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Original Article

Assessment of grazing impact on deep canopy-forming species in the western Ionian Sea, Central Mediterranean

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Abstract: Marine forests are experiencing a severe decline in many Mediterranean areas. One of the major causes of the loss of the canopy-forming species is the overgrazing by herbivorous fishes. In the present study, the status of *Treptacantha ballesterosii* and *Carpodesmia zosteroides* populations was checked in two areas located along the central-eastern sector of Sicily. In addition, monitoring of fish communities was realized to observe which herbivorous fishes, native or alien, affect canopy-forming species. It was observed that *T. ballesterosii* and *C. zosteroides* populations are in regression, particularly *T. ballesterosii*. Probably, the growth of this latter species may be limited by a strong herbivores' pressure. During the monitoring period, the highest number of fish species has been observed at the depths where there are *T. ballesterosii* thalli. Moreover, an expansion of populations of *Sparisoma cretense*, which seems to be a more competitive species than the other herbivorous fish *Sarpa salpa*, has been observed. Furthermore, the parrotfish has been observed several times in the bathymetric range where there is *T. ballesterosii*. Therefore, it may be hypothesized that in these areas the herbivorous fish which mostly hinder the development and growth of *T. ballesterosii* is *S. cretense*.

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Introduction

Canopy-forming algae constitute some of the most diverse, productive and valuable ecosystems along intertidal and subtidal rocky coasts (Steneck et al., 2002). Most of them belong to the order Fucales (Phaeophyceae), which in the Mediterranean Sea is represented by the species of the genera *Sargassum* C.Agardh and *Cystoseira sensu lato* C.Agardh. According to the recent systematic review (Orellana et al., 2019), some species of the latter genus have been transferred to the genera of *Treptacantha* Kützing and *Carpodesmia* Greville based on morphological and molecular features. Since Fucales forms extended populations that are complex in their structure, they are considered ecosystem engineers representing the photophilous vegetation of rocky shores in high natural environments (Furnari et al., 2003). These algae provide three-dimensional complexity and spatial heterogeneity of rocky bottoms constituting substrate for many other algae, and refuge, shelter and food for many species at different life-history stages (Grech et al., 2019). Therefore, benthic macrophytes are considered as good indicators of the water quality, and are used by CARLIT method (cartography of littoral and upper-sublittoral benthic communities) (Ballesteros et al., 2007), which determine the ecological quality status of any given coastal water body according to the European Water Framework Directive (2000/60/EC). Nevertheless, Fucales are sensitive to anthropogenic effects, which reduce their distribution (Chryssovergis and Panayotidis, 1995; Rodríguez-Prieto and Polo, 1996; Soltan et al., 2001; Arevalo et al., 2007; Sales et al., 2011; Mancuso et al., 2017). Close to urban areas, canopy-forming species are retracting their distribution being replaced by ephemeral, filamentous and turf-forming seaweeds or sea urchin barrens (Benedetti-Cecchi et al., 2001; Soltan et al., 2001; Thibaut et al., 2005, 2015; Ballesteros et al., 2007; Mangialajo et al., 2007, 2008; Perkol-Finkel and Airoldi, 2010).

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In many areas of the Mediterranean Sea, Fucales are encountered loss mainly by habitat destruction, pollution, eutrophication, increasing seawater temperature, presence of alien species and overgrazing by herbivores (Cormaci et al., 2001; Thibaut et al., 2005, 2015, 2016; Serio et al., 2006; Mangialajo et al., 2008; Sales and Ballesteros, 2009; Tsiamis et al., 2013; Templado, 2014; Mineur et al., 2015; Catra et al., 2019). In the most of Mediterranean, the sea urchins *Paracentrotus lividus* (Lamarck, 1816) and *Arbacia lixula* (Linnaeus, 1758) are primary grazers responsible for creation and persistence of rocky barrens (Bulleri et al., 1999; Guidetti and Dulcic, 2007; Bonaviri et al., 2011; Agnetta et al., 2015). Once sea urchin populations are established, their adults can facilitate juvenile survival by reducing micro-predator abundance offering refuge under their spine canopy avoiding predation (Tegner and Dayton, 1977; Zhang et al., 2011; Bonaviri et al., 2012; Hereu et al., 2012). Therefore, they represent an alternative stable state maintained by several feedback mechanisms that prevent the recovery of macroalgal forests (Medrano, 2020).

According to Gianni et al. (2017), the role of herbivorous fishes in temperate regions has been underestimated. There are growing evidences that herbivorous fishes can control the structure of macroalgal communities (Sala and Boudouresque, 1997; Hereu, 2006; Gianni et al., 2017). The native herbivorous fish *Sarpa salpa* (Linnaeus, 1758) is known to determine strong algal declines (Vergés et al., 2009; Gianni et al., 2017). It has been observed that more than 60% of *S. salpa*'s intestinal content consists of *Cystoseira* complex species (Verlaque, 1990). Furthermore, Gianni et al. (2017) observed that during the maximum growth period of *C. amentacea* (C.Agardh) Orellana & Sansón [syn. *C. amentacea* (C.Agardh) Bory], grazing by salema caused up to 78% reduction in algal size.

In the eastern Mediterranean, two alien herbivorous fishes, *Siganus luridus* (Rüppell, 1829) and *S. rivulatus* Forsskål & Niebuhr, 1775 that entered the Mediterranean from the Red Sea, has led to extensive areas of rocky barrens, causing phase-shifts and replacing the native *S. salpa* (Sala et al., 2011; Gianni et al., 2017; Tsirintanis et al., 2018). Generally, these species are selective when macroalgal assemblages are diverse and abundant, but they can consume whatever is available in macroalgal-deprived bottoms, maintaining microscopic carpets of filamentous algae and diatoms (Bariche, 2006). For that reason, this behavior was defined as "gardening" (Sala et al., 2011). The other herbivorous fish that could affect Mediterranean canopy-forming species is the parrotfish *Sparisoma cretense* (Linnaeus, 1758), that is one of the few temperate species of the family Scaridae Rafinesque, 1810 that is native to the Mediterranean (Bernardi et al., 2000). To date, the potential herbivory effect of this species on Fucales assemblages has not yet been reported.

Based on the above-mentioned background, the aims of this study are (1) to check the status of deep Fucales assemblages in two areas located along the central-eastern sector of Sicily, and (2) to analyse which herbivorous fishes, native or alien, mostly affect canopy-forming species in these areas.

Materials and Methods

Study area: This study was carried out in two stations located along the central-eastern coast of Sicily (Fig. 1): Santa Maria La Scala (37,617222°N, 15,172222° E) and Santa Tecla (37,639778°N, 15,184722°E), both in the municipality of Acireale. In these two stations, previously, some studies on the benthic macroalgal biodiversity have been conducted. The first studies on the seaweeds of these sites were performed in seventies (Furnari and Scammacca, 1970, 1973, 1975; Cormaci et al., 1979). Giaccone et al. (1985) published a revision on the marine flora of Sicily, including some data for the Santa Maria La Scala and Santa Tecla. Then, Pizzuto (1999) carried out a study on the morphological and reproductive phenology of *C. brachycarpa* (J.Agardh) Orellana & Sansón in Santa Maria La Scala. Also, in the same site, a PhD thesis on *Schizymenia dubyi* (Chauvin ex Duby) J.Agardh was conducted by Grimaldi (2004).

Figure 1. Study areas located along the central-eastern sector of Sicily, Italy.

Both stations are situated along Etna eastern slopes (Sciuto et al., 2017). The structural evolution of Etna's volcanic system in Acireale has led to the activation of a fault system, which originated a coastal slope extended for 6 km, locally denominated "Timpa". In the site of Santa Maria La Scala, there is an oriented natural reserve called "La Timpa", a protected area extending on the emerged part of Acireale coastal strip, and a site of community importance (SCI) named "Timpa of Acireale" (Catra et al., 2006). The Timpa's morphology is reflected in the submerged rocky outcrops. In both sites, from the coastline to 10-25 m, the bottom has a steeply sloping topography consisting basaltic bedrock covered by subvolcanic rocks (Sciuto et al., 2017). Offshore, the bottom gently slopes consisting sediments that become progressively muddier at major depths and there are locally exposed rocky outcrops (Rosso, 2001). Moreover, in these sites due to the high permeability of Etna's vulcanites, there are several springs related to the flow of freshwater from Etna to the sea (Catra et al., 2006). From a hydrogeological standpoint, this coastal area is influenced by Straits of Messina's tidal currents and Ionian upwelling currents.

The study areas were selected not only for the geomorphological and hydrodynamic similarities but also because they present related macroalgal communities. Indeed, in both areas, previously, the presence of populations of *Treptacantha ballesterosii* Orellana & Sansón (syn. *Cystoseira montagnei* J.Agardh) and *Carpodesmia zosteroides* (Turner) Greville [*Cystoseira zosteroides* (Turner) C.Agardh] was reported.

Experimental design: This study was carried out from 24th June 2017 to 24th February 2018. For each site, monitoring of the fish communities and the Fucales populations were performed. A total of 22 scuba dives were performed: 15 in Santa Maria La Scala and 7 in Santa Tecla. The scuba dives were conducted during daylight from about 9 to 11:30 am, with optimal marine-weather conditions. The two techniques of *the visual census* viz. *random courses* method (Harmelin-Vivien et al., 1985) and recording of underwater videos were performed during each scuba dive. The *random courses* are usually used for the faunistic characterization of different environments and are suitable for censusing shy and/or rare species (La Mesa et al., 2017). Instead, the recording of underwater videos allows to study habitat schemes or behavioral processes e.g. feeding (Adams et al., 2006). Furthermore, through this technique, it is not needed to transcribe the data during the scuba diving and the videos can be seen several times. Another advantage of this technique is that the subjects of the analysis are seen in motion and this could improve the identification of the species and reduce the subjectivity of the observer (Bortone et al., 1986; Harvey et al., 2010).

For each study area, the bathymetric ranges of 0-10 m and 20-25 m were selected. In past studies, at these depths, populations of *T. ballesterosii* and *C. zosteroides* were encountered. Through the *random*

Table 1. Group of “rare” species.

Species	Number of observations	Station
Bothus podas	2	Santa Maria La Scala
Enchelycore anatina	2	Santa Maria La Scala
Lophius piscatorius	1	Santa Maria La Scala
Myliobatis aquila	1	Santa Maria La Scala
Parablennius incognitus	1	Santa Maria La Scala
Parablennius sanguinolentus	1	Santa Maria La Scala
Scorpaena porcus	1	Santa Maria La Scala
Scorpaena scrofa	2	Santa Maria La Scala
Sphyraena viridensis	2	Santa Maria La Scala
Zebrus zebrus	2	Santa Tecla

Table 2. Group of “frequent” species.

Species	Number of observations	Station
Anthias anthias	10	Santa Maria La Scala
Chelon labrosus	3	Santa Maria La Scala, Santa Tecla
Diplodus annularis	10	Santa Maria La Scala, Santa Tecla
Epinephelus costae	4	Santa Maria La Scala
Epinephelus marginatus	8	Santa Maria La Scala, Santa Tecla
Lipophrys trigloides	3	Santa Maria La Scala
Muraena helena	13	Santa Maria La Scala, Santa Tecla
Oblada melanura	6	Santa Maria La Scala, Santa Tecla
Pagrus pagrus	5	Santa Maria La Scala, Santa Tecla
Seriola dumerili	4	Santa Maria La Scala, Santa Tecla
Spicara maena	10	Santa Maria La Scala, Santa Tecla
Trypterygion delaisi	5	Santa Maria La Scala, Santa Tecla

Table 3. Group of “very frequent” species.

Species	Number of observations	Station
Apogon imberbis	20	Santa Maria La Scala, Santa Tecla
Boops boops	22	Santa Maria La Scala, Santa Tecla
Chromis chromis	22	Santa Maria La Scala , Santa Tecla
Coris julis	22	Santa Maria La Scala, Santa Tecla
Diplodus sargus	17	Santa Maria La Scala, Santa Tecla
Diplodus vulgaris	16	Santa Maria La Scala, Santa Tecla
Mullus surmuletus	19	Santa Maria La Scala, Santa Tecla
Parablennius rouxi	19	Santa Maria La Scala, Santa Tecla
Sarpa Salpa	18	Santa Maria La Scala, Santa Tecla
Scorpaena notata	22	Santa Maria La Scala, Santa Tecla
Serranus cabrilla	17	Santa Maria La Scala, Santa Tecla
Serranus scriba	16	Santa Maria La Scala, Santa Tecla
Sparisoma cretense	22	Santa Maria La Scala, Santa Tecla
***Symphodus* sp.**	22	Santa Maria La Scala, Santa Tecla
Thalassoma pavo	22	Santa Maria La Scala, Santa Tecla

courses of about 30 minutes for each bathymetric range, data on the number of species, frequency and distribution were collected. The underwater videos were recorded through the Action Camera SJCAM SJ4000. The underwater videos were shot first in the bathymetric range of 20-25 m and then in the upper range, with two replies for each range. The identification of fish species was carried out by observing underwater videos based on Louisy (2015) and FishBase (Froese and Pauly, 2019). Subsequently, data on fish communities were processed in Excel through tables with information on the bathymetric

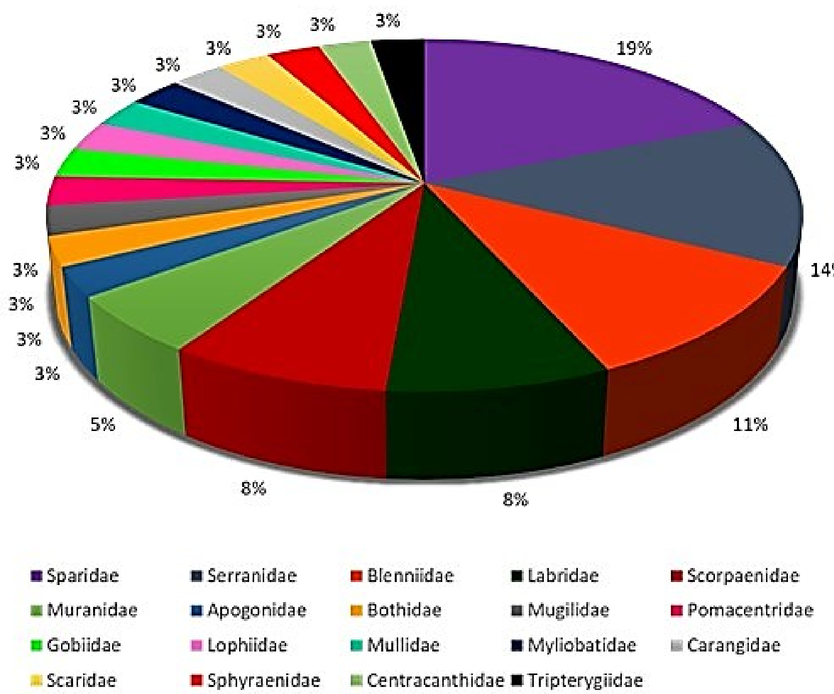

Figure 2. Pie chart showing the percentages of the found fish families.

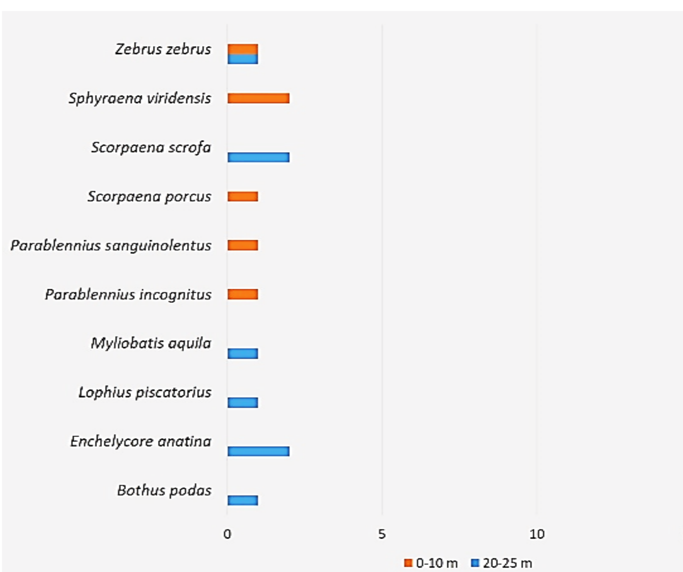

Figure 3. Bathymetric distribution of "rare" species.

range and the frequency in which the specimens were encountered, the number of specimens using seven abundance classes [1; 2-5; 6-10; 11-20; 21-30; 31-50; 51-100 (Harmelin-Vivien et al., 1985)] and the life stage (juvenile or adult).

Results

Through the monitoring of fish communities in the study areas, a total of 37 species belonging to 19 families was observed (Fig. 2). The most representative family was Sparidae Rafinesque, 1818 (19%), following by Serranidae Swainson, 1839 (14%), Blenniidae Rafinesque, 1810 (11%), Labridae Cuvier, 1816 (8%) and Scorpaenidae Risso, 1827 (8%). The Muraenidae Rafinesque, 1815 are represented by a percentage of 5% and the other 13 families represented only 3%. According to the frequency of the fishes' observation, the species were divided into three categories: "rare" (Table 1) (if the species was recorded only 1-2 times), "frequent" (Table 2) (if the species was recorded more than 2 times but not during the whole monitoring period, or if the species were observed only in one of the two bathymetric ranges) and "very frequent" (Table 3) (if the species were recorded during most scuba dives and in both bathymetric ranges). The distribution of the three categories of fish species in the different bathymetric ranges were presented in Figures 3, 4 and 5.

The number of specimens (between 0 and 100) in seasons, summer and winter are shown in Figures 6 (for S. Maria La Scala) and 7 (for S. Tecla). During

Table 4. Presence of *Treptacantha ballesterosii* and *Carpodesmia zosteroides* during the monitoring period in the study areas.

Month	*Treptacantha ballesterosii*	*Carpodesmia zosteroides*
June	Santa Maria La Scala	Santa Maria La Scala
July	-	Santa Maria La Scala
Aug.	-	-
Sep.	Santa Maria La Scala	-
Oct.	Santa Tecla	-
Nov.	Santa Maria La Scala, Santa Tecla	Santa Maria La Scala, Santa Tecla
Dec.	Santa Tecla	Santa Tecla
Jan.	Santa Maria La Scala	Santa Maria La Scala, Santa Tecla
Feb.	Santa Maria La Scala, Santa Tecla	Santa Maria La Scala, Santa Tecla

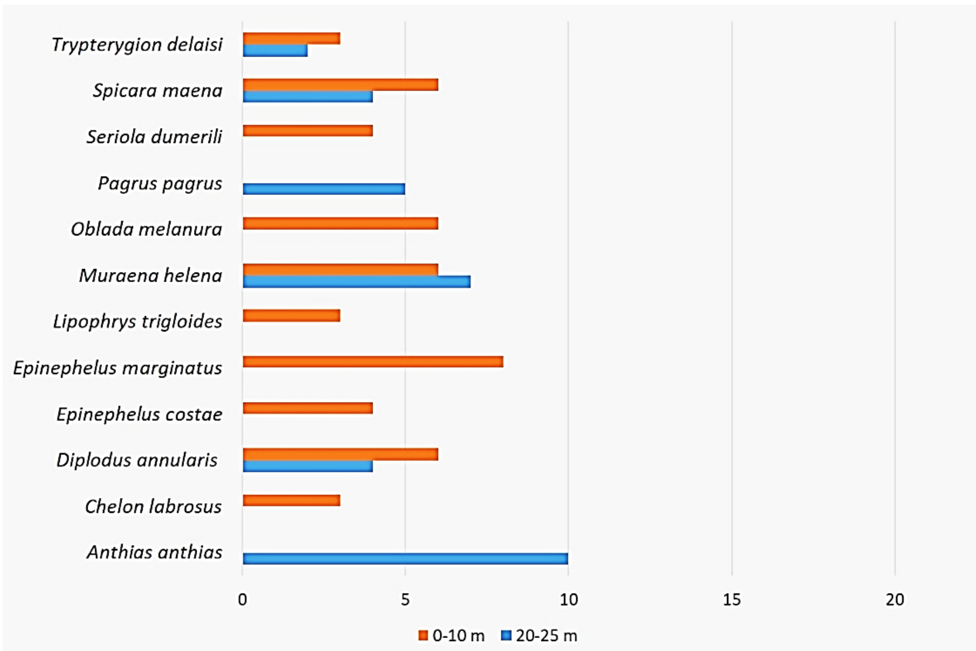

Figure 4. Bathymetric distribution of “frequent” species.

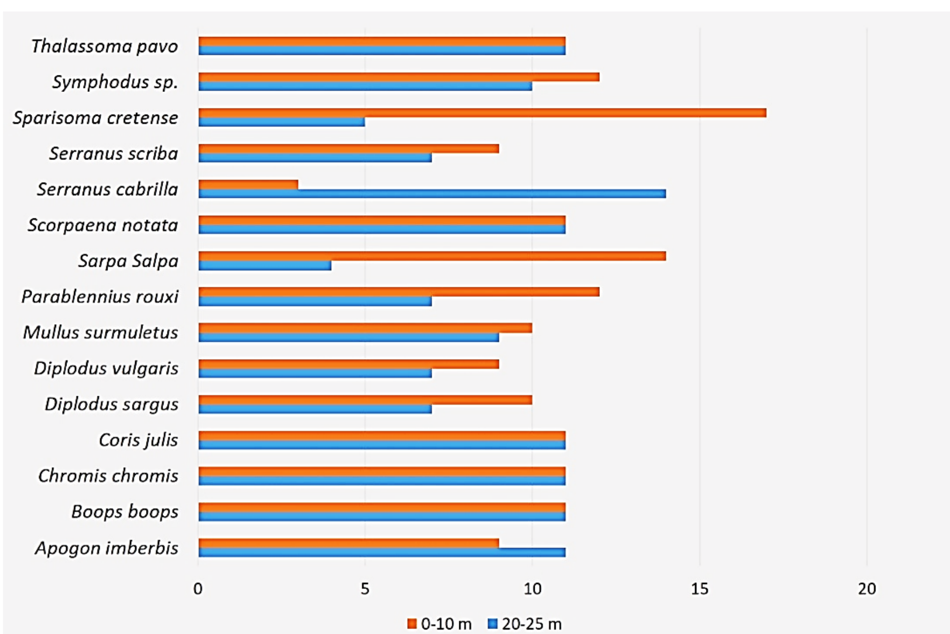

Figure 5. Bathymetric distribution of “very frequent” species.

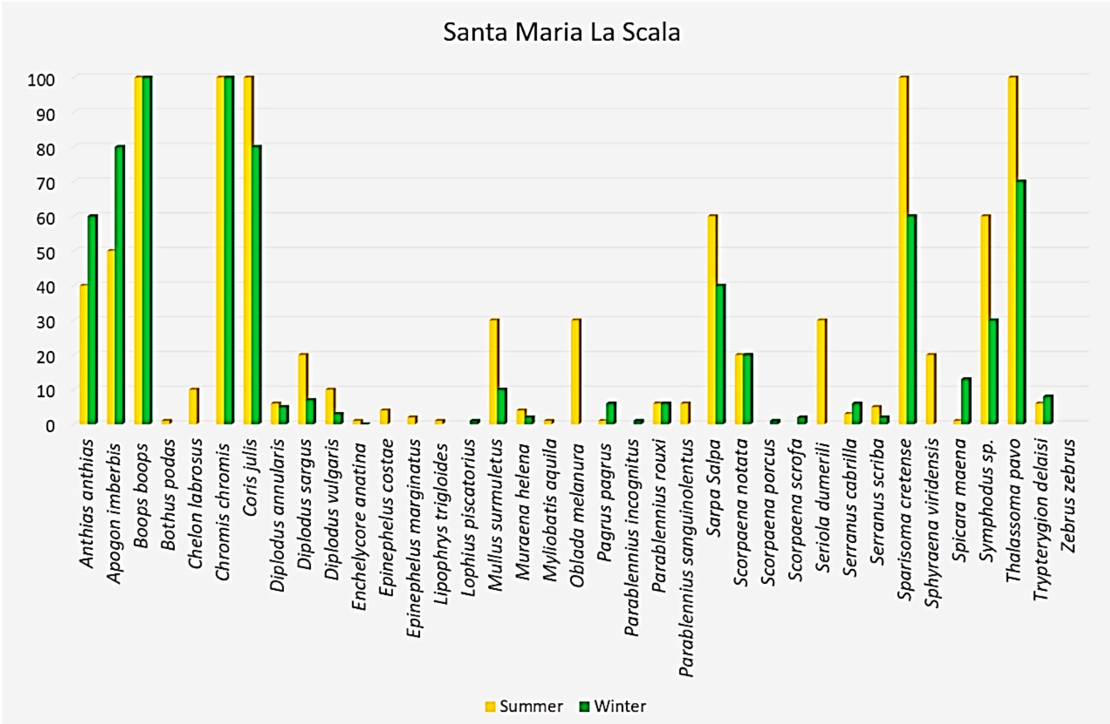

Figure 6. Bar chart showing the number of fish specimens in summer and winter, in Santa Maria La Scala.

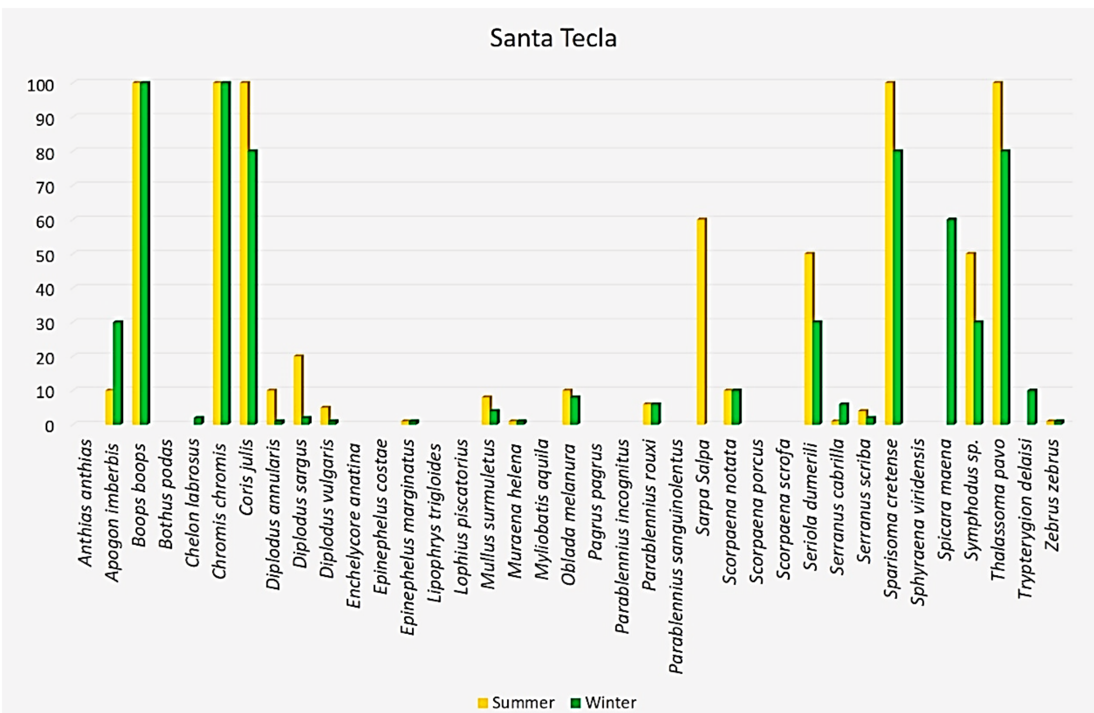

Figure 7. Bar chart showing the number of fish specimens in summer and winter, in Santa Tecla.

the monitoring, a few thalli of *T. ballesterosii* were observed, and most of them presented scars along the thallus related to the activity of grazing; instead a higher number of thalli of *C. zosteroides* were found. Table 4 shows the presence of *T. ballesterosii* and *C. zosteroides* in the different sites throughout the monitoring period.

Discussions

Through the two techniques of the underwater *visual* *census*, the fish communities of Santa Maria La Scala and Santa Tecla have been surveyed. In particular, the *random courses* were useful to analyse rare or cryptic species, while the underwater videos were helpful to improve the identification of pelagic and benthic species. Through data collection, the most “rare” species were found in the bathymetric range of 20-25 m, while the most “frequent” species were in the upper range. Regarding the “very frequent” species, a total of 20 species were recorded several times in the range of 0-10 m, 7 species were equally distributed in both ranges and 10 species were seen more times in the range 20-25 m. Since the highest number of species was seen more times in the upper bathymetric range, it could be hypothesized that at these depths the grazing could impact greater. Subsequently, the development and growth of *T. ballesterosii* may be limited by the herbivores’ pressure in the bathymetric range of 0-10 m.

Concerning Fucales communities, during summer, decline of *T. ballesterosii* and *C. zosteroides* populations was observed. In August, neither species was observed in both sites. From December to February, new *C. zosteroides* thalli have been seen growing, however, new *T. ballesterosii* thalli have never been observed during this study and thalli of this species already present in the sites did not develop new branches. Moreover, during the whole monitoring period, thalli of this species have more rarely been found.

Concerning fish communities, the highest number of the recorded species was observed in summer, in both sites. Therefore, in summer the herbivores' impact could be stronger contributing Fucales decline. The alien fishes of *S. luridus* and *S. rivulatus*, which in other Mediterranean areas were main factors to decline of Fucales assemblages (Sala et al., 2011; Vergés et al., 2014a, b), have never been observed during this study. It may be no favourable conditions for the establishment of these species, which have already been reported in other sites of Sicily (Azzurro and Andaloro, 2004; Castriota and Andaloro, 2008; Cavallaro et al., 2016; Azzurro et al., 2016; Karachle et al., 2016; Stamouli et al., 2017). This could depend on the hydrodynamic regime of the study areas that are related to the Straits of Messina’s tidal currents and the Ionian upwelling current. Furthermore, the springs present in both sites could maintain the local waters fresher, reducing the settlement of Siganidae Richardson, 1837.

During the monitoring period, it was observed that *S. cretense* populations are stable in summer and winter. Nevertheless, a higher number of parrotfish was found in summer than winter, confirming the thermophilic nature of this species. In the last few years, local fishermen and divers have observed an expansion in parrotfish populations in these areas. In addition, in many Mediterranean areas, it has been documented an extension of the parrotfish distributional pattern (Guidetti and Boero, 2002; Abecasis et al., 2005; Astruch et al., 2016). This northward expansion of thermophilic species is an indirect sign of the rise in temperature of Mediterranean waters, which has been defined as "meridionalisation” (Boero et al., 2008).

During the monitoring period, it has been seen a lower number of *S. salpa* than those of *S. cretense* in both study areas. Therefore, in these sites *S. cretense* could be more competitive than *S. salpa*. In addition, since the parrotfish was observed several times in the upper bathymetric range and also in Apulia was reported in a depth range of 5-15 m (Guidetti and Boero, 2002), it may be hypothesized that this species could hinder the development and growth of *T. ballesterosii* populations.

In conclusion, a higher number of fishes has been seen in summer and this could be related to the loss of *T. ballesterosii* and *C. zosteroides* in summer. Most of the species, and especially *S. cretense* was observed in the bathymetric range of 0-10 m and, thus, the grazing could be more impactive at this depth range and affect mostly *T. ballesterosii* populations. Moreover, through the present study, the status of *T. ballesterosii* and C. *zosteroides* has been checked revealing the populations are in regression, particularly *T. ballesterosii*. During the monitoring period, the alien fishes of *S. luridus* and *S. rivulatus* have not been observed, but a high number of *S. cretense* has been detected in both study areas. In these sites, *S. cretense* seems to be more competitive than the other native herbivorous fish i.e. *S. salpa*. These results could be useful in a Fucales conservation or any restoration plan. Indeed, herbivory is considered one of the major threats to marine forest ecological conservation and restoration (Gianni et al., 2020) especially for early stages and juveniles. Therefore, a knowledge of the herbivorous fish that mostly affect Fucales assemblages in an area, could be useful to project adapted anti-grazing devices, within the context of canopy-forming species restoration. Recently, Gianni et al. (2020) presented an innovative herbivorous fish deterrent device (DeFish), that was tested on *C. amentacea*. Therefore, since it has been observed that in the study areas, one of the major threats for the canopy-forming species is overgrazing, researches on this field will continue to promote the conservation of the marine forests in these sites.

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