The underreported presence of the subtidal seagrass *Cymodocea nodosa* in rocky intertidal pools of the Canary Islands

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Abstract

During 2014, 21 patches of *Cymodocea nodosa* were found in intertidal pools in Fuerteventura (Canary Islands). Pool substratum was mixed sand and rock, but mostly dominated by stone bottoms. Most plants were established with fully exposed rhizomes, filling small fissures without sediment. During subsequent sampling surveys between 2016 and 2019, the presence of these patches was consistent over time in an environment normally considered extreme for most seagrasses. As far as we know, the presence of various intertidal areas with *Cymodocea nodosa* patches has not been observed previously in the Canary Islands. If the presence of *C. nodosa* patches in these intertidal pools is stable over time, it raises new environmental management and conservation questions for this endangered species in the Canary Islands. In addition, due to the current regression of *C. nodosa* meadows, our observations represent an optimistic perspective that underline the need for specific monitoring plans for this ecosystem.

Keywords

Intertidal, rocky pools, Macaronesia, *Cymodocea* beds, exposed habitats

Introduction

Seagrasses are a main foundation species on soft bottoms of temperate and tropical coastlines worldwide (Duarte, Dennison, Orth, & Carruthers, 2008), serving as nursery areas, containing high biodiversity, and providing important ecosystem services (Heck & Orth, 1980). Although global seagrass diversity is low (72 species), seagrasses grow along thousands of kilometers of coastline and can occur from intertidal to very deep waters (Hemminga & Duarte, 2000; Short, Carruthers, Dennison, & Waycott, 2007). In order to survive in different environmental conditions, seagrasses have developed unique ecological, physiological and morphological adaptations (den Hartog, 1970). These adaptations have enabled seagrasses to inhabit all the world's oceans, with six seagrass biogeographical regions being recognized. Higher seagrass diversity is found in tropical, temperate southern oceans and north Pacific bioregions, while Mediterranean and temperate north Atlantic host lower levels of diversity (Short et al., 2007). In the most diverse areas, it is common to find seagrass genera living in both intertidal and subtidal zones and in habitats with different substrates such as *Phyllospadix*, *Amphibolis* or *Thalassodendron* (Duffy et al., 2019; Stephens et al., 2019). In the northeast Atlantic, three seagrass species are present: *Zostera marina*, *Zostera noltei* and *Cymodocea nodosa*. While *Z. marina* and *Z. noltei* are temperate species widely distributed along the European Atlantic and Mediterranean coastlines, *C. nodosa* is a tropical seagrass present throughout the Mediterranean sea, the Macaronesian archipelagos of Madeira and the Canary Islands, the Mauritania region, and the Algarve coastline, where it occurs intermixed with temperate seagrasses (Cacabelos et al., 2015; Hemminga & Duarte, 2000; Short et al., 2007). Although *C. nodosa* can be present in intertidal zones such as sheltered bays (Bay of Cádiz; de los Santos, Brun, Vergara, & Pérez-Lloréns, 2013; Lara et al., 2012) or coastal lagoons (Ria Formosa; Silva & Santos, 2003), its distribution is mostly restricted to the subtidal or lower intertidal zones, and always associated with sandy substrates. In the particular case of the Bay of Cadiz, *C. nodosa* is also present in one exposed site facing the open ocean, forming small-scattered patches in intertidal pools with sandy accumulations (de los Santos et al., 2013).

In the Canary Islands, *C. nodosa* is the most common seagrass on shallow sandy bottoms (Afonso-Carrillo & Gil Rodríguez, 1978; Pávon-Salas, Garrido, & Haroun, 1998; Reyes, Sansón, & Afonso-Carrillo, 1995). Moreover, *C. nodosa* is mainly located in the wave-protected areas of the east, southeast, south and southwest coasts of most islands in the archipelago, but it is especially abundant in the easternmost islands (La Graciosa, Lanzarote, Fuerteventura, Gran Canaria, Tenerife and La Gomera) (Barquín-Diez, González-Lorenzo, Martín-García, María Candelaria, & Brito-Hernández, 2005; Pavón-Salas, Herrera, Hernández-Guerra, & Haroun, 2000; Reyes et al.,

1995). This species is mostly restricted to subtidal areas between depths of 2 and 35 m, though it is more common from 10 to 20 m in depth. The only exception is Isla de Lobos, where some studies have observed its presence in sandy intertidal pools (Pavón-Salas et al., 2000; Reyes et al., 1995). Distributional and structural patterns of *C. nodosa* meadows depend on various environmental factors that characterize the coastline such as substrate, depth, slope, lighting and salinity (Barberá et al., 2005; Barquín-Diez et al., 2005; Reyes et al., 1995). However, coastal hydrodynamics may be the driving force that controls the upper limit distribution of *C. nodosa*, as found in the case of *Z. noltei* (Lara et al., 2012). Herein, we report on the rare but consistent presence of the common seagrass *C. nodosa* in several semi-exposed and sheltered intertidal rocky pools of Fuerteventura (Canary Islands) throughout a six-year period.

Material and methods

Data were initially collected along 250 km of coastline during 2014, covering the entire potential habitat of *Cymodocea nodosa* in the north, northeast and south semi-exposed and sheltered zones in Fuerteventura (Canary Islands) (Fig. 1). The spatial distribution of *C. nodosa* intertidal patches was georeferenced with ArcGIS 10.5.1 software. During sampling surveys in spring and winter of 2017, 2018 and 2019, *C. nodosa* patches were monitored to confirm their presence. In addition, during 2019 spring, leaf length measurements were taken in 10 plants per patch selected randomly over the seabed in the south of Fuerteventura, for comparison with data from subtidal seagrass meadows collected during spring 2014 (González-Lorenzo et al., 2014). All measurements were made at the sheath due to the difficulty in taking measurements at the first rhizome node, which were attached to stones and in fissures.

Results and discussion

Since Afonso-Carrillo and Gil Rodríguez (1978) confirmed the presence of *Cymodocea nodosa* along the Canary Island coastline in shallow subtidal zones, several studies have been carried out on this seagrass due to its importance as an ecosystem engineer (Cacabelos et al., 2015, and references therein; Tuya et al., 2014). During this time, the presence of *C. nodosa* was only reported once associated with sandy shallow tide pools on the Isla de Lobos (0.3 m depth) (Pavón-Salas et al., 2000). However, its presence cannot be reconfirmed in spite of having sampled the entire intertidal zone of the islet. In this regard, our observations are the first georeferenced report and mapped citation of the presence of *C. nodosa* in intertidal rocky pools of the Canary Islands.

We found 21 intertidal patches of *C. nodosa* along the rocky shore coastline of Fuerteventura, most of them located at the top of the mid-intertidal level dominated by *Chthamalus* spp. and algal turfs. In addition, all patches were located in areas with subtidal *C. nodosa* meadows (Fig. 1; Table S1 Mat. Suppl.). The highest number of patches was found in Punta Percebe (n= 18), the southernmost area, while only one patch was observed in the other sites. Punta Percebe is characterized by a flat rocky shore intertidal dominated by algal turfs, with small and shallow pools (50 x 50 cm, 14 cm depth max.), where it is difficult to establish intertidal zone boundaries. A patch was found in the lower intertidal in Jacomar, while in Jorós and Puerto del Rosario patches were found in the middle intertidal zone. In this regard, the Jacomar site was more similar to the subtidal *C. nodosa* meadows, forming patches of approximately 10 x 4 m in pools with mud bottoms. At the remaining sites, patches were smaller (50x40 cm to 2x1 m) and in small pools of 15 to 40 cm depth. At these sites, the substratum of pool bottoms was mixed with sand and rock though dominated in most cases by small stones (Fig. 2). In this habitat, plants were often observed with fully exposed rhizomes, filling small fissures without sediments. This type of growth is very different to the growth of *C. nodosa* in subtidal meadows and, as far as we know, has not previously been observed in the Canary Islands. In fact, the only seagrass genus that are known to grow preferably on rocky substrate is *Phyllospadix*

(Cooper & McRoy, 1988; Stephens et al., 2019). However, it is also common to find seagrasses that prefer sediment substrates like *Amphibolis Antarctica*, *Thalassodendron pachyrhizum* or *T. ciliatum* growing on hard substrates (den Hartog, 1970; Kirkman & Kuo, 1990)

Despite this study being mostly descriptive, its aim is to highlight the continuous presence of *C. nodosa* over time in an environment, such as intertidal pools, considered extreme for most seagrasses (Hemminga & Duarte, 2000). Most references related to *C. nodosa* in the Canary Islands have underlined the limiting role that environmental conditions play in its distribution and structure (e. g. Barberá et al., 2005; Pávon-Salas et al., 1998; Pávon-Salas et al., 2000; Tuya et al., 2019). One of the main limiting factors for the distribution of this species is water hydrodynamics (Infantes, Orfila, Bouma, Simarro, & Terrados, 2011). This is confirmed by the fact that seagrass meadows of the Canary Island archipelago are located along the most wave-protected coastlines –east, southeast, south and southwest of most islands— (Barberá et al., 2005; Barquín-Diez et al., 2005; Pávon-Salas et al., 1998; Pávon-Salas et al., 2000; Reyes et al., 1995). In these areas, seagrass stabilizes sediments and reduces wave energy, thus preventing coastal erosion (Hemminga & Duarte, 2000). Most patches found in the Fuerteventura intertidal were in areas with high hydrodynamics (Fig. 2), as is the case of Punta Percebe, popularly known as a surfing spot. This is particularly interesting, since, although *C. nodosa* can grow at exposed sites, this species normally grows on sandy bottoms deeply rooted in the substrate and, therefore, vulnerable to digging by waves in the intertidal (Cacabelos et al., 2015). In fact, seagrass species limited to exposed rocky shores such as genus *Phyllospadix*, exhibit anatomical features that indicate adaptations to an environment characterized by wave action on rocky substrates (Cooper & McRoy, 1988). Previous studies have shown the role of extreme wave events in modifying *C. nodosa* meadow structure, exposing roots and rhizomes, and even changing the distribution of some seagrasses (Portillo, 2014). This agrees with the personal observations of the authors who, on several occasions, have found large *C. nodosa* beach-cast after extreme wave events, and seagrass meadows with bald patches, and uprooted plants on the sand.

Living in intertidal zones means being regularly exposed to high stress such as desiccation, oversaturating irradiances or high temperatures, and therefore seagrasses have to adapt their morphology and physiology to survive such stressful conditions (Silva & Santos, 2003). Our observations showed a mean total leaf length of 17.9 ± 6.06 cm, with a minimum length of 8 cm, and a maximum of 30 cm. Interestingly, the maximum leaf length of the intertidal *C. nodosa* match that of the subtidal meadows of Fuerteventura, with a total average leaf length ranging from 23.1 to 32.3 cm (minimum = 15 cm and maximum = 44 cm) (González-Lorenzo et al., 2014), which agrees with similar observations in other areas (de los Santos et al., 2013). Although most *C. nodosa* patches were found totally submerged in the intertidal pools, leaves of some plants were air-exposed at some sites, since their leaves were larger than the pool depth. In these cases, leaf necrosis was observed suggesting a negative effect of the intertidal aerial exposure, which has been widely studied in other common subtidal seagrasses in which desiccation leads to reduced leaf length (Boese, Alayan, Gooch, & Robbins, 2003; Shafer, Sherman, & Wyllie-Echeverria, 2007).

Our observations have been regarded as anecdotal until now. However, this study could indicate a mechanism of adaptation of this seagrass, as has been observed in other seagrasses (Shafer et al., 2007; Stephens et al., 2019), favoring its steady presence in the intertidal over almost six years in this region. In fact, these observations do not concur with other results that show low resistance to local disturbances and environmental stress in the Canary Islands' seagrass meadows, because of their low genetic diversity compared to Mediterranean populations (Tuya et al., 2019). Thus, if the establishment of *C. nodosa* in intertidal areas is confirmed, it would pose new questions related to the environmental management and conservation status of this endangered species. Informing on the

status and condition of this species, and identifying the potential impacts is one of the major challenges of seagrass conservation (de los Santos et al., 2019). Subtidal *C. nodosa* meadows have been widely studied in the Canary Islands, and there are various legal instruments to protect them in Europe and Spain (Order AAA/1351/2016 and ARM/2417/2011 of the Spanish Government, and the European Union's Council Directive 92/43/EEC). However, the Canary Islands autonomous Government reduced the protection status of *C. nodosa* in 2010 to the category of "species of interest for Canary Island ecosystems" (BOC n° 112, Law 4/2010 of the Canary Islands Catalogue of Protected Species). Intertidal habitats are subject to several impacts derived from human activities such as climate change, species exploitation, or habitat destruction (Bulleri & Chapman, 2010; Mieszkowska et al., 2019; Piñeiro-Corbeira, Barrientos, Olmedo, Cremades, & Barreiro, 2018). Thus, given the current environmental framework characterized by the regression of *C. nodosa* meadows (de los Santos et al., 2019; Tuya et al., 2019), our observations represent an optimistic perspective that underline the need for specific monitoring in intertidal habitats. Annual monitoring programs of the conservation and health status of these *C. nodosa* intertidal patches, as well as the identification of potential impacts in the area would provide very useful information to implement effective management actions to halt their loss and promote their conservation over time.

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243 **Legends**

244 Fig. 1. Map of the study area showing sites with intertidal patches of *Cymodocea nodosa* (red stars) and location of
245 patches on each site (red circles). Green patches are areas with *C. nodosa* subtidal meadows. All sites are located
246 in Fuerteventura (Canary Islands).

247 Fig. 2. *Cymodocea nodosa* growing on intertidal pools in Fuerteventura (Canary Islands).

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