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Comparative assessment of trace element accumulation and bioindication in seagrasses *Posidonia oceanica*, *Cymodocea nodosa* and *Halophila stipulacea*

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ABSTRACT

Accumulation and bioindication of trace elements were compared in three seagrasses growing in the Mediterranean Sea: *Posidonia oceanica*, *Cymodocea nodosa* and *Halophila stipulacea*. The levels of the elements As, Cd, Cr, Cu, Hg, Mn, Ni, Pb and Zn were investigated in water, sediments, and roots, rhizomes and leaves of seagrasses. Results showed that seagrasses can accumulate comparable levels of trace elements, but *P. oceanica* and *C. nodosa* showed higher mean values of element accumulation. Moreover, *P. oceanica* and *C. nodosa* may accumulate high element concentrations in their leaves, whereas in *H. stipulacea* restricted with the bulk of trace elements in roots and rhizomes. Seagrasses reflected to a different degree the levels of several trace elements in sediments, especially *P. oceanica* and *C. nodosa*, whose use as bioindicators is recommended. The future step for an effective use of seagrasses as bioindicators of marine pollution is to set up biomonitoring networks on a large scale.

1. Introduction

Marine ecosystems are worldwide subjected to an ever-increasing degree of pollutants, among which trace elements have reached dramatic levels in the last two decades (Millennium Ecosystem Assessment, 2005; Serrano et al., 2011; Bonanno and Orlando-Bonaca, 2018a). Trace elements owe their adverse effects to the fact that unlike organic chemicals, they cannot be easily removed by natural processes, tend to accumulate in sediments and to move up food networks, biomagnifying at superior trophic levels, and finally posing a threat to human beings (Bargagli, 1998; Rainbow, 2007; Kabata-Pendias, 2011). In particular, due to the high levels of trace elements detected across the Mediterranean Sea in the last decade (Boudouresque et al., 2009; Bonanno and Orlando-Bonaca, 2018b), monitoring effectively the environmental state of these marine habitats is of vital importance for the preservation of functioning marine ecosystems and associated biodiversity. In compliance with the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC), several studies tested the efficacy of new species as biological indicators of aquatic pollution (Conti and Cecchetti, 2003; Bonanno and Lo Giudice, 2010; Richir and Gobert, 2014). Seagrasses, in particular, are usually considered as interesting bioindicator organisms due to their capability of integrating biological and physico-chemical parameters (Martínez-Crego et al., 2008; Orlando-Bonaca et al., 2015). Previous studies found also that seagrasses could be used as suitable bioindicators of marine pollution caused by trace elements (Lafabrie et al., 2008; Malea and Kevrekidis, 2013; Bonanno and Di Martino, 2017).

The study aimed to compare the accumulation of trace elements in three Mediterranean seagrasses: *Posidonia oceanica*, *Cymodocea nodosa* and *Halophila stipulacea*. Neptune grass (*Posidonia oceanica* (L.) Delile; Fig. 1) is a widely distributed vascular plant, endemic to the Mediterranean Sea, where it forms dense monospecific communities located within 100 m from the shoreline at depth of 0–40 m (IUCN, 2015). Specifically, *P. oceanica* ecosystems play a prominent role in the ecology of the Mediterranean Sea, both as main contributors to coastal primary production and as permanent habitats for many plant and animal species (Hemminga and Duarte, 2000). The little Neptune grass (*Cimodocea nodosa* (Ucria) Asch.; Fig. 2), has similar ecology to *P. oceanica*, but occurs also from Portugal to Senegal (Borum and Greve, 2004; OSPAR, 2010). The last seagrass, *Halophila stipulacea* (Forsskål) Ascherson (Fig. 3), is instead an alien species, native to the Indian Ocean, whose spreading across the Mediterranean Sea was facilitated by the opening of the Suez Canal in 1869 (Gambi et al., 2009; Short et al., 2010). Studies on the capacity of trace element accumulation in *H. stipulacea* are scarce (Malea, 1994). In particular, this study aimed to compare the movement of trace elements between the various parts of the seagrasses, ie roots, leaves, stems, in *P. oceanica*, *C. nodosa* and *H. stipulacea*, and the usefulness of these plants to monitor pollution levels.

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Fig. 1. Seagrass *Posidonia oceanica*.

Fig. 2. Seagrass *Cymodocea nodosa*.

Fig. 3. Seagrass *Halophila stipulacea*.

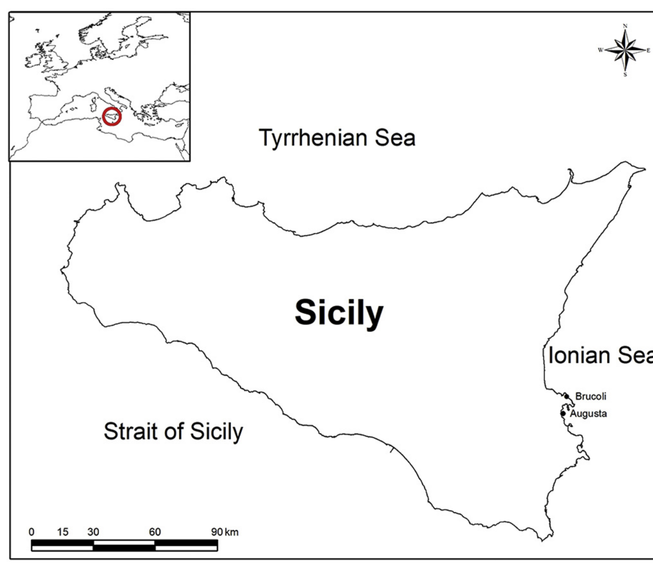

Fig. 4. Location of the sampling areas.

2. Materials and methods

2.1. Study areas and sampling

This study was conducted in two locations of eastern Sicily (Italy), which are subjected to intense human pressure (Fig. 4). The samples of *H. stipulacea* were collected in the site "Augusta" (37°14′11.60″N, 15°13′46.69″E), a city of almost 40,000 inhabitants, with one of the largest Italian commercial ports, and with a large petrochemical industrial area. *Posidonia oceanica* and *C. nodosa* were collected in the site "Brucoli" (37°16′57.30″N, 15°11′33.08″E), a seaside resort affected by high maritime traffic and untreated municipal wastewaters. Annual mean values of temperature and rainfall were respectively 18 °C and 600 mm in both study areas. All three seagrasses formed thick monospecific beds located at an average depth of 4 m within a variable distance of 5–50 m from the shoreline. Sampling was conducted in each study area in February and October 2017. In particular, sample collection took place during calm days with no previous rain. The seagrass beds were in the range of 10 × 10 m to 30 × 30 m. Three types of samples were collected: water, sediments and individuals of *P. oceanica*, *C. nodosa* and *H. stipulacea*, totalling 40 samples per type in each site during February and October. Plant samples were randomly collected in each bed within an average sampling area of 2000 × 100 m in both study sites. Seagrass samples were then gathered on the shore, gently shaken to remove coarse attached material, rinsed with distilled water, and dried with a linen cloth. Plant samples were then sealed in sterilized and airtight plastic bags. One sample of water and sediment was collected per each sampled seagrass. Specifically, sediment samples were collected from the top 5 cm of the seabed upper layer through a Plexiglas corer (internal diameter 10 cm). Water and sediment samples were stored in 1.0-L polyethylene bottles. All samples were put in PVC containers and kept at 2 ± 1 °C until chemical analysis.