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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Relationships between environmental variables and abundance of Cnidaria and Echinodermata in Çardak Lagoon, Çanakkale Strait

Çanakkale Boğazı, Çardak Lagünü'ndeki Cnidaria ve Echinodermata gruplarının bolluğu ile çevresel değişkenler arasındaki ilişkiler

Seçil Acar[1]* ● Abdullah Suat Ateş[2] ● Ertan Dağlı[3] ● Alper Doğan[4]

[1]Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, 17100, Çanakkale, Türkiye https://orcid.org/0000-0002-6426-8095
[2]Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, 17100, Çanakkale, Türkiye https://orcid.org/0000-0002-4682-1926
[3]Ege University, Faculty of Fisheries, Department of Hydrobiology, Bornova, 35040, İzmir, Türkiye https://orcid.org/0000-0001-6579-505X
[4]Ege University, Faculty of Fisheries, Department of Hydrobiology, Bornova, 35040, İzmir, Türkiye https://orcid.org/0000-0002-4871-4059

*Corresponding author: secilkolsal@comu.edu.tr
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Abstract: This study is on the relationships between the abundances, of cnidarians and echinoderms found in Çardak Lagoon and environmental variables. The benthos samples were collected in three replicates in October 2018, February, April, and June 2019, using a metal framed quadrat system of 100 x 100 cm and 393 cm³ sediment core by a SCUBA diver. Sediment material was collected at 7 sampling points of Çardak Lagoon in Çanakkale Strait. A total of 259 individuals belonging to phylum, Cnidaria and Echinodermata were found in the study area. Cnidarian, *Actinia* sp. and echinoderm, *Asterina gibbosa* were the most dominant species. The highest positive correlation value was between Cnidaria species number and organic matter (OM%) content in the sediment. The highest negative correlation value was between Echinodermata species number and NO_2+NO_3 in lagoon system.

Keywords: Macrozoobenthos, lagoon biodiversity, environmental variables, Çardak Lagoon, Çanakkale Strait

Öz: Bu çalışma, Çardak Lagünü'nde bulunan Cnidaria ve Echinodermata gruplarının bollukları ile çevresel değişkenler arasındaki ilişkiyi araştırmaktadır. Benthos örnekleri, bir SCUBA dalgıcı tarafından 100 x 100 cm'lik metal çerçeveli bir kuadrat ve 393 cm³'lük kor kullanılarak Ekim 2018, Şubat, Nisan ve Haziran 2019'da üç tekrarlı olacak şekilde toplandı. Sediment materyali, Çanakkale Boğazı'ndaki Çardak Lagünü'nün 7 örnekleme noktasından toplanmıştır. Çalışma alanında Cnidaria ve Echinodermata şubelerine ait toplam 259 birey tespit edilmiştir. Knidaria türü *Actinia* sp. ve ekinoderm, *Asterina gibbosa* en baskın türlerdir. En yüksek pozitif korelasyon değeri (r=0.94; p<0.01), Cnidaria tür sayısı ile sedimandaki organik madde (%OM) içeriği arasında olmuştur. Lagün sistemde en yüksek negatif korelasyon değeri (r=-0.921; p<0.01) Echinodermata grubuna ait tür sayısı ile NO_2+NO_3 arasında bulunmuştur.

Anahtar kelimeler: Makrozoobentoz, lagün biyoçeşitliliği, çevresel değişkenler, Çardak Lagünü, Çanakkale Boğazı

INTRODUCTION

Coastal lagoons are complex systems that are highly affected by biological and physical changes. Due to the low influx of seawater (Ranasinghe and Pattiaratchi,1999), lagoons are often characterized by strong fluctuations in environmental variables that change the structure and distribution pattern of organisms. The diversity of the macrozoobenthos is very important in determining the quality of the biodiversity of a lagoon. Macrozoobenthos is an important component of lagoon systems, significantly altering the physical structure of the abiotic or biotic formations that make up the habitat and directly or indirectly affecting the availability of resources for other species (Lu, 2005). Macrozoobenthic assemblages are an important food source for organisms in the upper group of the trophic chain (Dauer, 1993). In addition, benthic macrofauna protects the water and contributes to improving water quality by mineralizing and recycling organic material, as well as decomposing organic material. (Sarker et al., 2016). Benthic communities are used as indicators in environmental impact studies (Warwick, 1993) to determine the types and levels of pollutants and to assess the environmental quality of coastal systems (Ponti and Abbiati, 2004; Boutoumit et al., 2021; Hisli et al., 2022).

Cnidarians and echinoderms are important components of the macrozoobenthos and indicators for ecological quality (Boutoumit et al., 2021). The phylum, Echinodermata is one of the major components commonly found in marine benthos and plays a variety of important ecological roles (Menge, 1992). Echinoderms, being sensitive to environmental changes, are important for ecological studies as indicator organisms for detecting changes in the food chain (Özbek, 2013). Echinoderms are associated with commercially important benthic resources and are the most commonly affected epibiotic community, accounting for a large proportion of bycatch in coastal or open-water fisheries (Escolar, 2010). Cnidarians are common in marine environments and they are represented by several species in estuaries, lagoons and/or freshwater. Benthic Cnidaria in particular is an important group of the benthos of various marine habitats, where they often form characteristic assemblages (Boero, 1984). They are

known as indicator species in the marine environment because their colonies are sessile and respond rapidly and variably to stress (Mergner, 1977; Gili and Hughes, 1995).

Although many studies on the biological status and aquaculture of Çardak Lagoon were carried out (Alparslan et al., 1999; Alparslan et al., 2004; Calıskan et al., 2011; Vural et al., 2015; Vural and Acarlı, 2021a, b; Vural, 2022), there is no detailed study on the macrozoobenthic structure of the lagoon. Knowledge of species composition of an ecosystem is one of the most fundamental aspects of biodiversity studies (Nascimento et al., 2019; Ahuatzin-Hernández et al., 2020). Providing this information enriches the value of an ecosystem and enables better management of natural resources. Therefore, the aim of this study is to determine the relationship between cnidaria and echinoderm species distributed in Çardak Lagoon, which has ecological and economical importance, with environmental variables.

MATERIALS AND METHODS

Study area

The study site is Çardak Lagoon has a 180-ha saltwater area with an average depth of 1,5 m (GTHB, 1997) in the northeast of Çanakkale Strait is one of the most important wetlands in the Strait. The lagoon formed between the coastal arrow and the land area has a length of 7,5 km and an area of 1.3 km^2 (Calıskan et al., 2011). The lagoon is under the influence of the sea waters due to its deep and constantly open passage. In the lagoon area, sampling was carried out at 7 stations whose coordinates are given below (Figure 1):

St1; 40˚22´906˝ N, 26˚43´103˝ E,
St2; 40˚23´053˝ N, 26˚43´264˝ E,
St3; 40 ˚23´203˝ N, 26˚43´491˝ E,
St4; 40˚23´345˝ N, 26˚43´399˝ N,
St5; 40˚23´278˝ N, 26˚42´988˝ E,
St6; 40˚23´236 ˝ N, 26˚42´800˝ E,
St7; 40˚22´931˝ N, 26˚42´768˝ E)

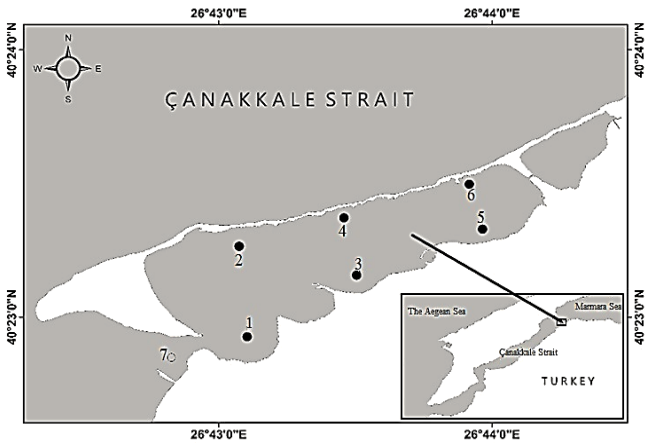

Figure 1. Sampling stations in Çardak Lagoon

Sampling

The benthos samples were collected in three replicates in October 2018, February, April, and June 2019, using a metal framed quadrat system of 100 x 100 cm and 393 cm^3 sediment core by a SCUBA diver. The deepest part of the lagoon area is roughly 2 m and there is a dense accumulation of photophilic algae and organic matter on the bottoms of the land side of lagoon. This has led to an increase in the turbidity of the underwater. Therefore, the samplings carried out at 1.5 and 1,8 m depths were performed by a scuba diver. Sediment material was collected at 7 sampling points of Çardak Lagoon, Çanakkale Strait. The samplings were performed from sandy and mud (silt+clay) bottoms between 1 and 1,8 m depths in the Çardak Lagoon (Figure 1). Sediment material collected in quadrate samples was fixed in 4% neutralized formaldehyde in 1 and 5L plastic jars. Sediment samples collected with quadrate and core were sieved and washed under laboratory conditions using pressurized water through a triple sieve system with a 0.5 mm mesh size. After the material of all faunal species remaining on the sieves had been separated at the macro and micro levels, it was fixed in groups in 70% ethyl alcohol in 50 cm³ glass tubes. The definitions are based on the reference studies by Mortensen (1927), Belloc (1948) and Tortonese and Demir (1960). The number of species (S), total abundance (N), and dominance index (DI) (Bellan Santini, 1969) were calculated for each sampling station and season. The dominance index was estimated by d = m / M x 100, where m = individual number of a species in the stations and M = total individual numbers of all species.

The physicochemical variables of the lagoon water (salinity, temperature, dissolved oxygen, pH) were measured in situ with the YSI 600 QS Multiprobe System (Yellow Springs Instruments). Amounts of nutrients such as NO^{-}_{2}, NO^{-}_{3}, NH^{+}_{4}, PO^{-}_{4}-P and SiO^{-}_{2}, were measured with a Jasco Brand UV Spectrophotometer using chemical and biological analysis techniques (Strickland and Parsons, 1972). Measurements were made at different wavelengths of 543 nm, 410 nm, 640 nm, 850 nm and 810 nm for NO^{-}_{2}, NO^{-}_{3}, NH^{+}_{4}, PO^{-}_{4}-P, SiO^{-}_{2}, respectively. Total suspended solids (TSS) determination was performed gravimetrically after the water samples were filtered through GF/C filters (Clesceri et al., 1998). Chemical oxygen demand (COD) analysis was conducted using the open reflux method and standard methods for the examination of water and wastewater according to Eaton and Franson (2005). For the spectrophotometric determination of anionic surfactants, a standard procedure was conducted using methylene blue (APHA, 1992). Acrylic material was used for the organic matter and the particle size analyses in the soft bottoms of the lagoon. A total of 28 core samples for both analyses were obtained from soft sediments at each sampling point in each sampling period. Particle size analyses of the sediment were performed according to Allen (1997). Organic matter (OM%) content was determined as the difference between the dry weight (80 ◦C, 24 h) of the sediment and the residue left after combustion at 450°C for 2 h (Parker, 1983).

Data analysis

Relationships between abundance and environmental factors were analyzed using MDS (Multidimensional Scaling Analysis). Correlations between environmental variables and the number of species and the number of individuals were determined using Pearson correlation. Pearson correlation was performed using PAST and MDS analysis in SPSS 25.

RESULTS

A total of 8 species and 259 specimens (4 cnidarians, 4 echinoderms) were collected in the Çardak Lagoon between autumn 2018 and summer 2019. (Table 1). A total of 212 Echinodermata individuals and 47 Cnidaria individuals were recorded. *Actinia* sp. from the group of cnidarians (Cnidaria) was the predominant species (22 individuals). Echinoderm *Asterina gibbosa* was the most dominant species in different seasons. Cnidarians, *Actinia* sp. were most abundant in summer (6.67 ind.m^{-2}), while *Asterina gibbosa* was represented with a high number of individuals in winter (19.67 ind.m^{-2}) (Table 1).The distribution of species numbers by stations is shown in Table 2. The total number of individuals per m^2 in the study area is 86.33 (ind.m^{-2}). The species with the highest number of individuals belonging to cnidarians is *Actinia* sp. and has the highest number of individuals at station 3 (4.67 ind.m^{-2}). Looking at the dominance values, the most abundant species is *Asterina gibbosa* from echinoderms with 127 individuals.

Correlations between the environmental variables and the abundances are shown in Table 3. The number of cnidarian species is negatively correlated with temperature and sand content in sediment, while the organic matter in sediment has a strong positive relationship. The environmental variable that affects the echinoderm abundance is NO_2+NO_3 concentration in lagoon water. The relationship was found to be statistically significant in the negative direction.

Correlations between the environmental variables and the abundance are shown in Figure 2 for the MDS (multidimensional scaling analysis). The variables that have the greatest effect on the number of cnidarian individuals are temperature and pH, while the factors that affect the distribution of echinoderm are organic matter and NO_2+NO_3.

Table 1. The number of individuals (average number of individuals per m^2) of Cnidaria and Echinodermata species in Çardak Lagoon (sum of all stations) by seasons (∑: Abundance DI%: Dominance)

Taxa	Autumn-18	Winter-19	Spring-19	Summer-19	∑	DI%
Cnidaria						
Cerianthus membranacea (Spallanzani, 1784)	-	-	0.33	-	0.33	0.39
Edwardsia claparedii (Panceri, 1869)	1	3	2	0.33	6.33	7.34
Edwardsia sp.	0.33	0.67	0.67	-	1.67	1.92
Actinia sp.	-	-	0.67	6.67	7.33	8.46
Echinodermata						
Asterina gibbosa (Pennant, 1777)	4	19.67	13	5.67	42.33	49.03
Amphiura chiajei Forbes, 1843	2.67	16.67	7.67	-	27	31.15
Ophiuroidea (sp.)	-	-	0.33	0.67	1	1.15
Holothuroidea (sp.)	-	0.33	-	-	0.33	0.38
Total	8	40.33	24.67	13.33	86.33	

Table 2. The number of individuals (average number of individuals per m^2) of Cnidaria and Echinodermata species in Çardak Lagoon (sum of all seasons) by stations (∑: Abundance, DI%: Dominance)

Taxa	St1	St2	St3	St4	St5	St6	St7	∑	DI%
Cnidaria									
Cerianthus membranacea (Spallanzani, 1784)	-	-	-	-	-	-	0,33	0.33	0.39
Edwardsia claparedii (Panceri, 1869)	2.33	-	-	-	4	-	-	6.33	7.34
Edwardsia sp.	0.67	-	0.67	-	0.33	-	-	1.67	1.93
Actinia sp.	1.33	0.33	4.67	0.33	0.33	-	0,33	7.33	8.49
Echinodermata									
Asterina gibbosa (Pennant, 1777)	-	18.67	0.33	21	1	1	0,33	42.33	49.03
Amphiura chiajei Forbes, 1843	-	0.67	-	25	1.33	-	-	27	31.27
Ophiuroidea (sp.)	0.67	-	0.33	-	-	-	-	1	1.16
Holothuroidea (sp.)	-	-	-	-	0.33	-	-	0.33	0.39
Total	5	19.67	6	46.33	7.33	1	1	86.33	

Table 3. Correlations between the number of cnidarian and echinoderm species and the environmental variables (TP: Total phosphate, NO_2+NO_3: Nitrite + Nitrate, TN: Total nitrogen, TSS: Total suspension solid, COD: Chemical oxygen demand, AnDet: Anionic detergent, OM: Organic matter)

	Echinodermata (NS)		Cnidaria (NS)	
	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Temperature (°C)	0.116	0.804	**-0.871***	0.011
Salinity (‰)	0.093	0.843	-0.002	0.997
DO (mgL^{-1})	-0.135	0.773	-0.143	0.759
pH	0.354	0.436	-0.679	0.094
SiO_2 (µg L^{-1})	0.575	0.177	-0.187	0.688
TP (µg L^{-1})	-0.448	0.313	-0.193	0.679
NO_2+NO_3 (µg L^{-1})	**-0.921****	0.003	0.226	0.625
TN (µg L^{-1})	**-0.773***	0.042	0.650	0.114
TSS (µg L^{-1})	-0.595	0.159	0.191	0.682
COD	-0.530	0.221	0.168	0.718
AnDet (µg L^{-1})	0.125	0.789	0.237	0.609
PO_4 (µg L^{-1})	-0.016	0.973	-0.058	0.902
OM (%)	-0.365	0.421	**0.924****	0.003
Sand (%)	0.511	0.242	**-0.888****	0.008
Gravel (%)	-0.520	0.231	0.669	0.100

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

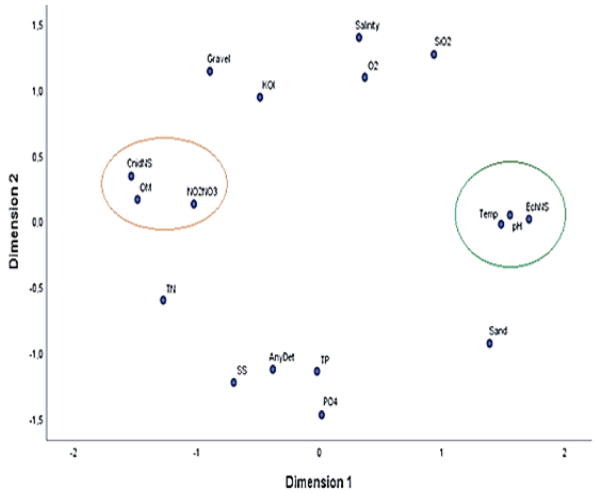

Figure 2. Results of MDS analysis between environmental variables and abundance (stress= 0.11)

DISCUSSION

The biodiversity of such ecosystems is thought to be spatially distributed, e.g. in terms of salinity, temperature and sediment properties (particle size, mud and/or organic matter enrichment) (Fišer, 2004; Karachle and Stergiou, 2008; Politou and Papaconstantinou, 1994). This structure results from organisms having an environmental tolerance to the stresses in lagoon systems (water body dynamics, physiological stress and biotic interactions). Changes in the distribution and abundance of marine invertebrates have been used as a measure of environmental impact (Warwick and Clarke, 1991), and changes in species composition may be of interest for retrospective or prospective monitoring (Philippi et al., 1998).

Mainly, excessive salinity, temperature, nutrient changes, and slowing of water regeneration in the environment affect the structure of benthic macrofauna (Afli et al., 2008). According to many previous studies performed on lagoon systems, the distribution and abundance of macrobenthos are highly influenced by the degree of salinity in water (Lardicci et al., 1997; Gamito, 2008; Specchiulli et al., 2010). Approximately 60% of the species found in this study were collected from seaside stations. Since these sampling points are under the influence of the sea, salinity has a positive effect on echinoderms, while it has a negative effect on the distribution of cnidarians. While the number of species and individuals of macrozoobenthic communities, which are very important in the nutrient cycle of coastal lagoons in Mediterranean Ecosystem (Cataudella et al., 2015), increases in winter-spring, it decreases in the summer-autumn period (Lardicci et al., 1997). Similarly, in this study, it was observed that the number of individuals increased in the winter and spring periods.

Cnidarians play an important role in coastal ecosystems due to their biological and ecological properties and are known to be good bioindicators. Due to their constant presence in the benthic fauna, they are used as bioindicators to evaluate environmental conditions. Their distribution depends on the nutrient abundance of benthic and planktonic communities, biotic factors and various environmental factors such as human activities (Arai, 1992; Bourget et al., 2003). The distribution of some cnidarian species depends on their narrow tolerance to salinity and temperature variation (Russel, 1953; Gusmão et al., 2015; Govindan and Ramanibai, 2017; Yüksel, 2019; Ahuatzin-Hernández et al., 2020). This study also found that the distribution of cnidarians was most strongly related to temperature. It is also known as a potentially invasive group due to its wide distribution in polluted areas, harbors and shipping, and its tolerance to temperature and salinity variations (Megina et al., 2013).

Cnidarian, *Actinia* sp. which is the most dominant species in this study, was previously reported from Turkish coasts. Çınar et al. (2014) reported that *Actinia* sp. was common in Turkish Seas, generally distributed at depths of 0-10 m and preferring hard bottoms as habitat. Recently, Hisli et al. (2022), recorded *Actinia* sp. at a station near the sea within Hersek Lagoon in Sea of Marmara. Conversely, we recorded most *Actinia* sp. samples (19 samples) from the stations (St1, St3 and St5), mainly on the land side. Another cnidarian, *Cerianthus membranaceus*, was recorded from Sea of Marmara and Aegean Sea by Çınar et al. (2014). *Cerianthus membranaceus* is one of most abundant species in Çanakkale Strait (Özalp and Ateş, 2015) that there are Cnidaria species, were abundant at the stations (especially at station 3, where the highest organic matter in the sediment) near the land side of the lagoon area under the influence of light pollution.

Echinoderms comprise a large number of species that dominate the benthos qualitatively and quantitatively and play

a structuring role in the habitat through their circulation. Changes in their populations can affect the entire ecosystem (Saier, 2001; Coteur et al., 2003). It is a key species for marine life as they all live in the benthos. The echinoderm species provide the balance of organic matter in the benthos. It is thought that changes in the food chain occur when they are removed from the environment because the input of organic matter is disturbed. In addition, members of Asteroidea group are known to be predators of some bivalves such as clams and oysters. In this study, *Asterina gibbosa* and *Amphiura chiajei* were the most abundant echinoderm species. These two species have a wide distribution in shallow waters of Turkish Seas (Öztoprak et al, 2014). *Amphiura chiajei* is an infaunal species typically burrowing in soft bottom sediments, especially in muddy sands (Bengil et al., 2012). In the present study, *Asterina gibbosa* and *Amphiura chiajei* are found to be quite shallow (1 m) in Çardak Lagoon and the sediment was quite clean. MDS analysis showed that environmental variables such as pH and temperature have a quite strong effect on echinoderm distribution. In addition, NO_2+NO_3 concentrations in water have statistically significant and negative correlations with echinoderm distribution. Previous studies indicated that sediment structure and especially temperature have an influence on the distribution of echinoderm species. The results found in the study, support those found in similar studies (Aronson, 1992; Hinchey et al., 2006; Rosellon-Druker and Stokesbury, 2019).

CONCLUSION

The relationships between the species diversity, abundance and environmental variables in the Çardak Lagoon are presented herein. We think that the results obtained in this study allow us to have information about the ecological quality condition of the lagoon. 80% of the species found in the study area were found in the clean areas of the lagoon under the influence of the sea. Sand content, OM%, temperature and NO_2+NO_3 were found to be the most effective parameters for the distribution of Cnidaria and Echinoderm species. Our research showed that cnidarians are dominant on the bottoms that are observed to carry the pollution load (with high organic matter content) of the study area. Whereas, echinoderms are abundant on the bottoms of seaside stations where contamination is traced (with low organic matter content).

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AUTHOR CONTRIBUTIONS

Seçil Acar: Designing of the study, identification of the investigated species, writing of the draft, submission, writing-review, and editing. A. Suat Ateş: Designing of the study, sorting the materials into taxonomic groups, and checking the original draft. Ertan Dağlı and Alper Doğan: Sorting the materials into taxonomic groups and checking the original draft.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for the study.

DATA AVAILABILITY

For any questions, the corresponding author should be contacted.

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