Ecological study of phytoplankton of the Anzali lagoon (N Iran) and its outflow into the Caspian Sea

Ekologická studie fytoplanktonu laguny Anzali (severní Irán) a jejího vtoku do Kaspického moře

Zohreh R a m e z a n p o o r

International Sturgeon Research Institute. P. O. Box: 41635 – 3464 Rasht – Iran, e-mail: *zohreh_66@yahoo.com*

Abstract

A study of phytoplankton communities of western regions of the Anzali lagoon, rivers flowing from the lagoon, and Anzali Harbor (navigation channel), located in the southern coast of the Caspian Sea was carried out. Samples were collected monthly at nine sites from May 1992 to April 1993 from the surface, 1 m, 5 m and from the final depths of each sampling site using Ruttner sampler with 1 lit. volume. Water and air temperature, turbidity, pH, Cl^-, PO_4^{3-}, NO_3^-, SO_4^{2-} and salinity were measured. Phytoplankton samples were fixed in 4% formaldehyde solution and then identified and counted using inverted microscope. A total of 97 taxa of phytoplankton were identified during the studied period. Phytoplankton species and environmental variables confirmed that the western part of the Anzali Lagoon has fresh water and eutrophic character. However, alkalinity in this region was high and high amount of sulfate at this region indicates the influence of the Caspian Sea in the area. As the Harbor is under combined influence of the Caspian Sea and freshwater rivers, it showed mostly estuarine phytoplankton communities with some species of marine origin. Few sources of pollution were identified that reduced the species diversity and alternatively some other species became dominant.

Introduction

The shallow coastal Anzali lagoon is located in the province of Gilan (a temperate region) in Northern Iran. It covers an area of about 200 km^2 situated between 37°28′ N and 49°25′ E. It is 26 km long and 2.0 - 3.5 km wide, surrounded by reed-beds which extend its eastern limits by a margin up to 7 km wide. It is located at the southwestern coast of the Caspian Sea, close to the city of Bandar-e-Anzali, and colonized by a pretty diverse wetland flora and fauna. The water system is comprised of large, eutrophic freshwater basins, shallow impoundments, marshes and seasonally flooded grasslands. It is separated from the Caspian Sea by a sand dune barrier of about 1 km wide. Over 11 rivers are entered the Anzali lagoon in their way towards the Caspian Sea. The entire marsh and lagoon are drained into the Caspian Sea through deep-water harbour

of Bandar-e-Anzali, which is the main channel at the Northeast end of the lagoon. The wetland is bordered to the north by sand dunes and to the south by cultivated land (mainly rice fields) and patches of woodland. The dominant vegetation throughout the Anzali wetland consists mainly o*f Phragmites australis,* which occasionally grows to six meters of height. Due to falling levels of the Caspian Sea in the period of 1960 to 1980, a rapid expansion of th*e Phragmites* reed began, and about 1980 large parts of the main wetland were covered by this plant. The recent rapid rise of water level in the wetland stopped the expansion o*f Phragmites* and renovated open water areas. The new water areas support vast beds of the water lil*y Nelumbo nucifera* v*ar. caspica*, and rich growth of other floating and submerged vegetation.

The average annual rainfall at the Anzali lagoon is 1900 mm, with rain falling throughout the year but mainly in winter.

An ecological study of the phytoplankton of the Anzali lagoon was carried out for a period of one year starting from May 1992 and ending in April 1993. In this period 9 sampling localities characterized by A, B, C, D, F, H, I, J, K letters were sampled (Fig.1, Tab. 1). Samples were taken in the last week of each month between 8-10 am. Ruttner sampler was used for sampling water at the depths of 0 (20m below water surface), 1 and 5m and in the final depth of localities of A, B, C, D. At sites F, H, I, J and K only samples from water surface were taken (depth reaches there only to 2 m). During the sampling some physical and chemical parameters including transparency (measured by Secchi disc), water and air temperature, water velocity and pH were measured. Dissolved oxygen concentration was measured using Winkler method. Concentrations of other chemical factors such as orthophosphates ($P\text{-}PO_4^{3-}$), nitrate-nitrogen ($N\text{-}N0_3^-$), sulfates and salinity were determined in the laboratory according to ASTM (1996). Phytoplankton samples were also collected simultaneously from the same depths. Phytoplankton samples were preserved by formalin (4%) or Lugol's solution. Species counting was performed by inverted microscope. Identification was done according to literature cited (BOLD & WYNNE 1985, KOMÁREK & ANAGNOSTIDIS 1998, KOMÁREK & FOTT 1983, PATRICK & REIMER 1966, 1975, PRESCOTT 1962, 1970).

Results

Anzali lagoon is situated in a temperate area without substantial difference in day and night temperature (influence by the near Caspian Sea). During the period of study air temperature ranged from 5.6 ^oC to 26.3 ^oC, with average of 17.7 ^oC. Average of measured temperature of water surface layer

throughout the year was 16.3 ^{o}C. Receiving some 11 rivers and streams the lagoon is not only a stagnant water body but a system of active running water streams. The highest water velocity was 22.7 m/min in site D (Nahang roga), but in the western part (localities H- K) the water was almost stagnant. Physical and chemical parameters are presented in Tables 1 and 2. Detailed vertical distribution of sulphates and salinity shown in Figure 2.

In this study, 97 taxa of phytoplankton including 37 species of Chlorophyta, 24 species of Cyanophyta (Cyanoprokaryotes/Cyanobacteria), 32 species of Chromophyta (mainly diatoms), 3 species of Euglenophyta, 1 species of Cryptophyta and 4 species of Pyrrhophyta (Dinophyta) were identified (Table 3). Diatoms were dominant in locality A (the Caspian Sea) with brackish water, with main species *Rhizosolenia calcar-avis*, *Thalassionema nitzschioides* and *Cyclotella meneghiniana*. Pyrrhophyta were in second position in this locality with dominant *Exuviaella cordata*. Cyanobacteria, Chlorophyceae and Desmids were of less significance. At sites C and D situated in the navigation channel (harbor), diatoms were dominant, with species similar to locality A, but with limited distribution (diverse phytoplankton community in upper layers of water column). Sampling localities situated in rivers (F and D) showed the highest phytoplankton density in spring and summer seasons. Although diatoms were very common in phytoplankton, they were not dominant except of bottom depths, where *Thalassionema nitzschioides* and *Cyclotella* sp. dominated in autumn. Cyanophyta, Cryptophyta, Pyrrhophyta and Chlorophyta were with lesser significance respectively. *Cylindrospermopsis raciborskii* and *Oscillatoria* sp. were dominant after flooding events only for a short period. Western part of the lagoon (localities of H - K) is an open fresh water basin. Phytoplankton growth starts in mid-spring (May) and reaches its maximum in August. In this part of the lagoon Cyanophyta were dominant almost throughout the whole year. *Cylindrospermopsis raciborskii* and *Oscillatoria* sp. were dominant and subdominant species in summer. Chlorophyceae were present throughout the year with the most common species including *Scenedesmus acuminatus*, *S. quadricauda, Tetraedron minimum, Pediastrum simplex, P. duplex* and *Mougeotia* sp. Chromophyta were represented by *Dinobryon sociale* and *Synedra* sp.

Discussion

Physical and chemical parameters of water showed that there was no water stratification in the Anzali lagoon. Water velocity in western part of the lagoon is low, but in rivers, harbor (navigation channel) and Nahang Roga (locality D) is high due to the periodical flooding. Nevertheless, this velocity does not influence phytoplankton concentration. Due to dense growth of

submerged plants and also phytoplankton production, oxygen level in western part of the lagoon is high, but in Shanbe Bazar Roga River (F) heavy load of domestic waste water degrades oxygen for oxidation processes. Therefore, oxygen level for the whole period of the year was low. Anzali lagoon has usually alkaline water, and this phenomenon is more obvious in western part where most phytoplankton species and macrophytes are alkaliphil. This part of the lagoon has fresh water throughout the year while salinity gradient in sampling localities situated in rivers and harbor (navigation channel) showed estuarine (brackish) characteristic which extends to some significant distances from the Caspian Sea. Factors related to salinity such as concentration of SO_4^{2-} and Cl^- ions and typical phytoplankton species of estuarine waters (e.g. *Exuviaella cordata* and *Prorocentrum* cf. *scutellum*) confirm the penetration of the Caspian Sea brackish water into these areas. Although western part of the lagoon is typical fresh water basin, sulfate concentration is also slightly higher than in freshwater systems. Considering the geology of entering rivers and their origin, this level of sulfate could not be related to water inflow by rivers. The influence of the Caspian Sea (income of sulfates from the Caspian Sea into the Anzali lagoon) is caused probably by underground waters (seepages). High concentration of orthophosphate, nitrate and high biomass of phytoplankton in western part suggests euthrophic status of this part of the lagoon. The most important phytoplankton species which occurred in brackish water (Fig. 4) or localities influenced by the Caspian Sea water were:

Rhizosolenia calcar-avis: this marine species (ROUND 1981) is the most abundant Diatom of the Caspian Sea. It is euryhaline and present throughout the year. This species is capable to tolerate salinity ranging from 1.33-13 ppt. (salinity range in different part of the Caspian Sea) and temperature ranging from 6.4-25.9 ^oC (PROŠKINA-LAVRENKO & MAKAROVA 1968).

Exuviaella cordata: this species is brackish, euryhaline, eurythermic of neritic zone with vast distribution in the Caspian Sea. It occurs from early summer to late autumn from surface to the depth of 75-100 m, with salinity of 1.4-13 per mille and temperature of 14.2-26 ^oC in the Caspian Sea.

Cylindrospermopsis raciborskii (Cyanoprokaryotes, Nostocaceae) is the most important phytoplankton species which occurred in west part of the lagoon (H-K localities). It is a pantropical and subtropical freshwater species with vast distribution over all tropical regions, but it occurs now also in the USA, on many places of southern and central Europe, in the estuary of Danube River, in Volga River, Caspian Sea, Azov Sea and in central Asia, e.g., in Kazakhstan, Uzbekistan, and Turkmenistan (PROŠKINA-LAVRENKO & MAKAROVA 1968, KOMÁREK & KOMÁRKOVÁ 2003). This species is dominant in western part of the Anzali lagoon.

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Tab. 1: Annual averages of environmental variables 1992-1993

Station	Depth	Water velocity	Secchi depth	DO	pH
	M	$m.s^{-1}$	Cm	$mg.l^{-1}$	
A-Caspian Sea	8	6	86	7.1	8.37
B-Harbor	5	10	65	6.26	8
C-Harbor	6	19	75	6.51	8.15
D- Nahang Roga River	6	23	87	6.48	8.11
F- Shanbe Bazar Roga River	2	3	100	4.09	7.8
H-K-Lagoon (west area)	2	0	87	8.82	8.72

Tab. 2: Annual averages of nutrients, Cl^- and conductivity (EC) at sites A-K (sites see Tab. 1)

Sites	Depth m	N-NO_3 mg.l^{-1}	P-PO_4 mg.l^{-1}	Cl^- mg.l^{-1}	EC µS.cm^{-2}
A	0	0.189±0.19	0.072±0.04	2867±12	10798±43
	1	0.103±0.08	0.062±0.05	4327±60	14609±21
	5	0.047±0.03	0.052±0.03	5206±28	17577±54
	8	0.052±0.03	0.072±0.05	4966±64	18271±32
B	0	0.296±0.20	0.076±0.04	1100±11	4530±38
	1	0.276±0.20	0.073±0.51	1511±13	5984±46
	5	0.136±0.14	0.061±0.041	3790±16	13954±56
C	0	0.306±0.21	0.137±0.08	707±866	3092±3092
	1	0.290±0.18	0.090±0.04	866±979	3569±3409
	5	0.149±0.14	0.116±0.07	3542±1578	12368±5375
	6	0.116±0.15	0.111±0.04	4104±1671	13980±5752
D	0	0.281±0.20	0.106±0.03	686±865	3051±3148
	1	0.296±0.21	0.079±0.02	722±961	3183±3545
	5	0.263±0.25	0.072±0.01	2122±1873	8328±6539
	6	0.219±0.25	0.061±0.03	3280±2040	11508±6535
F	0	0.143±0.10	0.114±0.07	1059±1290	4298±4536
H-K	0	0.105±0.10	0.052±0.03	171±140	1010±573

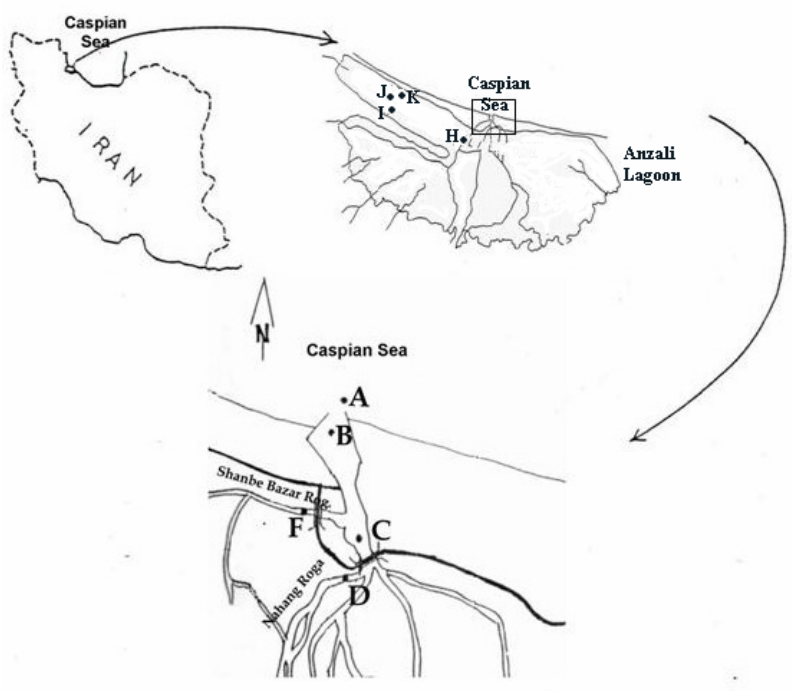

Fig. 1: Map of the sampling sites

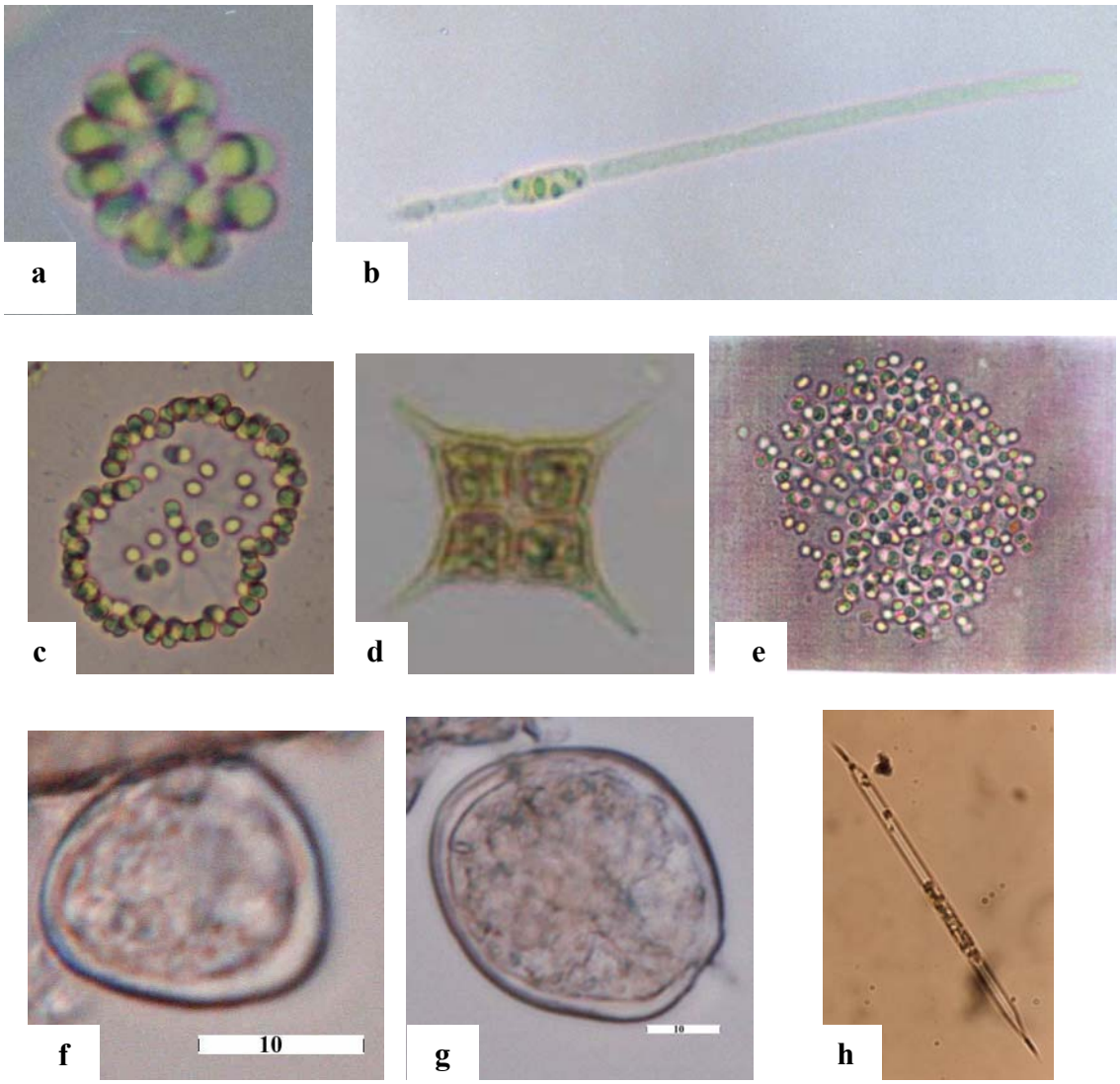

Fig.4: **a.** *Coelomoron pusillum* VAN GOOR (400x); **b.** *Cylindrospermopsis raciborskii* WOLOSZ. (400x); **c.** *Snowella litoralis* HÄYRÉN (400x); **d.** *Pediastrum simplex* MEYEN (400x); **e.** *Radiocystis geminata* SKUJA (400x); **f.** *Exuviaella cordata* OSTENFELD, fixed in formalin (400x); **g.** *Prorocentrum* cf. *scutellum* SCHRÖD, fixed in formalin; ***h.*** *Rhizosolenia calcar avis* M. SCHULTZE (100x).

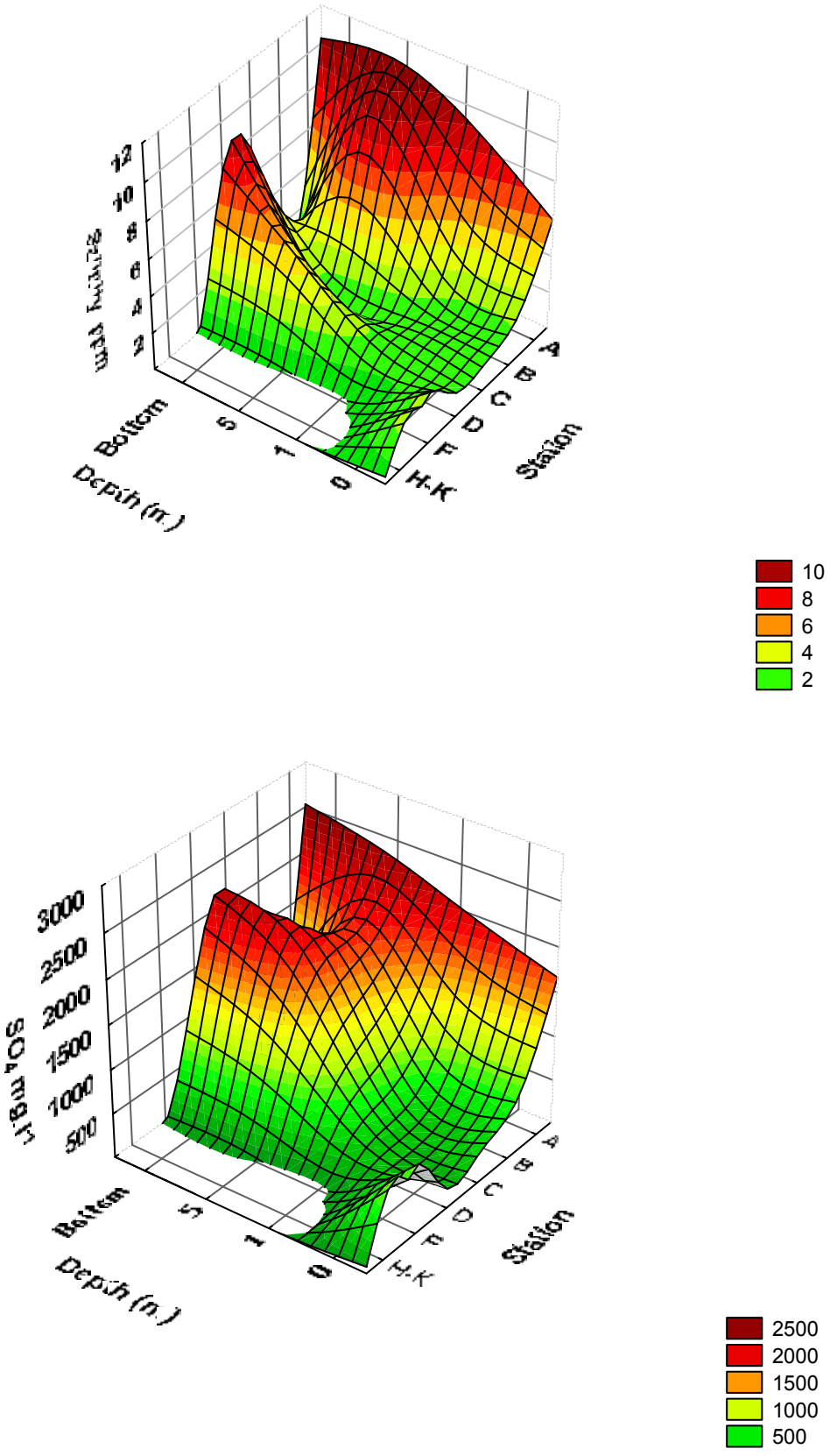

Fig. 2: Annual average of salinity and SO_4^{2-} at different depths of water column of the sampling stations 1992-1993.

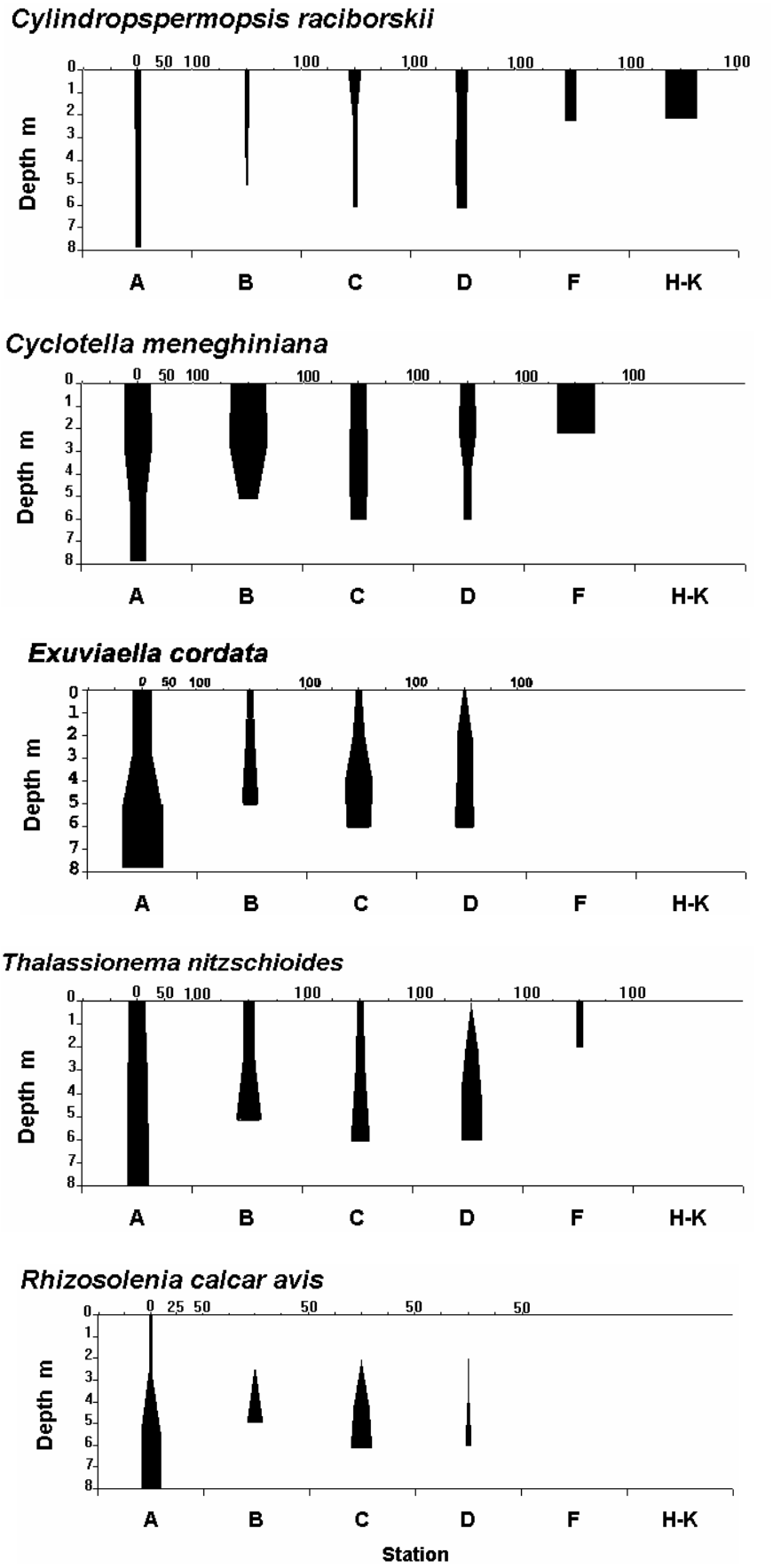

Fig.3: Annual Horizontal and vertical distribution of dominant and subdominant phytoplankton species 1992-1993.

Tab. 3: List of species

Cyanoprokaryota

Anabaena spiroides KLEB.
Anabaena viguieri DENIS et FRÉMY
Anabaenopsis arnoldii APTEK.
Anabaenopsis kelifii KOGAN
Aphanocapsa incerta (LEMM.) CRONB. et KOM.
Chroococcus minor KÜTZ.
Chroococcus sp.
*Coelomoron pusillum (*VAN GOOR) KOM.
Cyanodictyon imperfectum CRONB. et WEIBULL
Cylindrospermopsis raciborskii (WOLOSZ.) SEENAYA et SUBBA RAJU
Gomphosphaeria sp.
*Komvophoron minutum (*SKUJA) ANAGN. et KOM.
Merismopedia elegans A. BRAUN in KÜTZ.
Microcystis aeruginosa (KÜTZ.) KÜTZ.
? Oscillatoria tenuis AG. ex GOM.
Planktothrix isothrix (Skuja) KOM. et KOMÁRKOVÁ
Phormidium chalybeum (MERT. ex GOM.) ANAGN. et KOM.
? Pseudanabaena limnetica (LEMM.)KOM.
Radiocystis geminata SKUJA
Raphidiopsis sp.
Snowella litoralis (HÄYRÉN) KOM. et HIND.
Spirulina major Kütz. ex GOM.
Spirulina sp.

Chlorophyceae

Actinastrum hantzschii LAGERH.
Ankistrodesmus falcatus (CORDA) RALFS
Closterium sp.
Closteriopsis sp.
Coelastrum reticulatum (DANG.) SENN..
Cosmarium sp.
Crucigenia quadrata MORREN
Crucigenia tetrapedia (KIRCHN.) W.et G.S.WEST
? Dictyosphaerium pulchellum WOOD
Dimorphococcus sp.
Elakatothrix genevensis (REVERD.)HIND.
Golenkinia sp.
Kirchneriella sp.
Lagerheimia ciliata (LAGERH.) CHOD.
Lagerheimia longiseta (LEMM.) WILLE
Lagerheimia subsalsa LEMM.
Micractinium sp.
Monoraphidium arcuatum (KORŠ.) HIND.
Monoraphidium griffithii (BERK.) KOM.-LEGN.
Nephrochlamys subsolitaria (G.S.WEST) KORŠ.
Oocystis sp.
Pediastrum duplex MEYEN
Pediastrum simplex MEYEN
Radiococcus sp.
Scenedesmus abundans (KIRCHN.) CHOD.
Scenedesmus acuminatus (LAGERH.) CHOD.
Scenedesmus quadricauda (TURP.) BRÉB.
Selenastrum bibraianum REINSCH
Tetraedron caudatum (CORDA) HANSGIRG
Tetraedron minimum (A. BRAUN) HANSGIRG
Tetraedron regulare KÜTZ.
Tetrastrum triangulare (CHOD.) KOM.
Treubaria schmidlei (SCHRÖD.) FOTT et KOVAČ.

Conjugatophyceae

Mougeotia sp.
Staurastrum gracile RALFS
Staurastrum natator WEST

Xanthophyceae

Goniochloris mutica (A. BRAUN) FOTT

Bacillariophyceae

Aulacoseira granulata (EHRENB.)SIMONS
Caloneis sp.
Cocconeis sp.
Coscinodiscus granii GOUGH.
Coscinodiscus sp
Cyclotella meneghiniana KÜTZ.
Cyclotella sp.
Cymbella sp.
Diatoma vulgaris BORY
Entemoneis cf. *paludosa* (W. SMITH) REIMER
Epithemia sp.
Fragilaria sp.
Gomphonema sp.
Gyrosigma sp
Melosira varians AG.
Navicula sp.
Nitzschia acicularis (KÜTZ.)W. SMITH
Nitzschia reversa W. SMITH
Nitzschia sp.
Rhizosolenia calcar avis M. SCHULTZE
Stephanodiscus sp.
Surirella sp.
Synedra ulna EHRENB.
Synedra acus KÜTZ.
Synedra sp.
Thalassionema nitzschioides GRUNOW

Chrysophyceae

Dinobryon sociale Ehrenb.
Mallomonas sp.

Dinophyta

Exuviaella cordata OSTENFELD
Gymnodinium sp.
Glenodinium sp.
Prorocentrum scutellum SCHRÖD cf.

Cryptophyta

Cryptomonas marssonii SKUJA

Euglenophyta

Euglena sp.
Phacus sp.
Trachelomonas sp.