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Preferences of the Common Octopus *Octopus vulgaris* Cuvier, 1797 (Cephalopoda: Octopodidae) to Artificial Nests Placed in Different Habitats at Urla Islands, Aegean Sea, Turkey

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Abstract: The common octopus *Octopus vulgaris* Cuvier, 1797 exhibits specific building den characteristics. This specific sheltering behaviour is a factor affecting distribution and abundances of octopuses in the marine environment. Based on this, the preference of octopuses to natural dens and artificial nests located in two habitats, i.e. sea-grass meadows of Neptune grass *Posidonia oceanica* (L.) Delile and sandy bottom areas, was determined. Totally, 200 artificial nests were placed along shores of Urla Islands, Aegean Sea, and observed through three years. During the study, a total of 245 octopuses were observed and 107 of them (43.67%) inhabited natural dens while 138 were found in artificial nests (56.33%). For those from artificial nests, octopuses preferred Neptune grass habitats (66.33%) and only 33.33% of individuals gave a preference to sandy areas. In the case of natural dens, these rates were 52.34% for Neptune grass meadows and 47.66% for sandy habitats. These results indicate that Neptune grass areas are preferred by octopuses in terms of using artificial nests with higher ratio.

Key words: Artificial reef, den ecology, Aegean Sea

Introduction

Octopus vulgaris Cuvier, 1797 is a member of the family Octopodidae, which consists of more than 200 species (Jereb et al. 2016). This species has a wide geographical distribution and is the most studied species of the genus; it is a coastal inhabitant, living in rocky areas or reefs in shallow-waters (Belcari & Sartor 1999, Quetglas et al. 2000, Silva et al. 2002, García & Valverde 2006, Garofalo et al. 2010, Ibáñez & Keyl 2010). It has a short life span of 12-18 months (Iglesias et al. 2004, Katsanevakis & Verriopoulos 2006) and exhibits a rapid growth rate of more than 5% increase of its total body weight per day (García & Valverde 2006, Ibáñez & Keyl 2010). Its reproduction period spreads throughout the entire year (Hastie et al. 2009). The common octopus is a mobile predator, which seeks and finds its food and suitable shelter (building shelters called “dens”) using both tactile and visual senses (Forsythe & Hanlon 1997, Carvalho & Sousa Reis 2003, Rodríguez-rúa et al. 2005). However, there is a paucity of information on the preferred habitat and behaviour of *O. vulgaris* in its natural environment (Anderson 1997, Meisel et al. 2006, De Beer & Potts 2013).

Cephalopods have a high socioeconomic significance for local fisheries in the Mediterranean (Keller et al. 2015, Sartor et al. 1998). Octopuses play an important role in resources of fisheries, espe-

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cially for small-scale fisheries (Fonseca et al. 2008). For *O. vulgaris* only, total catches were 80.247 t in 1991, which gradually decreased to 33,598 t until 2008, continued around 40,000 t in the following years, and calculated to be 43,334 t in 2014 (FAO 2018). The common octopus landing data in Turkey showed that 1,114 t in 2006 were the highest value in the last years, while total landing entered into a period of constant decreasing to this day. Landings decreased to 664 t in 2007, 510 t in 2010, 321.8 t in 2011, and 245.9 t in 2016. The total octopus landing data covering the period between 2000-2016 showed that 72.50% of the octopus landing in Turkey was caught in the Aegean Sea (TSI 2016).

Studies on artificial reefs have been conducted throughout the world in order to improve both large- and small-scale fisheries, protect sensitive habitats from fishing activities and illegal fishery, create new habitats for marine species, protect, restore and improve existing habitats, and increase species diversity and populations in coastal zones (Pickerin & Whitmarsh 1997, FAO 2015, Castège et al. 2016). In addition, artificial reefs provide home/nest-dependent species such as lobster, spiny lobster and octopus with the habitat needed, which has led to the development of species-specific artificial reefs (e.g. Ulaş et al. 2011).

The present study aims to identify habitat preferences of the common octopus by using artificial nests placed in two different habitats, i.e. meadows of Neptune grass *Posidonia oceanica* (L.) Delile and sandy bottom areas, around Urla Islands in the Izmir Bay, Aegean Sea. As a result of three years observation and sampling efforts, we collected information about preferences of the common octopus regarding natural dens and artificial nests (dens) as well as on habitats where these dens are located. Since habitat preferences may vary in the various areas of the geographical range this species, the novelty of this study is the first report on the habitat preferences of *O. vulgaris* using artificial nest in Turkish waters.

Materials and Methods

This study was designed to examine artificial nest and habitat preferences of *Octopus vulgaris* and performed monthly around Urla Islands in the Izmir Bay, Aegean Sea (Fig. 1) between November 2014 and June 2017. The study material consisted of concrete artificial nests designed for octopuses and octopuses sampled from these nests. Underwater sampling works and monitoring of the visual census data were performed via Scuba and free diving. The artificial nests were manufactured from compressed concrete. The nests were cylindrical, closed on one side, had an outer diameter of 20 cm and an inner diameter 14 cm (3 cm wall thickness), a height of 45 cm. Their volume was 6923.7 cm^3 (Fig. 1).

Totally, 200 artificial nests were placed on the sea floor in 10 m intervals by Scuba diving. Of them, 100 nests were placed on sandy bottom and 100 nests were placed in Neptune grass meadows. Natural dens and artificial nests in the region were checked by Scuba diving once per week. Nests with octopuses were immediately recorded and animals were captured for further examinations. Sex of octopuses was identified and their weights were measured using a scale (up to 0.01 g).

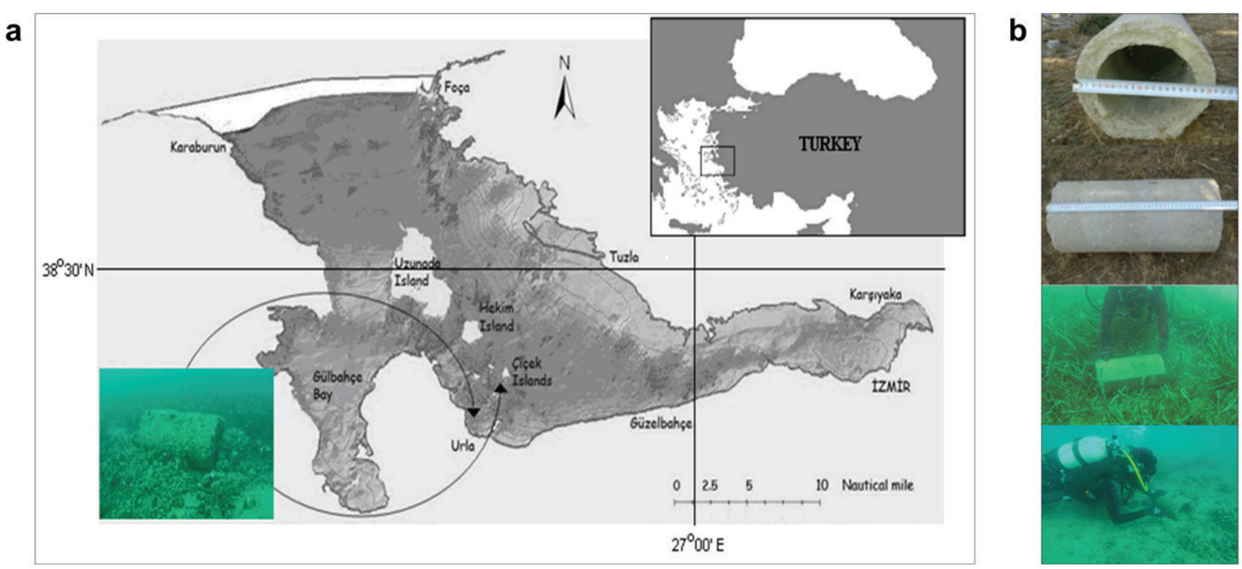

Fig. 1. a. Study area: Urla Islands, Izmir Bay, Aegean Sea; b. Front and top view of the designed artificial octopus nests and placed in sand and Neptune grass areas.

Microsoft Office Excel was used to process data collected, and SPSS 20 was used for statistical analysis. Multivariate analysis and similarities between groups were identified applying package PRIMER v6, including calculating the Bray-Curtis similarity index and the Multi-Dimensional Scaling (MDS) (Clarke & Gorley 2006) for numbers and biomass.

Results

Observations were carried out on a weekly basis, especially between November – April, for 3 years via Scuba diving. The data obtained from sampling efforts were used to examine weight distribution, natural den and artificial nest preferences, habitat preferences of octopuses using artificial nests, nest preferences by sex and distribution by depth of the common octopus.

Habitat, natural den and artificial nest preferences of the common octopus

In total, 138 (56.33%) out of 245 octopuses sampled throughout the study were captured in artificial nests, whereas 107 octopuses (43.67%) were captured in natural dens. The total weight of these 245 octopuses was 652.770 kg. The total weight of those sampled in natural dens was 341.371 kg, and the total weight of those sampled in artificial nests was 311.399 kg. According to the Bray-Curtis Similarity Index, the similarity between octopuses captured in natural dens and artificial nests was 96.82 by number and 98.85 by biomass.

In terms of habitat preferences of octopuses captured in natural dens, it was observed that 52.34% preferred Neptune grass areas and 47.66% preferred sandy areas. It was determined that 66.67% of octopuses captured in artificial nests preferred Neptune grass areas, whereas 33.33% preferred sandy areas. In terms of biomass, these values were 50.70% in Neptune grass meadows and 49.30% in sandy habitats for natural dens, and 65.24% in Neptune grass meadows and 34.76% in sandy areas for artificial nests. Cluster and MDS analyses based on the Bray-Curtis Similarity Index were performed to reveal the similarities between octopuses captured in natural dens and artificial nests in Neptune grass and sandy areas in terms of number and weight (Fig. 2). Natural

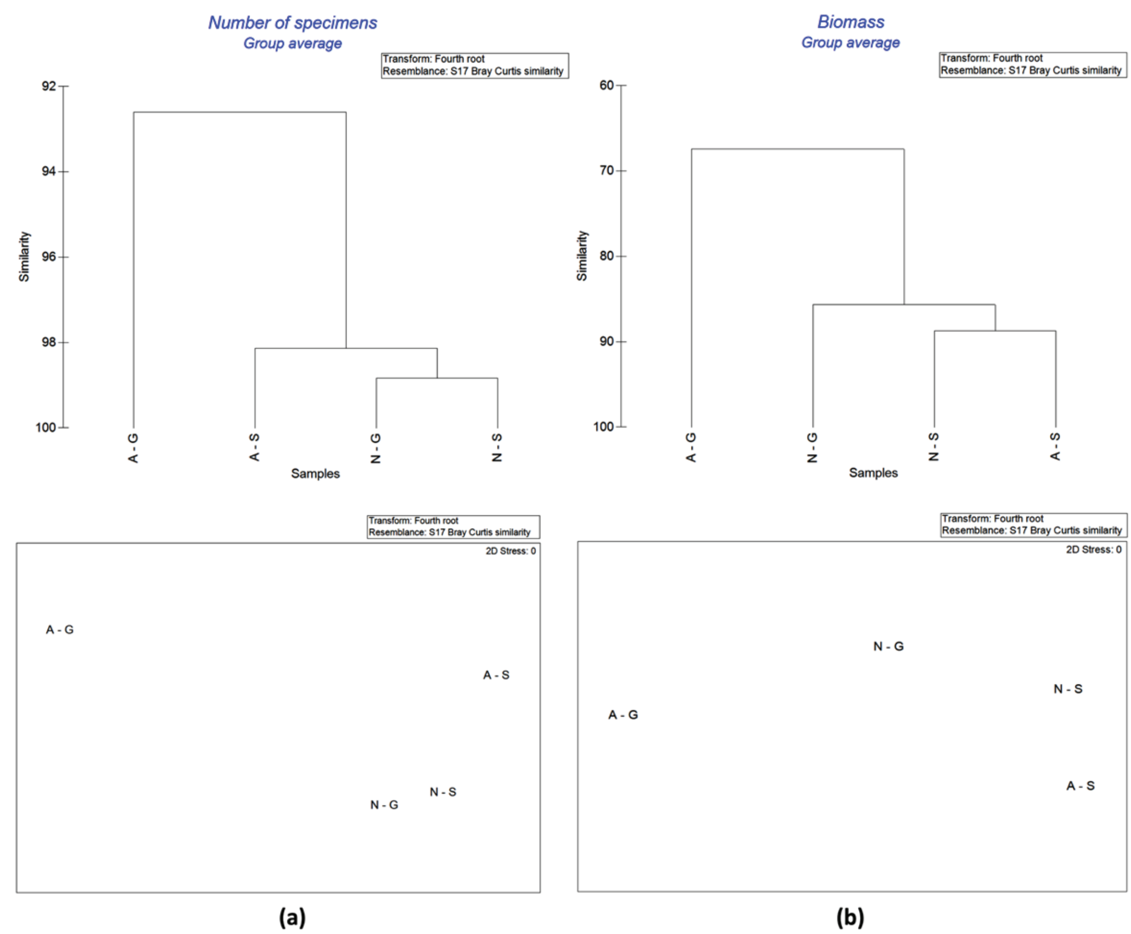

Fig. 2. Cluster and MDS analyses of specimens in natural dens (N) and artificial nests (A) in terms of number (a) and biomass (b) based on Bray-Curtis Similarity Index depending on Neptune grass (G) and sandy (S) areas.

dens and artificial nests in sandy areas showed 88.68 similarity in terms of biomass. These two groups showed 85.65 similarity with natural dens located in Neptune grass areas. However, artificial nests located in Neptune grass areas showed a similarity of only 67.42 when compared to other group of habitats and nest types. In terms of numbers, natural dens in Neptune grass and sandy areas showed 98.83 similarity, the similarity of these with artificial nests in sandy areas was found to be 98.13. Artificial nests in Neptune grass areas showed 92.6 similarity with other groups shown in Fig. 2.

Nest preference of the common octopus by sex

In total, 127 out of 245 individuals from natural dens and artificial nests were female (F; 51.84%), while 118 were male (M; 48.16%). Among males, 56.78% preferred artificial nests and 43.22% preferred natural dens. Among female individuals, 55.91% preferred artificial nests and 44.09% preferred natural dens. Thus, sex was found to be statistically insignificant in nest preference ($p<0.05$). The total weight of 127 female individuals was 341.763 kg, while the total weight of 118 male was 311.007 kg. The average weight of females and males in natural dens was 3203.11 g and 3176.41 g, respectively. The average weight of females and males in artificial nests was calculated as 2287.17 g and 2224.03 g, respectively. Comparisons between nests in terms of weight and between females and males in terms of average weight showed that the differences were statistically insignificant ($p<0.05$). The similarity between female and male octopuses in natural dens and artificial nests was found to be 98.85 in terms of biomass and 96.81 in terms of number. For the weight structure of samples of females and males from natural dens and artificial nests, see Fig. 3.

The similarities in terms of nest preference by biomass were examined using the Bray-Curtis Similarity Index (Fig. 4); the similarity was found higher than 80 for each group. The similarity rate was 93.39 between females and *males* sampled from artificial nests and 88.49 between females and males collected from natural dens. The similarity rate between natural dens and artificial nest preferences of female and male individuals was determined 81.99. In terms of number, these values were determined as 99.28, 98.83, and 96.81, respectively (Fig. 4). The results of MDS analysis in terms of number and biomass can be seen in Fig. 4. In terms of habitat preferences of octopuses by sex, 39.37% of females preferred sandy areas and 60.63% preferred Neptune grass; 39.83% of males preferred sandy areas and 60.17% preferred Neptune grass habitats. Sex was found to be statistically insignificant for habitat preferences ($p<0.05$).

Distribution by depth

The distribution of octopuses was examined according to the depth scale formed in 2 m intervals. It was found that the 4-5 m range was in the first place with 55.92% by number and 50.25% by biomass. It was followed by the 6-7 m range with 15.92% (number) and 16.21% (biomass). The 12-13 m range showed the lowest values, with 1.63% (number) and 1.50% (biomass). For the depth frequency distributions of individuals sampled in natural dens and artificial nests by number and biomass, see Fig. 5. When depth distributions of individuals captured in natural dens and artificial nests were examined separately, it could be seen that the 4-5 m range had the first place. However, according to the depth, it was found that individuals captured in natural and artificial nests showed a similarity (Bray-Curtis Similarity Index) in number 75.99 and weight 74.52. For the depth distribution of females and males captured in natural dens and artificial nests presented as number and biomass, see Fig. 6.

Fig. 7 shows cluster and MDS analyses per-

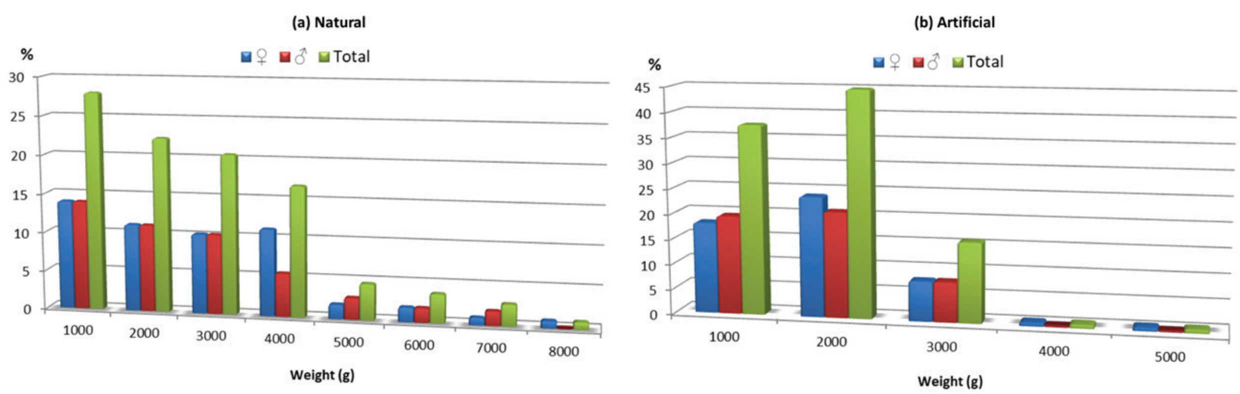

Fig. 3. The total weight frequency distribution of specimens in natural dens (a) and artificial nests (b) by sex.

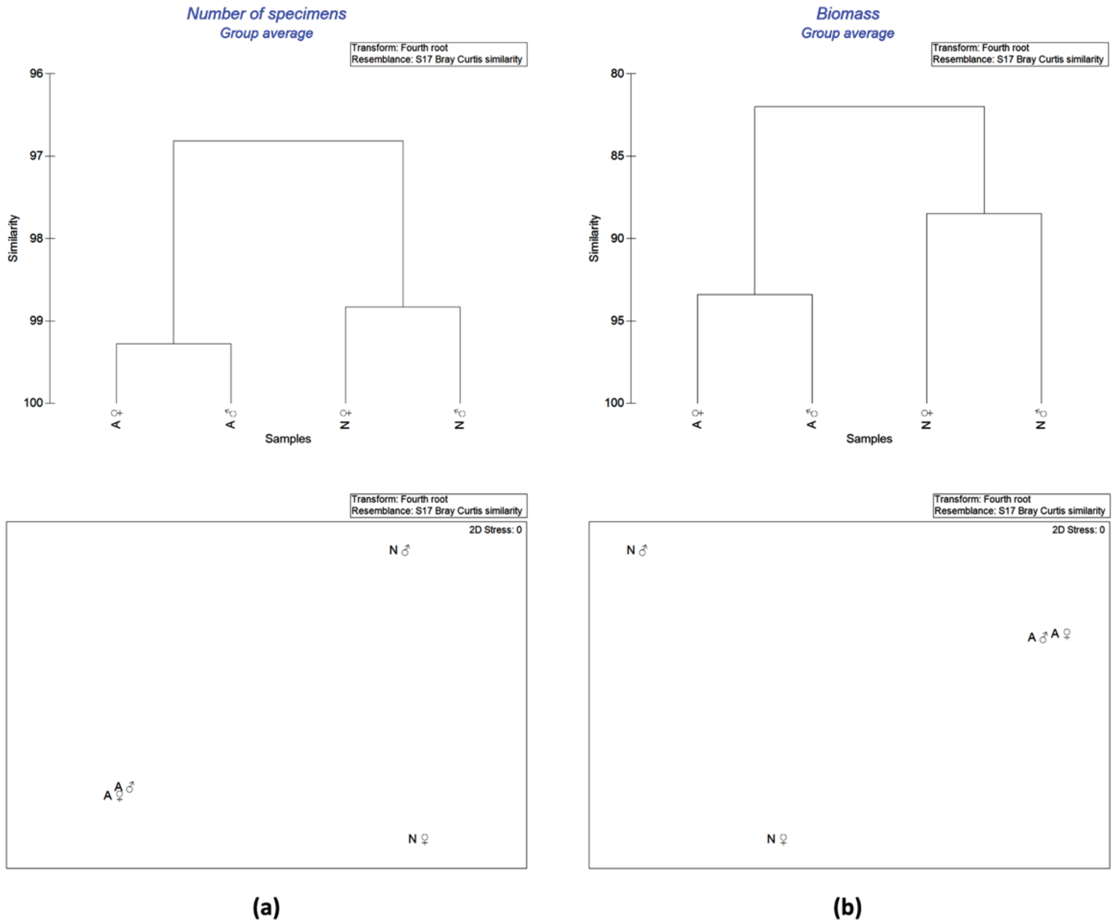

Fig. 4. Cluster and MDS analyses of specimens in natural dens (N) and artificial nests (A) in terms of number (a) and biomass (b) by sex based on Bray-Curtis Similarity Index.

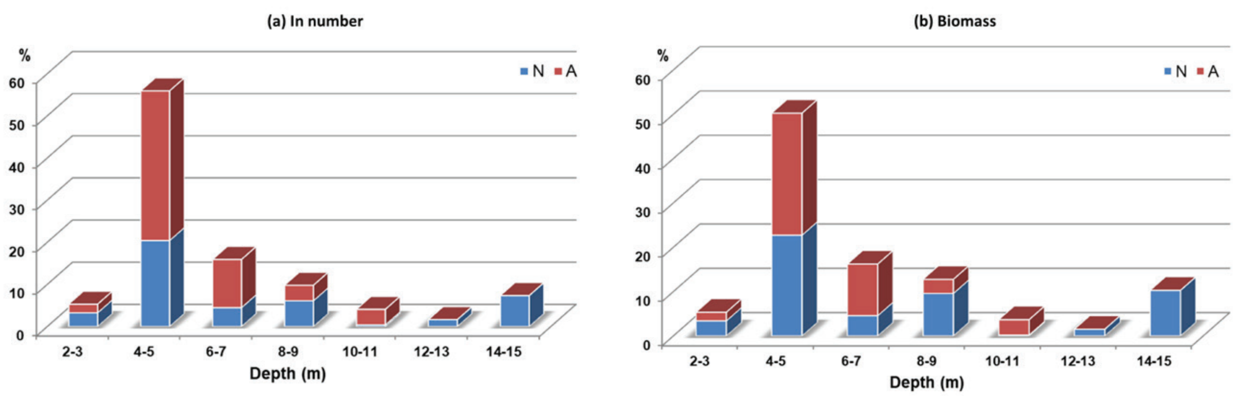

Fig. 5. Depth frequency distributions of specimens in terms of number (a) and biomass (b) based on den/nest type (N: Natural, A: Artificial).

formed according to the Bray-Curtis Similarity Index to reveal the similarities between specimens sampled in natural dens and artificial nests in terms of number and biomass by depth.

Discussion

Because the common octopus is a nest-dependent species and forms its own shelter to survive in its natural environment, we designed species-specific artificial nests for *O. vulgaris* in this study. We placed these nests in two different habitats and compared these with natural dens to investigate nest preferences of octopuses. Comparisons between natural dens and artificial nests revealed that sex had no effect on dens/nest preference, and the similarity in terms of number and biomass was found to be higher than 95. However, it was found that 20.41%

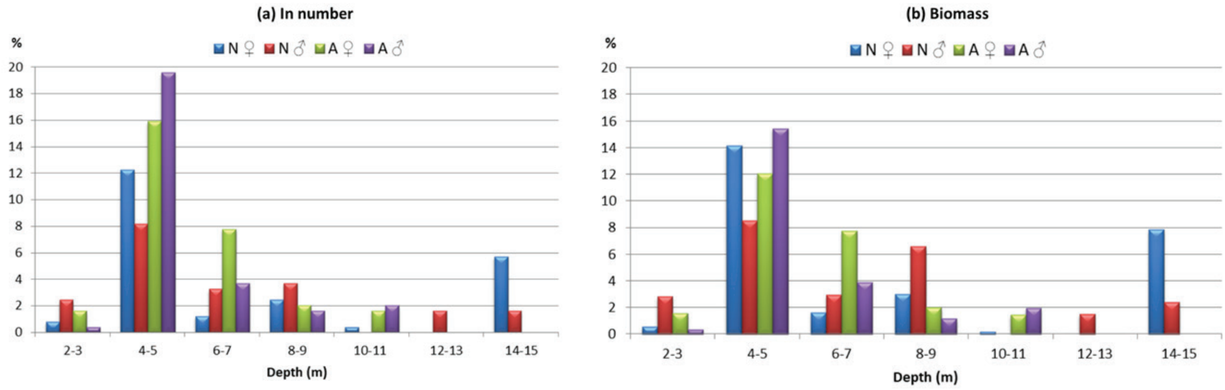

Fig. 6. Depth frequency distributions of specimens in terms of number (a) and biomass (b) based on den/nest type and sex (N: Natural, A: Artificial).

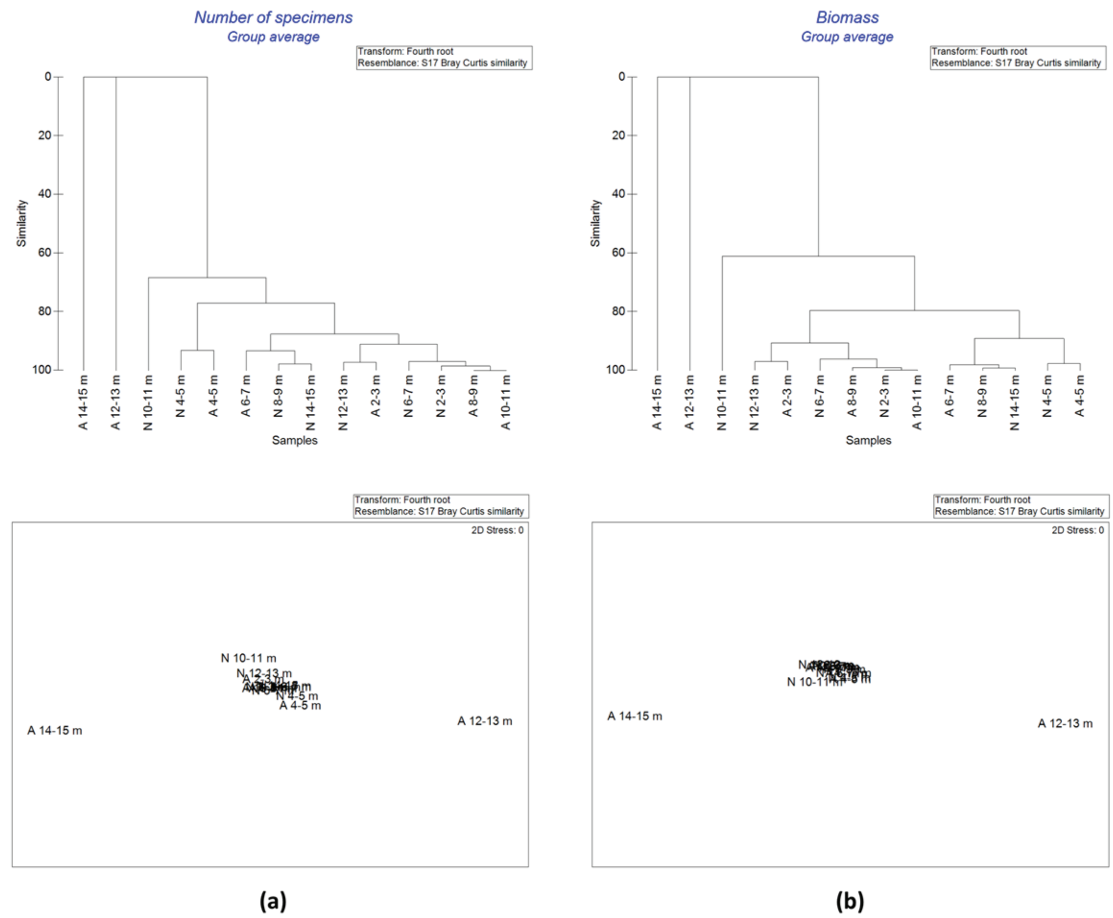

Fig. 7. Cluster and MDS analyses of specimens in natural dens (N) and artificial nests (A) in terms of number (a) and biomass (b) by depth based on Bray-Curtis Similarity Index.

of females and 17.14% of males most commonly preferred artificial nests located in the Neptune grass meadows, with the highest ratios in terms of habitat. The sex ratio was 1:1 for natural dens and artificial nests in both Neptune grass and sandy areas. This is consistent with findings of Silva et al. (2002), Barry et al. (2009) and Sobrino et al. (2011) related to the common octopus fishery in different regions.

The average weight of individuals sampled in natural dens was 3190.38 g, while the average weight of individuals sampled in artificial nests was 2256.51 g. The lowest weight for individuals sampled in natural dens was 1020 g, while the highest weight was 8100 g. The lowest weight for individuals sampled in artificial nests was 1040 g, while the highest weight was 5270 g. The average weight of individuals sampled in natural dens in Neptune grass areas was 3090.38 g, whereas the average weight of individuals sampled in natural dens in sandy areas was 3300.20 g. The average weight of individuals sampled in artificial nests in Neptune grass areas was 2208.30 g, whereas the average weight of individuals sampled in artificial nests in sandy areas was 2352.93 g. In terms of weight distribution by depth, the minimum average weight in natural dens, 1400 g, was found in the 10-11 m range, whereas the maximum average weight, 3726.11 g, was found in the 14-15 m range. In artificial nests, these values were determined 2065.28 g in the 4-5 m range and 2711.79 g in the 6-7 m range, respectively. The highest number of specimens and the highest total weight were observed in the 4-5 m range for both natural dens and artificial nests. The average weight of individuals sampled in natural dens in this depth range was 2967.32 g, whereas the average weight of individuals sampled in artificial nests in this depth range was 2065.28 g. Regarding distribution by number of individuals, 35.51% preferred artificial nests in this depth range, while 20.41% preferred natural dens in this depth range (Fig. 5). The number of specimens captured in artificial nests was 1.74 times higher than specimens captured in natural dens in the 4-5 m range. This may be explained with the higher number of specimens between 4000-8000 g (max: 8100 g) in natural dens, while the maximum biomass for specimens captured in artificial nests was 3000-4500 g (max: 4500 g). However, the distribution of specimens between 1000-2000 g in artificial nests in the 4-5 m range was calculated 51.72% (min. 1040 g; max. 1990 g), whereas it was calculated 34.00% in natural dens (min. 1020 g; max. 1950 g). Lauria et al. (2016) reported that depth was the main environmental predictor for habitat preference of cephalopods, while the effects of other environmental factors varied. Studies conducted in various regions of the Mediterranean basin reported that cephalopod species were observed in different abundance at different depths (Jereb & Ragonese 1995, Katsanevakis et al. 2008, Krstulovic et al. 2013, Lefkaditou et al. 2008, Quetglas et al. 2000, Sánchez et al. 1998). These mobile species can live in different biotopes such as sandy and muddy bottoms, rocks, coral reefs, and sea-grass habitats; it is an opportunistic carnivore predator preying on crabs, molluscs, polychaetes and bony fish throughout their adulthood (Mangold 1983). *Octopus vulgaris* preys on a high variety of prey items (Nixon 1987). Guerra et al. (2014) reported that as a result of patchy distribution of *O. vulgaris* within a certain area was influenced by food, and this may be concluded that higher density of specimens was observed in Neptune grass areas as well as in the 4-5 m range in our study area.

In total, 56.33% of 245 individuals were sampled in artificial nests, while 43.67% were sampled in natural dens during the present study. In total, the similarity between specimens captured in natural dens and artificial nests in terms of biomass and number was higher than 95%. This can be said that artificial nests were generally preferred by the common octopus as much as natural dens. However, in terms of preference rate by number, artificial nests were more commonly preferred by the common octopus with a difference of 12.66%. Regarding to distribution by number, 52.34% of natural dens preferred by the common octopus were in Neptune grass areas, whereas 66.33% of habitat preferences in artificial nests were determined again in Neptune grass areas. These tendencies observed in terms of number were determined similar in terms of biomass as well; 50.70% for natural dens and 65.24% for artificial nests in Neptune grass. It can be seen that artificial nests located in Neptune grass habitats with a high number of the common octopus differs from the other dens and nests located in sand and Neptune grass according to the Bray-Curtis Similarity Index performed Cluster and MDS analysis (Fig. 2). The characteristics of the bottom have been thought to be the main factor influencing their density and distribution patterns (Aronson 1991, Hanlon & Messenger 1996, Leite et al. 2009). Octopuses need hard structures on soft substrates or penetrable areas in hard substrates (Guerra et al. 2014). Forsythe & Hanlon (1997) conducted a study in French Polynesia and suggested that areas with sandy bottoms with gravels did not provide a suitable habitat for octopuses, which usually preferred rock crevices and space between rocks and reefs. In addition, Katsanevakis & Verriopoulos (2004) conducted a study in coastal areas of Greece and reported that the excavation of holes under rocks was an important strategy for *O. vulgaris* inhabiting softer sediments. Guerra et al. (2014) carried out a study in Spain and reported that some old and well-built dens on a soft bottom could be used successively by several generations of *O. vulgaris* (they called them "permanent"). Den physical modifications by octopuses during long-term occupation is called as "ecosystem engineering" (Hartwick & Thorarinssson 1978, Godfrey-Smith & Lawrence, 2012) and this quite impressive activity mostly involves handling of shells brought in during foraging (Guerra et al. 2014). In this study conducted around Urla Islands, in the case of natural dens, it was observed that the den entrances were quite small and it was not possible to see octopuses easily in dens most of the time; they were usually recognized by their tentacles. There were always stones at the den entrances; sometimes, also empty shells of bivalves were placed at the den entrances. These stones and shells were placed around dens in a way that they would form a very narrow entrance. In spite of this behaviour of octopuses in their natural dens, only empty shells of bivalves, preyed for feeding, were found around entrances of artificial nests in Neptune grass areas, which were the most commonly preferred habitat among all nests examined in the present study. This indicates that octopuses were able to hide and feel secure in artificial nests placed in Neptune grass areas, and the most commonly observed shells in den entrances were those of *Pinna nobilis* L., 1758.

In marine species, the relationships between species distribution and environmental factors are essential to comprehend many aspects of their ecology towards effective conservation management and assessment of possible impacts of anthropogenic activities (Macleod et al. 2008, Valavanis et al. 2008, Hermosilla et al. 2011), especially in view of the sustainable exploitation and the conservation of their habitats. The necessity of integrating this aspect into marine resources management to protect commercial or conservation interest species was emphasized in the latest European policy such as European Marine Strategy Framework Directive and Common Fisheries Policy (Lauria et al. 2016). Habitat suitability modelling is an important tool to quantify a species' realised niche and understand species-environment relationships (Araújo & Guisan 2006, Elith & Leathwick 2009, Lauria et al. 2016). Cephalopods, in particular, are highly sensitive to changes in environmental conditions at a range of spatial and temporal scales due to their specific biology, e.g. rapid growth rate, short lifespan and little generation overlap (Pierce et al. 2008, Lauria et al. 2016). The effect of environmental factors on cephalopod habitat selection varies amongst species as a function of their biology and ecology; oceanographic conditions are more relevant for pelagic species while the typology of substrata and bathymetry can affect demersal and benthic species (Bakun & Csirke 1998, Pierce et al. 2008, Wright et al. 2012, Smith et al. 2013). There are several studies performed to determine characteristics used in home choice and selection of hiding places, and the availability of shelters is reported to be a limiting factor for octopus distribution (Altman 1967, Mather 1982, Katsenevakis & Verriopoulos 2004, Guerra et al. 2014). However, the number of studies characterizing cephalopod habitats or assessing cephalopod stocks in the Mediterranean is limited (Mehanna & Haggag 2011, Perdichizzi et al. 2011, Regueira et al. 2014, Keller et al. 2015, Puerta et al. 2014, 2015, Lauria et al. 2016).

Although there are very comprehensive artificial reef studies, the number of species-specific artificial reef studies is quite limited. According to the results of the present study performed around Urla Islands in the Izmir Bay, Aegean Sea, artificial octopus nests tested in this region were functional and relevant to protection and hiding behaviour of *O. vulgaris*. Comparisons between natural dens and artificial nests showed that octopuses preferred artificial nests with a rate higher than 50%, which is an indication of high functionality of these artificial nests. In addition to all these, the fact that artificial octopus nests in Neptune grass areas were clearly the most commonly preferred among all dens/nests shows that octopuses regard these nests as satisfying their protection and sheltering behaviour. In addition, high density of octopuses in the 4-5 m range is an indication of depth-related preferences of octopuses for the studied region.

In conclusion, it is considered that Neptune grass areas in the 4-5 m depth range may be suitable for placing octopus artificial nests within the scope of species-specific artificial reefs to improve both small-scale fisheries and conservation of the species in this region. According to the Notification No. 2016/35 on commercial fishing issued by the Turkish Ministry of Food, Agriculture and Livestock (Anonymous 2016), the minimum landing weight is 1 kg for *O. vulgaris*, which is met by octopuses captured in this area. Based on the data presented in this study, the identification of habitat and nesting preferences of *O. vulgaris* in different regions is of great importance to produce and process data, which can be used in stock and fisheries management.

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