Science of the Total Environment 621 (2018) 663–669

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Fresh carbon inputs to seagrass sediments induce variable microbial priming responses

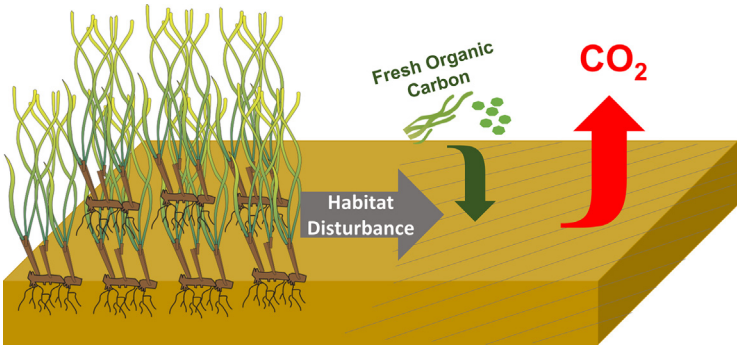
Stacey M. Trevathan-Tackett [a,b,*], Alexandra C.G. Thomson [a], Peter J. Ralph [a], Peter I. Macreadie [a,b]

[a] Climate Change Cluster, University of Technology, 15 Broadway, Sydney, NSW 2007, Australia
[b] Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, 221 Burwood Hwy, Burwood, VIC 3125, Australia

HIGHLIGHTS

- Microbial priming is a potential mechanism for remineralization of carbon (C) stocks to CO_2.
- CO_2 emissions were measured from sediments exposed to fresh C and disturbance
- Priming resulted in a 2–3-fold increase in CO_2 released from sediment C compared to control
- Priming is likely a greater threat to deep C stocks undergoing physical disturbance

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 August 2017
Received in revised form 14 November 2017
Accepted 17 November 2017
Available online xxxx

Editor: Jay Gan

Keywords:
Remineralization
Priming effect
CO_2 release
Seagrass sediments
Labile organic carbon
Sediment organic carbon

ABSTRACT

Microbes are the 'gatekeepers' of the marine carbon cycle, yet the mechanisms for how microbial metabolism drives carbon sequestration in coastal ecosystems are still being defined. The proximity of coastal habitats to runoff and disturbance creates ideal conditions for microbial priming, i.e., the enhanced remineralisation of stored carbon in response to fresh substrate availability and oxygen introduction. Microbial priming, therefore, poses a risk for enhanced CO_2 release in these carbon sequestration hotspots. Here we quantified the existence of priming in seagrass sediments and showed that the addition of fresh carbon stimulated a 1.7- to 2.7-fold increase in CO_2 release from recent and accumulated carbon deposits. We propose that priming taking place at the sediment surface is a natural occurrence and can be minimised by the recalcitrant components of the fresh inputs (i.e., lignocellulose) and by reduced metabolism in low oxygen and high burial rate conditions. Conversely, priming of deep sediments after the reintroduction to the water column through physical disturbances (e.g., dredging, boat scars) would cause rapid remineralisation of previously preserved carbon. Microbial priming is identified as a process that weakens sediment carbon storage capacity and is a pathway to CO_2 release in disturbed or degraded seagrass ecosystems; however, increased management and restoration practices can reduce these anthropogenic disturbances and enhance carbon sequestration capacity.

1. Introduction

Vegetated coastal ecosystems, including seagrasses, mangroves and saltmarshes, have a disproportionately large influence on ocean carbon sequestration considering their relatively small (0.1%) footprint on the

* Corresponding author at: Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, 221 Burwood Hwy, Burwood, VIC 3125, Australia.
E-mail address: s.trevathantackett@deakin.edu.au (S.M. Trevathan-Tackett).

https://doi.org/10.1016/j.scitotenv.2017.11.193
0048-9697/

seafloor (Duarte et al., 2013; McLeod et al., 2011). For this reason, coastal ecosystems are at the forefront of research aimed at using these ecosystems to offset atmospheric CO_2 through the natural process of 'biosequestration' (Macreadie et al., 2017). Microbial metabolism ultimately determines how much organic carbon is sequestered and stored or returned to the atmosphere (Arnosti, 2011; Burd et al., 2016). The accumulation of organic carbon (OC) deposits is enhanced in predominantly anoxic and low-nutrient conditions that limit microbial remineralisation rates (Burdige, 2007) – conditions characteristic of vegetated coastal habitats. Despite these ideal characteristics for long-term carbon accumulation and preservation in vegetated coastal habitats, these ecosystems have been challenged by high rates of habitat degradation and losses in recent decades, much of which has been attributed to anthropogenic activities, such as nutrient and organic matter runoff and physical disturbances (Hopkinson et al., 2012; Orth et al., 2006; Serrano et al., 2016; Waycott et al., 2009). Habitat destruction not only diminishes the sediment organic carbon (SOC)-accumulation capacity of vegetated coastal habitats (Macreadie et al., 2012), but increases the risk of losing existing SOC (Fourqurean et al., 2012; Graca et al., 2004; Macreadie et al., 2015; Marbà et al., 2015).

The combination of fresh OC inputs and physical disturbances of deep SOC also creates ideal conditions for exacerbated SOC loss via the stimulation of microbial remineralisation, i.e., the 'microbial priming effect'. The priming effect is a phenomenon in which a disturbance or access to fresh, organic carbon (OC, e.g. priming source) or inorganic nutrients stimulates microbes to metabolise SOC that would not have been otherwise utilised or would have been utilised at considerably slower rates (Kuzyakov et al., 2000). This concept is widely accepted for terrestrial soil ecosystems and marine pelagic and seafloor sediments, and has been shown in some instances to more than double the amount of soil or sediment OC metabolised by microbes (Bianchi, 2011; Fontaine et al., 2007; Guenet et al., 2010; van Nugteren et al., 2009), Yet, microbial priming has yet to be directly quantified in coastal vegetated ecosystems.

The microbial priming effect is likely to pose a significant threat to net SOC loss and CO_2 release within marine or coastal ecosystems via (1) the injection of fresh OC into deep sediments by bioturbation (Kristensen et al., 2011); (2) the addition of inorganic nutrients causing changes to porewater dynamics and bacterial nutrient limitations (López et al., 1998); and (3) the displacement of deep sediments (Kuzyakov et al., 2000) to the water column or sediment surface (and fresh nutrients or OC) via physical disturbances like dredging and boating activities. The addition of fresh OC in the form of microalgae or seagrass detritus has been shown to increase bacterial respiration and biomass in coastal sediments (Danovaro et al., 1994; Farjalla et al., 2009), indicating the potential for enhanced SOC remineralisation. Since the quality of the priming source provided to microbes by microalgae and seagrass detritus produces differential microbial remineralisation patterns (Enríquez et al., 1993) and microbial communities (Trevathan-Tackett et al., 2017b), different types of priming sources could likewise induce different degrees of priming.

This study quantified the existence of the microbial priming effect in coastal seagrass sediments and revealed its potential role in weakening seagrass SOC stocks. We added two common, natural priming sources: microalgae (*Chlorella*) to represent an algae bloom and *Zostera muelleri* seagrass to represent leaf inputs during senescence. Both priming sources were enriched with ^{13}C before adding them to the sediments from two depths in order to simulate undisturbed (surface) and disturbed (deep) sediments. To assess the microbial priming effect, we quantified the amount of CO_2 respired after fresh OC additions in comparison to controls. Using the enriched isotope signatures, we also traced the OC source (priming source or SOC) being metabolised by microbes by analysing $\delta^{13}C$ values of CO_2. We hypothesised that the addition of both forms of fresh OC will induce a priming effect, but microalgal OC would be utilised more rapidly than detrital seagrass OC due to higher relative lability. We also hypothesise that since total OC typically decreases with sediment depth that surface sediments may produce a larger priming effect due to a higher existing SOC content available for remineralisation.

2. Materials and methods

2.1. Sediment sampling and characterisation

The sediment (i.e., sediment organic carbon or SOC) used in this project was collected from Fagans Bay in New South Wales, Australia (33.4306 S, 151.3211 E). The bay was characterised as a high sediment, nutrient and pollution input environment, with patchy seagrass *Zostera muelleri* Irmisch ex Ascherson meadows along the shore at 0.2–0.5 m depth (Collier and Mackenzie, 2008). We chose to quantify priming for surface sediments (0–1 cm), which routinely come in contact with fresh OC, and deep sediments (29–30 cm) to simulate the reintroduction to the surface after a physical disturbance (Walker et al., 1989).

Sediments were sampled in August 2014 with PVC cores of 5 cm in diameter and at least 50 cm in length. A total of 20 cores were taken along a transect parallel to the shore, with each core at least 1 m apart. Once the core met refusal in the sediments, measurements of the inner and outer core lengths (top of sediment to top of core) were taken. These measurements were used to correct for compaction (% compaction applied equally across the core) before obtaining the 0–1 cm and 29–30 cm slices. Cores for the incubation were capped and stored at 4 °C for a maximum of 4 days, until randomly assigned to the priming source (*Chlorella* or *Zostera*) treatments and processed using a core extruder. An additional three cores were used to calculate approximate bulk density and for isotopic and elemental analysis for the surface and deep samples used in the incubation.

2.2. Isotopic labelling of seagrass

Zostera muelleri seagrass plants were collected at Fagans Bay in August 2014 and labelled on the same day. Epiphytes were gently removed before leaves were labelled with 99% atm ^{13}C–enriched sodium bicarbonate (Novachem, VIC, Australia) in the laboratory. The labelled sodium bicarbonate (0.6 g) was mixed with 20 L of water collected from Fagans Bay (Kaldy et al., 2013). The labelled seawater was transferred to a clean 80 L plastic bin holding the submerged seagrass leaves (Kaldy et al., 2013). The leaves were incubated in the labelling solution under 150 μmol photons m^{-2} s^{-1} of light for 1–1.5 h before washing excess label, salts and leached dissolved organic carbon with ultrapure water (Sartorius AG, Goettingen, Germany) (Kaldy et al., 2013). Labelled seagrass leaves were removed from the below-ground tissue, dried at 60 °C and shredded with a handheld blender. Only fragments < 3 mm length were used in the study to remove size bias.

2.3. Incubation experiment

Pre-labelled *Chlorella vulgaris* were used for the microalgal treatments due to its occurrence in eutrophic estuaries (Costa et al., 2009) and its use as a model laboratory microalga (97.2% atm; IsoLife, Wageningen, Netherlands). The experimental design was fully-orthogonal (3 replicates) with two SOC sediment depths (0–1 cm, 29–30 cm) and three priming source treatments: control (unamended), microalgal addition (+*Chlorella*), seagrass detritus addition (+*Zostera*). A procedural control (i.e., blank) was included to account for the background CO_2 concentrations within the chamber without sediment. The priming source was added to the sediments immediately before closing the incubation chamber at the start of the experiment. The area of each 1 cm sediment slice was 19.63 cm^2 (0–1 cm = 6–10 g; 29–30 cm = 24.5–40.4 g). For the microalgal priming treatments, 30 mg dry weight (DW; 46.5% C) of lypholised *Chlorella* was mixed with 2 mL of sterile CO_2-free seawater at a salinity of ~22 before adding to the surface of the sediment. The