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# Experimental assessment of critical anthropogenic sediment burial in eelgrass *Zostera marina*

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ABSTRACT

Seagrass meadows, one of the world's most important and productive coastal habitats, are threatened by a range of anthropogenic actions. Burial of seagrass plants due to coastal activities is one important anthropogenic pressure leading to the decline of local populations. In our study, we assessed the response of eelgrass *Zostera marina* to sediment burial from physiological, morphological, and population parameters. In a full factorial field experiment, burial level (5–20 cm) and burial duration (4–16 weeks) were manipulated. Negative effects were visible even at the lowest burial level (5 cm) and shortest duration (4 weeks), with increasing effects over time and burial level. Buried seagrasses showed higher shoot mortality, delayed growth and flowering and lower carbohydrate storage. The observed effects will likely have an impact on next year's survival of buried plants. Our results have implications for the management of this important coastal plant.



## 1. Introduction

Seagrass meadows are one of the world's most important and productive coastal habitats (Costanza et al., 1997). They provide a variety of ecosystem services (Hemminga and Duarte, 2000; Larkum et al., 2006) including the stabilization and accretion of sediments in shallow coastal areas (for a review see Fonseca, 1996) as well as some coastal protection by dampening waves and currents (Fonseca and Cahalan, 1992; Fonseca and Koehl, 2006). Seagrass meadows have a positive effect on water transparency, their leaves and rhizomes take up and store nutrients and by that they are reducing eutrophication effects (e.g. McGlathery et al., 2007). Seagrasses provide nursery grounds and shelter for many faunal species, including commercially important fish and shellfish species (for a review see Heck et al., 2003). At the same time, seagrass meadows are threatened worldwide by anthropogenic impacts (eutrophication, overfishing, coastal development, diseases, invasive species, and climate change; e.g. Bockelmann et al., 2013; Munkes, 2005; Orth et al., 2006; Waycott et al., 2009; Williams, 2007).

While eutrophication is considered as the main reason for large-scale losses of seagrass habitats, burial of seagrass plants either through anthropogenic sedimentation or through natural events like storms or mobile sandy bed forms has been identified as an important cause for local die-offs (Cabaço and Santos, 2014; Cabaço et al., 2008; Erftemeijer and Lewis, 2006; Orth et al., 2006; Short and Wyllie-Echeverria, 1996; Tu Do et al., 2012). Additionally, we can expect to see an increase of sediment mobility due to changes in hydrodynamics as one of the consequences of sea level rise (Dolch and Reise, 2010). This will add to the pressures for seagrasses.

Despite the acknowledged importance, in situ experiments testing the effects of increased sedimentation or burial on different seagrass species are rare and short term (for a review of six published studies see Cabaço et al., 2008), and none deals with the most important seagrass of the northern hemisphere, *Zostera marina*, in its core distribution range (Boström et al., 2014).

Along the German Baltic Sea, *Z. marina* (eelgrass) is the dominant seagrass species (Boström et al., 2014). As an ecosystem engineering species (sensu Wright and Jones, 2006) it forms one of the most important coastal habitats in the Baltic Sea. Since the 1950s the areal extent of eelgrass has decreased by at least 51% or 148 km$^2$ along the northern German coast (Schubert et al., 2015), comprising at least one tenth of all known seagrass beds in the area (Boström et al., 2014). In addition to substantial eutrophication accompanied by an increase in turbidity, Baltic eelgrass meadows are experiencing increased sedimentation through beach nourishment, dredging of waterways, discharging of dredged material, and shoreline protection.

For coastal managers and other stakeholders, the height of anthropogenic sediment burial tolerated by eelgrass plants is of particular concern. While sedimentation within existing meadows is in some cases unavoidable as corollary of dredging or beach maintenance, its extent may be manageable.

Additionally, for coastal management and restoration projects, the development of early stress indicators for eelgrass, which hint to

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existing stressors long before meadows disappear, would be a valuable tool. But despite a variety of existing indicators for seagrass health (Marbà et al., 2013; McMahon et al., 2013), suitable early stress indicators for eelgrass are still lacking or costly (Macreadie et al., 2014). Storage carbohydrates namely starch and sucrose could have the potential to fill this gap and function as cost-effective indicators for the health status of eelgrass habitats (Govers et al., 2015).

The main aim of this study was to understand the effects of sedimentation level and duration on the seagrass species *Z. marina*. In contrast to previous studies, we were interested to detect a wide range of eelgrass responses to sediment burial and sedimentation duration. Additionally, our aim was to identify burial threshold levels, above which significant negative effects are likely. Effects on eelgrass plants were measured on three different organizational levels: physiological (carbohydrate content), morphological (shoot biomass, leaf length), and population (shoot density, flowering shoot density, total biomass).

In the present study we investigated the effects of different sediment levels and burial durations within a continuous eelgrass meadow in the western Baltic Sea. We supposed that the relative (% of plant height) rather than absolute (in centimeters) sediment burial level is determining the plants response and survival. Hence, we expected tall eelgrass from the Baltic to be less sensitive to low absolute levels of burial than previously thought (Cabaço et al., 2008).

## 2. Materials and methods

### 2.1. Study area and abiotic environment

The study was conducted in Kiel Bight, a shallow bay of the Baltic Sea with average depths between 16 and 20 m. In Kiel Bight the seagrass species *Z. marina* is found along most of the coastline in shallow waters between 0.6 and 7.6 m depth (Schubert et al., 2015). It grows between spring (March) and autumn (October) with its peak biomass in late August, early September (Gründel, 1982). In autumn and winter biomass is reduced considerably by storm events, but eelgrass is a perennial species in Kiel Bight. We chose a site called 'Falckenstein' in Kiel Bight for the experiment (Fig. 1, 54°24.388′ N, 010°11.575′ E). This site features an undisturbed *Z. marina* meadow with an areal extent of ca. 130 ha within water depths of 0.5 to 5 m on sandy substratum. The seagrass bed consists mainly of *Z. marina* (95%), interspersed with some red algae (e.g. *Delessaria sanguinea* and *Ceramium virgatum*) and green algae (e.g. *Ulva* spp.). Also you will find patches of *Mytilus edulis* in the meadow. The eelgrass plants are up to 1.8 m in height during summer, the maximum density during summer is about 500 shoots per $m^2$. It is one of the largest and most consistent eelgrass meadows in this area. At the beginning of the experiment, the water at the study site had a temperature of 9.7 °C. The highest water temperature at the study site

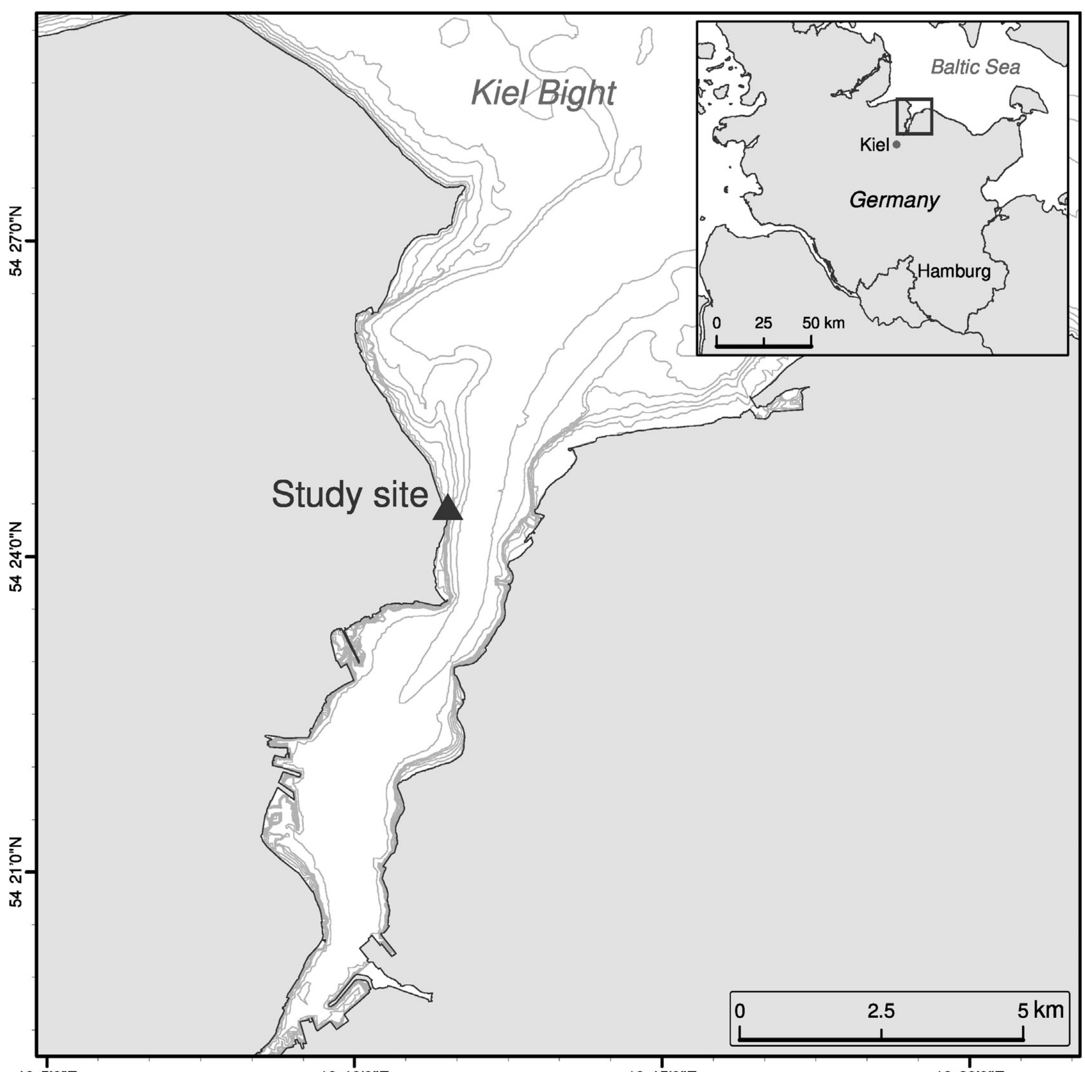


**Fig. 1.** Map of the study site (black triangle) and surrounding area. Insert: overview of Northern Germany, study area marked with black square.

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