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The composition and seasonal distribution of epiphytic algae in Anzali lagoon, Iran

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Abstract – Epiphytic algae are an important constituent of any aquatic ecosystems. These algae form the base of the food web in littoral microhabitats in freshwater lakes. Our study was conducted for one year, from September 2000 through August 2001, when epiphytic algal samples were taken from natural and artificial substrata. In this study, 150 species have been identified belonging to 64 genera and 7 classes. Bacillariophyceae, with 95 species, had the highest species diversity. Chlorophyceae were represented by 29 species, Cyanophyceae 15 species, and Euglenophyceae by 9 species. Dinophyceae and Chrysophyceae were represented by one species each. The population density of Chlorophyceae in spring and Cyanophyceae in late summer was high. Chlorophyceae and Cyanophyceae often were absent in winter but Bacillariophyceae were present with high percent. *Navicula* spp and *Nitzschia* spp were the most abundant genera over the study.

algae / Anzali lagoon / bacillariophyceae / epiphyte / floristic / Iran / seasonal distribution

Résumé – Composition et distribution saisonnière des algues épiphytes dans le lagon Anzali, Iran. Les algues épiphytes constituent un élément important de tout écosystème aquatique. Ces algues constituent la base de la chaîne alimentaire dans les micro-environnements littoraux des lacs d'eau douce. De septembre 2000 à août 2001, les algues épiphytes ont été prélevées sur des substrats naturels et artificiels. 150 espèces, appartenant à 64 genres et 7 classes, ont été identifiées. Les Bacillariophyceae avec 95 espèces montrent la plus grande diversité spécifique. Les Chlorophyceae sont représentées par 29 espèces, les Cyanophyceae, par 15 espèces, et les Euglenophyceae par 9 espèces. Les Dinophyceae et Crysophyceae ne sont représentées chacune que par une seule espèce. La densité des Chlorophyceae au printemps et des Cyanophyceae en été est grande. Les Chlorophyceae et les Cyanophyceae sont souvent absentes en hiver, mais les Bacillariophyceae sont présentes en grande abondance. Les genres *Navicula* et *Nitzschia* ont été les plus abondants au cours de cette étude.

algues / lagune d'Anzali / bacillariophyceae / épiphyte / floristique / Iran / distribution saisonnière

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INTRODUCTION

Anzali lagoon is located between 49°13′ - 49°37′ E and 37°21′ – 37°32′ N in the south part of the Caspian Sea in Gilan province, Iran (Fig. 1). This lagoon is included in the Ramsar list of 'Wetlands of International Importance', primarily as a waterfowl habitat. Ramsar is an Iranian city lying on the shores of the Caspian Sea, and it was here, in 1971, that the wetland convention was adopted. Anzali lagoon's catchment area is approximately 150 km^2. Industrial, agricultural and household sewage enters the lagoon and as a result it is fertile system. The algal flora of Iran has received little attention and there are only a few published surveys (Compere, 1981; Wasylik, 1975; Kimball & Kimball, 1977). Epiphytic algae are a component of the periphyton, which Wetzel (1983) defined as "a complex community of microbiota (algae, bacteria, fungi, animals, inorganic and organic detritus) that is attached to substrata. The substrata are inorganic or organic, living or dead." These microalgal communities grow well on the sediments and on floating and submerged macrophytes in shallow aquatic ecosystems (Wetzel, 1990). It is desirable to establish the autecological characteristics of epiphytic algae, as they can be used as biomonitors (Salome *et al.*, 2001), for example as indicators of water quality in running water (Ibeling *et al.*, 1998). Epiphytic algae have been used as a tool in studying the environmental effects of heated and chemical effluents (Siver, 1977). In addition, periphyton, particularly diatoms are good indicators of heavy metal toxicity (Ivorra *et al.*, 1999). Periphyton produces 20-50% of the primary productivity of lakes and diverse organisms in the food chain utilize their organic metabolites (Siver, 1977). Many factors, like substratum type, texture, position, current and wave action influence the taxonomic composition of attached microalgal communities (Luttenton *et al.*, 1986).

Due to temporal and spatial variations in macrophyte surfaces, the patterns of epiphytic algal growth are complex (Gons, 1982; Morin & Kimball, 1983; Riber *et al.*, 1984). The biomass of epiphytic algae is very variable, and as result they have patchy distribution (Cattaneo *et al.*, 1993). In epiphytic communities, biraphid diatom genera of Naviculales and Nitzschiales are common. However, monoraphid Achnanthales, pseudoraphidean Fragilariales and weakly motile Eunotiales assume proportionately greater significance in epiphytic communities as do the stalked and dowelling Naviculales (Crumpton, 1989). The present work examines the systematic and seasonal distribution of epiphytic algae in Anzali lagoon.

MATERIALS AND METHODS

The study was done in Anzali lagoon in Gilan province of Iran. Samples were collected from six stations in order to evaluate difference in ecological characteristics of the lagoon (Fig. 1). Geographical characteristics of the stations were determined by G.P.S.

- Station 1: Pirbazar river: 37°23′/392 N & 49°31′/576 E
- Station 2: Sheijan river: 37°25′/170 N & 49°30′/116E
- Station 3: Sophiandeh river: 37°25′/361 N & 49°27′/85E
- Station 4: Rastekhale river: 37°25′/487 N & 49°25′/352 E
- Station 5: Siah keshim: 37°25′/09 N & 49°24′/345 E
- Station 6: Mahrozeh duct: 37°24′/568 N & 49°24′/557 E

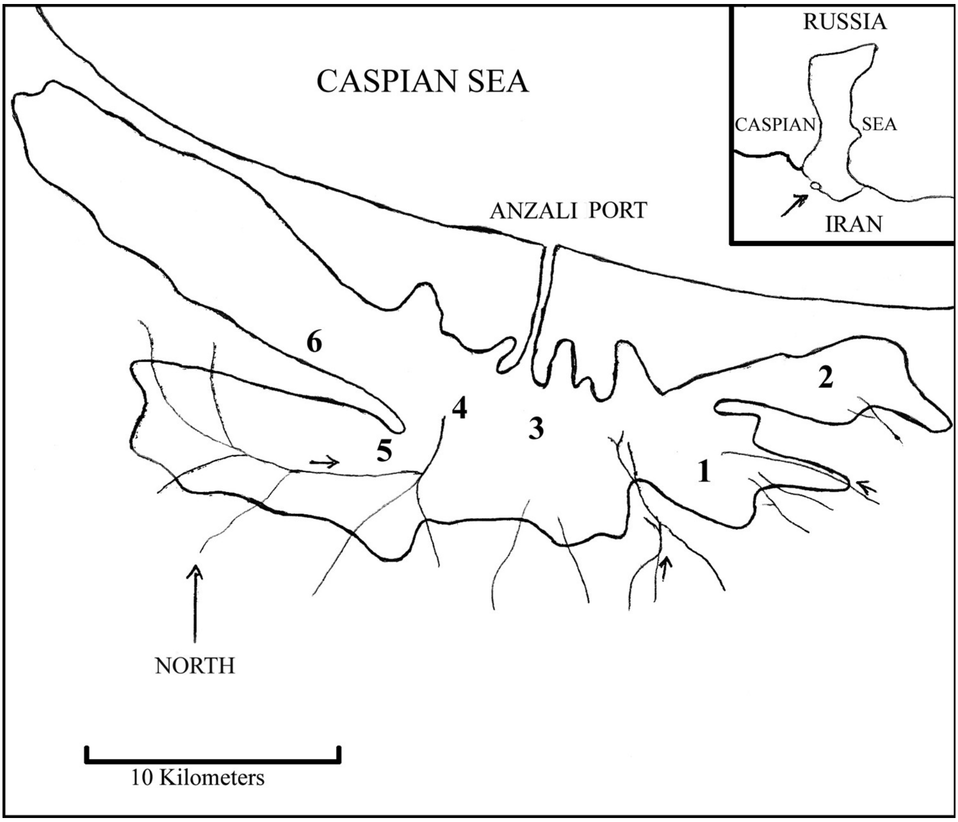

Fig. 1. The map of Anzali lagoon and situation of stations.

There are substantial growths of macrophytes in Anzali lagoon, but in some sampling stations their distribution was spotty. Five macrophyte species: *Polygonum persicaria* L. *Sparganium neglectum* Beeby, *Nelumbium capsicum* Eichew, *Phragmites australis* Cav. and *Typha latifolia* L. were chosen as natural substrata. Pieces of cylindrical wood (1.5 cm diameter) were used as artificial substrata.

Artificial substrata were left in stations for one month prior to sampling. Samples were taken at monthly intervals from September 2000 through August 2001. From each station, triplicate samples were taken according to the following procedure: To avoid from water disturbance due to wave action, macrophytes were cut 10 cm below water surface and the second 10 cm section was gathered in a vial. Samples were fixed in 4% formaldehyde and transported to the laboratory. Epiphytic algae were separated by brushing the surface of the substratum and collected in 125 ml vials. Permanent mounts were prepared according to procedure described by Yang *et al.* (1996). The samples were digested with H_2O_2 40% and washed at least five times with distilled water. 1 ml of subsample was dried on a slide cover and mounted on glass slides with Hyrax. Identification of algal species was done by using Prescott (1970), Patrick & Reimer (1966, 1975), Boney (1989), Maosen (1978), Tiffany (1971), Edmonson (1959), Desikachary (1959), Hustedt (1930) & Peragallo (1908).

Sedgwick-rafter cell was used for algal counts and chemical analysis of water was done according to Eaton *et al.*, (1995). 1 ml of subsample was placed in sedgwick rafter cell. Cells were counted along transects, using a wild M20 microscope at 200× magnification, until at least 300 cells were counted. These counts were corrected for dilution to yield cells ml^{-1} data for each species. Since a known area of macrophyte was sampled, we were able to calculate the number of cells mm^{-2}. Total number of cells in S-R cell was calculated by multiplying actual counts in the transect by the number representing the portion of S-R cell counted.

RESULTS

Physicochemical conditions

Some chemical features of stations are shown in Table 1. Water temperature range varied from 12°C to 29.5°

Table 1. Chemical analysis of water during the study.

Factors \ *Stations*	*1*	*2*	*3*	*4*	*5*	*6*
ph	6.90 – 8.14	6.80 – 8.80	6.75 – 7.56	6.96 – 8.15	6.90 – 8.20	7.00 – 8.35
CO_2 mgl^{-1}	5 – 32	1 – 32	5 – 17	3 – 35	3 – 35	2 – 35
HCO_3^- mgl^{-1}	198 – 372	128 – 335	128 – 425	204 – 290	205 – 295	204 – 299
T.N mgl^{-1}	3.33 – 5.98	0.73 – 2.98	0.62 – 1.68	0.76 – 2.45	0.412 – 1.73	0.75 – 4.15
T.P mgl^{-1}	0.06 – 4.90	0.100 – 0.354	0.067 – 0.851	0.033 – 0.172	0.038 – 0.826	0.008 – 0.444
NO_3^- mgl^{-1}	0.029 – 0.174	0.019 – 0.176	0.024 – 0.410	0.047 – 0.265	0.023 – 0.110	0.026 – 0.081
SIO_2 mgl^{-1}	5.84 – 11.03	0.49 – 7.63	1.14 – 5.68	3.29 – 6.01	2.26 – 6.68	2.19 – 8.94

Algal communities

A total of 150 algal taxa were identified (Tab. 2). The most diverse group was Bacillariophyceae with 95 species, second was Chlorophyceae with 29 species, and third was Cyanophyceae with 15 species. Euglenophyceae was the next most diverse group with 9 species. Dinophyceae and Chrysophyceae were represented by one species each.

The distribution patterns of epiphytic algae on the wood and macrophytes are shown in Figs 2 and 3. Members of Bacillariophyceae were encountered in all samples throughout the study. Chlorophyceae occurred during warm months, except when the substrata were out of water due to low water levels. Members of Cyanophyceae were encountered in late summer and sometimes in early autumn.

Standing crops varied between substrata, within sampling sites, and between sampling dates (Fig. 3). Species of *Navicula* on wooden rods reached the highest standing crop of any substratum. Standing crop maxima were also variable between substrata at all stations. Cell densities of *Navicula* on wooden rods reached a maximum in May, whereas the highest densities of *Nitzschia* occured in May and July. Total cell numbers were also highest during May. Cell densities on

Table 2. Epiphytic and associated algae collected from different substrata and stations

Taxon	Substrates						Stations
	Wo	*Ph*	*Ty*	*Sp*	*Ne*	*Po*	
Bacillariophyceae							
Achnanthes brevipes Agardh	*	*	*	*	*		2,4,5,6
A. exigua Grun.	*	*	*	*			1,2,4,5,6
A. peragallii Brun.					*		2,5
Amphiprora costata Hustedt	*	*	*			*	1,2,3,6
Amphora ovalis Kützing	*	*	*	*	*	*	1,2,3,4,5,6
A. ovalis var.*pediculus* Kützing	*	*	*		*		4,5,6
A. veneta Kützing	*	*	*	*	*	*	1,2,3,4,5,6
A. coffeiformis Agardh	*	*	*	*			3,5
Bacillaria paxillifera (Of.Null)Hendey	*	*	*	*	*	*	1,2,3,4,5,6
Cyclotella meneghiniana Kützing	*	*	*	*	*	*	1,2,3,4,5,6
Cocconeis placentula var. *euglypta* Ehrenberg	*	*	*	*	*	*	1,2,3,4,5,6
C. placentula var. *Lineata* Ehrenberg	*		*		*		3,4,5,6
Caloneis amphisbaena (Bory) Cleve	*	*	*	*	*	*	1,2,4,5,6
C. silicula (Ehr.) Cleve		*					2,6
Cymbella tumida (Breb.) Van Heurck	*	*	*	*	*	*	1,2,3,4,5,6
C. turgida (Greg) Cleve	*	*	*	*	*		2,3,4,5,6
C. cistula (Ehr.) Kirchn.	*	*	*		*		3,4,5,6
C. lanceolata (Ehr.) Van Heurck	*				*		2,3,4,5,6
C. minuta Hilse ex Rabh.	*	*	*			*	1,2,3,4,5,6
Cymatopleura solea Bréb. (W.Sm.)	*	*	*	*	*	*	1,2,4,5,6
C. solea var. *apiculata* (W.Sm.) Ralfs		*		*			2,5,6
C. elliptica (Bréb.) W.Sm.			*				4
Diploneis finnica (Ehr.) Cleve		*	*				4,6
Diatoma vulgare Bory	*	*	*		*	*	1,2,4,5,6
Epithemia adnata var *adnata (*Kütz.) Breb.			*				4
E. turgida (Ehr.) Kützing	*		*	*			4,5,6
E. turgida var. *granulata* (Ehr.) Brun	*		*	*			2,4,6
E. turgida var *westermannii* Grun		*					2,6
E. sorex Kützing					*		5
E. arcus var. *alpestris* Grun.	*	*	*				6
Eunotia soleirolii (Kützing) Ralfs	*	*	*	*			2,3,4,5,6
Eunotia sp.	*	*	*	*			2,4,5,6
Fragilaria virescens Ralfs	*	*	*	*	*	*	1,2,3,4,5,6
F. pinnata var. *lancettula* Schumann		*					3,4
Fragilaria sp.		*	*		*		4
Gyrosigma scalproides (Rabh.) Cleve	*	*	*	*	*		1,2,3,4,5,6
G. acuminatum Kützing	*		*	*			2,5
G. attenuatum Kützing (Ralfs.)	*	*		*	*		2,4,5,6
G. distortum (W.Sm) Griff. & Henfr.	*	*	*	*			2,4,5,6
G. nodiferum(Grun.) Reimer		*	*				2,4,5
Gomphonema constrictum Ehrenberg	*	*	*	*			1,2,3,4,5,6
G. constrictum var. *capitatum* Ehrenberg		*	*		*		2,3,4,6
G. olivaceum var. *minutissima* Hust.	*	*	*				1,2,3,4,5,6

Table 2. Epiphytic and associated algae collected from different substrata and stations *(following)*

Taxon	*Substrates*						*Stations*
	Wo	*Ph*	*Ty*	*Sp*	*Ne*	*Po*	
Bacillariophyceae *(suite)*							
G. olivaceum var. calcarea Cleve	*	*	*				2,3,4,5,6
G. parvulum Kützing	*	*	*	*		*	1,2,3,4,5,6
G. lanceolatum Ehrenberg	*						
G. augur Ehrenberg	*	*	*	*			4,5,6
G. acuminatum Ehrenberg	*	*	*				2,3,4,5,6
G. acuminatum var.*clavus* (Breb.) Grun.			*				2,3,4,5,6
G. acuminatum var.*trigonocephalum* Ehrenberg		*					2,4,6
Melosira varians C.A.Agardh	*	*	*	*	*	*	1,2,3,4,5,6
M. nummuloides Dillw.	*	*	*		*		2,3,4,5,6
Navicula rhynchocephala Kützing	*	*	*	*	*	*	1,2,3,4,5,6
N. cryptocephala Kützing	*	*	*	*	*	*	1,2,3,4,5,6
N. cuspidata Kützing	*	*	*	*	*		1,2,3,4,5,6
N. elginensis var. *lata* M. Perag.					*	*	5
N. gibula Cleve	*	*	*	*	*	*	1,2,3,4,5,6
N. gastrum (Ehr.) Kützing	*	*	*	*	*	*	1,4,5,6
N. placenta (Ehr.) Kützing				*			5,6
N. placenta var. *lanceolata* Grun.			*				4
N. radiosa Kützing	*	*	*	*	*		1,2,3,4,5,6
N. semen Kützing			*				4
Neidium iridis (Ehr.) Cleve			*				4
Nitzschia. apiculata Gregory	*	*	*	*		*	1,2,5
N. angustata W.Smith	*	*	*	*		*	1,2,5,6
N. distans Gregory	*	*	*	*	*	*	1,2,3,4,5,6
N. filiformis W. Smith	*	*	*	*	*	*	1,2,4,5,6
N. longissima Bréb.	*	*	*	*	*	*	1,2,4,5,6
N. longissima var. *reversa* (W.Sm.) Grun.	*		*				1,2,3,4,5,6
N. palea Kützing	*	*	*	*	*	*	1,2,3,4,5,6
N. paleacea Grun.	*	*	*	*	*	*	1,2,3,4,5,6
N. obtusa W.Smith	*	*	*	*	*	*	1,2,3,4,5,6
N. rigida Grun.	*		*	*	*		5,6
N. vermicularis (Kützing) Hantzsch	*	*	*	*			2,4,5,6
N. recta Hantzsch	*					*	1
N. subcoherens Grun.	*	*	*	*	*	*	1,2,4,5,6
Pleurosigma angulatum (Quekett) W.Sm.	*	*	*	*	*		1,2,3,4,5,6
Pinnularia abaujensis (Pant.) Ross	*	*	*				2,5,6
P. major Kützing	*	*	*				2,3,4,6
Rhopalodia parallela (Grun.) Müller	*	*	*	*		*	1,2,3,4,5,6
R. gibba (Ehr.) O. Müller	*	*	*	*	*		2,4,5,6
R. gibba var. *ventricosa* Kützing.		*	*	*			4,6
R. gibberula (Ehr.) O. Müller	*	*	*	*			4,6
R. musculus (Kützing.) O. Müller			*				5,6
Rhoicosphenia curvata Kützing	*	*	*	*	*	*	1,2,3,4,5,6

Table 2. Epiphytic and associated algae collected from different substrata and stations *(following)*

Taxon	*Substrates*						*Stations*
	Wo	*Ph*	*Ty*	*Sp*	*Ne*	*Po*	
Bacillariophyceae *(suite)*							
Stephanodiscus hantzschii var. *delicatula* Cleve	*		*				2,4
Synedra. actinastroides Lemmermann	*	*	*		*		2,3,4,5,6
S. capitata Ehrenberg	*	*					6
S. parasitica var. *constricta* Grun.			*				4
Synedra ulna Ehrenberg	*	*	*	*	*	*	1,2,3,4,5,6
S. ulna var. *danica* (Ehr.) Kützing	*	*	*	*			1,2,3,4,5,6
Surirella. biseriata Bréb.			*				4,5
S. robusta Ehrenberg	*	*	*	*	*	*	1,2,3,4,5,6
Surirella sp.			*				4
Tabellaria flocculosa (Roth) Kützing		*	*				2,3,4,5,6
Chrysophyceae							
Chrysosphaerella longispina Lauterborn			*				4
Chlorophyceae							
Ankistrodesmus convolutus Corda	*	*	*	*	*	*	1,2,3,4,5,6
A. falcatus (Corda) Ralfs	*	*				*	2,3
Actinastrum hantzschii Lagerheim	*	*	*				2,3,4,6
Cosmarium botrytis var. *tumidum* Wolle	*	*	*	*	*		1,2,4,5,6
C. botrytis var. *gemmiferum* Meneghini	*		*				2,4,5
Coelastrum reticulatum (Dang.) Senn			*				5
C. microporum Nägeli				*			6
Chlamydomonas fenestrata Whitford		*	*				2,4,5,6
Chlorella sp.	*	*	*				2,4,5,6
Cladophora sp.	*	*	*				3,4,5,6
Characium sp.	*	*					2
Draparnaldia plumosa Agardh	*	*	*		*		2,3,4,5,6
Hydrodictyon reticulatum Lagerheim			*				6
Mougeotia sp.		*	*		*		2,4,5,6
Oedogonium sp1	*	*	*	*	*	*	1,2,3,4,5,6
Oedogonium sp2		*	*				1,2,3,4,5,6
Pediastrum duplex Meyen	*	*	*				1,2,3,4,5,6
Phyllosiphon arisari Kühn	*	*	*		*		4,6
Rhizoclonium sp.	*	*	*				2,3,4,5
Schizomeris leibleinii Kützing	*	*	*	*			2,3,4,5,6
Stigoclonium sp.	*	*	*	*		*	1,2,3,4,5,6
Spirogyra sp.	*	*	*	*	*	*	1,2,3,4,5,6
Scenedesmus bijuga (Turp.) Lagerheim	*	*	*	*	*	*	1,2,3,4,5,6
S. quadricauda (Turp.) Brebisson	*	*	*	*	*	*	1,2,3,4,5,6
S. hantzschii Lagerheim	*	*	*	*	*		1,2,5,6
Selenastrum sp.	*	*	*	*		*	1,2,4
Tetraedron sp.	*	*		*			6
Ulothrix zonata (Weber & Mohr) Kützing	*	*	*	*	*		1,2,3,4,5,6
U. subtilissima Rabenhorst	*	*	*	*	*	*	1,2,3,4,5,6

Table 2. Epiphytic and associated algae collected from different substrata and stations *(following)*

Taxon	*Substrates*						*Stations*
	Wo	*Ph*	*Ty*	*Sp*	*Ne*	*Po*	
Dinophyceae							
Peridinium volzii Lemmermann	*	*	*	*	*		2,3,4,5,6
Euglenophyceae							
Euglena.acus Ehrenberg	*	*	*	*	*	*	1,2,5,6
E. spirogyra Ehrenberg	*	*				*	1,2,4,5,6
Lepocinclis fusiformis var. *major* Fritsch & Rich	*	*	*	*		*	1,2,3,4,5,6,
Lepocinclis ovum (Ehr.) Lemm.	*	*	*	*		*	1,2,3,4,5,6
Phacus.anacoelus Skvortzow						*	1
P. curvicauda Swirenko	*	*	*	*	*	*	1,2,4,5,6
P. lemmermanii (Swir) Skvortzow	*	*	*	*	*	*	1,2,3,4,5,6
P. swirenkoi Skvortzow		*				*	2,5
Trachelomonas sp.	*	*					1
Cyanophyceae							
Anabaena azollae Strasburger	*	*	*	*	*	*	1,2,3,4,5,6
Aphanothece microscopica Nägeli	*						3,6
Calothrix sp.	*	*	*				2,3,4,5,6
Lyngbya birgei G.M. Smith	*	*	*	*	*	*	1,2,3,4,5,6
Merismopedia major G.M. Smith	*	*	*	*	*	*	1,2,4,5,6
M. elegans A.Br.	*				*		5,6
Nostoc sp.		*					2,6
Oscillatoria. formosa Bory ex Gomont	*			*			1,2,3,4,5,6
O. limosa Roth ex Gomont	*	*	*	*	*	*	1,2,3,4,5,6
O. princeps Vaucher ex Gomont	*	*					4,6
O. raoi De Toni. J.	*			*			1,3,4,6
Phormidium angustissimum West & West	*	*	*	*	*		1,2,3,4,5
Spirulina major Kützing ex Gomont	*	*	*	*			1,2
S. subsalsa Oersted		*					2
Stigonema turfaceum Cooke ex Bornet & Flahault	*	*	*	*	*		4,5,6

Wo = Wood (Artificial substrate) Ph = *Phragmites*
Ty = *Typha* Sp = *Sparganium*
Ne = *Nelumbium* Po = *Polygonum*

Typha peaked in April and May and decreased throughout the remainder of the study period. On *Phragmites*, cell densities were highest in April, decreasing toward May and July (Fig 3).

DISCUSSION

In this study, members of Bacillariophyceae were the most abundant in epiphytic algal assemblages. Cell densities upon substrata were extremely vari-

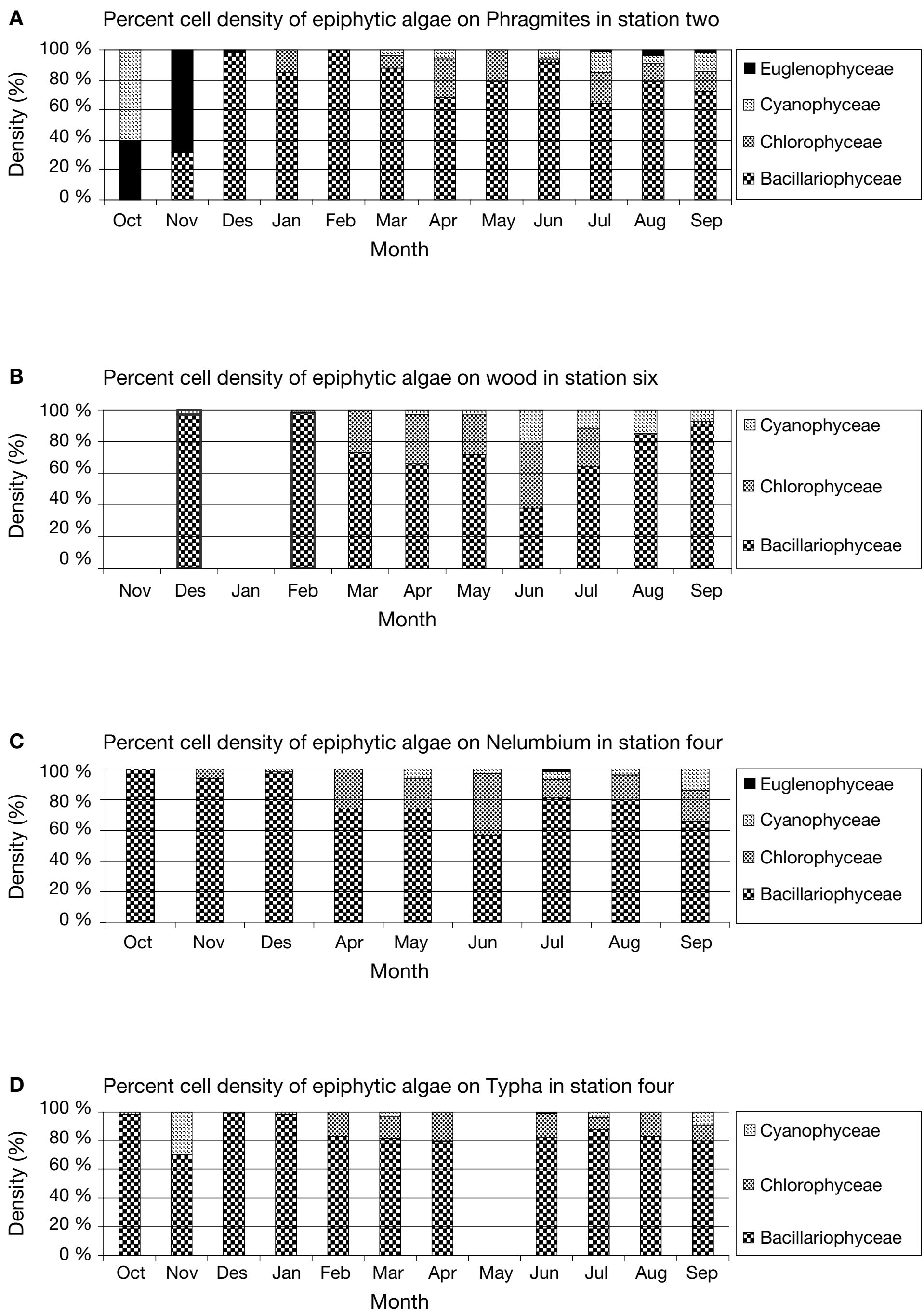

Fig. 2. Abundance and percentage cell density of epiphytic algae on different substrata and different stations. During Nov. & Jan. in Fig 2 - B and May in Fig 2 - D we hadn't data.

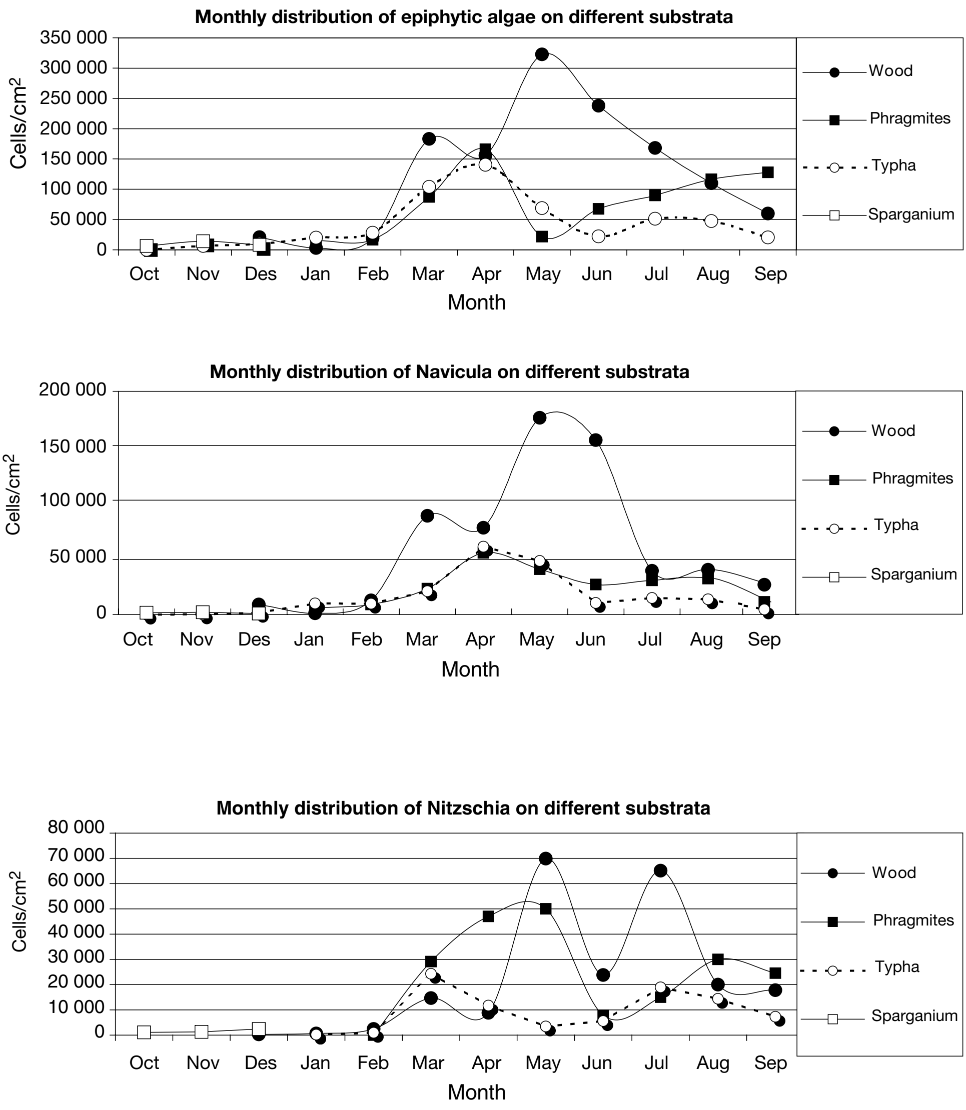

Fig. 3. Monthly distribution of *Navicula* and *Nitzschia* and total cells of epiphytic algae on different substrata.

able. The variability of standing crop maxima upon natural substrata has been attributed to different growth rates of the host macrophyte (Millie & Lowe, 1983). Therefore, epiphytic colonization would be expected to differ between macrophytes. During the study period the colonization rates of *Navicula, Nitzschia* and total epiphytic assemblages on wooden rod were high and peaked on May. There was another peak of *Nitzschia* in July. On natural substrata, in constrast, densities were lower and they peaked in April on *Phragmites* and *Typha* and in March on

Sparganium. The relationship of epiphytic algae with their substratum is not fully understood. Eminson & Moss (1980) reported a definite host specificity by epiphytes, whereas Millie & Lowe (1983) showed no substrata specificity. There were difference in physicochemical factors among sites, but these were minimal. Four Cyanophycean algae, *Oscillatoria, Lyngbya, Calothrix* and *Nostoc* were important components of the epiphyton complex. *Navicula* and *Nitzschia* were the two dominant diatom taxa during the study, with 10 and 14 species respectively. *Nitzschia* shows active growth during spring, summer and fall, reflecting its broad tolerance. Species of *Synedra, Melosira, Amphora* and *Fragilaria* were encountered in winter with high frequency. *Rhopalodia* and *Cocconeis* peaked in spring and other diatoms had sporadic distributions. Spring and autumn increases in diatom numbers and their abundance relative to total cell number is not uncommon. In this respect, temperature has been considered the major controlling factor (Patrick, 1971).

Two most encountered chlorophycean algae were *Oedogonium* and *Spirogyra* reached maximum standing crop during summer. Cyanophycean and chlorophycean epiphytes have been associated with high temperatures.

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