

## Biodiversity of freshwater macroinvertebrates on Gökçeada Island (North Aegean Sea, Turkey)

by

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### Abstract

Island ecosystems have attracted the attention of scientists since the early days of science because of their formation and biodiversity. Despite their abundant freshwater resources, data on freshwater diversity of Gökçeada are incomplete, especially for macroinvertebrates. This study was conducted in a wide range of freshwater ecosystems on Gökçeada between May 2016 and September 2018. Sampling of macroinvertebrates was performed using a hand net from 34 pre-selected sampling sites on the island. A total of 78 aquatic macroinvertebrate taxa were found, 46 of which are new records for the island. The most common species during the study were *Gammarus komareki* and *Bythinella gokceadaensis* with a frequency of 25.93%, followed by *Tubifex tubifex*, *Gammarus* sp. and *Caenis* sp. with a frequency of 22.22%. Endemic and invasive species on the island were assessed according to their presence and frequency values. Based on the results of the current study and previous data, it can be concluded that Gökçeada is characterized by a remarkable species diversity compared to aquatic macroinvertebrates on other Aegean islands.

**Key words:** aquatic macroinvertebrates, freshwater, biodiversity, Gökçeada Island, Aegean Sea, Turkey

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## 1. Introduction

Islands have been of great importance to biology and evolution since the beginning of science, and scientists have carried out research in all aspects, including biodiversity, biogeography, geology, and archaeology.

The Aegean Sea is one of the major sea basins within the Mediterranean Sea, with approximately 7500 islands and islets that have undergone different geological formation processes (Hupało et al. 2020). The Aegean Sea plays an important role as a habitat or migration route for many species (Poulakakis et al. 2014). It also has the most interesting archipelagoes in terms of biodiversity due to its high species diversity with a large percentage of endemism (Bittkau & Comes 2005; Lymberakis & Poulakakis 2010). The Aegean Islands have undergone different formation processes, including volcanic and tectonic processes, which resulted in geographic isolation and different biogeographical histories between them and the neighboring mainland (Kougioumoutzis et al. 2017). Two of the Eastern Aegean Islands, namely Gökçeada (Imbros) and Bozcaada (Tenedos), are located in the northeastern part of the Aegean Sea, which is part of the Turkish territory. The islands have a typical Mediterranean climate with dry summers and warm and rainy winters.

Gökçeada is located in the northeastern Aegean Sea, northwest of the entrance to the Dardanelles (Çanakkale Boğazı). It is the largest Turkish island with a coastline of 92 km and an area of 289 km<sup>2</sup>. Due to fairly high precipitation, Gökçeada has a great potential for freshwater resources. The average annual rainfall on the island reached 740 mm over the last thirty years (Cengiz et al. 2013), while the adjacent mainland received 574 mm per year in the last decade, which is considerably less.

Research on the freshwater macroinvertebrates of the Aegean Islands (Greece) dates back to the 19th century and has largely focused on Mollusca (Georgopoulou et al. 2016). The freshwater invertebrate fauna of the Aegean Islands, on the other hand, is poorly researched. Similar to the Aegean Islands, no complete documentation is available for freshwater invertebrates of Gökçeada and Bozcaada (the northeastern Aegean Sea). Several studies have been carried out to investigate specific taxa on Gökçeada, including Chironomidae, Ephemeroptera, Odonata, Amphipoda, Isopoda, Gastropoda, and Oligochaeta (Şahin et al. 1988; Özkan 2006; Özbek & Özkan 2017; Zeybek et al. 2017; Aslan et al. 2018; Odabaşı et al. 2019).

Most studies on Turkish freshwater macroinvertebrates have largely focused on the

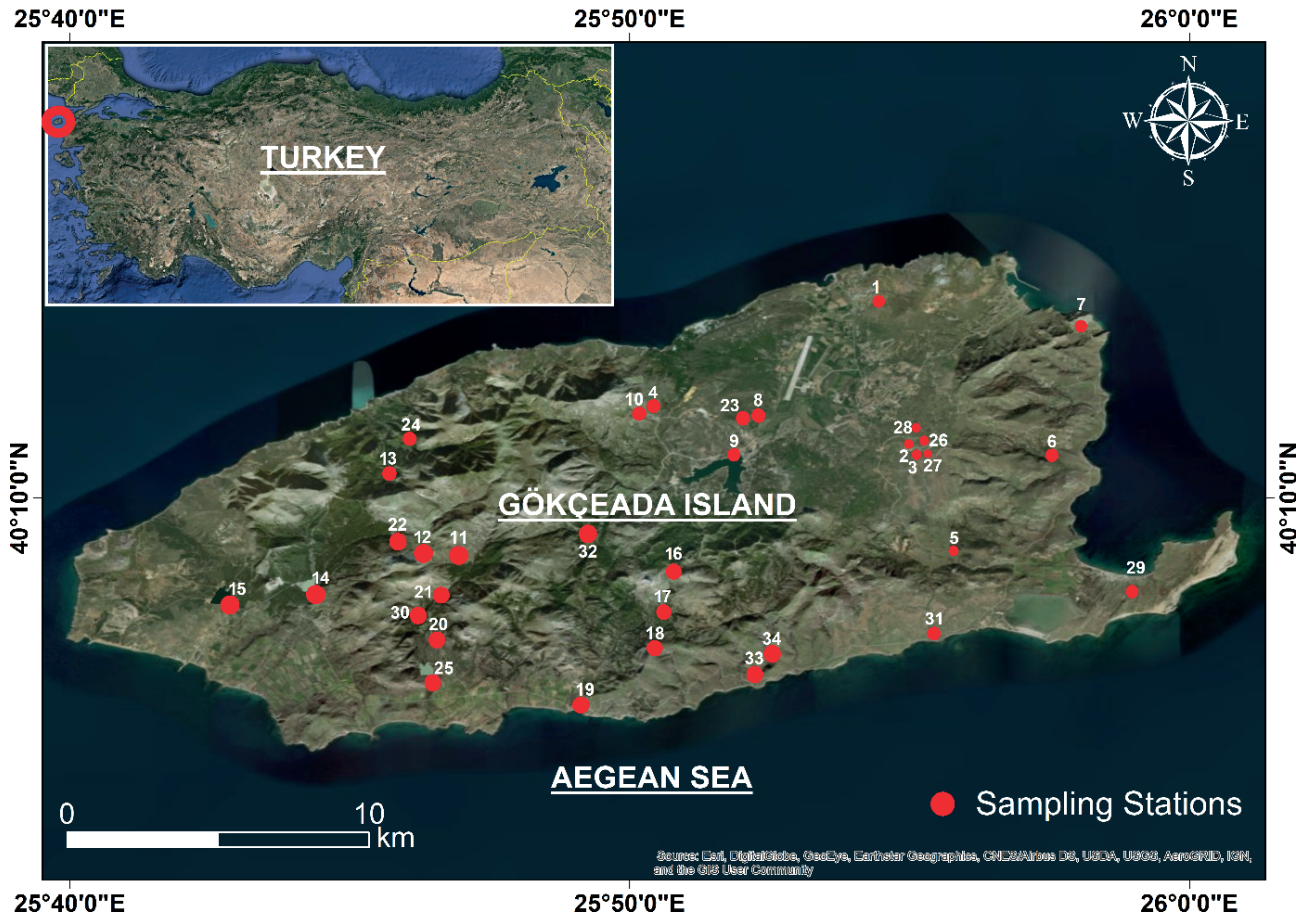
continental part. However, an inventory of freshwater invertebrates on freshwater-rich Gökçeada is needed from a biogeographical aspect. In this study, we aimed to explore the fauna of freshwater invertebrates on Gökçeada. To this end, some accessible groundwater fountains and surface water bodies, including ponds and streams (both temporary and permanent), were sampled.

## 2. Materials and methods

In order to study the freshwater macroinvertebrates of Gökçeada, different freshwater bodies, such as springs, fountains, brooks, and reservoirs, were surveyed between May 2016 and September 2018. The island has three artificial ponds and two reservoirs: Aydıncık (site 5), Şahinkaya (site 25) and Uğurlu (site 14) ponds, and Zeytinli (site 9) and Uğurlu reservoirs (site 15). In addition, some temporary streams occur on the island, such as the Marmaroz Brook (site 13) and the slow-flowing Aya Todoro Seep (site 7), which are located on the northern and eastern sides of the island, respectively. Drinking fountains are very common all over the island and provide potable water for people and wildlife. Among the sampling sites, nineteen are fountains scattered around the island and located mainly along the roadsides, while some are located in old laundries that were formerly used for washing clothes. All of these fountains provide habitat for aquatic macroinvertebrates in their concrete basins. Sampling sites selected in the streams were very shallow or even dried up in the dry season. Site 7 is an interesting aquatic habitat consisting of water seeping from a rock block located around the Aya Todoro Monastery at the eastern end of the island.

Freshwater macroinvertebrates were collected at 34 pre-selected sampling sites (e.g. St 1–34; Fig. 1) using a hand net (500 µm) and a sieve. The sampling sites are distributed throughout the island and include ponds, reservoirs, fountains, and some ephemeral water bodies such as brooks and a seep (Table 1). The fountains on the island serve as a source of drinking water for humans, whereas those for animals are generally located along the roads that are currently in use. Fountains that were formerly used for washing in old laundries are now visited only by tourists. Some of these fountains still provide habitat for macroinvertebrates. Macroinvertebrates were collected individually with forceps and fixed with 80% ethanol in plastic tubes. All material was deposited in the private collection of the author.





**Figure 1**

Map of Gökçeada and the location of the sampling sites

### 3. Results

A total of 78 macroinvertebrate taxa belonging to five taxonomic classes were found in various aquatic ecosystems on Gökçeada. Aquatic Insecta were the largest group, with 50 taxa representing six orders and 25 families (some taxa were identified only to the family level). The other classes (in order of taxonomic richness) were Clitellata (10 taxa), Gastropoda (8 taxa), Malacostraca (8 taxa), and Bivalvia (2 taxa; Table 2). The highest taxonomic richness was found at site 6 (21 taxa), followed by site 34 (15 taxa), site 9 (14 taxa), and site 7 (13 taxa). At sampling sites 10, 15, 23, 24, 26, 27 and 30, no macroinvertebrates were found throughout the study period. In terms of species richness, Insecta accounted for 64% of all taxa, followed by Clitellata (13%), Gastropoda and Malacostraca (10%), and Bivalvia (3%; Fig. 2).

Several studies have been carried out on benthic macroinvertebrates in freshwater ecosystems of Gökçeada (i.e. Şahin et al. 1988; Balık & Ustaoglu

1993; Özkan 2006; Çamur-Elipek & Aslan 2007; Özbek & Özkan 2017; Zeybek et al. 2017; Aslan et al. 2018; Odabaşı et al. 2019). In addition to the records of benthic macroinvertebrates reported in the above studies, 51 taxa were recorded for the first time during this study.

The list of invertebrate taxa identified on Gökçeada along with their localities is provided in Table 2. New records for the island are marked with asterisks.

The most frequent taxa in this study are *G. komareki* and *B. gokceadaensis* with a frequency of 25.93%, followed by *T. tubifex*, *Gammarus* sp., and *Caenis* sp. with a frequency of 22.22% (Table 2).

### 4. Discussion

In the present study, four taxa of Gastropods were recently described and are endemic to Gökçeada (Odabaşı et al. 2019). In addition, some invasive species were also recorded in this study. *Physella acuta* is the

Table 1

Sampling sites with their coordinates in DMS (degrees minutes and seconds)

No.	Local Names	Coordinates
1	Bademli Çamaşırhane (laundry)	40°13'18.7"N; 25°54'27.5"E
2	Mezbaha Çeşmesi (fountain)	40°11'5.12"N; 25°55'32.9"E
3	Mezbaha Üstü Kaynak (fountain)	40°11'14.6"N; 25°55'09.0"E
4	Pınarbaşı Fountain	40°12'5.96"N; 25°49'59.6"E
5	Aydıncık Göleti (pond)	40°09'03.1"N; 25°55'40.9"E
6	Civaki Deresi (brook)	40°10'40.6"N; 25°57'32.85"E
7	Aya Todoru Manastırı (seep)	40°13'03.4"N; 25°58'03.6"E
8	Zeytinli Köy Çeşmesi (fountain)	40°11'25.5"N; 25°52'15.5"E
9	Zeytinli Baraj Gölü (dam lake)	40°10'41.4"N; 25°51'46.3"E
10	Tepeköy Çamaşırhane (laundry)	40°11'42.3"N; 25°50'17.7"E
11	Fehim Akdemir Çeşmesi (fountain)	40°08'58.2"N; 25°46'56.9"E
12	Dereköy Çamaşırhane (laundry)	40°09'03.7"N; 25°46'19.7"E
13	Marmaroz Deresi (brook)	40°10'19.7"N; 25°45'38.3"E
14	Uğurlu Göleti (pond)	40°08'21.3"N; 25°44'16.5"E
15	Uğurlu Barajı (dam lake)	40°08'16.5"N; 25°42'41.3"E
16	Karayolları Çeşmesi (fountain)	40°08'37.4"N; 25°50'45.0"E
17	Cugura Çeşmesi (fountain)	40°07'49.1"N; 25°50'35.2"E
18	Erenyurt Deresi (brook)	40°06'59.4"N; 25°49'25.9"E
19	Karakol Çeşmesi (fountain)	40°06'10.2"N; 25°49'06.6"E
20	Recep Çınar Çeşmesi (fountain)	40°07'27.9"N; 25°46'29.4"E
21	Taşoluk Çeşme (fountain)	40°08'35.0"N; 25°46'55.6"E
22	Mavisu Çeşmesi (fountain)	40°09'11.9"N; 25°45'16.8"E
23	Zeytinli Çamaşırhane (laundry)	40°11'28.3"N; 25°52'11.4"E
24	Marmaroz Şelalesi (brook)	40°10'52.3"N; 25°46'04.6"E
25	Şahinkaya Göleti (pond)	40°06'48.5"N; 25°46'23.7"E
26	Orman Kulesi Altı (fountain)	40°11'07.4"N; 25°55'13.7"E
27	Orman Kulesi Altı (brook)	40°11'29.5"N; 25°54'49.1"E
28	Börekçi Cafer Hayratı (fountain)	40°11'38.2"N; 25°54'44.6"E
29	Aydıncık Burnu (fountain)	40°08'17.7"N; 25°58'56.7"E
30	Şahinkaya Deresi (brook)	40°08'11.7"N; 25°46'32.7"E
31	İncesu (brook)	40°07'34.33"N; 25°55'27.2"E
32	Kaymakam Rampası (brook)	40°09'40.8"N; 25°49'35.6"E
33	Nusret Bağları (brook)	40°06'47.6"N; 25°52'18.3"E
34	Recep Erden Kaynağı (fountain)	40°07'5.03"N; 25°52'31.6"E

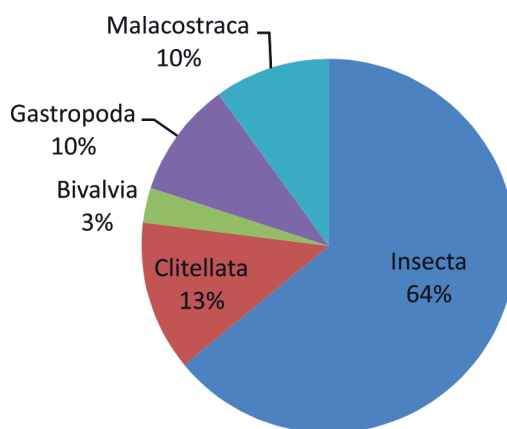


Figure 2

Species richness of taxonomic classes



Table 2

List of aquatic macroinvertebrates identified in freshwater habitats of Gökçeada Island with their localities and percentage frequency of occurrence (\* indicates new records for the island)

Taxonomic Order	Site No./% F
Phylum: Annelida Class: Clitellata Subclass: Oligochaeta Order: Tubificida Family: Naididae	
<i>Nais barbata</i> Müller, 1773*	7, 11/7.41
<i>Nais stolci</i> Hrabec, 1981*	7/3.70
<i>Nais elinguis</i> Müller, 1774*	19, 11/7.41
<i>Nais communis</i> Piguët, 1906*	11/3.70
<i>Pristina</i> sp.*	19, 11/7.41
<i>Limnodrilus udekemianus</i> Claparède, 1862*	7, 11/7.41
<i>Tubifex tubifex</i> (Müller, 1774)*	7, 19, 21, 11, 33, 34/22.22
<i>Psammoryctides albicola</i> (Michaelsen, 1901)	7, 8, 19, 11, 34/18.52
<i>Psammoryctides barbatus</i> (Grube, 1861)*	19/3.70
Family: Lumbriculidae	
<i>Stylodrilus parvus</i> (Hrabec & Cernovítov, 1927)*	16/3.70
Phylum: Mollusca Class: Bivalvia Order: Sphaeriida Family: Sphaeriidae	
<i>Pisidium subtruncatum</i> Malm, 1855	7, 29, 34/11.11
Order: Myida Family: Dreissenidae	
<i>Dreissena polymorpha</i> (Pallas, 1771)	9, 25/7.41
Class: Gastropoda Subclass: Heterobranchia Superorder: Hygrophila Family: Planorbidae	
<i>Ancylus fluviatilis</i> O. F. Müller 1774	7, 34/7.41
Family: Lymnaeidae	
<i>Galba truncatula</i> (O.F. Müller, 1774)*	34/3.70
Family: Physidae	
<i>Physella acuta</i> (Draparnaud 1805)	9, 25/7.41
Subclass: Caenogastropoda Family: Melanopsidae	
<i>Melanopsis buccinoidea</i> (Olivier, 1801)*	34/3.70
Order: Littorinimorpha Family: Bythinellidae	
<i>Bythinella gokceadaensis</i> Odabaşı, 2019*	3, 4, 16, 17, 11, 12, 19/25.93
Family: Hydrobiidae	
<i>Pseudamnicola cirikorum</i> Odabaşı, 2019*	8/3.70
<i>Pseudamnicola radea</i> Odabaşı, 2019*	29/3.70
<i>Grossuana kayrae</i> Odabaşı, 2019*	1, 16, 19/11.11
Phylum: Arthropoda Class: Malacostraca Order: Amphipoda Family: Gammaridae	
<i>Gammarus komareki</i> Schaférna, 1922	1, 3, 6, 13, 16, 33, 34/25.93
<i>Gammarus</i> sp.	2, 6, 16, 21, 22, 28/22.22
<i>Echinogammarus</i> sp.*	19/3.70
<i>Pontogammarus robustoides</i> (Sars, 1894)*	9/3.70
Family: Niphargidae	

Taxonomic Order	Site No./% F
<i>Niphargus</i> sp.*	17, 19, 20/11.11
Family: Talitridae	19/3.70
Order: Decapoda	
Family: Potamidae	
<i>Potamon ibericum</i> (Bieberstein, 1809)*	16/3.70
Order: Isopoda	
Family: Asellidae	
<i>Asellus aquaticus</i> (Linnaeus, 1758)	1, 8, 12, 19, 34/18.52
Class: Insecta	
Order: Ephemeroptera	
Family: Caenidae	
<i>Caenis</i> sp.	6, 9, 25, 31, 33, 34/22.22
Family: Baetidae*	6, 9, 13, 31, 34/18.52
Family: Heptageniidae*	13, 31, 33/11.11
Family: Ameletidae*	34/3.70
Order: Hemiptera	
Family: Corixidae	
<i>Arctocorisa</i> sp.*	5, 6, 34/11.11
Family: Micronectidae	
<i>Micronecta</i> sp.*	5, 6, 9, 14/14.81
Family: Notonectidae	
<i>Notonecta</i> sp.*	2, 6, 13/11.11
Order: Coleoptera	
Family: Dytiscidae*	6, 13, 16, 29, 34/18.52
Family: Hydrophilidae*	6, 28/7.41
Family: Curculionidae*	9/3.70
Family: Elmidae*	9/3.70
Order: Diptera	
Family: Chironomidae	
<i>Clinotanytus pinguis</i> (Loew, 1861)	5/3.70
<i>Procladius</i> ( <i>Holotanytus</i> ) sp. Roback, 1982	6, 7, 9/11.11
<i>Paramerina cingulata</i> (Walker, 1856)*	7/3.70
<i>Krenopelopia binotata</i> (Wiedemann, 1817)*	7/3.70
<i>Krenopelopia</i> sp.	6/3.70
<i>Natarsia punctata</i> (Fabricius, 1805)*	6/3.70
<i>Rheocricotopus</i> ( <i>Rheocricotopus</i> ) <i>fuscipes</i> (Kieffer, 1909)	31, 34/7.41
<i>Halocladus fucicola</i> (Edwards, 1926)*	22/3.70
<i>Cricotopus</i> ( <i>Cricotopus</i> ) <i>tremulus</i> (Linnaeus, 1758)*	6, 20, 28/11.11
<i>Cricotopus</i> ( <i>Cricotopus</i> ) <i>triannulatus</i> (Macquart, 1826)*	6/3.70
<i>Cryptochironomus defectus</i> (Kieffer, 1913)	9/3.70
<i>Einfeldia pagana</i> (Meigen, 1838)	2, 7/7.41
<i>Chironomus tentans</i> Fabricius, 1805	7/3.70
<i>Chironomus thummi</i> (Kieffer 1911)	2, 19, 11, 34/14.81
<i>Chironomus anthracinus</i> Zetterstedt, 1860	5, 4, 19, 28/14.81
<i>Chironomus viridicollis</i> (van der Wulp, 1877)	11, 28/7.41
<i>Polypedilum</i> ( <i>Pentapedilum</i> ) <i>exsectum</i> (Kieffer, 1916)	5/3.70
<i>Polypedilum</i> ( <i>Polypedilum</i> ) <i>nubeculosum</i> (Meigen, 1804)*	9/3.70
<i>Polypedilum</i> ( <i>Tripodura</i> ) <i>scalaenum</i> (Schrank, 1803)	1, 3, 9, 16/14.81
<i>Stictochironomus yalvacii</i> Şahin, 1971	5, 31/7.41
<i>Microtendipes pedellus</i> (De Geer, 1776)*	3, 34/7.41
<i>Paratanytarsus lauterborni</i> (Kieffer, 1909)	6, 9/7.41
<i>Rheotanytarsus exiguus</i> (Johannsen, 1905)	6/3.70
<i>Cladotanytarsus mancus</i> (Walker, 1856)	9/3.70
Family: Simuliidae	



Taxonomic Order	Site No./% F
<i>Simulium</i> sp.*	31, 34/7.41
Family: Stratiomyidae*	7, 13/7.41
Family: Tabanidae	
<i>Tabanus</i> sp.*	6, 13/7.41
Family: Ephydriidae*	6/3.70
Family: Dolichopodidae*	6/3.70
Order: Odonata	
Family: Cordulegasteridae	
<i>Cordulegaster</i> sp.*	6, 28/7.41
Family: Libellulidae	
<i>Brachythemis leucosticta</i> (Burmeister, 1839)*	6/3.70
<i>Crocothemis erytraea</i> (Brullé, 1832)	29/3.70
Family: Aeshnidae	
<i>Boyeria irene</i> (Boyer de Fonscolombe, 1838)*	33/3.70
Family: Gomphidae	
<i>Onychogomphus forcipatus</i> (Linnaeus, 1758)*	13/3.70
Family: Coenagrionidae	
<i>Erythromma viridulum</i> Charpentier, 1840*	25/3.70
Order: Trichoptera	
Family: Hydropsychidae	
<i>Hydropsyche instabilis</i> (Curtis, 1834)*	13, 32/7.41
<i>Hydropsyche bulbifera</i> McLachlan, 1878*	18/3.70
Family: Polycentropodidae	
<i>Cyrnus</i> sp.*	29/3.70
Family: Ecnomidae	
<i>Ecnomus tenellus</i> (Rambur, 1842)*	25/3.70

only invasive and alien species that was recorded at two sampling sites, site 9 and site 25, i.e. Zeytinli Dam Lake and Şahinkaya Pond, respectively. It is a globally invasive freshwater snail, native to North America and found in a wide variety of aquatic habitats due to its resistance to organic pollution. It is a pioneer species that easily establishes a population in a new habitat and spreads via aquatic birds (Taylor 2003; Ebbs et al. 2018). *Dreissena polymorpha* is an invasive bivalve species, but unlike *P. acuta*, it is native to Eastern Europe and the Black Sea catchment area. Similarly, this species was found at sampling sites where *P. acuta* occurs with large colonies on all hard substrates. The main route of the species introduction may be associated with some vehicles or equipment such as boats and fishing gear that bear *D. polymorpha* clumps (Benson et al. 2020). *P. acuta* and *D. polymorpha*, which were recorded in some freshwater habitats of Gökçeada, were not mentioned in previous studies except Odabaşı et al. (2019). However, according to the field observations in this study, *D. polymorpha* had probably entered the ecosystem before the year it was found.

There are several studies dedicated to freshwater macroinvertebrates on Aegean Islands. Taxa belonging

to the families Hemerobiidae, Chrysopidae and Myrmeleontidae found in Samothraki (Dvořák & Georgiev 2018), the island closest to Gökçeada, were not found in freshwater bodies of Gökçeada. Eidinger et al. (2016) also reported the occurrence of taxa representing several families of macroinvertebrates, including Gammaridae, Baetidae, Chironomidae, and Hydropsychidae, which are similar to those of Gökçeada. Moreover, Reischults (1988) reported six freshwater Mollusca species: *Theodoxus fluviatilis euxinus*, *Islamia bendidis*, *Bythinella carpentieri cabirius*, *Ferrissia wautieri*, *Ancylus fluviatilis*, and *Pisidium casertanum*. These species, with the exception of *A. fluviatilis*, are different from those found on Gökçeada.

Freshwater mollusks are one of the most studied taxa in the Aegean Sea archipelago. For example, researchers such as Schütt (1980), Bank (2004), Radea et al. (2016), Falniowski (2016), Georgopoulou et al. (2016), Szarowska et al. (2016), Glöer et al. (2018), Glöer & Hirschfelder (2019), Szarowska et al. (2014) reported the presence of taxa belonging to the families of Hydrobiidae, Bythinellidae, Planorbidae, Neritidae, Melanopsidae, Physidae, and Sphaeriidae. Most of the taxa listed by the above authors are local endemics,

except Melanopsidae and Sphaeriidae. According to the study by Georgopoulou et al. (2016), eight freshwater Mollusca taxa occur on Andros Island located in the Northern Cyclades. When comparing taxa between the islands of Andros and Gökçeada, four of the ten gastropods are common, while *Bythinella* and *Pseudamnicola* species are local endemics for both islands.

Seven species of aquatic Heteroptera belong to the families Corixidae, Gerridae, Hydrometridae, Notonectidae, and Micronectidae known from Rhodes Island (Csabai et al. 2017), while only two species belong to Micronectidae and Notonectidae found in freshwater ecosystems of Gökçeada. According to the studies carried out on Gökçeada so far, the Chironomidae family is represented by 68 species, while 34 species belonging to this taxon were identified on Rhodes (Mora & Csabai 2008). Of the Chironomidae found on both Aegean islands, only two are common, i.e. *Procladius (Holotanypus) sp.* and *Cricotopus triannulatus*.

While one species belonging to the Gammarid family was recorded on the islands of Samothraki and Lesbos of the Aegean Islands (Hupalo et al. 2020), four taxa – *Gammarus sp.*, *G. komareki*, *Echinogammarus sp.*, and *Pontogammarus robustoides* – were found in this study. Considering the occurrence of species belonging to the Gammaridae family, it is clear that Gökçeada is characterized by high taxonomic diversity compared to other islands with the same geography.

Regarding freshwater macroinvertebrates, several authors have reported the occurrence of 80 taxa on Gökçeada. In addition to the taxa reported in previous studies, 46 taxa were identified in the present study for the first time. Thus, a total of 126 taxa of freshwater macroinvertebrates occur on Gökçeada. In conclusion, the taxonomic analysis shows that Gökçeada Island is very diverse in terms of freshwater macroinvertebrate fauna.

Considering all taxonomic studies on freshwater macroinvertebrates on the Aegean Islands, Gökçeada Island was found to occupy a prominent place among them in terms of macroinvertebrate diversity. It was hypothesized that habitat diversity (ponds, reservoirs, streams, and springs), geographical location and relief (Sarı et al. 2015) were the main driving factors that increase the aquatic biodiversity of Gökçeada.

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