Estuarine, Coastal and Shelf Science 97 (2012) 58–65

Contents lists available at SciVerse ScienceDirect

Estuarine, Coastal and Shelf Science

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

Hydrodynamic constraints to the seaward development of *Posidonia oceanica* meadows

Matteo Vacchi [a,b,*], Monica Montefalcone [a], Carlo N. Bianchi [a], Carla Morri [a], Marco Ferrari [a]

[a] DipTeRis, Department for the Study of the Territory and of its Resources, University of Genoa, Corso Europa 26, 16132 Genoa, Italy
[b] SeaMap srl, Via Greto di Cornigliano 6R, 16152 Genova, Italy

ARTICLE INFO

Article history:
Received 16 May 2011
Accepted 11 November 2011
Available online 27 November 2011

Keywords:
seagrass
coastal hydrodynamics
meadow lower limit
Posidonia oceanica
benthic zonation
Ligurian sea
Mediterranean sea

ABSTRACT

Posidonia oceanica, the most important and abundant seagrass in the Mediterranean Sea, forms large meadows from the sea surface down to 40 m. The depth of the lower limit of the meadows marks the boundary between the infralittoral and the circalittoral zone, and is said to be normally set by light attenuation underwater, while the role of water movement has been little explored. In this paper, the position (i.e. distance from the shoreline and depth) of *P. oceanica* meadow lower limits along the whole Ligurian coastline (about 350 km) was related to the annual storm wave base. This depth represents the limit of interaction between waves and seafloor and corresponds to $L_0/2$, where L_0 is the annual offshore wave length. In all meadows, the lower limit has never been found deeper than the annual storm wave base, and its depth (Z_c) showed related to L_0 according to the equation $Z_c = 0.32 \cdot L_0 + 5.62$. In the coastal tracts affected by the least intense waves, the reduction of water movement with depth represents the most important constraint to the seaward development of the meadow, whereas light availability plays a major role in meadows affected by the most intense waves. The present study represents the first attempt at understanding the role of hydrodynamic factors in setting the depth limit of seagrass meadows. If corroborated by future research at other sites, this will have important implications for both basic and applied science, as it would imply rethinking about the relative importance of water movement and light in seagrass depth distribution, and could allow for a better estimate of the extent of meadow regression in anthropized areas.

1. Introduction

Seagrass meadows are key ecosystems in coastal waters (Short and Wyllie-Echeverria, 1996), influencing coastal zone features in terms of wave attenuation (Gacia and Duarte, 2001) and shoreline stabilization (Short et al., 2007). The interaction between wave energy and seagrass ecosystems has been extensively investigated (La Loggia et al., 2004; Folkard, 2005; Koch et al., 2006; Wicks et al., 2009). Several studies emphasized the role of seagrass in modifying water movement at the seafloor, in favoring fine sediment deposition and in buffering sediment re-suspension (De Falco et al., 2000, 2008 and references therein). Landscape patterns observed in seagrass habitats are often associated with disturbances induced by waves (Koch et al., 2006); however, the effects of water movement on the depth distribution of seagrass meadows has been little investigated (van Katwijk et al., 2000; Short et al., 2001).

Posidonia oceanica (L.) Delile, the most abundant and important seagrass in the Mediterranean Sea, actively contributes to coastal dynamics (Fonseca, 1996; Koch et al., 2006), because of its unique ability, among seagrasses, to develop on either sand or rock to eventually build the “matte”, i.e. an extensive terrace constituted of roots, rhizomes and entangled sediment (Giovannetti et al., 2008). The depth extent of *P. oceanica* meadows ranges from 0.5 to 40 m (Pergent et al., 1995; Gobert et al., 2006), but living plants have been found down to 48 m depth in particularly clear waters (Boudouresque et al., 1990; Borg et al., 2006). The meadow lower limit is defined as the greatest depth reached by the plants, and it is commonly considered as being dictated by water transparency (Boudouresque et al., 2006). The study of light requirements is a major focus of research on seagrass growth (Onuf, 1996), and different quantitative models provide predictions of the depth of meadow lower limits (Infantes et al., 2009 and reference therein). Seagrass can thrive up to depths where the irradiance at the top of the leaf canopy is above 11% of surface irradiance (Duarte, 1991) or where the number of hours with values of irradiance above photosynthetic saturation is 6–8 (Dennison and Alberte, 1985). Deep portions of *P. oceanica* meadows often manifest important signs of regression, due to a reduction in water transparency caused by the exploitation of coastal areas (Peirano and Bianchi, 1997; Ardizzone et al., 2006; Montefalcone et al., 2009).

* Corresponding author. SeaMap srl, Via Greto di Cornigliano 6R, 16152 Genova, Italy.
E-mail address: matteo.vacchi@unige.it (M. Vacchi).

0272-7714/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2011.11.024

In addition to light, water movement may be a relevant factor controlling the distribution and the growth dynamics of seagrass meadows (Boström et al., 2006). Coastal hydrodynamics influence the position and state of health of the meadow upper limit, i.e. the shallowest depth reached by the plants toward the shoreline (Folkard, 2005; Infantes et al., 2009). In particular, the position of the meadow upper limit has been shown to be related to the morphodynamic domain of the beach (i.e. distinctive types of beach produced by the topography, wave climate and sediment composition), meadows in areas with a comparatively lower wave energy areas having their upper limit closer to the shoreline (Vacchi et al., 2010). Relationships between lower limit and coastal hydrodynamics (down to 30 m depth) have been identified in *Posidonia oceanica* meadows off Corsica (Clabaut et al., 2010).

The present study relates the bathymetric position of *Posidonia oceanica* meadow lower limits along the whole Ligurian coastline (about 330 km) to the limit of interaction between waves and seafloor. Surface wave motion produces a velocity field that extends to some depth in the water column. This depth for an offshore wave is $L_0/2$, where L_0 is the offshore wave length. If the water depth is less than $L_0/2$, the motion extends to the bottom. In cases where the wave motion interacts with the bottom, several physical changes occur (Dean and Dalrymple, 1991; Linwood et al., 2003; Svendsen, 2006; Svendsen, 2006). This paper hypothesizes whether such changes could play a role in controlling the seaward limit of the *P. oceanica* meadow.

2. Methods

2.1. Study area

The study was carried out in the Ligurian Sea (NW Mediterranean Sea), along the coastline of Liguria (Fig. 1), an administrative Region of NW Italy where all the *Posidonia oceanica* meadows have been included in the Sites of Community Importance (SCIs) according to the European Community Directive (EEC, 1992). The total of 26 *P. oceanica* meadows occurring in Liguria, corresponding to 26 SCIs (Bianchi and Peirano, 1995; Relini, 2000; Diviacco and Coppo, 2006), was investigated. The large-scale urban and industrial coastal development which occurred in Liguria during the 1960s led to a very large decline of *P. oceanica* meadows, which formerly occupied a wide and continuous strip along the coast (Bianchi and Morri, 2000; Peirano et al., 2005; Montefalcone et al., 2010a, 2010b). It has been estimated that in total ca. 30% of the original surface covered by *P. oceanica* has been lost in less than 50 years (Bianchi and Peirano, 1995; Peirano and Bianchi, 1997), with most of the regressed areas concentrated in the deepest portions of the meadows (Montefalcone et al., 2009).

The Ligurian coastline can be divided in two sectors: 1) the Western Riviera, extending for about 130 km from the French frontier to the chief town of Genoa and characterized by rocky headlands alternating with sandy to gravelly beaches at the end of alluvial plains; 2) the Eastern Riviera, extending for about 120 km from Genoa to the Tuscany frontier, mainly characterized by rocky coasts with sheer cliffs and pocket beaches (Fanucci, 1987; Rovere et al., 2010, 2011a,b). The 13 *Posidonia oceanica* meadows investigated along the Western Riviera were: Capo Mortola (MO), Sanremo (SR), Arma di Taggia (AT), Riva Ligure (RL), Porto Maurizio (PM), Diano-Capo Mimosa (DM), Capo Mele-Alassio (CM), Santa Croce-Gallinara (SG), Loano-Albenga (LA), Finale Ligure (FL), Noli-Bergeggi (NB), Albisola-Varazze (AV), and Arenzano-Cogoleto (AR). The 13 meadows along the Eastern Riviera were: Boccadasse-Nervi (BN), Nervi-Sori (NS), Camogli-Portofino (CP), Rapallo (RA), Sestri Levante (SL), Punta Manara (MA), Punta Baffe (BP), Punta Moneglia (MG), Apicchi (AP), Anzo (AN), Levanto (LE), Punta Picetto (PI), and Monterosso al Mare (MM) (Fig. 1).

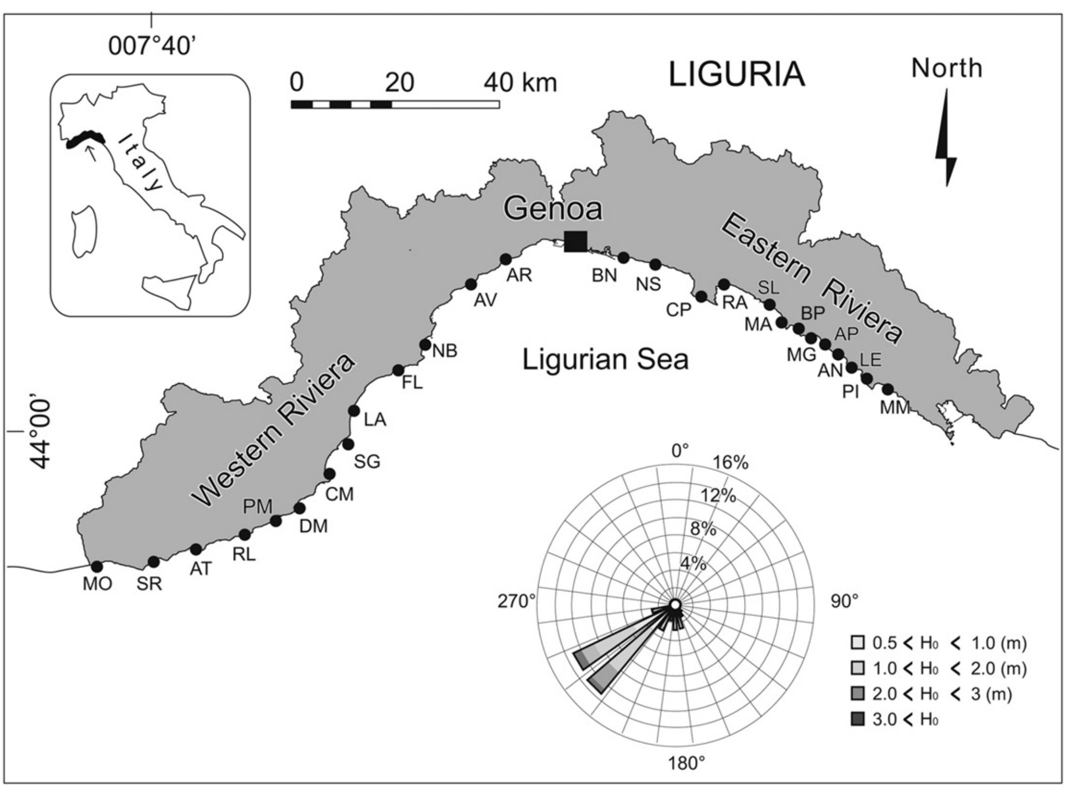

Fig. 1. Location of the 26 coastal areas investigated along the Ligurian coastline, with the relative annual wave climate (data from Corsini et al., 2006, modified). See methods for the code of each area. HS0 is the significant offshore wave height (m) recorded by the La Spezia buoy (43°55′41.99″N; 09°49′36.01″E).