Determining seagrass depth distribution in the Swan River – a test of the dumpy level method with recommendations for alternatives

Example of typical cover of *Halophila ovalis* in the Swan River

Report prepared for

**The Water Science Branch, Department of Water**

By

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20 June 2008

CMER report no. 2008-02
Summary
The depth distribution of seagrasses integrate environmental conditions and thus provide a robust measure of the general water quality conditions relative to physico-chemical measurements, which are highly variable and sensitive to conditions at the time of sampling. The dump-level method is used to measure the depth distribution of seagrasses for ecosystem health monitoring in Queensland. The aim of this report was to assess the feasibility of monitoring the depth distribution of *Halophila ovalis* in the Swan-Canning Estuary using the dumpy level method. While *H. ovalis* appeared to be a suitable indicator species, our investigations highlighted a number of problems with the dumpy-level method such as lack of suitable sites, large impracticalities associated with extent and depth of seagrasses and future difficulties with increasing water clarity. This led us to conclude that the dumpy-level method is not suitable for the Swan River. Instead, we recommend a combination of broad-scale spot-dive surveys and monitoring of permanent fixed depth transects.

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Introduction
Seagrass distribution is affected by several environmental drivers including: light, nutrients, depth, salinity, temperature, grazing, competition, bioturbation, hydrodynamics, and sediment quality including grain size. Of these, light is the single most important driver and it integrates the effects of several other environmental factors. For example: nutrients reduce light due to increased shading from phytoplankton and epiphyte growth; depth reduces light of the wavelengths necessary for photosynthesis (i.e., photosynthetically active radiation); grazing may increase with greater epiphyte growth and increase light penetration to leaves; and competition can increase shading from drift algae or other seagrass species. Thus with the complexity and diversity of the factors affecting seagrass growth, there has been a consensus that in many areas where loss of seagrass has occurred light may generally be responsible (Middelboe et al. 2003, Krause-Jensen et al. 2005).

Light affects seagrass survival, growth, density, leaf length, leaf cluster density and depth penetration or depth range (Larkum et al. 1989). Depth range is the simplest to measure of all these factors. Depth range relies on the premise that seagrass meadows are restricted in their upper limit (shoreline) by tolerance to desiccation, uv-radiation, light-inhibition, storminess and substratum instability, and in their lower limit by light penetration of photosynthetically active radiation. Reduced light penetration through the water could result in loss of seagrass from the outer (deep) edge of a meadow while disturbance from waves (e.g., wakes of boats) could result in losses from the upper edge in shallower areas. Reduced light can occur by increased turbidity from living or non-living particulates in the water, or increased shading by silt deposits or epiphytes on leaf surfaces or stems. Depth range can provide an indicator of ecosystem health by integrating total available light over extended periods with other environmental drivers that affect seagrass survival described earlier. Therefore a measure of light penetration and depth limit of seagrass could provide an index of ecological health of a system. The Ecosystem Health Monitoring Program in south east Queensland uses seagrass depth range as an indicator of ecological health (EHMP 2007), where the depth range is defined as the difference in elevation between the upper and lower depth record of the seagrass at a site.

The depth range of paddle weed, *Halophila ovalis* - the most abundant seagrass in the Swan-Canning Estuary could be used as a biological indicator of ecological health. The aim of this project was to test if depth distribution and range of *H. ovalis* could be used as an indicator in the Swan River, and to assess the effectiveness and usefulness of the ‘dumpy-level method’, as used by the EHMP in Queensland, in detecting the depth limits in the Swan River.

Methods

Survey of suitable sites
A survey of the lower reaches of the river was done to assess the general availability of suitable sites. Sites were required to have enough slope (i.e. 1:3 gradient) to include the depth limit of seagrasses within reasonable distance from shore, and a minimal influence from human activity (e.g., away from mooring sites and ferry routes). Potentially suitable sites were identified on a chart and visited by boat. Additional sites were visited *ad hoc*. At most sites, spot snorkel dives were done to determine the presence of seagrasses and their approximate depth limit.
Seagrass depth distribution (duumpy-level method)

The dumpy level method is well established and is used for monitoring seagrass depth distribution elsewhere, for example in Moreton Bay, Queensland. To the extent possible, the guidelines of EHMP (2007) were followed. Suitable sites were selected (cf. survey of suitable sites) to be Como Beach (northern end), Matilda Bay (towards the rowing club) and Waylen Bay (Heathcote). GPS coordinates are given in Table 1. Substantial amount of time was spent organising and obtaining equipment so a fourth site could not be done due to time constraints. The first site was slow, but once routines were established and equipment obtained, it took approximately 2-3 hours to complete a site.

At each site, a central (main) transect was established and its beginning marked in the sand (cf. GPS coordinates are given in Table 1). On either side of the main transect, 5 additional transects were marked ~10m apart (Figure 1). A theodolite was set up a couple of metres away from the beginning of the main transect (Figure 2). First, readings were taken to the inner edge at all 10 transects (Figure 2). This required one person in the water holding the staff to the edge of the seagrass meadow (Figure 3), one person on the beach marking the position of the transect, and one person reading the theodolite. Subsequently, readings were taken for the outer (deep) edge of all 10 transects. The depth of the outer edge was ~2-3m, so a scuba diver was required to locate the edge and to hold the staff in place. In addition to being a safety requirement, a snorkel diver was required at the surface to align the diver with each transect, and to ensure the staff was held vertical. Distances were too great to allow voice communication between the shore and the divers, so, a system of arm signals were devised. The person reading the theodolite also had to mark the position of each transect on the beach until the divers were in place for each measurement. She therefore had to run back and forth between the theodolite and transects; a fourth person would have facilitated these measurements greatly.

Figure 1. Sketch of measurements and site set-up.
In order for all depth measurements to be related to a standard, fixed baseline (height above mean sea level = Australian Height Datum, ADH), the elevation of all measurements must be levelled back to a position of known elevation – a Standard Survey Mark (SSM); these are permanently marked positions, where the elevation has been officially established by professional surveyors. This could not be done as SSM’s were not known at the time of sampling. Instead, all measurements were levelled back to a permanent landmark (see Table 1 and Figures 4, 5, 6), from which AHD can be established at a later date if the method is continued. In order to determine the position of the edges of the seagrass meadows, depths were related to the water surface on the day of measurement. While this is accurate enough for assessing the feasibility of the method, it potentially introduces a considerable uncertainty with respect to the absolute depth limits. It is therefore essential that the absolute depth limits reported here are adjusted to AHD before comparison with measurements done in the future. The depth range is independent of tides etc. and do not need to be adjusted.
Information on the position of relevant SSM’s has subsequently been obtained from Landgate and this information is provided as files on the enclosed CD (see appendix 2). If the method is continued, it is not feasible to level back to the SSM’s at every sampling. However, the landmarks given in Table 1 can be used for all subsequent sampling if their elevations are established once. If measurements are continued over long times scales (many years), it would be pertinent to check the AHD every couple of years.

### Table 1. Sites and GPS coordinates (WGS84)

<table>
<thead>
<tr>
<th>Site</th>
<th>GPS main transect</th>
<th>Landmark</th>
<th>GPS Landmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Como Beach</td>
<td>31°58.450S 115°50.850E</td>
<td>Fence post, Fig. 4</td>
<td>31°58.453S 115°50.854E</td>
</tr>
<tr>
<td>Matilda Bay</td>
<td>31°58.480S 115°49.461E</td>
<td>Sign post, Fig. 5</td>
<td>31°58.465S 115°49.462E</td>
</tr>
<tr>
<td>Waylen Bay</td>
<td>32°00.285S 115°50.427E</td>
<td>Sign post, Fig. 6</td>
<td>32°00.295S 115°50.437E</td>
</tr>
</tbody>
</table>

Figure 4. Como Beach – the landmark is the 6th black fence post north of the 3rd light pole south of the car overpass.

Figure 5. Matilda Bay; the landmark is a signpost on Mounts Bay Road (just visible to the right of the tree) with the text "service vehicles using pathway".
Water quality

Water quality data were collected to give an indication of any major differences among sites that could explain potential differences in depth distribution. Sampling included Secchi depth, light extinction coefficient, TSS (total suspended solids), Chl a (chlorophyll a), temperature, oxygen, salinity and turbidity. Measurements were taken at 2-3m depth at 3 stations 50-100m apart, immediately offshore of each site. Secchi depth was measured with a standard 20cm diameter secchi disc. The light extinction coefficient was calculated as the slope between depth and Ln-transformed light-measurements (spherical light sensor) immediately below the surface and at the bottom; in contrast to the raw light measurements, this adjusts for variation in the light (e.g., due to cloud cover) at the time of sampling. TSS and Chl a were measured by collecting water samples (1-2 L) from the surface. These were stored on ice and brought back to the laboratory and filtered onto 0.45 µm filter paper which was analysed by the Marine and Freshwater Research Laboratory (MARFL) at Murdoch University in Perth. The remaining parameters were measured with a Hydrolab probe. Data on temperature, dissolved oxygen, salinity and turbidity could not be reported for Matilda Bay and Waylen Bay as the probe data were accidentally erased before they were down loaded. Data are presented from Como and given lack of significant differences among sites for all other environmental parameters, we do not anticipate great departure from this.

Results

Survey of suitable sites

Many sites were visited (Table 2). While several looked very promising on the chart, once at location, most were discarded. The two most common reasons for deeming a site unsuitable were the presence of large aggregations of moorings (e.g., Mosman Bay) or a depth limit for seagrasses vastly exceeding the ~3m maximum possible with the standard surveying equipment available to us (5m staff). Essentially, the depth restriction limited useful sites to those up-river from Point Walter.
<table>
<thead>
<tr>
<th>Site</th>
<th>Suitability</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chidley Point</td>
<td>✗</td>
<td>Both <em>H. ovalis</em> and <em>H. decipiens</em> growing deeper than 5m</td>
</tr>
<tr>
<td>Freshwater Bay, Claremont College</td>
<td>✗</td>
<td>Lots of seagrass deeper than 4m, distance from shore to seagrass edge extensive (2-300m)</td>
</tr>
<tr>
<td>Freshwater Bay, ~500m further into the bay from Claremont College</td>
<td>✗</td>
<td>Depth limit of seagrass ~5m</td>
</tr>
<tr>
<td>Mosman Bay</td>
<td>✗</td>
<td>Many moorings, very rocky</td>
</tr>
<tr>
<td>Point Resolution (entry to Freshwater Bay)</td>
<td>✗</td>
<td>Seagrasses growing deeper than 5m, both <em>H. ovalis</em> and <em>H. decipiens</em>.</td>
</tr>
<tr>
<td>Point Resolution (+ ~100m further into the river)</td>
<td>✗</td>
<td>Depth limit ~3m but no <em>Halophila</em> bed, only sparse and scattered individuals.</td>
</tr>
<tr>
<td>Point Resolution (+ ~400m further into the river)</td>
<td>✗</td>
<td>Depth limit ~5m, both <em>H. ovalis</em> and <em>H. decipiens</em>.</td>
</tr>
<tr>
<td>Whaylen Bay (jetty, opposite end to Heathcote)</td>
<td>✓</td>
<td>Depth limit ~ 2.5-3m.</td>
</tr>
<tr>
<td>Whaylen Bay (Heathcote)</td>
<td>✓</td>
<td>Depth limit ~2.5m; looked like a clear gradient/transition (nb the two Whalan Bay sites are ~1km apart).</td>
</tr>
<tr>
<td>Como beach (north)</td>
<td>✓</td>
<td>Depth limit ~3m.</td>
</tr>
<tr>
<td>Matilda Bay (rowing club)</td>
<td>✓</td>
<td>Depth limit of seagrass ~2.5m.</td>
</tr>
</tbody>
</table>
Seagrass depth distribution (dummy-level data)
The inner edge of the seagrass meadows were located in 0.8-1m water (Figure 7) and the depth of the outer edge around 2.7-2.8m (Figure 8). The depth of the inner edge varied considerably less within a site compared to the depth of the outer edge, and consequently the differences between sites were significant for the inner edge but not the outer edge (Table 3). This probably reflects the difficulties associated with measuring the outer edge (cf. appendix 1 – list of difficulties encountered). However, a number of ecological processes could also explain why seagrass meadows expand deeper at some transects than others, for example the ability to successfully send out propagules and biological disturbances.

Depth differences between the inner and outer depth limit (i.e., the depth range, Figure 9) and the extent of seagrass meadows (Figure 10) were also significantly different between sites (Table 3). Meadows at Como Beach had the greatest depth range and meadows in Waylen Bay the smallest. Clearly, this pattern was driven by the depth of the inner edge (Figure 7). Although the meadow at Como Beach had the broadest depth range, its extent was smaller than the meadow at Matilda and Waylen Bay. This pattern reflects the steepness of the near-shore area. Patterns of depth range and extent of seagrass meadows are unaffected by the lack adjustment for AHD, and should represent robust patterns.
Table 3. Statistical analyses, 1-way ANOVA to test differences among sites

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>MS</th>
<th>F</th>
<th>P'</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seagrass depth distribution (df = 2,30)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth, inner edge</td>
<td>0.1087</td>
<td>14.269</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Depth, outer edge</td>
<td>0.0289</td>
<td>1.832</td>
<td>0.178</td>
</tr>
<tr>
<td>Depth difference</td>
<td>0.8030</td>
<td>29.701</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Meadow extent</td>
<td>8066.4</td>
<td>32.154</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Water Quality (df = 2,6)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secchi depth</td>
<td>0.0453</td>
<td>0.921</td>
<td>0.448</td>
</tr>
<tr>
<td>Extinction coefficient</td>
<td>0.0193</td>
<td>1.214</td>
<td>0.361</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>12.4444</td>
<td>1.750</td>
<td>0.252</td>
</tr>
<tr>
<td>Chlorophyl a</td>
<td>1.7344</td>
<td>3.708</td>
<td>0.089</td>
</tr>
</tbody>
</table>

* The small P-values cannot be interpreted as strength of patterns; they reflect the power of the test with n=11.


**Water Quality**

Water quality data are shown in Figures 11-15. There were no differences ($P>0.089$) among the 3 sampling sites for any of the water quality parameters measured (Table 3). The Secchi depths varied around 2.5-2.7 (Figure 11) suggesting that light would penetrate to the maximum depth distribution. Moreover, the extinction coefficients (Figure 12) varied around -0.55 m$^{-1}$ which imply that on a day with full sunlight (≈2000 µE m$^{-2}$ s$^{-1}$), light levels at ~7m depth would equal the compensation point for *Halophila ovalis* (40 µE m$^{-2}$ s$^{-1}$, Hillman et al. 1995).

TSS (Figure 13) and Chl a (Figure 14) levels varied around 6 mg L$^{-1}$ and 2.5 µg L$^{-1}$ respectively. This is within the range observed in this lower region of the Swan River estuary (Thomson et al 2001) and the Chl a concentration is below the target set for this part of the river, 3.5 µg L$^{-1}$ (SRT 2007).

The water column did not show any signs of stratification (Figure 15).
Figure 13. Total suspended solids (TSS) (mean + s.e.m., n=3).

Figure 14. Chlorophyll a (mean + s.e.m., n=3).

Figure 15. Water column characteristics at Como Beach 28/3/08 as measured by the hydrolab probe. From left to right: temperature (°C), dissolved oxygen (% saturation), salinity (‰) and turbidity (% of maximum reading).
Discussion
The aim of this project was to assess the application of the seagrass depth range method using the dumpy level approach in the Swan Canning estuary as an indicator of ecosystem health.

The seagrass depth range method is a site-specific approach to monitor the change in the depth distribution of seagrasses, a reduction in depth distribution at the deeper edge implying a reduction in light penetration and water quality. It is more unclear what a change in the depth of the shallow (inner) edge signify as multiple processes could be causing these changes (e.g., disturbances from boat wakes vs. wind waves vs. UV damage). Also, in contrast to the outer depth limit, the inner edge do not provide a clear link to anthropogenic pollution, but is more likely to represent natural environmental fluctuations.

The main requirement of site selection was a steep gradient (1:3) with a continuous Halophila seagrass meadow present on sandy substrate without any permanent structures such as jetties or moorings and in safe water for snorkellers and divers (ie no ferry routes or jet ski areas). A number of sites were assessed in the Swan Canning estuary from the Narrows bridge (Melville Waters) downstream to Rocky Bay that met these conditions.

There was a gradient in the deepest depth limit of seagrasses in the Swan Canning estuary from upstream with relatively lower water quality to downstream with relatively higher water quality. Seagrasses were observed down to 2.5 m at the most upstream site, and down to 6 m at the most downstream site. It should be emphasised that, the ‘quality gradient’ is a partially natural phenomenon, driven by gradients in salinity and substratum (sediment) conditions. Nevertheless, the observed patterns support the assumption of the seagrass depth range methodology, that greater water quality leads to greater depth range of seagrasses and indicates that the seagrass depth range monitoring is an appropriate approach in the Swan Canning estuary for Halophila meadows.

The seagrass depth range approach would not be appropriate for other seagrass species in the Swan Canning estuary such as Ruppia or Zostera. Ruppia has a growth form that can reach the surface from depths of 4 m so does not have the same light limits placed on it as a species such as Halophila that grows close to the sediment surface (Carruthers & Walker 1999). Zostera has a restricted distribution in the Swan Canning estuary (McMahon et al. 2007) and would not be appropriate to compare between different parts of the lower estuary.

Hillman et al. (1995) did not find H. ovalis below 2 m depth except in small areas around the mouth of the river, where it was found to 4 m. We found H. ovalis beyond 2.5 m in the main basin (Melville Waters) and beyond 5 m as far upstream as Chidley Point and Freshwater Bay (Table 2). This suggests that the water quality (clarity) has increased over the past 10-15 years. With climate change and decreasing precipitation and run-off, this trend of increasing water clarity is likely to continue, exacerbating the problems associated with the dumpy level method and the depth of measurements.

As the seagrasses grew down to 2.5 m at the shallowest depth, and over a distance of generally greater than 50m, the dumpy level methodology was not appropriate to measure the depth range as the staff to measure height only just reached above the water. In addition, a range of other impracticalities were encountered (see appendix 1: list of ‘problems encountered). Therefore a different approach is required and we recommend following the depth transect methodology of the seagrass health monitoring programme run by Department
of Conservation and Environment in the Perth coastal waters (EPA 2005). This approach is described in more detail under ‘recommendations’ below.

There are at least two distinct morphologies of *Halophila* in the Swan River, most likely representing respectively *H. ovalis* (broad-leaved, often dark green) and *H. decipiens* (narrow-leaved, typically light and bright green) (Figure 16). They can be tricky to distinguish in situ but it is possible with some experience. It is important that depth limits are based on *H. ovalis* (or both species separately). While little hard data exist on the ecological differences between these two species, *H. decipiens* tends to be more tolerant of low light levels and have a more ephemeral habit than *H. ovalis* (Waycott et al. 2004); *H. decipiens* apparently responds quickly to environmental changes, and has been reported to be found at all depths, although often substantially deeper than *H. ovalis*. Our observations corroborate the latter, i.e. *H. decipiens* were typically found deeper than *H. ovalis*. Other observations are; hardly any *H. decipiens* were observed in shallow water (< 1-5-2m), *H. decipiens* do not form ‘dense meadows’ but were always scattered with low leaf densities. Also its rhizomes often grew ‘out of the substrate’ (see figure 16) which may be an opportunistic trait that is particular useful in deeper areas characterized by high levels of sedimentation, re-suspension events and hypoxia. Where seagrass beds of *H. ovalis* often have a fairly well defined edge, *H. decipiens* often just thin out with decreasing shoot densities and sometimes ‘re-appear’ at greater depth with a few leaves, making it very uncertain, difficult and time-consuming to determine definite depth limit for this morph. Given the relative scarcity of ecological data on the ecological properties of these species we suggest it should be considered to support a student project to highlight their ecological differences.

![Figure 16. Right: Broad-leaved, dark green (*H. ovalis*) and narrow-leaved bright green (*H. decipiens*) morphologies of *Halophila* growing next to eachother in the Swan River. Left: Isolated shoots of *H. decipiens* (left) creates a sparse cover at 5m. Note how the rhizome is located on top of the sediment surface.](image)

**Conclusion**

This project has revealed a number of issues, such as substantial impracticality and impediments in future environments, which leads us to conclude that the dumpy level method is unsuitable for the monitoring of seagrass depth distribution in the Swan-Canning River. Instead, we recommend a combination of infrequent (years apart), spatially extensive surveys of random spot-dives and annual monitoring of fixed permanent depth transects at selected locations. These two approaches complement each other (Table 4).
Recommendations
Here we briefly outline two complementary methods, spot dives and permanent transects, recommended for monitoring the depth distribution of *Halophila* in the Swan River. We explain how each method would be executed. However, the exact experimental design and sampling protocol for both spot-dive surveys and permanent transects would have to be investigated further before a monitoring program is implemented.

Spot dives
A diver swims along, towing a float on a taut line, with a gps in a water proof box. The gps should be set to frequently record the travelled track (at least 3-4 recordings per minute). The divers watch and the clock in the GPS should be synchronised. The diver starts at a random point inshore of the expected depth limit and swims parallel to the depth gradient until the depth limit is reached. At the depth limit the diver records the time and the depth before returning to shallower water. The diver then travels perpendicular to the depth gradient for a random distance (20-50m) and repeats the excursion to the depth limit. One diver should be able to do this at least 10-20 times (= same number of independent points) in one dive. There are no issues with decompression because everything will be at depths ranging from 2-10m. The diver must have an accurate depth gauge which is sensitive enough to record increments of 0.1m in the depth range 2-10m. Divers times and depth limits are subsequently matched up with the track log from the GPS to provide waypoint for each measurement. Dive times are also used to adjust depths for tides on the day of sampling by reference to measurements in Fremantle and at Barrack Street Jetty. The recorded depth limit way-points can either be plotted on a bathymetric map of the river for visual display and calculation of spatially explicit measures (e.g., distance edge has moved, area lost/gained) or the depth measurements used directly for statistical analyses (e.g., correlation analyses of change with year, distance from mouth). We suggest to focus on the same 10 general areas as covered by the recent acoustic mapping (Parnum and Gavrilov 2008) wherever a suitable depth gradient exist.

Permanent depth transects
We suggest permanent depth transects are set up at at least 5 sites along the length of the River from Como to Rocky Bay. The methodology should follow the depth transect methodology of the *Posidonia* seagrass health monitoring in Perth Coastal Waters (EPA 2005). Potentially suitable sites that have an appropriate depth gradient and continuous seagrass meadows down that gradient include Como, Matilda Bay, Waylen Bay (Heathcote), Freshwater Bay, Point Walter, Chidley point and Rocky Bay (see Table 2). Within each site 3 parallel transects (~ 20m length) should be established 10m apart down the bathymetric gradient, perpendicular to and passing the depth-limit of the seagrass meadow. Transects should start at the shallow end, well within the main seagrass bed, and end well outside the deep edge of the seagrass bed. Three replicate transects should be established at each site to account for natural variability in seagrass depth limits and colonisation at small spatial scales.

Start pickets hammered into the bottom should mark every 5m along each transect (use temporary floats on the day, at the shallow end if permanent star pickets are a safety hazard to users). At each sampling time, the depth should be measured at each star picket (and the time recorded to adjust for tides – see above). A tape measure is run along the starpickets and the exact depth and distance of the seagrass meadow edge (start and end) recorded. The edge of the meadow can be difficult to determine in a *Halophila* meadow as the meadow can be quite patchy with continuous aggregations of leaf pairs and then very small distinct patches with 1
or 2 leaf pairs. A standard approach needs to be taken to define the deep edge. Based on our observations from the current study the edge should be defined as when the continuous meadow ends i.e. when small patches of leaf pairs and more than 50 cm apart.

At every 5m distance along each transect 5-10 photographs of a 20x20cm quadrat over the Halophila meadow should be taken (cf. the cover photo, but including a quadrat frame) and the percent cover of Halophila determined by standard photoanalysis (Roelfsema et al. 2008). Photoanalysis of percent cover is a more standard methodology than in situ estimation and removes the variability of observer bias (Joyce et al. 2002, Roelfsema et al. 2008).

Both Halophila ovalis and Halophila decipiens (in addition to Rupia sp. and Zostera sp.) were observed in the current study, growing in both mixed and single species meadows (no ‘meadows’ of H. decipiens, only scattered groups of leaves), as has been described previously in south coast estuaries of Western Australia (Kuo & Kirkman 1995). These species have different light requirements and physiology, with inferences that H. decipiens has lower light requirements than H. ovalis due to its deeper depth distribution, and H. decipiens tends to be more ephemeral (Waycott et al. 2004). Therefore it would be important to identify the species in each photo-quadrat. The best approach would be to have a person with the ability to identify the two species taking the photographs and recording underwater the species present, or taking a voucher specimen from the start and end of each transect.
### Table 4. Contrasting survey methods

<table>
<thead>
<tr>
<th>Property</th>
<th>Spot dives</th>
<th>Permanent transects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity to detect changes</td>
<td>Less because of element of spatial variation</td>
<td>High because the same areas are sampled every year</td>
</tr>
<tr>
<td>Extrapolative power of effects</td>
<td>High; independent samples; effects are general</td>
<td>Low; non-independent samples; effects apply only to the study sites</td>
</tr>
<tr>
<td>Sampling design and flexibility</td>
<td>Flexible; no of sites and dives can vary from survey to survey</td>
<td>Rigid; sampling protocol must be identical each year</td>
</tr>
<tr>
<td>Permits</td>
<td>Only for operating on/in the water</td>
<td>Additional permit required for underwater installations (Swan River Trust)</td>
</tr>
<tr>
<td>Vulnerability to unforeseen events</td>
<td>Low; not tied to specific sites or structures</td>
<td>High; sites can be 'lost' if a larger structure is installed around it (e.g. new jetties, piers etc). Site markers can be lost or vandalised.</td>
</tr>
<tr>
<td>Field work</td>
<td>Simple; requires identification of depth limit; boat and scuba required</td>
<td>Complex; requires in situ assessments of abundance, relocation of fix-points. Boat and scuba required.</td>
</tr>
<tr>
<td>Installation and maintenance</td>
<td>None</td>
<td>Requires permanent structures (star pickets); needs cleaning and maintaining every couple of years</td>
</tr>
<tr>
<td>Sampling equipment</td>
<td>GPS, surface float, water proof pen and paper</td>
<td>Transect line or tape measure, quadrats, camera, water proof pen and paper.</td>
</tr>
<tr>
<td>Data analysis</td>
<td>Simple; nested ANOVA with time and areas; correlation</td>
<td>Complex; repeated measures ANOVA</td>
</tr>
<tr>
<td>Proposed sampling frequency</td>
<td>Infrequent, years apart</td>
<td>Annually, at the same time each year; March to coincide with maximum seagrass abundance (Hillman et al. 1995).</td>
</tr>
</tbody>
</table>
References


Hillman, K et al. (1995) The distribution, biomass and primary production of the seagrass Halophila ovalis in the Swan/Canning Estuary, Western Australia. Aquatic Botany 51:1-54


Appendix 1 – list of difficulties encountered

- Depth limits are substantially deeper (ie >5m) than what is possible with this method for large parts of the river; the method is restricted to the inner part of Melville water.
- It will not be possible to continue this method of if water quality improves (depth limits increase) in the river.
- Very difficult to find areas without moorings; many potentially useful sites were full of moorings.
- The method is impractical, particularly where the horizontal distance is >100m and water depth > 1.5m; need 2 people in the water to hold the staff (surface and bottom), and 2 people on shore to read the theodolite and guide the people in the water (mark transects).
  - difficult to hold staff vertical and still at the outer edge even with a diver below and a snorkeller above; this introduces a reading error of +/- several cm’s
  - difficult to find and define outer edge of seagrasses; patches thin out and are not well defined and poor visibility (<1m) makes searching difficult.
  - Staff sinks in up to 10cm, particularly at the deep end with silty sediments.
  - At some sites it will be difficult/impossible to establish a landmark because the beach is below a steep/high cliff or seawall.
- Water quality data should be collected for all sites on the same day and as close in time as possible as this is the only way they can reasonably be benchmarked against each other. The instantaneous water quality measures vary too much with short-term changes in wind, flow etc. It would be better to benchmark depth distribution patterns against some average of ongoing water quality monitoring than once-off sampling.

Appendix 2 – list of files provided on CD

- Pdf file with this report
- Pdf files obtained from Landgate with information on the position of standard survey marks (SSM’s) relevant for each of the three sites.
- Excel spreadsheet with dumpy-level data, graphs and calculations.
- Excel spreadsheet with raw results from TSS and Chl a analyses done by MAFRL.