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Rapid Communication

The macroalgae *Lophocladia lallemandii* and *Sarconema filiforme* and the spaghetti bryozoan *Amathia verticillata* in native seagrass beds in the Gulf of Gabès (southeastern Tunisia, Mediterranean Sea)

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Abstract

The macroalgae *Lophocladia lallemandii* (Montagne) F. Schmitz and *Sarconema filiforme* (Sonder) Kylin and the spaghetti bryozoan *Amathia verticillata* (delle Chiaje, 1822) are here first reported in native seagrass beds in the Gulf of Gabès (southeastern Tunisia, Mediterranean Sea). Among them, the sighting of *S. filiforme* constitutes the first record of this species in Tunisia. The co-occurrence of these species was observed in the study area with variable abundances, and *L. lallemandi* appeared to impact the local seagrass meadows of *Posidonia oceanica* (Linnaeus) Delile. Further studies are needed to monitor the distribution of these non-native and cryptogenic taxa in Tunisia and to confirm or infirm the potential negative impacts of the non-indigenous macroalgae on local biota and seagrass beds.

Key words: biological invasions, non-native and cryptogenic species, range expansion, coastal monitoring, southern Mediterranean Sea

Introduction

Biological invasions are one of the main factors behind biodiversity changes and shifts in species abundances in the Mediterranean Sea. Anthropogenic activities, including shipping, aquaculture, and corridor creation, have previously and continue to facilitate the introduction of about 1,000 species to the area (Katsanevakis et al. 2014a). The majority of these introduced species are now mostly established in the Levant basin, although their distribution is increasing throughout the entire Mediterranean Sea (Zenetos et al. 2017; Servello et al. 2019). Moreover, while some marine non-indigenous species have the potential to enhance ecosystem services and biodiversity of colonized areas (Schlaepfer et al. 2011; Simberloff et al. 2013; Katsanevakis et al. 2014b), others are highly invasive and may have harmful impacts on local species, assemblages, and habitats (Grosholz 2002; Wallentinus and Nyberg 2007; Molnar et al. 2008; Vilà et al. 2010; Katsanevakis et al. 2014b).

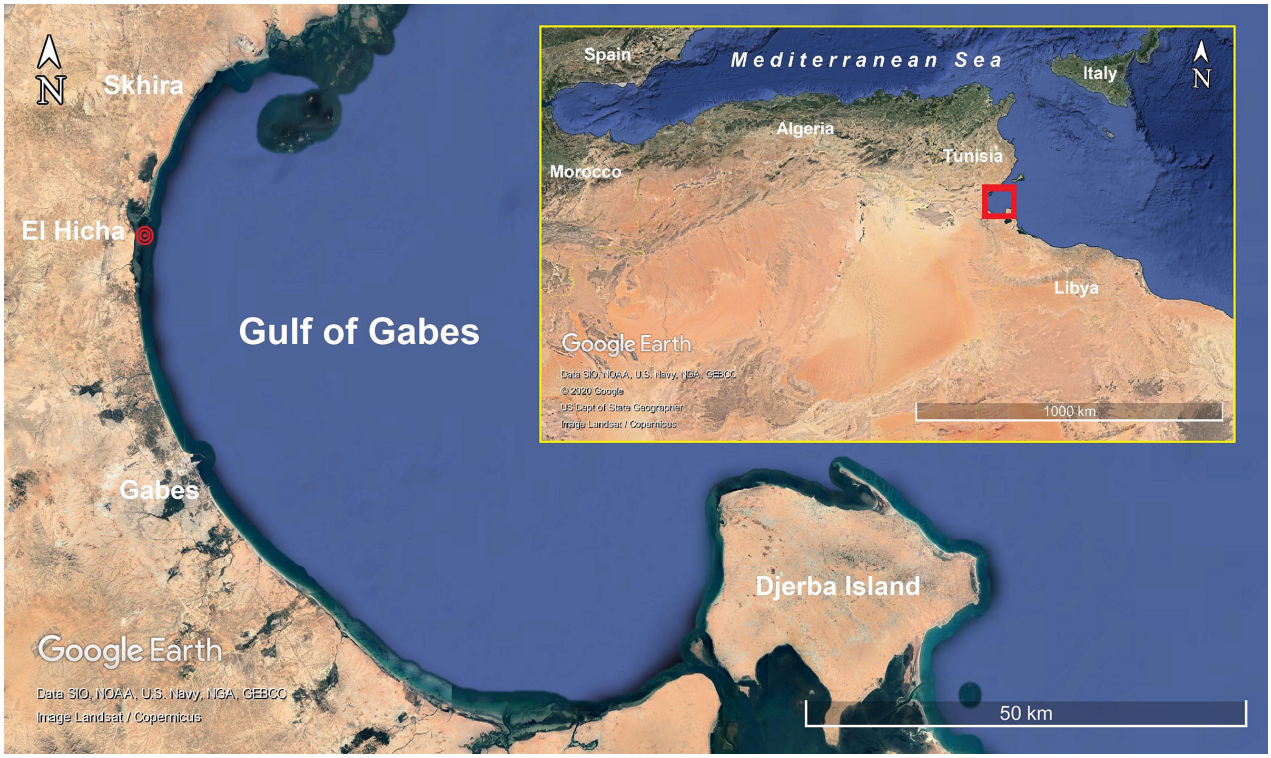

Figure 1. Location of El Hicha (Gulf of Gabès, Tunisia), where *Lophocladia lallemandii*, *Sarconema filiforme*, and *Amathia verticillata* were found.

Historical monitoring efforts in Tunisia have detected a recent trend showing a notable increase in species arrival and/or detections in the last decades (Ounifi-Ben Amor et al. 2016). In the Gulf of Gabès, newly arrived species have been connected to recent changes in local species composition, and these shifts were linked with socio-economic problems and losses (Crocetta et al. 2015; Rabaoui et al. 2015; Stamouli et al. 2018). Here, we report the presence of two non-native macroalgae, namely *Lophocladia lallemandii* (Montagne) F. Schmitz and *Sarconema filiforme* (Sonder) Kylin, and of the cryptogenic bryozoan species *Amathia verticillata* (delle Chiaje, 1822) in the Gulf of Gabès. All these species were visually detected while conducting seagrass monitoring. Among them, *S. filiforme* has to date only been recorded in the easternmost Mediterranean Sea, and thus our detection extends its current known range in the basin. The present manuscript also provides information on density and habitat preference of the three taxa and discusses their potential impacts on local habitats.

Materials and methods

During coastal monitoring aiming to evaluate the status of the native seagrass beds of *Cymodocea nodosa* (Ucria) Ascherson and *Posidonia oceanica* (Linnaeus) Delile in the Gulf of Gabès (southeastern Tunisia, Mediterranean Sea), a snorkeling survey was conducted on August 3rd 2017, in El Hicha (34.149522°N; 10.040956°E; Figure 1). The region is located northeast of Gabès and is generally characterized by dense seagrass (*P. oceanica* and

Table 1. Numbers of *Sarconema filiforme* and *Amathia verticillata* colonies as well as the approximate percentage of the surface area covered by *Lophocladia lallemandii*, estimated during the survey of the three transects (T1, T2, and T3) defined in the *Posidonia oceanica*-*Cymodocea nodosa* seagrass meadows of El Hicha (Central Gulf of Gabès, south-eastern Tunisia). Note that the surfaces of *L. lallemandii*-covered areas were estimated qualitatively based on the visual assessments of the divers who surveyed the three transects. The total numbers of colonies of *S. filiforme* and *A. verticillata* and total area covered by *L. lallemandii* (estimated in a total surveyed area of 1.5 ha) are given in the last row of the table.

Transects	Surface Area (ha)	Number of *Sarconema filiforme* colonies	Number of *Amathia verticillata* colonies	Approximate percentage of area covered with *Lophocladia lallemandii*
T1	0.5	16	19	20%
T2	0.5	9	14	25%
T3	0.5	13	21	30%
Total	1.5	38	54	20–30%

C. nodosa) meadows, extended on muddy and/or sandy areas at depths ranging between 1 and 10 m (Hattour and Ben Mustapha 2013; El Zrelli et al. 2017). As two non-native macroalgae species, namely *Lophocladia lallemandii* (Montagne) F. Schmitz and *Sarconema filiforme* (Sonder) Kylin, and one cryptogenic bryozoan species, namely *Amathia verticillata* (delle Chiaje, 1822), were soon noticed by one of the authors (REZ), various pictures and videos were taken in situ using NIKON COOLPIX AW130 underwater camera. Representative samples of the two macroalgae were also collected and their identification was further verified in the laboratory using specialistic guides (Kylin 1932; Schmitz 1893; Verlaque et al. 2015). In order to estimate the density of the three species in the seagrass meadows of El Hicha, three linear transects (T1, T2, and T3), of 0.5 ha (625 m × 8 m = 5000 m^2) each, were defined in parallel to the coastline and surveyed, on August 4th 2017, by four divers (two divers from each side of the transect). While surveying both corridors (left and right) of the transects, divers counted the number of *S. filiforme* and *A. verticillata* colonies. The spatial occupancy of *L. lallemandii* was qualitatively estimated based on the visual assessments of the divers.

Results and discussion

All the three species found were observed scattered in most of the area occupied by *P. oceanica* and *C. nodosa* in El Hicha, at depth ranging between 0.7 and 2.5 m (Figure 2 and Supplementary material Figure S1) and seemed to show different habitat preferences. Table 1 shows the abundance/density of the three species in each of the three transects (T1, T2, and T3), as well as in the total area surveyed (1.5 ha). In total, 38 colonies of *S. filiforme* were overall observed, and mainly found in small areas with low *P. oceanica* and *C. nodosa* rhizome densities (Figure 2a). For *A. verticillata*, 54 colonies were overall observed, and mainly found in *P. oceanica* areas already colonized by *L. lallemandii* (Video S1). Finally, *L. lallemandii* occupied 20–30% of the surveyed *P. oceanica*-*C. nodosa* seagrass area, and at certain zones it covered the leaves of *P. oceanica*, corresponding with leaf senescence of covered shoots – an indicator of seagrass shoot stress (Videos S2 and S3).

Among the species found herein, the record of *S. filiforme* constitutes the first record of this species in Tunisia and considerably widens its non-native

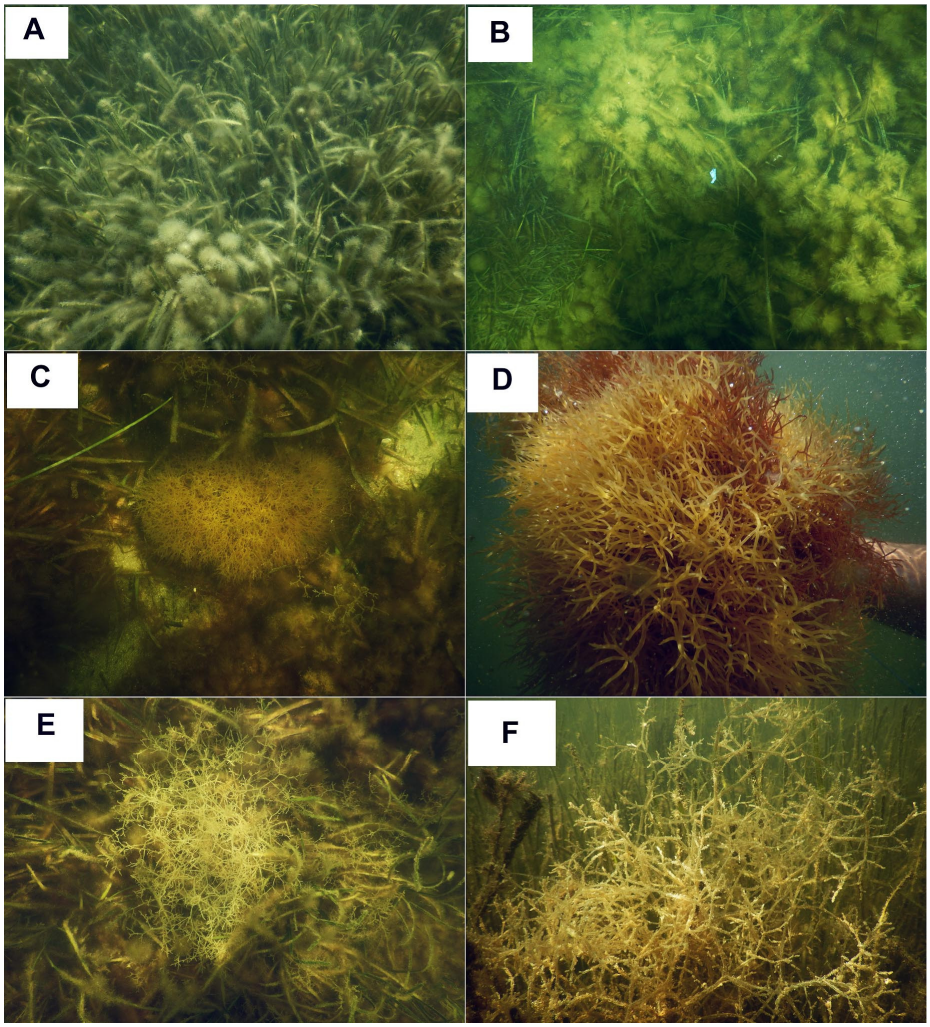

Figure 2. *In situ* photographs of the non-native and cryptogenic species found in the *Posidonia oceanica-Cymodocea nodosa* seagrass beds at El Hicha (Gulf of Gabès, Tunisia). A–B. *Lophocladia lallemandii*. C–D. *Sarconema filiforme*. E–F. *Amathia verticillata*. Photos by Radhouan El Zrelli.

presence in the Mediterranean basin. In fact, this species, originating from the Red Sea and the Indian Ocean, was only recorded in Egypt, and subsequently in the south Levantine coast, Syria, and Lebanon (Bitar et al. 2017). On the contrary, *L. lallemandii* was only known from the northern and southern edges of the Gulf of Gabès (Kerkennah Island and Djerba Island) (Sghaier et al. 2015), so that the present record fills a gap in its known distribution in Tunisia. Sghaier et al. (2015) also reported that *L. lallemandi* proliferates in summer (July 2009 and 2010) on disturbed and dead *P. oceanica* and *C. nodosa* meadows, and a similar observation was also noted during our survey in El Hicha (Videos S2 and S3). However, we highlight here that disturbance and/or mortality of seagrass species may be also due to the consequence of the proliferation of *L. lallemandi*. In fact, comparing our observations on areas invaded and non-invaded by *L. lallemandi*, it can be deduced that the proliferation of this non-indigenous taxon may reduce gradually the mobility of seagrass leaves, diminish the quantity of light received, and affect the metabolism of the plant leading to its death. This is in agreement with the observations of Ballesteros et al. (2007), who reported

that *L. lallemandii* induced a decrease in size and weight of *P. oceanica* shoots, leaf chlorosis, leaf necrosis, and finally, shoot death of *P. oceanica* plants in Spain. Within the same context, Marbà et al. (2014) assessed the impact of *L. lamellandii* on *P. oceanica* seagrass meadows in Balearic Islands (Spain) and found that seagrass mortality is 2.5–5 times higher in invaded than in turf-free sites. The latter authors also reported an increase in *P. oceanica* mortality when the algal turf biomass exceeded 200–300 g DW m^{-2}. Finally, to the best of our knowledge, although the spaghetti bryozoan *A. verticillata* was considered as common in the Tunisian lagoons of Tunis and Boughrara (Ounifi-Ben Amor et al. 2016), this is the first record of this taxon in the central area of Gabès Gulf.

Conclusion

Among the three species recorded herein, *L. lallemandii* seems to have potential negative effect on local *P. oceanica* seagrass meadows. In addition to its potential fatal effect on *P. oceanica* and *C. nodosa* meadows, the establishment of *L. lallemandii* seems to facilitate the settlement of other non-native and cryptogenic species, including *A. verticillata* and *S. filiforme*, in the Gulf of Gabès. Further studies are needed in order to define the factors behind the settlement and proliferation of these species in the central area of the Gulf of Gabès and better understand their interaction with local biota and habitats.

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Supplementary material

The following supplementary material is available for this article:

Figure S1. Additional photos of the three non-native and cryptogenic species.

Video S1. Video showing the co-occurrence of *Lophocladia lallemandii* and *Amathia verticillata* in the seagrass meadow of El Hicha (central Gulf of Gabès, south-eastern Tunisia).

Video S2. Video showing the *Posidonia oceanica* areas covered by *Lophocladia lallemandii* in El Hicha (central Gulf of Gabès, south-eastern Tunisia).

Video S3. Video showing the easy removal of *Posidonia oceanica* leaves in the area covered by *Laphocladia lallemandii* in El Hicha (central Gulf of Gabès, south-eastern Tunisia).

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