m reference site was dominated by *P. sinuosa* and there were a few patches of the seagrass *Syringodium isoetifolium*. Algal epiphytes were mostly erect calcified forms with some smaller macroalgae and filamentous algae. Detritus was low, there were no bare patches in the meadow and no colonising seagrass species observed. At the 3.5 m site only *P. sinuosa* was observed with mostly erect calcified algal epiphytes, some small macroalgae and filamentous algae. Some of the leaves were bound together with the filamentous algae. Detritus was moderate, no bare patches were observed and no colonising seagrass species observed. Similar conditions were observed at the 5.5 m site except that there were a few patches of the seagrass *Syringodium isoetifolium*.

Table 3a: Results of one-way ANOVA on the dependent variables, shoot density and maximum canopy height with year as the independent variable for each Fishermans Island Reference site. n=24 for each year. Significant level set at <0.05 (*), <0.01 (**), <0.001 (***). a = data natural log transformed, b = data did not conform to assumptions of ANOVA so significance set at 0.01.

Parameter	FI 2.5 m		FI 3.5 m		FI 5.5 m	
	F	p	F	p	F	p
Shoot density	10.9_a	***	0.891	ns	1.39	ns
Max canopy ht	9.04_b	**	6.26_b	*	5.54	**

Table 3b: Results of LSD post-hoc tests where there was a significant ANOVA result.

	Shoot density FI 2.5 m				Max canopy ht FI 2.5 m			
Years	03	04	05	07	03	04	05	07
03	-	-	-	-	-	-	-	-
04	**	-	-	-		-	-	-
05			-	-	**		-	-
07	*	***	***	-	**	**		-
	Max canopy ht FI 3.5 m				Max canopy ht FI 5.5 m			
03	-	-	-	-	-	-	-	-
04		-	-	-	**	-	-	-
05	*		-	-	**		-	-
07	**			-	**			-

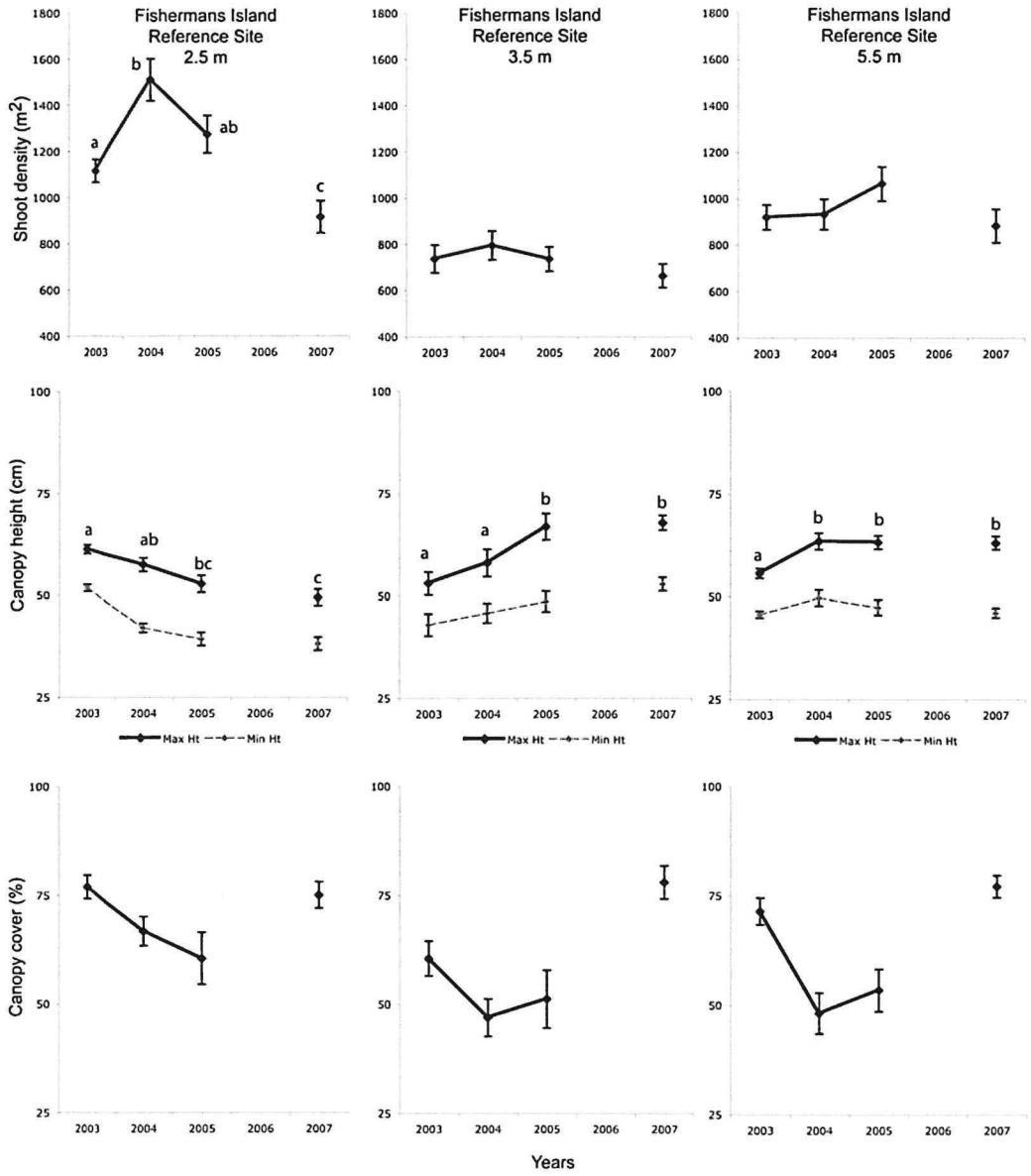

Figure 3: Shoot density (m^2), canopy height (cm) and canopy cover (%) for Fishermans Island Reference sites from 2003 – 2007. Note no measurements were collected in 2006. Letters on graphs indicate which years with a site are significantly different.

2007 comparison

A new site was established in 2007 as an impact site in 2.5 m of water. This site has been compared to the other reference sites in 2.5 m. The highest average shoot density was recorded at Jurien Impact Site 1, 1053 shoots m^{-2}, and this was significantly higher than the Boullanger Island 2.5 m site, 730 shoots m^{-2} (Table 4, Figure 4). Maximum canopy height was significantly different between all sites, the minimum was recorded at Fishermans Island 2.5 m site, 49 cm, the highest at Boullanger Island 2.5 m site, 79 cm, and intermediate values at Jurien Impact Site 1, 72 cm (Table 4, Figure 4). The average canopy height followed similar patterns (Figure 4). Average canopy cover was lowest at Jurien Impact Site 1, 71%, followed by Fishermans Island 2.5 m, 75% and Boullanger Island 2.5 m, 88% (Figure 4).

The meadow at Jurien Impact Site 1 was dominated with *P. sinuosa* but mixed through the meadow was *A. antarctica* with a few patches of *A. griffithii* and *P. australis*. The algal epiphytes were dominated by erect calcified and encrusting forms. Small patches of the cyanobacteria were observed growing on *Amphibolis*. Detrius was low and no bare patches of rhizome was observed.

Table 4a: Results of one-way ANOVA on the dependent variables, shoot density and maximum canopy height with site as the independent variable for each Fishermans Island Reference site. n=24 for each year. Significant level set at <0.05 (*), <0.01 (**), <0.001 (***). a = data natural log transformed, b = data did not conform to assumptions of ANOVA so significance set at 0.01.

Shoot density		Max canopy ht	
F	p	F	p
4.99	**	75.0	***

Table 4b: Results of LSD post-hoc tests for parameters with a significant ANOVA test.

	Shoot density			Max canopy ht		
Sites	BI	FI	JIS1	BI	FI	JIS105
BI	-	-	-	-	-	-
FI	*	-	-	***	-	-
JIS1	**		-	**	***	-

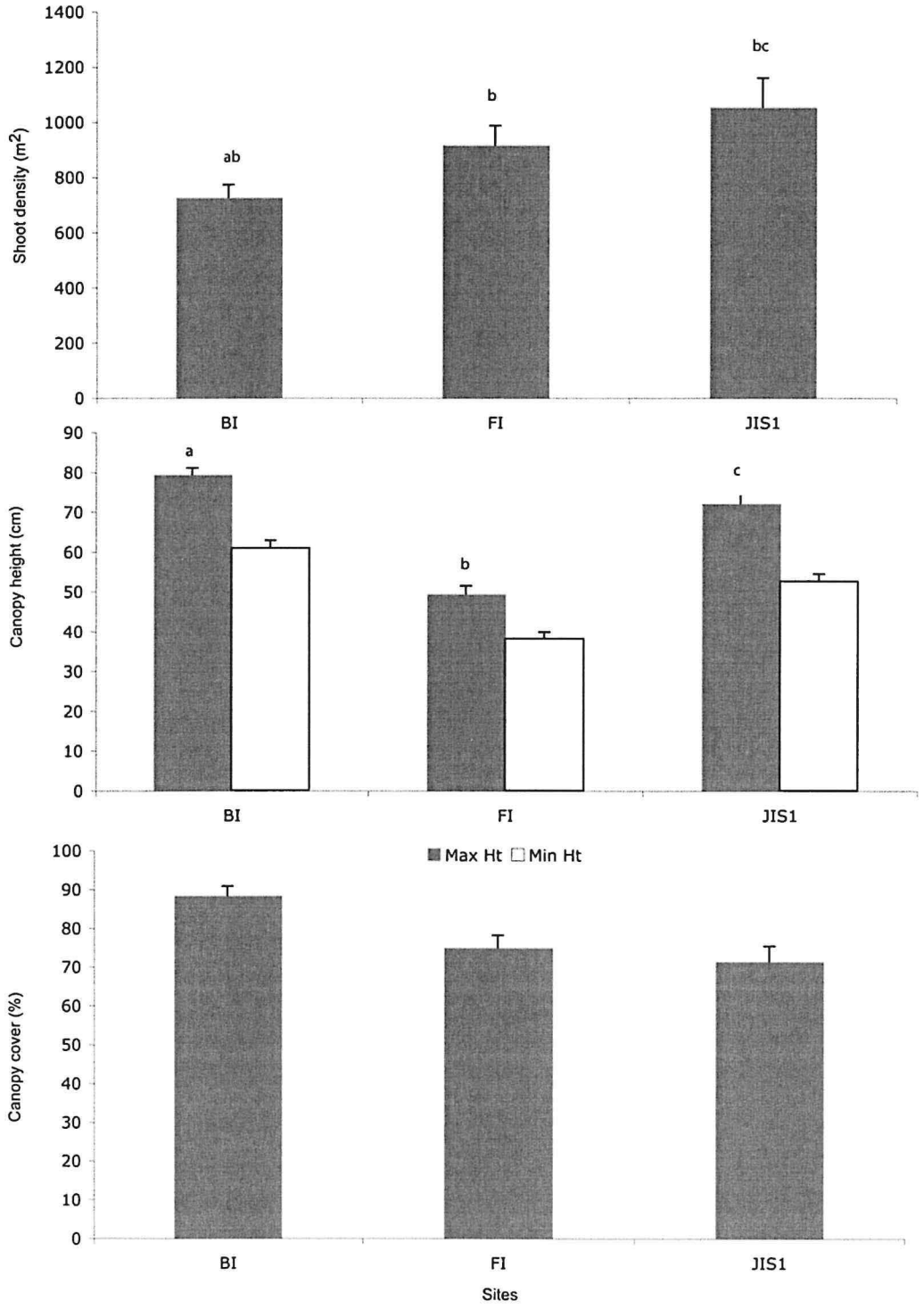

Figure 4: Shoot density (m^2), canopy height (cm) and canopy cover (%) for 2.5 m sites in 2007. BI: Boullanger, FI: Fishermans Island, JIS1: Jurien Impact Site 1. Letters on graphs indicate which sites are significantly different.

Environmental Quality Criteria Assessment

The Jurien Impact Site passes the EQC conditions where the median for shoot density ($0.04m^2$) must not fall below the 20^{th} percentile of the reference sites. The median of 34 is greater than the 20^{th} percentile at both BI 2.5 m and FI 2.5 m (Table 5).

Table 5: Percentiles for shoot density ($0.04m^2$) of the reference site based on 2003-2007 data (n=96) and the impact site (n=24).

Site	5^{th} percentile	20^{th} percentile	Median
BI 2.5 m	14	25	34
BI 3.5 m	9	19	32
BI 5.5 m	14	22	31
FI 2.5 m	25	32	46
FI 3.5 m	13	21	27
FI 5.5 m	19	27	26
JIS1 2.5 m			34

Conclusions and recommendations

Generally there were no significant changes in shoot density at the reference sites over the monitoring period (2003-07). One exception was the Fishermans Island reference site at 2.5 m, there were significant fluctuations over the monitoring period, with minimums observed in 2007. However, light reduction is not likely to be the cause of the decline in 2007 as similar reductions were not observed at the other, nearby Fishermans Island reference sites. In other seagrass health monitoring locations in Cockburn and Warnbro Sound, Western Australia, high water motion has been implicated as a cause of reduced shoot density (Paul Lavery, personal communication), and this may be influencing shoot density at Fishermans Island 2.5 m site.

The trend of lower shoot densities in 2007 at Jurien Bay reflects patterns observed in the Garden Island and Warnbro Sound Reference sites in Perth Coastal Waters (Lavery and McMahon, 2007). This indicates that the 2006/07 seagrass growing season was not as good as 2005/06 when higher shoot densities were observed.

It is recommended to re-establish annual monitoring of seagrass health reference and impact sites in Jurien Bay following the methods already established and outlined by the Environmental Protection Authority (2005). Annual monitoring then follows the same methodology as carried out in the Perth Coastal waters and also allows routine maintenance of the permanent transects and quadrats. To ensure easy identification of the permanent transects underwater it is recommended to mark the start of the transects with closed cable ties and end of the transects with open cable ties. Replace any missing star pickets and pins marking the quadrats as required. Also place PVC caps over the star pickets as a safety measure.

The new Jurien Impact Site 1 was installed and monitored in 2007. The potential impact at this site is urbanisation, where increased nutrients and/or sediments may enter the near-shore environment and lead to light reduction through phytoplankton or algal blooms or suspended sediments. At this stage there is only one time point so changes over time could not be assessed, however, the Jurien Impact site was compared with reference sites of similar depth. The highest shoot density was observed at the impact site in 2007. The median shoot density at the Jurien Impact Site 1 was above the 5^{th} and 20^{th} percentile of the reference sites over the entire monitoring period. This indicates that based on the Environmental Quality Conditions as stipulated in the State Environmental Policy (Cockburn Sound) (Environmental Protection Authority, 2005) for this seagrass health monitoring program, the Jurien Impact Site has passed.

Generally impact sites are compared against reference sites to assess if there are significant changes over time, above the natural variation observed at the reference sites. Boullanger Island reference sites are in a north-east facing embayment, large accumulations of wrack on the shore were observed in 2007. The water clarity here as measured through visual observation was considerably lower than at Fishermans Island reference site, which is located west of the coast in a more exposed position compared to Boullanger Island reference site. The Jurien Impact Site 1 is more similar in distance from shore and exposure to the Fishermans Island reference site. These factors need to be taken into consideration when deciding on the most appropriate reference site for the Jurien Impact Site 1.

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Appendix 1 – Site and Transect Locations for Boullanger Island (BI) and Fisherman's Islands Seagrass Health Monitoring sites.

Site	Transect #	Compass bearing from central picket	Distance to transect picket (m)	Transect Bearing	Quadrat distances
BI 2.5	1	180	7.3	155	1, 2.5, 3, 6, 7.2 ,9.5
	2	260	6	220	0, 0.5, 3 ,3.5, 7 ,8.9
	3	330	5	330-10	2.5, 3.5, 4, 4.5, 5, 9.5
	4	30	5.2	30-130	3, 5 ,8, 8.5 ,9, 9.5
BI 3.5	1	310	9	55	1.5, 2.5, 3, 4.5, 7, 8,
	2	190	7	260	1, 1.5, 4, 4.5, 6, 8.5,
	3	130	8	110	3.5, 5.5, 6, 7.5, 8, 9
	4	10	4	40	1.5, 2, 2.5, 7, 8, 9.5
BI 5.5	1	310	3.8	215	1.5, 2.5, 3, 6.5, 7, 7.5
	2	190	3.3	190	1, 4, 4.5, 6.5, 8, 8.5
	3	160	3.8	120	1, 3, 5, 5.5, 8, 9,
	4	100	4.5	130	2, 2.5, 5.5, 8.5, 9, 9.5
FI 2.5	1	210	2	180	4, 5, 6, 7.5, 8, 8.5
	2	130	5.2	130	0.5, 1, 3, 4, 4.5, 5
	3	90	3.5	110	1, 4, 4.5, 6, 8.5, 9
	4	60	4.5	60	1, 1.5, 2, 3, 4.5, 6
FI 3.5	1	210	7	320	1.5, 2.5, 3, 4.5, 7, 8
	2	20	8	75	1, 1.5, 4, 4.5 ,6, 8.5
	3	130	6	95	3.5, 5.5, 6, 7, 8, 9
	4	5-	3	80	1, 1.5, 2, 7, 8, 9.5
FI 5.5	1	350	1.7	0	0.5, 1.5, 2, 6.5, 7.5, 8
	2	260	2.5	330	2.5, 3.5, 4, 5.5, 6.5, 9
	3	230	3.4	175	3.5, 5, 5.5, 6, 6.5, 9
	4	150	3.5	150	2, 2.5, 3 ,7.5, 8, 8.5
JIS1	1	60	4	60	4, 5, 6, 7.5, 8, 9
	2	90	3	90	0.5, 2, 3.5, 5, 7, 9
	3	130	5	130	1, 3, 4.5, 6, 7.5, 8.5
	4	210	2	210	0.5, 1.5, 3, 4.5, 6, 8

BI = Boullanger Island sites, FI = Fisherman Islands sites, JIS1 = Jurien Impact Site 1.

Appendix 2: 2007 Raw Data

Site	Depth	Tr	Sh Den (0.04 m2)	Max Can Ht (cm)	Avg Can Ht (cm)	Can cov (%)	Site	Depth	Tr	Sh Den (0.04 m2)	Max Can Ht (cm)	Avg Can Ht (cm)	Can cov (%)
BI	2.5	1	22	74	52	80	FI	2.5	1	20	36	28	65
BI	2.5	1	22	76	62	75	FI	2.5	1	33	39	24	80
BI	2.5	1	26	68	60	75	FI	2.5	1	19	37	30	60
BI	2.5	1	35	88	88	100	FI	2.5	1	24	42	27	70
BI	2.5	1	35	84	72	100	FI	2.5	1	26	46	37	75
BI	2.5	1	29	75	75	90	FI	2.5	1	44	36	29	90
BI	2.5	2	35	85	72	100	FI	2.5	2	31	49	37	80
BI	2.5	2	40	80	65	100	FI	2.5	2	38	59	42	80
BI	2.5	2	40	86	76	100	FI	2.5	2	71	66	58	100
BI	2.5	2	24	90	75	100	FI	2.5	2	52	50	34	80
BI	2.5	2	11	81	64	60	FI	2.5	2	32	52	44	75
BI	2.5	2	25	89	59	90	FI	2.5	2	41	62	45	80
BI	2.5	3	29	81	68	90	FI	2.5	3	32	51	42	90
BI	2.5	3	26	57	40	80	FI	2.5	3	47	62	44	80
BI	2.5	3	38	81	48	100	FI	2.5	3	33	50	32	80
BI	2.5	3	21	85	68	80	FI	2.5	3	71	45	39	100
BI	2.5	3	40	90	73	100	FI	2.5	3	34	39	31	90
BI	2.5	3	23	73	50	90	FI	2.5	3	32	50	43	80
BI	2.5	4	38	78	62	90	FI	2.5	4	32	53	40	40
BI	2.5	4	40	82	59	95	FI	2.5	4	28	62	50	60
BI	2.5	4	20	85	60	75	FI	2.5	4	25	50	43	50
BI	2.5	4	15	70	46	75	FI	2.5	4	52	66	40	75
BI	2.5	4	25	73	57	80	FI	2.5	4	31	48	42	60
BI	2.5	4	39	75	64	95	FI	2.5	4	32	39	34	60
BI	3.5	1	9	30	24	50	FI	3.5	1	22	55	42	60
BI	3.5	1	26	81	70	60	FI	3.5	1	26	77	63	60
BI	3.5	1	16	76	63	50	FI	3.5	1	27	63	52	70
BI	3.5	1	24	75	56	75	FI	3.5	1	21	58	50	50
BI	3.5	1	19	67	59	75	FI	3.5	1	20	55	49	90
BI	3.5	1	24	64	48	90	FI	3.5	1	27	47	33	90
BI	3.5	2	20	42	38	50	FI	3.5	2	63	72	55	100
BI	3.5	2	23	60	48	75	FI	3.5	2	33	64	53	100
BI	3.5	2	17	75	60	60	FI	3.5	2	42	82	43	80
BI	3.5	2	19	66	57	75	FI	3.5	2	13	69	58	50
BI	3.5	2	29	54	48	80	FI	3.5	2	12	73	60	50
BI	3.5	2	20	52	40	90	FI	3.5	2	28	71	49	70
BI	3.5	3	12	53	44	50	FI	3.5	3	23	62	47	80
BI	3.5	3	25	44	30	90	FI	3.5	3	28	64	47	100
BI	3.5	3	26	60	45	80	FI	3.5	3	24	76	60	75
BI	3.5	3	34	99	62	90	FI	3.5	3	28	65	57	100
BI	3.5	3	24	62	43	80	FI	3.5	3	33	77	60	100
BI	3.5	3	33	73	54	90	FI	3.5	3	21	65	53	100
BI	3.5	4	47	53	39	90	FI	3.5	4	32	75	51	80
BI	3.5	4	32	77	59	90	FI	3.5	4	19	87	62	90
BI	3.5	4	41	71	47	90	FI	3.5	4	25	77	67	90
BI	3.5	4	37	74	55	80	FI	3.5	4	25	69	44	80
BI	3.5	4	34	78	55	90	FI	3.5	4	28	66	54	80
BI	3.5	4	21	68	46	80	FI	3.5	4	22	69	59	80
BI	5.5	1	7	68	56	40	FI	5.5	1	36	65	42	70
BI	5.5	1	12	86	46	50	FI	5.5	1	37	72	46	80
BI	5.5	1	22	84	69	60	FI	5.5	1	34	56	43	80
BI	5.5	1	20	83	65	75	FI	5.5	1	19	51	35	70
BI	5.5	1	14	71	57	70	FI	5.5	1	46	64	48	80
BI	5.5	1	19	75	59	75	FI	5.5	1	23	71	46	80
BI	5.5	2	49	92	79	100	FI	5.5	2	38	64	43	80
BI	5.5	2	24	69	54	90	FI	5.5	2	25	55	40	70
BI	5.5	2	26	75	65	90	FI	5.5	2	43	64	47	80
BI	5.5	2	39	78	62	100	FI	5.5	2	44	54	44	80
BI	5.5	2	25	78	69	65	FI	5.5	2	60	68	57	100
BI	5.5	2	21	60	50	70	FI	5.5	2	39	51	43	80
BI	5.5	3	27	69	55	60	FI	5.5	3	32	59	43	90
BI	5.5	3	27	73	47	50	FI	5.5	3	22	62	40	70
BI	5.5	3	39	66	42	30	FI	5.5	3	44	54	41	80
BI	5.5	3	31	89	60	50	FI	5.5	3	32	58	42	70
BI	5.5	3	46	67	51	90	FI	5.5	3	61	58	44	100
BI	5.5	3	31	61	50	80	FI	5.5	3	70	57	48	100
BI	5.5	4	39	78	58	75	FI	5.5	4	13	63	50	75
BI	5.5	4	36	65	53	70	FI	5.5	4	20	77	44	50
BI	5.5	4	38	81	63	75	FI	5.5	4	29	64	52	60
BI	5.5	4	35	75	60	80	FI	5.5	4	26	72	54	70
BI	5.5	4	24	83	61	90	FI	5.5	4	26	80	59	75
BI	5.5	4	38	84	58	90	FI	5.5	4	27	75	53	60
JIS1	2.5	1	24	90	49	50							
JIS1	2.5	1	47	59	38	60							
JIS1	2.5	1	34	68	43	50							
JIS1	2.5	1	30	64	36	60							
JIS1	2.5	1	35	70	39	30							
JIS1	2.5	1	34	71	40	40							
JIS1	2.5	2	36	75	53	75							
JIS1	2.5	2	32	74	64	80							
JIS1	2.5	2	33	71	56	90							
JIS1	2.5	2	35	66	55	70							
JIS1	2.5	2	30	71	62	45							
JIS1	2.5	2	32	61	55	65							
JIS1	2.5	3	25	68	44	70							
JIS1	2.5	3	32	74	58	80							
JIS1	2.5	3	37	81	62	70							
JIS1	2.5	3	24	69	57	75							
JIS1	2.5	3	28	98	71	90							
JIS1	2.5	3	21	73	55	75							
JIS1	2.5	4	66	76	53	90							
JIS1	2.5	4	73	79	57	90							
JIS1	2.5	4	102	68	54	100							
JIS1	2.5	4	64	64	50	80							
JIS1	2.5	4	60	68	55	90							
JIS1	2.5	4	77	74	56	90							

Appendix 3: Percentile Data (2003-07)

BI 2.5 m				BI 3.5 m				BI 5.5 m				FI 2.5 m				FI 3.5 m				FI 5.5 m				JIS1	
2003	2004	2005	2007	2003	2004	2005	2007	2003	2004	2005	2007	2003	2004	2005	2007	2003	2004	2005	2007	2003	2004	2005	2007	2007	2007
35	37	38	22	48	70	48	9	15	17	10	7	52	33	30	20	39	35	23	22	32	33	29	36	24	
46	54	44	22	15	9	8	26	42	51	33	12	53	45	52	33	21	36	22	26	27	45	40	37	47	
44	50	51	26	35	37	24	16	27	27	26	22	53	39	26	19	22	21	18	27	24	34	47	34	34	
31	48	48	35	20	25	24	24	28	34	34	20	47	40	45	24	41	36	38	21	18	16	42	19	30	
42	43	57	35	48	54	57	19	20	28	25	14	54	34	29	26	24	24	13	20	29	38	46	46	35	
32	35	23	29	52	64	69	24	31	45	52	19	35	80	72	44	6	8	14	27	32	30	67	23	34	
32	29	21	35	52	45	36	20	42	44	36	49	58	78	55	31	44	40	49	63	27	27	39	38	36	
27	33	32	40	37	55	41	23	14	10	27	24	57	79	58	38	13	15	26	33	57	51	62	25	32	
40	63	45	40	30	32	31	17	28	33	32	26	36	73	74	71	45	35	32	42	57	53	66	43	33	
34	29	33	24	54	59	47	19	30	23	36	39	65	83	69	52	51	53	51	13	36	51	71	44	35	
21	17	13	11	36	47	25	29	30	51	40	25	32	74	64	32	38	38	34	12	41	34	42	60	30	
26	34	36	25	24	20	18	20	45	48	33	21	51	74	74	41	34	39	45	28	33	29	38	39	32	
53	49	43	29	5	3	3	12	36	49	32	27	46	73	58	32	17	23	29	23	44	53	52	32	25	
42	38	32	26	25	25	22	25	35	38	23	27	47	60	60	47	31	35	34	28	38	51	45	22	32	
55	56	56	38	33	42	30	26	32	38	39	39	36	51	46	33	23	31	24	24	41	36	52	44	37	
7	56	24	21	40	38	54	34	27	31	31	31	22	76	64	71	21	22	22	28	43	50	34	32	24	
29	28	28	40	40	49	45	24	33	50	61	46	44	85	62	34	24	46	36	33	41		45	61	28	
34	29	30	23	52	66	53	33	14	17	24	31	37	73	62	32	27	34	21	21	42	65	45	70	21	
42	38	36	38	11	11	14	47	33	38	34	39	38	40	37	32	37	32	33	32	38	12	13	13	66	
52	48	43	40	56	51	28	32	41	41	31	36	46	47	48	28	17	15	16	19	40	33	29	20	73	
28	23	28	20	39	34	14	41	41	37	30	38	38	39	21	25	33	31	25	25	26	27	36	29	102	
8	4	24	15	28	44	34	37	21	18	19	35	44	73	47	52	45	27	36	25	58	36	29	26	64	
25	25	26	25	18	15	16	34	16	13	29	24	40	60	39	31	36	63	37	28	32	29	19	26	60	
46	46	32	39	29	40	32	21	17	23	28	38	40	42	32	32	17	23	27	22	25	26	31	27	77	
Annual median			28				24				27				32				26				33	34	
Percentiles (03-07)																									
5th			15				9				14				25				13				19		
20th			25				19				21				32				21				27		
50th			34				32				31				46				28				36		
Count			96				96				96				96				96				95		