Project Progress Reporting Form
WAMSI Top-up Scholarship

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SUPERVISOR:	**Prof. Diana Walker**	**Nov**	**2009**

PROJECT TITLE:	**The role of seedling recruitment in maintaining seagrass diversity**
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PROJECT NUMBER:	

Aims of Project:

This project examined the processes of seagrass settlement and recruitment in gaps, with the broad aim of understanding the role of seedling recruitment in seagrass population maintenance and recovery from disturbance. Gaps are patches of exposed substratum within a seagrass meadow that are completely surrounded by seagrass. They form either through disturbance removing seagrass or from the joining of two growing sections of seagrass at the edge of a meadow (Bell *et al.* 1999). Gaps make useful natural experimental units for studying the role of seagrass seedling recruitment in recovery from disturbance.

Gaps are known to increase seagrass diversity by providing space for colonization (Rasheed 2004). The role of seagrass seedling recruitment in the infilling of gaps is dependent on the life history strategies of local species. Some species produce seeds capable of remaining dormant in the sediment, and rapid colonization of gaps can occur when suitable conditions for seed germination exist (McMillan 1983; Preen *et al.* 1995). For species which produce large seeds or seeds with no dormancy period, seedling recruitment events are less common and gap infilling may be dominated by vegetative growth from the gap margin (Williams 1990; Rollón *et al.* 1998). However, occasional recruitment events create new seagrass patches in the gap interior and vegetative growth of these patches can rapidly increase the rate of gap infilling (Olesen *et al.* 2004).

Temperate Western Australian seagrass meadows are dominated by two genera of seagrass, *Amphibolis* and *Posidonia* (Walker 2003). *Posidonia* species produce large seeds that germinate before or soon after dehiscence from the fruit (Kuo and Kirkman 1996). *Amphibolis* species produce viviparous seedlings which germinate and develop while attached to the parent plant, being released after several months (Kuo and Kirkman 1990). Direct studies of seedling recruitment in these genera are rare (Kirkman 1998), although indirect evidence suggests seedling recruitment may be a critical process in the population maintenance of these plants. Frequent high seed production rates indicate that seedling recruitment likely contributes to the population maintenance of *P. coriacea* (Campey *et al.* 2002). Change analysis of seagrass coverage over a 20 year period showed a dramatic increase in coverage of *A. griffithii* which could not be accounted for by vegetative growth alone (Kendrick *et al.* 1999). Despite such evidence, rates of seedling recruitment remain unquantified for these genera and mechanisms controlling recruitment remain poorly understood.

This project addressed the knowledge gap for seedling recruitment in temperate Western Australian seagrass meadows. Specific aims of this work included: 1) to determine the contribution of seedling recruitment and new patch formation vs. vegetative growth towards the infilling of gaps; 2) to compare seedling recruitment strategies between the two most abundant Western Australian seagrass genera, *Amphibolis* and *Posidonia*; 3) to determine how settlement site and physical disturbance affect recruitment success of one species, *Amphibolis antarctica*, into gaps; and 4) to quantify long term (decade) changes in gap size at four seagrass meadows across a seagrass landscape.

Summary of Progress:

1.) Contribution of seedling recruitment to gap infilling

This study documented the evolution of gaps by quantifying infilling and erosion rates. An emphasis was placed on comparing infilling from seedling recruitment with infilling from vegetative growth of plants along the gap margin. Three gaps in Shoalwater Islands Marine Park were mapped using a grid system with cell size 0.25 m^2. Gaps were mapped monthly for 18 months, from November 2007 to June 2009. During each mapping effort the change in location of the gap perimeter was recorded. Maps were compared between consecutive samples to determine a monthly infilling and erosion rate for each gap. Seedling recruitment was tracked during the study, and the size of new seagrass patches formed by seedlings was measured. Patch formation data were compared with mapping data to determine the contribution of seedling recruitment and vegetative seagrass growth to the infilling of gaps. Data collection and analysis for this work has been completed and results were presented at the Coastal and Estuarine Research Federation conference in Portland, Oregon in November 2009.

2.) Seedling recruitment strategies of Posidonia *and* Amphibolis

Gaps influence the seedling recruitment of seagrasses by providing open spaces where new colonisation can occur. In the Shoalwater Islands Marine Park, gaps typically have three substrata associated with them: the intact seagrass meadow surrounding the gap, the sandy floor of the gap, and seagrass matte – exposed seagrass roots and rhizomes – along the edge of the gap. These substrata can affect settlement and survival of seagrass seedlings and thus influence recruitment success. The aim of this study was to compare seedling recruitment strategies of two genera of seagrasses, *Posidonia* and *Amphibolis*, in and around gaps. This study coincided with the previous study, *Contribution of seedling recruitment to gap infilling*, and the same three gaps in Shoalwater Islands Marine Park were monitored. During each monthly mapping effort, seagrass seedlings that settled in and around the gaps were tagged and their survival tracked. Settlement and survival rates were correlated to substratum, and data were compared with a literature review of seedling development processes for each genus. Data collection was completed in June 2009 and data analysis is nearing completion.

3.) Settlement and survival of Amphibolis *seedlings – effect of seed density and microsite*

Seedling recruitment in plants may be limited by the number of seeds produced or by the availability of suitable sites for colonization. A seed-limited plant population does not produce enough seeds to withstand the abiotic and biotic factors inhibiting successful recruitment. A site-limited population occurs when the seeds that are produced do not arrive at suitable sites for growth, either due to lack of available sites or to poor seed dispersal. For the seagrass *Amphibolis antarctica,* it is unknown whether populations were seed or site limited.

The previous study, *Seedling recruitment strategies of* Posidonia *and* Amphibolis, demonstrated that *A. antarctica* seedlings settle preferentially on the seagrass matte along the perimeter of gaps. It was unknown, however, wether seagrass matte provided a survival advantage compared to the sand or established seagrass meadow substrates. The aims of this study were to 1) to identify substrates suitable for short-term survival of *A. antarctica* seedlings; 2) to determine if *A. antarctica* is site limited by examining whether seedlings survive when transplanted to unoccupied substrates; 3) and to determine if *A. antarctica* recruitment is seed limited by comparing survivorship of seedlings growing at different densities.

In August 2009, a transplantation experiment was conducted to examine recruitment limitation in *A. antarctica*. Seedlings were collected and transplanted to six gaps within Shoalwater Islands Marine Park. Three gaps were within *Posidonia* dominated seagrass meadow and three were within *Amphibolis* dominated meadow. Within each gap, seedlings were planted in each of three substrata – established seagrass meadow, seagrass matte, and sand. At each substratum, two seedling densities were planted – control and saturated density. Control density (400 seeds m^{-2}) represented the maximum natural recruitment density for this species. Saturated density (800 seeds m^{-2}) represented a theoretical maximum recruitment density. Transplanted seedlings were monitored for two months to track survival. Survival rates were compared between gap, substratum and density treatments.

4.) Gap formation in seagrass meadows

The aim of this study was to quantify the size and frequency of gap formation, stability, and size frequency of gaps in the seagrass meadows of Owen Anchorage, Fremantle. In cooperation with Cockburn Cement, Ltd. and Oceanica Marine Consultants, aerial photography of Owen Anchorage seagrass meadows from 1999 to 2009 has been obtained. The presence and absence of seagrass was classified at replicate 0.5 km^2 plots at four seagrass meadows across the Owen Anchorage landscape. Currently, the classified plots are being compared between years to quantify changes in gap size frequency as well as formation of new gaps. The analysis is expected to be completed in January 2010 and preliminary results are discussed in the Summary of Major Findings section below.

Summary of Major Findings to Date

1.) Gap infilling and erosion rates

This study revealed the wide variation in infilling, erosion and seedling settlement rates among gaps in a seagrass landscape. The variation suggested stochastic or unpredictable processes drive gap dynamics in this system. This study also demonstrated that gaps maintain seagrass diversity in the Shoalwater Islands Marine Park. We showed that the seagrass genus *Amphibolis* was recruiting successfully from seedlings, whereas the genus *Posidonia* was propagating via clonal expansion from the gap perimeter. The presence of gaps therefore allows *Amphibolis* to become established in a *Posidonia* dominated landscape.

Gap A was the largest gap mapped (70 m^2) and showed overall expansion after 18 months, with the erosion rate almost double the rate of infilling. In contrast, for Gap B (47 m^2) the rate of infilling was twice as much as the rate of erosion over the course of the study. The smallest gap (Gap C, 15 m^2) showed very little overall change in area over the course of the study. The spatial pattern of infilling and erosion was consistent with the Patriquin (1975) model for gap 'migration', which predicts erosion on the gap edge facing the ocean swell and infilling on the opposite edge. Much of the Shoalwater Islands Marine Park is exposed to high wave energies and large variations in sediment movement within and around seagrass beds have been previously reported (Walker *et al.* 1996; van Keulen and Borowitzka 2003).

There were also widely varying responses in seedling settlement rates among gaps, with most settlement occurring in the largest gap (Gap A) and almost no settlement occurring in Gap B. In spite of this difference in settlement, the total area of new patch formation from seedling recruitment was similar among all three gaps. New seagrass patches were mostly comprised of *A. antarctica* and *A. griffithii*, which had markedly higher seedling survival rates (20% for *A. griffithii* and 32% for *A. antarctica*) than *Posidonia* (>2% survival). Two patch formation methods were identified: patches were either created by a single seedling expanding vegetatively over time or were comprised of a cluster of multiple seedlings. Patches of multiple seedlings generally had short life spans due to high seedling turnover, and single seedling patches had a higher contribution to gap infilling. The total contribution of seedling recruitment towards gap infilling ranged from 1 – 17% among gaps.

2.) Seedling recruitment strategies of Posidonia *and* Amphibolis

The seedling settlement and survival data, combined with a literature review of seedling development processes, showed that *Amphibolis* and *Posidonia* each have unique strategies for seedling recruitment in a disturbance-dominated system. *Amphibolis* seedlings were more likely to settle on seagrass matte substratum than on sand or in seagrass meadow, and seedling survival was likewise highest on seagrass matte. *Posidonia* seedling settlement showed no correlation with substrate, but seedling survival was lower in the seagrass meadow than on sand or matte. *Amphibolis* seedlings disperse and settle in winter months (June – September) when storm activity and water turbulence is greatest (Cambridge 1975). *Posidonia* seedlings disperse and settle in summer months (Dec – February) when weather related disturbance is reduced (Cambridge 1975).

Amphibolis seedlings have a unique adaptation, a modified pericarp with hardened comb-like teeth, which may aid the seedlings to settle(Kuo and Kirkman 1990). This 'comb anchor' allows *Amphibolis* seedling to cling to any fibrous substrate such as seagrass matte or turf algae. Field trials were conducted to measure the force required to dislodge *Amphibolis* seedlings from seagrass matte and sand. It required significantly more force (166 grams ±127 grams) to remove seedlings entangled in seagrass matte than to remove seedlings from sand (10 grams ± 8 grams). *Amphibolis* recruits in winter months and by settling and becoming entangled in seagrass matte, the seedlings are able to withstand disturbance from storm activity. In contrast, *Posidonia* seedlings recruit in summer months and quickly grow a primary root (Kuo and Kirkman 1996). This root grows deep into the substratum and may assist with anchoring the seedling, as has been hypothesized for the species *P. oceanica* (Belzunce *et al.* 2008). *Posidonia* seedlings develop a large belowground component during the summer months, which may allow them to withstand the greater physical disturbances during winter months.

3.) Settlement and survival of Amphibolis *seedlings – effect of seed density and microsite*

A. antarctica seedlings showed the greatest short-term survival on the seagrass matte substratum, while no seedlings survived on sand. Patches of seagrass matte, such as those found along the margins of gaps, provide suitable sites for *A. antarctica* seedling recruitment. Because *A. antarctica* is not site limited, the population in this study is more likely limited by its ability to disperse to unoccupied sites. There was no difference in survival among the density treatments, suggesting that *A. antarctica* is not limited by the number of seedlings produced.

Physical removal of seedlings was the primary mechanism preventing successful recruitment. Of over 4000 seedlings planted, only 238 remained by the end of the two month study. The reduced light within the seagrass canopy (Carruthers and Walker 1997) did not appear to directly affect seedling survival, as no physical differences (shoot length, number and size of leaves) was observed between seedlings planted within or outside the seagrass meadow. No seedlings showed evidence of predation, and only two seedlings were lost due to fungal infection and subsequent stem rot. The remainder of seedlings were dislodged by water motion from waves and swell. Seedling loss showed an expected exponential decay at all sites, with the greatest loss occurring in the first three days after planting. Data collected from a current profiler showed that maximum water velocity was only 0.4 m s^{-1} during the first three days of the study, yet this was enough to cause dislodgement of the majority of seedlings, especially from the sand substratum.

4.) Gap formation in seagrass meadows

Results of this study to date showed that gap size frequency distribution varied widely among seagrass meadows within the Owen Anchorage landscape. Similarly, the year to year and decadal change in gap size frequency varied among meadows, indicating that the major processes affecting gap evolution also differ among meadows. Processes affecting gap formation and stability include the seagrass assemblage including species recruitment and growth rates; meadow exposure to physical disturbance; and anthropogenic impacts such as dredging operations.

Aerial photography and GIS analysis are becoming more widely used as management tools for examining the status of seagrass meadows (Pasqualini *et al.* 2001). Since gaps play an important role in maintaining seagrass diversity (see *1)* above) as well as in the fragmentation and loss of meadows (Fonseca *et al.* 2000), it is beneficial to include gap metrics as part of an assessment of meadow health. Often, only snapshot or infrequent imagery is available for use in making management decisions. In systems where gap metrics are likely to change over time, gap analysis based on a single image cannot contribute towards modelling future meadow health unless the nature of gap change is understood.

Conference Papers Presented

1. School of Plant Biology Rottnest Student Conference (February 2009)
    a. Talk: Recruitment Limitation in the Seagrass *Amphibolis antarctica*

2. Western Australian Marine Science Institution (WAMSI) Symposium, CSIRO Floreat (February 2009)
    a. Talk: Recruitment Limitation in the Seagrass *Amphibolis antarctica*

3. Australian Marine Sciences Association (AMSA), Western Australian Division, Student Conference at Rottnest Island (July 2009)
    a. Talk: Recruitment Limitation in the Seagrass *Amphibolis antarctica*

4. Coastal and Estuarine Research Federation (CERF) bi-annual conference, Portland Oregon, USA (November 2009)
    a. Talk: Contribution of Seedling Recruitment to the Infilling of Gaps in a Western Australian Seagrass Meadow

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