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Species composition and distribution of diatoms from the Lower Ferlo Valley (Senegal)

Alassane Sarr*[1], Seyni Sané[2], Ebrima Njie[3], Alioune Faye[1], Ngassoumana Ba[2], Waly Ndiaye[1]

[1]*Institut Universitaire de Pêche et d'Aquaculture (IUPA), University Cheikh Anta Diop of Dakar, Dakar-Fann, Senegal*

[2]*Département de Biologie végétale, University Cheikh Anta Diop of Dakar, Dakar-Fann, Senegal*

[3]*School of Arts and Sciences, Division of Physical and Natural Sciences: University of The Gambia, Brikama Campus, Gambia*

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Abstract

Species composition and abundance of Diatoms in the lower Ferlo valley were studied after ten years of its reflooding. A qualitative sampling of diatom from upstream waters toward the downstream side was carried out in five stations using a Phytoplankton net of 30µm mesh size. A total of 71 species of diatoms belonging to 25 genera were identified in this study. The species richness decreased with increasing level of salinity from upstream toward the downstream side. The highest species richness and abundance were observed in upstream stations. The most abundant species were *Aulacoseira granulata, Nitzschia compressa, Nitzschia desertorum, Navicula halophila, Surirella robusta, Gomphonema truncatum, Fragilaria ulna and Cocconeis placentula*. While the most abundant species in the upstream stations was *Aulacoseira granulata*, *Navicula halophila* dominated in the downstream side stations with higher salinity values. Thus, the salinity concentration seems to play a major role in the diatom species distribution in lower Ferlo valley.

***Corresponding Author:** Alassane Sarr ✉ alassanesarr@hotmail.com

Introduction

The Senegalese Government has undertaken many hydro-agricultural rehabilitation projects to provide freshwater to its population. The completion of the Diama and Manantali dams in 1986 and 1988 respectively in the Senegal River allowed streaming of a huge freshwater volume above Diama dam and the progressive reflooding of the fossil valleys. The lower Ferlo valley, as part of these fossil valleys, is currently supplied by the Senegal River through the Guiers Lake. Prior to 1956, Senegal River and the sea alternatively provided the water supply to the lower Ferlo valley. During high tide, waters flowing from the Senegal River flooded the lower Ferlo valley through the Guiers Lake. During low tide, the sea water flows into the Senegal River from its lower course and spreads into the lower Ferlo valley through Guiers Lake (Trochain, 1940).

In 1956, a dyke (Keur Momar Sarr dyke) was built in the south of Guiers Lake to increase its water level capacity while preventing water inflow from the Senegal River into the lower Ferlo valley. Since the construction of Keur Momar Sarr dyke, the lower Ferlo valley has been isolated from Guiers Lake. Consequently, the lower Ferlo valley was totally dry for over three decades. However, there were few small temporary ponds in the mean bed region of the valley during the wet season. These ponds rapidly dry out during the dry season due to infiltration and intense evaporation. Since 1988 after 32 years, the Government of Senegal through its fossil valleys revitalization program (FVRP) framework decided to channel water from Senegal River into the lower Ferlo valley. The aim of FVRP is to make better use of the water made available by the construction of the Mantali and Diama dams, by diverting to central areas of Senegal the excess water that would otherwise be discharged into the sea during the annual flood.

The reflooding of the lower Ferlo valley has brought in ecological changes conducive to the development of algae, including diatom. Several studies have been carried out on algae of the Senegal River and the Guiers Lake (Dia and Renaud, 1982; Ba, 2006; Bouvy *et al.,* 2006; Sané, 2013). Yet the diatoms of the lower Ferlo valley have never been scientifically investigated.

The present study was conducted with the aim to investigate the species composition, distribution and abundance of diatoms that inhabited the lower Ferlo valley after its permanent flooding.

Materials and methods

Study Area

The lower Ferlo valley forms a vast basin in the south of Guiers Lake, which connects it to the Senegal River. The catchment area of the lower Ferlo valley spreads from 14° 30' to 16° North latitude and from 12° 45' to 16° West.

The lower Ferlo valley is edged on both of its banks by a wide sandy plateau overlapped by red Ogolian sand hill (Dagassan 1967). During the past several decades the lower Ferlo valley has been filling up progressively with debris through wind erosion and drying out effect. Annual average temperatures are high and vary between 22°C and 40°C, with a maximum in May/June and a minimum in December/January. The rainfall is very irregular in amount, duration and location. The study area is situated between isohyets 300mm and 500mm (Sahel zone). The climate is characterized by two seasons: a dry season from November to June, and a rainy season from June to October. The lower Ferlo valley is a part of Senegal River-Guiers Lake system wich it depends for its filling. During high water periods, the tidal wave from the Senegal River used to flood the Ferlo Valley's bed through a floodgate at the southern end of the Guiers Lake. The length of the water body is 60km and the maximum depth 3m.

Methods

The sampling was carried out in 5 stations from the upstream of the lower Ferlo valley toward the downstream waters (Fig. 1). A qualitative sampling was conducted using a plankton net of mesh size 30µm. The collected samples were immediately preserved with lugol's solution and brought to the laboratory for species identification.

Diatom cells observed were identified to the lowest possible taxonomic rank and counted using an inverted microscope. Diatom species were identified according to Hustedt (1930), Bourrely (1970), Krammer and Lange-Bertalot (1986, 1988, 1991). The relative abundance was calculated for every species.

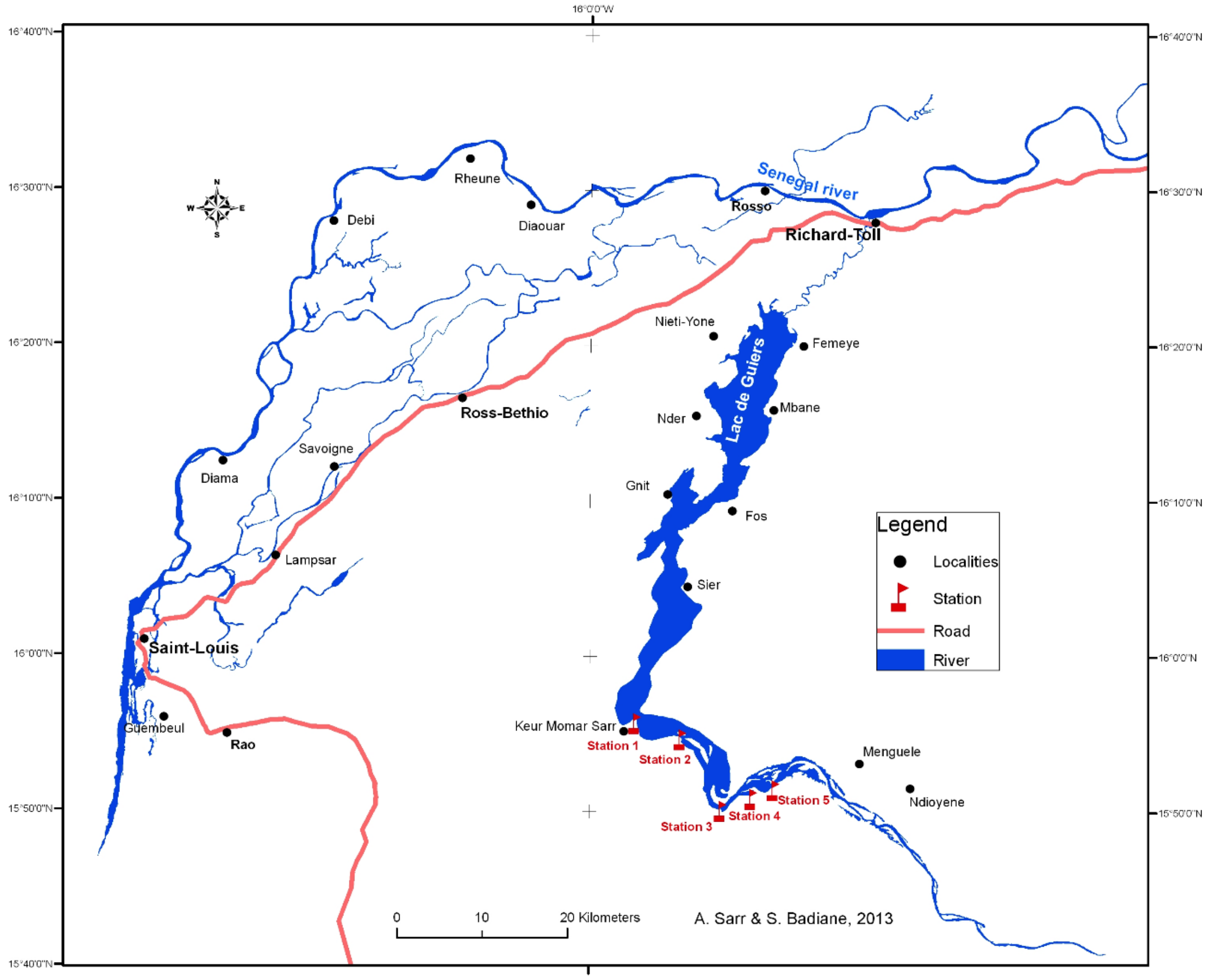


Fig. 1. Location of the study stations.

In each sampling station, the water parameters including salinity, dissolved oxygen, pH and temperature were measured near-surface waters (0,5m). Salinity and temperature were recorded using a LF 330/LF 340 Set. Dissolved oxygen (DO) and pH were measured using a MColortest™ colorimtric method (formerly aquamerk).

The data was compiled, analysed and graphically mapped out using a Excel spreadsheet. Correspondence factorial analysis was used to link the species occurrence to the different stations accordingly to the salinity gradient using the R software package (version 3.3.3 with the FactoMineR package, R Core Team [2014]).

Results

Water Parameters

The table 1 presents a summary of average values of water parameters of all sampling stations. It was revealed that pH, temperature and dissolved oxygen showed same trend between different stations, while salinity was different at the 5 stations.

The study revealed a pronounced salinity gradient that increases from the upstream of the lower Ferlo valley toward the downstream. The lowest salinity value was observed at station 1 in the upstream, which increases progressively from station 2 and reaches a maximal value of 4g L^{-1} in the downstream water in station 5 (Table 1).

Table 1. Average values of water parameters recorded in different sampling stations.

Stations	1	2	3	4	5
Salinity (g L^{-1})	0	0,2	0,4	2	4
Dissolved oxygen (mg L^{-1})	3,6	3,6	3	3	3
pH	8	8	8,5	9	9

Water pH varied from 8 to 9. Maximum pH (9) was recorded in stations 3,5 and minimum (8) in stations 1,2. The water temperature varied from 22,2°C to 28°C. The average concentration of dissolved oxygen (DO) ranged from 3 to 3,6mg L^{-1}. Maximum DO (3,6mg L^{-1}) was recorded in stations 1, 2 and minimum in stations 3,4 and 5 (3mg L^{-1}).

Diatoms composition and spatial distribution

A total of 71 species belonging to 25 genera were identified from the samples in all stations (Table 2). The species richness in different sampling stations varies from the upstream toward the downstream of the lower Ferlo valley. A fast drop in the number of species from 44 species in the upstream to 9 species in the downstream was observed. The number of species recorded was maximum at station 2 and minimum at station 5. The seven most commons species were *Cocconeis placentula*, *Fragilaria ulna*, *Aulacoseira granulata*, *Cyclotella ocellata*, *Epithemia adnata*, *Gomphonema gracile*, *Nitzschia compressa* found in 4 or 5 sampling stations. 22 species were observed in 2 or 3 sampling stations. Notably, *Cocconeis placentula* and *Fragilaria ulna* were present in all the 5 stations, while 44 species were found only at one station (Table 2). The most represented genera in the lower Ferlo valley were *Navicula* (13 species), *Nitzschia* (8 species), *Amphora* (6 species) and *Surirella* (6 species). A total of 12 genera were represented by 1 or 2 species (Table 2).

A correspondence factorial analysis (CFA) was used to organize the typology of the stations according to the collected phytoplankton species. Table 2 shows variance distribution based on selected factorial axes.

Table 2. List of the collected species in the different stations (+ = occurring species).

Species	Station				
	S1	S2	S3	S4	S5
Achnantes clevei		+			
Achnantes deliculata	+	+			
Achnantes exigua	+	+			
Achnantes minutissima		+			+
Amphora aequalis			+		
Amphora coffeaeformis		+	+		
Amphora commutata	+		+		
Amphora lybica			+		
Amphora montana		+			
Amphora pediculis		+			
Amphora veneta	+	+			
Anomoeoneis sphaerophora			+	+	+
Aulacoseira granulata	+	+	+	+	
Cocconeis placentula	+	+	+	+	+
Cyclostephanus dubius		+			
Cyclotella dubia		+			
Cyclotella meneghiniana	+	+			
Cyclotella ocellata	+	+	+		+
Cyclotella radiosa		+			
Cymbella elginensis		+			
Cymbella minuta			+		
Cymbella silesiaca		+			
Denticula kuetzingii		+			
Diatoma vulgaris		+			
Diploneis parma			+	+	
Diploneis puella		+	+		
Epithemia adnata		+	+	+	+
Eunotia praerupta		+			

Species	Station				
	S1	S2	S3	S4	S5
Fragilaria pinnata		+			
Fragilaria ulna	+	+	+	+	+
Gomphonema angustatum	+				
Gomphonema gracile	+	+	+	+	
Gomphonema parvulum		+	+		
Gomphonema truncatum		+		+	
Gyrosigma parkerii		+			
Mastogloia elliptica		+			
Mastogloia smithii		+	+	+	
Navicula absoluta	+		+		
Navicula citrus			+		
Navicula cryptocephala			+		
Navicula cuspidata			+		
Navicula elginensis	+				
Navicula halophila			+	+	+
Navicula praeterita		+			
Navicula pseudotusculata			+	+	
Navicula pupula		+			
Navicula pusilla		+			
Navicula seminulum	+				
Navicula subrhyncocephala			+		
Navicula vitabunda		+			
Nitzschia amphibia	+	+	+		
Nitzschia brevissima		+			
Nitzschia commutata			+		
Nitzschia compressa	+	+	+	+	
Nitzschia constricta	+	+	+		
Nitzschia desertorum			+		
Nitzschia levidensis		+	+		
Nizschia palea	+				
Pinnularia appendiculata	+				
Pinnularia microstaurum	+				
Pleurosigma angulatum	+		+		+
Rhopalodia acuminata	+		+		
Rhopalodia gibba	+	+	+		+
Stauroneis acuta		+			
Stephnodiscus alpinus			+		
Surirella amphioxys		+			
Surirella capronii	+	+			
Surirella elegans	+				
Surirella robusta	+	+	+		
Surirella splendida			+		
Surirella tenera	+		+		
Total	27	44	36	12	9

Fig. 2 allows us to regroup the species based on their occurrence in the study stations. The two first axes or dimensions make up 66.68% of the total variance displayed. With axe 1 (Dim1) that contains 36.94% of the total variance, there is a splitting between frequent species groups in station 2 and the frequent species groups in stations S3, S4 and S5. Yet, axe 2 (Dim 2) which carries 29.74% of the total variance is on the salinity gradient axe. The station 1 is characterized by the presence of species that live in low salinity concentration waters while the stations S3, S4, and S5 are predominently populated by species tolerent to high levels of salinity concentrations.

Relative abundance of Diatom species

Fig. 3 displays the relative *abundance* of diatom species in the investigated 5 stations. The dominant species were *Aulacoseira granulata, Nitzschia compressa, Nitzschia desertorum, Navicula halophila, Surirella robusta, Gomphonema truncatum, Fragilaria ulna* and *Cocconeis placentula*. *Aulacoseira granulata* was mostly dominant in stations 1 and 2, with 92% and 54% respectively of the total diatoms. *Nitzschia compressa* (14%) and *Nitzschia desertorum* (12%) were dominant at station 3. *Navicula halophila* was dominant in stations 4 and 5 with 96% and 85% respectively, of the total diatoms. The subdominant species in the sampling stations were *Surirella robusta (station 1), Gomphonema truncatum* (station 2), *Gomphonema gracile* (station 2), *Fragilaria ulna* (station 2,3) *and Cocconeis placentula* (station 2,4), *Epithemia adnata* (station 3), *Cyclotella meneghiniana* (station 3), *Nitzschia amphobia* (station 3), *Nitzschia constricta* (station 3).

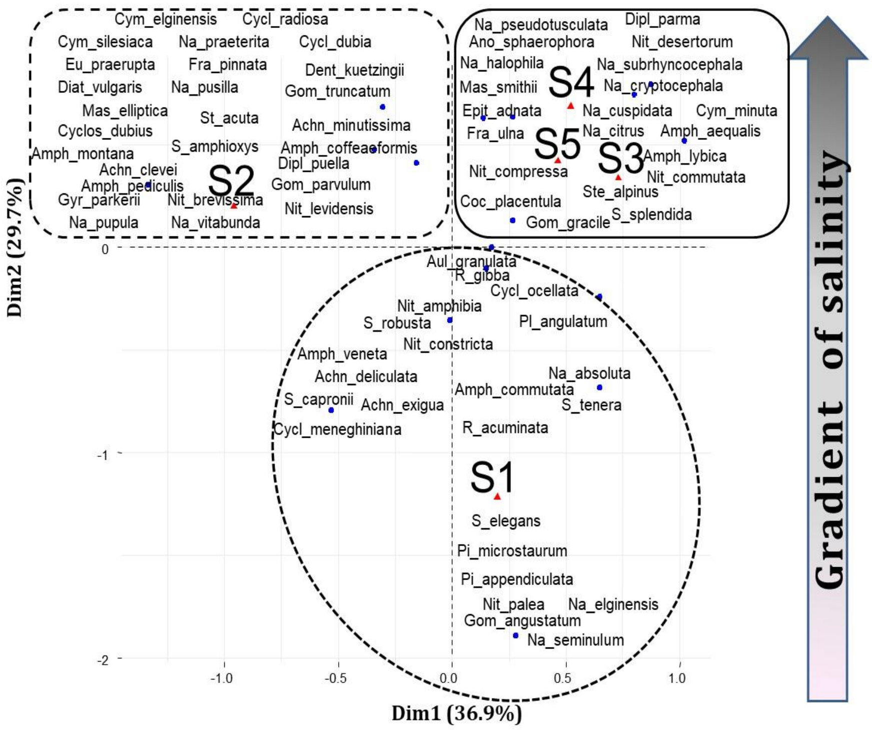
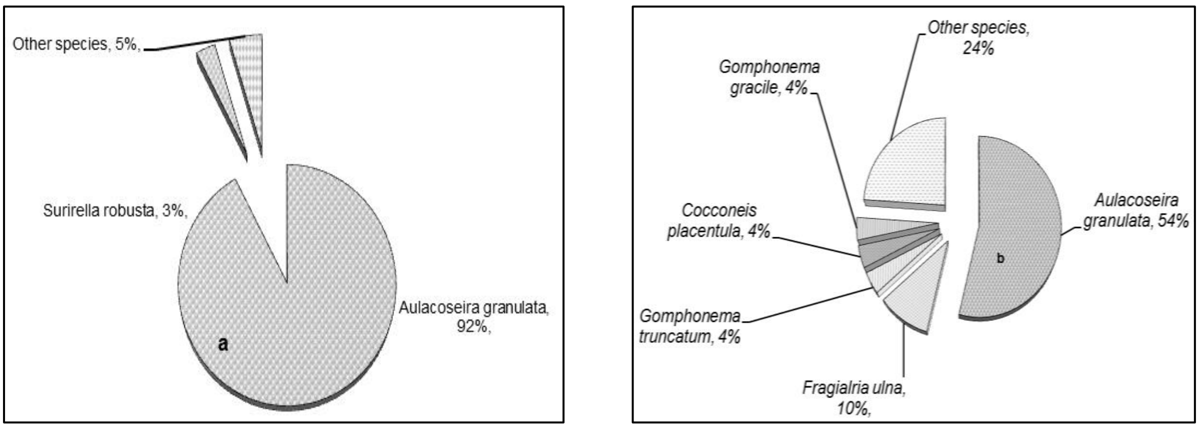


Fig. 2. Species distribution based on the salinity gradient following the factorial plan Correspondance Factorial Analysis (CFA) Dim 1 x Dim 2.

Table 3. Variances of the different factorial dimensions (axes).

	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Eigen values	0.52	0.42	0.42	0.29	0.18
Percentage of variance (%)	36.94	29.74	29.74	20.52	12.80
Cumulative percentage of variance (%)	36.94	66.68	66.68	87.20	100.000



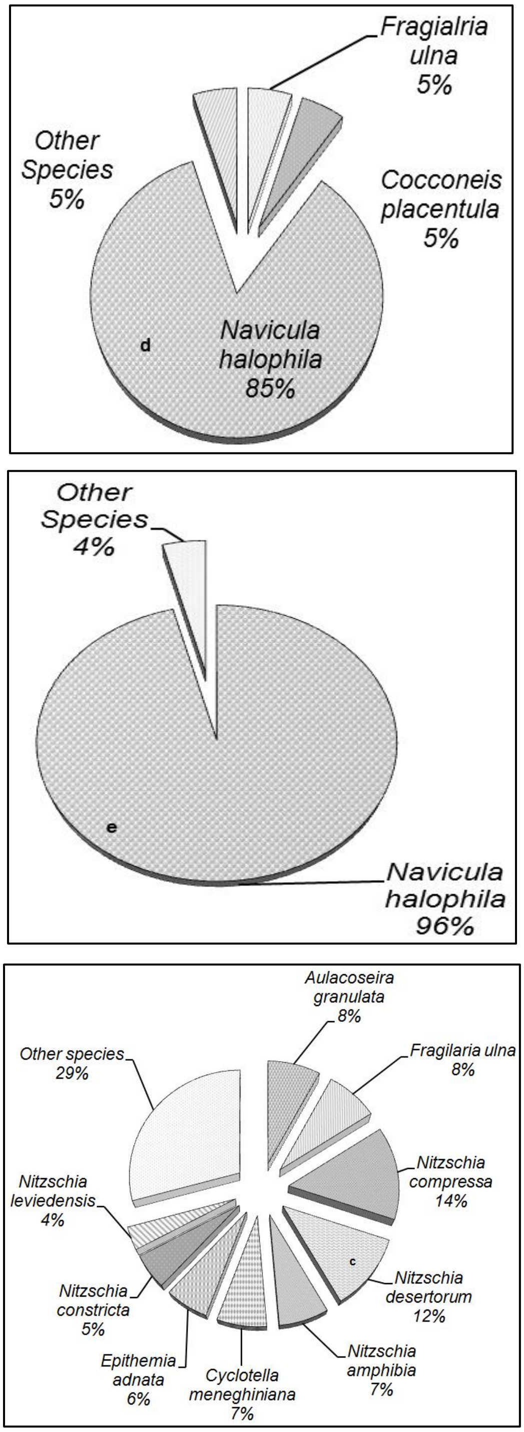


Fig. 3. Relative abundance of Diatoms in different sampling stations: station (a), station 2 (b), station 3 (c), station 4 (d), station 5 (e).

Discussion

The lower Ferlo valley diatoms species richness is fairly high compared to that previously reported for Guiers Lake and Senegal River (Dia and Renaud 1982; Ba Dia and Reynaud (1982) produced an inventory of 23 species of Diatomophycea. Compere (1991) inventoried 98 species of Diatomophycea in the downstream area of Senegal River, 66 and 183 species of Diatomorphycea in the lower side of the Senegal River and Guiers Lake, respectively. However, this study focused only on diatom types (benthic, pelagic, epiphytic).

The number of species varies according to the location of the station sampled. The upstream stations (1,2,3) showed the highest species diversity. However, these stations showed the lowest salinity concentration rates. The salinity concentration level seems to play a major role in the distribution of species. Approximately 70% of the diatom species in the lower Ferlo valley reside in stations with the lowest salinity concentration values (stations 1, 2, and 3).

Aulacoseira granulata, Nitzschia spp, *Navicula spp, Surirella* spp, *Gomphonema spp, Fragilaria ulna and Cocconeis placentula* were the most abundant species in the samples. This is in agreement with many studies showed that these species form a large group in different fresh waters.

Aulacoseira granulata, a freshwater species, thrives mainly in low salinity concentration (stations 1 and 2). However, this species is scarce in the stations 4 and 5 with high salinity concentration levels (2 to 4g L^{-1}). Dong *et al.,* (2016) conducted a paleolimnology study of several floodplain lakes along the mighty Yangtze River, where they found large numbers of *Aulacoseira granulata*. Dong *et al.* (2016) linked the large number of *Aulacoseira granulata* to the medium nutrients levels (mesotrophic) and turbulent conditions of the medium. Increased turbulence and corresponding nutrient levels increases during low water stages in a lake can favor this genus over other planktonic species (Wolin *et al.,* 2010). The stations 1 and 2 are situated near floodgates, where turbulence is often extensive during high-water periods. Species *Fragilaria ulna, Cocconeis placentula* and *Navicula halophila* showed particulary a high salinity optimum of 2 to 4g L^{-1}.

Many studies point to *Fragilaria ulna* as one of the most widely distributed taxa within Bacillariophyceae (Akbulut, 2003). Rijtenbil *et al.* (1993, cited by Akbulut, 1993) mentioned that *Fragilaria ulna* is found at a 5.2% salinity level.

Navicula halophila is particularly dominant in stations 4 and 5, and accounted for 85-96% of the total diatoms in both stations. However the species was not found in the upstream stations where the salinity concentration is very low. Compared to other species, *Navicula halophila* seems to have adapted and thrives well under high salinity concentrations. Indeed, *Navicula halophila* has been described as a Diatom brackish water species (Cholnocky, 1962), and has previously been described as a mesohalophilic species (Kolbe, 1927); Hustedt, 1937). The high occurrence of *Navicula halophila* in the downstream side of the valley may be considered as an indicator salinization of waters.

Nitzschia desertorum and *Nitzschia compressa* species seem to prefer low salt over high salt concentrations. Cholnocky (1962) reported that *Nitzschia desertorum* is not a brackish water species. *Cocconeis placentula* has been found in all the stations, which indeed confirmed Hustedt (1937) work that supported the characterization of *Cocconeis placentula* as a versatile species that grows in low and high salt concentrations. Although the salinity concentration is the only measured parameter in this study, other ecological factors such as nutrient elements content, and temperature variations could equally play important roles in the distribution of the diatom species

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