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Seasonality of *Edmundsella pedata* (Montagu, 1816) (Nudibranchia Flabellinidae) along the Ionian coasts of Sicily (Central Mediterranean Sea)

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ABSTRACT This work explores the seasonality of *Edmundsella pedata* (Montagu, 1816) (Nudibranchia Flabellinidae) in three sites located along the central-eastern coast of Sicily (Italy). Since most of aeolidacean nudibranchs are subannual, it has been hypothesized that *E. pedata* is also a subannual species with several generations per year. Therefore, *E. pedata*'s trend was studied in the three study areas throughout three years (from 2017 to 2019). Through data collection, it was observed that this nudibranch is an opportunistic and subannual species, which in natural habitats, has an increase in autumn, a peak in winter and a decrease during spring and summer. Instead, in anthropized sites, it was not possible to define a real seasonality of *E. pedata*. In conclusion, throughout the three years, a strong increase in the number of *E. pedata* specimens in all study areas has been seen.

KEY WORDS Aeolidacea; *Edmundsella pedata*; Nudibranchia; seasonality; Sicily.

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INTRODUCTION

Edmundsella pedata (Montagu, 1816) (Figs. 1-4) is a nudibranch of the family Flabellinidae Bergh, 1889, which includes 121 species with a worldwide distribution. In particular, *E. pedata* is a common species along the coasts of eastern Atlantic and Mediterranean Sea (Barletta & Melone, 1976; Thompson & Brown, 1984; Malaquias et al., 2014; Öztürk et al., 2014; Trainito & Doneddu, 2014).

This nudibranch was found in several habitats such as coralligenous, zosteraceae meadows, sandy bottoms, coastal seaweeds, *Peyssonellia polymorpha* (Zanardini) F. Schmitz bottoms, among sublittoral hydrozoans, both on illuminated and shaded rocky walls, rarely on Clorophyta and sponges (Barletta & Melone, 1976). Moreover, *E. pedata* was found also on bryozoans as *Flustra foliacea* (Linnaeus, 1758) and on the sea anemone *Sagartia elegans* (Dalyell, 1848) (McDonald & Nybakken, 1997). According to Clark (1975) and Todd (1981), most of the aeolidacea are considered subannual species with regard to their life cycle. Indeed, these species are ephemeral, with several generations during the year and a r-strategy, showing large fluctuations in abundance during a short time. The rapid growth in size of these species is related to the presence of cerata, which are an adaptation permitting increased rates of assimilation and metabolism (Clark, 1975). In addition, the cerata provide an increase in both respiratory and digestive surface area. These characteristics allow aeolidaceans to feed on transient food which appears early in the microsuccesion of fouling communities (Clark, 1975).

Considering that *E. pedata* feeds on hydrozoans (McDonald & Nybakken, 1997), undergoes wide fluctuations and breeds at different times of the year, it might be assumed that this species is subannual. For that reason, *E. pedata* could be an opportunistic species that tolerates different environmental conditions. The aim of this work is to gain knowledge on the seasonality of this species in the Ionian coasts of Sicily.

MATERIAL AND METHODS

This study was carried out during three years (from 2017 to 2019) in five sites of the central-eastern coast of Sicily (Ionian Sea). Geologically, this area consists of subvolcanic rocks: columnar basalts and effusive submarine products forming fields of pillow lavas (Sciuto et al., 2017). The whole area is characterized by a belt of rocks, up a few meters in size, which are accumulated along the coast and at the base of shallow cliffs (Sciuto et al., 2017). Five stations were studied: two sites, Ognina (37°31'50.4"N, 15°07'10.8"E) and Bellatrix (37°32'03.2"N, 15°07'35.2"E) are located in the municipality of Catania; while three sites, Santa Maria La Scala (37°36'46.5"N, 15°10'31.4"E), Acque Fredde (37°38'15.7"N, 15°10'52.1"E) and Scalo Pennisi (37°38'23.2"N, 15°11'04.6"E), are located in the municipality of Acireale (Fig. 5). These sites were chosen considering different environmental conditions. Indeed, the Ognina and Bellatrix stations are strongly anthropized and, since they are located near each other and have similar ecological conditions, were considered as a single site, listed from now on as "Catania". Moreover, the same reasoning was made for Acque Fredde and Scalo Pennisi, which are situated near each other and are both least impacted sites, thus, are listed from now on as "Santa Tecla". The station of Santa Maria La Scala was considered individually because is far from the other sites and has intermediate conditions between those of Catania and Santa Tecla. Data were collected through underwater visual census with scuba diving. In particular, a total of 224 dives was realized: 74 in Santa Maria La Scala, 83 in Catania (Bellatrix and Ognina), 67 in Santa Tecla (Scalo Pennisi and Acque Fredde). Each scuba dive was carried out about from 9:00 to 11:30 a.m. For each site the same path was followed and specimens of *E. pedata* were photographed with an Olympus TG4 camera and counted in situ. The seasons were considered as follows: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November). Through data collection, the demographic trend of *E. pedata* was assessed. In addition, for each station, specific density was evaluated as mean number of individuals/diving number per site. Using the Arcgis 10.3 software (ESRI® Software, USA), the different sampling areas were geo-referenced (Fig. 5). The experimental design adopted was completely randomized and replicated four times. Data were subjected to analysis of variance (ANOVA). Mean comparisons were performed according to Tukey Minimal Difference (MDS).

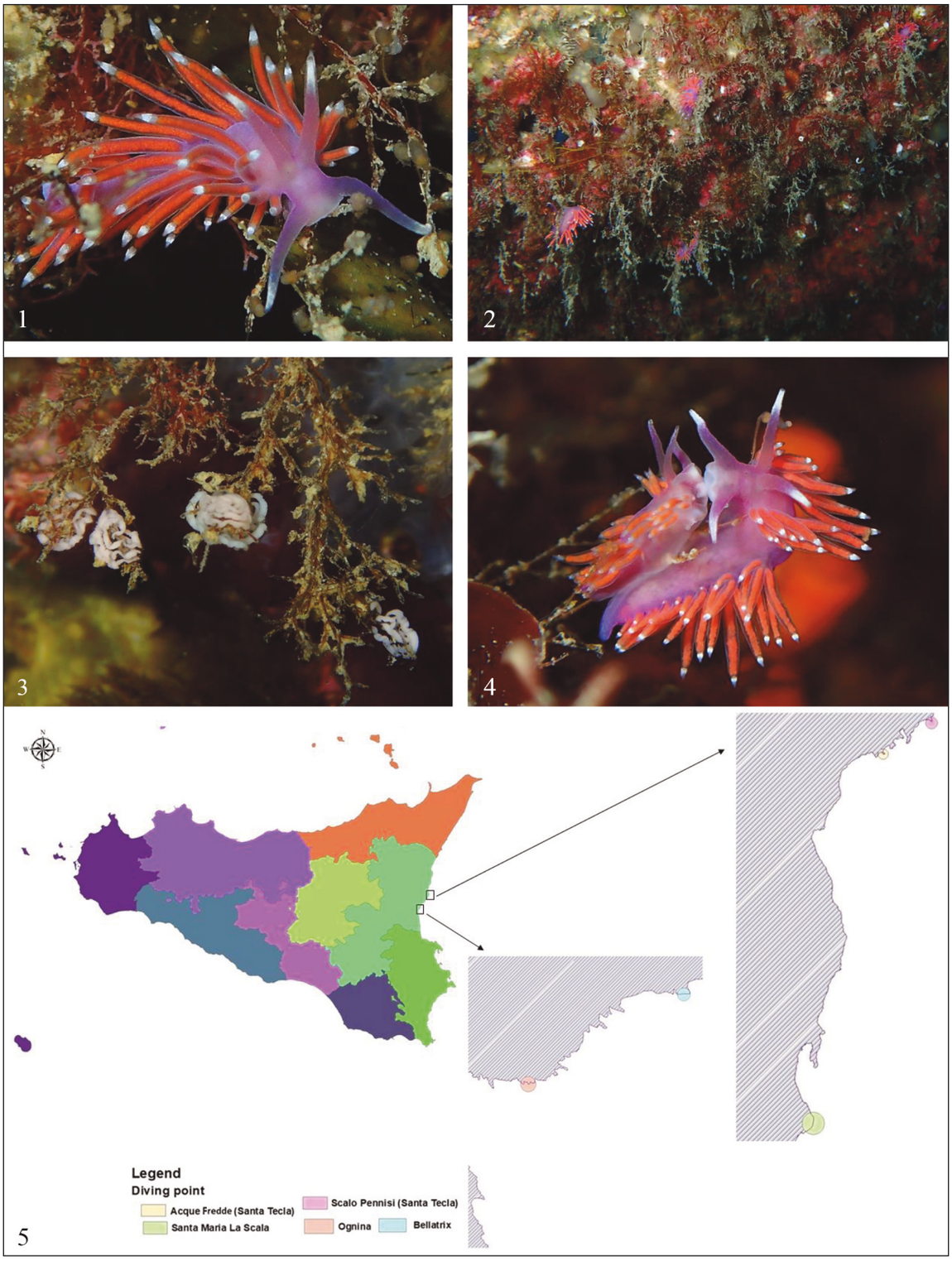
RESULTS

The results showed that *E. pedata* populations were significantly influenced by spatial (different sampling points) and temporal (different years) variations. In "Santa Tecla" station, the *E. pedata* populations showed a significantly demographic increasing, compared to the "Santa Maria la Scala" and "Catania" stations. The communities sampled in Santa Tecla were +56% ($p<0.01$) compared to those found in Santa Maria La Scala and +71.8% compared to those observed in Catania. During the three years' trial, a demographic growing trend was observed in *E. pedata* populations. From 2017 to 2019, an increase in the population of +55% ($p<0.01$) was observed. No differences were observed between 2018-2019 (Fig. 6).

Santa Maria La Scala

In Santa Maria La Scala, the *E. pedata* populations, were significantly influenced by an interaction between seasonal and annual fluctuations (Fig. 7). Over the three years, the communities sampled showed a significantly peak during the winter season. On the contrary, in the other seasons, the observed populations were similar to each other. This trend did not show significant differences between 2017 and 2018.

In 2019 a significant season effect on the populations under study was observed; winter and spring



Figures 1-4. *Edmundsella pedata* from Ionian coasts of Sicily. Fig. 1: lateral view of a *E. pedata* specimen. Fig. 2: *E. pedata* assemblages on *Eudendrium* colonies. Fig. 3: *E. pedata* eggs on *Eundendrium* sp. Fig. 4: two specimens before breeding (photos A. Lombardo). Figure 5. Territorial framework of the diving points.

were the seasons in which the communities showed the highest average number of organisms, while during the summer and autumn the number started to decline. In 2018 the populations showed lowest number of organisms. Comparing 2017 and 2018, the population had suffered a decrease equal to -21% ($p< 0.01$) (Fig. 7).

Santa Tecla

In Santa Tecla area, the *E. pedata* communities were significantly influenced by seasonal fluctuations (Figs. 8, 9). Winter and spring showed a significantly growing trend compared to autumn and summer. These two seasons showed a reduction in organisms' average number. We observed a reduction of 79.5% between winter and autumn, and a reduction of 87.9% ($p< 0.01$) between winter and summer (Fig. 8). During the three years of observation, the *E. pedata* communities showed a significantly demographic increase (from 2017 to 2019) of + 65.5% ($p<0.05$) (Fig. 9).

Catania

Like in Santa Maria La Scala, in Catania too (Fig. 10) the *E. pedata* communities were significantly ($p< 0.05$) influenced by an interaction between seasonal and annual fluctuations. The average number of counted organisms was significantly different over the three years. Unlike the other sampling areas, the maximum number of *E. pedata* was observed during the spring (2018-2019) and during the summer (2017). In 2017 there was a similar growing trend between the winter, spring and autumn seasons. In summer 2018 we observed an absolute absence of *E. pedata* in the study area.

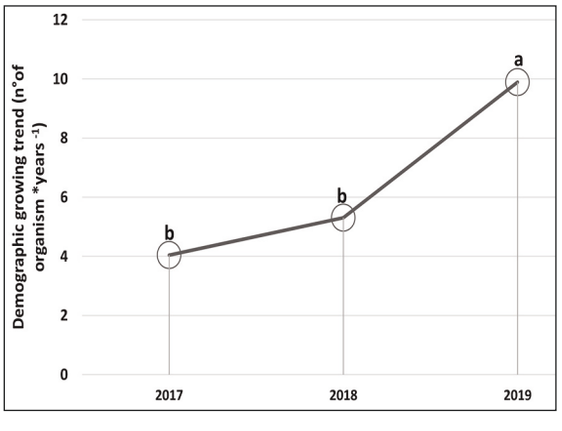


Figure 6. Demographic growing trend observed in a three-year cycle. Different letters indicate differences at $p<0.01$.

Between the spring of 2018 and 2019, an increasing average number of *E. pedata* was observed (+ 27%). The year 2019 showed the highest organisms' average number, despite the marked differences due to seasonality. Indeed, in autumn there was a decrease in communities of -90% compared to spring. In the three years of experimentation, autumn was the only season in which the species showed a significantly similar growing trend (Fig. 10).

DISCUSSIONS

In this work, *E. pedata*'s seasonality in the Ionian coasts of Sicily was explored. The majority of aeolidacean nudibranchs feed on hydrozoans and because there is an intimacy of this feeding relationship, a discussion of nudibranch's ecology must consider the biology of the food species. Todd (1981) highlighted that *E. pedata* is specialized in feeding on the hydrozoan *Ectopleura larynx* (Ellis & Solander, 1786). Moreover, according to Thompson & Brown (1984), juveniles of this species feed on calyptoblastic hydroids (Leptothecata), while adults eat gymnoblastic hydroids (Anthoathecata). Among the Leptothecata, *E. pedata* prey on *Abietinari aabietina* (Linnaeus, 1758), *Aglaophenia* spp., *Halecium halecinum* (Linnaeus, 1758), *Hydrallmania falcata* (Linnaeus, 1758), *Nemertesia* spp., *Obelia geniculata* (Linnaeus, 1758), *Sertularella gayi* (Lamouroux, 1821) (Barletta & Melone, 1976; Todd, 1981; Thompson & Brown, 1984; McDonald & Nybakken, 1997). Among the Anthoathecata, the prey are *Bougainvillia* spp., *Ectopleura larynx*, *Eudendrium racemosum* (Cavolini, 1785), *Eudendrium rameum* (Pallas, 1766), *Eudendrium ramosum* (Linnaeus, 1758), *Eudendrium glomeratum* Picard, 1952, *Garveia nutans* Wright, 1859, *Tubularia indivisa* Linnaeus, 1758 (Barletta & Melone, 1976; Todd, 1981; Schmekel & Portmann, 1982; Thompson & Brown, 1984; McDonald & Nybakken, 1997; Rudman, 1999 [In] Sea Slug Forum; Betti, 2011). During our data collection, the main assemblages of *E. pedata* were often found on *Eudendrium* facies

(Fig. 2). According to Betti (2011), *Eudendrium* (Ehrenberg, 1834) is the favorite source of food of this species and, in particular in the Adriatic Sea, *E. pedata* was often observed on *E. glomeratum*, a hydrozoan that lives in cold waters.

Generally, the hydrozoans are opportunistic and can tolerate different environmental conditions, as for example the species of the genera *Eudendrium* and *Obelia* Péron et Lesueur, 1810. Nevertheless, the temperature has an important role in the composition of hydroid population. In particular, *E. glomeratum* is a winter species that appears in mid-October, reaching the average height of colonies in January, and decreases until April (Boero, 1984). On the other hand, the life cycle of *Eudendrium racemosum* is opposite of *E. glomera*tum's one: the colonies become active from April and are fertile during the summer, but degenerate in autumn (Bavestrello et al., 2006). According to Azzini et al. (2003), in natural oligotrophic habitats, the main factors that establish the seasonality of *E. racemosum* are the temperature and the solar irradiance; while in harbors, in habitats with eutrophic waters and low competition, the life cycle of the colonies is strongly modified and this species is present during the whole year.

Considering these hydrozoans main characteristics, illustrated above, now *E. pedata*'s seasonality in three stations of the Ionian coast of Sicily is described in detail.

Santa Tecla

Santa Tecla is the area of this study in which there are the most stable environmental conditions. In fact, during the three year of observation, *E. pedata* had the same seasonal trend: large assemblages in winter, a starting decrease of the population in spring, the disappearance of almost all individuals in summer and then a new increase

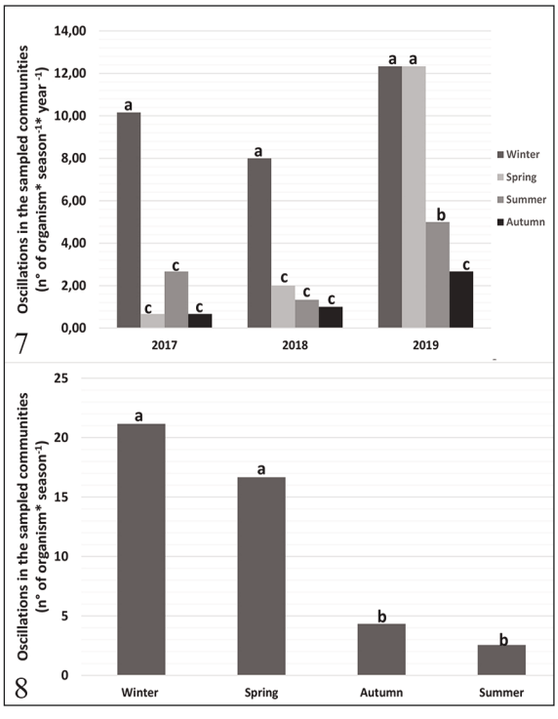


Figure 7. Oscillations in the sampled communities of Santa Maria La Scala during the three years' trial. Different letters indicate differences at $p<0.01$.

Figure 8. Organism number in Santa Tecla sampled communities influenced by seasonal fluctuations. Different letters indicate differences at $p<0.01$.

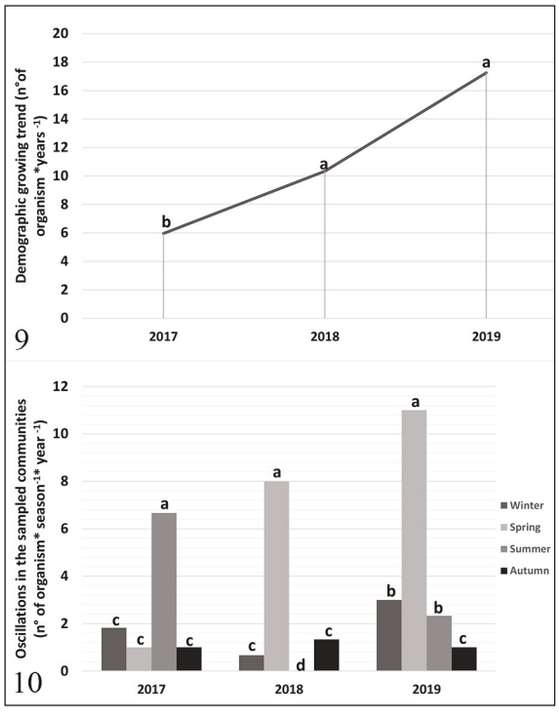


Figure 9. Demographic growing trend observed in a three-year cycle in Santa Tecla. Different letters indicate differences at $p<0.05$.

Figure 10. Oscillations in the sampled communities of Catania during the three years' trial. Different letters indicate differences at $p<0.05$.

in autumn. The stability of the *E. pedata*'s cycle depends on the marked seasonality that its fundamental sources of food, *Eudendrium* spp., present in this site. In fact, a large part of the specimens was found in assemblages on *Eudendrium* colonies where large-sized individuals were frequently observed. In particular, since the highest number of *E. pedata* specimens was observed during the winter, we suppose that probably *E. glomeratum* is its favorite prey in this site in a range of depth of 10-15 m. Moreover, in this station *E. pedata* has found good conditions to grow and reproduce (Fig. 4). During 2018, the spawning activity was observed in winter, spring and summer. In 2019, the activity of spawning was seen during the whole year. From 2017 to 2019, *E. pedata* populations increased (Fig. 9) and thus the probability of breeding was higher. This could explain why in 2019 the eggs were present in all seasons (Fig. 3).

In Santa Tecla generally it has been observed the highest number of specimens compared to the other sites. In fact, Santa Tecla is the northernmost of the locations studied and consequently is the first to be influenced by the currents coming from the Strait of Messina (Di Stefano et al., 2013) and bearing veligers and waters rich in nutrients. Therefore, this area could be the site where the majority of *E. pedata* larvae settles and subsequently metamorphoses.

Santa Maria La Scala

As in Santa Tecla, even in Santa Maria La Scala throughout the three years the highest number of *E. pedata,* specimens were observed during the winter. Only in the spring of 2019 the number of specimens reached the same levels of the winter. Consequently, the winter seems to be the favorite season for the settlement of this species, probably due to the presence of *E. glomeratum* also in this site. Nevertheless, contrary to Santa Tecla, this winter abundance of specimens was followed by a drastic decline, probably due to the overgrazing activity on *Eudendrium*. In fact, according to Clark (1975) during population peaks, the overgrazing on arborescent food species causes disappearance of nudibranchs populations, because the food source serves also as microhabitat.

The high number of specimens in spring 2019 could be explained by allochthonously-produced larvae. In fact, according to Clark (1975), the sudden appearances of populations are due to the arrival of large numbers of larvae, that is related to critical temperatures that stimulate settling and metamorphosis.

In figure 7, it can be observed that in 2017 and 2018 there are two different trends throughout the year, which show a remarkable difference between winter and the other seasons. Only during 2019, there was another trend in summer, that is intermediate between winter-spring and autumn.

In this site, during 2017, *E. pedata* eggs were found only in summer. In 2018, the spawning activity was observed in winter and spring. Instead in 2019, the spawning activity was observed in winter, summer and autumn. The eggs were laid on *Eudendrium* colonies, but also on red and brown seaweeds. Most of the specimens was found in a range of depth of 7-20 m.

Catania

In Catania there was a completely different situation compared to the other sites (Fig. 10). In fact, throughout the three years, the winter has never been the season with a major number of *E. pedata* specimens. Instead, in 2017 the summer was the season with the highest number of specimens, with a little number of individuals in the other seasons. During 2018, the season with major number of specimens was the spring that was followed by summer in which there was an absence of *E. pedata* specimens. Also, the spring of 2019 presented the major number of *E. pedata* specimens, but with a number of individuals even greater than the previous years.

This instability of *E. pedata*'s seasonality in Catania reflects the instability of the cycle of its preys. In fact, in harbors and in eutrophic waters, *Eudendrium*'s seasonality is strongly modified (Azzini et al., 2003). Catania is the most polluted site among the studied ones, because of the nearby harbor, the presence of sewerage and the coastal exploitation. Therefore, in these waters, since *Eudendrium* spp. are probably present during the whole year, *E. pedata* larvae could settle in any time of the year. Thus, the *E. pedata*'s seasonality with a highest number of individuals in winter, in this site, was not maintained. Moreover, in Catania it was observed the lowest number of individuals throughout

the three years, compared to the other sites. This phenomenon could be related to the southernmost position of Catania compared to the other studied sites and thus, Catania is the area which receive the lowest number of *E. pedata* larvae. With regard to *E. pedata* eggs, they were observed only in summer during 2017, in winter and spring during 2018 and, finally, in spring and summer during 2019. The eggs were laid on *Eudendrium* colonies, but also on red and brown seaweeds. Therefore, in Catania during the three years of study, there was not a real seasonality of *E. pedata*, as in the other sites. In this site, most of the specimens were found in a range of depth of 4-15 m

CONCLUSIONS

The aim of this study was to verify if *E. pedata* is a subannual species and to describe its seasonality along the Ionian coasts of Sicily. Through our observations, we found that *E. pedata* generally prefers cold waters, as in the Adriatic Sea (Betti, 2011), but can tolerate also different environmental conditions. In fact, it is an opportunistic species that feeds on different species of hydrozoans. Its subannual cycle can be deduced also for the spawning activity that is present throughout the year. Moreover, through data collection, we observed that probably *Eudendrium pedata* has a life span of maximum three months because changes in the populations happened in every season.

The only station where the seasonality of *E. pedata* was observed was S. Tecla, where there are the most stable environmental conditions and this species presents two trends. On the contrary, Catania is the most polluted and anthropized site and for this reason there is not a real seasonality of this species, which throughout the three years had an irregular trend. Finally, Santa Maria La Scala presents an intermediate situation between Santa Tecla and Catania, showing for the first two years a trend similar to Santa Tecla's, while the third year is different. Therefore, the optimal situation which represents *E. pedata*'s seasonality in the study areas is that observed in S. Tecla, where there is an increase in autumn, a peak in winter and a decrease during spring and summer. Regarding the *E. pedata*'s general demographic trend in all study sites, between 2017 and 2019, there was a strong increase in the number of specimens.

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