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Phytoplankton Composition and Water Quality of Kamil Abduş Lagoon (Tuzla Lake), Istanbul-Turkey

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Abstract: In the present study, the water quality and pollution status of Kamil Abduş Lagoon (Tuzla Lake), which is located in Istanbul Metropolitan area, were investigated by determining the phytoplankton composition, some physicochemical parameters, and nutrient concentrations. Water samples were collected at 3 sampling sites between February 2016 and January 2017 on a monthly basis. A total of 32 taxa, belonging to Bacillariophyta (12), Charophyta (1), Chlorophyta (4), Cryptophyta (1), Cyanobacteria (5), Euglenozoa (5) and Miozoa (4) divisions were identified. Both freshwater and marine species were recorded in the study area. The presence of mesotrophic and eutrophic species of phytoplankton, high concentrations of chlorophyll-*a* and nutrients indicated that the trophic level of the lake is near to eutrophic. Water quality parameters studied in the current research were investigated to evaluate the input data significance using Artificial Neural Network analysis, specifically to ensure the limitation of regression analysis overfitting. Due to the fact that the lagoon is under threat by pollution it needs to be urgently protected. Therefore, detailed studies on phytoplankton including physicochemical parameters and nutrients have to be carried out in order to select appropriate management routes for improving the water quality in the lagoon.

Keywords: phytoplankton; water pollution; nutrients; Kamil Abduş Lagoon

1. Introduction

It has been reported by many scientific types of research that climate changes have caused many environmental problems. The rapid pollution of water resources and risk of extinction is placed at the top of these environmental issues. Increasing population, unplanned industrialization and urbanization are also accelerating this process day by day. Therefore, protecting our water resources and improving trophic conditions have been given greater importance recently.

Lagoon systems are very special aquatic ecosystems in terms of hosting quite various species of living beings. They constitute a habitat for both freshwater and marine life forms. Also, they are important lying areas for fish and other aquatic organisms and shelter areas for birds. Due to high nutrient concentrations, lagoons are one of the most productive coastal ecosystems. Furthermore, they provide appropriate conditions for agriculture, aquaculture, fishing, tourism and recreation. For all these reasons, lagoons must be kept under constant protection. Coastal lagoons are under pressure from physical, chemical and biological changes in both terrestrial and marine environments. Hence, the changes in these parameters can be regarded as an indicator of the pollution [1,2].

Phytoplankton constitute the first circle of the food chain in aquatic systems, producing high-energy organic compounds from carbon dioxide and inorganic substances by photosynthesis with the aid of light. As is well known, the food chain starts with phytoplankton and continues with zooplankton, small fish, big fish and ends with a human. Because of these functions, phytoplanktonic organisms have a very important role in the feeding of animals that sustain their life in freshwaters and seas, and they form the basis of primary production in aquatic environments. Also, they are one of the biological indicator organisms which are used extensively in many water pollution investigations all over the world [3–6]. It is known that Cyanobacteria, Bacillariophyta, and Chlorophyta members are used as available taxonomic groups for determination of biological conditions in aquatic systems. Dominant presence of colonial blue-green algae like *Microcystis* and *Anabaena* genera, form dense summer blooms due to high nutrient concentrations. Also these alga group is accepted as a key component of various trophic indices. Species of Bacillariophya group were used as bioindicators of past lake acidification, point sources of eutrophication and total phosphorus concentration within lake sediments. It is known that species of filamentous green algae, usually dominate environments stressed by cultural eutrophication, acidification and metal contamination [6,7].

Kamil Abduş Lagoon is one of the lagoons which is placed in the Marmara Region. It is also known as Tuzla Fish Lake or Tuzla Bird Lake due to its rich bird and fish fauna especially before the introduction of industrial works in the nearest lagoon surroundings. The reedbeds on the shoreline provide nutrition and housing opportunities for many species of birds. Kamil Abduş Lake is the only one wet area in the field that contains various bird species, especially at the time of migration. 46 different species of birds are recorded in the lake during the year. Some of the birds belong to species which are in danger of extinction. Kamil Abduş Lake and its vicinity were proclaimed as a first and second-degree natural site in terms of flora and fauna due to its shallow characteristics with the decision taken on 26 January 1993/3019 and 16 July 1997/4535. It was stated that this lagoon was a birds' paradise until 1969 and it was also famous for its variety of fish, and the mastic (*Pistacia lentiscus*) trees which are grown only in Sakız (Mastic) Island. Furthermore, it has been reported that this lake has started to deteriorate with the construction of the shipyard and lost its natural balance and dried up completely in 2001. It was stated that in earlier studies after the drought, most of the birds migrated. Nowadays, there are only a few bird species leaving in the central part of the dried lake [8]. Recently, a landscaping project of this lagoon is continued by the Municipality of Tuzla. Ateş [8] took attention to the project which will be prepared at this lagoon in an earlier study. Also, it was reported that the Tuzla Municipality should take care of the redevelopment of the eco-biological characteristics of the lake during this project.

Only a few studies have been conducted on Kamil Abduş Lagoon and most of them are on its geomorphological and geological characteristics. The benthic invertebrate fauna of the lagoon was investigated by Altınsaçlı et al. [9] at the same sampling stations simultaneously. This is the first detailed report on phytoplankton composition of the lagoon. The objectives of the current research are to determine the water quality of Kamil Abduş Lake and reveal the relations between phytoplankton species and some physicochemical parameters. An additional objective is to create consideration for taking necessary precautions against the ecological problems in this lagoon ecosystem.

2. Materials and Methods

2.1. Study Area

Istanbul is situated in Marmara Region of Turkey with an area of 5343 km^2. The Istanbul Metropolitan area, the largest city of Turkey, has an approximately 4.5% annual population growth rate. Istanbul has a Mediterranean climate in terms of the Koppen climate classification. It has high temperature and less precipitation in the summers; the mean total precipitation per year was 640 mm and the annual average temperature was recorded as 14.5 °C for the last two decades [10]. Kamil Abduş Lagoon (40°49′47.20′′ N–29°17′12.80′′ E) is located on the Anatolian side of Istanbul (Figure 1,

Table 1). Redistribution and reaccumulation of the sediments of Aydınlı Creek caused the bay changed into a lagoon. The lake has an approximately 0.7 km^2 area and the maximum depth is 1.3 m. The average water reserve of the lagoon is 500,000 m^3 [9,11].

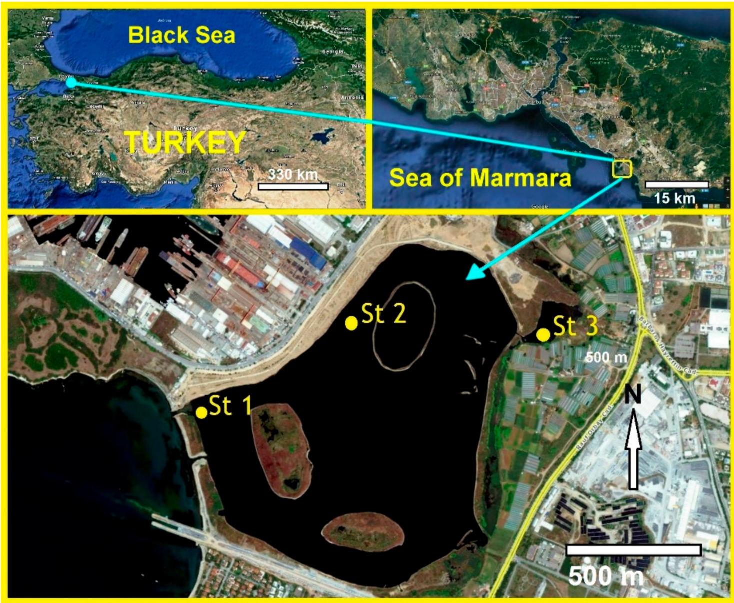

Figure 1. Map of Kamil Abduş Lagoon and sampling sites.

Table 1. Coordinates and characteristics of sampling stations.

STATIONS	COORDINATES	CHARACTERISTICS
St. 1	40°49′50.69″ N 29°16′43.35″ E	It is located where the lagoon is connected to the Marmara Sea.
St. 2	40°49′58.09″ N 29°17′03.18″ E	It was selected near to the Tuzla Shipyard.
St. 3	40°49′58.66″ N 29°17′32.45″ E	It takes place in the freshwater entry and greenhouses are located around.

2.2. Sampling and Analyses

The study was carried out between February 2016 and January 2017 at three different sampling stations (Table 1). Sampling stations were selected according to represent all the lagoon system and located especially near to the pollution sources. Also, the sampling stations allowed the samples to be taken in all seasons during the study period from the lake. Samples were collected monthly, using Nansen bottles. Samples were taken to glass tubes of 50 cc and they were fixed with Lugol's iodine. Phytoplanktonic organisms were left to stand for 24 h to be sink to the bottom. The remaining 5 cm^3 of samples were taken in counting chambers. After waiting for a period of time (4 h) for the collapses of the organisms, the counts were made with a Nikon TMS inverted microscope at a magnification of 400 according to Lund et al. (1958) [12]. Water samples were filtered through Whatman GF/A glass fiber filter and these filters were stored in petri dishes for phytoplankton identification. The identifications of algae, except the diatoms, were made by examining these filter papers from temporary preparations prepared by scraping the surface of a filter with a light microscope. The diatoms in the water samples were boiled for 10 to 15 min in a heat-resistant glass beaker by adding a mixture of HNO_3-H_2SO_4. After a few drops of material taken on a slide were evaporated from water on a heating plate, a permanent preparation was prepared and the identification was carried out.

The taxonomic identification of phytoplankton were done in reference to Hustedt [13,14]; Desikachary [15]; Prescott [16,17]; Patrick & Reimer [18,19]; Huber-Pestalozzi [20]; Krammer &

Lange-Bertalot [21] and John et al. [22]. All the recorded species were checked in algabase cite [23]. Chlorophyll-*a* measurements were estimated according to Parsons and Strickland [24]. Water temperature, dissolved oxygen, pH, salinity and electrical conductivity were measured with the WTW Multi 340i/set in the field. Nitrite (NO_2), nitrate (NO_3) and orthophosphate (PO_4) concentrations in the water were analyzed at the laboratory according to standard methods [25].

2.3. Statistical Analyses

Statistical practices were exercised in the present study to envisage the interrelated acquaintances of the used input parameters for an adequate comprehensive comprehension of the issue. The statistical practices basically depended on the Artificial Neural Network (ANN) analysis [26]. The investigated input parameters were the chlorophyll-*a*, dissolved oxygen, pH, temperature, salinity and electrical conductivity. ANN was applied throughout intermediate steps of Multivariate Analysis [27] and Pairwise Comparison [28].

3. Results

3.1. Phytoplankton Composition

In total, 32 taxa belonging to Bacillariophyta (12), Charophyta (1), Chlorophyta (4), Cryptophyta (1), Cyanobacteria (5), Euglenozoa (5) and Miozoa (4) were identified. Both freshwater and marine species constituted the phytoplankton community in Kamil Abduş Lagoon. The list of recorded taxa of phytoplankton was given in Table 2 and the distribution of phytoplankton groups was shown in Figure 2. The relative seasonal density of phytoplankton groups according to stations were given in Figure 3. *Cryptomonas ovata* of Cryptophyta division constituted the 16.20% of the total phytoplankton density at station 2, located close to the Tuzla Shipyard in October 2017. While the Cyanobacterium *Spirulina* sp. constituted the 77.70% of total phytoplankton density at station 3 which is located close to the greenhouses in February 2017; *Aphanizomenon spiroides* constituted the 36.50% at station 2 in April 2017. At station 1, *Microcystis aeruginosa* was found the dominant species with the density of 47% in July 2017 and *Merismopedia glauca* became the dominant species and constituted the 72% of the total phytoplankton density in October 2017. *Prorocentrum lima of* Miozoa division constituted the 63.20% of the total density at station 2 in February 2017. *Peridinium bipes* was recorded the dominant species at stations 1 (22.80%) and 3 (45.10%) in April 2017. Also, this species was found dominant in July 2017 at stations 2 (41.80%) and 3 (45.10%).

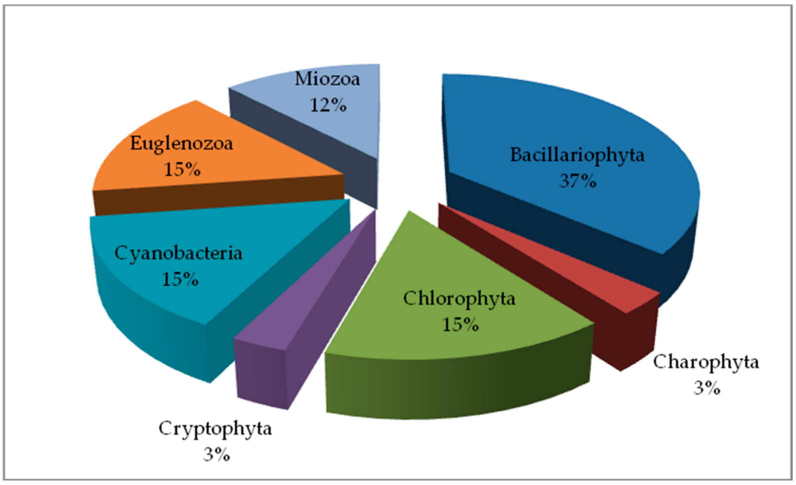

Figure 2. Percentage of recorded species as their divisions.

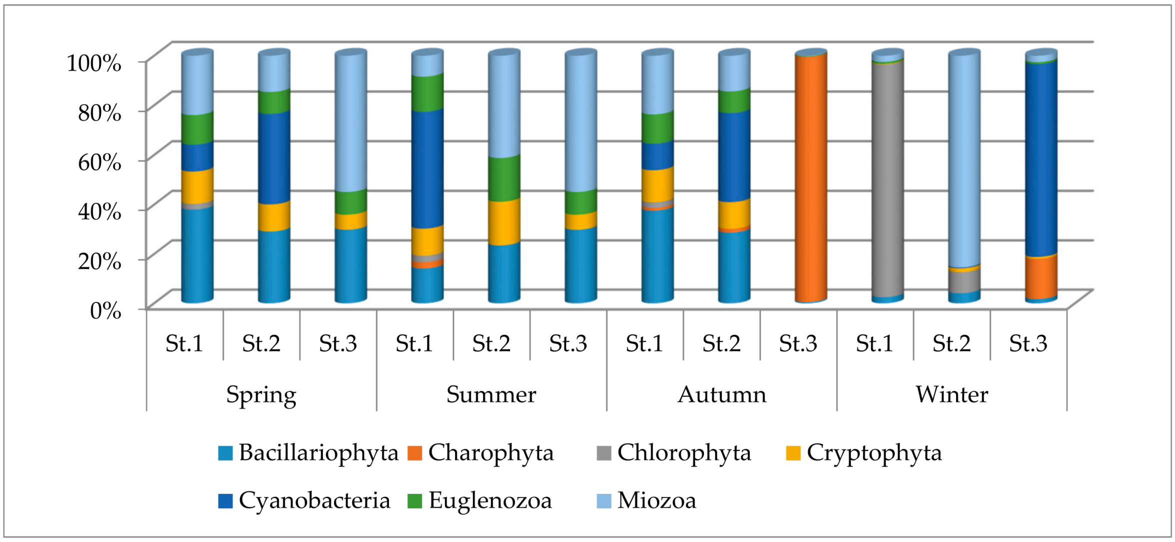

Figure 3. The relative density of phytoplankton groups at sampling stations.

Table 2. List of phytoplankton taxa in the lagoon.

DIVISIO: BACILLARIOPHYTA	DIVISIO: CHAROPHYTA
Order: Aulacoseirales	**Order: Desmidiales**
Aulacoseira italica (Ehrenberg) Simonsen	*Closterium acutum* Brébisson
Order: Bacillariales	**DIVISIO: CRYPTOPHYTA**
Nitzschia acicularis (Kützing) W.Smith	**Order: Cryptomonadales**
Order: Cocconeidales	*Cryptomonas ovata* Ehrenberg
Cocconeis placentula Ehrenberg	**DIVISIO: CYANOBACTERIA**
Order: Cymbellales	**Order: Chroococcales**
Cymbella affinis Kützing	*Microcystis aeruginosa* (Kützing) Kützing
Gomphonema truncatum Ehrenberg	**Order: Nostocales**
Order: Licmophorales	*Anabaena spiroides* Klebahn
Ulnaria acus (Kützing) Aboal	**Order: Oscillariotales**
Ulnaria ulna (Nitzsch) Compère	*Oscillatoria tenuis* C.Agadh ex Gomont
Order: Melosirales	**Order: Spirulinales**
Melosira varians C. Agardh	*Spirulina* sp.
Order: Naviculales	**Order: Synechococccales**
Navicula cryptocephala Kützing	*Merismopedia glauca* (Ehrenberg) Kützing
Order: Rhopalodiales	**DIVISIO: EUGLENOZOA**
Epithemia sp.	**Order: Euglenales**
Order: Stephanodiscales	*Euglena gracilis* G.A. Klebs
Cyclotella atomus Hustedt	*Euglena variabilis* G.A. Klebs
Order: Thalassiophysales	*Euglena viridis* (O.Müller) Ehrenberg
Amphora ovalis (Kützing) Kützing	*Phacus* sp.
DIVISIO:CHLOROPHYTA	*Trachelomonas hispida* (Perty) F. Stein
Order: Chlamydomonadales	**DIVISIO: MIOZOA**
Chlamydomonas sp.	**Order: Noctilucales**
Order: Oedogoniales	*Noctiluca miliaris* Suriray, nom. inval.
Oedogonium sp.	**Order: Peridiniales**
Order: Sphaeropleales	*Peridinium bipes* Stein
Ankistrodesmus falcatus (Corda) Ralfs	**Order: Prorocentrales**
Scenedesmus sp.	*Prorocentrum lima* (Ehrenberg) F. Stein
	Prorocentrum micans Ehrenberg

3.2. Physicochemical Parameters and Chlorophyll-a

In the study done by Atınsaçlı et al. [9] at the same term and locations, the minimum and maximum values of some physicochemical parameters and nutrients were analyzed. Water temperature (7.1–30.6 °C), dissolved oxygen (0.93–12.17 mg/L), pH (7.29–9.22), salinity (4.2–25.4‰), electrical conductivity (7.74–58.40 mS/cm), nitrite (0.0001–2.431 mg/L), nitrate (0.007–2.48 mg/L) and orthophosphate (0.031–3.087 mg/L) were observed. Measured chlorophyll-*a* concentrations varied between 0.46 and 349.20 µg/L (Table 3).

Table 3. Some measured physicochemical parameters, nutrients and chlorophyll-*a* of the lagoon [8].

Months		Temp. (°C)	pH	Dis.O_2 (mg/L)	Sal. (‰)	Cond. mS/cm	Chl-*a* (µg/L)	NO_2 (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)
February 2016	St.1	11.9	8.17	10.79	24.5	39.7	0.46	0.015	0.417	0.031
	St.2	11.9	8.25	11.50	24.5	39.6	0.84	0.008	0.855	0.045
	St.3	13.6	8.60	10.66	21.1	34.2	11.40	0.053	2.463	0.045
March 2016	St.1	11.3	8.39	8.39	25.4	40.9	2.01	0.008	0.125	0.040
	St.2	11.3	8.38	7.42	24.6	39.6	2.15	0.002	0.046	0.054
	St.3	11.0	8.62	9.66	18.4	30.4	20.10	0.052	1.618	0.111
April 2016	St.1	18.8	8.39	8.65	24.1	58.4	1.36	0.041	0.035	0.049
	St.2	21.4	8.16	5.86	25.1	39.5	3.11	0.232	0.217	0.072
	St.3	19.5	7.90	3.10	23.2	37.0	21.50	0.925	0.390	0.147
May 2016	St.1	24.3	8.61	6.19	21.5	34.3	0.71	0.018	0.041	0.035
	St.2	27.2	8.57	5.54	23.2	36.5	4.06	0.022	0.015	0.041
	St.3	30.6	8.63	6.02	17.1	27.7	22.90	0.018	1.591	0.054
June 2016	St.1	29.4	8.81	5.05	23.4	36.9	6.99	0.071	0.038	0.057
	St.2	29.3	8.72	4.93	23.4	36.8	5.31	0.008	0.016	0.055
	St.3	29.7	8.38	3.23	21.0	33.3	33.5	0.039	0.049	0.777
July 2016	St.1	27.6	8.62	4.16	23.8	37.3	1.93	0.002	0.031	0.051
	St.2	28.1	8.64	3.64	24.6	38.5	2.28	0.013	0.016	0.035
	St.3	28.6	9.22	7.03	23.1	36.2	16.10	0.009	0.012	1.057
August 2016	St.1	28.8	8.5	5.33	23.3	36.7	0.71	0.005	0.028	0.062
	St.2	28.6	8.83	4.99	25.2	39.2	7.37	0.012	0.012	2.818
	St.3	27.9	8.89	4.11	25.2	39.3	34.20	0.014	0.007	0.547
September 2016	St.1	21.0	7.82	5.70	23.6	37.8	2.71	0.004	0.044	0.068
	St.2	20.7	8.1	4.11	24.9	39.6	0.64	0.006	0.036	2.915
	St.3	20.8	8.44	7.61	22.9	36.8	166.60	0.006	0.035	0.112
October 2016	St.1	17.8	7.93	6.45	24.2	38.4	5.78	0.007	0.025	0.075
	St.2	18.3	8.04	7.47	24.0	38.1	1.96	0.005	0.031	2.627
	St.3	17.9	7.85	4.70	21.0	34.2	64.50	0.039	0.071	0.142
November 2016	St.1	14.7	8.12	6.70	23.8	38.2	1.88	0.007	0.025	0.043
	St.2	12.7	8.13	7.87	23.4	37.5	2.96	0.005	0.601	0.046
	St.3	13.1	8.6	12.17	17.0	28.0	349.20	0.0001	2.481	0.082
December 2016	St.1	8.4	7.97	9.50	24.4	39.6	5.22	0.0161	0.069	2.651
	St.2	7.5	7.96	8.67	23.1	37.9	5.88	0.035	0.382	0.121
	St.3	8.6	7.09	0.93	4.2	7.74	8.45	2.431	0.436	3.087
January 2017	St.1	7.1	8.00	8.00	24.4	39.6	5.22	0.0161	0.069	2.651
	St.2	7.4	8.00	9.41	23.1	37.9	5.88	0.035	0.382	0.121
	St.3	11.0	7.29	1.76	4.2	7.74	8.45	2.431	0.436	3.087

3.3. Application of the ANN

The use of ANN was carried out under limited conditions of 1 hidden layer and 8 nodes with activation function of a hyperbolic tangent for each station independently. These conditions were defined to avoid the algorithmic overfitting. Results of the different stations were demonstrated in

Table 4. Selected evaluation parameters of root mean squared error (RMSE) and negative log-likelihood were exercised to evaluate interrelated acquaintances of the input parameters in the designated study area. Apart from the slight increase in Temperature and in pH, station 3 showed a different behavior to the other 2 stations (Figure 4).

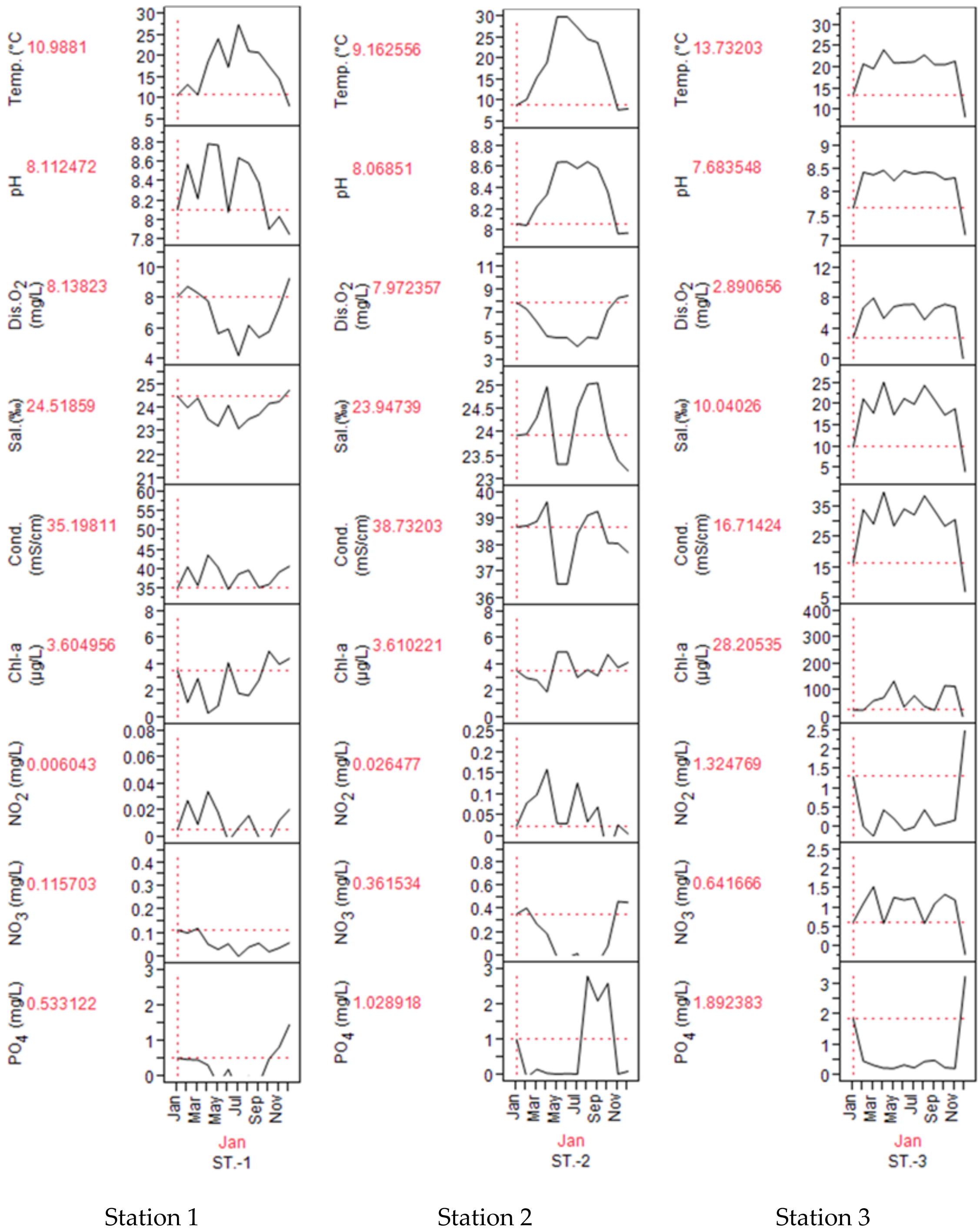

Figure 4. Artificial Neural Network profilers of sampling stations.

Table 4. Artificial Neural Network analysis.

Parameters	Station 1		Station 2		Station 3	
	Training	Validation	Training	Validation	Training	Validation
Temp. (°C)						
RSquare	0.9999737	0.4596033	0.8838093	0.631399	0.3086698	0.3748334
RMSE	0.0310153	7.3130269	2.6150308	2.9529559	6.5201517	5.838559
Mean Abs Dev	0.0240022	6.1902893	2.199174	2.7058061	5.7914644	4.6785388
-LogLikelihood	−16.4347	13.634383	19.041715	10.006981	26.350689	12.73369
SSE	0.0076956	213.92145	54.707088	34.879794	340.09902	136.35509
Sum Freq	8	4	8	4	8	4
pH						
RSquare	0.1668538	−0.853992	0.7435473	−2.726735	0.6022838	0.5610022
RMSE	0.267187	0.4237442	0.1625936	0.2792107	0.3485397	0.4631205
Mean Abs Dev	0.19454	0.3370907	0.1326328	0.2269885	0.2977953	0.3587391
-LogLikelihood	0.7930575	2.2412528	−3.180506	0.5726001	2.9194836	2.5966824
SSE	0.5711113	0.7182366	0.2114933	0.3118345	0.9718395	0.8579225
Sum Freq	8	4	8	4	8	4
Dis.O_2 (mg/L)						
RSquare	0.9163089	0.7379888	0.9261704	0.3033255	0.2448014	0.8748499
RMSE	0.4764616	1.1898445	0.4363866	2.2727797	3.1580448	1.0308688
Mean Abs Dev	0.3834798	0.9991211	0.3407872	1.8561	2.8588008	0.9330222
-LogLikelihood	5.4205636	6.3710446	4.7176952	8.9597687	20.551133	5.797362
SSE	1.8161255	5.6629195	1.5234664	20.662111	79.785974	4.2507621
Sum Freq	8	4	8	4	8	4
Sal. (‰)						
RSquare	0.3954401	0.3160244	0.9844877	0.4322861	0.9262025	0.8076052
RMSE	0.8005208	0.4567412	0.1002207	0.5230365	1.6483301	3.3814941
Mean Abs Dev	0.6163722	0.3929383	0.0899393	0.4522695	1.2181054	2.7069999
-LogLikelihood	9.5715661	2.5412011	−7.051536	3.0833379	15.34961	10.549025
SSE	5.1266683	0.8344503	0.0803535	1.0942686	21.735936	45.738009
Sum Freq	8	4	8	4	8	4
Cond. (mS/cm)						
RSquare	0.241318	-3.241563	0.9383862	0.1330518	0.9251709	0.8187747
RMSE	6.0577539	2.9393084	0.246665	0.6854032	2.5334666	5.0402667
Mean Abs Dev	4.3259859	2.6573154	0.1652148	0.6478408	1.8956645	4.0361131
-LogLikelihood	25.762221	9.9884515	0.1537138	4.1647622	18.788217	12.14559
SSE	293.57106	34.558137	0.4867488	1.8791103	51.347625	101.61716
Sum Freq	8	4	8	4	8	4
Chl-*a* (μg/L)						
RSquare	0.6644175	0.6276704	-0.108688	0.0295825	0.1909539	−0.495111
RMSE	0.9893484	1.7277083	1.8797527	2.0723419	96.648065	80.49158
Mean Abs Dev	0.7513394	1.5335083	1.5308088	1.945856	66.256978	67.232993
-LogLikelihood	11.265838	7.8629375	16.40063	8.5904715	47.920118	23.228364
SSE	7.8304822	11.939904	28.267762	17.178404	74726.787	25915.578
Sum Freq	8	4	8	4	8	4
NO_2 (mg/L)						
RSquare	0.7840246	−1.181181	0.4387834	−27.67934	0.894466	0.700029
RMSE	0.0054927	0.0382467	0.0543981	0.0697605	0.2625079	0.5713248
Mean Abs Dev	0.0049184	0.0272054	0.0436844	0.0614943	0.2137998	0.3580636
-LogLikelihood	−30.28323	−7.379034	−11.9399	−4.974996	0.6517157	3.4365644
SSE	0.0002414	0.0058513	0.0236732	0.0194661	0.5512832	1.305648
Sum Freq	8	4	8	4	8	4

Table 4. *Cont.*

Parameters	Station 1		Station 2		Station 3	
	Training	Validation	Training	Validation	Training	Validation
NO_3 (mg/L)						
RSquare	0.7769353	0.0377191	0.8604199	0.419233	0.0932847	−0.639227
RMSE	0.0148754	0.1587079	0.0779262	0.2543058	0.9577898	0.8361007
Mean Abs Dev	0.0119939	0.0988195	0.0611344	0.1972806	0.853357	0.6502993
-LogLikelihood	−22.31288	−1.687007	−9.064436	0.1988823	11.006493	4.9597293
SSE	0.0017702	0.1007527	0.0485799	0.2586857	7.3388901	2.7962575
Sum Freq	8	4	8	4	8	4
PO_4 (mg/L)						
RSquare	0.5161065	0.0681952	0.9999878	0.7559572	0.9329395	0.6151915
RMSE	0.5980807	1.0872444	0.0040252	0.6080376	0.2508698	0.7536434
Mean Abs Dev	0.52071	0.6955629	0.0031952	0.481501	0.214833	0.6552709
-LogLikelihood	7.2392722	6.0103398	−32.76994	3.6856798	0.2889379	4.5444103
SSE	2.8616046	4.7284014	0.0001296	1.4788388	0.5034852	2.2719136
Sum Freq	8	4	8	4	8	4

4. Discussion

In lagoons all over the world, Bacillariophyta, Dinophyta, Chlorophyta and Cyanobacteria divisions were usually found to be the most important groups [6,29]. There is still insufficient research on phytoplankton composition in lagoons located in different regions of Turkey and the whole world [2,3,30–34]. Bacillariophyta was determined the richest group in terms of species numbers as Bafa [30], Chilika [29], Liman [3], Paradeniz [33], Homa [34], Lesina [6], Akyatan and Tuzla lagoons [32]. The algal flora of the lagoon did not have rich species variation, except some dominant species, because of the eutrophic conditions. The phytoplankton species richness in Bafa Lake [30], Homa Lagoon [34], Akyatan and Tuzla lagoons [32] were recorded in low numbers like Kamil Abduş Lagoon and the phytoplankton composition showed similarity.

Bacillariophyta was represented by 12 taxon and most common diatoms were recorded as *Aulacoseira italica*, *Cyclotella atomus*, *Cymbella affinis*, *Melosira varians*, *Navicula cryptocephala*, *Nitzschia acicularis*, *Ulnaria acus* and *U. ulna*. It is stated that *Aulocoseira italica* and *Cyclotella atomus* of diatoms are found generally in vertical mixed mesotrophic small-medium lakes with tolerance to light deficiency and sensitive to a rise in pH. *Ulnaria acus* and *Nitzschia acicularis* of pennate diatoms are habitants of shallow enriched waters and streams with sensitivity to nutrient deficiency. While *Gomphonema truncatum*, *Navicula cryptocephala*, and *Ulnaria ulna* are usually present in mixed inorganically shallow lakes, *Melosira varians* is known as a lotic habitat member [35,36]. This species was recorded very few in station 1 where the lagoon is connected to the sea in February and April 2017 samples. It was reported that *M. varians* became one of the dominant species of diatoms in May 2003 in a lake which has eutrophic characteristics [3].

Charophyta was represented by a desmid *Closterium acutum* which has tolerances to light and carbon deficiencies. *C. acutum* was recorded as the dominant species at station 3 in October 2017 and constituted the 99% of the total phytoplankton density. Different species of the *Closterium* genus were found in the eutrophic-characterized Liman Lake [3]. Chlorophyta was represented by 4 species. A member of green algae *Ankistrodesmus falcatus* is recorded generally in shallow eutrophic and mesotrophic waters and it is sensitive to nutrient deficiency. *Ankistrodesmus falcatus* was recorded in July and October 2017 samples in low numbers. *Scenedesmus* sp. of this division is sensitive to low light and presents in enriched ponds, lakes and streams [35,36]. This green alga was recorded only at station 1 in April 2017 in very low amounts. During the study *Chlamydomonas* sp. which indicates eutrophic aquatic systems, was constituted the 93.70% of the total phytoplankton density at station 1 in February 2017. *Chlamydomonas globosa* and *C. pseudopertyii* composed 82.3% of phytoplankton density in Lake Mogan [37]. Also, Obalı (1984) noted that *Chlamydomonas* sp. was recorded as dominant in Lake Mogan during the spring. *Chlamydomonas* spp. has been identified as one of the inhabitants of eutrophic lakes and reservoirs [37].

Cryptophyta was represented by *Cryptomonas ovata* which is presented in small enriched lakes [35,36]. Cyanobacteria (Cyanophyta) was represented by 5 species. It is known that *Anabaena spiroides*, *Merismopedia galauca*, *Microcystis aeruginosa* and *Oscillatoria tenuis* of blue-green algae are indicated eutrophic conditions. It was noted that *M. glauca* was determined the subdominant species in eutrophic Küçükçekmece Lagoon [2]. Especially *A. spiroides* and *M. aeruginosa* indicate high organic matter levels and agriculturally enriched eutrophic, and also hypereutrophic, waters. Also, toxin-producing Cyanobacteria like *M. aeruginosa*, pose a big threat both to the lake ecosystem and public health, additionally they could be very dangerous for migratory birds [32].

Euglenozoa (Euglenophyta) was represented by 5 species. It was stated that species of *Euglena* genus are found commonly in shallow mesotrophic and polluted lakes [35,36]. *Euglena* spp. were recorded except February 2017 in all sampling terms and points in low numbers. *Euglena gracilis* was determined as a subdominant in eutrophic featured Küçükçekmece Lagoon [2]. Miozoa (Dinophyta) was represented by 4 species which are found both in freshwaters and marine systems. It was expressed that these dinoflagellates are presented from oligotrophic to eutrophic waters in a wide range and *Prorocentrum micans* and *P. lima* of dinoflagellates were recorded as euryhaline species and tolerated salinity changes [36,37]. Similarly *P. micans* had peaked in August and November in Lake Bafa [30]. In addition, *P. bipes* and *P. micans* of Dinophyta division were stated as dominant species in Küçükçekmece Lagoon by Yilmaz [2] and Caroppo et al. [6] reported blooms that *Prorocentrum cordatum* was made in Lesina Lagoon. In the present study, the dinoflagellates recorded, such as *Prorocentrum micans*, *P. lima* and *P. bipes*, are considered to be harmful algae because of they cause excessive blooms under appropriate conditions and cause red-tides [38].

Electrical conductivity values were found higher than the standard limits (150–500 µS/cm) of the protocols assigned for protection of surface water sources against pollution [39]. In terms of salinity concentrations, the lagoon has been described as a poly-euhaline saline coastal lagoon [9]. According to the measured pH values, the water of Kamil Abduş Lagoon is slightly alkaline (within normal limits) and class I and II water quality. During the study, dissolved oxygen concentrations were measured at low levels. The minimum concentration of dissolved oxygen was measured in station 3 in December 2016. In general nitrite, nitrate and orthophosphate concentrations were high especially at stations 2 and 3. This was a result of inputs from Tuzla Shipyard and greenhouses to the lagoon system. Chlorophyll-*a* distribution is used for determining the algal biomass and primary production in many limnological studies and it is an important indicator of water quality and pollution [39]. In the present study, chlorophyll-*a* concentrations were estimated between 0.46 and 349.2 µg/L and the average was 23.59 µg/L. It was expressed that chlorophyll-*a* concentrations between 5 and 140 µg/L indicates an eutrophic lake [40]. High levels of chlorophyll-*a* concentration, which shows hypereutrophic conditions, were measured in station 3 in autumn when the maximum concentrations of NO_3 were recorded in the lagoon. The source of recorded high nutrient concentrations was determined as the inputs from the greenhouses. *Closterium* genus of desmids (Charophyta), which dominated the phytoplankton in autumn at station 3, is described as an indicator of eutrophic conditions in freshwater [6].

The critical factors acquired from the examination infer their significance to decide the lagoon's water quality [41]. Chlorophyll-*a* and dissolved oxygen (DO) came in second in the significance, while conductivity positioned the last. This could be disclosed because of the short proximity of pH and temperature varieties inside the gathered information from the diverse three stations. In contrast, conductivity demonstrated the most elevated scope of information fluctuation where the input inconsistencies were plotted against its average [42,43].

5. Conclusions

Mesotrophic and eutrophic species of phytoplankton, high levels of chlorophyll-*a* and nutrients indicated that the trophic state of the lake is near to eutrophic. Supplementary care must be given to the habitat of living beings in this type of lagoon, and its surrounding area. The lagoon is under the threat of water pollution, so it must be immediately taken under protection by the environmental regulations. Especially wastewaters which are discharged from the greenhouses and the shipyard to the lagoon should be controlled according to standards of Water Pollution Control Regulations in Turkey [44]. Limnological studies, including phytoplankton composition, heavy metals and nutrient concentrations, have to be carried out for monitoring the water quality in Kamil Abduş Lagoon.

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