

## EPILITHIC DIATOM-BASED ECOLOGICAL ASSESSMENT IN TAŞMANLI POND (SINOP, TURKEY)

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**Abstract:** The common goal of the Water Framework Directive (WFD) published by The European Parliament and European Council and the Regulation on the Management of Surface Water Quality Directive (RMSWQ) published by the Republic of Turkey, Ministry of Forestry and Water Affairs, is to provide all water bodies to achieve a fine ecological status. These directives require the use of relevant biological quality elements and diatoms constitute an important group within these elements. The use of diatom based indices for assessing ecological conditions in inland water systems is increasing day by day. The current study was performed with the aim of determination of the ecological status of the Taşmanlı Pond based on epilithic diatoms, physico-chemical parameters and to estimate pond water quality using diatom indices. For this purpose, epilithic diatom and water samples were collected from 3 stations in the pond in monthly intervals from March 2008 to March 2009. The identifications of the sampled revealed presence of a total of 46 taxa in the sampled stations. *Achnanthydium minutissimum* (Kützing) Czarnecki, *Nitzschia acicularis* (Kützing) W. Smith, *Navicula cincta* (Ehrenberg) Ralfs in Pritchard and *Navicula cryptocephala* Kützing were the dominant taxa in all stations. According to Regulation on the Management of Surface Water Quality directive, the pond water was classified as III-IV quality class and trophic status changed from mesotrophic to eutrophic. Significant correlation was determined between LTDI (Lake Trophic Diatom Index) and EQR (Ecological Quality Ratio). The values of LTDI and EQR indicate that, pond water has class III (poor, moderately polluted site) water quality.

**Key words:** Epilithic, Diatom, LTDI, EQR, Pond, Taşmanlı, Sinop, Turkey.

**Özet:** Avrupa Parlamentosu ve Avrupa Birliği tarafından yayınlanan Su Çerçeve Direktifi (WFD) ve Türkiye’de “Orman ve Su İşleri Bakanlığı, Su Yönetimi Genel Müdürlüğü” tarafından yayınlanan “Yüzey Suları Su Kalite Yönetmeliği”nin ortak hedefi, tüm su kütlelerinin iyi bir ekolojik statüye ulaşmasıdır. Bu yönetmelikler, amaca uygun biyolojik kalite öğelerini kullanmayı gerektirmektedir ve diyatome bu öğeler içerisinde oldukça önemli bir grubu oluşturmaktadır. Diyatome temelli indislerin işsu kütlelerinde ekolojik parametrelerin belirlenmesi amacı ile kullanımı günden güne artış göstermektedir. Bu çalışmada, Taşmanlı Göleti’nin ekolojik durumunun değerlendirilmesinde epilithic diyatome, fizikokimyasal parametrelerin ve diyatome indislerinin ekolojik kalitenin belirlenmesinde, bir araç olarak test edilmesi amaçlanmıştır. Bu nedenle, Mart 2008 - Mart 2009 tarihleri arasında göletten alınan diyatome ve su örnekleri analizleri sonucunda, toplam 46 takson gözlenmiştir. Bunlardan *Achnanthydium minutissimum* (Kützing) Czarnecki, *Nitzschia acicularis* (Kützing) W. Smith., *Navicula cincta* (Ehrenberg.) Ralfs in Pritchard, *Navicula cryptocephala* Kützing tüm istasyonlardaki baskın türlerdir. Yapılan fizikokimyasal testler sonucu gölet suyu “Yüzeysel Su Kalitesi Yönetmeliği” ne göre III-IV kalite sınıfı olarak sınıflandırılmış ve trofik durumu mezotrofikten ötrofiye doğru değişmiştir. LTDI (Göl Trofik Diatom İndeksi) ve EQR (Ekolojik Kalite Oranı) değerleri gölet suyunun sınıf III (tamamen kirli alan) su kalitesine sahip olduğunu göstermektedir.

### Introduction

Water is vital for any type of life on earth. The world contains aquatic and terrestrial ecosystems that are in very close contact with each other resulting in a delicate balance. The continuity of life is directly related to the continuity of this dynamic ecosystem interaction. Moreover, the continuity of socioeconomic inputs for humans is realized by the continuity of this system. Algae are primary producers of aquatic ecosystems and ensure the continuity of the systems they are involved in. This

essential component creates the natural energy inputs of aquatic ecosystems and forms the most fragile link.

Aquatic systems, freshwater ecosystems in particular, are under a constant and strong pressure of human related activities (Gümüş 2010). Therefore, protection of natural water resources and the dominance of aquatic systems is one of the most important elements to be used in determination of future standard of life quality. Small physico-chemical changes in water initiate a chain

reaction that affects both algae and our life quality. Phytobenthos is one of the biological quality elements that must be contained in The Water Framework Directive (WFD, "Directive 2000/60/EC" The European Parliament and European Council 2000) assessments of ecological status of freshwaters and diatoms are good environmental indicators and are often the main component of phytobenthos (Della Bella *et al.* 2007). Although diatoms are one of the important components of phytobenthos in aquatic systems, only some countries have yielded WFD-compliant phytobenthos tools specifically for lakes (Bennion *et al.* 2014). Diatoms are also taken into account as key organisms used as biological indicators in ecological quality analysis. Diatom-based water quality evaluation is a new process for Turkey and the first studies have begun after 2000s. Some of these studies were performed in Antalya River basin (Kalyoncu 2002, Solak *et al.* 2007a, Kalyoncu *et al.* 2009), Büyük Menderes River basin (Barlas *et al.* 2001, 2002, Solak *et al.* 2007b), Fırat River basin (Gürbüz & Kıvrak 2002), Kızılırmak River basin (Akbulut *et al.* 2010), Sakarya River basin (Solak *et al.* 2009, Solak 2011) and Susurluk River basin (Dalkıran *et al.* 2008, Karacaoğlu *et al.* 2008, Solak *et al.* 2011, Solak & Acs 2011), showing that no study has been performed so far in Taşmanlı Pond on the subject of diatom-based water quality evaluation.

The present study was performed in order to determine the ecological status of Taşmanlı Pond based on epilithic diatoms and to estimate pond water quality using diatom indices.

## Materials and Methods

### Study Area

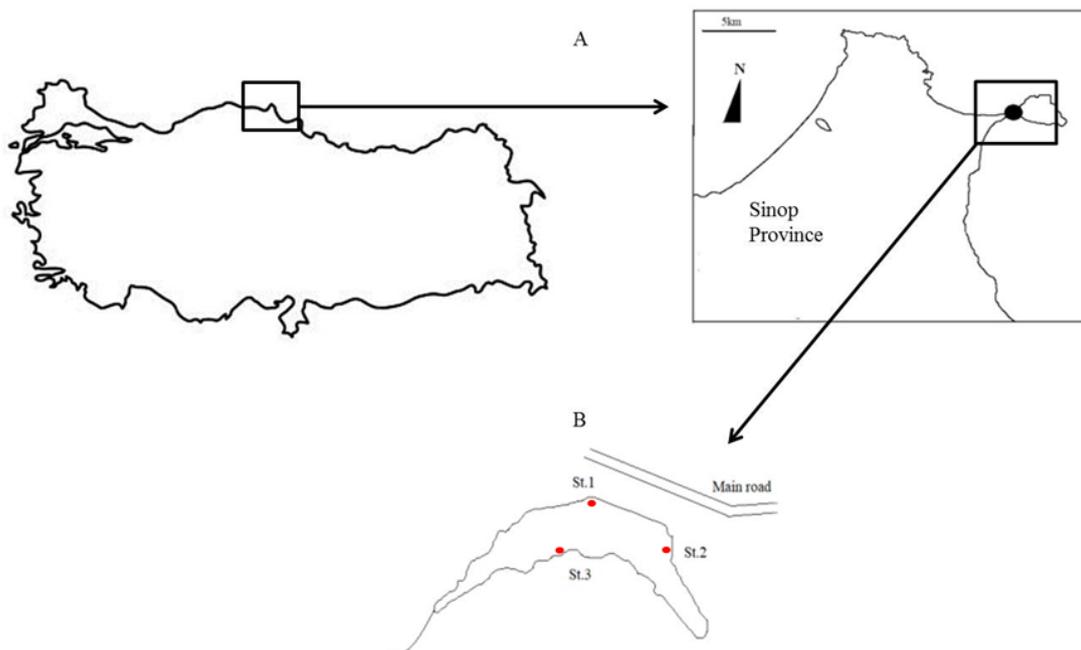
Taşmanlı Pond (41°54'N, 35°02'E) is located in the southern part of Sinop (Fig. 1) and covers an area of

222.000 square meters. The maximum depth of the pond is 15m and the minimum is 3-4m. The pond was constructed in 1977 by the General Directorate of State Hydraulic Works (DSI) for irrigation and it does not freeze in winter. The pond is free of industrial waste water discharge and juvenile common carp (*Cyprinus carpio* Linnaeus) were released a few times to the pond with the aim of breeding. Forest and scrub vegetation is observed in the drainage basin of the pond.

### Sampling and Chemical Analysis

The samples were collected monthly from March 2008 to March 2009. Epilithic samples were collected from the stones by brushing, brought to the laboratory in plastic cups then preserved in 4% formalin solution. Diatoms were cleaned using hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and diluted hydrochloric acid (3%) was added to purify calcium carbonate (Renberg 1990). After cleaning, the diatom frustules were washed with distilled water and rinsed. Clean diatom frustules were mounted in a synthetic resin (Naphrax). Diatom species were identified according to Krammer & Lange-Bertalot (1991a, 1991b, 1999a, 1999b), Round *et al.* (1990) and Sims (1996). Relative abundances of diatom species were evaluated by counting 300 valves per sample (Round 1953). Identified species were checked in algae databases and necessary taxonomic corrections were made (Guiry & Guiry 2017, Gönülol 2017). The author names were abbreviated according to Brummit & Powell (1992).

The surface water samples for physico-chemical analysis in laboratory were taken from all stations using plastic bottles. Environmental parameters such as dissolved oxygen of the water, temperature were measured in field with portable instruments.



**Fig. 1.** A) The maps showing locations of Sinop in Turkey (on the top left) and Taşmanlı Pond in Sinop (on the top right) and B) the schematic representations of the locations of the stations in the pond.

Chemical analysis were carried out according to APHA protocols (APHA 1998) and contained nutrients and ions such as chloride, nitrates, alkalinity, silica and phosphates. The water conductivity and pH were measured using a portable digital pH meter (Hach®HQ40d). The temperature and the dissolved oxygen values –as environmental parameters- of the water samples were measured in the field using a portable handheld dissolved oxygen and temperature system (YSI®55).

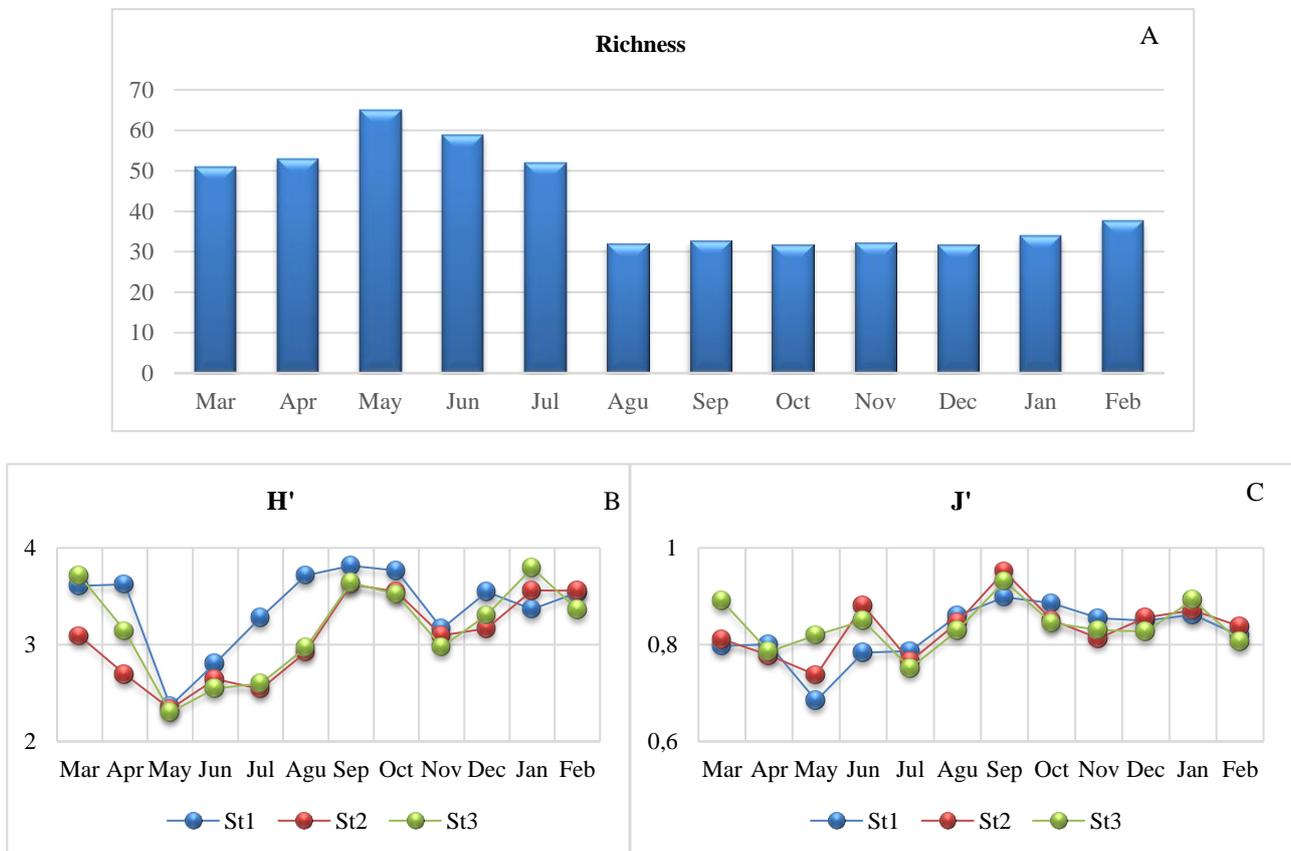
Data Analysis

The average values and standard errors of all physico-chemical analysis were computed using “Microsoft® Office Excel 2003”. Diatom diversity “H’” (Shannon & Weaver 1949) and evenness “J’” (Pielou 1975) indexes were computed with Primer5 software (Clarke 1993). Trophic diatom indices were computed by two different softwares; i) Trophic Diatom Index for Lakes (TDIL) was computed with the DILSTORE software (Hajnal *et al.* 2009) and ii) Lake Trophic Diatom indices (LTDI) developed based on modification of the trophic diatom index (TDI) (Kelly & Whitton 1995) and Ecological Quality Ratio (EQR) were computed with the DARLEQII Software (WFD-UKTAG 2014).

**Results**

The identifications of the collected material showed that a total 46 taxa were present in the sampled stations of

the pond (Table 1). The numerical distributions of the taxa with respect to the sampling months were given in Figure 2. *Achnanthydium minutissimum* (Kützing) Czarnecki, *Nitzschia acicularis* (Kützing) W.Smith, *Navicula cincta* (Ehrenberg) Ralfs in Pritchard and *Navicula cryptocephala* Kützing were the dominant taxa in all stations. The lowest nitrate value was measured in March 2008 with 1.17mgL<sup>-1</sup> in St1 and the highest value was measured in August 2008 with 1.46mgL<sup>-1</sup> in St2. The lowest phosphate value was measured in March 2009 in St2 with 0.14mgL<sup>-1</sup> and the highest value was measured in August 2008 in St 1 with 2.97mgL<sup>-1</sup>. The lowest value of silica was recorded in May 2008 in St3 with 0.09mgL<sup>-1</sup> and the highest value was measured in March 2009 in St1 with 3.10mgL<sup>-1</sup>. Total alkalinity ranged from 12.20 to 109mgL<sup>-1</sup> CaCO<sub>3</sub>. Maximum, minimum and average values and the standard deviations of measured physico-chemical variables were given in (Table 2). The lowest values of Shannon-Weaver and Evenness indices for all three stations were calculated in May. Although the numbers of sampled individuals for the identified taxa were higher than other months, all stations were represented with a less diverse species moiety in May. In particular, *Pantocsekiella ocellata* and *Achnanthydium minutissimum* reached the dominant position by reaching their highest numbers in this month. This is also consistent with the low index values observed in May. Diversity (H’) and evenness (J’) indices and species richness were shown graphically in Fig. 2.



**Fig. 2.** Graphical representation of A) species richness and B) diversity and C) evenness indexes. The sampling months were given as abbreviations.

**Table 1.** Epilithic diatom list of Taşmalı Pond.

Phylum: Bacillariophyta  
 Class: Bacillariophyceae  
 Order: Mastogloiales  
*Achnanthes brevipes* C.Agardh  
*Achnanthes coarctata* (Bréb. ex W.Sm.) Grunow  
*Mastogloia baltica* Grunow

Order: Cocconeidales  
*Achnantheidium exiguum* (Grunow) Czarnecki  
*Achnantheidium minutissimum* (Kütz.) Czarnecki

Order: Bacillariales  
*Hantzschia amphioxys* (Ehrenb.) Grunow  
*Nitzschia acicularis* (Kütz.) W.Sm.  
*Nitzschia dissipata* (Kütz.) Rabenh.  
*Nitzschia gracilis* Hantzsch  
*Nitzschia palea* (Kütz.) W.Sm.  
*Nitzschia recta* Hantzsch ex Rabenh.  
*Nitzschia sigmoidea* (Nitzsch) W.Sm.

Order: Cymbellales  
*Cymbella affinis* Kütz.  
*Cymbella* sp.  
*Encyonema silesiacum* (Bleisch) D.G.Mann  
*Gomphonema affine* Kütz.  
*Gomphonema gracile* Ehrenb.  
*Gomphonema parvulum* (Kütz.) Kütz.  
*Placoneis clementis* (Grunow) E.J.Cox

Order: Fragilariales  
*Fragilaria capucina* Desmaz.  
*Fragilaria capucina* var. *gracilis* (Oestrup) Hustedt

Order: Licmophorales  
*Ulnaria ulna* (Nitzsch) Compère

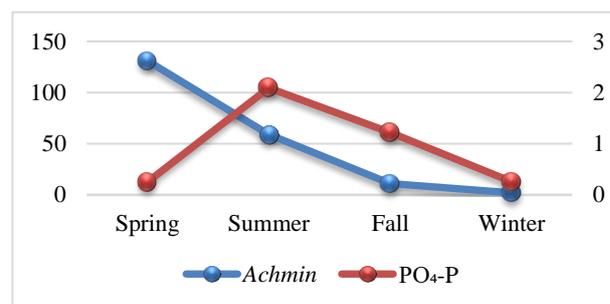
Order: Naviculales  
*Craticula halophila* (Grunow) D.G.Mann  
*Diploneis parva* Cleve  
*Gyrosigma acuminatum* (Kütz.) Rabenh.  
*Halamphora veneta* (Kütz.) Levkov  
*Luticola mutica* (Kützing) D.G.Mann  
*Luticola nivalis* (Ehrenb.) D.G.Mann  
*Luticola ventricosa* (Kütz.) D.G.Mann  
*Navicula cari* Ehrenb.  
*Navicula cincta* (Ehrenb.) Ralfs  
*Navicula cryptocephala* Kütz.  
*Navicula rhynchocephala* Kütz.  
*Navicula trivialis* Lange-Bert.  
*Navicula veneta* Kütz.  
*Neidium dubium* (Ehrenb.) Cleve  
*Sellaphora pupula* (Kütz.) Mereschk.

Order: Surirellales  
*Surirella amphioxys* W.Sm.  
*Surirella angusta* Kütz.  
*Surirella librile* (Ehrenb.) Ehrenb.  
*Surirella minuta* Bréb. ex Kütz.  
*Surirella ovalis* Bréb.

Order: Thalassiosiphales  
*Amphora ovalis* (Kütz.) Kütz.

Class: Mediophyceae  
 Order: Stephanodiscales  
*Cyclotella meneghiniana* Kütz.  
*Cyclotella* sp.  
*Pantocsekiella ocellata* (Pant.) Kiss & Acs

According to the Regulation on the Management of Surface Water Quality Directives “Republic of Turkey, Ministry of Forestry and Water Affairs, 2015”, the water bodies of all stations in Spring/Winter and Summer/Fall seasons have been identified as Class III and Class IV, polluted areas respectively. According to Trophic Classification System Limit Values in the directive, the water body of Taşmalı Pond is in the limit values from mesotrophic to eutrophic waters. Index values of measured based on the sampled epilithic diatoms were given Table 3.

**Fig. 3.** The relationship between phosphate (PO<sub>4</sub>-P) values determined in the pond with respect to seasons and the abundance of *Achnantheidium minutissimum* (Achmin).**Table 2.** The minimum, maximum and average values of the measured physico-chemical parameters of surface water in all sampling stations.

Parameter	Min.	Max.	Average
Dissolved O <sub>2</sub> (mgL <sup>-1</sup> )	5.40	15.62	9.88 ± 3.32
pH	7.28	9.06	8.14 ± 0.56
Alkalinity (mgL <sup>-1</sup> )	12.20	109.80	49.26 ± 0.62
Chloride (mgL <sup>-1</sup> )	46.40	72.70	59.24 ± 7.18
Temperaturew (°C)	6.00	26.00	15.00 ± 7.37
Nitrate (mgL <sup>-1</sup> )	0.17	1.46	0.52 ± 0.44
Phosphate (mgL <sup>-1</sup> )	0.14	2.97	0.98 ± 0.12
Silica (mgL <sup>-1</sup> )	0.09	3.10	0.85 ± 0.47

**Table 3.** Index values for the sampling stations.

	St.1	St.2	St.3
Trophic Diatom Index for Lakes (TDIL)	1.38	1.42	1.48
Lake Trophic Diatom Index (LTDI)	76.57	80.17	75.21
Ecological Quality Ratio (EQR)	0.36	0.31	0.38

**Table 4.** Ecological Quality Ratio (EQR) class boundaries for the 3 alkalinity types (Bennion *et al.* 2014). LA: low alkalinity, MA: medium alkalinity, HA: high alkalinity. H: high, G: good, M: moderate, P: poor, B: bad ecological status.

Alkalinity type (Annual mean CaCO <sub>3</sub> mgL <sup>-1</sup> )	H/G	G/M	M/P	P/B
LA (<10)	0.92	0.70	0.46	0.23
MA (10-50)	0.95	0.70	0.46	0.23
HA (>50)	0.92	0.70	0.46	0.23

**Table 5.** Class boundaries and trophic status according to TDIL.

Class boundary	Ecological status
4 – 5	Excellent
3 < 4	Good
2 < 3	Medium
1 < 2	Tolerable
0 < 1	Bad

## Discussion

*Achnantheidium minutissimum* (Kütz.) Czarnecki, was described as the most common and abundant diatom in well-oxygenated, neutral or alkaline lakes and streams with low or moderate concentrations of nutrients and organic pollution. It can also be present in high numbers in streams exposed to heavy metal pollution and in eutrophic inland waters (Bennion *et al.* 2014, Stenger-Kovács *et al.* 2007, Kelly *et al.* 2005). Some former studies suggested that taxa in the *A. minutissimum* complex can be assigned to morphological groups, each with differing ecological preferences though these morphological groups are not discontinuous (Potapova and Hamilton 2007). However, palaeoecological works indicates that a slightly change in planktonic diatoms suggest the early stages of nutrient enrichment rather than changes in non-planktonic diatoms (Bennion *et al.* 2004). Indeed, as revealed in the present study, *A. minutissimum* became a dominant species in spring months when the pond water began to be enriched with nutrients (Fig. 3). *Cyclotella meneghiniana* Kütz., *Gyrosigma acuminatum* (Kütz.) Rabenh., *Luticola mutica* (Kütz.) D.G.Mann,

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