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Quantifying the dispersal potential of seagrass vegetative fragments: A comparison of multiple subtropical species

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ABSTRACT

Seagrass meadows are threatened by anthropogenic and natural disturbances on both a local and global scale. Understanding the potential for seagrasses to disperse, connecting populations separated by unsuitable habitat is important to assess the resilience of regional populations. This study investigated the relative dispersal potential of vegetative fragments of seagrass from five subtropical species (*Zostera muelleri, Halodule uninervis, Halophila ovalis, Halophila spinulosa, Halophila decipiens*). Five questions were examined: 1) do vegetative fragments of different species settle at different velocities; 2) does a species morphometric variables influence settling velocities; 3) is a species settling velocity related to the species local distribution; 4) does temperature stress affect settling velocity; and 5) what is the composition and potential viability of seagrass fragments floating in the bay. A proportional distribution index for each species was determined using data from a habitat prediction model. It was found that *H. spinulosa* settled significantly faster than the remaining species and *Z. muelleri* settled the slowest. Variables influencing settling velocity included rhizome length, weight and surface area. In both *Z. muelleri* and *H. ovalis* settling velocities were significantly greater at higher temperatures (although there was no significant difference between approximately 5 and 10 °C above ambient temperature). *H. uninervis* was not significantly influenced by temperature. There was a significant negative correlation between species settling velocities and their distribution.

1. Introduction

Understanding the potential for seagrasses to disperse, connecting populations separated by unsuitable habitat, is of prime importance to assessing the resilience of regional populations. The dispersal of a species is only effective (or successful) when a pathway exists between a donor and a settlement site, and where the site of settlement is suitable for growth and reproduction (Reynolds et al., 2013; Campbell, 2002). Successful dispersal and recruitment can create a seagrass metapopulation: spatially separated populations that are linked by the effective dispersal of viable propagules. Connectivity in the metapopulation can be facilitated by ocean currents (e.g., Harwell and Orth, 2002), dislodgement and hitchhiking on species (e.g., Baldwin and Lovvorn, 1994; Dos Santos et al., 2012) and movement via vessels (Ruiz and Ballantine, 2004). Yet, what occurs when a classic metapopulation (sensu Hanski and Gilpin, 1997; Hanski, 1998) is interrupted by disturbance? Does local species extinction occur or does the disturbance create opportunities for different recruitment and colonisation possibilities? Within the literature studies have investigated the dispersal potential of seeds (Orth et al., 1994, 2006; Berković et al., 2014), yet few have examined the dispersal of vegetative fragments and even fewer compared multiple species.

Understanding how a species disperses and recruits is particularly important in coastal areas where both natural and anthropogenic stressors have the potential to fragment seagrass meadows at a landscape scale (Short and Wyllie-Echeverria, 1996). Seagrass have four life stages capable of dispersal: pollen, sexual propagules, vegetative fragments, and vegetative growth of individuals (McMahon et al., 2014). Dispersal can occur on the water surface, in the water column, on or in the sediment, via animal vectors and through clones, and the movement path is influenced by external factors (vectors and environment), internal states and navigation capacity which change over space and time (McMahon et al., 2014). With few exceptions seagrass pollen and seeds tend to be negatively buoyant and have restricted dispersal distances, perhaps to

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only a few meters (Reusch, 2002; Berković et al., 2014). Yet, this can be overcome if sexual propagules attached to seagrass fragments are dispersed. For example, in *Zostera* species, seeds can be transported by positively buoyant flowering branches (rhipidia) hundreds of kilometers for weeks to months (McMahon et al., 2014).

Seagrasses invest energy in sexual reproduction as it enhances genetic diversity and hence long-term resilience (Short, 1987). Vegetative reproduction is also employed by seagrasses through rhizome elongation, and the breaking off and recolonisation by viable fragments (Rasheed, 2004; DI Carlo et al., 2005, Short, 1987). Dislodged fragments can occur naturally by storm events and foraging herbivores, and by vessel anchoring and water craft activity (Coyer et al., 2008). Recruitment and establishment of dislodged vegetative fragments has been detected over both short (10–100 s of metres; Campbell, 2003; Touchette and Burkholder, 2000; Hall et al., 2006) and long-distances (100–1000 s of kilometres; Olsen et al., 2004; DI Carlo et al., 2005, Muñiz-Salazar et al., 2006; Berković et al., 2014). Seeds and reproductive structures can raft on vegetative fragments, transporting genes amongst spatially separated populations (Patterson et al., 2001; Källström et al., 2008). Understanding how recruitment and recolonization occurs in disturbed industrial locations is even less understood. Hence, this study occurs in Port Curtis Bay, which is located on the central Queensland coast in a subtropical climate (Fig. 1). This site is within the Great Barrier Reef World Heritage Area and includes the industrial Port of Gladstone. The Port of Gladstone has recently undergone rapid industrial expansion with three new liquefied natural gas plants on Curtis Island as well as an additional coal export terminal. Associated with these projects are dredging operations, increased shipping movements, land reclamation and both land and marine based construction activity. These disturbances continue to threaten the health of seagrasses, with seagrass monitoring already reporting 50%–75% losses of local seagrass over the last five years (Bryant et al., 2014; Coles et al., 2015).

The results of this study provide valuable information on the dispersal potential of five tropical seagrass species that use fragmentation as a method of reproduction, which can be utilised in seagrass dispersal modelling to identify the sources and sinks of detached material and demonstrate population connectivity. The endpoint of this information is to aid prediction potential for restoration (facilitated and un-facilitated) and concentrate conservation and restoration efforts to critical seagrass beds. Thus, this study aims to investigate the settling velocities of vegetative fragments from five subtropical seagrass species growing in Port Curtis, to gain an indication of their relative dispersal potential, and assess how it may vary with morphometric variables and temperature. Specifically, four null hypotheses were tested. Firstly, that there was no significant difference in settling velocities between species of seagrass; that there was no relationship between morphometric variables and settling velocity; that there was no significant difference in settling velocity between fragments in ambient water temperatures compared to plus 5 °C and plus 10 °C; and that there is no relationship between settling velocity and the distribution of each species. In addition, to provide some qualitative context, surveys were carried out to examine the composition and potential viability of floating seagrass fragments within the bay.

2. Materials and methods

2.1. Study area

A lot of effort has been expended mapping and monitoring the seagrass patches in Port Curtis Bay, Queensland (23° 55′ 38″ S, 151° 25′ 24″ E) (Thomas et al., 2010, Davies et al., 2013). There are over 100 distinct seagrass dominated patches (Fig. 1), which occur across a range of environmental gradients and vary in terms of configuration (patch size, species composition), environment (depth, wave and current exposure, turbidity) and human pressures (in particular increased turbidity and sedimentation from dredging activities, land reclamation, nutrient enrichment and boat propeller damage).

Patches of seagrass (Fig. 1) include multi-specific and mono-specific stands of seagrass of varying densities and configurations. Five species of seagrass currently grow in Port Curtis; *Halophila spinulosa* (R.Brown) Ascherson, *Halophila ovalis* (R. Brown) J.D.Hooker, 1858, *Halophila decipiens* Ostenfeld, 1902, *Halodule uninervis* (Forsskål) Ascherson, 1882 and *Zostera muelleri* subsp. *capricornii* Irmisch ex Ascherson, 1867. The species have various global distributions. *H. ovalis* is the most widespread, found in the Indo-Pacific and has recently been discovered in the Atlantic Ocean on the Island of Antigua (Short et al. 2010). *Z. muelleri* has a broad but disjunctive distribution around southern and eastern Australia, and is also found in New Zealand and Papua New Guinea (Short et al. 2010). *H. decipiens* is circum-global and widespread in the tropics, whereas *H. spinulosa* occurs in the Indo-Pacific, the Philippines, Malaysia, Indonesia, Singapore and northern Australia (Short et al. 2010). Finally, *H. uninervis* is widespread in the Indo-Pacific (Short et al. 2010). Locally, all the species are found primarily on the intertidal, with the exception of *H. decipiens* which occurs primarily in the subtidal. In the tropical Indo-West Pacific *H. spinulosa* is reported as a sub-tidal species (Waycott et al., 2004), but in Port Curtis, at the time of the study, it was found only on the extreme lower shore.

2.2. Fragment settling velocities

The settling velocities of vegetative fragments of *Z. muelleri*, *H. ovalis*, *H. spinulosa*, *H. decipiens* and *H. uninervis* were measured. Due to the lack of knowledge on the influence of age of floating fragments, fresh fragments of seagrasses were collected directly from intertidal meadows at Pelican Banks, Port Curtis Bay (23°46′S, 151°17′E) during October 2013. Fragments were collected by disturbing the seagrass patch and collecting detached fragment. Upon collection vegetative fragments were placed in shaded, seawater filled containers, and returned to the laboratory where they were immediately placed in indoor, seawater mesocosms. The mesocosms were filled with artificial seawater (Aquasonic Ocean Nature) and artificially lit on a 14:10 h light:dark cycle using twin T5 Razor lights with alternate Actinic Blue and Coral Plus light tubes. Average daily PAR for the tanks was 8.16 (±1.28 S.D.) mol m^{-2} d^{-1}. A maximum of 30 fragments were allocated to each individual mesocosm.

The following seagrass fragment morphometric variables were measured: meristem presence, number of shoots, rhizome length, weight and surface area. No action was taken to achieve consistency in the morphometric variables of fragments, with the exception of the presence of a meristem. Surface area was determined by analysing scanned images of the fragments using image analysis software (Adobe Lightroom, version 5). The settling velocity of the fragments was determined by releasing the fragments just under the water-surface, in a horizontal position, in a 400L (1200 × 600 × 600 mm) tank of seawater (maintained at 25 °C and a salinity of 35). Five-centimetre intervals were marked on the side of the tank, beginning 10 cm below the water surface. The time for the fragment to sink over each interval was measured with a stopwatch and averaged to determine its mean sinking velocity. This ensured that an accurate average speed could be calculated to account for any acceleration as the fragment settled. Fragments that remained floating (that is, no downwards movement) after a period