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# Nutrient, benthic algae relationships in the Sinop Karagol-Aksaz Marsh, Turkey

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**Investigation of nutrient and composition of benthic algae from chosen random sampling station on Karagöl-Aksaz Marsh were researched between November 2005 and November 2006. In addition, some physical and chemical parameters (soluble reactive phosphorus, total phosphorus, $NH_4$, $NO_3$, Cl, chlorophyll-*a* (Chl-*a*), carotenoid, pH, $O_2$) were measured. Benthic algae diversity was calculated by using the Shannon-Weaver ($H^{'}$) and evenness (J) index. ($H^{'}$) indices varied from 1.03 to 1.48, and (J) from 0.42 to 0.67. Cluster analysis produced the three major groups, A-B swamp-wet and C swamp-dry, and occurs at the highest level of similarity. The analyses were recognized at the 0.4 dissimilarity level. A total of 55 benthic algae taxa were identified in Kargöl-Aksaz Marsh lake. Although the species of genus *Gomphosphaeria* spp., *Dictyosphaerium* spp., *Navicula* spp., and *Gomphonema* spp. constituted the main composition of the benthic flora, the species belonging to genus *Sellaphora* spp., *Frustulia* spp., *Pinnularia* spp. and *Stauroneis* spp. were found to be less numerous. The flora as a whole increased in March, April and May (swamp-wet) and decreased in July and August (swamp-dry).**

**Key words:** Marsh, benthic algae, cluster, diversity, nutrient.

## INTRODUCTION

Marsh is a type of wetland which is an important ecological unit. Hydrological cycle of a Marsh is variable and distinguishes itself from other ecosystems. It can vanish from reconstruction by geology, meterological movements and human impact (Fleeger et al., 2008). Marsh landscapes include unvegetated mudflats, a creek-Marsh ecotone between vegetated and non-vegetated sediments and a densely vegetated high Marsh platform. The gradient of elevation/inundation in Marshes vary with biotic factors (inundation, aerial exposure, flow, light, and sediment chemistry) (Menéndez and Sanmarti, 2007). Soluble organic matter in Marsh is a considerable energy source for microorganisms (Newell and Porter, 2000).

Nutrient load imported to Marsh areas has increased annually with the increase of waste from human activity, agricultural runoff and industrial production, especially drought. Water is the essential element that dominates in Marsh habitats. Marshes and other wetland ecosystems undergo cyclical periods of flooding, drought, and deterioration. Water levels in Marsh environments are continuously fluctuating and individual Marshes have unique water level patterns. Generally, primer production in the Marsh has three components; benthic algea, planktonic algae and angiosperms. It has long been recognized that algae distributions in Marshes are strongly affected by water chemistry and different water cyclical periods. Seasonal succession of algae is

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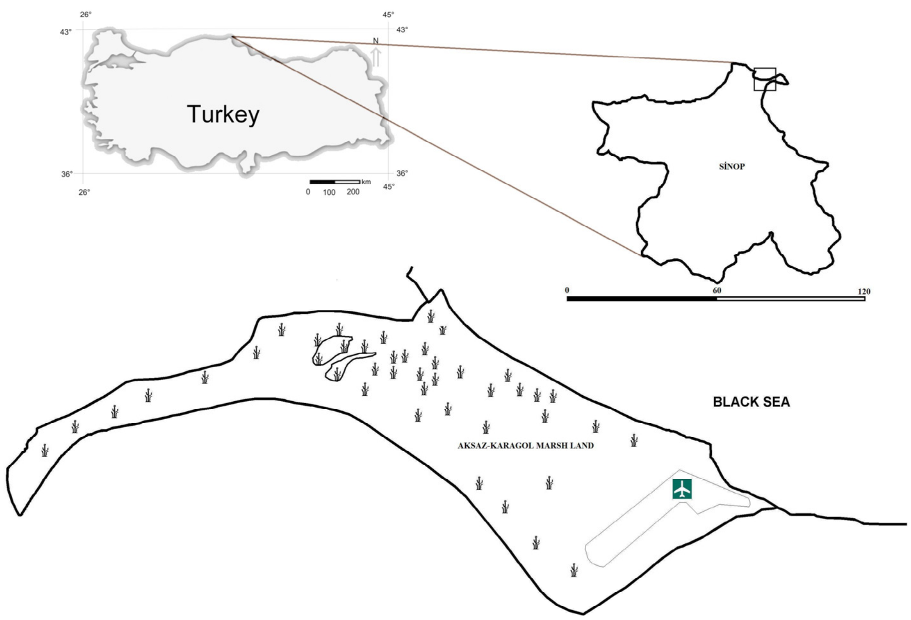


**Figure 1.** The location of Karagöl-Aksas Marsh in Turkey.

conditioned by the joint action of biotic and abiotic factors of environment in Marsh (Danilov, 2002). Therefore, many algal including diatoms species are indicators of Marsh conditions reflecting the influence of hydrological cycle. Diatoms constitute an important group of algae. The cell wall is silicified to form a frustule, comprising two valves. They have been recorded and classified for over 200 years (Horton et al., 2006). One of the important factors affecting the distribution algae (especially diatoms) of the water chemistry is known to be a long time. Therefore, algae are precious indicators of water quality characteristics including pH, nutrient satus, and salinity. As an advantage over other bioindicators, they have shorter generation times, showing a rapid response to environmental changes and therefore become early warning indicators of changes in nutrient status (Smol and Stoermer, 2010).

## MATERIALS AND METHODS

### Description of the study site

Anatolian region for more than the total size of 2,000,000 ha (2,155,045 ha), 135 units of international importance are wetlands. These fields are required to enter into this important wetland in the Sinop region, which is our study area is swampy Karagöl-Aksaz. Karagöl-Aksaz Marshes in the Sinop Black Sea shore line which exists at the interface of freshwater through inflow salt water entering the Karasu stream from the Black Sea. The Marsh surrounds Aksaz lake, a shallow tidal lake that has developed in effect of a sandy barrier Black Sea beach since 4,000 or 5,000 years ago. The crest of the barrier beach is approximately +2 m above the elevation of the Marsh, which is drained by means of a culvert through the barrier (Özaner, 1998) (Figure 1). This study aims to determine the benthic algae composition and relations amongs nutrient, water regime and divercity of Karagöl-Aksaz lake.

Measurements were taken from January, 2005 to March, 2006 in sampling periods set at random according to the hydro-period changes. Sediment samples were collected from random stations by means of a glass pipe 11 mm in diameter and 1 m in length. The pipe was lowered by hand to the surface of the sediment, while one end was closed with the thumb. The pipe was then moved in a circular direction on the surface and the thumb was slightly loosened to suck the sediment into the pipe. The collected sediment samples were transferred into plastic bottles and taken to the laboratory for further examination. The sediment samples were put into petri dishes and allowed to settle for 4 to 6 h. The supernatant was removed from the petri dishes by micropipetting and cover glasses were placed over the sediments. After 24 h, the cover glasses were carefully taken and washed into beakers. All benthic algae were identified and counted before fixation. Thereafter, diatoms were prepared following standard techniques: carbonate dissolution by HCl followed by oxidation of organic matter using $H_2O_2$ and repeated washing of the resultant diatom frustule in demineralized water (Battarbee, 1986). At least 400 diatom valves were counted on each slide along randomly chosen transects. Identification and enumeration was made using an Olympus Vano microscope with brightfield optics at a magnification of 1600×. The number of total diatoms (per $cm^2$) was calculated by using Round's methodology (Round, 1953) ($p \leq 0.05$) (Table 1). Then, all benthic algae were converted to relative abundances (that is, proportions of species to the total for each sample). Taxonomic identifications of species were made following Patrick and Reimer (1966, 1975), Komárek and Anagnostıdıs (2005) and Krammer and Lange-Bertalot (1986, 1988, 1991a, 1999a,b).

### Environmental variables

Dissolved oxygen (DO) concentration, water temperature (YSI 55B Model), conductivity and pH (Cyber Scan 510) were measured in the field. Water for chemical analyses was stored under cold dark conditions in acid-washed 1-L Pyrex bottles, following filtration through glass fiber cartridges (GF/C) filters for ammonium, nitrate and soluble reactive phosphorus (SRP) determinations. Unfiltered water was used for other variables. All analyses were completed within 18 h of sampling. Alkalinity was determined by titration with HCI using BDH 4.5 indicator. SRP, total soluble phosphorus (TSP), total phosphorus (TP), silicate ($SiO_3$), chlorine ($Cl^-$), calcium ($Ca^{2+}$), sulphate ($SO_4^{2-}$) and ammonium ($NH_4^+$), and were determined according to Mackereth et al. (1978) to a precision of ±4%. Nitrate was determined by reduction to nitrite on spongy cadmium and subsequent diazotization to a pink dye, determined spectrophotometrically, to a precision of ±3%. For determination of chlorophyll-*a* (Chl-*a*) concentration, water volumes of 500 $mL^{-1}$ were filtered immediately through GF/C filters after the addition of 0.2 $mL^{-1}$ saturated $MgCO_3$. Filters were extracted in cold 90% acetone for 18 to 24 h. Following absorption measurements, the equations of Tailing and Driver (1961) were used to determine Chl-*a* concentrations corrected for phaeopigments.

#### Diversity indices

A comparative analysis of these diatom communities was performed by means of diversity measures. We calculated diatom diversity using the Shannon-Weaver ($H'$) and evenness (J) index:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i \;\; (P_i = N_i / N) \; ; \; J = H' / \log_2 S$$

Where $P_i = N_i /N$ relative abundance for each species; S = total number of species, $N_i$ = number of individuals of a species in sample; N = total number of individuals of all species in the sample (Shannon Weaver, 1949; Pielou, 1966).

#### Cluster analysis

Investigation of similarities in benthic algae compositions among the samples was performed by means of cluster analysis based on the Euclidean distance calculated from square root transformed relative abundance (an alternative method of calculating the Hellinger distance as proposed by Legendre and Gallagher (2001). The complete linkage method was preferred to determine the groups of samples that are most similar. Computations were performed using Mınıtab v 13.1.

## RESULTS AND DISCUSSION

During the sampling period, we determined total of 55 taxa. Predominantly *Gomphosphaeria*, *Dictyosphaerium*, *Nitzschia*, *Navicula* and *Gomphonema* often have been observed but *Bacillariophyta* were dominant in terms of species number during the study period. Cyanobacteria, especially *Gomphosphaeria* sp. and *Chlorophyta*, *Dictyosphaerium granulatum* became dominant in Karagöl Marsh with a rapid increase in late spring. Komárek and Anagnostıdıs (2005) reported that *Gomphosphaeria* and *Dictyosphaerium* are the majority of species free living in the methaphyton of the littoral of lakes and in swamps and pools, among other algae and water plants (one in salinic swamps), usually with limited areas of distribution. As mentioned in the report that such a limited amount of space has been determined at very high rates (Figure 3). The reason for this in our opinion is a very high phosphate and nitrate was caused by the rapid change of water regime (Table 2). Because of the hydro-period and ionic composition of the Marsh, system affects benthic algae flora both drectly via their influence on physiological processes and indrectly via their influence on biogeochemical cycles. A combination of high water, N and P availability over the sediment surface increased the density of meiofauna, cyanobacteria, diatoms and also probably bacteria in autumn during the decay after leaf fall, by enhancing macrophyte decomposition.

Our results indicated that some major environmental factors such as hydro-period, phosphate, nitrate and temperature control the benthic algae assemblages. Thomas et al. (2006) indicated that changes in the hydrologic regime (that is, duration and timing of flooding, water depth) can greatly influence periphyton community structure and function. During the dry season in short-hydroperiod Marshes, periphyton communities are dormant and unproductive. Following re-flooding, periphyton recovers within days, but not before large quantities of nutrients has been released back into the water column. In stagnant situations, these nutrients may be re-sequestered by the community upon recovery but if water is flowing, the released nutrients can affect downstream communities (Gottlieb et al., 2006). One of the most important factors affecting the development of benthic algae was nutrients and hydro-period. We showed that periphyton communities can quickly adapts in composition and structure if exposed to alternating hydrologic regimes. These fast responses to environmental changes strongly advocates for the use of periphyton as an indicator for environmental monitoring in Aksaz-Karagöl Marsh.

The paltern of Shannon-Weaver ($H'$) has shown that the diversity is greater in the period of elevated water than in period of decreased water. This diversity may be related to greater environmental variability (tidal fluctuations, nutrient and temperature). Shannon-Weaver ($H'$) indices varied from 1.03 to 1.48, and evenness from 0.42 to 0.67, giving averages as 1.21 and 0.52, respectively ($p \leq 0.05$). The highest diversity index was recorded in March (swamp-wet) and the lowest in July and August (swamp-dry). The diversity index values tend to increase during swamp-wet (March, April and May) and certain species, especially *Gomphosphaeria* spp. and *D. granulatum* are dominant.

The dendogram in Figure 2 shows sample affinities based on the root transformed relative abundance of a total of 36 benthic algae species using the Euclidean measure of similarity. The dashed line drawn at the arbitrary similarity level of 40% clearly defines threemajor clusters. Three major clusters, diatom groups A-B swamp-wet and C swamp-dry, occur at the highest level of similarity. A useful clustering can also be recognized at the 0.4 dissimilarity level and this has been used to distinguish each of the benthic algae groups shown in

**Table 1.** Benthic algae flora of Karagöl-Aksaz Marsh.

| Division | Class | Species |
|---|---|---|
| Chlorophyta | Trebouxiophyceae | *Chlorella vulgaris* Beijerinck |
| | Chlorophyceae | *Acutodesmus acuminatus* (Lagerheim) Tsarenko<br>*Desmodesmus opoliensis* (P. G. Richter) E.H.Hegewald<br>*D. granulatum* Hindák<br>*Kirchneriella incurvata* Belcher and Swale<br>*Micromelum minutum* (Nägeli) Komárková-legnerová<br>*Micromelum pusillum* ( Printz) Komárková-L.<br>*Pediastrum* spp.<br>*Scenedesmus Bijuga* (Turpin) Lagerheim<br>*Scenedesmus obliquus* (Turpin) Kützing)<br>*Scenedesmus* spp.<br>*Tetraedron* spp. |
| Cyanobacteria | Cyanophyceae | *Chroococcus* spp.<br>*Gomphosphaeria* spp.<br>*Microcystis* spp.<br>*Phormidium limosum* (Dillwyn) Silva<br>*Pseudanabaena limnetica* (Lemmermann) Komárek |
| Euglanazoa | Euglenophyceae | *Euglena acus* Ehrenberg<br>*Lepocinclis acus* (O. F. Müller) Marin and Melkonian |
| Bacillariophyta | Coscinodiscophyceae | *Aulacoseira* spp.<br>*Melosira* spp. |
| | Bacillariophyceae | *Amphipleura pellucida* Kützing<br>*Amphora ovalis* (Kützing) Kützing<br>*Bacillaria paxillifer* (O.F. Müller) Hendey<br>*Cocconeis placentula* var. euglypta (Ehr.) Grunow<br>*Caloneis silicula* (Ehrenberg) Cleve<br>*Cymatopleura solea* (Brébisson) W. Smith<br>*Epithemia sorex* Kützing<br>*Encyonema silesiacum* (Bleisch) D.G. Mann<br>*Eucocconeis flexella* (Kützing) Meister<br>*Frustulia rhomboides* (Ehrenberg) De Toni<br>*Gomphonema acuminatum* Ehrenberg<br>*G. truncatum* Ehr.<br>*Gyrosigma acuminatum* (Kützing) Rabenhorst<br>*Navicula capitatoradiata* Germain<br>*Navicula cryptocephala* Kutz.<br>*Navicula radiosa* Kutz.<br>*Navicula rhyncocephala* Kützing<br>*Navicula tripunctata* (O.F.Müll.) Bory |
| | Bacillariophyceae | *Nitzschia capitellata* Hustedt<br>*Nitzschia dissipata* (Kützing) Grunow<br>*Nitzschia linearis* (Agardh) W. Smith<br>*Nitzschia recta* Hantzsch<br>*Nitzschia sigmoidea* (Ehrenberg) W. Smith<br>*Nitzschia tryblionella* Hantzsch<br>*Nitzschia veneta* Kutz.<br>*Pinnularia divergens* W. Smith<br>*Rhoicosphenia abbreviata* (Agardh)Lange-Berthalot |

**Table 1**. Contd.

| | |
|---|---|
| | *Rhopalodia gibba* (Ehrenberg) O. F. Müler |
| | *Sellaphora pupula* (Kützing) Mereschkovsky |
| | *Surirella minuta* Brébisson |
| | *Surirella ovalis* Brébisson |
| | *Tryblionella hungarica* (Grunow) Frenguelli |
| | *T. calida* (Grun.in Cleve and Grun.) D.G. Mann |
| Fragilariophyceae | *Fragilaria ulna* (Nitzsch) Lange-Bertalot |

**Table 2.** Abbreviations and units of environmental variables with basic statistical summaries (p ≤ 0.05).

| Environmental variable | Abbreviation | Unit | Min | Max | Mean | SE |
|---|---|---|---|---|---|---|
| Soluble reactive phosphorus | SRP | $\mu g.L^{-1}$ | 14.10 | 58.98 | 27.42 | 8.31 |
| Total phosphorus | TP | $\mu g.L^{-1}$ | 48.39 | 230.72 | 119.58 | 33.34 |
| Ammonium | $NH_4$ | $\mu g.L^{-1}$ | 14.76 | 76.50 | 36.69 | 11.59 |
| Nitrate | $NO_3$ | $\mu g.L^{-1}$ | 0.03 | 0.07 | 0.06 | 0.01 |
| Chlorine | Cl | $mg.L^{-1}$ | 10.23 | 96.20 | 50.64 | 23.07 |
| Chlorophyll-*a* | Chl-*a* | $\mu g.L^{-1}$ | 0.88 | 12.54 | 5.5 | 2.50 |
| Caroten | Chr | $\mu g.L^{-1}$ | 1.40 | 12.40 | 6.4 | 2.09 |
| Temperature | Temp. | °C | 11.6 | 23.50 | 15.4 | 2.15 |
| pH | pH | | 8.08 | 8.66 | 8.48 | 0.10 |
| Dissolve oxygen concentration | DO | $mg.L^{-1}$ | 8.9 | 11.1 | 9.9 | 0.46 |

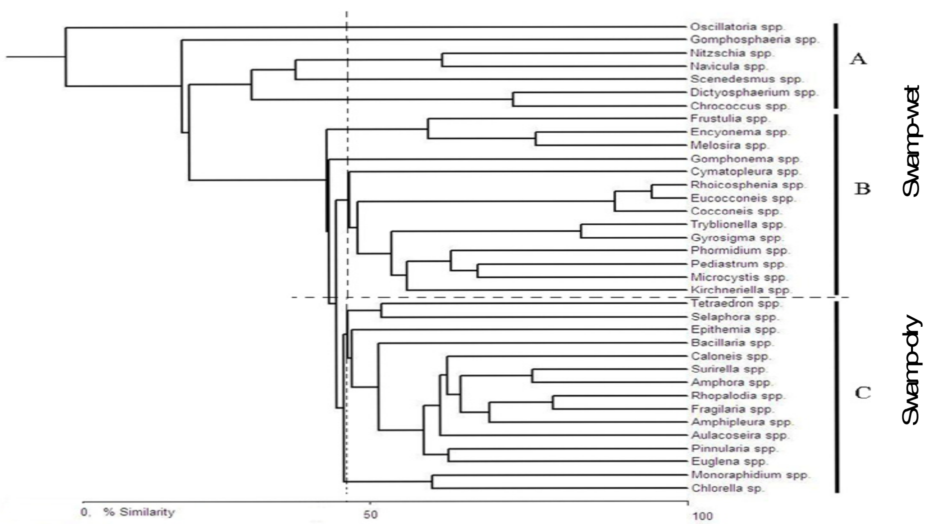


**Figure 2.** Dendogram resulting from cluster analysis A, B (Swamp-wet) and C (Swamp-dry) indicate three groups defined by the dotted line arbitrarily drawn at 40% similarity.

Figure 2. The Cluster A corresponds to spring months involving high percentage of *Gomphosphaeria* spp., largely *D. granulatum*, along with *Navicula* spp. and veryclosely associated with increasing the amount of water, which are areas of high nutrient concentration. Cluster Group B, composed mainly of last spring months and decreasing amount of water, is characterized by the notable decrease in relative abundance of *Gomphonema* spp. and also by the increase in number of species derived primarily from *Rhoicosphenia* spp., *Cocconeis* spp. and *Pediastrum* spp. Summer months formed the Cluster Group C (third group) dominated by *Selaphora* and *Fragilaria* species. The main benthic algae are cyanobacteria rather than diatoms. Cyanobacteria can reproduce quickly in high temperatures and nutrient-rich conditions (Meng et al., 2010; Mın et al., 2012). Due to a massive outburst, it makes all samples have the highest percentage of *Gomphosphaeria* (37%) throughout the

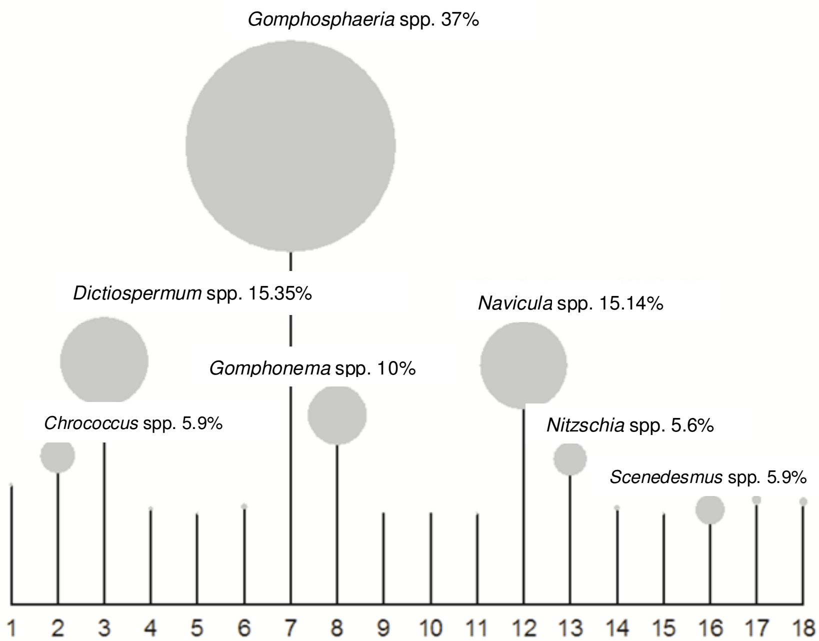


**Figure 3.** Percantage rates of some dominat genus in total benthic algae.

year (Figure 3). Nutrient availability also greatly influences benthic algae. Nutrient parameters were important determinants of benthic algae distribution patterns in both swamp-wet and dry. However, due to high concentrations of dissolved organic material in these systems (Arts et al., 2000), nutrients may be complexed and unavailable for biological uptake and diversity by benthic algae. Information on seasonal changes in benthic algae community structure and distribution patterns in Karagöl-Aksaz Marsh lake will allow us to understand mechanisms behind changes in important ecosystem processes such as water regime, changing nutrient, diversity and how these valuable Marsh systems may respond to future climate changes.

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