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RESEARCH ARTICLE

Seasonal and vertical variations of phytoplankton composition in Marine Park of Gökçeada Island in the North Aegean Sea

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Abstract

This study was conducted to understand the seasonal and vertical variations in the composition and abundance of phytoplankton assemblages in the Marine Park of Gökçeada Island and to evaluate the relations of phytoplankton community structure with the environmental parameters. Water samples were taken from the water column at surface water, 10 m, 20 m and 28 m depths in Yıldız Bay seasonally between May 2009 and January 2010. A total of 28 species belonging to Bacillariophyceae (61%) and 18 species belonging to Dinophyceae (39%) were identified. *Cerataulina pelagica*, *Cylindroteca closterium*, *Leptocylindrus minumus* from Bacillariophyceae were present in all seasons and reached high individual numbers that these species have a wide ecological tolerance to environmental factors. *Prorocentrum micans* from Dinophyceae was present throughout the seasons in small numbers. The maximum density of total phytoplankton (67987 cells L^{-1}) was observed in the winter period. Accordingly the water became turbid by mucilage clouds due to the excessive growth of the species known as producing mucilage, *Skeletonema costatum*, *Cylindrotheca closterium* and *Gonyaulax fragilis*. The ratio of nitrogen to phosphorus in the water column was recorded high (50.9) in this period. Lowest diversity and similarity between seasons were recorded in the summer period due to the excessive growth of *Proboscia alata* from Bacillariophyceae. Consequently it can be assumed that since Yıldız Bay is exposed to touristic activities in summer months, environmental disturbance causes unnecessary growth of opportunistic species and these species reduce the species diversity in the region by pressuring the growth of other species.

Keywords: Phytoplankton, Marine Park of Gökçeada, North Aegean Sea, Eastern Mediterranean

Introduction

Although the eastern Mediterranean Sea is distinguished by its low nutrient values and primary production, the North Aegean Sea is comparatively more productive than the southern part (Siokou-Frangou *et al*. 2002). Gökçeada Island located in the North Aegean Sea where the dense Mediterranean waters at the bottom and inflow of the lighter brakish Black Sea waters from the Dardanelles come across (Uçkaç 2005; Pazı 2008). The island has a coastal line of 91 km. A specific part of the northern coast of the island was declared as the first Marine Park of Gökçeada Island by Turkish Marine Research Foundation in 1999 due to its ecological importance between the Black Sea and the Mediterranean Sea. The borders of the Park later had extended to Çiftlik Bay in 2012 proposed by the Turkish Marine Research Foundation. At present, the Park extends over the 1.5 miles-long coast between Yıldız Bay (40° 14.186′ N - 25° 54.230′ E) and Çiftlik Bay (40° 14.432′ N - 25° 56.112′ E) and the area of 200 m from the coasts to offshore.

The studies in the Aegean Sea generally have concentrated on spatio-temporal distributions of phytoplankton in the water column (Gotsis-Skretas *et al*. 1996; Ignatiades 1969, 1976; Ignatiades *et al*. 1995). A few studies have been conducted on ecological characteristics of phytoplankton in the North Aegean Sea (Balkis 2009). It is true that phytoplankton composition and their variations among seasons are effected by different hydrodynamic conditions existing in the Aegean Sea as a result of inflows of the Black Sea and the Mediterranean Sea (Balkis 2009). In our study, we aimed to find out the seasonal and vertical variations of the composition and abundance of phytoplankton assemblages and evaluate the relations of phytoplankton community structure with the environmental parameters in Yıldız Bay that is situated in the Park.

Materials and Method

This study was conducted seasonally between May 2009 and January 2010 in the Marine Park of Gökçeada Island (Yıldız Bay 40° 07' N, 25° 55' E) (Figure 1). Transparency of the water was measured with a Secchi disc. Water temperature was recorded with a multiparameter. Water samples (1 L) were taken with Nansen bottle water sampler in the water column at 0 m, 10 m, 20 m and 28 m depths and fixed in 4% formaldehyde solution *in situ*. In the laboratory, sub-samples (10 ml) were allowed to settle for 24 h in HydroBios chambers until the identification process (Utermöhl 1958). Phytoplankton assemblages were identified and counted in Nikon TE 2000 U model inverted microscope (10×, 20×, 40×). During the identification process, Tomas (Tomas 1996), Cupp (Cupp 1943) and Hendey (Hendey 1964) were utilized. According to the results, the excessive cell counts of *Emiliania huxleyi* from Haptophyceae made the results incomprehensible that we had to discard this group.

In addition to the measurement of suspended particulate materials in the water column, dissolved inorganic nitrogen, total phosphorus, silicate, and chlorophyll a concentrations were measured spectrophotometrically. After all, ratio of nitrogen to phosphorus was calculated. Analysis of similarity percentages

(SIMPER) was applied to detect the species responsible for the dissimilarity between seasons by using Primer-6 software. Species diversity was also estimated by using the Shannon-Weaver diversity index (H′ loge).

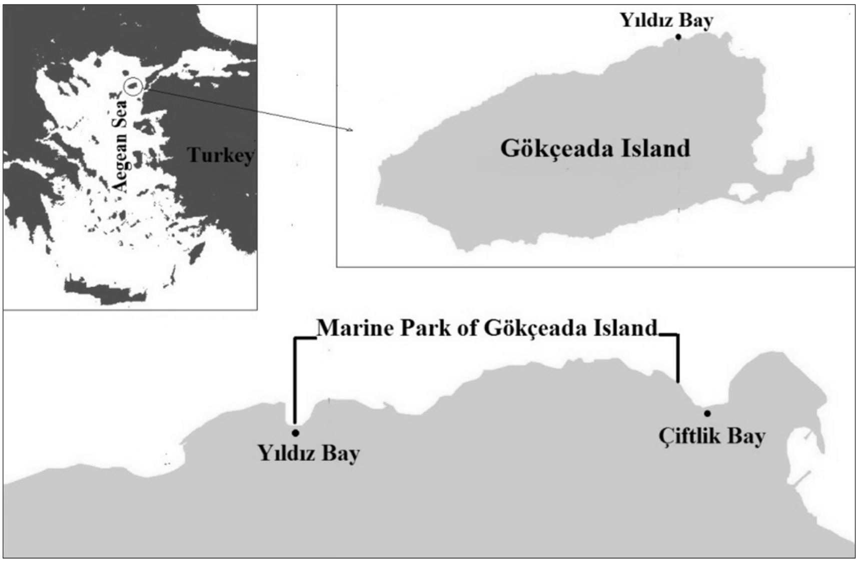

Figure 1. Study area - Yıldız Bay in Marine Park of Gökçeada Island

Results and Discussion

In total, 46 species belonging to two classes, Bacillariophyceae (61%) and Dinophyceae (39%), were identified and their densities declined significantly depending on depth throughout the year.

In the spring period, Bacillariophyceae reached to 8884 cell L^{-1} maximum at surface water and Dinophyceae reached to 5031 cell L^{-1} at 20 m (Figure 3). *Prorocentrum scutellum* (4726 cell L^{-1}) dominated the phytoplankton. Chlorophyll a, the characteristic pigment in all photosynthetic organisms (Wetzel 1983) reached high values (0.028 μg^{-1}) parallel to the growth of phytoplankton. The ratio of nitrogen to phosphorus has recorded lower (8.8) than the Redfield ratio of 16 for ocean plankton due to the consumption of nitrogen by the phytoplankton in this period.

The suspended particulate materials in the water column depends on the growth of phytoplankton and the movements of sediment that occurs with the effect of wind and waves (Kocataş 1999). The low recorded water transparency (10 m) in spring was related not only with the growth of phytoplankton and the highest values of suspended particulate materials (37.18 mg/L) at 28 m. The northern coasts of the island are exposed to strong winds in spring and as observed by Pazı (2008) in the Notheastern Aegean, the summer stratification causes water currents to be stronger in spring.

In the summer period, the density of total phytoplankton was recorded minimum (18378 cell L^{-1}) among the seasons (Figure 2). Bacillariophyceae showed their lowest value (2105 cell L^{-1}) at 28 m. There was no record of Dinophyceae at 20 m and 28 m. Due to the phytoplankton depletion, the N/P ratio increased to 58.2 at 20 m.

In the autumn period, the highest water transparency was recorded as 18 m and the highest silicate values (0.1 µg L^{-1}) were recorded at 10 m when the total phytoplankton density (53956 cell L^{-1}) was characterized as low (Figure 2). Therefore it can be stated that the growth dynamics of phytoplankton affected the silicate concentrations adversely in all seasons.

Contrary to expectations, total phytoplankton density reached maximum values (186398 cell L^{-1}) in the winter period among seasons (Figure 2). Bacillariophyceae showed maximum growth (67987 cell L^{-1}) at surface water. Accordingly the restrictive element for the growth of diatoms (Reynolds 1984; Round 1973), silicate values (0,025 µg L^{-1}) at 20 m and the Secchi disc depth (11 m) were recorded low comparing to other seasons owing to the mucilage aggregations developed by diatomes and dinoflagellates.

Dinophyceae displayed maximum growth (5817 cell L^{-1}) at 10 m. As a result of the intense growth of phytoplankton, chlorophyll a reached high values (0.023 µg^{-1}) at 10 m (Table 1).

Skeletonema costatum, *Cylindroteca closterium*, *Pseudonitzschia seriata*, *Proboscia alata*, *Cerataulina pelagica*, *Thallassiosira* sp., *Rhizosolenia setigera* and *Leptocylindrus minumus* among diatoms and *Prorocentrum micans* among dinoflagellates that are capable of surviving in well mixed conditions (Godrijan *et al*. 2013) dominated phytoplankton populations in this period. As the well-known species to form mucilage, *S. costatum*, *C. closterium* and *P.micans* have also been reported with previous researches (Pompei *et al*. 2003; Najdek *et al*. 2005; Urbani *et al*. 2005).

Moreover, the N/P ratio was recorded high (50.9) in this period as it is characteristic in the water column during the mucilage phenomena (Aktan and Gümüşoğlu 2010).

While evaluating the results of the statistical analyses, Shannon-Weaver index values proved that the highest species diversity (H′ loge) was recorded in winter at 10 m (Figure 4) and the lowest diversity was recorded in summer at 10 m due to an extreme increase of *P. alata* (3353 cell L^{-1}) characterized as typical summer diatom species (Godrijan *et al*. 2013). In autumn, the diversity increased sharply after summer.

As shown in the SIMPER analysis (Table 2), similarity among the seasons was low and the lowest similarity (ave. 15.67) was measured in summer that *P. alata* (6193 cell L^{-1}) contributed to the similarity of the total phytoplankton density (18378 cell L^{-1}) with the value of 49.26 %. In the following season, autumn, *Hemiaulus hauckii* (33164 cell L^{-1}) dominated the Bacillariophyceae and contributed to the similarity of the total phytoplankton density (53957 cell L^{-1}) with the value of 1.04%.

In this research, Bacillariophyceae and Dinophyceae, the most principal groups in terms of species number in phytoplankton assemblages (Balkıs 2003; Taş 2013) reached generally high numbers in the surface water compared to other depths.

The phytoplankton community structure changed throughout the seasons depending on the positive relations with the nutrients in the water column. The presence of underwater discharge pipes of domestic sewage in Kaleköy Port that is about 0.7 miles (1.3 km) far from Yıldız Bay make diatom species frequent in the region during the year. High quantities of nutrients carried to the aquatic media by domestic discharges cause high levels of primary production. The highest abundances of phytoplankton community in the winter period were related with high values of N/P ratio and low temperatures as also described by Godrijan *et al*. (2013).

In aquatic environment, one of the nutrients that regulates algal growth (Fisher *et al*. 1999; Stevenson *et al*. 1996) is phosphorus. The decline in phosphorus concentrations in the summer period caused the regression of the phytoplankton density. Depleted phosphorus concentrations in the water column were regarded as a limiting factor on phytoplankton growth (Aydin and Buyukisik 1994).

Ignatiades (1969) stated that species diversity decreases to a minimum rank in the occurrence of unexpected increases of phytoplankton. Considering our research, touristic activities in the summer period caused an excessive growth of only a few species and especially *P. alata* was the dominant species responsible for the lowest diversity. Therefore it can be declared that antropogenic effects on aquatic environments caused by tourism activities accelerate the excessive growth of opportunistic species.

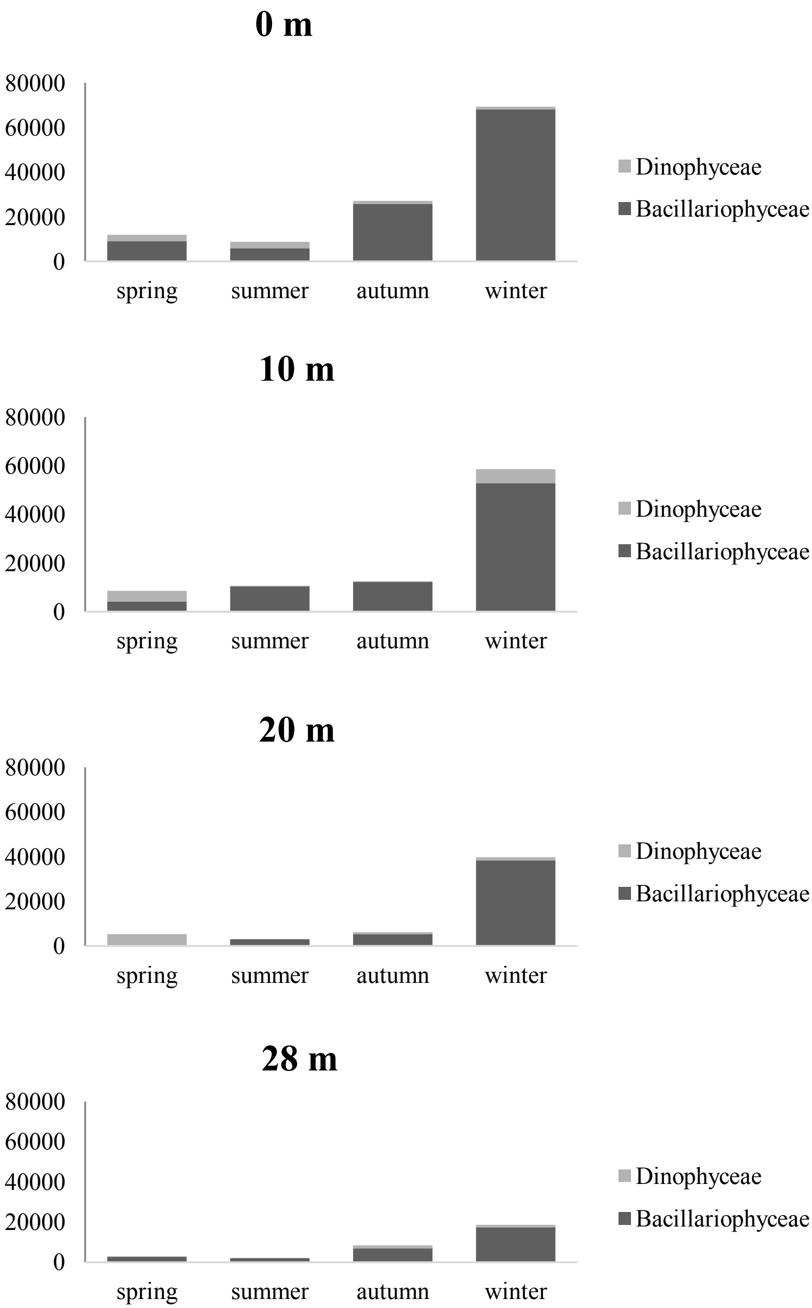

Figure 2. Seasonal variation in the abundance (cell L^{-1}) of the phytoplankton groups

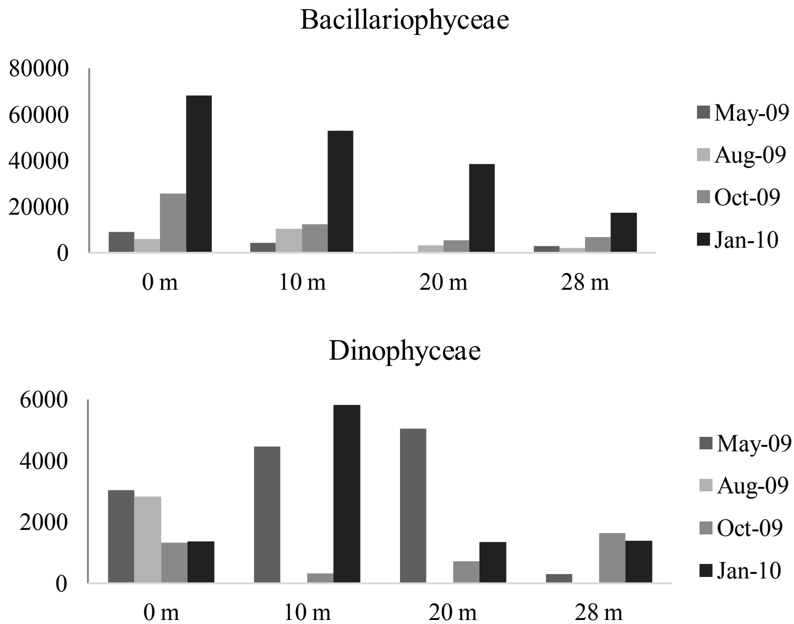

Figure 3. Variations in the abundance (cell L^{-1}) of the two major phytoplankton groups

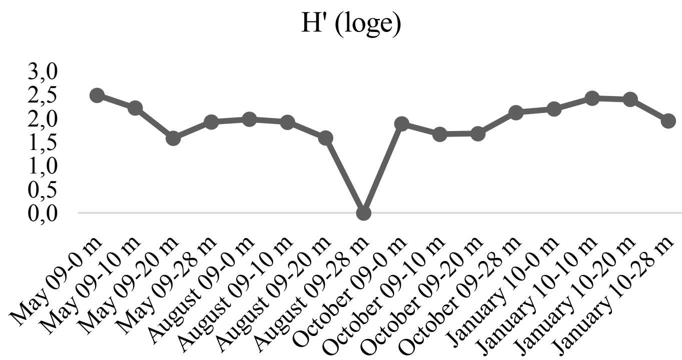

Figure 4. Variations of the Shannon-Weaver index (*H'*loge) of the sampling stations

Table 1. The mean values and standart deviation of the parameters analysed in the water column (0-28 m) of Yıldız Bay

	May-09		**Aug-09**		**Oct-09**		**Jan-10**	
	Range	**mean±SD**	**Range**	**mean±SD**	**Range**	**mean±SD**	**Range**	**mean±SD**
Temperature (^{o}C)	21-17	19±1.82	26-25	25±0.50	21-20	20.5±0.57	15-13	13.75±0.95
N/P	12.9-8.8	10.7±1.97	58.2-52.4	55.6±2.44	48.6-37.2	42.6±5.26	50.9-42.9	46.6±4.21
Si O_2 (μg 1^{-1})	0.024-0.014	0.017±0.005	0.042-0.022	0.032±0.011	0.100-0.022	0.067±0.035	0.075-0.025	0.051±0.023
SPM (mg l $^{-1}$)	37.2-26.4	30.3±4.69	19.9-16.5	18.2±1.45	35.6-26.7	31.2±3.85	23.7-11.4	18.8±5.19
Chlorophyll *a* (μg 1^{-1})	0.028-0.015	0.021±0.005	0.022-0.008	0.017±0.006	0.008-0.006	0.007±0.001	0.023-0.015	0.018±0.004
total density (cell $^{-1}$)	11922-3064	7214±3878	10463-2105	6084±4162	26956-6070	13489±9360	69365-18724	46599±22251
Sechi disc depth (m)		10		12		18		11

Table 2. Contribution percentages of dominant species in the studied region

May 09 – Species	Av.Abund	Av.Sim*	Sim/SD**	Contrib%	Cum.%
Prorocentrum scutellum	38.91	12.84	5.10	41.58	41.58
Gyrodinium fusiforme	15.90	5.96	5.09	19.31	60.89
Oxytoxum sp.	27.05	5.00	0.58	16.18	77.07
Diploneis sp.	24.32	3.36	0.58	10.87	87.94
Cerataulina pelagica	20.34	3.00	0.58	9.72	97.66
August 09 – Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Proboscia alata	32.58	7.72	0.89	49.26	49.26
Cerataulina pelagica	22.38	4.95	0.41	31.62	80.88
Navicula sp.	15.52	2.78	0.41	17.75	98.63
October 09 - Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Hemiaulus hauckii	77.84	17.09	1.52	41.04	41.04
Cerataulina pelagica	32.20	10.79	2.53	25.89	66.93
Proboscia alata	24.76	8.13	4.94	19.53	86.46
Cylindroteca closterium	21.16	2.98	0.89	7.15	93.61
January 09 - Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Skeletonema costatum	97.99	14.59	4.20	24.19	24.19
Pseudonitzschia seriata	110.51	13.26	1.98	21.99	46.18
Proboscia alata	87.03	11.13	5.56	18.46	64.64
Leptocylindrus minumus	54.09	6.63	7.03	10.99	75.63
Cerataulina pelagica	61.00	5.92	3.02	9.82	85.45
Chaetoceros sp.	22.00	2.06	0.91	3.42	88.87
Thallassiosira sp.	23.37	1.85	0.82	3.06	91.93

*: Average similarity, **: Standart deviations of similarities

C. pelagica, *C. closterium*, *L. minumus* and *P. micans* were present in all seasons as in the study of Godrijan (Godrijan *et al.* 2013) that it can be assumed that these species have a wide ecological tolerance so they can be used as bio-indicators for monitoring the environmental alterations in the park. Owing to its active swimming cell phases, *P. micans* has the ability of adaptation to various environmental factors and shows tolerance to wide varieties of water temperatures (Dodge 1982; Alkawri and Ramaiah 2010). Although *P. micans* form massive blooms, it is generally regarded as nontoxic species (Graneli *et al.* 1990).

The results of the study pointed out that seasonal variation of total phytoplankton abundance is directly proportional with chlorophyll a. With regard to the results of high chlorophyll a values and the high abundance of phytoplankton, the trophic status of the area was accepted as productive comparing to other regions.

We highlighted that the phytoplankton composition can easily be affected by the environmental factors and as a consequence they could be used as bioindicators of monitoring environmental fluctuations. Therefore more attempts should be made to provide valuable data on the phytoplankton composition and to protect this ecologically important marine region.

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Kuzey Ege Denizi'ndeki Gökçeada Deniz Parkı'nda fitoplankton kompozisyonunun mevsimsel ve vertikal değişimi

Özet

Bu çalışma, Gökçeada Deniz Parkı'nda fitoplankton topluluklarının kompozisyonunun ve bolluğunun mevsimsel ve vertikal değişimlerini ortaya koymak ve fitoplankton komünite yapısının çevresel faktörlerle ilişkilerini değerlendirmek için yürütülmüştür. Su örnekleri, Yıldız Koy'daki su kolonunun yüzeyi, 10 m, 20 m ve 28 m'sinden Mayıs 2009 ve Ocak 2010 ayları arasında mevsimsel olarak alınmıştır. Çalışma boyunca, Bacillariophyceae (%61) grubuna ait toplamda 28 tür ve Dinophyceae (39%) grubuna ait 18 tür teşhis edilmiş ve birey sayıları her mevsim ve derinlik için kaydedilmiştir. Bacillariophyceae divizyosuna ait *Cerataulina pelagica*, *Cylindroteca closterium* ve *Leptocylindrus minumus* her mevsim mevcudiyet göstermiştir ki bu da onun çevresel koşullara geniş bir ekolojik toleransı olduğunu göstermektedir. Dinophyceae divizyosuna ait *Prorocentrum micans* yüksek birey sayılarına ulaşmamakla birlikte mevsimler boyunca mevcudiyet göstermiştir. Maksimum fitoplankton yoğunluğu (67987 cell L^{-1}) ise kış döneminde gözlenmiştir ve *Skeletonema costatum*, *Cylindrotheca closterium* ve *Gonyaulax fragilis* gibi müsilaj ürettiği bilinen türlerin aşırı gelişimi nedeniyle sualtı, müsilaj bulutlarıyla kaplanmıştır. Bu nedenle su kolonundaki azot-fosfor oranları bu dönemde yüksek olarak kaydedilmiştir (50.9). Bacillariophyceae divizyosuna ait *Proboscia alata* türünün aşırı gelişimi nedeniyle mevsimler arası en düşük tür çeşitliliği ve benzerlik yaz döneminde kaydedilmiştir. Dolayısıyla Yıldız Koy'un yaz aylarında turistik aktivitelere maruz kalması sonucu bozulan çevresel koşulların, fırsatçı türlerin aşırı gelişimine neden olduğu söylenebilir ve bu türler, diğer türlerin gelişimlerini baskılayarak bölgedeki tür çeşitliliğini azaltmaktadırlar.

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