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Effects of burial and erosion on the seagrass *Zostera noltii*

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Abstract

The effects of experimental burial and erosion on the seagrass *Zostera noltii* were assessed through *in situ* manipulation of the sediment level (−2 cm, 0 cm, +2 cm, +4 cm, +8 cm and +16 cm). Shoot density, leaf and sheath length, internode length, C and N content and carbohydrates of leaves and rhizomes were examined 1, 2, 4 and 8 weeks after disturbance. Both burial and erosion resulted in the decrease of shoot density for all the sediment levels. The threshold for total shoot loss was between 4 cm and 8 cm of burial, particularly during the 2nd week. A laboratory experiment confirmed that shoots did not survive more than 2 weeks under complete burial. There was no evidence of induced flowering by burial or erosion. As well, no clear evidence was found of sediment level effects on leaf and sheath length. Longer rhizome internodes were observed as a response to both burial and erosion, suggesting a plant attempt to relocate the leaf-producing meristems closer to sediment surface or in search of new sediment avoiding the eroded area. The C content of leaves and rhizomes, as well as the non-structural carbohydrates (mainly the starch in rhizomes), decreased significantly along the experimental period, indicating the internal mobilization of carbon to meet the plant demands as a consequence of light deprivation. The significant decrease of N content in leaves, and its simultaneous increase in rhizomes, suggests the internal translocation of nitrogen from leaves to rhizomes. About 50% of the N lost by the leaves was recovered by the rhizomes. Our results indicated that *Z. noltii* has a high sensitivity to burial and erosion disturbance, which should be considered in the management of coastal activities.

Keywords: Burial; Disturbance; Erosion; Seagrass; Sedimentation; *Zostera noltii*

1. Introduction

Natural and human-induced activities can change the sedimentary dynamics of coastal areas and impact the aquatic vegetation. Although natural events such as the migration of sand barrier-island inlets (Cunha et al., 2005), earthquakes, volcanic eruptions or hurricanes (Short and Wyllie-Echeverria, 1996) may contribute to local and large-scales losses, most of the seagrass declines are attributed to anthropogenic disturbances (Short and Wyllie-Echeverria, 1996). Coastal activities that change sedimentary dynamics constitute a threat to seagrass survival, resulting in plant removal from the substratum and in burial or erosion of the seagrass meadows (Short and Wyllie-Echeverria, 1996; Hemminga and Duarte, 2000). Dredging, coastal engineering, beach stabilization, siltation, among others, are examples of human activities related to sediment redistribution in coastal areas with potential impacts for seagrasses (Onuf, 1994; Burdick and Short, 1999; Halun et al., 2002; Daby, 2003; Ruiz and Romero, 2003).

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Burial and erosion have been reported to negatively affect seagrasses. Shoot mortality and changes in plant morphology were the main responses to experimental changes in sediment level of *Cymodocea nodosa* (Marbà and Duarte, 1994), of *Posidonia oceanica* (Manzanera et al., 1998), of *Zostera marina* (Mills and Fonseca, 2003) and of a mixed seagrass meadow (Duarte et al., 1997). Nevertheless, seagrasses may inhabit highly dynamic substrates. Marbà and Duarte (1995) demonstrated the coupling between the patch dynamics of *C. nodosa* and the migration of subaqueous dunes, whereas Cunha et al. (2005) reported on the landscape-scale changes of *Zostera noltii* patches associated with a highly dynamic sand barrier-island inlet.

Z. noltii is a small seagrass species occurring in the intertidal and subtidal areas of the Northern and Western Europe, Mediterranean Sea and North–West Africa (den Hartog, 1970). In the Ria Formosa lagoon (southern Portugal), *Z. noltii* is the most abundant seagrass species, playing an important role in the lagoon productivity (Santos et al., 2004). Changes in the sedimentary dynamics of Ria Formosa occur due to natural causes (e.g. inlet migration, storms) or as a result of human activities such as dredging of navigation channels, opening of artificial inlets, addition of allochthonous sediments in clam culture beds. The present study aimed to assess: (1) the effects of burial and erosion on the shoot density, plant morphology, carbon and nitrogen contents, and non-structural carbohydrates reserves of the seagrass *Z. noltii*, through the *in situ* experimental manipulation of the sediment level; and (2) the survivorship, longevity, production and growth of *Z. noltii* plants submitted to experimental burial in laboratory conditions.

2. Methods

2.1. In situ manipulation of the sediment level

The experiment was conducted in a homogenous and undisturbed *Z. noltii* meadow of the Ria Formosa lagoon (southern Portugal) in June and July 2004. This time of year was chosen to conduct the experiment because this period corresponds to the species higher growth rate (Peralta et al., 2005). The experimental design included 6 different imposed sediment levels: one erosion level (−2 cm), one level with the sediment maintained at the original position (0 cm), and four burial levels (+2, +4, +8 and +16 cm). Experimental treatments were performed using PVC cylinders (12 cm i.d.), placed at a 5 cm depth into the sediment. The cylinders were introduced in the sediment at referred depths to avoid them to be dragged by the strong tidal currents that occur in intertidal areas of the Ria Formosa lagoon. Cylinder height above the sediment was equivalent to the corresponding burial treatment, except in control and erosion where cylinders were placed at the sediment level. Erosion was imposed with a Venturi-effect suction device operated with a diving tank, which gently removed the sediment down to a depth of −2 cm without damaging the plants. The different burial levels were obtained by adding sandy sediments from the adjacent unvegetated area. Each treatment consisted of 20 replicates, randomly installed at about 1 m apart from each other. Five cylinders of each treatment were randomly collected 1, 2, 4 and 8 weeks after the onset of the disturbance. Additionally, five samples were also collected from the surrounding meadow, with a 12 cm diameter core, to control for the cylinder effect. In each sample, the number of shoots was counted to estimate shoot density. The leaf length and the sheath length were measured from intact shoots and the internode length was measured from intact rhizomes. The above- and belowground biomass of *Z. noltii* was dried at 60 °C for 48 h. Subsamples of dried leaves and rhizomes were ground on a ball mill for tissue content analysis ($n=3$). C and N contents were determined using a CHN Perkin Elmer elemental analyser. The non-structural, soluble, carbohydrates (sugars) from the ground tissues (5 mg) were extracted in hot ethanol (80 °C) and measured by the phenol sulphuric acid method using glucose as standard (Dubois et al., 1956). Starch was extracted from the ethanol-insoluble fraction. Samples were washed in deionised water, autoclaved for 15 min, hydrolysed to glucose with an enzymatic suspension (α-amilase and amiloglucosidae), and determined spectrophotometrically as described before.

2.2. Laboratory burial experiment

In order to estimate the *Z. noltii* survivorship and longevity under complete burial, as well as its growth and production, 60 plants composed of 3 modules (i. e. 1 apical shoot plus 2 shoots and respective internodes) were collected in the field and immediately transported to the laboratory in seawater. Plants with 3 modules were selected as those with fewer modules may have higher survivorship due to clonal integration effects (Cabaço et al., 2005). Each plant was placed in an acrylic container (8.5 cm of diameter) filled with sandy sediments obtained from the same location where plants were collected. Half of the plants were completely buried, while the other half remained as controls, i.e. with sediment maintained at meristem level. Half of the buried ($n=15$) and half of the control ($n=15$)