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HABITAT PREFERENCE OF COMBTOOTH BLENNIES (ACTINOPTERYGII: PERCIFORMES: BLENNIIDAE) IN VERY SHALLOW WATERS OF THE IONIAN SEA, SOUTH-EASTERN SICILY, ITALY

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Background. In the Mediterranean Sea, habitat preferences of small benthic fishes of shallow waters have been poorly investigated. Although combtooth blennies are not of interest for fisheries, they are often the dominant fish community on rocky bottoms within the first meter of depth and in tidal pool environments, playing so an important role in the functioning of the coastal ecosystem. This study represents the first detailed investigation concerning habitat preference and depth distribution of combtooth blennies in the Ionian Sea.
Materials and methods. Occurrence and abundance of species were investigated by a non-destructive visual census method using snorkelling or SCUBA diving. We investigated 5 habitat types (bathymetric intervals between 0 and 3 m of depth) to find difference in species richness and abundance in each one and between. Studies were conducted from June to October 2014 in the south-eastern coast of Sicily. Statistical method of the electivity index (EI) and principal component analysis (PCA) were utilized for the evaluation of the habitat preference of 11 species of combtooth blennies. Depth distribution for each species was box-plotted. For each habitat and depth, the Shannon–Wiener Index (*H*') and the Simpson Index (*D*) were calculated. Diversity profiles were performed in order to give a better understanding of the correlation between diversity and both habitat types and depth.
Results. During a total of 2485 observations of combtooth blennies a total of 11 species were recorded: *Aidablennius sphynx* (Valenciennes, 1836); *Coryphoblennius galerita* (Linnaeus, 1758); *Lipophrys trigloides* (Valenciennes, 1836); *Microlipophrys canevae* (Vinciguerra, 1880); *Parablennius gattorugine* (Linnaeus, 1758); *Parablennius incognitus* (Bath, 1968); *Parablennius pilicornis* (Cuvier, 1829); *Parablennius sanguinolentus* (Pallas, 1814); *Parablennius zvonimiri* (Kolombatović, 1892); *Salaria pavo* (Risso, 1810); *Scartella cristata* (Linnaeus, 1758). The maximum Shannon–Wiener Index (*H*'= 2.335) and Simpson Index (*D* = 0.898) values were recorded on "rocks with algal cover"; while, concerning the depth, the maximum values of both indices were recorded within the first meter. The diversity indices showed the highest values in the most heterogeneous habitat types. There was a negative correlation between depth and diversity indices. Results showed a clear habitat preference for the following species: *A. sphynx*, *P. gattorugine*, *P. sanguinolentus*, *S. pavo* and *S. cristata*.
Conclusion. This study highlights the importance of depth and habitat heterogeneity in biological diversity, species richness and population abundances of combtooth blennies in the Mediterranean Sea.

Keywords: microhabitat, cryptic species, habitat types, Mediterranean Sea, depth distribution, tidal pool, shallow waters

INTRODUCTION

In the Mediterranean Sea, the habitat preferences concerning small benthic fishes ("cryptobenthic" in particular) have been poorly investigated. This is certainly at least in part due to the fact that fishes such as combtooth blennies are not of commercial interest for fisheries. Even from the point of view of sport fishing, because of their small size, blennies are not an attractive target. However, in many cases they represent the most abundant fish community in very shallow waters and in

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tidal pools environments (Golani et al. 2014), thereby playing an important role for the biodiversity and in the functioning of coastal ecosystems. The majority of species have cryptobenthic behaviour, sensu Miller (1979, 1996), especially those of smaller size, who live inside holes of endolithic bivalves which are positively correlated with the body size of the fish (Kotrschal 1988). The majority of the marine Italian species, 19 in all (Relini and Lanteri 2010), can be found within the first meters of depth with preference for the bathymetric range between the tidal zone and the first meter of depth (Zander 1972, Patzner 1985, Illich and Kotrschal 1990, La Mesa and Vacchi 2005, Orlando-Bonaca and Lipej 2007, Duci et al. 2009). Many species occur in this bathymetric range as true resident and show both morphological end ethological adaptations to this environment (Gibson 1969, 1982, Zander 1972). Concerning the Italian species, in terms of the recent new records (Tiralongo 2012a, 2012b, Tiralongo et al. 2013, Tiralongo and Villani 2014), the majority of the species are widely distributed. In this study we have taken into account only very shallow waters, focusing our efforts within the first 3 m in depth. We have investigated habitat/depth preferences for a total of 11 species of combtooth blennies in 5 different habitat types.

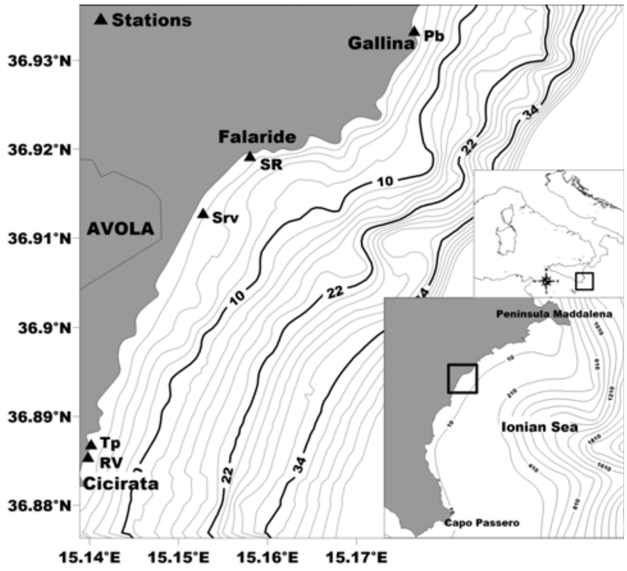

Fig. 1. The study area in the south-eastern coast of Sicily (Ionian Sea); Black triangles indicate the locations of the selected habitat types; Abbreviations: RV = rocks with algal cover, Tp = tidal pool, Srv = subhorizontal hard substrate with algal cover, SR = sand and rocks, Pb = pebbles

MATERIALS AND METHODS

Study area. The study area was located in the south east coast of Sicily (Ionian Sea), exactly along the coast of Avola (Fig. 1). The 5 selected habitat types were distributed along 6 km of coastline. These environments were selected because they represented quite well all the main different habitat types of shallow waters blennies in the Mediterranean Sea. Since the majority of the species of combtooth blennies inhabit very shallow waters, we focused our efforts in the bathymetric range between 0 and 3 m. In two cases, it was not possible to investigate depths exceeding 1 m: "tidal pool" (maximum depth of about 1 m) and "subhorizontal hard substrate with vegetation" (an habitat discontinuity occurred after a depth of about 1 m). Visual census was conducted from June to October 2014, with a periodicity of about 14 days and for a total time of 3850 min. Each of the five habitat types was surveyed eleven times.

Sampling method. Fish-habitat associations were studied by visual census along horizontal transects (21 in spring, 147 in summer, and 63 in autumn). We utilized strip transect 25 m long and 0.5 m wide. Transects tapes were laid at: 0.25 m, 0.5 m, 1 m, 2 m, and 3 m. The number of the performed transects per depth was of 55 in each of the 3 first bathymetric intervals (0.25 m, 0.5 m, 1 m) and 33 in each of the 2 deepest bathymetric intervals (2 m, 3 m). With the exception of the first transect (0.25 m), the transect width included 25 cm to the right and 25 cm to the left of the transect tape. In the shallower transect, the rope was laid along the depth of 25 cm and we registered all observations from about 25 cm above the surface to the rope line. For convenience, in order to standardize the data, we indicatively considered this transect as laying at 0 m. Each transect was kept close to the bottom by weights. Snorkelling equipment was utilized until a depth of 1 m; while SCUBA diving was performed in deeper waters. In very shallow waters, snorkelling is not significantly different from SCUBA diving and, in general, it appears there is not significantly difference between the two methods (Giordano and Neves dos Santos 2014). Bearing in mind the depth, snorkelling is more comfortable in very shallow waters, where SCUBA diving equipment is a hindrance to the normal activity of visual census. The presence of the rope did not significantly disturbed the fishes, that are in general not disturbed even by the presence of the diver. Because of the small sizes and cryptic behaviour of many species, visual census was performed at low speed (1.5 m · $\min^{-1}$). Visual census activities were carried out in the morning between 0800 and 1300 h, with good visibility and sea conditions. We took into account only the presence of the different species of blennies (Blenniidae) at the different habitat types. No distinction was made among sexes, nesting males, and juveniles. In all cases, most of the observations referred to adults.

Habitat types. We defined five types of habitat:

- **Tidal pool** (Tp). The selected tidal pool is the largest (27 m along the coast by 7 m width) of a tidal pools system area. Maximum depth is of about 1 m in the central area. The bottom was covered by sand and large pebbles (>40 cm) located mainly in the central zone. The north side was connected to the sea by a narrow opening of about 1 m width. Green algae of the genus *Enteromorpha* and *Ulva* covered the edges of the pool. Along the rocky edges of the pool, at depths not exceeding 20–30 cm, there were crevices and holes. Some of these shelters were partially or totally covered by algae.

- **Pebbles** (Pb). The bottom was entirely covered by pebbles. The majority of the pebbles ranged from 10 to 30 cm in diameter. Benthic macroalgae were absent. Sea urchins, limpets, and chitons occurred in the lower surface of the pebbles.
- **Sand and rocks** (SR). In this habitat, large rocks were more or less homogeneously distributed on a sandy bottom covering about the 50% of the total bottom surface. The majority of the submerged rocks had a diameter more than 1 m and were covered with algae and encrusting and sessile invertebrates such as limpets and barnacles. Algal cover was composed primarily of *Wrangelia penicillata*, *Dictyota dichotoma*, *Laurencia* spp., *Caulerpa racemosa*, *Halimeda tuna*, *Padina pavonica*, *Acetabularia acetabulum*, and *Ellisolandia elongata*. Few empty date-mussel holes and crevices were scattered on the rocks surface.
- **Subhorizontal hard substrate with algal cover** (Srv). A subhorizontal rocky surface extending down to a depth of 1 m and covered by macroalgae and several encrusting and sessile organisms such as limpets and barnacles. Algal cover was mainly composed by *Ellisolandia elongata*, *Amphiroa sp.,* and Dictyotales gen. sp. The surface was quite smooth, well exposed to the sunlight and to the wave action. Empty date-mussel holes and crevices were present but not abundant and rather scattered.
- **Rocks with algal cover** (RV). The bottom was entirely rocky. Algal cover was abundant and rather evenly scattered. The main species were *Cystoseira* sp., *Ellisolandia elongata*, *Acetabularia acetabulum*, *Cladophora* sp., and *Padina pavonica*. Encrusting and sessile invertebrates were present but not abundant as in the subhorizontal hard substrate. This habitat is the more "cryptic" of the sampled habitat: crevices and holes were quite abundant and the bottom surface was more irregular and showed steep slope features in some areas.

Data analysis. Habitat preference of fish species was evaluated by the statistical method of EI (electivity index), usually used in similar studies in the Mediterranean Sea (Wilkins and Myers 1992, Orlando-Bonaca and Lipej 2005). The relation is defined by the following formula (Strauss 1979):

$$E = \frac{r_i - p_i}{r_i + p_i}$$

where, r_i is the relative abundance of a species in the habitat (as a percentage of the number of specimens in that habitat) and p_i is the relative abundance of the same species in all the habitat types. In order to better support our results concerning habitat preference, data were analysed by principal component analysis (PCA) (Jolliffe 2002). The Jolliffe cut-off value gives an indication of how many principal components should be considered as significant (Jolliffe 2002). Shannon–Wiener Index (H') and Simpson Index (D) (Heip et al. 1998) were calculated for each habitat type and depth interval. Diversity profiles for both habitat types and depths intervals were computed with PASTE 3.11 software. The use of diversity profile allows comparing a number of diversity indices (H' and D) to make sure that the diversity ordering is robust. A formal way of doing this is to define a family of diversity indices, dependent upon a single continuous parameter (Tóthmérész 1995). Depth preference had been highlighted by the use of box plots (Turkey 1977). Box plots are non-parametric: they display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. Concerning the presence, we considered widespread those species found in at least 4 different habitat types.

RESULTS

Habitat biodiversity. During a total of 2485 observations of combtooth blennies a total of 11 species were recorded: *Aidablennius sphynx* (Valenciennes, 1836); *Coryphoblennius galerita* (Linnaeus, 1758); *Lipophrys trigloides* (Valenciennes, 1836); *Microlipophrys canevae* (Vinciguerra, 1880); *Parablennius gattorugine* (Linnaeus, 1758); *Parablennius incognitus* (Bath, 1968); *Parablennius pilicornis* (Cuvier, 1829); *Parablennius sanguinolentus* (Pallas, 1814); *Parablennius zvonimiri* (Kolombatović, 1892); *Salaria pavo* (Risso, 1810); *Scartella cristata* (Linnaeus, 1758). Additional two species—*Parablennius tentacularis* (Brünnich, 1768) and *Microlipophrys dalmatinus* (Steindachner et Kolombatović, 1883)—although recorded, were excluded from analyses because their rarity. Concerning the number of species and specimens, there were clear trends in preferences for habitat and depth. In the lower bathymetric intervals (0 m, 0.5 m, and 1 m) the number of species was high (9, 11, and 11, respectively) and all the species were recorded between the 2 bathymetric intervals of 0.5 and 1 m. In this bathymetric range, the number of observations comprised the 87.3% of the total, while only 6 species were recorded in the two deeper depth intervals, between 2 and 3 m (Table 1). The distribution of species and specimens in relation to the depth was best highlighted through the diversity index values and biodiversity profiles (Fig. 2a). Indeed, the highest diversity values were within the first meter of depth. In the first 3 bathymetric ranges (0 m, 0.5 m, and 1 m) the values of Simpson- and Shannon–Wiener indices were: $D = 0.813$, $H' = 1.864$; $D = 0.820$, $H' = 2.007$; and $D = 0.803$, $H' = 1.978$, respectively. In the last 2 bathymetric intervals (2 m and 3 m), we found the lowest values: $D = 0.741$, $H' = 1.513$ and $D = 0.652$, $H' = 1.317$, respectively (Table 1). The negative correlation between diversity indices and depth was evident: Shannon–Wiener: $r = -0.91$, $P < 0.05$; Simpson: $r = -0.96$, $P < 0.05$. Concerning the habitat type, all the species were recorded in "Sand and rocks" and in "Rocks with algal cover" and 10 species in "Subhorizontal hard substrate with algal cover" (Fig. 3). Instead, in the other two habitat types, "Tidal pool" and "Pebbles", only 5 species were recorded. However, the highest diversity values of Simpson- and Shannon–Wiener indices were found on hard substrate with algal cover (Table 1, Fig. 2b): "Subhorizontal hard substrate with algal cover" (*D* = 0.813; *H*'= 1.932) and "Rocks with algal cover" (*D* = 0.898; *H*'= 2.335). On the other hand, with only 5 species (3 of which were occasional), "Tidal pool" showed the lowest values (*D* = 0.535; *H*'= 0.8717). Intermediate and similar biodiversity values were obtained for "Pebbles" (*D* = 0.678; *H*'= 1.331) and "Sand and rocks" (*D* = 0.644; *H*'= 1.567). In this latter habitat type, although the number of species was maximal, the majority of them were represented by a low number of specimens. Indeed, only *Parablennius sanguinolentus* was represented by a large number of specimens, with a density of 5.8 spec · m^{-2} (specimens per 1 square meter) (Fig. 3). From the PCA emerged a clear association for *A. sphynx* and *S. cristata* concerning the 2nd component; while in *P. sanguinolentus*, *P. gattorugine*, and in *S. pavo* the association concerned the 1st component. The 1st component was highly correlated with "Pb", "SR" and, although in minor amounts, with "Tp"; while, the 2nd component showed a high correlation with "Srv" (Fig. 4).

Individual species preferences. We defined preferences for 11 fish species:

Aidablennius sphynx

This widespread species occurred in all the habitat types and showed a clear bathymetric preference from the surface until a depth of 0.5 m (Fig. 5). It achieved its maximum abundance on "subhorizontal hard substrate with algal cover", which was the more exposed habitat to the wave action. The corresponding density in this habitat was of 3.46 spec · m^{-2} (Fig. 3). This fish so clearly showed a distinct preference for this habitat type, as indicated by the EI value and from PCA (Figs. 4 and 6). Specimens were found both on the bottom surface and inside empty holes of the date mussel, *Lithophaga lithophaga*.

Coryphoblennius galerita

This stenobathic and semi-amphibious fish preferred to stay within the first bathymetric range (Fig. 5), several specimens were observed out of water. This fish mainly occurred on "subhorizontal hard substrate with algal cover" (Fig. 6), where it reached the maximum abundance,

Table 1

Number of species, abundance and diversity of combtooth blennies recorded in this study in the south-eastern coast of Sicily, Ionian Sea

	Depth [m]					Habitat type				
	0	0.5	1	2	3	Tp	Pb	SR	Srv	RV
No. of species	9	11	11	6	6	5	5	11	10	11
No. of specimens	723	803	644	181	134	237	492	628	685	443
Simpson Index	0.813	0.820	0.803	0.741	0.652	0.535	0.678	0.644	0.813	0.898
Shannon–Wiener Index	1.864	2.007	1.978	1.513	1.317	0.871	1.331	1.567	1.932	2.335

Tp = tidal pool, Pb = pebbles, SR = sand and rocks, Srv = subhorizontal hard substrate with algal cover, RV = rocks with algal cover.

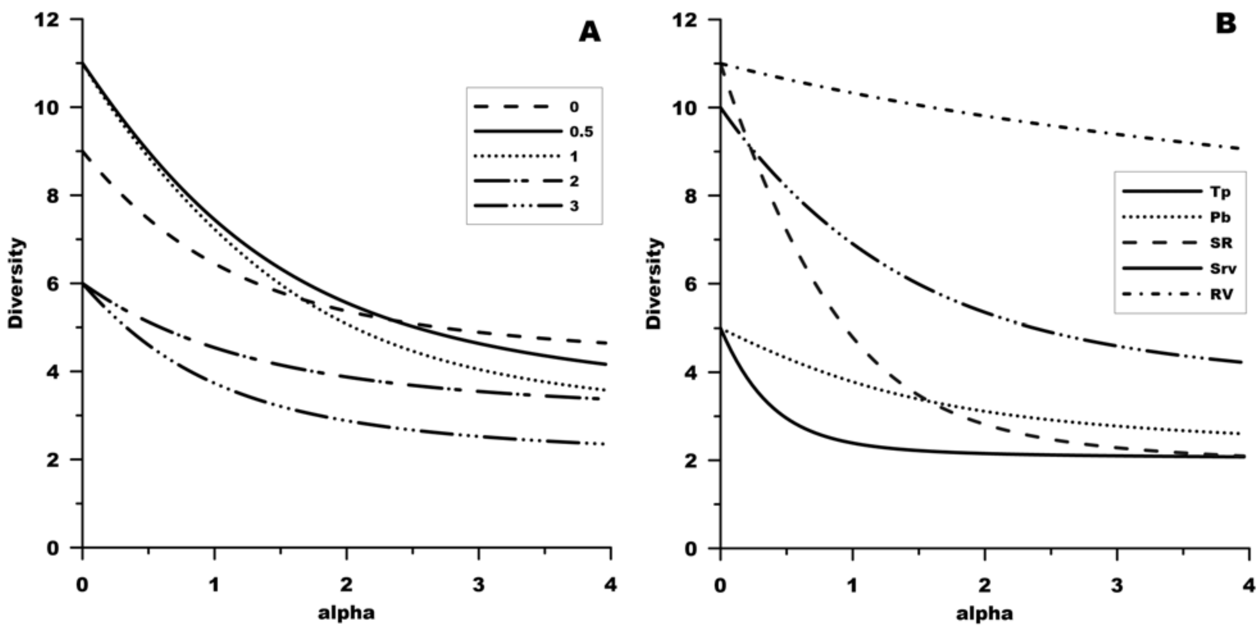

Fig. 2. Diversity profiles of the area studied (south-eastern coast of Sicily, Ionian Sea); in relation to the depth (**A**) and in relation to the habitat type (**B**); Abbreviations: RV = rocks with algal cover, Tp = tidal pool, Srv = subhorizontal hard substrate with algal cover, SR = sand and rocks, Pb = pebbles

with a density of 0.56 spec · m^{-2} (Fig. 3). The majority of the observed specimens were on the bottom. Above the surface, its specimens were found in wet crevices regularly reached by waves.

Lipophrys trigloides

This species inhabited the water volume from the surface to the first meter of depth, with preference for the bathymetric range of 0–0.5 m (Fig. 5), and showed preference for both hard substrate types (Srv and RV) with algal cover and encrusting organisms (Fig. 6). The species density was 0.94 and 0.83 spec · m^{-2}, respectively (Fig. 3). It was usually observed on the hard bottom and rarely into holes or crevices.

Microlipophrys canevae

This species showed a preference—both in terms of depth and habitat selection—similar to that of *Lipophrys trigloides* (Figs. 5 and 6). This fish, however, preferred a wider bathymetric range, from 0 to 1 m depth. The species' densities were slightly lower than those of *L. trigloides* and amounted to 0.67 and 0.54 spec · m^{-2}, respectively for Srv and RV (Fig. 3). *Microlipophrys canevae* was observed on hard substrate and in holes, both on steep and subhorizontal rocks.

Parablennius gattorugine

Compared to all the other species (with the exception of *P. pilicornis*), *P. gattorugine* preferred deeper waters (Fig. 5). This species was never recorded in the first bathymetric interval (0 m) and was observed at depths between 0.5 m and 3 m, with preference for the bathymetric range of 1–3 m. Concerning the habitat type, this species was not widespread and although was present in three habitat types, "pebbles", "sand and rocks", and "rocks with algal cover", it showed a preference for the former (Fig. 6), in which it reached a maximum density of 2.08 spec · m^{-2} (Fig. 3). *Parablennius gattorugine* was only rarely observed in shelters such as crevices or in empty shells of bivalve molluscs. Usually, it occurred on pebbles or rocks surface and hidden under the roof of the pebbles or in crevices if it felt threatened.

Parablennius incognitus

This species was found only in three habitat types ("sand and rocks", "subhorizontal hard substrate with algal cover", and "rocks with algal cover") but in all bathymetric ranges, from the intertidal to the maximum depth investigated (Fig. 5). However, *P. incognitus* preferred depths between 0.5 and 1 m and did not show a clear preference for any of the 3 habitat types (Figs. 4 and 6). The majority of the specimens were observed in empty holes of date mussels. The species' density was 0.784, 1.06, and 1.10 spec · m^{-2}, respectively for SR, Srv, and RV habitats (Fig. 3).

Parablennius pilicornis

This fish was essentially found in "pebbles, "sand and rocks", and "rocks with algal cover" (Fig. 3) and did not show a clear preference for any of these habitat types (Figs. 4 and 6). In "subhorizontal hard substrate with algal cover" the density of the species was negligible (0.08 spec · m^{-2}) while

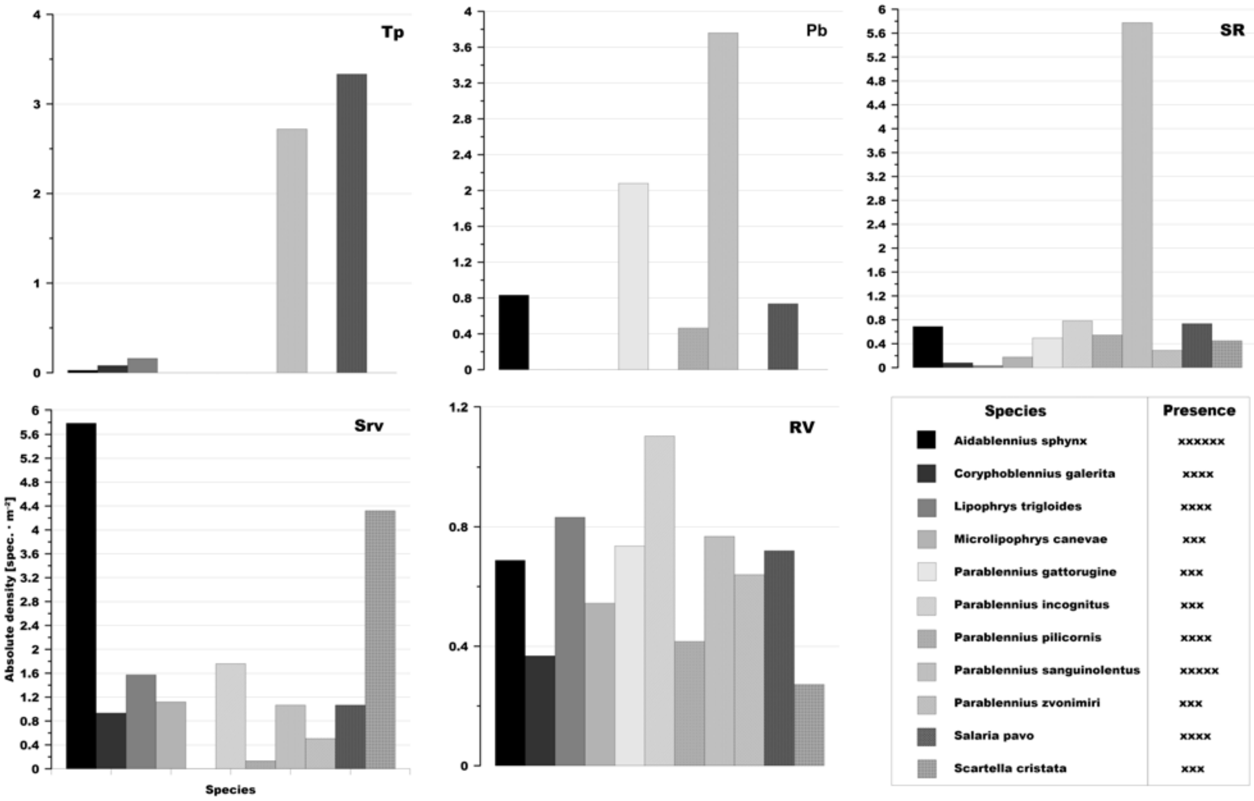

Fig. 3. Specimens' density per m^2 for each species at each habitat type in the area studied (south-eastern coast of Sicily, Ionian Sea); each X indicates the presence of a species in a habitat type; Species with at least four X were considered widespread; Abbreviations: RV = rocks with algal cover, Tp = tidal pool, Srv = subhorizontal hard substrate with algal cover, SR = sand and rocks, Pb = pebbles

in the first 3 habitat types mentioned, the density was 0.46, 0.54, and 0.42 spec · m^{-2}, respectively (Fig. 3). Concerning the depth, we found this species from 0.5 m down to 3 m (Fig. 5). The majority of the specimens were observed on pebbles and on rocks and only rarely in holes or in crevices.

Parablennius sanguinolentus

This fish, similarly to *P. gattorugine*, was never found in empty holes or in other shelters. It was always observed on sand, pebbles, or rocks, at all bathymetric ranges and in all habitat types (Figs. 3 and 5). However, this species clearly showed a preference for "sand and rocks", with a considerable density of 5.78 spec · m^{-2} (Figs. 3, 4 and 6), and was abundant within the first meter of depth with preference for the bathymetric range 0.5–1 m (Fig. 5). Furthermore, *P. sanguinolentus* was the most abundant species in the whole study, with an overall density of 2.99 spec · m^{-2} (Fig. 7).

Parablennius zvonimiri

This species was recorded from the surface down to a depth of 3 m. The majority of the specimens were recorded between 0.5 and 2 m of depth (Fig. 5). *Parablennius zvonimiri* inhabited "sand and rocks", "subhorizontal hard substrate with algal cover", and "rocks with algal cover", with a preference for the latter (Fig. 6), where the species reached a relatively high density of 0.64 spec · m^{-2} (Fig. 3). In SR and RV habitats, the species seemed to prefer the steep rocks with holes; while, in Srv all the specimens were observed on the hard substrate and not in shelters.

Salaria pavo

This species, with a density of 2.0 spec · m^{-2} (Fig. 3), was, together with *Parablennius sanguinolentus*, the most abundant in the "tidal pool" (Fig. 3). Unlike *P. sanguinolentus*, however, *S. pavo* showed a clear preference for this environment (Fig. 6). The species was also present in all the other habitat types, although with a lower number of specimens. Its bathymetric distribution range was between 0 and 1 m (Fig. 5). The majority of the specimens were recorded in the first bathymetric interval. We found specimens both on the bottom and in holes and crevices.

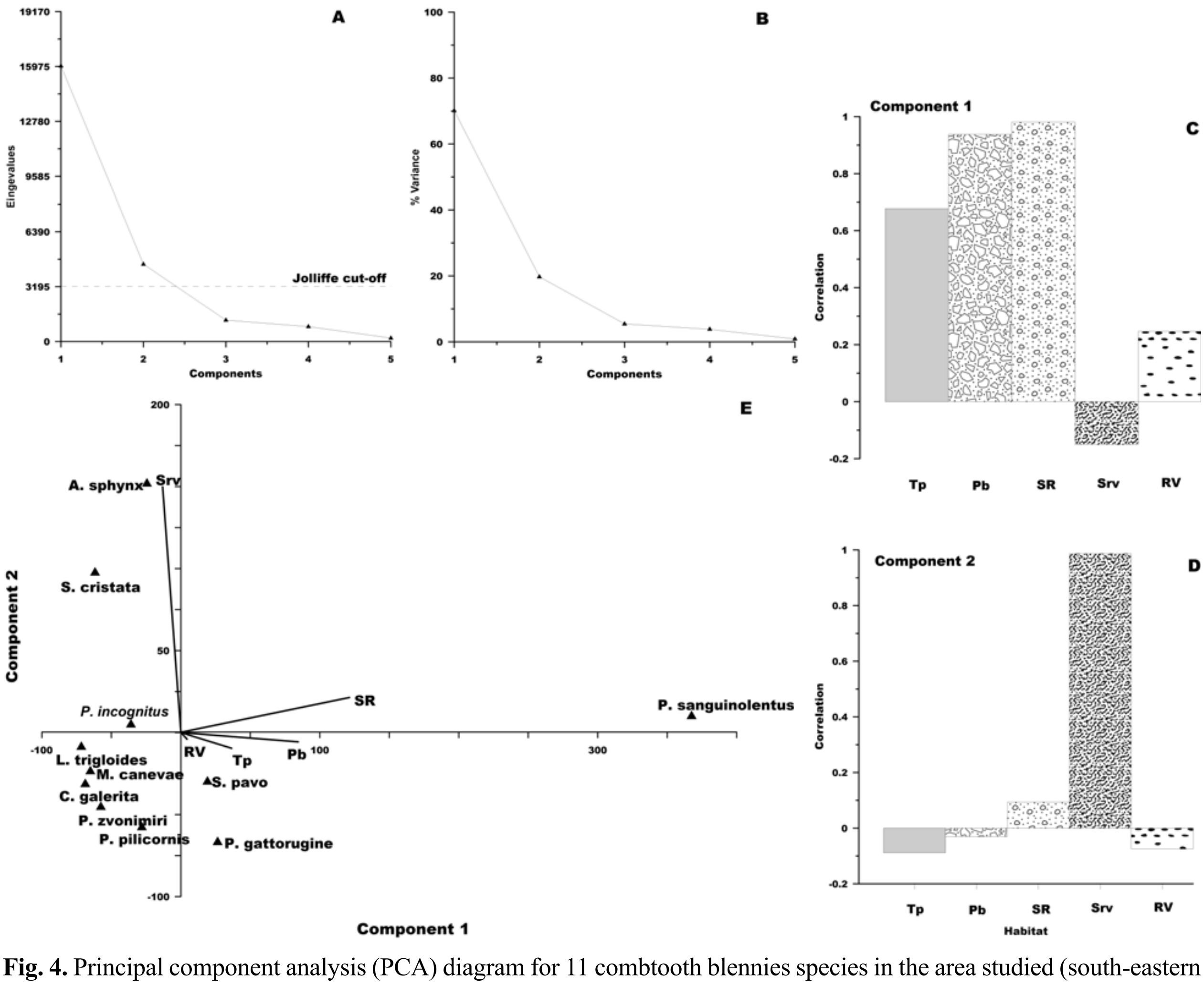

Fig. 4. Principal component analysis (PCA) diagram for 11 combtooth blennies species in the area studied (south-eastern coast of Sicily, Ionian Sea); eigenvalue for each component (dotted line indicate Jolliffe cut-off value) (**A**); percentage of the variance for each component (**B**); correlation between variables and components (**C** and **D**); diagram with the results of PCA (**E**); Abbreviations: RV = rocks with algal cover, Tp = tidal pool, Srv = subhorizontal hard substrate with algal cover, SR = sand and rocks, Pb = pebbles

Scartella cristata

This fish, similarly to *Aidablennius sphynx*, preferred "subhorizontal hard substrate with algal cover" (Figs. 4 and 6) but showed preference for a wider bathymetric range (0–1 m) (Fig. 5). This species was found down to a depth of 3 m, although only few specimens were observed between 2 and 3 m. Specimens were recorded in both in holes and crevices and on rocks surface. On Srv, *Scartella cristata* reached a quite high density of 2.59 spec · m^{-2} (Fig. 3).

DISCUSSION

This study provides new data about the ecology of fishes of the family Blenniidae in the Mediterranean Sea and the first such detailed data for the Ionian Sea. From all the analysis conducted in this research, it can be concluded that the majority of the species prefer to inhabit the first meter of depth (Figs. 2a and 5) and that the habitat types with higher diversity indices are represented by RV and Srv (Table 1, Fig. 2b), where we found a great variety of algae and encrusting invertebrates and/or a considerable number of holes and crevices. On the other hand, simpler habitat, in which vegetation and likewise shelters are scarce or absent, showed lower diversity values, in particular Pb and Tp (Table 1, Fig. 2b). In this latter habitat in particular, with only five species recorded (three of which should be considered occasional), the number of specimens reached the minimum and Simpson index (D = 0.535) and Shannon–Wiener index (H'= 0.872) reached their lower values. The three occasional species found here were: *Aidablennius sphynx*, *Coryphoblennius galerita*, and *Lipophrys trigloides*. In all cases, these species had always been recorded in the side of the pool directly connected with the sea. Among all the species recorded in Tp, only *Salaria pavo* and *Parablennius sanguinolentus* are well adapted to this habitat (Fig. 3). *Salaria pavo*, in particular, even showed a preference for tidal pool, as clearly showed by EI (Fig. 6). Data concerning habitat selection, obtained on the basis of the PCA and EI results (Figs. 4 and 6), assert a clear preference in *A. sphynx* and in *S. cristata* for "subhorizontal hard substrate with algal cover", in *P. sanguinolentus* for "sand and rocks", in *Parablennius gattorugine* for "pebbles". For all the other species investigated, our results did not show any clear preference for any of the 5 habitat types investigated. The benthic fish assemblage recorded in the whole study area consisted additionally of eight small fish species: *Clinitrachus argentatus* (Risso, 1810); *Tripterygion tripteronotum* (Risso, 1810); *Tripterygion melanurum* Guichenot, 1850; *Gobius bucchichi* Steindachner, 1870; *Gobius cobitis* Pallas, 1814; *Gobius paganellus* Linnaeus, 1758; *Scorpaena scrofa* Linnaeus, 1758; and *Scorpaena maderensis* Valenciennes, 1833. As the box plots and the diversity profile of the depth show (Fig. 5, Fig. 2a), the majority of blenniids were recorded in the first meter of depth (all the 11 species were recorded in the bathymetric range between 0.5 and 1 m). The number of species then decreased in deeper waters—in the bathymetric range between 1 and 3 m it remained constant at six. *Parablennius sanguinolentus* was recorded in all the bathymetric intervals investigated, with preference for the bathymetric range 0–1 m, and was the most abundant species in the whole study (Fig. 7). In "pebbles" and "sand and rocks", it reached the maximum density

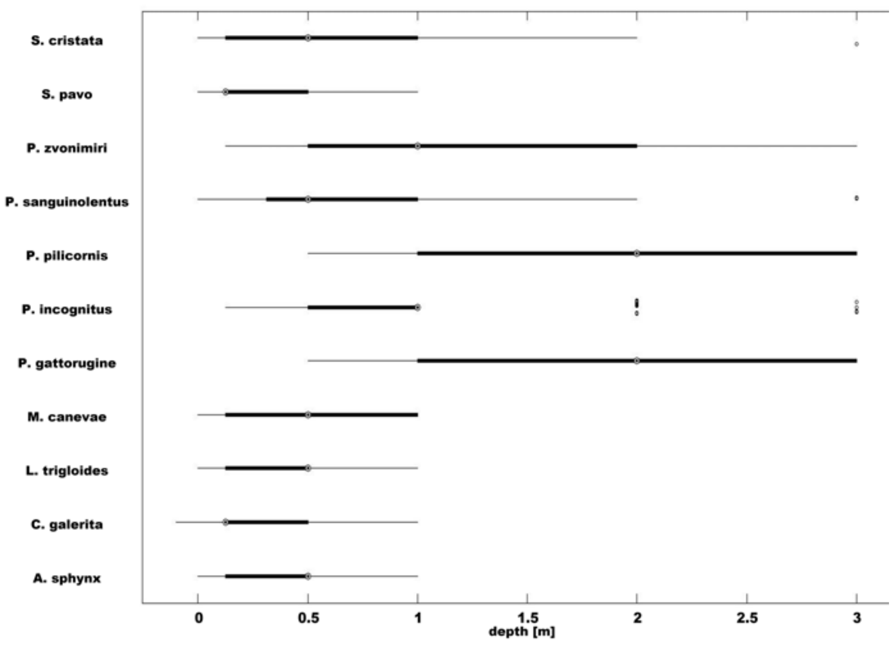

Fig. 5. Box-plot of depth distribution of the studied combtooth blennies in the south-eastern coast of Sicily (Ionian Sea); For each box, the central mark is the median, the edges of the box are the 25th and the 75th percentiles, and the line (whiskers) extend to the most extreme data points without including the outliers; outliers are plotted individually

with 3.76 spec · m^{-2} and 5.78 spec · m^{-2}, respectively (Fig. 3). We never found the fish in holes, which are anyway scarce or absent in the two habitat types. We can therefore consider *P. sanguinolentus* as a eurybathic and widespread species. *Lipophrys trigloides* and *Microlipophrys canevae* showed very similar preferences in terms of habitat type and depth, reaching their maximum abundance within the bathymetric range of 0–0.5 m and 0–1 m, respectively (Fig. 5), on hard substrate with vegetation: RV and Srv (Figs. 3 and 6). We can so consider these species as

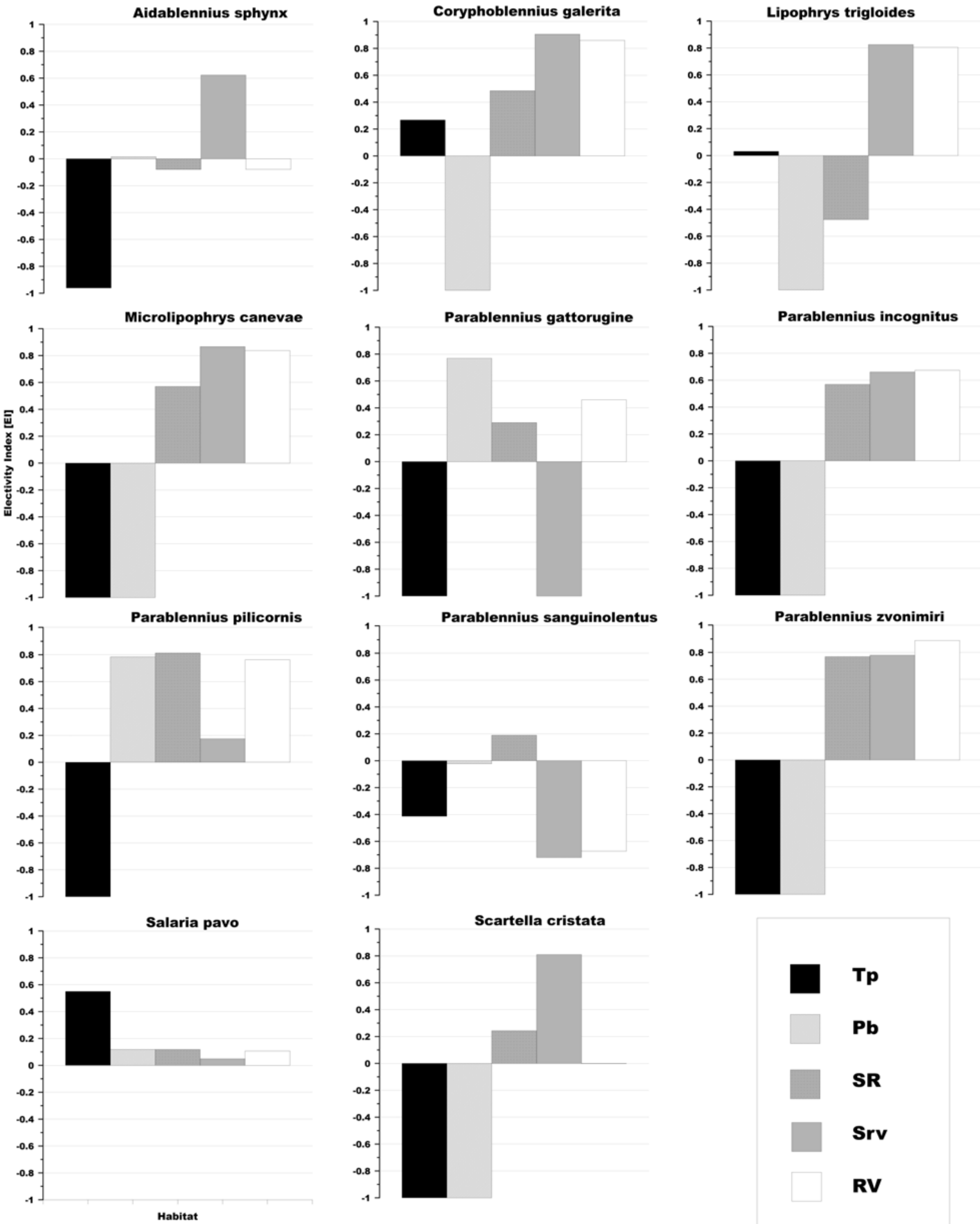

Fig. 6. Electivity indices for the studied 11 combtooth blennies in the south-eastern coast of Sicily (Ionian Sea) at each habitat type; Tp = tidal pool, Pb = pebbles, SR = sand and rocks, Srv = subhorizontal hard substrate with algal cover, RV = rocks with algal cover

syntopics. In contrast with other studies (Zander 1980, Zander 1983, Zander 1986, La Mesa and Vacchi 2005), these species were not necessarily associated with the steep rocks, as also reported by La Mesa et al. (2004) for *Lipophrys trigloides* in the Ionian Sea. *Coryphoblennius galerita* showed a preference for the intertidal (from 25 cm above the surface to 25 cm below the surface), on hard substrate with vegetation. The abundance of barnacles, the main food item of the species (Zander 1986), most likely plays a fundamental role for the presence of *C. galerita* in these habitat types. A noteworthy observation was that *P. zvonimiri*, unlike other studies (Patzner 1999, Orlando-Bonaca and Lipej 2007, Duci et al. 2009), was found starting from the surface (Fig. 5). We can so consider it as eurybathic in comparison with the majority of the other shallow water species studied in this work. However, according to La Mesa and Vacchi (2005), *P. zvonimiri* prefers to inhabit steep rock surfaces, where there is a good availability of holes and crevices. *Aidablennius sphynx* and *Scartella cristata* were very abundant in the first meter of depth, on subhorizontal hard substrate exposed to wave action and light with algal cover mainly represented by *Ellisolandia elongata*, *Amphiroa* sp., and Dictyotales. These syntopic species prefer this type of habitat, in which vegetation and shelters were abundant. Furthermore, the abundance of these herbivorous/detrivorous species, *S. cristata* in particular (Nieder 1997, Mendes et al. 2009), in this wave-exposed habitat was probability also due to the positive correlation with the availability of epilithic algae and detritus (Wilson 2001). In this habitat type, *Parablennius incognitus*, which is a species that mainly feeds on algae and detritus (Goldschmid and Kotrschal 1981), was also relatively abundant. This species was found as the most abundant in a study conducted in the Adriatic Sea (Illich and Kotrschal 1990); while, in our study it represented only the 7.4% of the total (Fig. 7), with a maximum density of 1.1 spec · m^{-2} and 1.06 spec · m^{-2} reached, respectively, in RV and Srv (Fig. 3). *Parablennius pilicornis*, a non-indigenous species that was only recently recorded in the area (Tiralongo 2012a), was found between 0.5 and 3 m depth in all habitat types, with the exception of the tidal pool. Although it is abundant in some areas of the western Mediterranean Sea (Pastor and Francour 2010), in the study area *P. pilicornis* was not abundant and reached its maximum abundance on "sand and rocks", with a density of 0.53 spec · m^{-2} (Fig. 3). *Parablennius gattorugine* showed the same depth distribution of *P. pilicornis*, but, unlike *P. pilicornis*, it showed a preference for "pebbles" (Fig. 6). However, because we focused our efforts in the first 3 m depth, in the cases of *P. pilicornis* and *P. gattorugine*, that appear to inhabit in a wider bathymetric range (Fig. 5), we are not able to make considerations about their depth preferences, but we can assert that they are not abundant in the first meter depth. *Parablennius tentacularis* and the recently first recorded species *Microlipophrys dalmatinus* (see Tiralongo et al. 2013) were excluded from analyses because their rarity in the study area (Fig. 7). However, the former was recorded with 19 observations only in "sand and rocks", between 1 and 3 m in depth. The latter was instead recorded with only nine observations: three on "subhorizontal hard substrate with algal cover" at 0.5 m in depth and six on "rocks with algal cover" at the same depth. *Blennius ocellaris* Linnaeus, 1758; *Parablennius rouxi* (Cocco, 1833); and *Microlipophrys nigriceps* (Vinciguerra, 1883), although recorded in this area of the Ionian Sea (Relini and Lanteri 2010), were never observed in our study. The former inhabits deeper waters (Lipej and Richter 1999), while *P. rouxi* and *M. nigriceps*, although they were observed in shallow waters, still show a preference for deeper waters (Orlando-Bonaca and Lipej 2007). The most widespread species in our study were the following: *A. sphynx*, *C. galerita*, *L. trigloides*, *P. pilicornis*, *P. sanguinolentus*, and *S. pavo* (Fig. 3). Concerning the depth, we were able to consider 6 stenobathic species: *A. sphynx*, *C. galerita*, *L. trigloides*, *M. canevae*, *P. incognitus*, and *S. pavo*. In particular, *A. sphynx*, *C. galerita, L. trigloides*, and *S. pavo* were more abundant within the bathymetric range of 0–0.5 m (Fig. 5). Among these latter species, *S. pavo* and the semi-amphibious *C. galerita* showed a preference for the intertidal zone. The three most abundant species observed that, all together, represent the 58.1% of the total were: *P. sanguinolentus* (31.6%), *A. sphynx* (14.3%), and *S. pavo* (12.2%) (Fig. 7). In conclusion, the highest values of Shannon–Wiener (*H*') and Simpson index (*D*) were found within the first meter of depth (Table 1, Fig. 2a). Then, the values of both indices decreased in deeper waters. Concerning the habitat type preferences, the highest diversity values were found in the two hard rocky substrates with algal cover (Table 1, Fig. 2b): Srv and RV.

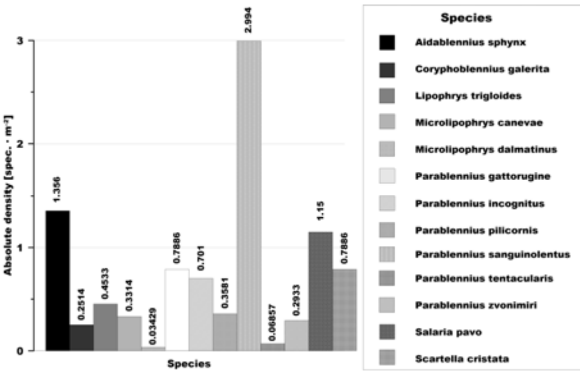

Fig. 7. Absolute specimens' density per m^2 for each species of Blenniidae in the south-eastern coast of Sicily (Ionian Sea)

Although further investigations needed, yet the results obtained in the study area clearly indicate depth and habitat preference for some species of combtooth blennies in the Ionian Sea. For the other species, the results did not show clear evidence of habitat preferences and further studies are necessary to better understand the correlation between blennies presence/abundance and habitat/microhabitat features. In all cases, maximum biodiversity values were found for those habitat types that showed a well developed cover of algae and sessile and encrusting organisms abundance with the presence of holes and crevices. These environments with a high degree of physical heterogeneity would offer greater shelters and food availability used by blennies community to growth and reproduce. However, as reported in other studies (Abel 1962, Zander and Heymer 1977, Illich and Kotrschal 1990, Macpherson 1994, Macpherson and Zika 1999, Nieder et al. 2000), a lot of variables such as bottom slope, bottom nature, cover type, substratum complexity, light, and exposure to water movements, are relevant in determining the habitat choice, playing a fundamental role in the distribution pattern of combtooth blennies, and should therefore be further investigated.

REFERENCES

Abel E.F. 1962. Freiwasserbeobachtungen an Fischen im Golf von Neapel als Beitrag zur Kenntnis ihrer Ökologie und ihres Verhaltens. Internationale Revue der gesamten Hydrobiologie **47** (2): 219–290. DOI: 10.1002/iroh.19620470204

Duci A., Giacomello E., Chimento N., Mazzoldi C. 2009. Intertidal and subtidal blennies: Assessment of their habitat through individual and nest distribution. Marine Ecology Progress Series **383**: 273–283. DOI: 10.3354/meps07986

Gibson R.N. 1969. The biology and behavior of littoral fish. Oceanography and Marine Biology Annual Review **7**: 367–410.

Gibson R.N. 1982. Recent studies on the biology of intertidal fishes. Oceanography and Marine Biology Annual Review **20**: 363–414.

Giordano R.G., Neves dos Santos L. 2014. Comparative analysis of free and scuba diving for benthopelagic and cryptic fish species associated with rocky reefs. Latin American Journal of Aquatic Research **42** (2): 301–306. DOI: 10.3856/vol42-issue2-fulltext-2

Golani D., Reef-Motro R., Ekshtein S., Baranes A., Diamant A. 2014. Ichthyofauna of the rocky coastal littoral of the Israeli Mediterranean, with reference to the paucity of Red Sea (Lessepsian) migrants in this habitat. Marine Biology Research **3** (5): 333–341. DOI: 10.1080/17451000701635110.

Goldschmid A., Kotrschal K. 1981. Feeding ecology of three populations of *Blennius incognitus* Bath 1968 (Pisces: Teleostei: Blenniidae) during the reproductive period and under human influence. Marine Ecology **2** (1): 1–14. DOI: 10.1111/j.1439-0485.1981.tb00087.x

Heip C.H.R., Herman P.M.J., Soetaert K. 1998. Indices of diversity and evenness. Océanis **24** (4): 61–87.

Illich I.P., Kotrschal K. 1990. Depth distribution and abundance of northern Adriatic littoral rocky blennioid fishes (Blenniidae and *Tripterygion*). Marine Ecology **11** (4): 277–289. DOI: 10.1111/j.1439-0485.1990.tb00384.x

Jolliffe I.T. 2002. Principal component analysis. 2nd edn. Springer, New York.

Kotrschal K. 1988. Blennies and endolithic bivalves: Differential utilization of shelter in Adriatic Blenniidae (Pisces: Teleostei). Marine Ecology **9** (3): 253–269. DOI: 10.1111/j.1439-0485.1988.tb00332.x

La Mesa G., Micalizzi M., Giaccone G., Vacchi M. 2004. Cryptobenthic fishes of the "Ciclopi Islands" marine reserve (central Mediterranean Sea): assemblage composition, structure and relations with habitat features. Marine Biology **145** (2): 233–242. DOI: 10.1007/s00227-004-1315-9

La Mesa G., Vacchi M. 2005. Analysis of blennioid assemblages associated with different rocky shore habitats in the Ligurian Sea. Journal of Fish Biology **66** (5): 1300–1327. DOI: 10.1111/j.1095-8649.2005.00684.x.

Lipej L., Richter M. 1999. Blennioids (Blennioidea) of the Slovenian coastal waters. Annales Series Historia Naturalis **9**: 15–24.

Macpherson E. 1994. Substrate utilization in a Mediterranean littoral fish community. Marine Ecology Progress Series **114** (2): 211–218. DOI: 10.3354/meps114211

Macpherson E., Zika U. 1999. Temporal and spatial variability of settlement success and recruitment level in three blennoid fishes in the northwestern Mediterranean. Marine Ecology Progress Series **182**: 269–282. DOI: 10.3354/meps182269

Mendes T.C., Villaça R.C., Ferreira C.E.L. 2009. Diet and trophic plasticity of an herbivorous blenny *Scartella cristata* of subtropical rocky shores. Journal of Fish Biology **75** (7): 1816–1830. DOI: 10.1111/j.1095-8649.2009.02434.x

Miller P.J. 1979. Adaptiveness and implications of small size in teleosts. Symposia of the Zoological Society of London **44**: 263–306.

Miller P.J. 1996. The functional ecology of small fish: some opportunities and consequences. Symposia of the Zoological Society of London **69**: 175–199.

Nieder J. 1997. Seasonal variation in feeding patterns and food niche overlap in the Mediterranean Blennies *Scartella cristata*, *Parablennius pilicornis* and *Lipophrys trigloides* (Pisces: Blenniidae). Marine Ecology **18** (3): 227–237. DOI: 10.1111/j.1439-0485.1997.tb00439.x

Nieder J., La Mesa G., Vacchi M. 2000. Blenniidae along the Italian coasts of the Ligurian and the Tyrrhenian sea: Community structure and new records of *Scartella cristata* for northern Italy. Cybium **24** (4): 359–369.

Orlando-Bonaca M., Lipej L. 2005. Factors affecting habitat occupancy of fish assemblage in the Gulf of Trieste (Northern Adriatic Sea). Marine Ecology **26** (1): 42–53. DOI: 10.1111/j.1439-0485.2005.00037.x

Orlando-Bonaca M., Lipej L. 2007. Microhabitat preferences and depth distribution of combtooth blennies (Blenniidae) in the Gulf of Trieste (North Adriatic Sea). Marine Ecology **28** (4): 418–428. DOI: 10.111/j.1439-0485.2007.00185.x

Pastor J., Francour P. 2010. Occurrence and distribution range of *Parablennius pilicornis* (Actinopterygii: Perciformes: Blenniidae) along the french mediterranean coast. Acta Ichthyologica et Piscatoria **40** (2): 179–185.
DOI: 10.3750/AIP2010.40.2.11

Patzner R.A. 1985. The blennies (Pisces, Blennioidea) at the Marine Biological Station of Aurisina (Gulf of Trieste, Italy). Nova Thalassia **7**: 109–119.

Patzner R.A. 1999. Habitat utilization and depth distribution of small cryptobenthic fishes (Blenniidae, Gobiesocidae, Gobiidae, Tripterygiidae) in Ibiza (western Mediterranean Sea). Environmental Biology of Fishes **55** (3): 207–214.
DOI: 10.1023/A:1007535808710

Relini G., Lanteri L. 2010. Osteichthyes. Biologia Marina Mediterranea **17**(1): 649–674.

Strauss R.E. 1979. Reliability estimates for Ivlev's Electivity index, the forage ratio, and a proposed linear index of food selection. Transactions of the American Fisheries Society **108** (4): 344–352.
DOI: 10.1577/1548-8659(1979)108<344:refiei>2.0.co;2

Tiralongo F. 2012a. Prima segnalazione di Bavosa africana, *Parablennius pilicornis* (Cuvier, 1829), nelle acque ioniche della Sicilia sudorientale, Avola (SR). [First record of the Ringneck blenny, *Parablennius pilicornis* (Cuvier, 1829), in Ionian waters of the south-east Sicily, Avola (SR).] Notiziario S.I.B.M. **62**: 62–64. [In Italian.]

Tiralongo F. 2012b. Prima segnalazione di Bavosa crestata, *Scartella cristata* (Linneo, 1758), nelle acque ioniche d'Italia. [First record of the Molly Miller, *Scartella cristata* (Linnaeus, 1758), in the Italian Ionian sea.] Notiziario S.I.B.M. **62**: 65–68. [In Italian.]

Tiralongo F., Villani G. 2014. New record of the rare combtooth blenny *Hypleurochilus bananensis* (Poll, 1959) (Pisces Blenniidae) for the Mediterranean Sea. Naturalista Siciliano **38** (1): 85–88.

Tiralongo F., Tibullo D., Baldacconi R. 2013. First record of *Microlipophrys dalmatinus* (Steindachner & Kolombatovic, 1883), (Pisces: Blenniidae), in the Ionian Sea. Pp. 472–473. *In*: Bilecenoglu M., Alfaya J.E.F., Azzurro E., Baldacconi R., Boyaci Y.Ö., Circosta V., Compagno L.J.V., Coppola F., Deidun A., Durgham H., Durucan F., Ergüden D., Fernández-Álvarez F.Á., Gianguzza P., Giglio G., Gökoğlu M., Gürlek M., Ikhtiyar S., Kabasakal H., Karachle P.K., Katsanevakis S., Koutsogiannopoulos D., Lanfranco E., Micarelli P., Özvarol Y., Peña-Rivas L., Poursanidis D., Saliba J., Sperone E., Tibullo D., Tiralongo F., Tripepi S., Turan C., Vella P., Yokeş M.B., Zava B. New Mediterranean marine biodiversity records (December, 2013). Mediterranean Marine Science **14** (2): 463–480.
DOI: 10.12681/mms.676

Tóthmérész B. 1995. Comparison of different methods for diversity ordering. Journal of Vegetation Science **6** (2): 283–290.
DOI: 10.2307/3236223

Turkey J.W. 1977. Exploratory Data Analysis. Addison-Wesley, Reading, MA, USA.

Wilkins H.K.A., Myers A.A. 1992. Microhabitat utilization by an assemblage of temperate Gobiidae (Pisces, Teleostei). Marine Ecology Progress Series **90**: 103–112.
DOI: 10.3354/meps090103

Wilson S. 2001. Multiscale habitat associations of detrivorous blennies (Blenniidae: Salariini). Coral Reefs **20** (3): 245–251.
DOI: 10.1007/s003380100165

Zander C.D. 1972. Beiträge zur Ökologie und Biologie von Blenniidae (Pisces) des Mittelmeeres. Helgoländer Wissenschaftliche Meeresuntersuchungen **23** (2): 193–231.
DOI: 10.1007/BF01609689

Zander C.D. 1980. Morphological and ecological investigations on sympatric *Lipophrys* species (Blenniidae, Pisces). Helgoländer Wissenschaftliche Meeresuntersuchungen **34**: 91–110.

Zander C.D. 1983. Terrestrial sojourns of two Mediterranean blennioid fish. Senckenbergiana Maritima **15**: 19–26.

Zander C.D. 1986. Blenniidae. Pp. 1096–1112. *In*: Whitehead P. J. P., Bauchot M. L., Hureau J. C., Nielsen J., Tortonese E. (eds.) Fishes of the North-eastern Atlantic and the Mediterranean. UNESCO, Paris.

Zander C.D., Heymer A. 1977. Analysis of ecological equivalents among littoral fishes. Pp. 621–630. *In:* Keegan B.F., Ceidigh P.O., Boaden P.J.S. (eds.) Biology of benthic organisms. Pergamon Press, Oxford, UK.

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