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Spatial scale and the detection of impacts on the seagrass *Posidonia australis* following pier construction in an embayment in southeastern Australia

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Abstract

Coastal development can impact on ecologically significant seagrasses. We sought to determine whether the construction of a pier and associated boat launching facilities would impact on *Posidonia australis* within Jervis Bay Marine Park, New South Wales, Australia. Using a modified 'beyond BACI' analysis we tested for impacts at three spatial scales; directly beneath the pier deck, within metres of the pier and approximately 50 m from the construction zone. We compared shoot density, leaf length and epiphytic cover prior to the commencement of construction to 7 months and 46 months later. Impacts were highly localised; we detected significant seagrass loss directly below the open-mesh deck of the pier, but not at the scale of metres and tens of metres relative to two non-impacted reference locations. Our data also supported the use of the trigger point approach to initiate management intervention; shoot density beneath of the deck of the pier fell below the 30th percentile, ending 73% lower than the mean after 46 months. If similar developments occur in waterways supporting seagrass species of high conservation significance, then management agencies need to weigh the inevitable loss of a small area of meadow with the advantages the development will provide.

Keywords: asymmetrical ANOVA; BACI design; coastal development; ecological impact; *Posidonia australis*; seagrass loss; southeastern Australia

1. Introduction

Seagrasses are recognised as playing a crucial role in coastal ecosystem function (Hutchings and Recher, 1974; Coles et al., 1993; Heck et al., 2003), yet in southeastern Australia estuaries have lost up to 85% of their seagrass beds in the last 30–40 years (Smith and Pollard, 1999). Most seagrass loss, both natural and anthropogenic, can be attributed to reduced light intensity; either as a result of sedimentation and/or eutrophication which promotes excessive epiphyte growth (Shepherd et al., 1989; Dennison et al., 1993; Short et al., 1995; Short and Wyllie-Echeverria, 1996; Touchette and Burkholder, 2000). Both processes effectively reduce the amount of light available for seagrass photosynthesis and although seagrass plants carry sufficient starch in the rhizomes to survive short term events, plant death occurs when these reserves are exhausted by extended periods of light reduction (McComb et al., 1981; Walker et al., 1999).

Recreational boat usage and the construction of boating facilities have been shown to increase turbidity, erosion, nutrient enrichment (Kirkman, 1996) and cause mechanical damage to seagrass beds from boat propellers (Pasqualini et al., 1999), mooring and anchor chains (Hastings et al., 1995). Boating facilities may also introduce other more insidious long-term pollution events associated with antifoulants and introduced marine pests that can impact on seagrass meadows. However, one of the most obvious impacts is the construction of wharfs or jetties, which shade the habitat, block photosynthesis and result in localised dieback of seagrasses (Kirkman, 1989). Artificial shading experiments confirm the drastic effects on *Posidonia* spp. (Gordon et al., 1994; Fitzpatrick and Kirkman, 1995). In

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southeastern Australia the rate of natural recovery following disturbance to *Posidonia australis* J. Hooker can be extremely slow (Meehan and West, 2000) and restoration may not be feasible in many situations (Kirkman, 1989; Kirkman and Kuo, 1990).

If managers are to detect impacts from anthropogenic disturbances to seagrass meadows, then dieback must be separated from the underlying levels of natural variability and the scales over which processes are operating determined; 'beyond BACI' designs are highly effective in achieving this (Underwood, 1993; Guidetti, 2001). Shoot density is generally considered a good sublethal biological indicator of stress because it responds rapidly and predictably to disturbances such as shading (Bulthuis, 1984; Neverauskas, 1988; Dennison, 1990; Alcoverro et al., 2001) while measures of productivity do not respond consistently (Kirkman, 1996). In addition, shoot density generally does not follow seasonal patterns and remains fairly constant throughout the year (Kirkman et al., 1995) as well as showing low levels of natural variation within a meadow (Meehan, 2001). Shoot dieback typically occurs over a time frame of months or years in stressed seagrass beds (Pergent-Martini and Pergent, 1996; Kirkman, 1989), hence, monitoring changes in shoot density is a useful and sensitive means of detecting impacts within any particular meadow.

There are other morphological changes indicative of seagrass stress including lengthening of the leaves and stems to raise the seagrass closer to the water surface and therefore to the light source. This strategy is particularly effective for seagrass growing in shallow turbid water since light is attenuated exponentially (Vermaat et al., 1996). Epiphyte growth on seagrass leaves may also act as an early indicator of changing light or nutrient levels in the water column because epiphytes respond rapidly to changes in water condition (May et al., 1978; Kirkman, 1997). In general, macroalgal epiphytes tend to die quickly under shade and may be replaced by encrusting invertebrates, e.g. bryozoans and spirorbid polychaetes (Kirkman, 1989). The leaf turnover rate for *Posidonia australis* is 140 days and since epiphytes begin to build up significantly on new leaves after about 2 weeks (Marbá and Walker, 1999), leaf length and epiphyte cover may offer rapid and sensitive measures of changing water quality conditions that could impact on seagrass health.

In this study we examined the impact of redevelopment of boat launching facilities at Callala Bay in the Jervis Bay Marine Park. The redevelopment included removal of the existing boat ramp, upgrading of the access road and parking facilities, construction of a new concrete boat ramp and construction of a 75 m long pier adjacent to the ramp. The pier consisted of a timber deck for the first 40 m and an open mesh aluminium deck over the seaward 35 m, supported on timber pilings. Construction began in July 2000 and was completed by early December 2000. Jervis Bay is home to some of the most extensive and pristine seagrass meadows on the New South Wales coast, mainly due to limited disturbance by human activities (Kirkman et al., 1995).

We sought to determine the impact of pier and boat ramp construction on the seagrass at three spatial scales: (1) directly beneath the open mesh deck of the pier; (2) in the immediate vicinity of the pier (i.e. within metres); and (3) in Callala Bay (i.e. within 10s to 100s of metres). We anticipated that direct shading would negatively impact *Posidonia australis* directly beneath the pier, but the nature and severity of impacts at other spatial scales were unknown. These locations of potential development impact were compared with two reference locations within Jervis Bay several kilometres south of Callala. Monitoring focussed on shoot density, maximum leaf length and degree of epiphytic cover on *P. australis* at the putatively impacted and reference locations.

2. Methods

2.1. Study area and sampling methods

Callala Bay (35°00′S 150°44′E) lies within the Jervis Bay Marine Park in southeastern Australia. *Posidonia australis* meadows were monitored at the location of the putative impact and nearby within Callala Bay approximately 50 m south of the development. We subsequently refer to these locations as the Callala pier and Callala South locations respectively. Data from these locations were compared with that collected at two distant reference locations; Bindijine Beach on the eastern side of the Bay and Plantation Point on the western side (Fig. 1). The distant reference locations supported dense, large and continuous meadows of *P. australis* similar to those found in Callala Bay, and would not be affected by the development of the boating facilities at Callala. Furthermore, we reasoned that the reference locations would be unlikely to suffer any significant small-scale anthropogenic impacts from other sources during the study because of the pristine nature of Jervis Bay, due to a lack of development within the catchment.

At the Callala pier, seagrasses were sampled within ten 0.25 m^2 quadrats placed directly under the pier and a further ten quadrats placed each side of the pier, within 5 m of the edge of the structure, providing samples at the scale of metres. A further 20 quadrats were sampled at Callala South (scale of 10s of metres) and at each of the reference locations at Plantation Point and Bindijine Beach. Quadrats were placed at random no closer than 2 m from the seagrass/sand boundary on the shoreward edge of the *Posidonia australis* meadow. Within each quadrat, the number of *P. australis* shoots, maximum leaf length and the degree of fouling of the leaves was assessed by divers on SCUBA. The longest leaf found within the quadrat was measured to give maximum leaf length while the percent cover of fouling organisms was visually estimated from one mature leaf and one recently emerged leaf within each quadrat. As these variables maybe depth-dependent, all data was collected from the same bathymetric range across study sites (2–4 m).

2.2. Experimental design and statistical analysis

We used a slightly modified 'beyond BACI' design to test for impacts of development on seagrass condition in Callala