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Effects of Costa Concordia shipwreck on epiphytic assemblages and biotic features of *Posidonia oceanica* canopy

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ABSTRACT

This research provides first information about *Posidonia oceanica* canopy in the area affected by Costa Concordia wreck. Percentage cover of algal and animal taxa on the leaves was estimated and biotic features of the meadow were measured in the period just after the shipwreck until its removal from the impacted site. Changes in epiphytic assemblages and some biotic features were detected in the Disturbed site compared with Control ones, highlighting effects due to the wreck presence and activities related to its removal. A temporary decrease of encrusting macroalgae and an increase of erected macroalgae and foraminifers, as well as a temporary increase of tip erosion of the canopy were detected in the Disturbed site. The obtained results were discussed and hypotheses about possible synergic effects occurred near the wreck were commented.

1. Introduction

Human induced pressures on coastal ecosystems affect seagrasses through both physical damage and alterations of the water and sediment quality (Orth et al., 2006; Roca et al., 2016). In this framework, the Mediterranean seagrass *Posidonia oceanica* (L.) Delile has been shown to be an effective bioindicator to assess the health status of marine coastal environment (Boudouresque et al., 2009; Buia et al., 2004; Montefalcone, 2009; Pergent et al., 1995).

P. oceanica meadows have traditionally been considered to act as sinks for particles due to the reduction of flow velocities by the plant canopy; the canopy can slow down water currents, trapping particles, nutrients and pollutants from the water column (Gacia et al., 1999; Gacia and Duarte, 2001; Hendriks et al., 2007; Short and Short, 1984).

In this regard, biotic features of *P. oceanica* leaves certainly reflects the physiological state of the canopy, but may also reflect the quality of the surrounding environment. Accelerated senescence, tip erosion and biometric features of the leaves may highlight possible changes in water transparency and hydrodynamic characteristics (Buia et al., 2004; Giraud, 1979; Pergent et al., 1995).

Epiphytic community can be an indicator of the ecological quality of coastal waters (Piazzi et al., 2015), being more sensitive and reacting more rapidly than the host plant to alterations (Delgado et al., 1999; Giovannetti et al., 2010; Nesti et al., 2009). In this regard, increases in the epiphyte biomass, differences in their spatial heterogeneity, shifts in species composition, morphological groups and main taxonomic groups have been observed under human disturbance regimes (Balata et al., 2007; Ben Brahim et al., 2010; Martínez-Crego et al., 2010; Piazzi et al., 2004, 2015; Ruiz et al., 2001).

Epiphytic composition and abundance result from the interplay between bottom-up and top-down forces (Peterson et al., 2007), as they are mainly controlled by nutrient availability, physical constraints (hydrodynamic flows, sediment features) and biological interactions such as grazing by herbivores, competition for nutrients, light and space (Bell and Hall, 1997; Lavery and Vanderklift, 2002; Neckles et al., 1993; Prado et al., 2007; Wear et al., 1999).

The impact/response relationship between epiphytic community and human pressure factors have been investigated mainly in relation to the increase of nutrient availability (Balata et al., 2010; Borum, 1985; Prado et al., 2008), and to the discharge of products of specific human activities such as industrial effluents (Cambridge et al., 1986), mining wastes (Marín-Guirao et al., 2005), fish farming (Delgado et al., 1997), drilling fluids (Allen Price et al., 1986), sewage and agricultural runoff (Lapointe et al., 2004) or effluents from desalination plants (Gacia et al., 2007). Instead, there are no available data in the literature regarding possible effect of human disturbance linked to a ship disaster.

The Costa Concordia ship collided with a submerged natural rocky reef close to the Giglio Island (Tuscany, Italy) and the wreck was stranded on a rocky bottom, near a slope that leads to bathymetry between 50 and 90 m.

The monitoring plan was a multiannual work aimed at assessing possible impacts on the marine ecosystem due to direct effect of the shipwreck. In fact, the presence of the wreck could have been a source

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of uncontrolled spillage of pollutant substances such as organic waste and stocks deriving from content galley, fuel and paint residues.

In this context, the present study provides first data about *P. oceanica* leaves epiphytes and biotic features of shoots in the area affected by Costa Concordia disaster; these biological and ecological traits are commonly used as early warning indicators of environmental quality (Giovannetti et al., 2010; Leoni et al., 2006; Marbà et al., 2006; Martínez-Crego et al., 2010), but they had never been used for this purpose in a case of study of naval disaster. The aim of the study was to evaluate the possible direct effects related to the Costa Concordia event on the epiphytic assemblages and biotic features of *P. oceanica* canopy in the period between the time just after shipwreck until its removing from the impact site. In this regard, under the hypothesis that both epiphytic community of seagrass leaves and biotic features of shoots may change when subjected to anthropogenic stressors, we test these differences in the period investigated with an asymmetric hierarchical experimental design that enabled comparisons of disturbed and control sites.

2. Material and methods

2.1. Study area

The wreck laid on a seabed that goes from 18 m to more than 40 m depth, oriented to NE, with the stern post near Punta Gabbianara and the bow continued toward the Giglio Island harbour. In this context, the activities for the removal of the wreckage have further modified the submerged and emerged landscape (Fig. 1).

The shallower part of the seabed in the shipwreck area was mainly characterized by assemblages of photophilous macroalgae over a granitic basement and by *P. oceanica* meadow on *matte*, which extended from 6 m to 35 m depth. The deeper part was characterized by coralligenous assemblages.

Chlorophyll-*a* values indicated a HIGH ecological status sensu Water Framework Directive (WFD 2000/60/CE; ARPAT, 2012). This result was also supported by the TRIX Index data (Giovanardi and Vollenweider, 2004), confirming a low trophic level of the study marine ecosystem (ARPAT, 2012).

2.2. Sampling design and data collection

Three sampling sites were selected at 10 m depth along a gradient of increasing distance from the stern of Costa Concordia wreck and according to an asymmetric hierarchical experimental design. The Disturbed site (D) was located at the stern of the wreck and two Control sites (C_1 and C_2) were selected northwards from the wreck, at Cupa Bay and Arenella Bay (Fig. 2). Reference shores should occur on both sides of the disturbed ones to avoid spatial segregation, but in some cases this is not possible (Benedetti-Cecchi and Osio, 2007).

The Control sites, characterized by meadows on sand or *matte*, were geomorphologically and ecologically similar to the Disturbed one, as they were located in enclosed bays and exposed to the same prevailing winds.

In each site three sampling areas of approximately 5 × 5 m were randomly selected. Five orthotropic shoots were collected haphazardly for each area. Samples were collected by SCUBA diving just after the shipwreck (July 2012) and afterwards (March 2013, July 2013, March 2014), until its removing from the impact site (July 2014) which took place in August 2014. Samples were stored at −20 °C pending the laboratory examinations.

Biotic features of shoots (including leaf surface, brown senescent tissue length, broken tips) were gathered according to Giraud (1979). Moreover, the internal side (Alcoverro et al., 2004; Casola and Scardi, 1989) of the four outer leaves in three shoots for each area were analysed for the epiphytes community. The cover percentage of algal and animal taxa of each fields of view of 1 cm^2 were estimated for each leaf under a stereo microscope, starting from the ligule up to the leaf apex. The estimates were based on the portion occupied by taxa, ideally brought together in the same segment of the leaf sensu Morri (1991). The cover percentage of the erected species was evaluated as the area occupied by their projection on portions of leaf examined. Epiphytes were analysed in accordance with the following groups: encrusting algae, erected algae (in this group the non-calcified Ochrophyta *Myrionema* spp. is included given its ecological relevance with epiphytic associations of mature assemblages), bryozoans, hydroids, foraminifers, spirorbids and ascidians.

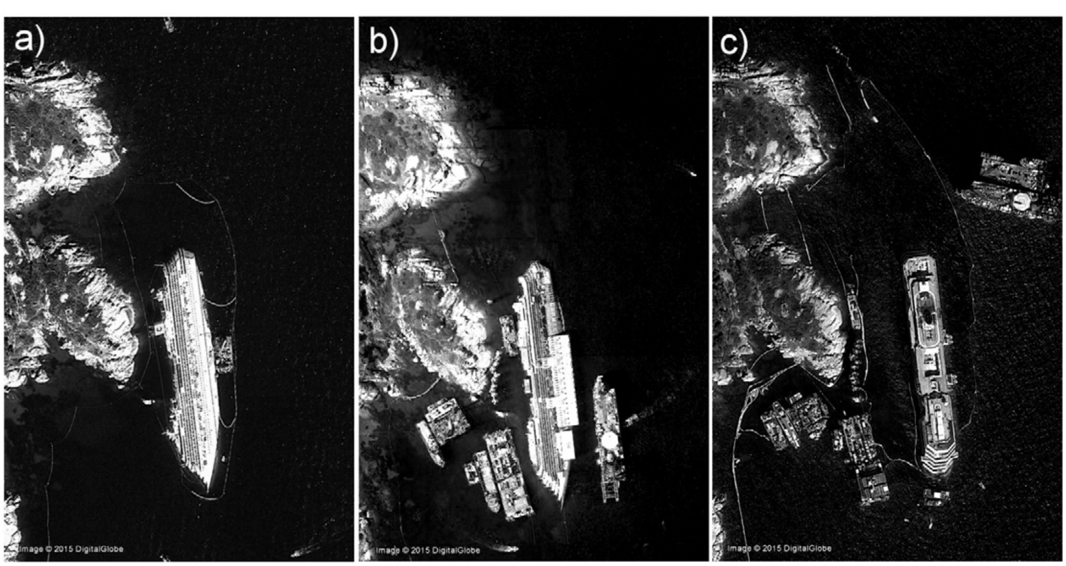

Fig. 1. Panoramic view of the Disturbed site. a) Just after the shipwreck (March 13th, 2012); b) before the parbuckling of the wreck (August 8th, 2013); c) after the parbuckling and before the removal of the wreck from the site (September 19th, 2013).