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Seagrass mortality due to oversedimentation: an experimental approach

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Abstract. Mortality due to oversedimentation of the Mediterranean seagrass *Posidonia oceanica* was experimentally evaluated by field manipulations of the sediment level. Increased levels of sediment placed over plant shoots and rhizomes induced significant shoot mortality, even at moderate burial levels (ca. 5 cm). When sediment was added to reach levels 15 cm higher than the initial one, a 100 % mortality was observed after 200 - 300 days. The response of the plant was independent of site and depth. These results can be used in ecological risk assessment of coastal activities which potentially affect sediment deposition.

Keywords: Ecological risk assessment; *Posidonia oceanica*; Shoot mortality; Sedimentation.

Introduction

Several coastal activities can induce changes in sediment dynamics, which involves an increase in the sedimentary rate and the burial of the benthic community. Despite the increasing frequency of such activities (artificial beach nourishment, harbour building, etc.) the ecological risks involved are poorly understood, especially those concerning the response of highly sensitive benthic organisms such as seagrasses. Seagrass beds are key ecosystems in the coastal zone (Larkum et al. 1989; Pasqualini et al. 1998; this issue), and have been shown to be affected by changes in sedimentation rates (Patriquin 1975; Boudouresque et al. 1984; Marbˆ et al. 1994). A close interaction between seagrass dynamics and sedimentary processes (i.e. sand waves) has been reported for *Cymodocea nodosa* (Marbˆ & Duarte 1994), although seagrass persistence under a highly dynamic sedimentary environment is possible due to the high growth rate and colonizing capacities of this species. However, in the case of the Mediterranean species *Posidonia oceanica* (L.) Delile, seagrass growth rates are too low to either compensate sedimentary rates (maximal reported growth rates of vertical axis: 1.5 cm/yr, Boudouresque et al. 1984; Pergent et al. 1989) or to recolonize after an eventual destruction due to burial (i.e. maximal growth rates of horizontal axis: 6.0 cm/yr, Caye 1980; Caye 1982; Mosse 1984; Molenaar 1992). Hence, the evaluation of mortality derived from oversedimentation, as can be seen following artificial beach nourishment or other coastal works, is of major importance for the protection of Mediterranean littoral ecosystems. Here we present the first results of a study the aim of which was to examine the response of the major Mediterranean seagrass, *Posidonia oceanica*, to increasing sedimentation rates, i.e. to assess quantitative relationships between burial and mortality, as obtained by *in situ* experimentation.

Methods

Experiments were conducted in two *Posidonia oceanica* beds off the Catalan coast (NE Spain), with two sampling stations at each meadow. Stations ÔCenterÕ and ÔSant AntoniÕ were located at Port-Lligat, 200 m from each other, and at 4m depth; stations ÔMedes shallowÕ and ÔMedes deepÕ were located at 5 m depth (close to the upslope limit of the bed), and 13 m (close to the depth limit of the plant distribution), respectively.

Experimental burial was performed using PVC cylinders, height 35 cm, ∅ 33 cm, which were placed on the seagrass bed leaving ca. 20 cm above the seabed. Sediment was added to these cylinders to induce different levels of plant burial. Four sedimentary conditions were simulated: no addition (control), moderate (5-7 cm sediment relative to the original level), intermediate (9-10 cm) and severe (13 - 14 cm). In all cases, three replicated plots were used for each treatment; treatments were assigned randomly to the plots. The initial number of shoots per plot ranged from 18 (the less dense station, Medes deep) and 38 (Medes shallow).

Experiments in Port-Lligat Center were started in July 1994, including only control plots and moderate treatment. The other experiments were started in September 1994, and included control, moderate and severe treatments in Deep Medes and all four treatments at the other two sites (Sant Antoni and Shallow Medes).

Every 1-2 months, each of the sites was visited and the shoots inside each experimental plot were counted, with appropriate inter-diver calibrations; sediment level in the plots was recorded and corrected if necessary. The experiment lasted ca. 250 days.

To assess the statistical significance of the differences among the treatments, data were analysed using ANOVA after testing for homogeneity of variance assumption. One-way repeated-measures ANOVA was performed for the data from each site, with treatment as between-subjects factor and time as within-subjects factor; two-way repeated measures ANOVA was performed for all the data, with site and treatment as between-subjects factor and time as within-subjects factor; in this case, only data from control and moderate treatments were used. In all cases, the dependent variable was the number of shoots (as a percentage relative to the original number) recorded at each time inside each plot.

Results

Shoot mortality in buried plots increased significantly relative to the controls (Table 1, Fig.1). Mortality was progressive, and the time-course differed following the treatments, as shown by the significant interaction between treatment and time (Table 1, Fig. 1). No differences were found among the different sites (Table 1), suggesting a species-specific rather than a site-specific response. Even at moderate burial levels (i.e. 5-7 cm), a significant mortality was found, reaching 50 % of the original number of shoots by the end of the experiment (Fig. 1).

Mortality was significantly correlated with the burial level (correlation between mortality after ca. 250 days and burial level: $r = 0.55$, $p < 0.001$; see Fig. 2). However, a different response pattern was found following each treatment level. The severe (i.e. 15 cm burial) treatment led to total seagrass disappearance within the experimental plots after 200-300 days (Fig. 1), while in the other treatments a stabilization of shoot number to ca. half of those found at the beginning, was apparent after ca. 200 days.

Discussion

The results suggest that a burial level of 15cm represents the critical level beyond which total seagrass destruction occurs while a burial level of 5 cm induces a significant mortality but allows survival of the majority of the shoots.

The relationship between sedimentation and mortality has been demonstrated for other seagrasses, such as *Cymodocea nodosa* (Marbˆ & Duarte 1994) and *Thalassia testudinum* (Gallegos et al. 1993). Also, for terrestrial plants inhabiting sand dunes a close relationship between sand accretion and growth exists, with mortality occurring beyond a given threshold. This is the case with *Ammophila breviligulata* (Disraeli 1984), which seems much more resistant to burial than seagrasses.

Boudouresque et al. (1984) observed shoot mortality in *Posidonia oceanica* when the sediment reached ca. 6 cm over the ligula (i.e. the contact between the leaf blade and the leaf sheath of the outermost leaf in a shoot). In our experiments, the ligula was originally situated 2-5 cm over the sediment, and thus total mortality occurred when the ligula was around 8-11 cm below the sediment surface, and significant mortality was seen when the ligula was 0-3 cm below the sediment.

The physiological causes of the observed mortality are unclear. However, an evident necrose of the leaf meristem was observed in the dead shoots. We suggest that burial of the leaf meristem (and maybe also of the vegetative apex of the rhizome) reduces oxygen availability for the tissues, and exposes them to toxic compounds such as sulfide, a compound shown to be very toxic for *Thalassia testudinum*, even at low concentrations (Carlson et al. 1994).

Table 1. Significance of the tested effects in the one-way and two-way ANOVA performed. * = $P < 0.05$.

Site	Treatment	Time	Treatment × time	Site
Port-Ligat Centre	0.007 *	< 0.001 *	<0.001 *	-
Port-lligat Sant Antoni	<0.001 *	<0.001 *	<0.001 *	-
Medes Shallow	0.117	<0.001 *	0.016 *	-
Medes Deep	0.068	<0.001 *	0.209	-
All sites	0.002 *	<0.001 *	<0.001 *	0.503

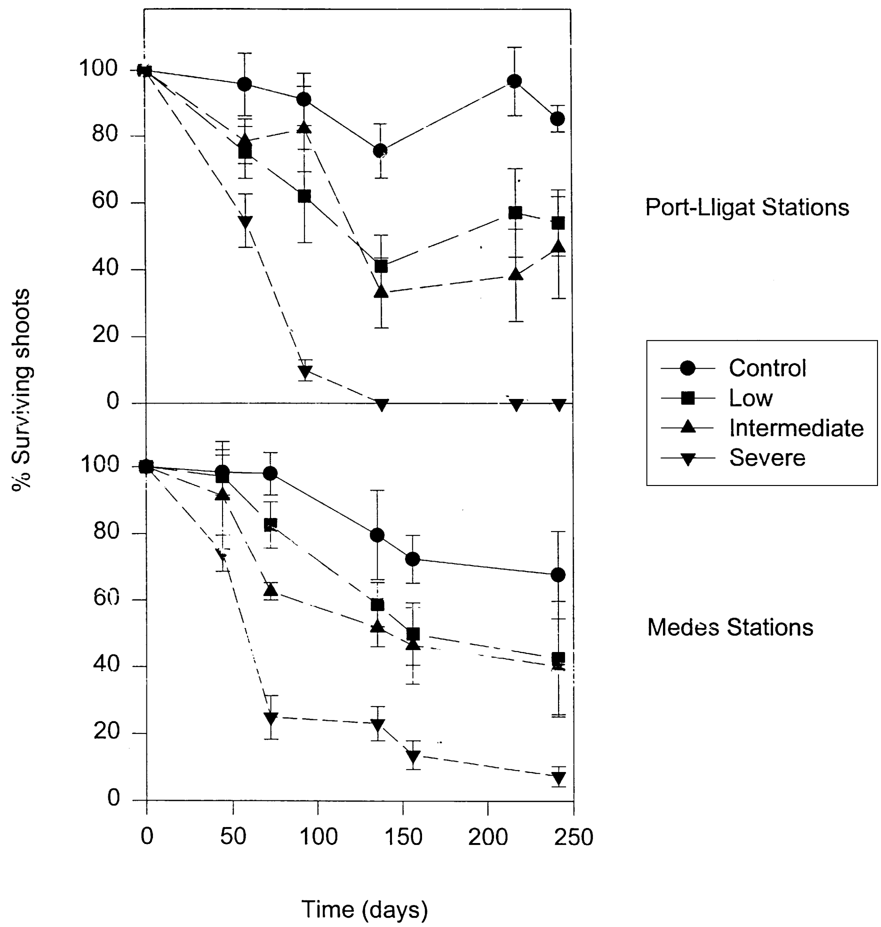

Fig. 1. Changes in the percentage surviving shoots during the experiment.

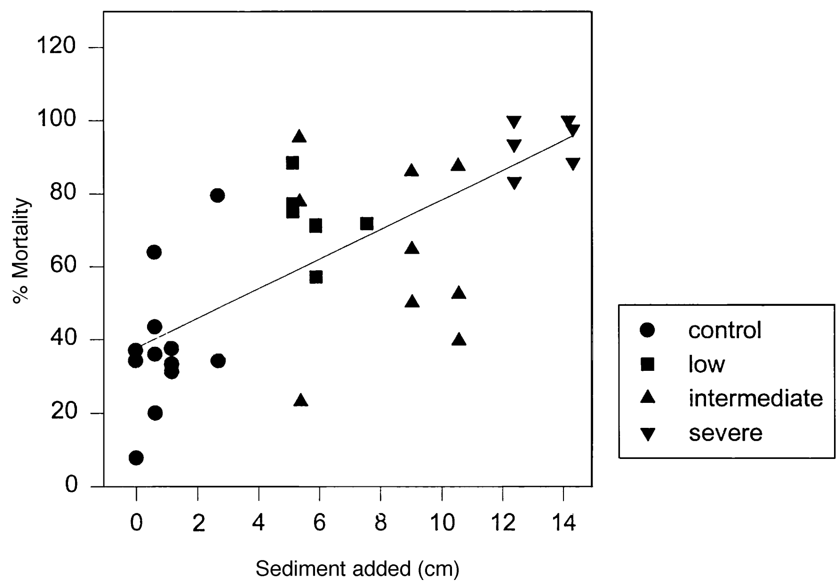

Fig. 2. Mortality of shoots as a function of sediment added to the different plots. Dashed lines are the limits of the confidence interval (95%).

Seagrasses, in particular *Posidonia oceanica*, appear to be very sensitive to sudden increases in sedimentary rates. Such sudden increases of sediment level can be the result of some coastal works, while in other cases the sediment level would be modified more progressively. But even if our experimental conditions do not fully reproduce the entire range of possibilities that can be encountered in the coastal zone, given the very low recovery rate (Meinesz & Lefevre 1984) of the meadows of this species, managers and policy-makers should take into consideration this sensitivity when planning and developing coastal activities if these seagrass meadows are to be preserved.

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