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Posidonia bonsai: Dwarf *Posidonia oceanica* shoots associated to hydrothemal vent systems (Panarea Island, Italy)

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Highlights

- Dwarf Posidonia oceanica (bonsai) observed in hydrothermal vents off Panarea.
- Bonsai shoots are from 61–75% smaller in leaf biomass than regular-sized shoots
- Bonsai shoots lacks the regular seasonal pattern in sheath thickness (lepidochronology) of normal-sized shoots

Abstract

Very small-sized shoots of the Mediterranean seagrass Posidonia oceanica, defined as "bonsai" shoots, were found in areas with most intense CO_2 emissions and low pH

associated with four vents systems off Panarea island (Aeolian Archipelago, Sicily, Southern Tyrrhenian Sea). Bonsai shoots were sampled in September 2021 and October 2022: Bottaro crater (8 m depth), Camp 7 (16 m and 21 m), Black Point (20 m) and Hot/Cold Points (10 m). They had 2–6 leaves, and adult-intermediate leaves were 5–21 cm long and 3.5–7 mm wide, with leaf shoot surface ranging 4.8 and 44.5 cm^2, and shoot leaf biomass between 16 and 89 mg (d.w.). These values were all significantly lower (t-test $p<0.006–0.0001$) than those measured in normal-sized shoots collected within the vents and in control sites not affected by gas emissions. Bonsai shoots had 86–89% lower leaf surface, and 61–75% lower leaf biomass than all normal-sized shoots measured. The sheath thickness of the bonsai shoots was very low (0.1–0.8 mm), and the temporal trend of sheath thickness along the rhizome (lepidochronology) showed an irregular pattern, without the clear cyclical seasonal variation typical of normal-sized shoots. The reasons of size reduction and lack of temporal cycle in lepidochronology are discussed in the light of plant acclimatization and the constraints imposed by the continuous exposure to the stressful conditions of seawater acidification and presence of phytotoxic gases (e.g. hydrogen sulfide) in the vents.

Introduction

The seagrass *Posidonia oceanica* L. (Delile) is the Mediterranean endemic most widespread marine plant. It covers about 12000 km^2 of the Mediterranean Sea (Telesca et al., 2015) and has a distribution from 0 to 40 m depth, representing the largest depth range among seagrasses. *Posidonia oceanica* dense meadows represent key habitats for the functioning of the Mediterranean coastal ecosystem, and provide many and valuable associated ecological services (Boudouresque et al., 2009). The species colonizes both soft and hard substrates (Giakoumi et al., 2015), and it is exposed to multiple stress conditions and threats, experiencing a worrying decline (Telesca al, 2015). Although the species is subjected to human pressures and environmental changes (e.g. increasing seawater temperature and salinity), it can settle and survive in stressful environments with nutrient enriched waters (e.g. below fish cages; Pergent-Martini et al., 2006), fluctuating salinity (Marín-Guirao et al., 2017), low hydrodynamic exposure and low water turnover (Tomasello et al., 2009), and low pH conditions near hydrothermal vent systems (Vizzini et al., 2010, Garrard et al., 2014, Foo et al., 2018). *P. oceanica* shows a high seasonal variability in its morphology/phenology during the year with a fast leaf-growth season from April to June, a maximum development of the leaf canopy during summer, and a slow leaf-growth in autumn and winter (Buia and Mazzella, 1991). Environmental stressors are reported to modulate its morphology. For instance, a size reduction of 65% was found in areas under the influence of the Mar Menor coastal lagoon hypersaline waters (Ruiz et al., 2009, Marín-Guirao et al., 2017), and reduced

growth rates (Tomasello et al., 2009) were found in plants inside the shallow Stagnone of Marsala (Sicily).

P. oceanica is well known to thrive also under ocean acidification (OA) conditions since it occurs, and sometimes even flourishes, in hydrothermal vent systems (Vizzini et al., 2010, Garrard et al., 2014, Guilini et al., 2017, Mecca et al., 2020).

Under OA conditions, sizes of various invertebrates were constrained, likely because the stress under ocean acidification conditions may reduce the energy available for somatic growth (Calosi et al., 2013, Garilli et al., 2015). However, up to date, such a size reduction has not been observed in seagrasses under such low pH conditions. In low-pH systems, an increase in *P. oceanica* shoot density is typically observed, along with a reduction in leaf canopy height, due to intense grazing by the herbivorous fish *Sarpa salpa* (salema) (Donnarumma et al., 2014; Mirasole et al., 2021). While, under OA exposure, higher N content and lower C/N ratio than under normal pH conditions are reported in leaf tissues (Ricevuto et al., 2015), as well as in leaf sheaths (Vizzini et al., 2010). Also the amount of phenols, lower in various seagrasses under OA conditions (Arnold et al., 2012), seems to be higher in *P. oceanica* (Migliore et al., 2012). Furthermore, under OA conditions, a strong reduction of all the calcareous organisms in the leaf epiphytic community is reported by many authors (Mecca et al., 2020 and references herein).

In the frame of a larger study on the morphological and bio-ecological responses of *P. oceanica* to ocean acidification conditions in vents systems, here we report the occurrence of size-reduced, dwarf *P. oceanica* shoots, observed in areas of highest CO_2 venting, and consequent ocean acidification, of four vents systems off Panarea island (Aeolian Archipelago; Southern Tyrrhenian Sea), that we defined as “Posidonia bonsai”. This study deals with a first descriptive analysis of this unique plant morphology for this species, as well as a discussion of possible hypotheses on the size reduction. This represents a first step towards further analyses to highlight acclimatization features and possible local phenotypic and genetic adaptations of this species to future climate change scenario (Pazzaglia et al., 2021).

Panarea, the smallest island of the Aeolian Archipelago, has geological and geomorphological characteristics that makes it, and its surrounding complex archipelago, the largest hydrothermal system of the Mediterranean Sea (Vizzini et al., 2020). The area consists of numerous and diversified hydrothermal submerged emissions of gas and hot waters of volcanic origin, including the “Smoking land” a recently described site with more than 200 active chimneys (Esposito et al., 2018). These features make the zone one of the most suitable places in the Mediterranean to study various aspects related to CO_2 capture

and storage, by geologists, the geochemistry of the hydrothermal fluids, as well as to assess the effects of water acidification on benthic (Goffredo et al., 2014, Rogelja et al., 2016; Esposito et al., 2017, 2021) and pelagic organisms and habitats (Karuza et al., 2012), including *P. oceanica* (Vizzini et al., 2010, Guilini et al., 2017, Gaglioti et al., 2019).

Section snippets

Study area

Bonsai or dwarf Posidonia shoots were observed and sampled the 2nd and 4th October 2021, and between 30th September and 9th October 2022, respectively during the 5th and the 6th edition of the Panarea School of scientific diving, a permanent yearly event to study the unique hydrothermal vents system of this island (Gambi et al., 2018). Undersized shoots were visually detected and sampled for the first time in 2021 by SCUBA diving at two hydrothermal vents off the main island: Bottaro crater and …

Results

Sixty-six bonsai shoots were analyzed together with 130 regular-sized shoots and 8 seedlings (see Table 2). *P. oceanica* bonsai shoots were found in rocky bottoms and in spots near the most intense CO_2 emissions of all vent systems considered, except at Hot/Cold Points where they were settled in the matte, and no under intense venting (Fig. 2). The bottom and *P. oceanica* shoots at Camp 7, Black Point and Bottaro were often covered by white floccules of sulfur prokaryotes (Fig. 1S).

The bonsai…

Discussion

In this contribution we describe the occurrence of dwarf *Posidonia oceanica* shoots thriving in close proximity to gas emissions in four hydrothermal vent systems off Panarea Island,

with a reduced total leaf surface by 86–89% and leaf biomass by 61–75% in respect to normal sized shoots. The few seedlings observed in one of the vents (Camp 7), showed similar morphology as the bonsai shoots, except for a higher number of leaves in seedlings.

Reduction in growth and productivity rates has been…

CRediT authorship contribution statement

MCG conceptualization, sampling, data acquisition and analyses; VE sampling, data acquisition; LMG sampling, data acquisition and analyses. All Authors discussed the results and participated in text writing and revision.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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