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Species composition of artificial reef models specifically designed for *Homarus gammarus* (Crustacea: Decapoda: Nephropidae) in the Sea of Marmara

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Abstract

This paper aimed to determine the species composition around artificial reefs specifically designed for lobsters in the Sea of Marmara, Turkey. The species composition around artificial reefs was observed during the period between May 2016 and April 2017 by visual census techniques. A total number of 988 individuals from 20 different species were recorded around the artificial reefs. These species include 10 actinopterygii, 6 crustacean, 3 echinodermata, and 1 mollusc species which of these, six species have economic value. The results demonstrated that artificial reefs could increase the species composition in the area. *Inachus dorsettensis* (28.64%) and *Carcinus aestuarii* (25.91%) species constitute 55% of the total individuals recorded around the artificial reefs. Therefore, although these artificial reefs are species-specific for lobsters, their ecological function is also important for other species. This paper put forward that different artificial reef models served as alternative habitats for feeding, sheltering, and protecting the marine species. Then, their ecological function should be studied in detail. On the other hand, more investigations on different artificial reef models are required to protect and ensure the sustainability of the marine species stocks around artificial reefs in further researches.

Keywords: Species-specific artificial reef; Lobster; Homarus gammarus; Species composition; Marmara Sea.

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1. Introduction

Artificial reefs are structures that are placed on the sea bottom in order to create and to serve as a new habitat type for marine species or to protect further to develop available habitats (Jensen, 2002). They being to create feeding, reproduction, protection and shelter areas for marine species (Aydın, 2011), and are of great importance for the planning of modern nature protection, such as sustainable use of marine living resources, integrated coastal zone management, and conservation of marine biodiversity. Japan and the United States of America are leading the studies on artificial reefs in the world and the artificial reefs studies along the coasts of these countries date back to 200 years (Stone *et al.,* 1991). Artificial reef practices in Japan aimed to improve fishing areas and increase production, while in the USA artificial reef practices are carried out to improve diving tourism, sport fishing, and angling. On the other hand, in Europe, artificial reef practices used to for prevention of illegal trawling (Ramos-Espla *et al.,* 2000), or to protection of sea-grass (*Posidonia oceanica*) beds (Guillén *et al.,* 1994) and increase species diversity. Artificial reef practices in Europe started in Italy in the 1970s, spreading first to other Mediterranean countries, then to the North Sea and Baltic Sea countries (Jensen, 2002). Artificial reefs were built to increase fish production until the 1980s. In recent years, environmental and conservative issues such as improving water quality (Angel and Spanier, 2002) and renewing the ecosystem (Rilov and Benayahu, 2000) were prioritized in artificial reef studies. In Turkey, artificial reef studies began in 1991. Afterwards, studies were carried out in the Sea of Marmara, Aegean Sea and the Mediterranean Sea (Lök *et al.,* 2002; Düzbastilar and Lök, 2004; Lök and Gül, 2005; Gül *et al.,* 2006; Ulas *et al.,* 2007; 2011; Acarli *et al.,* 2013; 2018; Altinağaç *et al.,* 2013; Acarli and Ayaz, 2015). Artificial reef activities in the South Aegean and Mediterranean, which are mostly directed towards diving tourism, also have contributed to the development of small-scale fishing in these regions in Turkey.

The European lobster (*Homarus gammarus* Linnaeus, 1758) is an important species due to its high economic value and consumption as human food. Therefore, design and analysis of species-specific artificial reef models are required to ensure the sustainability of lobster stocks in the natural environment (Acarli *et al.,* 2018). Species-specific artificial reefs for lobsters serve as new habitats and areas for feeding, reproduction, protection, and sheltering. The reefs also attract other marine species. In this study, therefore, it is aimed to determine the species composition around artificial reefs specifically designed for lobsters in the Sea of Marmara, Turkey. This paper will provide current information on marine species that occupy the artificial reef models to improve understanding the communities of such reefs, which are likely to be supported.

2. Materials and methods

Acarlı and Kale (2020) constructed eight different species-specific artificial reef models of different shapes and sizes by wooden, iron, and concrete materials. These models included flat (concrete and iron), grid (wooden and iron), U-type (concrete), cowl (concrete), fireplace chimney brick (concrete) shapes. Technical characteristics of artificial reef models are given in Table 1. Firstly, a reef deployment procedure was planned for aquanauts. Then, a total number of 24 artificial reefs (3 for each model) were deployed on the sea bottom at 10, 15, and 20 m water depths in Ocaklar Cove of Erdek Bay in the Sea of Marmara (Figure 1). All models are facing each other at an angle of 120°. Sea bottom is surrounded by *Posidinia oceanica* meadows among the depths of 2-11 m between the shore and the reef area (Acarli and Ayaz, 2015).

Artificial reef models were observed during the period between May 2016 and April 2017. Transect and quadrate monitoring methods as visual census technique were carried out by SCUBA divers that have ability to estimate the species in a monthly period at the same time of the days (10.00-12.00 AM). In addition, underwater video records were captured by GoPro underwater camera and Nikon CoolPix digital camera. The divers completed a 15-minute observation at each depth in the underwater observations. Thus, the time spent by each diver in the water for underwater observations was in minimum of 540 minutes. The effort that time spent under water for placing the models on the seabed as planned was calculated 233 min diver^{-1} on average.

3. Results

Species preferred the various reef models were observed during the monitoring period. As a result, a total 988 individuals from 20 different species belonging to 17 families were catalogued around the artificial reefs. These species included 10 actinopterygii, 6 crustacean, 3 echinodermata and 1 mollusc species (Table 2). The most frequent species was *Inachus dorsettensis* (283 individuals) while the least frequent was *Syngnathus acus* (2 individuals). *Inachus dorsettensis* and *Carcinus aestuarii* are the most observed species and constitute 55% of the total observed individuals (Table 2). *Paracentrotus lividus* is listed as vulnerable in the International Union for Conservation of Nature (IUCN) Red List. Species-specific artificial reefs for lobster served as an alternative area for threatened species such as *P.lividus*. In addition, Table 2 presents that which species prefers which artificial reef model.

Table 1. Technical characteristics of species-specific artificial reef models for European lobster

Model	Width (mm)	Length (mm)	Height (mm)	Thickness (mm)	Total Volume (m^3)	Weight (kg/piece)
Wooden (grid)	462	500	220	35	7.7×10^{-2}	20
Iron metal (flat)	420	500	275	2-3	8.723×10^{-2}	11
Iron (grid)	445	500	270	8	8.64×10^{-2}	15
Concrete (40×80 cm)	400	800	50	50	1.6×10^{-2}	35
Concrete (6-gate)	455	455	150	45	3.665×10^{-2}	28
Concrete (U-type)	400	500	200	55-60	6.75×10^{-2}	45
Cowl	200	390	195	50-55	1.521×10^{-2}	15
Fireplace Chimney Brick	280	380	150	40	1.596×10^{-2}	12

Figure 1. Study area

The distribution of the total number of species according to the preference of artificial reef models is shown in Figure 2. Of the 20 different species observed in artificial reef models, most species were recorded in both iron flat model and concrete 6-gate model and the fewest number of species were observed in the concrete U-type model.

Of the 988 individuals observed in artificial reef models, the most preferred model was the concrete flat (40 × 80 cm) model (245 individuals comprising 14 species) and the least preferred model was the fireplace chimney brick model (43 individuals comprising 14 species). However, it was determined that more individuals were observed in the models with

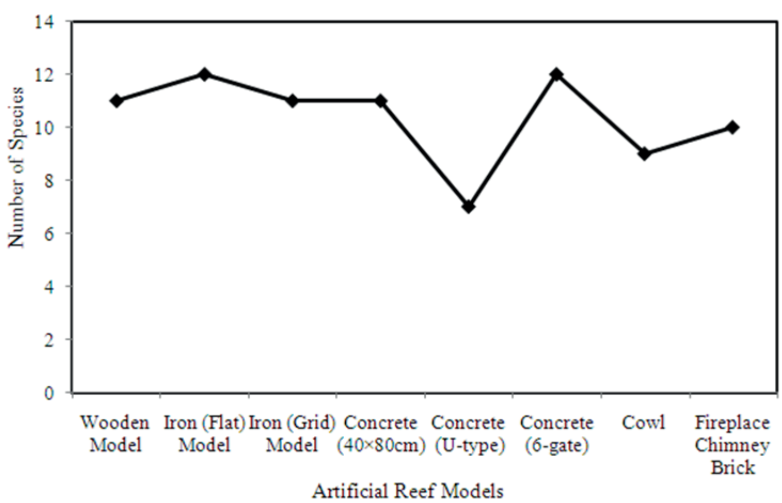

Figure 2. Total number of observed species in artificial reef models in Erdek Bay, Marmara Sea, during May 2016 to April 2017

Table 2. Species composition in artificial reef models and percentage distribution

Species	Ratio (%)	Economic Value	Wooden Model	Iron (Flat) Model	Iron (Grid) Model	Concrete (40×80cm)	Concrete (U-type)	Concrete (6-gate)	Cowl	Fireplace Chimney Brick
Inachus dorsettensis	28.64		*	*	*	*	*	*	*	*
Carcinus aestuarii	25.91		*	*	*			*		
Palaemon elegans	9.92	a				*				
Gobius bucchichi	5.47	a	*	*	*	*	*	*	*	*
Gobius niger	4.66	a	*	*		*		*	*	
Marthasterias glacialis	3.95		*	*	*	*		*	*	*
Serranus scriba	3.74			*				*		
Flexopecten glaber	3.24	a			*	*	*		*	*
Serranus hepatus	3.04		*	*		*	*	*		*
Homarus gammarus	2.63	a				*	*			
Symphodus tinca	1.92		*			*	*	*		*
Eriphia verrucosa	1.21	a	*							
Salaria pavo	1.01			*		*		*		
Holothuria (Holothuria) tubulosa	0.91	a					*	*	*	*
Scorpaena porcus	0.81	a	*		*				*	*
Symphodus cinereus	0.81		*		*	*		*	*	*
Maja crispata	0.71		*	*	*		*	*		*
Paracentrotus lividus	0.71	b		*	*				*	*
Chelidonichthys lucerna	0.51	a	*	*	*	*		*		
Syngnathus acus	0.20			*	*					

a This species has economic value.
b This species is listed as vulnerable in the IUCN Red List.
* The species observed in artificial reef model

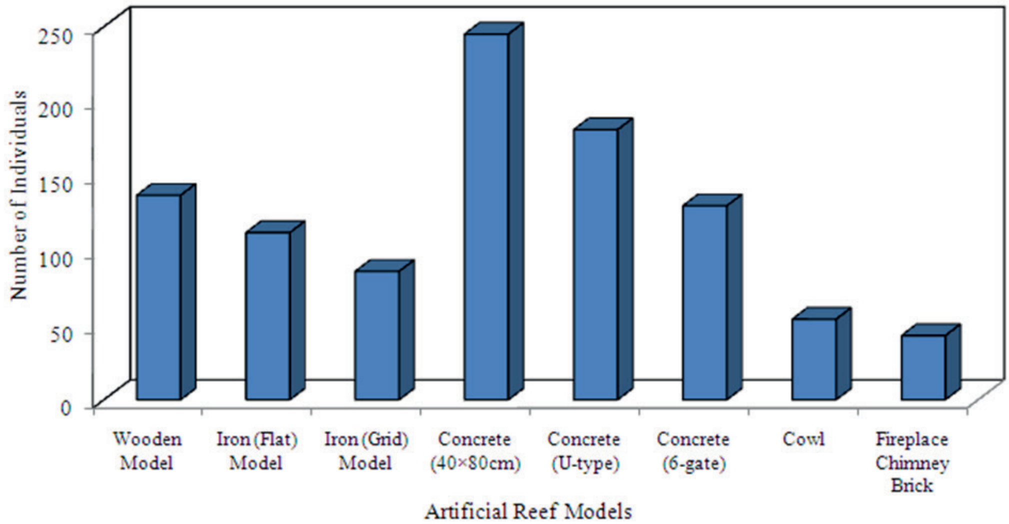

Figure 3. Total number of observed individuals in artificial reef models, in Erdek Bay, Marmara Sea, from May 2016 to April 2017

Table 3. Bray-Curtis similarity indices for artificial reef models

	Wooden	Iron (Flat)	Iron (Grid)	Concrete (40×80cm)	Concrete (U-type)	Concrete (6-gate)	Cowl	Fireplace Chimney Brick
Wooden	1							
Iron (Flat)	0.76	1						
Iron (Grid)	0.39	0.53	1					
Concrete (40×80cm)	0.63	0.49	0.30	1				
Concrete (U-type)	0.31	0.30	0.37	0.48	1			
Concrete (6-gate)	0.64	0.62	0.43	0.61	0.51	1		
Cowl	0.38	0.33	0.56	0.33	0.40	0.49	1	
Fireplace Chimney Brick	0.31	0.28	0.33	0.21	0.27	0.37	0.54	1

concrete construction material (556 individuals comprising 17 species), while fewer were observed in models with tile material (97 individuals) (Figure 3).

The abundance matrix of all the observed species was log (x + 1) transformed to create a triangular resemblance matrix based on Bray-Curtis similarity (the inverse of the Bray-Curtis index of dissimilarity). Multivariate analyses were based on Bray-Curtis similarity matrices generated from either raw or transformed data (Table 3). The community difference between artificial reef models was calculated as the Bray-Curtis dissimilarity and hierarchical clustering plot of artificial reef models was illustrated in Figure 4. Furthermore, ordination and visualization were performed using principal coordinate analysis (PCoA) (Figure 5) and the PAST (v3.23) software (Hammer *et al*., 2001).

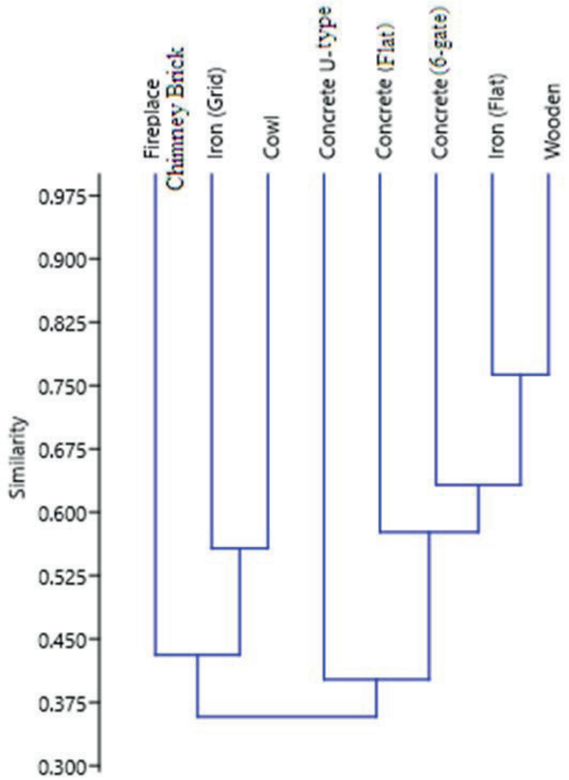

Figure 4. Hierarchical clustering plot of artificial reef models. Similarity index was described using Bray-Curtis index and dendrograms were constructed by the group average method on Bray-Curtis similarity matrices for number of species in artificial reef models in Erdek Bay, Marmara Sea during May 2016 - April 2017

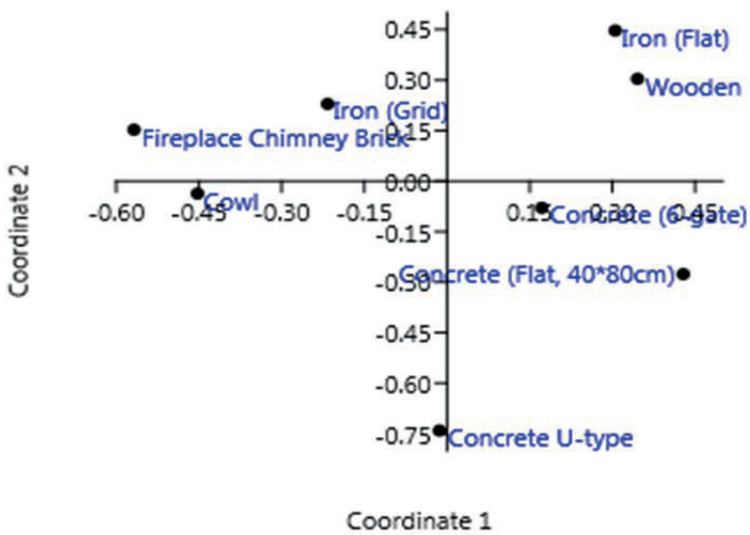

Figure 5. Principle coordinates analysis (PCoA) of artificial reef models derived from the Bray-Curtis dissimilarity

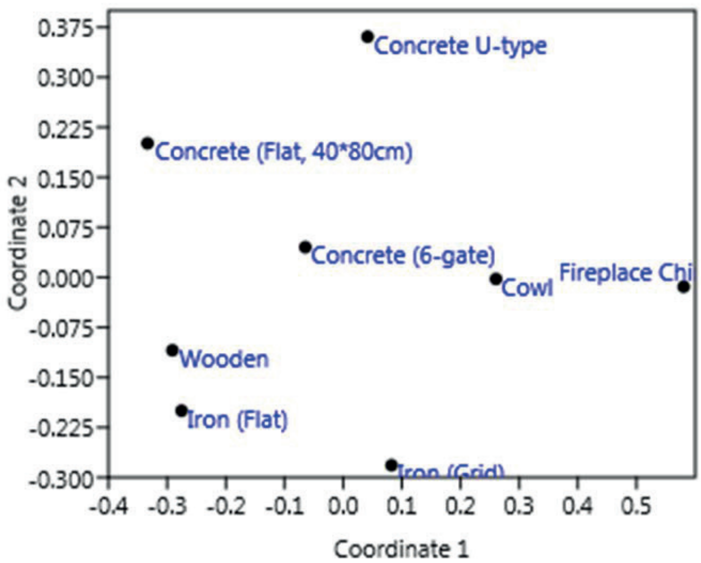

Figure 6. Non-metric multidimensional scaling (n-MDS) ordinates for artificial reef models in Erdek Bay, Marmara Sea, during May 2016 - April 2017

The pattern of species composition was compared among reefs using an ordination non-metric multidimensional scaling (n-MDS) method and the Bray-Curtis similarity index (Clarke *et al.*, 2014) (Figure 6). The figure indicates similarities of community composition between reef models and all values were calculated with Bray-Curtis similarity index on abundance data.

4. Discussion

During observations around the artificial reefs, 20 species from 16 families were recorded. Similarly, Lök and Gül (2005) recorded 25 species from 15 families whereas Gül *et al.,* (2006) recorded 41 species from 14 families and Acarli and Ayaz (2015) recorded 51 species from 35 families. Despite the fact that some observed species and families were similar with those studies, some species and families were found to be different. This could be due to the physicochemical characteristics and environmental conditions between locations.

Species observed around the artificial reefs were all benthic species. The most preferred artificial reef model was concrete flat model while the most diversity was observed in 6-gate concrete model. Concrete materials were more commonly preferred than other materials. One of the reasons why the most preferred artificial reef model was a concrete flat model is that these artificial reef models are less in height than the others are. In this way, although it has much less volume, because of its low height from the ground, it allows marine species to move easily on artificial reefs. Thus, species can easily climb on artificial reefs, create a living space around or within reefs and adopt reefs as nesting and shelter area. It will make them feel safe to be close to their living spaces. Consequently, artificial reefs will create alternative areas for increasing biodiversity, enriching and conserving marine species stocks. On the other hand, some migratory species may use the artificial reefs as sheltering and feeding area.

Similarly, Acarli and Ayaz (2015) reported that some migratory species such as *Pomatomus saltatrix* could have used the artificial reef areas as shelter area. Acarlı *et al.* (2019a) studied the species composition alternative gears for trap fisheries produced from waste recycle materials and indicated that newly developed fishing gears for trap fisheries have caught only two Muricid species and could be used for species-specific fisheries experiments. On the other hand, Acarlı *et al.* (2019b) investigated the fish species aggregating performance of brush parks and reported that they could attract the species in lagoon systems and served as potential living area such as artificial reefs. The species composition of brush parks was determined and 23 different marine species were recorded. It can be stated that the species compositions for both brush parks and trap fisheries presented a bit similarity with the present paper in terms of total number of species and individuals.

H. gammarus species were only observed in both concrete flat (40×80 cm) model and concrete U-type model. Therefore, the results clearly pronounced that lobster preferred the reef produced by concrete materials for living and nesting area. The most preferred model for *H. gammarus* was determined as concrete flat (40×80 cm) model whereas 75% of observed lobsters preferred this reef model. Although there were other reef models produced from concrete material in the environment, lobsters did not prefer concrete reef models other than flat and U-type models. This behaviour of lobster individuals clearly shows that lobsters prefer the reef model by considering the service provided by reefs rather than production material. Particularly, the low height of the concrete flat (40×80cm) model provides a strong protection. Unfilled floor of both (flat and U-type) models also allows the lobster to dig the ground behaviour. Therefore, lobsters possibly prefer only reef models that have unfilled floor to make possible the digging behaviours. This study put forward that these artificial reef models served as alternative habitats for feeding, sheltering, nesting and protecting areas.

Artificial reefs have been used and served for several purposes such as reestablishment of habitats, enrichment of fish stocks and fisheries management. Restoration of habitats is the primary objective for the usage of reef in the Black Sea whereas fisheries management and the enrichment of fish stocks are the main causes of reef construction in the Mediterranean Sea (Fabi *et al*., 2015). In this study, constructed artificial reef models from different materials on different shapes served as alternative habitats for feeding, sheltering, and protection of other species. Moreover, one threatened species listed in the IUCN Red List was observed around artificial reefs. Therefore, although these artificial reefs are species-specific for lobsters, their ecological function is also important for other species.

Conclusions

This research investigated the species composition around artificial reefs specifically designed for lobsters to understand which other marine species prefer these artificial reef models. As a result, 19 different species (except the lobster) were observed around species-specific artificial reef models. The most preferred artificial reef models were concrete models. It put forward that different artificial reef models served as alternative habitats for feeding, sheltering, and protection of marine species. Therefore, their ecological function should be studied in detail. On the other hand, more investigations on different artificial reef models are required to protect and ensure the sustainability of the marine species stocks around artificial reefs in further researches.

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