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Comparison of the Seasonal Distribution of Phytoplankton Composition Inside and Outside Mersin Marina

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ABSTRACT

The objective of this study was to ascertain the impact of the marine operation and breakwater on the phytoplankton composition, as sampled from both within and without the marina, on a seasonal basis. A total of 110 taxa belonging to Bacillariophyceae, Coscinodiscophyceae, Mediophyceae, Dinophyceae, Prymnesiophyceae, Cyanophyceae, and Thecofilosea were identified. The Dinophyceae class made the highest contribution to the phytoplankton composition. The average phytoplankton abundance in the Mersin Marina marine area was 19082 cells/L, with a biomass of 4.61 µg/L recorded throughout the year. *Emiliana huxley* accounted for 98% of phytoplankton abundance and 66% of biomass. Therefore, the abundance and biomass of phytoplankton were recalculated, excluding *E. huxley*. The mean abundance of phytoplankton within the marina and its surrounding waters was determined to be 279 and 289 cells/L, respectively. The mean biomass was found to be 1.21 and 1.88 µg/L in these environments. Microplankton abundance (except autumn) and biomass were higher outside the marina in all seasons. The dominant microplankton species were *Asterionellopsis glacialis, Chaetoceros curvisetus, Chaetoceros gracilis* and *Bacteriastrum comosum* in autumn, *Chaetoceros didymus* and *Chaetoceros lauderi* in spring, *Pseudo-nitzschia delicatissima, Gyrodinium fusiforme, Pseliodinium fusus* and *Heterocapsa pygmea* in summer. According to the Shannon (H') index, species diversity was higher outside than inside the marina. As indicated by the results of the analysis, species diversity (H=2.48) and homogenity (J=0.78) exhibited higher values during the summer months, while autumn (d=1.38) was associated with higher richness.

Keywords: Phytoplankton, Species composition, Abundance, Biomass, Mersin Marina

1. INTRODUCTION

Marinas are enclosed areas protected from the physical effects of wind and waves by a breakwater. In addition to the safe mooring of yachts and boats of various sizes and characteristics, marinas are port businesses that provide maintenance, repair, and

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other services. In this context, marinas constitute the highest source of income in marine tourism (Özkan & Ayıran, 2008; Muslu, 2017). Due to these anthropogenic activities, ecological changes in these areas are inevitable.

Phytoplankton, the first link in the marine food chain, is a crucial indicator of ecological structure and productivity. The composition of phytoplankton enables predictions regarding the length of the food chain and the pollution of the environment. Phytoplankton is responsible for more than half of the world's photosynthetic production. Consequently, the composition of phytoplankton plays a pivotal role in the absorption of carbon, a primary contributor to global warming. Due to their need for light, phytoplankton are distributed in the water column to depths where light can reach 1% (Hader, 1995). Phytoplankton are therefore sampled over multiples of the depth of the Secchi disk (SDDx1, SDDx2, SDDx3). The ability of plankton to migrate vertically within the illuminated zone allows them to achieve the highest production efficiency by moving toward nutrient salts and light (Hader, 1995).

Marine plankton is classified into various taxonomic groups, including dinoflagellates, diatoms, coccoliths, cryptophytes, cyanophytes, and small flagellates (Soydemir, 2004). It has been established that dinoflagellates and diatoms exhibit higher levels of species diversity compared to other groups. The increase in nutrient salts, such as nitrogen, phosphorus, and silica, in the environment has been shown to cause changes in water quality due to excessive reproduction of plankton. This, in turn, has been demonstrated to have adverse effects on organisms at the upper trophic level of the food chain (Gençay & Büyükışık, 2004). The viability of an ecosystem is contingent upon the maintenance of equilibrium within its food chain. In light of the ecological ramifications engendered by plankton, the examination of species composition assumes paramount importance in the context of environmental research.

The Mediterranean has an oligotrophic structure. While the amount of nutrients is low, biodiversity is relatively high. This situation causes the food chain links to extend into the Mediterranean Sea. Despite the existence of studies on phytoplankton composition in the Northeastern Mediterranean Sea (Salihoğlu et al., 1990; Polat et al., 2000; Eker-Develi et al., 2006; Aktan, 2011; Uysal, 2020), no research has been conducted in Mersin Marina, which was selected as the study area. The objective of this study was to investigate the seasonal changes in phytoplankton composition in Mersin Marina and to determine the ecological differences by comparing the local station with selected stations from offshore locations.

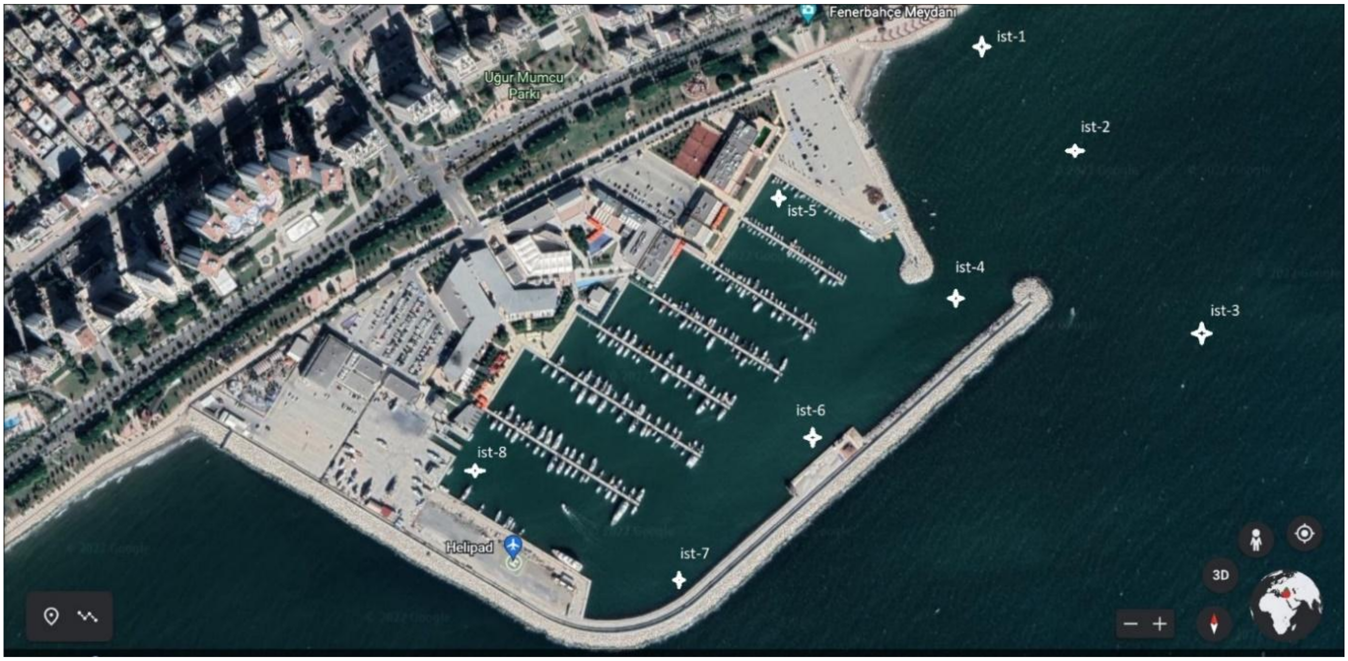


Figure 1. Sampling points

2. METHODOLOGY

Mersin Marina is the largest marina in the Eastern Mediterranean, with a mooring capacity of 500 yachts and a land parking capacity of 500 yachts located at coordinates 36°46′N 34°34′D in the Yenişehir district of Mersin province. The area of the marina where the facilities are located is 145 decares, and the sea area protected by the pier, and breakwater is 160 decares. The west breakwater is 1140 meters, the east breakwater is 265 meters and the pier length is 2500 meters. In this study, phytoplankton samples were collected from a total of eight stations, three of which were located outside the marina. Sampling was carried out in surface water and at multiples of Secchi disk depth (SDDx1, SDDx2, and SDDx3). As illustrated in Figure 1, the sampling stations were strategically positioned to ensure a comprehensive data collection.

Sampling was conducted in November 2022, April 2023, and June 2023. The months of November, April, and June correspond to the autumn, spring, and summer seasons, respectively. Conducting winter sampling proved unfeasible. The data from the sampling stations are presented in Table 1-3. The following are the physical and chemical properties of the water at the sampling stations: The CTD (Conductivity, Temperature, Salinity) was determined using a probe, while turbidity was determined using a Secchi disk. The dissolved oxygen was determined using an oxygen meter (Table 4).

Table 1. Data of sampling stations in November (2022)

Station	North (N)	East (E)	Depth	Secchi Disk	Sampling Date	Sampling Time
1	36.773230	34.574922	3m	3m	17.11.2022	10.00
2	36.77232	34.57583	4m	4m	17.11.2022	10.20
3	36.77070	34.57780	7m	3.5m	17.11.2022	10.40
4	36.77061	34.57411	5m	1.5m	17.11.2022	11.00
5	36.77167	34.57209	4m	1.5m	17.11.2022	11.20
6	36.76925	34.57239	5m	1.5m	17.11.2022	11.40
7	36.76806	34.57054	5m	1.5m	17.11.2022	12.00
8	36.76915	34.56841	4.5m	1.5m	17.11.2022	12.20

Table 2. Data of sampling stations in April (2023)

Station	North (N)	East (E)	Depth	Secchi Disk	Sampling Date	Sampling Time
1	36.773230	34.574922	3m	3m	06.04.2023	10.30
2	36.77232	34.57583	4m	4m	06.04.2023	10.55
3	36.77070	34.57780	7m	3.5m	06.04.2023	11.10
4	36.77061	34.57411	5m	3m	06.04.2023	11.40
5	36.77167	34.57209	4m	2.5m	06.04.2023	12.05
6	36.76925	34.57239	5m	2.5m	06.04.2023	12.30
7	36.76806	34.57054	5m	2.5m	06.04.2023	13.00
8	36.76915	34.56841	4.5m	2.5m	06.04.2023	13.28

Table 3. Data of sampling stations in June (2023)

Station	North (N)	East (E)	Depth	Secchi Disk	Sampling Date	Sampling Time
1	36.773230	34.574922	5.5m	4m	07.06.2023	13.30
2	36.77232	34.57583	7.5m	4m	07.06.2023	13.50
3	36.77070	34.57780	5m	4.5m	07.06.2023	14.15
4	36.77061	34.57411	7m	3.5m	07.06.2023	14.35
5	36.77167	34.57209	5m	3.5m	07.06.2023	15.00
6	36.76925	34.57239	5m	4m	07.06.2023	15.20
7	36.76806	34.57054	5.5m	4m	07.06.2023	15.40
8	36.76915	34.56841	5.5m	3.5m	07.06.2023	16.00

Table 4. Some physical and chemical properties of water determined at the time of sampling

Sea Water Physicochemical Properties	**November 2022**	**April 2023**	**June 2023**
Temperature (°C)	17.22 ± 0.03	25.03 ± 0.01	28.12 ± 0.02
Salinity (ppt)	37.89 ± 0.01	38.23 ± 0.01	39.41 ± 0.01
Density (sigma t)	29.04 ± 0.02	27.16 ± 0.02	24.71 ±0.01
Dissolved Oxygen (mgl^{-1})	8.32 ± 0.04	8.02 ± 0.01	7.89 ± 0.02
Secchi Disk Depth (m)	2.25 ± 0.07	2.93 ± 0.56	3.88 ± 0.35

Surface sampling was conducted using a scaled container, while depth sampling (SDDx1, SDDx2, SDDx3) was performed using a Nansen bottle. Furthermore, three vertical tows were conducted using a phytoplankton net at each station. Surface water and depth samples were placed in 1 L dark-colored bottles containing 2.5% formaldehyde buffer solution, and samples taken with the phytoplankton net were placed in dark-colored 50 ml sample bottles containing 2.5% formaldehyde buffer solution. The buffer solution was prepared by first dissolving 60 g of borax in 1 L of pure water. This solution was then left to sit overnight. Thereafter, 400 ml of the solution was taken and mixed with 2 L of 37% formaldehyde. The samples were transferred to the laboratory in one-liter sample bottles and left to sediment for a period of 15 days. Thereafter, the top water was meticulously removed drop by drop using a thin tygon hose. Once the total volume reached 100 milliliters, the samples were transferred to smaller dark bottles for further analysis. In order to concentrate the samples, 100 milliliters of each sample were subjected to a second round of sedimentation. Upon completion of this process, the seawater present in the samples was removed for a second time using a TyGon hose, reducing the total volume to 20 milliliters. Thereafter, the samples were transferred to 50-milliliter dark bottles for further analysis. The sedimentation process was concluded, and the phytoplankton species diversity was determined by employing a Sedgewick-Rafter counting chamber under a microscope. The abundance was subsequently calculated by enumeration. The examination of microplanktonic species was conducted within a Sedgewick-Rafter counting chamber, with a sample volume of 1 milliliter. In comparison, the nanoplanktonic species were examined in a drop of sample measuring 0.01 milliliters, which was placed between a slide and a coverslip. The presence of microplankton and nanoplankton was examined through a series of magnifications, with the samples being observed at x 40 and x 100 magnification, respectively. The number of columns counted in the counting chamber was documented, and the following formula was employed to determine the number of plankton in 1 L of seawater.

$$K = 1000 \times \frac{V1}{V2} \times V3$$

V1: Sample Volume in Sedgewick-Rafter Counting Chamber (1 ml)
V2: Sample volume obtained at the end of sedimentation (ml)
V3: Ratio of sample volume counted in the counting chamber to total volume (ml)

Shannon-Weiner Diversity Index (H'), Homogeneity and Relative Diversity Index Evennes (J), and Species Richness Index Margalef Rhichnes (d) were used to determine species diversity (Zar, 1984). A multidimensional scaling analysis was performed with the Past 6.0b program, and the changes in phytoplankton abundance and biomass depending on season and depth were analyzed using principal components analysis (PCA).

3. RESULTS

A total of 110 taxa belonging to Bacillariophyceae, Coscinodiscophyceae, Mediophyceae, Dinophyceae, Prymnesiophyceae, Cyanophyceae, and Thecofilosea were identified in the Mersin Marina in November (2022), April (2023), and June (2023) sampling. Among these, 13 genera and 15 species belonging to Bacillariophyceae, seven genera and nine species belonging to Coscinodiscophyceae, eight genera and 21 species belonging to Mediophyceae, 23 genera and 62 species belonging to Dinophyceae, one genus and one species belonging to Prymnesiophyceae, one genus and one species belonging to Cyanophyceae and one genus and one species belonging to Thecofilosea. One taxon belonging to the class Thecofilosea was identified in the April 2023 sampling, but this taxon was not found in the November and June samples (Table 5, 6).

A comparative analysis of species distribution within the Dinophyceae revealed the highest levels of diversity across various taxonomic categories. Furthermore, the study determined the Dinophyceae contributed 70% to the phytoplankton composition during the June sampling, 49% in November, and 48% in April. This was followed by Mediophyceae (22% in November and April, 11% in June), Bacillariophyceae (17% in November, 16% in April and 8% in June), and Coscinodiscophyceae (10% in November, 11% in April and 8% in June).

Table 5. Phytoplankton Species List Determined in Mersin Marina in November (2022), April (2023) and June (2023)

SPECIES	NOVEMBER (2022)	APRIL (2023)	JUNE (2023)
Bacillariophyceae			
Amphora sp.	+	+	-
Asterionellopsis glacialis (Castracane) Round 1990	+	+	-
Bacillaria paxillifera (O.F.Müller) T.Marsson	+	+	-
Cylindrotheca closterium (Ehrenberg) Reimann & J.C.Lewin	+	+	+
Gyrosigma fasciola (Ehrenberg) J.W.Griffith & Henfrey	+	+	-
Licmophora abbreviata C.Agardh	-	+	-
Navicula sp.	+	-	-
Pinnularia sp.	+	+	+
Pleurosigma angulatum (J.T.Quekett) W.Smith	+	+	+
Pleurosigma elongatum W. Smith 1852	+	+	+
Striatella unipunctata (Lyngbye) C.Agardh	+	+	-
Surirella sp.	+	+	-
Synedra sp.	+	-	-
Thalassionema frauenfeldii (Grunow) Tempère & Peragallo 1910	+	+	+
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	+	+	+
Coscinodiscophyceae			
Coscinodiscus centralis Ehrenberg	+	+	+
Coscinodiscus granii L.F.Gough	+	+	+
Dactyliosolen fragilissimus (Bergon) Hasle	+	+	-
Guinardia flaccida (Castracane) H.Peragallo	+	+	+
Guinardia striata (Stolterfoth) Hasle	+	+	-
Proboscia alata (Brightwell) Sundström	+	+	+
Pseudo-nitzschia delicatissima (Cleve) Heiden	+	+	+
Pseudosolenia calcar-avis (Schultze) B.G.Sundström	+	+	+
Rhizosolenia styliformis T.Brightwell	-	+	-
Mediophyceae			
Bacteriastrum comosum Pavillard	+	+	+
Bacteriastrum delicatulum Cleve	+	+	-
Bacteriastrum hyalinum Lauder, 1864	-	+	-
Chaetoceros affinis Lauder	+	+	+
Chaetoceros borealis Bailey	+	+	-
Chaetoceros compressus Lauder, 1864	+	+	+
Chaetoceros curvisetus Cleve	+	+	-

Chaetoceros decipiens Cleve	+	+	-
Chaetoceros densus (Cleve) Cleve	+	+	+
Chaetoceros didymus Ehrenberg	+	+	+
Chaetoceros gracilis Schütt, 1895 *furcellatuslar düzelecek*	-	+	+
Chaetoceros lauderi Ralfs, 1864	-	+	+
Chaetoceros peruvianus Brightwell	+	+	-
Chaetoceros similis Cleve	+	-	-
Chaetoceros simplex Ostenfeld	+	+	-
Chaetoceros tetrastichon Cleve	+	-	-
Ditylum brightwellii (T.West) Grunow	+	+	-
Hemiaulus hauckii Grunow ex Van Heurck	+	+	-
Leptocylindrus danicus Cleve	+	+	+
Thalassiosira angustelineata (A.W.F.Schmidt) G.Fryxell & Hasle	+	+	-
Trieres mobiliensis (Bailey) Ashworth & Theriot	+	+	-
Dinophyceae			
Akashiwo sanguinea (K.Hirasaka) G.Hansen & Moestrup	+	+	-
Amphisolenia bidentata Schröder	+	+	+
Centrodinium punctatum (Cleve) F.J.R.Taylor	+	-	+
Dinophysis acuminata Claparède & Lachmann	+	-	+
Dinophysis caudata W.S.Kent	+	+	+
Dinophysis hastata F.Stein	+	-	-
Diplopsalis lenticula Bergh	+	+	+
Gonyaulax scrippsae Kofoid	+	-	+
Gonyaulax spinifera (Claparède & Lachmann) Diesing	+	+	+
Gyrodinium Kofoid & Swezy 1921	-	-	+
Gyrodinium fusiforme Kofoid & Swezy	+	+	+
Gyrodinium lacryma (Meunier) Kofoid & Swezy	+	+	+
Heterocapsa pygmaea Loeblich III, Schmidt & Sherley	-	-	+
Karenia brevis (C.C.Davis) Gert Hansen & Moestrup	+	-	+
Lingulodinium polyedra (F.Stein) J.D.Dodge	+	+	-
Ornithocercus magnificus F.Stein	+	+	-
Oxytoxum scolopax Stein	-	-	+
Oxytoxum tesselatum (F.Stein) Schütt	+	+	+
Phalacroma rotundatum (Claparéde & Lachmann) Kofoid & Michener	-	-	+
Podolampas bipes Stein	+	+	+
Podolampas palmipes Stein	-	-	+
Polykrikos schwartzii Bütschli	+	+	-
Prorocentrum compressum (J.W.Bailey) Abé ex Dodge	+	+	+
Prorocentrum cordatum (Ostenfeld) J.D.Dodge	+	-	+
Prorocentrum micans Ehrenberg	+	+	+
Prorocentrum scutellum B.Schröder	+	+	+
Prorocentrum triestinum J.Schiller	-	-	+
Protoperidinium brevipes (Paulsen) Balech	+	-	+

Protoperidinium claudicans (Paulsen) Balech	+	+	+
Protoperidinium conicum (Gran) Balech	+	+	+
Protoperidinium curtipes (Jørgensen) Balech	+	+	+
Protoperidinium curvipes (Ostenfeld) Balech	-	-	+
Protoperidinium denticulatum (Gran & Braarud) Balech 1974	-	+	+
Protoperidinium depressum (Bailey) Balech	-	+	+
Protoperidinium divergens (Ehrenberg) Balech	+	-	+
Protoperidinium grande (Kofoid) Balech	+	+	+
Protoperidinium granii (Ostenfeld) Balech	-	+	+
Protoperidinium oblongum (Aurivillius) Parke & Dodge	-	+	+
Protoperidinium pellucidum Bergh	+	+	+
Protoperidinium steinii (Jörgensen) Balech	-	-	
Pseliodinium fusus (F.Schütt) F.Gómez	+	+	+
Pyrophacus horologium Stein	+	-	+
Scrippsiella trochoidea (Stein) Balech ex Loeblich III	+	-	+
Torodinium robustum Kofoid & Swezy	-	-	+
Tripos arietinus (Cleve) F.Gómez C	-	+	-
Tripos candelabrus (Ehrenberg) F.Gómez	-	-	+
Tripos carriensis (Gourret) F.Gómez	+	+	-
Tripos contrarius (Gourret) F.Gómez	+	+	+
Tripos declinatus (G.Karsten) F.Gómez	-	+	+
Tripos extensus (Gourret) F.Gómez	+	+	-
Tripos furca (Ehrenberg) F.Gómez	+	+	-
Tripos fusus (Ehrenberg) F.Gómezde	+	+	+
Tripos gibberus (Gourret) F.Gómez	-	+	-
Tripos longissimus (Schröder) F.Gómez	+	+	+
Tripos macroceros (Ehrenberg) F.Gómez	+	+	+
Tripos massiliensis (Gourret) F.Gómez	+	+	+
Tripos muelleri Bory	-	+	+
Tripos pavillardii (Jørgensen) F.Gómez	+	-	-
Tripos pulchellus (Schröder) F.Gómez	-	-	+
Tripos symmetricus (Pavillard) F.Gómez	-	+	-
Tripos teres (Kofoid) F.Gómez	-	-	+
Tripos trichoceros (Ehrenberg) Gómez	+	+	+
Ornithocercus quadratus Schütt	+	-	-
Prymnesiophyceae			
Emiliania huxleyi (Lohmann) W.W.Hay & H.P.Mohler	+	+	+
Cyanophyceae			
Oscillatoria sp.	+	+	+
Thecofilosea			
Ebria tripartita (J.Schumann) Lemmermann	-	+	-

Table 6. Taxonomic Distribution of Phytoplankton Classes in Mersin Marina in November, April, and June

CLASS	GENUS	NOVEMBER 2022	APRIL 2023	JUNE 2023
Bacillariophyceae	*Amphora*	1	1	-
	Asterionellopsis	1	1	-
	Bacillaria	1	1	-
	Cylindrotheca	1	1	1
	Gyrosigma	1	1	-
	Licmophora	-	1	-
	Navicula	1	-	-
	Pinnularia	1	1	1
	Pleurosigma	2	2	2
	Striatella	1	1	-
	Surirella	1	1	-
	Synedra	1	1	-
	Thalassionema	2	2	2
Coscinodiscophyceae	*Coscinodiscus*	2	2	2
	Dactyliosolen	1	1	-
	Guinardia	2	2	1
	Proboscia	1	1	1
	Pseudo-nitzschia	1	1	1
	Pseudosolenia	1	1	1
	Rhizosolenia	-	1	-
Mediophyceae	*Bacteriastrum*	2	3	1
	Chaetoceros	11	11	6
	Ditylum	1	1	-
	Eucampia	-	-	-
	Hemiaulus	1	1	-
	Leptocylindrus	1	1	1
	Thalassiosira	1	1	-
	Trieres	1	1	-
Dinophyceae	*Akashiwo*	1	1	-
	Amphisolenia	1	1	1
	Centrodinium	1	-	1
	Ceratocorys	1	1	2
	Dinophysis	3	2	2
	Diplopsalis	1	1	1
	Gonyaulax	2	1	2
	Gyrodinium	2	2	3
	Heterocapsa	-	1	1
	Karenia	1	-	1
	Lingulodinium	1	1	-
	Ornithocercus	1	1	-
	Oxytoxum	1	1	2
	Phalacroma	-	-	1
	Podolampas	1	1	2

	Polykrikos	1	1	-
	Prorocentrum	3	3	5
	Protoperidinium	7	9	11
	Pseliodinium	1	1	1
	Pyrophacus	1	-	1
	Scrippsiella	1	-	1
	Torodinium	-	-	1
	Tripos	10	14	11
	Ornithocercus	1	-	-
Prymnesiophyceae	*Emiliania*	1	1	1
Cyanophyceae	*Oscillatoria*	1	1	1
Thecofilosea	*Ebria*	-	1	-

The mean phytoplankton abundance was determined as 21052 cells/L within the marina and 17113 cells/L without, and the mean phytoplankton biomass was determined as 3.82 µg/L within the marina and 5.40 µg/L without. *E. huxley*, a nanoplanktonic species belonging to Prymnesiophyceae, constituted 98% of the abundance and 66% of the biomass. Therefore, the abundance and biomass values of microplanktonic species in the study area were recalculated by excluding *E. huxley*. The mean abundance of in-marina microplankton was 279 cells/L and biomass was 1.21 µg/L, while the mean abundance of out-of-marina microplankton was 289 cells/L and biomass was 1.88 µg /L.

Mean phytoplankton abundance was higher outside the marina except in summer (Figure 2a), while microplankton abundance was higher inside the marina except in autumn (Figure 2c). The mean phytoplankton biomass was higher inside the marina in all seasons (Figure 2b), while the mean microplankton biomass was higher outside the marina except in autumn (Figure 2d).

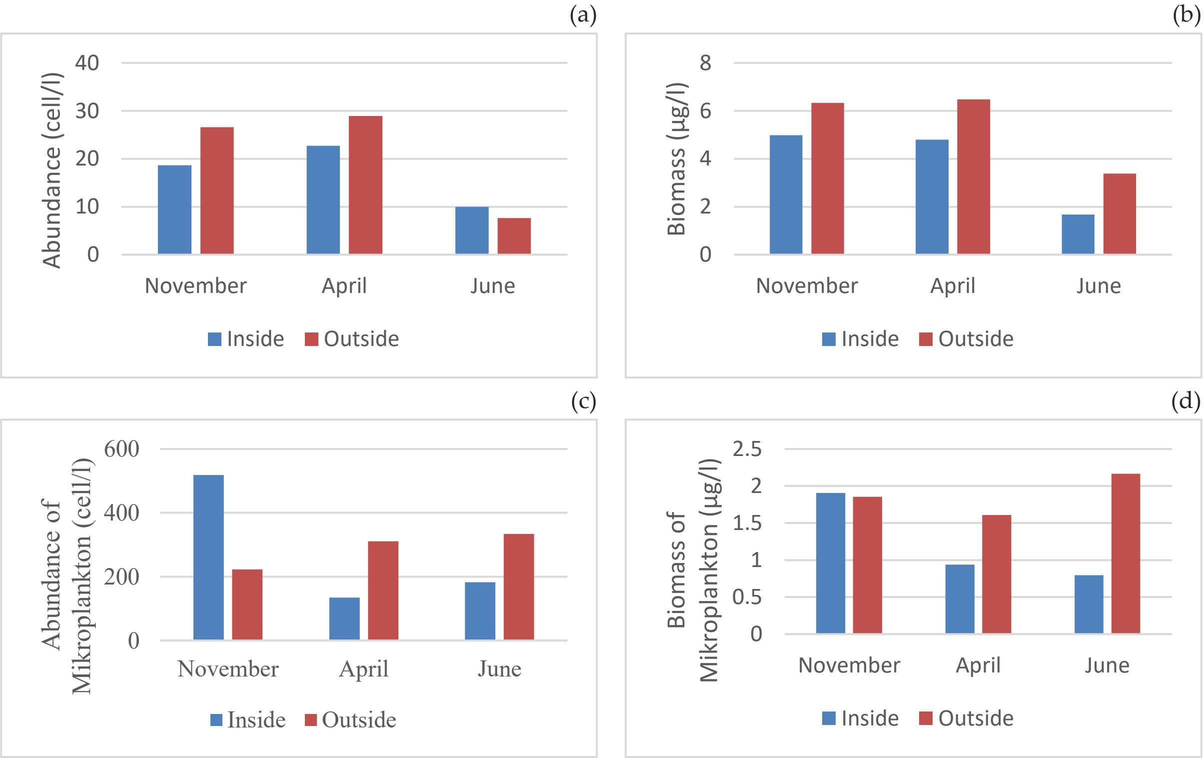


Figure 2. Seasonal comparison of phytoplankton (a) abundance (x10^3cells/L), (b) biomass (µg/L), (c) microplankton abundance (cells/L), (d) microplankton biomass (µg/L) determined inside and outside of Marina

The abundance of microplankton in the marina decreased with increasing depth in summer and autumn (except SDDx2). In contrast, the surface water abundance was found to be lower than the depths of the Secchi disc in spring (Figure 3a).

Microplankton abundance at stations outside the marina decreased with increasing depth in spring, and the surface water abundance was lower than the Secchi disk depths in autumn. In summer, the abundance at depth SDDx2 was higher than the surface and SDDx1, respectively (Figure 3b).

The average microplankton biomass in the marina underwent a decline during the summer months, attributable to the increase in depth. During the autumnal and vernal seasons, the surface water microplankton biomass exhibited a lower value compared to a multiple of the secchi disk depths, and the biomass demonstrated a decrease in proportion with increasing depth within the water column (Figure 3c).

Outside the marina, the average microplankton biomass increased in the autumn and summer (except SDDx1) due to the increase in depth, while it decreased in the spring season (Figure 3d).

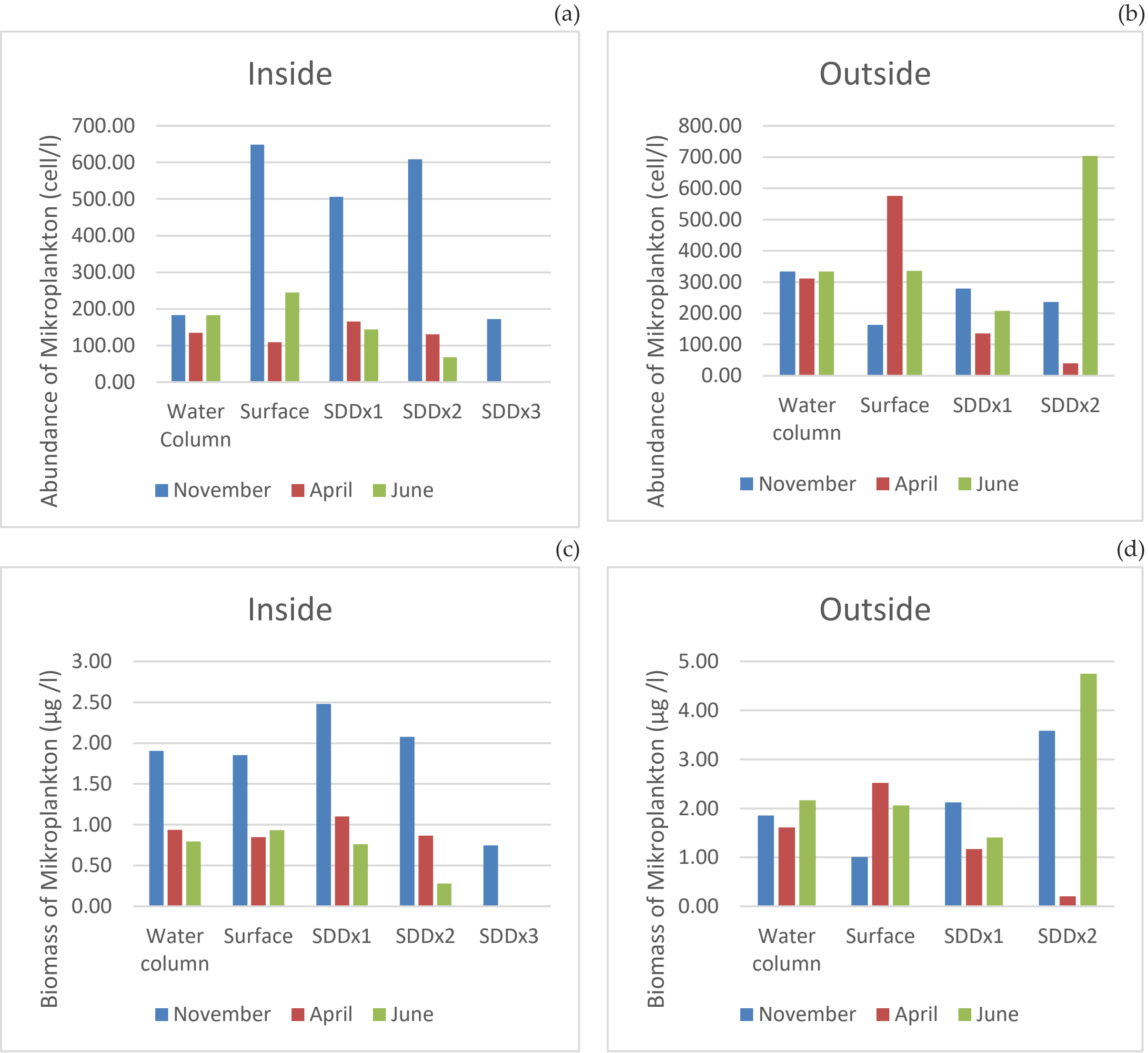


Figure 3. Depth-dependent variation of (a) inside (b) outside marina microplankton abundance (cells/L), (c) inside (d) outside marina microplankton biomass (µg /l).

The dominant species identified in November 2022 included *Asterionellopsis glacialis*, *Chaetoceros curvisetus*, *Chaetoceros gracilis*, and *Bacteriastrum comosum*. In April 2023, the presence of *C. didymus* and *C. lauderi* was documented, followed by *P.delicatissima*, *G. fusiforme*, *P. fusus*, and *H. pygmea* in June 2023. The highest contribution to abundance and biomass of Mediophyceae in autumn and spring and Dinophyceae in summer were found (Figure 4).

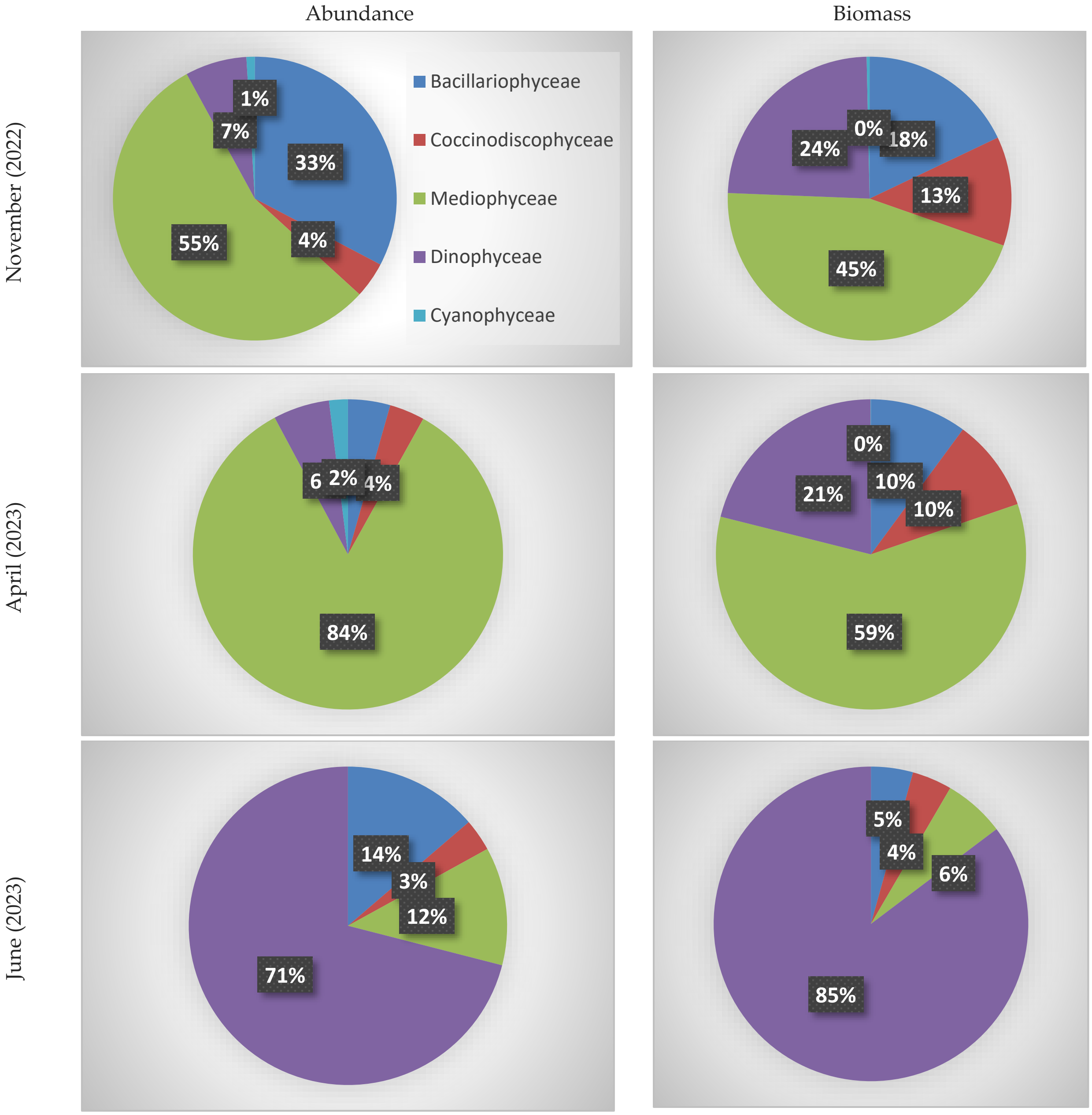
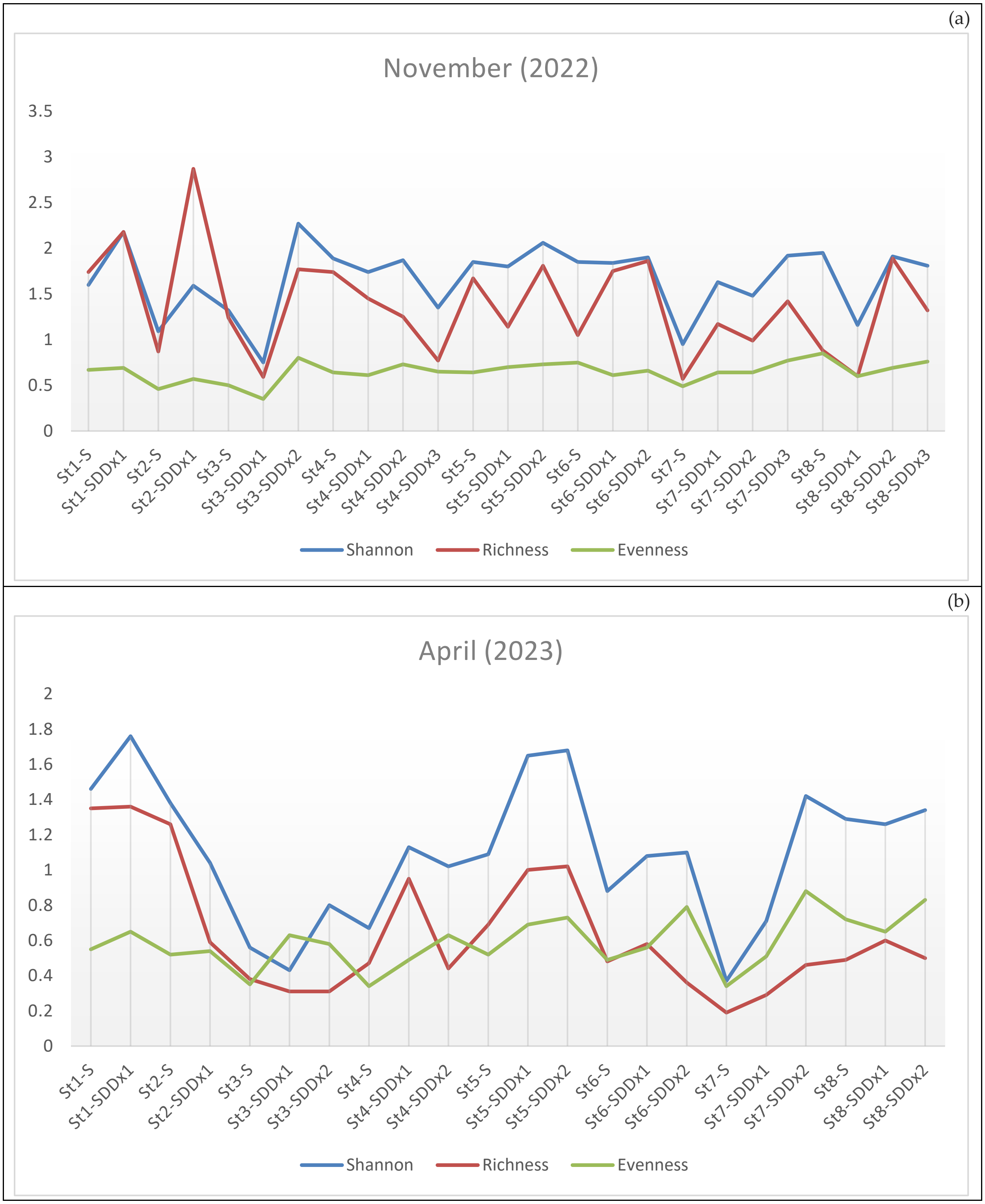


Figure 4. Contribution of phytoplankton classes to abundance and biomass in the marina

According to the Shannon (H') index, the diversity of phytoplankton species was higher outside the marina than inside the marina. The highest species diversity was found in summer (H' =2.48), autumn (H' =2.27) and spring (H' =1.76), respectively. Species richness (d) was determined as d=1.38 in the autumn; d=1.23 in the summer; and d=0.64 in the spring, and reached the highest value at station number two in the autumn. The evenness (J) value was J=0.78 in summer, J=0.65 in autumn, and J=0.59 in spring. The average J value in the summer indicates that species diversity has a homogeneous distribution at the stations and depths examined. (Figure 5).


(a)
November (2022)
3.5
3
2.5
2
1.5
1
0.5
0
St1-S
St1-SDDx1
St2-S
St2-SDDx1
St3-S
St3-SDDx1
St3-SDDx2
St4-S
St4-SDDx1
St4-SDDx2
St4-SDDx3
St5-S
St5-SDDx1
St5-SDDx2
St6-S
St6-SDDx1
St6-SDDx2
St7-S
St7-SDDx1
St7-SDDx2
St7-SDDx3
St8-S
St8-SDDx1
St8-SDDx2
St8-SDDx3
Shannon
Richness
Evenness
(b)
April (2023)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
St1-S
St1-SDDx1
St2-S
St2-SDDx1
St3-S
St3-SDDx1
St3-SDDx2
St4-S
St4-SDDx1
St4-SDDx2
St5-S
St5-SDDx1
St5-SDDx2
St6-S
St6-SDDx1
St6-SDDx2
St7-S
St7-SDDx1
St7-SDDx2
St8-S
St8-SDDx1
St8-SDDx2
Shannon
Richness
Evenness

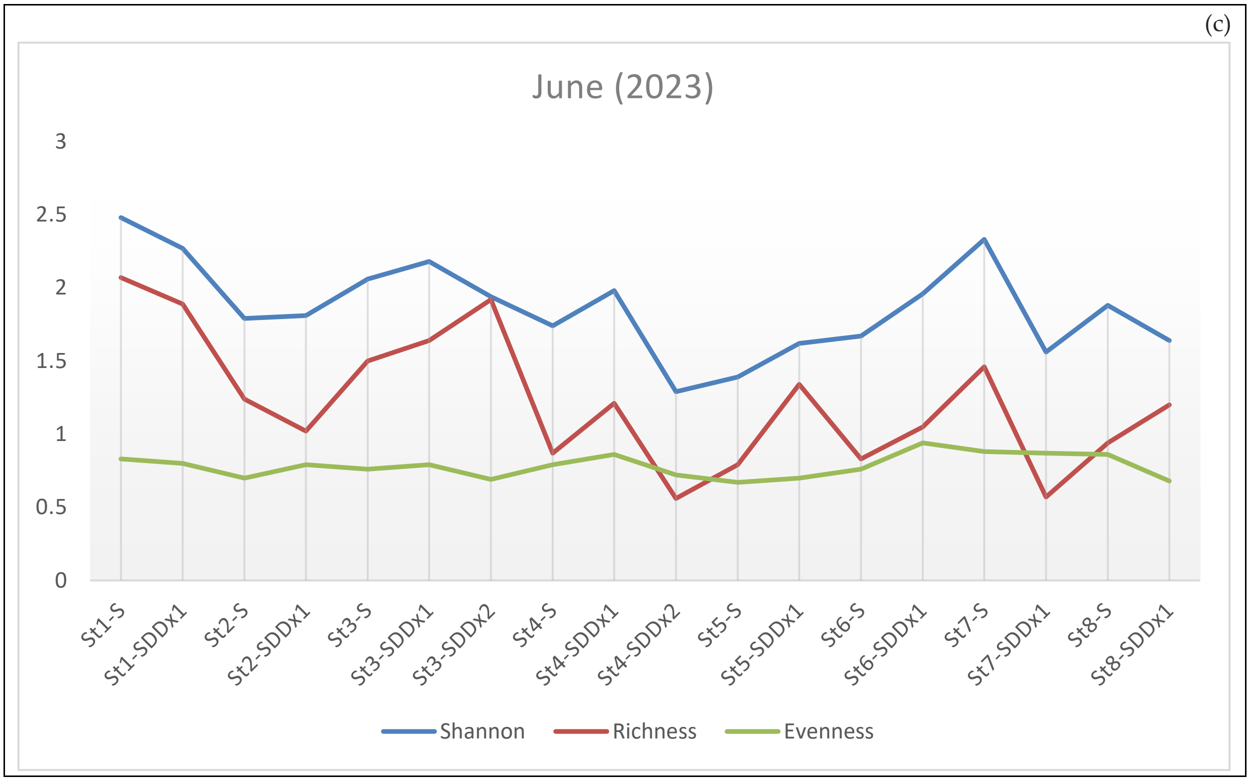


Figure 5. Comparison of marina phytoplankton diversity indices (a) November 2022, (b) April 2023, (c) June 2023

4. DISCUSSION

In the sampling conducted both inside and outside Mersin Marina in November, April and June, 110 taxa belonging to 7 classes were identified. In previous studies conducted in the Northeastern Mediterranean, Polat et al. (2000) reported 170 taxa belonging to 5 classes, Uysal (2000) reported 132 taxa belonging to 5 classes, Aktan (2011) reported 105 taxa belonging to four classes, and Özman-Say & Balkıs (2012) reported 95 taxa belonging to 3 classes. It was determined that the contribution of the Dinophyceae class to phytoplankton species diversity was the highest throughout the year. This result aligns with the findings of studies conducted in Iskenderun Bay (Polat et al., 2005; Özman-Say & Balkıs, 2012), yet it contrasts with the results of the survey conducted by Uysal (2020) at the mouth of the Lamas River. This discrepancy can be attributed to the impact of environmental factors on the study sites.

The average phytoplankton abundance in Mersin Marina throughout the year was 19082 cells/L with a biomass of 4.61 µg/L. The correlation of phytoplankton abundance and biomass between the inside and outside of the marina, as well as the influence of season and depth, was indicated by PCA (Figure 6). Phytoplankton was reported to bloom between late autumn and early spring in the oligotrophic Eastern Mediterranean (Yilmaz & Tuğrul, 1998; Ediger et al., 1999; Psarra et al., 2000; Krom et al., 2003; Tanaka et al., 2007) due to nutrient mixing in the photic zone due to thermal stratification (Krom et al., 2003). Atmospheric trace elements have been identified as vital nutrient sources for phytoplankton in oligotrophic seas (Rodhe et al., 1980; Duce, 1986; Prospero & Savoie, 1989; Loÿe-Pilot et al., 1990; Donaghay et al., 1991; Bergametti et al., 1992; Zhang and Liu, 1994; Markaki et al., 2003). The impact of Saharan dust, transported to the Mediterranean Sea during the spring months, on phytoplankton abundance has been extensively researched (see Loÿe-Pilot et al., 1990; Bergametti et al., 1992). This study, conducted in Mersin Marina, revealed that the abundance of phytoplankton was significantly impacted by the Saharan dust, which commenced its transportation during the spring season. The most significant contribution to phytoplankton abundance was provided by *E. huxley*. The findings are consistent with those of previous studies conducted in the Northeastern Mediterranean (Eker-Develi et al., 2006). As indicated by Aktan (2011), coccolithophores have been documented to exhibit an increase in abundance along the eastern Mediterranean coast under the influence of anthropogenic pressures, including domestic industrial waste, tourism activity, marinas, and marina traffic.

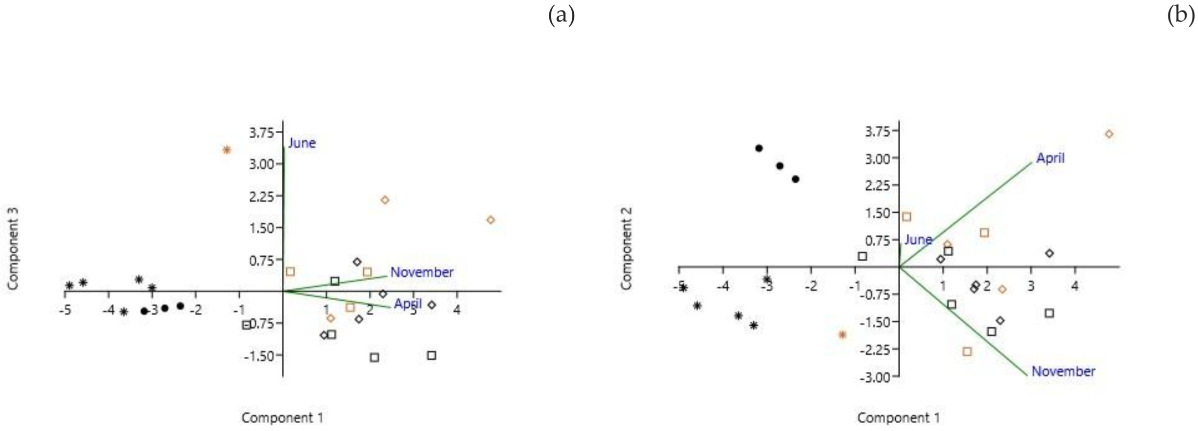


Figure 6. Phytoplankton (a) abundance (cell/L) (b) biomass (ug/L) in the marina marine area (Brown; inside the marina, Black; outside the marina, Quadrant; surface water, Square; SDDx1; Star; SDDx2; Dot; SDDx3)

The contribution of *E. huxley* to phytoplankton abundance in Mersin Marina was found to be high (98%); therefore, *E. huxley*, a nanoplankton was excluded from the study and microplankton abundance and biomass were calculated separately. The objective of the study was to make a comparison between phytoplankton species diversity, abundance, and biomass in the marine area both inside and outside the marina. Therefore, depth and seasonal variations in microplankton abundance and biomass were calculated separately inside and outside the marina. The average abundance of microplankton inside the marina was 278.84 cells/l, and the biomass was 1.21 µg/l. Outside the marina, the abundance was 289 cells/l, and the biomass was 1.88 µg/l. The abundance of microplankton, with the exception of the autumn season, and the microplankton biomass were found to be higher in the external environment in comparison to the internal environment of the marina, irrespective of the season. The higher abundance and biomass observed in the external area beyond the marina reflect the alterations in the sea area within the marina that is subject to anthropogenic influence. Autotrophic species such as *C. gracilis, C. curvisetus*, and *A. glacialis* were the dominant species found inside the marina in autumn. Diatom species have been documented as the predominant contributor to marine carbon absorption, accounting for approximately 40% of the total absorption (Konucu et al., 2022).

It was determined that microplankton abundance decreased with increasing depth in summer and autumn inside the marina and in spring outside the marina. The depth-dependent decrease can be explained by the mixing impact in the autumn season, albeit limited within the marina. The fluctuation observed in the Secchi disk depths in spring seasons may support the impact of mixing (Figure 5b). In the summer season, when tourism activities increase, the surface water, whose density increases with the effect of temperature and evaporation, carries the organic and inorganic substances in the water column to the bottom as it settles to the bottom. As a result, the limitation of light transmittance due to the increase in density may explain the depth-dependent decrease.

The depth-dependent decrease in plankton observed at stations outside the marina in spring may have been caused by plankton being transported below the light limit due to seasonal mixing. During the summer months, the elevated plankton abundance recorded at SDx2 depth can be attributed to the thermal stratification of the water column, leading to the accumulation of nutrients in the bottom waters and the extension of the euphotic zone to this depth. At the same time, fish groups living inside and outside the marina are natural sources of nutrients for plankton. Depth-dependent changes in microplankton biomass inside and outside the marina are related to abundance and can be explained by seasonal and depth-dependent changes in dominant species.

Studies conducted in the Mersin Marina marine area revealed that *C. didymus* and *C. lauderi* species were dominant in spring, while *A. glacialis*, *C. curvisetus*, *C. gracilis*, and *B. comosum* species were dominant in autumn. In the northeastern Mediterranean region, diatoms have been documented to play a substantial role in phytoplankton abundance, particularly in the vicinity of the Lamas River during the spring and autumn months (Uysal, 2020). Concurrent studies conducted along the Erdemli coast have demonstrated that diatoms significantly contribute to phytoplankton biomass throughout the year (Eker-Develi et al., 2006).

Seasonal studies conducted in the Mersin Marina marine area have revealed that the Mediophyceae class contributes to the highest abundance and biomass in the phytoplankton community during the spring and autumn seasons, while the Dinophyceae class contributes to the highest abundance and biomass during the summer season. *P.delicatissima*, *G. fusiforme*, *P. fusus* and *H. pygmea* were the dominant species in the marina marine area in summer. Among these species, *H. pygmea* (Hernández-Becerril et al., 2010) and *P. delicatissima* (Fehling et al., 2005) are recognized as toxic marine phytoplankton species. Although the majority of organisms implicated in harmful algal blooms (HABs) are classified as dinoflagellates, specific diatoms within the genus *Pseudo-nitzschia* have been identified as the causative agents of amnesic shellfish poisoning (ASP) on a global scale. These dinoflagellates are known to produce domoic acid (DA), a neurotoxic compound that has been implicated in the onset of ASP (Fehling et al., 2005). In this study, while the species responsible for toxin production were identified in the marina marine area, their population densities were not sufficiently high to cause a bloom. The substantial contribution of dinoflagellates to the total biomass during the summer months may be associated with physical and chemical alterations, including elevated sea water temperature, salinity, and density. Additionally, the impact of intense tourism activities and the concomitant environmental stress factors should be considered.

The Shannon diversity index revealed that phytoplankton diversity exhibited higher levels at stations located outside the marina compared to stations within the marina. The highest species diversity was (H' =2.48) in the surface water of Station 1 in June; (H' =2.27) in the SDDx3 depth of Station 3 in November; and (H' =1.76) in the SDDx1 depth of Station 1 in April. While the Shannon index values in November and April were similar to the findings of the research conducted in Iskenderun Bay, the index value in June was found to be higher in Mersin Marina (Polat et al., 2000). However, Evenness values were similar in both studies in the mentioned months (Polat et al., 2000). Species richness is a biological indicator that is widely used to determine the ecological status of phytoplankton communities. It provides important clues for monitoring anthropogenic pressures and environmental changes on water bodies (Aktan, 2011). The lower species richness in the Mersin Marina may be due to the limited water exchange within the marina and the marina effect, such as boat and yacht traffic. The high species richness outside the marina boundary gate is consistent with previous studies conducted in the Eastern Mediterranean (Polat et al., 2000; Aktan, 2011).

5. CONCLUSION

The region's maritime infrastructure, exemplified by the Mersin Marina, is distinguished by a serene sea environment throughout the year, primarily attributable to the protective effect of the breakwater. Water exchange is exclusively facilitated through the marina entrance gate, which limits horizontal water movement and promotes the retention of water masses within the marina basin. In this study, an analysis was conducted to compare the phytoplankton composition within the marina's inner sea area with that of three outer stations located along a transect extending from the marina entrance toward the open sea. The results indicated that phytoplankton species diversity, abundance, and biomass were, on average, higher at stations outside the marina compared to those inside. With respect to seasonal dynamics, the class Mediophyceae exhibited the highest abundance and biomass during the spring and autumn months, while the class Dinophyceae dominated during the summer. Dinoflagellates are predominantly mixotrophic organisms, capable of both photosynthesis and heterotrophic nutrition, allowing them to thrive under low-nutrient and stratified conditions typically found in summer months. Conversely, diatoms—predominantly autotrophic—are frequently linked to elevated primary productivity, a phenomenon attributable to their rapid growth rates and efficient nutrient uptake under well-mixed conditions. Despite the marina environment being subject to commercial maritime activities throughout the year, the intensification of tourism-related activities during the summer months may increase the sensitivity of the system to organic pollution. Notwithstanding the spatial constraints imposed by the nature of this study, the findings are consistent with those of prior research conducted in the Northeast Mediterranean–Levant Basin. In conclusion, the regular monitoring of phytoplankton abundance and biomass within and outside the marina, in conjunction with future studies incorporating seasonal and depth-resolved measurements of nutrients, salinity, and chlorophyll-a, will facilitate a more comprehensive evaluation of the ecological productivity and environmental health of the region.

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Authors contributions

All authors contributed to writing and editing the article. MD writing of the original draft. NÇ led the investigation, conceptualization, methodology, statistics, visualization, and the writing of the original and final draft. DA helped in the sampling of materials, reviewing, and editing of final draft.

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Conflict of Interest

The authors declare that there are no conflicts of interests.

Informed consent

Not applicable.

Ethical approval & declaration

In this article, as per the Phytoplankton regulations followed in the Mersin University Faculty of Fisheries, Mersin, TURKEY; the authors observed and compared the Seasonal Distribution of Phytoplankton Composition Inside and Outside Mersin Marina. The ethical guidelines for Plankton are followed in the study for species observation, identification & experimentation.

Data and materials availability

All data associated with this study are present in the paper.

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