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Fish biodiversity in the shallow waters around the Gökçeada Island, Turkey

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Abstract

The aim of the current study is to determine the fish biodiversity in the shallow waters (0 - 20 m) of Gökçeada in the North Aegean Sea. The samples were collected monthly between June 2013 - June 2014 using by a beach seine (0 - 2 m) and beam trawl (5 - 20 m). Field sampling was carried out in two stages. A preliminary sampling survey was carried out in the first phase (March-April 2013). During this period, sampling was conducted in each station around the entire island where sampling gear was feasible to use, and the most productive sampling stations were determined. The second stage was the biodiversity monitoring work. During the study period, 13-monthly sampling surveys were carried out at six seine and dredge stations around the island. During the whole period, a total of 30509 individuals belonging to 80 species were sampled. From the seine samplings (0-2 m), 18702 individuals from 40 species were obtained. The beam trawl samplings (5-10 and 10-20 m) identified 11807 individuals from 66 species. Biodiversity indices were calculated, and species diversities and abundances were determined for the seasons. The most copious seasons in terms of number of species abundance was identified in fall and summer. Fish species diversity and abundance maps were generated for each station. As a result, it was determined that the coastal ecosystems of Gökçeada, northern Aegean Sea, incorporated many important habitats that is rich in biodiversity. In addition, many commercial species that had been over-exploited in the region was determined to use these coastal habitats for feeding, breeding, sheltering, and growing.

Keywords: Gökçeada; Fish biodiversity; Coastal habitat; Juvenile.

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1. Introduction

The temporal and spatial distribution of fish communities affected by biotic (settlement, predator pressure, competition, spawning) and environmental factors (nutrient availability, depth, temperature, algae availability and habitat complexity) (Thrush *et al.*, 2001). Fish species diversity and stock fluctuations have attracted the attention of fishermen, fishing managers and scientists since the 19th century (Hjort, 1914). International Council for the Exploration of the Sea (ICES) focuses on two important mechanisms to explain the change in the stocks. These are the effects of the fisheries and fish migrations. In addition, they explained the fluctuation in the abundance of fish with their reproductive success and the recruitment rates of the adult populations rather than the migration routes of the fish. (Houde, 2008). While evaluating the success of the recruitment to the adult population, their environment cannot be ignored.

The Mediterranean is generally known as an oligotrophic sea. But in some regions or in some seasons, this mechanism getting richer and productivity can possibly increase (Sabates *et al.*, 2007). Although the Aegean Sea has low nutrient concentrations, plankton biomass, and production, the northern part of the area is under the influence of the Black Sea waters and is relatively more productive than the south part (Stergiou *et al.*, 1997). In addition, the Northwest Aegean Sea is supplied by powerful river systems (Nittis and Perivoliotis, 2002). Compared to the Mediterranean, the North Aegean Sea contains much more mesozooplankton (Isari *et al.*, 2006).

In this respect, the North Aegean Sea is one of the most important fishing areas in the Mediterranean, especially for small pelagic fish (Stergiou *et al.*, 1997). Aegean Sea stocks, which are shared stocks, are exploited by two countries. The Aegean Sea contains many endangered and vulnerable species (Coll *et al.*, 2010). It has been reported that fishing pressure is particularly intense in the North Aegean Sea and approximately 50% of the Greek trawl fleet operates in this region. It is also stated that 57% of the total amount of demersal fish landed in the country is obtained from this region (Labropoulou and Papaconstantinou, 2004; Labropoulou *et al.*, 2008). If the demersal fish distribution is analyzed based on depth intervals, it is known that the density of young fish that ensure the continuity of the stocks is high in the coastal waters, while the older fish have a wide spread area compared to the younger fish (Labropoulou *et al.*, 2008). In this respect, it is very important to know the fish biodiversity in coastal habitats, which are of great importance for young fish. Although some biodiversity studies have been carried out around the North Aegean Sea and Gökçeada Island (Keskin and Ünsal, 1998; Labropoulou and Papaconstantinou, 2000; Kalhaniotis *et al.*, 2004; Keskin, 2004; Koç *et al.*, 2004; Labropoulou and Papaconstantinou, 2004; Karakulak and Keskin, 2007; Altuğ *et al.*, 2011; Keskin *et al.*, 2011a; Keskin *et al.*, 2011b), no study exists in the literature which include shallow waters that is vital for young fish.

In the current study, we aimed to determine the fish biodiversity in the shallow waters (0 - 20 m) of Gökçeada in the North Aegean Sea. For this purpose, the temporal and spatial distribution of the shallow water fish community in Gökçeada has been determined.

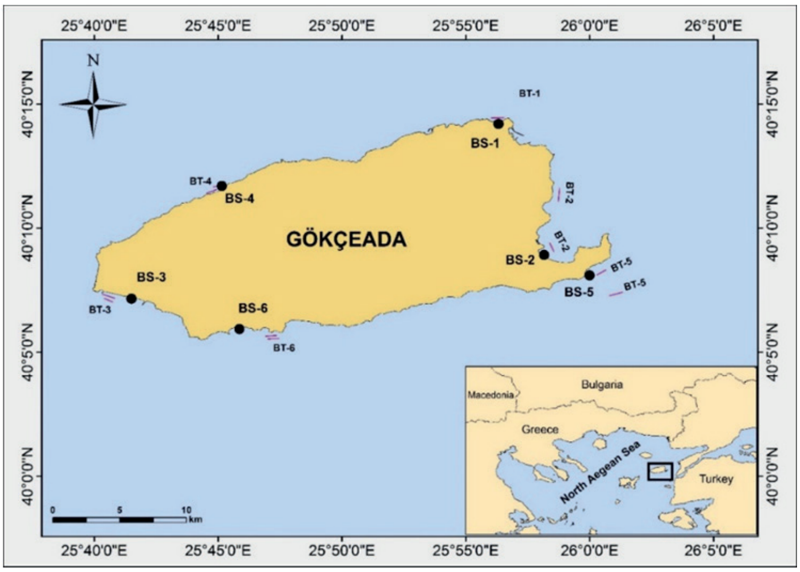

Figure 1. Sampling stations (BS: Beach seine, BT: Beam trawl)

2. Material and methods

This study was carried out at 6 sampling stations along the shallow waters of Gökçeada Island from the North Aegean Sea (Figure 1). The north and north-west coasts of Gökçeada Island consisting of large rocks. The south, south-west, and south-east sides composed of a mixture of small stones, sand, and Posidonia meadows. The north-west direction is under the influence of the Black Sea waters coming from the Saros Bay and the southern part affected from the Dardanelles.

In the current study, beach seine (0 - 2 m) and beam trawl (5 - 20 m) was used for sampling. Actually, the beach seine could not be used in waters deeper than 2 meters due to its height. In addition, the beam trawl boat cannot enter the shallower waters than 5 meters. Field sampling was carried out in two stages. A preliminary sampling survey was carried out in the first phase (March-April 2013). During this period, sampling was conducted in each station around the entire island where sampling gear was feasible to use, and the most productive sampling stations were determined. The second stage was the biodiversity monitoring work. During this period (June 2013 - June 2014), 13-monthly sampling surveys were carried out at six seine and dredge stations around the island. Beam trawling speed was 2-3 kt. The beach seine hauls were made parallel to the shore. The beach seine has 32 m in total length, with 15 m wing length. The net was constructed of 13 mm stretch mesh. The dimensions of the bag were 2 × 2 × 0.6 m, and the bag was constructed with 5 mm mesh.

Fish species were determined with the identification keys provided in Whitehead *et al.* (1986). Catch per unit effort (CPUE) was determined by dividing total catch of a species by the number of the beach seine and beam trawling hauls.

Shannon index (H) was used to characterize species diversity in the community using the following equation:

$$H = -\sum_{i=1}^{s} (p_i)(\ln p_i) \qquad (1)$$

where, S is the number of taxa, p_i is the proportion of individuals found in the i^{th} species (Shannon and Weaver, 1949).

Dominance index (D) was used to determine whether the number of individuals of a species in a community are evenly distributed, using the following equation: (*D*):

$$D = \sum_{i=1}^{s} (p_i)^2 \quad (2)$$

Seasonal species richness and the similarities of the stations were determined by the analysis of similarities (ANOSIM) and similarity percentage (SIMPER) tests. Statistical analyses were calculated by PAST version 3.1 package program (Hammer *et al.*, 2001). Statistical significance level (α) was set at 0.05. Groups with very different dispersions may produce high R values, even if there is no real difference in their centroids. See Clarke and Gorley (2001) for a guide to interpreting ANOSIM R values.

The species richness was classified and modelled in the shallow waters of Gökçeada Island. GIS and geo-statistical tools were used to model the species potential distributions in relation to the stations.

3. Results

A total of 152 beach seine and 156 beam trawl operations were conducted in the fish biodiversity monitoring study at the 6 stations determined in the shallow waters of Gökçeada for 13 months (June 2013 - June 2014). Furthermore, four seine hauling beaches were conducted, but any samples could not be taken because the dense of dead sea meadows filled the bag.

A total of 18702 individuals belonging to 40 species were obtained by the beach seine samplings (0-2 m). The CPUE of the total beach seine operations were calculated as 123 individuals/haul. The highest number of species and individuals was obtained from station 2. Although the number of individuals was high in stations 1 and 3, the number of species was the lowest (Figures 2 and 3).

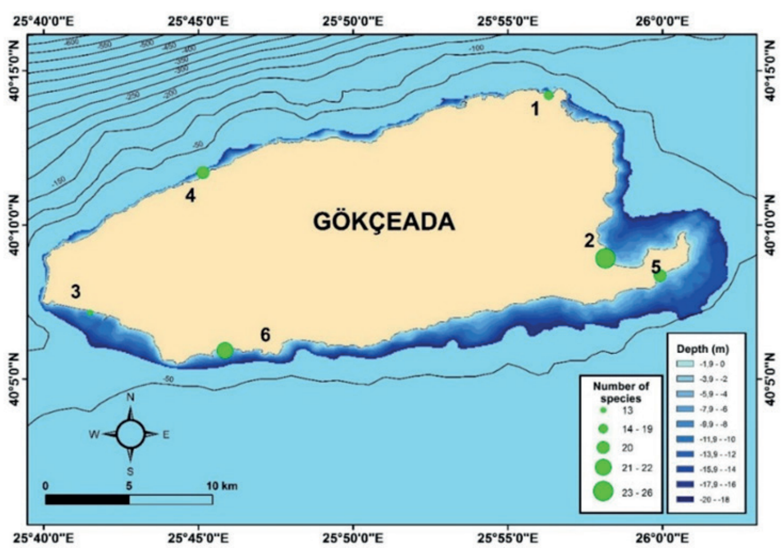

Figure 2. The density and spatial distributions of fish species obtained from the beach seine operations in the shallow waters of Gökçeada

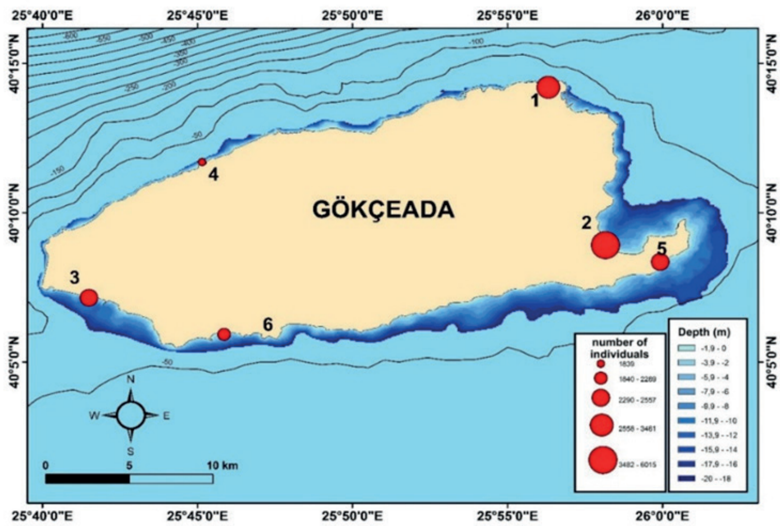

Figure 3. Density and spatial distributions of individual number of fish obtained from the beach seine operations in the shallow waters of Gökçeada

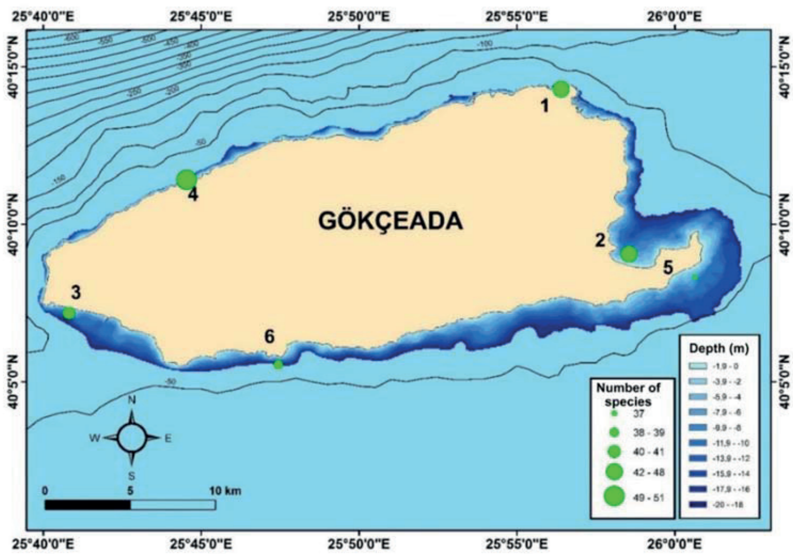

Figure 4. The density and spatial distributions of fish species obtained from the beam trawl operations in the shallow waters of Gökçeada

A total of 11807 individuals from 66 species were obtained by the beam trawl samplings (5-20 m). The CPUE of the total beam trawl operations were calculated as 75.6 individuals/haul. The highest number of species and individuals were obtained from the stations 4, 1, and 2, respectively (Figures 4 and 5). Although the number of individuals was high in stations 1 and 3, the number of species was the lowest (Figures 4 and 5).

During the whole sampling period, a total of 30509 individuals belonging to 80 species were

Table 1. Total number of the fish species caught during the whole sampling period in the shallow waters (0 - 2 m) of Gökçeada, according to seasons and stations

	Stations						Seasons			
Species	1	2	3	4	5	6	Sum	Aut	Win	Spr
Arnoglossus kessleri	51	37	35	33	117	120	90	140	90	73
Arnoglossus laterna	7	2	0	0	1	1	10	0	1	0
Arnoglossus thori	1	3	3	14	6	44	11	3	9	48
Atherina boyeri	1119	4512	1495	1579	1177	559	5772	1656	1043	1970
Belone belone	1	30	0	1	11	8	2	40	9	0
Boops boops	2	1	1	1	0	0	0	3	0	2
Bothus podas	30	1	49	55	17	44	54	56	40	46
Buglossidium luteum	0	0	0	0	0	4	0	0	2	2
Callionymus lyra	1	1	0	0	2	1	0	5	0	0
Chelidonichthys lucerna	0	1	0	0	0	1	1	0	0	1
Chelon labrosus	149	27	27	59	20	24	55	136	95	20
Chromis chromis	231	41	9	44	0	2	226	39	35	27
Clinitrachus argentatus	0	0	0	0	0	1	1	0	0	0
Conger conger	0	1	0	1	0	0	2	0	0	0
Coris julis	32	20	44	33	2	2	57	31	20	25
Dactylopterus volitans	0	0	0	3	0	0	0	0	0	3
Dentex dentex	0	0	0	2	0	0	2	0	0	0
Diplodus annularis	340	202	37	370	4	46	636	51	84	228
Diplodus puntazzo	9	0	22	2	0	54	0	6	73	8
Diplodus sargus sargus	160	139	68	118	79	20	515	46	6	17
Diplodus vulgaris	236	15	25	33	0	45	80	34	8	232
Engraulis encrasicolus	0	0	0	0	0	18	18	0	0	0
Gaidropsarus mediterraneus	1	2	0	1	0	0	1	2	1	0
Gobius geniporus	11	39	5	8	0	0	7	6	14	36
Gobius niger	0	0	0	0	1	0	0	0	1	0
Hippocampus hippocampus	0	0	0	0	1	1	0	0	0	2
Labrus viridis	3	1	0	3	0	0	4	1	2	0
Lepadogaster candolii	0	4	0	1	0	0	1	0	0	4
Lepadogaster lepadogaster	0	1	0	0	0	0	1	0	0	0
Lithognathus mormyrus	535	586	371	4	765	776	359	1963	383	332
Liza aurata	7	29	0	0	13	1	4	45	1	0
Liza saliens	0	0	4	0	0	0	0	0	4	0
Monochirus hispidus	0	0	0	0	3	0	0	3	0	0
Mullus barbatus barbatus	3	8	1	24	7	18	48	12	0	1
Mullus surmuletus	109	70	19	173	467	138	928	46	2	0
Nerophis ophidion	1	2	0	1	20	11	24	6	5	0
Oblada melanura	0	0	0	1	0	1	1	1	0	0
Pagellus acarne	322	261	145	17	183	171	98	450	266	285
Pagellus bogaraveo	522	128	1	1	0	298	1	0	0	949

Species	Stations						Seasons			
	1	2	3	4	5	6	Sum	Aut	Win	Spr
Pagellus erythrinus	20	7	32	79	56	65	143	104	11	1
Parablennius gattorugine	0	1	1	0	0	0	0	0	1	1
Parablennius tentacularis	2	0	1	0	0	0	2	0	0	1
Pomatoschistus marmoratus	369	388	406	99	666	343	972	601	346	352
Raja miraletus	2	0	0	0	1	1	3	1	0	0
Raja radula	2	3	10	5	6	5	12	6	4	9
Sardina pilchardus	2	0	3	1	1	89	93	3	0	0
Sarpa salpa	9	16	0	2	0	14	14	13	1	13
Sciaena umbra	0	0	0	2	0	0	0	1	1	0
Scorpaena maderensis	14	11	8	12	2	0	9	3	10	25
Scorpaena notata	8	0	1	9	1	1	7	3	3	7
Scorpaena porcus	19	19	9	34	1	0	44	15	15	8
Scorpaena scrofa	5	1	7	2	0	1	14	1	0	1
Serranus cabrilla	14	1	42	13	0	18	29	26	17	16
Serranus hepatus	32	5	10	39	5	42	68	47	15	3
Serranus scriba	201	153	93	163	13	15	252	113	138	135
Solea solea	0	1	0	0	1	1	1	1	0	1
Sparus aurata	0	2	0	0	0	0	0	1	1	0
Sphyraena viridensis	0	0	0	1	0	0	1	0	0	0
Spicara maena	4	29	28	16	0	1	36	7	2	33
Spicara smaris	410	54	7	578	524	438	1934	29	22	26
Spondyliosoma cantharus	16	4	0	7	0	2	17	9	1	2
Sprattus sprattus	110	0	0	0	23	1	134	0	0	0
Squatina squatina	0	0	0	0	0	1	0	1	0	0
Symphodus cinereus	189	85	49	138	30	67	352	91	74	41
Symphodus mediterraneus	30	13	7	16	1	5	44	15	4	9
Symphodus melanocercus	12	13	1	31	0	0	45	6	1	5
Symphodus ocellatus	938	694	168	218	24	61	729	585	419	370
Symphodus rostratus	285	222	84	466	3	33	631	145	184	133
Symphodus tinca	8	2	9	8	0	0	18	7	1	1
Syngnathus abaster	1	1	1	5	2	0	0	1	5	4
Syngnathus acus	3	1	3	2	1	4	1	6	4	3
Syngnathus typhle	10	6	11	7	13	23	35	8	13	14
Trachinotus ovatus	7	21	4	36	1	10	30	44	5	0
Trachinus draco	13	13	10	18	32	20	40	16	18	32
Trachinus radiatus	0	1	0	0	0	0	0	0	0	1
Trachurus mediterraneus	0	3	0	0	1	0	0	3	1	0
Trachurus trachurus	0	0	0	1	1	0	2	0	0	0
Umbrina cirrosa	1	5	0	1	0	0	1	6	0	0
Uranoscopus scaber	4	1	6	5	0	0	10	3	1	2
Zeus faber	0	0	1	1	1	0	0	3	0	0

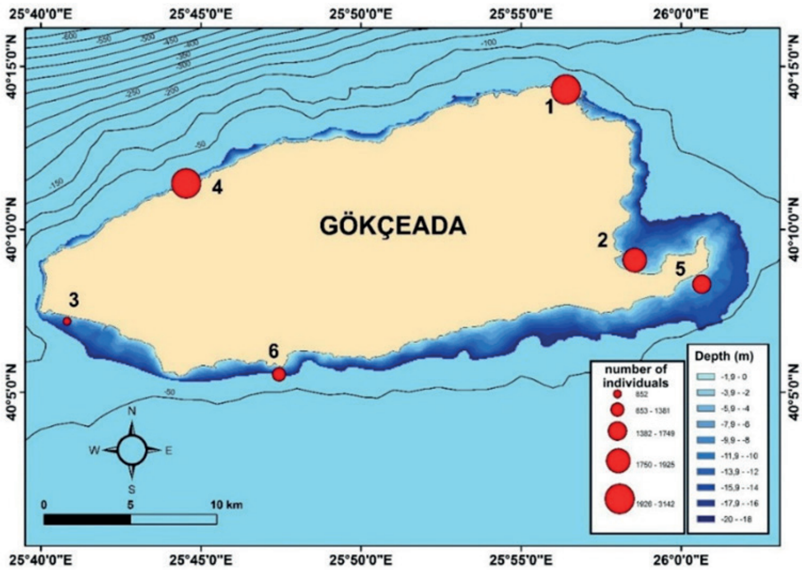

Figure 5. Density and spatial distributions of individual number of fish obtained from the beam trawl operations in the shallow waters of Gökçeada

obtained (Table 1). The most abundant species were *Atherina boyeri*, *Lithognathus mormyrus*, *Pomatoschistus marmoratus*, *Pagellus acarne* and *P. bogaraveo*, respectively. The maximum number of A. *boyeri* individuals caught from station 2 in summer, while the L. *mormyrus* was the most dominant species in autumn from station 6 (Table 1).

The highest number of species and individuals was obtained from station 2. In addition, the dominance index has reached its maximum level in the same station. The increase in the amount of *Atherina boyeri* has caused the dominance index to be highest. Although station number 1 was rich in both number of species and individuals, the dominance index had the lowest level in this station, while the Shannon index showed the highest level. The lowest values of both number of species and individuals were observed in station 3 (Figure 6).

The number of individuals was highest in summer, while it was lowest in winter (Figure 7). The number of individuals was 14732 in the summer, while this number decreased to 3512 in the winter. The increase in the amount of *Atherina boyeri* has caused the dominance index to be the highest in summer season. Also, the proportion of species and individuals in the winter has affected the Shannon index positively and reached its highest value in this season.

In the present study, significant seasonal species composition differences were found from the shallow waters (0-20 m) of Gökçeada Island (ANOSIM; R = 0.765; P = 0.0001). The results of SIMPER analysis indicated that the differences between seasons was mainly due to the variations of the dominant species that shown in Table 2. In addition, statistically significant differences in species richness were found between stations (R = 0.427; P = 0.0001) and months (R = 0.1647; P = 0.0011).

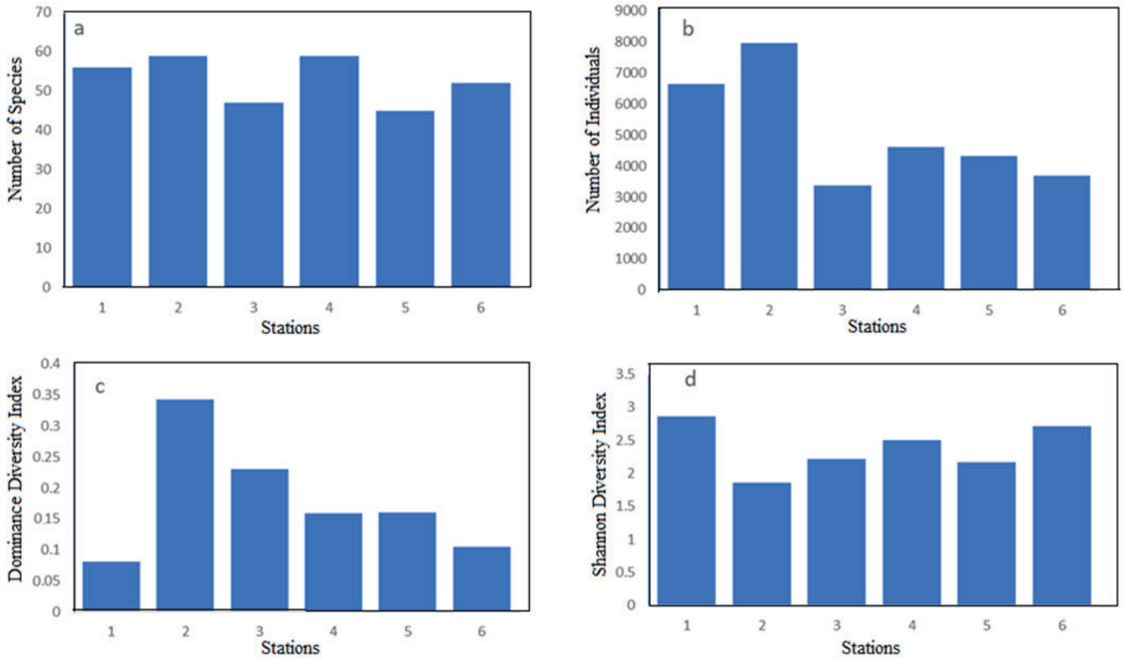

Figure 6. Number of species (a), individuals (b), and biodiversity indices (Dominance diversity index (c) and Shannon diversity index (d)) of fish obtained from the different stations of the shallow waters of Gökçeada

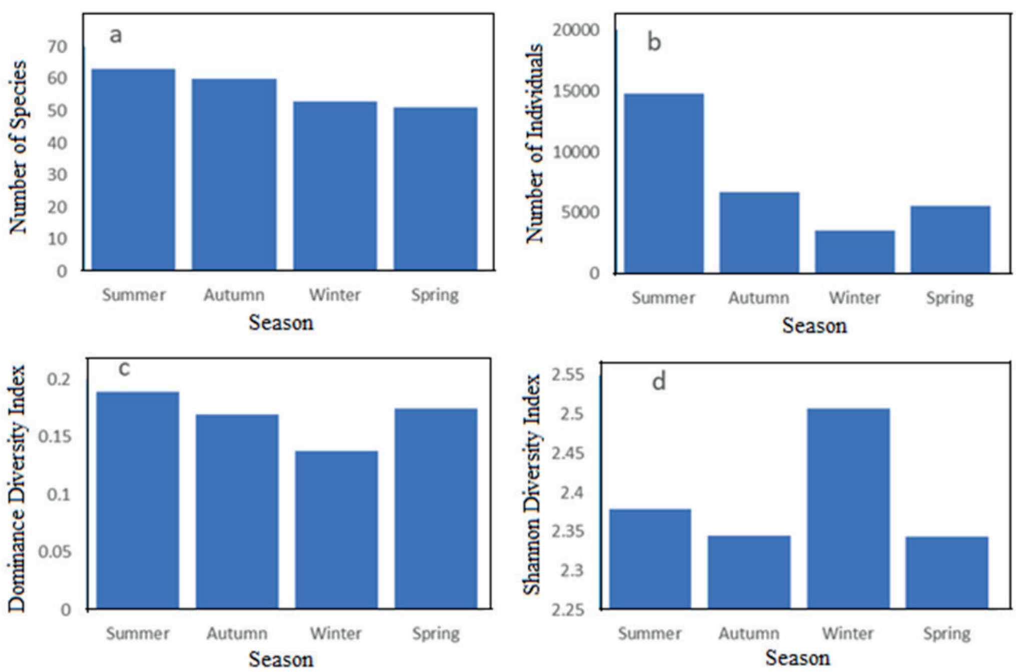

Figure 7. Number of species (a), individuals (b), and biodiversity indices (Dominance diversity index (c) and Shannon diversity index (d)) of fish according to the seasons from the shallow waters of Gökçeada

Table 2. Simper analysis results for fish species contributed to differences among seasons, collected by all operations from the shallow waters (0-2 m) of Gökçeada Island

Taxon	Average dissimilarity	Contribution %
Mullus surmuletus	1.684	4.973
Diplodus sargus sargus	1.364	4.028
Lithognathus mormyrus	1.307	3.859
Pagellus erythrinus	1.253	3.700
Pagellus acarne	1.121	3.309
Pagellus bogaraveo	1.030	3.041
Diplodus vulgaris	1.011	2.984
Spicara smaris	1.009	2.980

* The SIMPER analysis calculates the contribution of each species (%) to the dissimilarity between each season.

4. Discussion

Long-term sampling protocols are recommended to determine biodiversity. However, it has also been reported that the sampling with different fishing gears are more useful for the sampling strategy to determine the biodiversity of the coastal fish communities (Pollard, 1994; Nero and Sealey, 2005; Da Silva *et al.*, 2014). In this regard, the fishing gears of beach seine and beam trawl were used to determine fish biodiversity of the shallow waters (0 - 20 m) of Gökçeada. Fish species need specific coastal areas to feed, protection, breed and grow in the different life stages. Favorable conditions for the development of fish in coastal areas are affected by physical and biological factors.

The North Aegean Sea contains large amounts of nutrients because of the Black Sea currents and powerful river systems (Nittis and Perivoliotis, 2002). In this respect, the North Aegean Sea has a high biological diversity compared to the adjacent seas. The results obtained from the previous studies conducted from the North Aegean Sea showed that this region is very rich in fish biodiversity (Labropoulou and Papaconstantinou, 2004; Labropoulou *et al.*, 2008; Keskin *et al.*, 2011a). It has also been reported that the most diverse area in the North Aegean Sea is in the shallow waters less than 100 m (Labropoulou and Papaconstantinou, 2004). One of the most important coastal areas in the North Aegean Sea is the shallow waters of Gökçeada. The fact that Gökçeada Island is at the exit of Çanakkale Strait and therefore it is under the influence of nutrient and zooplankton-rich currents coming from the strait which increases the importance of this coastal ecosystem. It is reported that many zooplankton species belonging to the Black Sea are sampled in the coastal waters of Gökçeada (Tarkan, 2000). Ulutürk (1987), reported 144 fish species belonging to 60 families from Gökçeada Island. In the current study, 80 species were obtained in the shallow waters (0-20m) of Gökçeada Island. In addition, our sampling strategy allowed us to determine the spatial and temporal distributions of this species.

The north and the north east of Gökçeada Island has the highest number of species and individuals at the depths between 0 and 20m. During the whole sampling period conducted from the shallow waters of Gökçeada Island, Kefaloz Bay (Station 2) was found to be the most productive region in terms of both species and the number of individuals. Although the number of individuals was high in the station number 3 and 1, the number of species was the lowest. Specifically, the abundance of *Atherina boyeri* and *Lithognathus mormyrus* in these two stations explains the high number of individuals. Besides, when we look at the CPUE values showed that, the *A. boyeri* was heavily sampled in all seasons and stations. Giakoumi and Kokkoris (2013) reported that the Atherinidae family is dominant in all habitat types in the northeastern Mediterranean shallow waters. In addition, *Diplodus sargus sargus* were sampled at all sampling stations. It was also reported that the *D. sargus sargus* is a durable species and they can survive in many shallow areas with this durability (Mariani, 2006).

In the previous studies conducted around the Gökçeada Island, it was reported that the highest species diversity was observed between March and May, and the Shannon index reached the maximum level in spring while the lowest level observed in winter (Keskin and Oral, 2007; Keskin, 1996; Keskin, 2004; Keskin and Ünsal, 1998). In this study, it was determined that the most diverse season was the summer in terms of both species and individual number. In contrast to previous studies, our results showed that the Shannon index was found to be at the highest level in the winter months.

Coastal habitats are used for some species only in the juvenile period to feed, grow, and survive. In addition, some species were reported to use these coastal habitats in their both juvenile and adult periods (Beck *et al.*, 2003). Sampling of *Pomatoschistus marmoratus* species in all seasons in the shallow waters of Gökçeada can be given as an example to this situation. The current study found that species diversity between seasons was found to be significantly different from each other. For example, *Mullus surmuletus* and *D. sargus sargus* species were heavily sampled in the summer months, while they were almost nonexistent in the winter and spring. Similarly, *Lithognathus mormyrus* species was abundant in all seasons, however its amount in autumn was almost 5 times higher than the other seasons. In addition, the findings of the current study showed that the number of individuals reaches the highest level in summer. Furthermore, the results are consistent with those of Palomera (1992) who reported that the fish density is high in the coastal waters of the Mediterranean in spring and summer.

In this study, fish biodiversity of the shallow waters of Gökçeada Island and the distribution of these species according to the seasons was determined. As a result, it can be said that the coastal ecosystem of Gökçeada Island of the North Aegean Sea is very rich in terms of fish biodiversity. North Aegean Sea is an important fishing area besides being a feeding area for many fish species (Tsikliras *et al.*, 2009). This shared stock area is under intense exploitation by both countries (Labropoulou *et al.*, 2008; Labropoulou and Papaconstantinou, 2004). In this respect, it is necessary to protect these important habitats with appropriate management policies. The results obtained from the current study are important for monitoring biodiversity. Because biodiversity in marine ecosystems is an indicator of the health of that system (Coll *et al.*, 2010). The results showed that many economically important fish species exploited in this region use these coastal habitats to feed, reproduce, protect, and grow. It is apparent from that the station2 (Kefaloz bay) is very important area in both fish biodiversity and abundance. In this respect, these important habitats should be protected and even restored. Declaring such areas as Marine Protected Areas (MPA) will contribute to the sustainability of the resources.

Conclusion

In the present study, we determined the fish diversity with different sampling tools and the status of the coastal fish populations from the shallow waters of Gökçeada, Turkey. Coastal habitats were used for some species only in the juvenile period to feed, grow, and survive. Some other species were born from coastal habitats, settle into, and remain there in their entire life. The results of this study showed that 32.29% of the fish species registered in the Aegean Sea that were found to be in the shallow waters of Gökçeada, although the coasts of Gökçeada occupy a small area in the Aegean Sea.

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