Acta Bot. Croat. 68 (1), 11–27, 2009 CODEN: ABCRA 25
ISSN 0365–0588

Phytoplankton composition of the Ebro River estuary, Spain

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The composition of phytoplankton in the Ebro River estuary (Spain) was analyzed at six sampling stations in April, July and October 1999 and February 2000, based on plankton net and bottle samples. A total of 304 taxa belonging to 13 classes were identified. Bacillariophyceae and Chlorophyceae were the most important groups. The diatom genera *Nitzschia* and *Navicula* provided most species (25 and 17, respectively). *Thalassiosira duostra* is recorded for the first time for this ecosystem. We propose the following new combinations: *Monactinus simplex* (Meyen) Corda var. *echinulatum* (Wittrock) *comb. nov.* and *Monactinus simplex* (Meyen) Corda var. *sturmii* (Reinsch) *comb. nov.*

Keywords: phytoplankton, estuary, taxonomy, Ebro, Spain.

Introduction

Estuaries are highly productive systems in which nutrients are supplied from the land (Dyer 1973, Mc Lusky 1989). Phytoplankton study in the Ebro River was earlier concentrated on seasonality (Sabater and Muñoz (1990), small *Cyclotella* species (Sabater and Klee 1990), and Chlorophyceae (Pérez et al. 2002, Comas et al. 2006). Research into phytoplankton has been performed in the Ebro delta (Comin 1984) and near bays (López and Arté 1973; Delgado 1987; Delgado et al. 1990, 1995, 1996).

In the framework of the PIONEER European Project, seasonal collecting data campaigns were undertaken during 1999–2000 to understand the impact of nutrients in the lower Ebro River and in its plume. In this study we show the results of phytoplankton composition at six collecting sites from April 1999 to February 2000.

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Materials and methods

Study area

The Ebro River is 960 km long and is one of the biggest Spanish rivers discharging in the Mediterranean Sea (Fig. 1). The Ebro estuary is classified as a »salt wedge estuary« or »type 4« after Hansen-Rattray's classification (IBAÑEZ et al. 1997). It has a strong and clearly marked halocline due to the low tidal range. Circulation is primarily affected by the river discharge.

The annual discharge (424 $m^3 s^{-1}$ mean) is smoothed by the presence of about 170 dams (IBAÑEZ et al. 1999). In particular, the Mequinenza and Riba-Roja dams, located 100 km upstream from the mouth, have an important regulatory effect over the discharge in the Delta. Furthermore, these dams condition the suspended inert solids concentration (usually low) and the phytoplankton populations of the water.

In the Ebro delta, rice crops and cultivated fields alternate with coastal lagoons. The region has a dry Mediterranean climate with a mean annual temperature around 16–17 °C, with around 550 mm of precipitation per year (MARTINEZ et al. 1999).

Samplings

Four sampling campaigns on the Ebro estuary, April, July and October 1999 and February 2000, were performed within the framework of the European PIONEER Project. Electric conductivity, temperature and pH were measured *in situ* with a multiparametric sounding Hydrolab Surveyor 3. Phytoplankton samples for qualitative analyses were collected

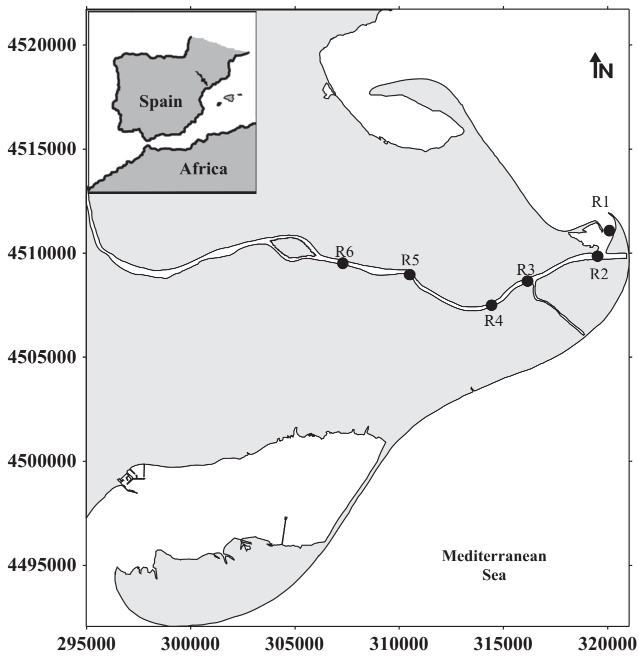

Fig. 1. Location of sampling stations in the Ebro Estuary.

with bottles at different depths trying to cover the whole water column and with 20µm mesh plankton net by horizontal tows in the centre of the stream at every sampling station (Fig. 1). All samples were fixed *in situ* with glutaraldehyde (2% final concentration) according to SOURNIA (1978), and they were deposited at the Laboratorio de Tecnologías del Medio Ambiente of the UPV, Valencia, Spain.

Detailed examinations and drawings of the material were made with Leitz Laborlux and Nikon Optiphot light microscopes with phase contrast optics. Part of each sample was prepared according to conventional methodology for the qualitative study of diatoms (HASLE and FRYXELL 1970). Observations were made with a JEOL JSM 6300 scanning electron microscope (SEM). For cryo-SEM analysis a drop of concentrated sample was placed on an isopore membrane-filter GTTP Millipore. The sample was frozen with liquid N_2, coated with gold and examined using a Jeol JSM-5410 scanning microscope equipped with cryo-station.

According to new results based on cytological studies and gene sequence analysis, the traditional Chlorophyceae is divided into different classes (MELKONIAN 1983, MATTOX and STEWART 1984, GRAHAM and WILCOX 2000); but, not all nomenclatural changes have been published, and therefore we are still using Chlorophyceae in the traditional sense. We accept new concept, the separation of *Scenedesmus* Meyen in two genera: *Desmodesmus* and *Scenedesmus* s.str. (AN et al. 1999, HEGEWALD 2000).

According to HEGEWALD in BUCHHEIM et al. (2005) based on inferences from rDNA data, *Pediastrum* Meyen could be divided into 5 independent genera. We follow this concept in this paper, with the exception of *P. willei* (Fig. 6-a), because molecular genetic data about this taxon are not yet available.

In the same way, the taxonomy of Bacillariophyceae at species, genus and higher levels, has been undergoing deep changes in the last decades (ROUND et al. 1990, MEDLIN and KACZMARSKA 2004, among others), introducing many changes and also leaving a high amount of incertitude that has to be settled, and therefore in this paper we use the criteria of ROUND et al. (1990).

Results

The water pH ranged between 7.86 and 8.55 (mean value 8.2), surface temperature between 9.81 and 27.26 °C (mean value 18.5) and the conductivity between 928 and 9071 µS cm^{-1} (mean value 3777). The surface salinity was measured on July 12th and October 5th 1999 and varied between 2.3 and 5.1.

Three hundred and four taxa included in 13 algal Classes were identified (Tab. 1, Fig. 2): Bacillariophyceae 175, Chlorophyceae 75, Chrysophyceae 2, Cryptophyceae 2, Cyanobacteria 12, Dinophyceae 17, Dictyochophyceae 2, Ebriidae 1, Euglenophyceae 9, Prasinophyceae 1, Prymnesiophyceae 2, Xanthophyceae 2 and Zygnemaphyceae 4. Considering the species numbers, Bacillariophyceae and Chlorophyceae were the most important classes with 57 % and 25 % of the recorded species, respectively (Fig. 2). The genera *Navicula sensu stricto* and *Nitzschia* presented the highest number of species, 25 and 17 species, respectively (Tab. 1). From the total of 149 observed genera, *Pediastrum, Pseudopediastrum, Monactinus, Stauridium* and *Monoraphidium* (Chlorophyceae), *Cryptomonas*

Tab. 1. List of algae species observed in the Ebro Estuary (1999–2000). * diatoms observed in only one sample.

BACILLARIOPHYCEAE

Achnanthes cf. *amoena* Hustedt
Achnanthidium minutissimum (Kützing) Czarnecki
Achnanthidium sp.
Actinocyclus normanii (Gregory) Hustedt
Amphora copulata (Kützing) Schoeman et Archibald
A. cf. *normanii* Rabenhorst
A. ovalis (Kützing) Kützing
A. pediculus (Kützing) Grunow in Schmidt et al.
A. veneta Kützing
Asterionella formosa Hassall
Asterionellopsis glacialis (Castracane) F.E. Round
Aulacoseira ambigua (Grunow) Simonsen
A. granulata var. *granulata* (Ehrenberg) Simonsen
A. granulata var. *angustissima* (Otto Müller) Simonsen
A. cf. *nyassensis* (Otto Müller) Simonsen
Bacillaria paradoxa Gmelin in Linneaeus
Bacteriastrum cf. *elongatum* Cleve
B. delicatulum Cleve
B. hyalinum Lauder
Caloneis amphisbaena (Bory) Cleve
**C. bacillum* (Grunow) Cleve
Cerataulina cf. *pelagica* (Cleve) Hendey
Chaetoceros cf. *laciniosus* Schütt
Ch. cf. *pseudocurvisetus* Mangin
Ch. didymus Ehrenberg
Ch. muellerii Lemmermann
Chaetoceros sp.
Cocconeis pediculus Ehrenberg
C. placentula var. *euglypta* (Ehrenberg) Grunow
C. placentula var. *lineata* (Ehrenberg) Van Heurck
**C. scutellum* Ehrenberg
Cocconeis sp.
Corethron criophyllum Castracane
Craticula cuspidata (Kützing) Mann in Round, Crawford et Mann
**C. molestiformis* (F. Hustedt) S. Mayama
Ctenophora pulchella (Ralfs ex Kuetzing) Williams et Round
Cyclostephanos dubius (Fricke) Round
C. invisitatus (Hohn et Hellerman) Theriot, Stoermer et Hakansson
Cyclotella atomus Hustedt
C. choctawhatcheeana Prasad
C. meduanae Germain
C. meneghiniana Kützing
C. ocellata Pantocsek
**C.* aff. *polymorpha* Meyer et Håkansson
C. rossii Håkansson
Cylindrotheca closterium (Ehr.) Reimann et Lewin
**Cymatopleura elliptica* (Brebisson ex Kutzing) W. Smith
C. solea (Brebisson in Brebisson et Godey) W. Smith
Cymbella helvetica Kützing
C. tumida (Brébisson in Kützing) Van Heurck
Diadesmis confervacea Kützing
Diatoma moniliformis Kützing
D. tenue Agardh
D. vulgaris Bory
Diatoma sp.
Discostella glomerata (Bachmann) Houk et Klee
D. stelligeroides (Hustedt) Houk et Klee
D. wolterecki (Hustedt) Houk et Klee
Ditylum brightwellii (T. West) Grunow
Encyonema minutum (Hilse in Rabenhorst) Mann in Round, Crawford et Mann
E. prostratum (Berk.) Kütz.
**Encyonopsis microcephalum* (Grunow) Krammer
**Entomoneis paludosa* (W. Smith) Reimer in Patrick et Reimer
Eolimna minima (Grunow in Van Heurck) H. Lange-Bertalot in G. Moser, H. Lange-Bertalot et D. Metzeltin
E. subminuscula (Manguin) G. Moser, H. Lange-Bertalot et D. Metzeltin
Eucampia zodiacus Ehrenberg

Tab. 1. – continued

Fallacia cf. *insociabilis* (Krasske) Mann in Round, Crawford et Mann
**F. subhamulata* (Grunow in Van Heurck) Mann in Round, Crawford et Mann
Fistulifera pelliculosa (Brebisson) Lange-Bertalot
Fragilaria capucina Desmaziéres
F. cf. *constricta* Ehrenberg
F. crotonensis Kitton
Gomphonema olivaceum (Hornemann) Ehrenberg
G. parvulum (Kützing) Kützing
Gomphonema sp.
Gomphosphenia lingulatiformis (H. Lange-Bertalot et E. Reichardt) H. Lange-Bertalot (=*Gomphonema lingulatiforme*)
Guinardia striata (Stolterfoth) Hasle
Gyrosigma acuminatum (Kützing) Rabenhorst
G. attenuatum (Kützing) Cleve
*G. sciotense (*Sulliv. et Wormley) Cl. KS: Curtis
Hemiaulus sinensis Greville
Karayevia clevei (Grunow in Cleve et Grunow) Round et Bukhtiyarova
Leptocylindrus danicus Cleve
L. minimus Gran
Lithodesmium cf. undulatum Ehrenberg
Luticola goeppertiana (Bleisch in Rabenhorst) Mann in Round, Crawford et Mann
L. mutica var. *ventricosa* (Kützing) Hamilton *in* Hamilton et al.
**L. nivalis* (Ehrenberg) Mann in Round, Crawford et Mann
Melosira varians C. A. Agardh
Navicula antonii Lange-Bertalot *in* Rumrich et al. (=*N. menisculus* var. *grunowii*)
N. capitatoradiata Germain
N. cryptotenella Lange-Bertalot
N. erifuga Lange-Bertalot
N. gregaria Donkin
N. cf. *hambergii* Hustedt
N. lanceolata (Agardh) Kützing
N. phyllepta Kützing
N. recens (Lange-Bertalot) Lange-Bertalot
N. rhynchocephala Kützing
N. rostellata Kützing
**N. salinarum* Grunow
**N. schroeteri* Meister
N. tripunctata (O. F. Müller) Bory
N. veneta Kützing
N. viridula (Kützing) Ehrenberg
Navicula sp.
Nitzschia acicularis (Kützing) W. Smith
N. amphibia Grunow
N. angustatula Lange-Bertalot
**N. brevissima* Grunow
N. cf. *capitellata* Hustedt
N. cf. *rautenbachiae* Cholnocky
N. constricta (Gregory) Grunow
N. dissipata (Kützing) Grunow
**N. dubia* W. Smith
N. filiformis (W. Smith) Van Heurck
**N. fonticola* Grunow
N. frustulum (Kützing) Grunow
N. gracilis Hantzsch
N. inconspicua Grunow
**N. intermedia* Hantzsch
N. linearis (Agardh) W. Smith
N. longisima var *reversa* Grunow
N. microcephala Grunow
N. palea (Kützing) W. Smith
N. recta Hantzsch
**N. sigma* (Kützing) W. Smith
N. sigmoidea (Nitzsch) W. Smith
**N. sinuata* var. *tabellaria (*Grunow) Grunow
N. sublinearis Hustedt
Nitzschia sp.
Odontella mobiliensis Bailey
**Planothidium ellipticum* (Cleve) Round et Bukhtiyarova
P. rostratum (Østrup) Round et Bukhtiyarova
Pleurosigma sp.
Pleurosira laevis (Ehrenberg) Compère
Proboscia alata (Brightwell) Sundström
Psammothidium subatomoides (Hustedt) Bukhtiyarova et Round
Pseudo-nitzschia cf. *pseudodelicatissima* (Hasle) Hasle

Tab. 1. – continued

Pseudo-nitzschia sp.
Pseudosolenia calcar-avis (Schultze) Sundstrom
Pseudostaurosira brevistriata (Grunow in Van Heurck) Williams et Round
Puncticulata bodanica (Grunow in Schneider) Håkansson
**P. radiosa* (Lemmermann) Håkansson
Reimeria uniseriata Sala, Guerrero et Ferrario
Rhizosolenia sp.
Rhoicosphaenia abbreviata (C. Agardh) Lange-Bertalot
Sellaphora pupula (Kützing) Mereschkowsky
Seminavis cf. *gracilenta* (A. Grunow ex A. Schmidt) DG Mann
Skeletonema cf..*costatum* (Grev.) Cleve
S. potamos (Weber) Hasle
Staurosira construens var. *subsalina* (Hustedt) Bukhtiyarova
S. construens var. *venter* (Ehrenb.) P. B. Hamilton in Hamilton, Poulin, Charles et Angell
Stephanodiscus hantzschii Grunow
S. hantzschii Morphotype *»tenuis«* (Hustedt) Håkansson et Stoermer
S. parvus Stoermer et Håkansson
S. rotula (Kützing) Hendey
Surirella brebissonii var. *kuetzingii* Krammer et Lange-Bertalot
**S. linearis* var. *helvetica* (Brun) F. Meister
**S. minuta* (Brun) F. Meister
Tabularia fasciculata (C. Agardh) D. M. Williams et Round
T. cf. *tabulata* (C. A. Agardh) Snoeijs
Thalassionema nitzschioides (Grunow) Mereschkowsky
Thalassiosira baltica (Grunow in Cleve et Grunow) Ostenfeld
T. duostra Pienaar in Pienaar et Pieterse
T. cf. *faurii* (Gasse) Hasle
T. pseudonana Hasle et Heimdal
T. cf. *visurgis* Hustedt
T. weissflogii (Grunow) G. Fryxell et Hasle
Thalassiosira sp. 1
Thalassiosira sp. 2
Tryblionella hungarica (Grunow) D. G. Mann
**T. suevica* Grunow (=*N. levidensis* var. *salinarum* Grunow)
Ulnaria acus (Kützing) Aboal
U. ulna (Nitzsch) P. Compère

CHLOROPHYCEAE s. l.

Chlorococcales s. l.

Actinastrum hantzschii var. *hantzschii* Lagerh.
A. hantzschii var. *subtile* Wolosz.
Ankyra ancora (G.M. Smith) Fott
Botryococcus cf. *braunii* Kütz.
Chlorotetraedron incus (Teil.) Kom. et Kovac.
Closteriopsis longissima (Lemm.) Lemm.
Coelastrum indicum Turn.
C. microporum Näg.
C. pseudomicroporum Kors.
C. reticulatum var. *polychordum* Kors.
Coenococcus fottii Hind.
Crucigenia smithii (Bourr. et Manguin) Kom.
C. tetrapedia (Kirchn.) W. et G.S. West
Crucigeniella cf. *pulchra* (W. et G.S. West) Kom.
Desmodesmus abundans (Kirchn.) Hegew.
D. armatus s.l. (Chod.) Hegew.
D. brasiliensis (Bohl.) Hegew.
D. communis (Hegew.) Hegew.
D. denticulatus var. *fenestratus* (Teil) Hegew.
D. intermedius (Chod.) Hegew.
D. maximus (Meyen) Hegew.
D. opoliensis (Richter) An et al.
D. pannonicus (Hortob.) Hegew.
D. spinosus (Chod.) Hegew.
Dictyosphaerium ehrenbergianum Näg.
D. tetrachotomum Printz
Dictyosphaerium sp.
Golenkinia radiata Chod.
Kirchneriella obesa (W. West) Schmidle
Lagerheimia ciliata (Lagerh.) Chod.
L. subsalsa Lemm.
Micractinium pusillum Fres.
Monactinus simplex var. *simplex* (Meyen) Corda
M. simplex var. *sturmii* (Reinsch) comb. nov.

Tab. 1. – continued

M. simplex var. *echinulatun* (Wittr.) comb. nov.
Monoraphidium arcuatum (Kors.) Hind.
M. contortum (Thur.) Kom-Legn.
M. griffithii (Berk.) Kom-Legn.
Nephrocytium schilleri (Kamm.) Com.
Oocystidium ovale Kors.
Oocystis lacustris Chod.
O. marssonii Lemm.
Pediastrum duplex var. *duplex* Meyen
Pediastrum willei Comas et al.
Planktosphaeria gelatinosa G.M. Smith
Pseudopediastrum boryanum var. *boryanum* (Turp.) Hegew.
Pseudoschroederia antillarum (Kom.) Hegew. et Schnepf
P. robusta (Kors.) Hegew. et Schnepf
Raphidocelis contorta (Schmidle) Marvan et al.
Scenedesmus acuminatus (Lagerh.) Chod.
S. arcuatus (Lemm.) Lemm.
S. ellipticus Corda
S. obliquus var. *dimorphus* (Turp.) Hansg.
S. obtusus Meyen
Schroederia setigera (Schröd.) Lemm.
Selenastrum bibraianum Reinsch.
S. gracile Reinsch.
Siderocelis ornata (Fott) Fott
Stauridium tetras (Ehrenb.) Hegew.
Tetrachlorella alternans (G.M. Smith) Kors.
Tetraedron caudatum (Corda) Hansg.
Tetrastrum komarekii Hind.
T. staurogeniaeforme (Schröd.) Lemm.
Treubaria triappendiculata Bern.
Westella botryoides De Wild

O. Ulotrichales s. l.
Elakatothrix genevensis (Reverdin) Hind.
E. subacuta Korš.
Klebsormidium subtile (Kütz.) Silva et al.
Koliella cf. *spiculiformis* (Vischer) Hind.
Planctonema lauterbornii Schmidle

O. Volvocales
Chlamydomonas sp.
Eudorina elegans Ehrenb.
Gonium pectorale O. F. Müller
Pandorina morum (Müller) Bory
Pseudoscourfieldia marina (Throndsen) Manton

CHRYSOPHYCEAE
Dinobryon sp.
Mallomonas sp.

CRYPTOPHYCEAE
Cryptomonas sp.
Rhodomonas sp.

CYANOPHYCEAE
Aphanizomenon flos-aquae (L.) Ralfs ex Bornet et Flahault
Coelomoron pusillum (Van Goor) Kom.
Chroococcus limneticus Lemm.
C. cf. *microscopicus* Kom-Legn. et Cronberg
Cyanobium sp.
Geitlerinema splendidum (Grez. ex Gom.) Anagn. et Kom.
Merismopedia sp.
Microcystis aeruginosa Kütz.
Planktolyngbya cf. *brevicellularis* Cronberg et Kom.
Planktothrix isothrix (Skuja) Kom. et Komark.
Pseudanabaena sp.
Spirulina major Kütz. ex Gom.

DINOPHYCEAE
Ceratium candelabrum (Ehrenb.) Stein
C. furca (Ehrenb.) Claparède et Lachmann
C. fusus (Ehrenb.) Duj.
C. hirundinella (O.F. Müller) Schrank
C. pentagonum Gourr.
C. tripos (O.F. Müller) Nitzsch
Dinophysis sacculus Stein
Dinophysis sp.
Gymnodinium sp.
Peridinium sp.
Podolampas sp.
Prorocentrum micans Ehrenb.
Prorocentrum sp. 1
Protoperidinium cf. *conicum* (Gran) Balech

Tab. 1. – continued

P. cf. *depressum* (Bailey) Balech
Protoperidinium sp. 1
Scrippsiella trochoidea (Stein) Balech

DICTYOCHOPHYCEAE
Dictyocha crux Ehrenb.
D. fibula Ehrenb.

EBRIIDEA
Hermesinum adriaticum Zacharias

EUGLENOPHYCEAE
Euglena spirogyra Ehrenb.
E. tripteris (Duj.) Klebs
Euglena sp.
Eutreptiella sp.
Lepocinclis texta (Duj.) Lemm. emend. Conrad
Lepocinclis sp.
Phacus acuminatus Stokes
P. tortus Lemm.
Trachelomonas sp.

PRASINOPHYCEAE
Pyramimonas sp.

PRYMNESIOPHYCEAE
Periphyllophora mirabilis (Schiller) Kamptner
Syracosphaera sp.

XANTHOPHYCEAE
Goniochloris cf. *muticum* (A. Braun) Fott
Pseudostaurastrum hastatum (Reinsch) Chod.

ZYGNEMAPHYCEAE
Closterium sp.
Cosmarium sp.
Staurastrum gracile var. *gracile* Ralfs
S. smithii (G.M. Smith) Teiling

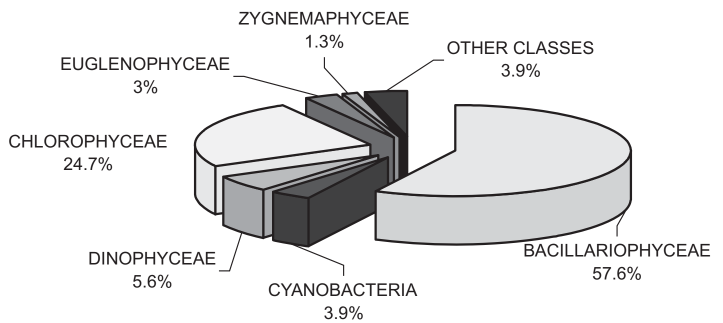

Fig. 2. Relative contribution of species among classes to total number of phytoplankton species in the Ebro Estuary (1999–2000).

(Cryptophyceae), and *Cyclotella* (Bacillariophyceae) (Figs. 3: a–d) were very frequent in our samples.

We identified 175 diatoms belonging to 69 genera (25 centrics and 44 pennates). Centric diatoms (Figs. 3, 4, 5) were less numerous than pennate. A high percentage of the identified species (82.3%) are known from non-marine habitats and only 34.8% of diatoms were planktonic.

Twelve species: *Amphora pediculus*, *Bacillaria paradoxa*, *Cocconeis placentula* var. *euglypta*, *Cyclostephanos dubius* (Fig. 4-a), *Cyclotella atomus*, *C. meduanae* (Figs. 3: a–b), *C. meneghiniana*, *Nitzschia palea*, *Skeletonema potamos* (Fig. 4-b), *Stephanodiscus rotula* (Fig. 4-e), *Thalassiosira weissflogii* (Fig. 5-b) and *Ulnaria ulna* were present in all the stud-

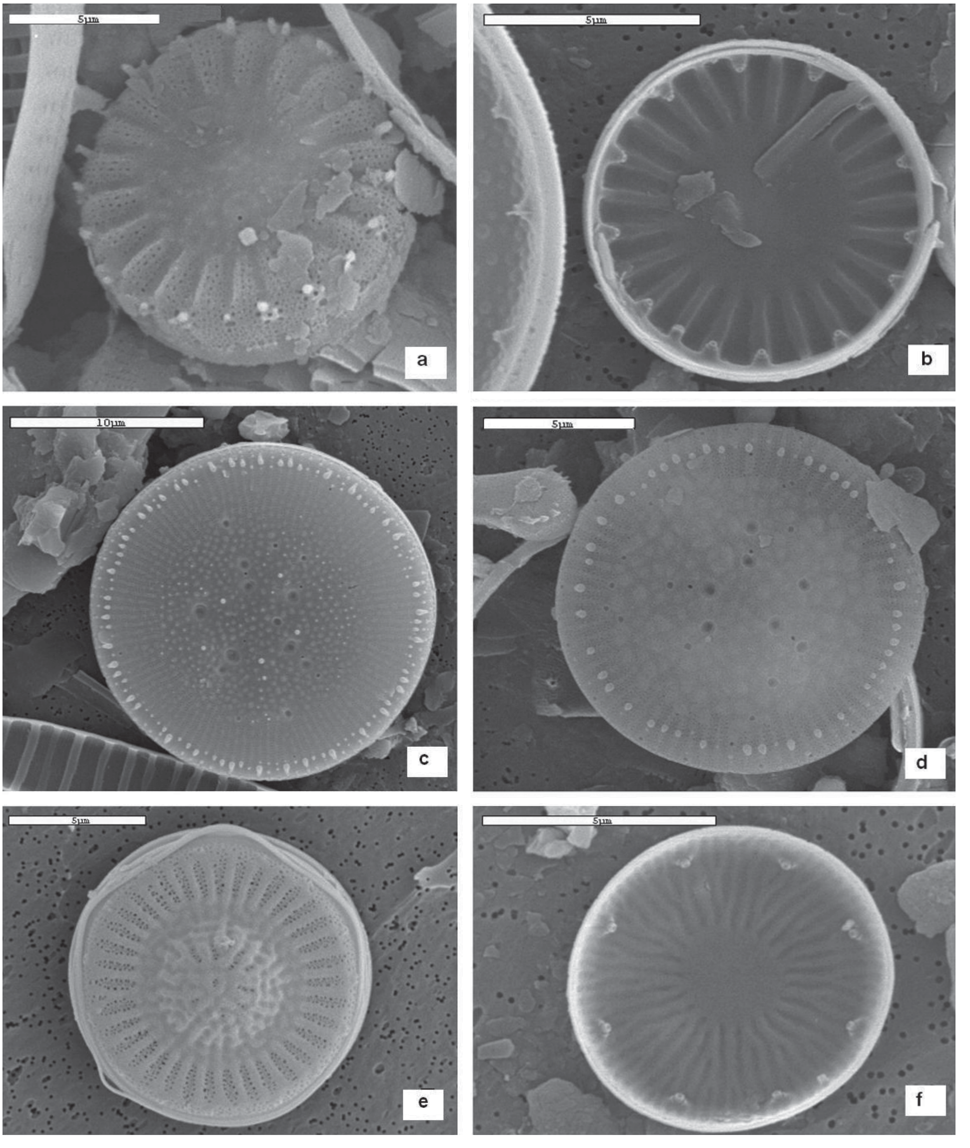

Fig. 3. SEM micrographs of *Cyclotella* and *Discostella.* a–b – *Cyclotella meduanae* (a – external view, b – internal view), c – *C. rossii,* d – *C.* aff. *polymorpha*, e – *Discostella pseudostelligera*, f – *D. woltereckii*

ied samples, while 22 diatoms were found in only one sample during the studied period (Tab. 1). *Thalassiosira duostra* (Figs. 5 c–f) is recorded for the first time in this ecosystem.

The present paper reports four new Chlorococcales *s.l.* and three Ulotrichales *s.l.* The new findings are: *Botryococcus* cf. *braunii*, *Lagerheimia ciliata*, *Lagerheimia subsalsa*, *Westella botryoides* and the Ulotrichales *s.l*: *Planctonema lauterbornii*, *Klebsormidium subtile* and *Koliella* cf. *spiculiformis*. We found two different varieties of *Pediastrum sim-*

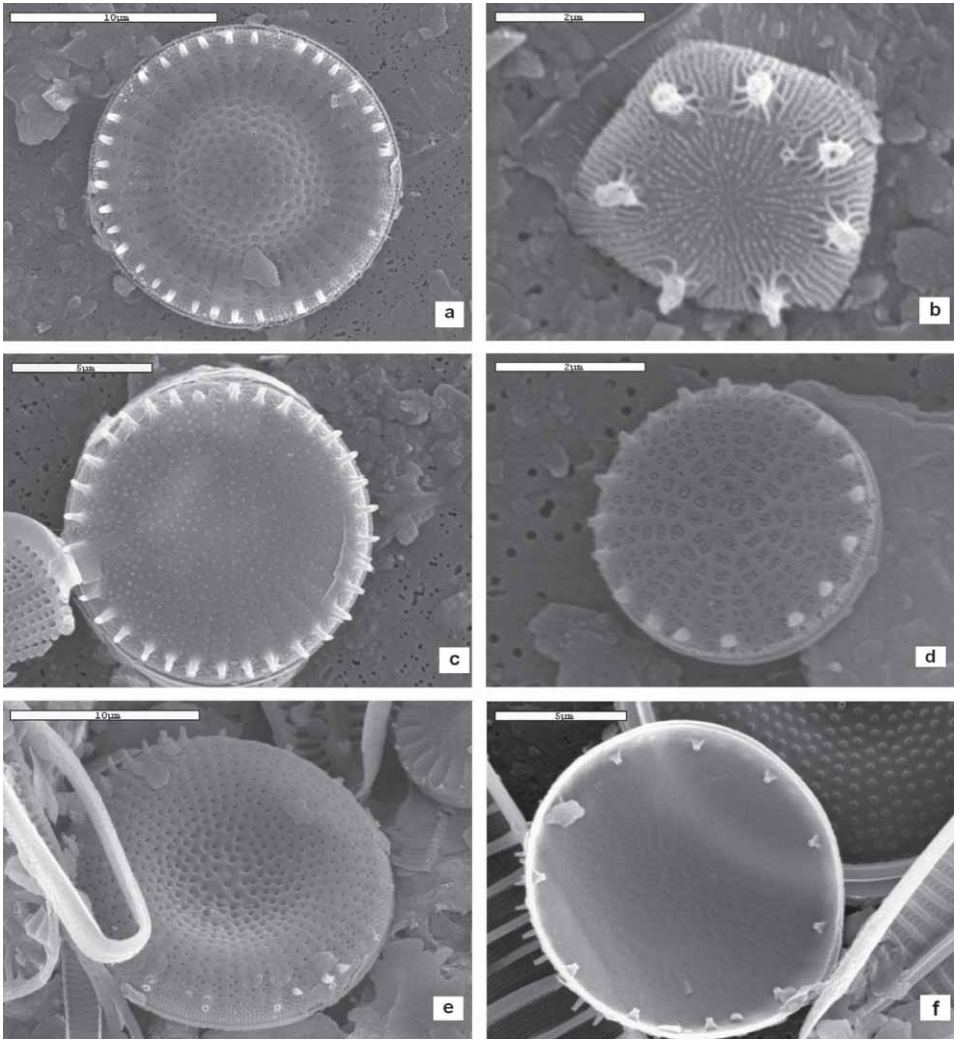

Fig. 4. SEM micrographs of *Cyclostephanos, Skeletonema and Stephanodiscus.* a – *Cyclostephanos dubius,* b – *Skeletonema potamos,* c – *Stephanodiscus hantzschii* Morphotype *»hantzschii«*, d – *St. parvus*, e – *St. rotula*, f – *St. hantzschii* Morphotype *»tenuis«*

plex (var. *sturmii* and var. *echinulatum*), which should be transferred to *Monactinus simplex* (Meyen) Corda (Chlorococcales *s.l.)*

Due to Cyanobacteria, a population probably belonging to *Cyanobium* was observed. This species was a representative of the picophytoplankton fraction for the whole of the study period.

Among Dinophyceae, several *Ceratium* and *Protoperidinium* marine species were observed near the river mouth (stations 1 and 2, Fig. 1). With respect to potentially harmful species, during this period were observed the dinoflagellates *Dinophysis sacculus* and *Prorocentrum* cf. *micans* (Fig. 6 b–c) in the samples closest to the sea.

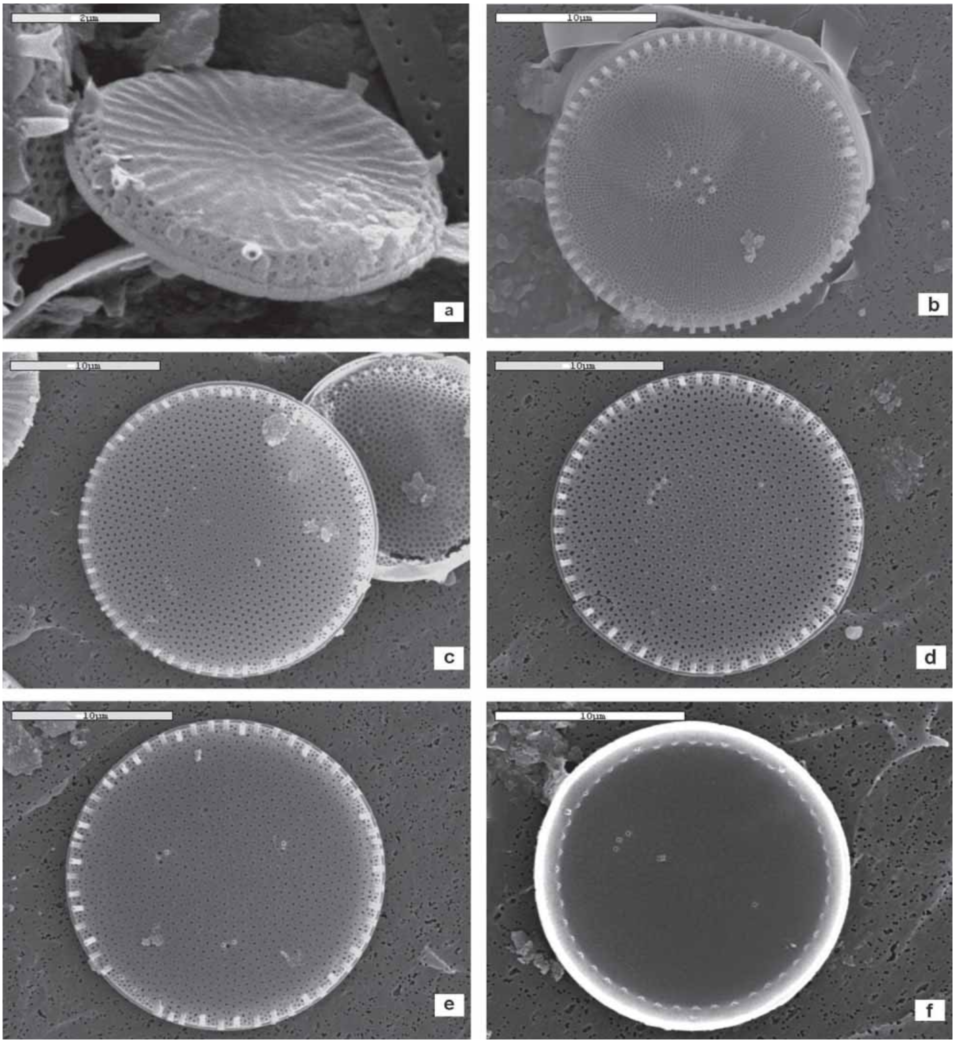

Fig. 5. SEM micrographs of Thalassiosira. a – *Thalassiosira pseudonana*, b – *T. weissflogii*, c – f – *T. duostra* (c–e – external views with different arrangements of the central groups of fultoportulae, f – internal view)

Discussion

The taxonomic inventory and quantitative description of organisms are important prerequisites for understanding the status and functioning of ecosystems (JOHN 1994). The high species richness of Chlorophyceae and Bacillariophyceae in the lower Ebro River (75 and 175 taxa respectively) may be interpreted as typical of freshwater ecosystems. When compared to other regional ecosystems, the species richness of Chlorophyceae in the Ebro estuary is evident (SABATER 1990, MONTESANTO et al. 2000).

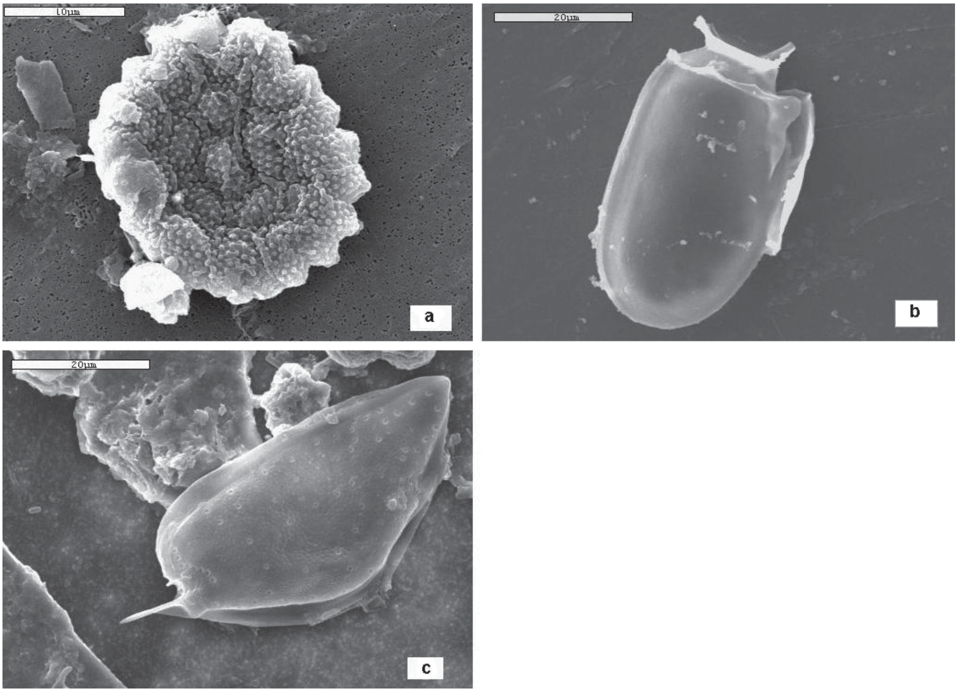

Fig. 6. SEM micrographs *Pediastrum*, *Dinophysis* and *Prorocentrum*. a – *Pediastrum willei*, b – *Dinophysis sacculus*, c – *Prorocentrum* cf. *micans*

With respect to Chlorococcales, this in its present concept comprises only the family Chlorococcaceae and is transferred to Chlamydophyceae (ETTL and GÄRTNER 1988), however several other genera have been replaced in Sphaeropleales (HEGEWALD and HANAGATA 2000) or in the quite different class of Trebouxiophyceae (FRIEDL 1995, HEPPERLE et al. 2000, WOLF et al. 2002).

Monactinus simplex (Meyen) Corda (= *Pediastrum simplex* Meyen) is more widely distributed in warm regions, but in recent years the area is a little more enlarged. According to the last monograph on the genus *Pediastrum* (KOMÁREK and JANKOVSKÁ 2001) few taxonomical varieties were accepted, *p.i.* the vars. *echinulatum* Wittr and *sturmii* (Reinsch) Wolle. In this study both taxa are very well represented, and, since they have not been yet transferred to *Monactinus* we propose here the following new combinations:

Monactinus simplex (Meyen) Corda var. *echinulatum* (Wittrock) *comb. nov.*

(Basionym: *Pediastrum simplex* var. *echinulatum* Wittrock *in* Wittrock, V. *et* Nordsted, O., Alg. Aq. Dulc. Exsicc. Praec. Scand. Fasc. 5, No. 235, 1833). A variety characterized by cell walls ornamented by prominent granules and coenobia usually with small and irregular holes (Fig. 7a).

Monactinus simplex (Meyen) Corda var. *sturmii* (Reinsch) *comb. nov.*

(Basionym: *Pediastrum sturmii* Reinsch, Die Alg. Fl. mittl. Theil. Frank., p. 90, Tab. 7: 1, 1867.) is characterized by the lateral sides of lobes in old coenobia distinctly convex and cell wall with very fine and regular granulations (Fig. 7-b).

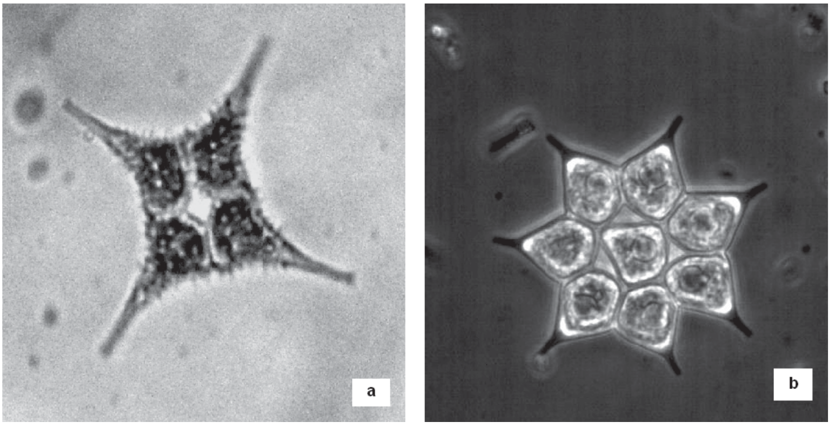

Fig. 7. Light microphotographs of *Monactinus simplex*. a – *Monactinus simplex* var. *echinulatum*, b – *Monactinus simplex* var. *sturmii*.

The genera *Scenedesmus* and *Desmodesmus* are represented by 5 and 11 species, respectively, being two of the richest genera (PÉREZ et al. 2002), resembling the situation in the Danube River (SCHMIDT et al. 1994, KISS and SCHMIDT 1998). On the other hand, the number of Chlorophyceae found in our study is higher (71 taxa) in comparison with the number found by SABATER and MUÑOZ (1990) between 1986 and 1987 in four sites located along the last 60 km of the river Ebro (41 taxa). It could indicate a higher trophic level.

In our results, as compared with those of SABATER and MUÑOZ (1990), 18 Chlorophyceae species were not observed in our samples. These authors observed that diatoms and green algae were the most abundant algae. They concluded that the phytoplankton dynamics of the Ebro River is based upon two major factors: water flow and water salinity.

MONTESANTO et al. (2000) recorded a total of 122 taxa of suspended algae in the Aliakmon River in Greece between February 1995 and January 1996. These authors observed that the two most important groups were Chlorophyta with 43.4% of total species number (53 representatives) and Bacillariophyceae with 19.7% containing a great number of tychoplanktonic species either from the phytobenthos or the littoral zone. On the other hand, VILIČIĆ et al. (2000) observed that the marine diatoms and dinoflagellates provided the dominant phytoplankton groups in the eastern Adriatic Zrmanja River Estuary (Croatia).

As was expected, diatoms were represented by more non-marine (80%) than marine (20%) taxa. Of the non marine diatoms, pennates were well represented with a high number of species (124) while centrics had the lower species numbers (16). On the other hand, marine diatoms were represented by similar numbers of centrics and pennates (20 and 15, respectively).

Among centrics, *Cyclotella* species are not easy to distinguish from each other due to their high degree of polymorphism (HÅKANSSON 2002, RIVERA et al. 2003) and the possible convergence of some ultrastructural features and they were usually included in species complex such is the case of some taxa recorded for the Ebro River.

Cyclotella rossii (Fig. 3-c) was present in all sampling sites along the study period. It clearly differs from *C. ocellata* and other related species due to the regularly aligned series of pores at the central part of the valves and by the marginal striae with similar length.

Cyclotella aff. *polymorpha* (Fig. 3-d) was found only in station R5 and was represented by only few valves that could be distinguished from *C. rossii* by the irregular length of the marginal striae and from *C. ocellata* mainly by the radially oriented rows of puncta or orbiculi in the central part of the valve. Although *C. ocellata* provides a variable *Cyclotella ocellata-krammeri-rossii* complex (KNIE and HÜBENER 2007), the differentiating features of *C. rossii* is that the valves are the regular length of the marginal striae. We agree with KNIE and HÜBENER (2007) and GENKAL and POPOVSKAYA (2008) about the need to perform further investigations into the autoecology as well as DNA sequence analyses to clarify the taxonomic status of this species, also including *C. polymorpha* in this group of taxa.

Stephanodiscus rotula (Fig. 4-e) and *S. parvus* (Fig. 4-d) were present in all the sampling stations. *S. rotula* should not be confused with other related species, such as *S. alpinus* because of the valves have the central fultoportulae in heterotopic position (according to HÅKANSSON 2002). On the other hand, *S. parvus* (Fig. 4-d) differs from the very closely related *S. minutulus* because it always has the single central fultoportula in an isotopic position.

Remarkable in the Ebro River samples was the presence of *Thalassiosira duostra* (Fig. 5: c–f), a diatom with a scarcely known geographical distribution. It was mentioned for South Africa (the type locality), and found in some European rivers and ponds and in a reservoir in Brazil (PIENAAR and PIETERSE 1990, TORGAN et al. 2004). The Ebro material agrees in every respect with the morphological characteristics of the species.

The higher relative abundance of benthic diatoms in February 2000 was probably related to rainfall occurring in the catchment area during the previous days to sampling. SABATER (1990) observed a great influence of diatom benthic species in the phytoplankton of the medium-sized Mediterranean river the Ter (Spain).

Previous studies dealing with the phytoplankton composition in the Ebro River, reported 59 freshwater diatoms (SABATER and KLEE 1990, SABATER and MUÑOZ 1990), which is lower number in comparison to 137 freshwater diatoms identified in this study.

The absence of marine taxa in those previous studies could be explained by the differences in sampling methodologies, i.e. the sub-superficial water samples in SABATER and KLEE (1990) and in SABATER and MUÑOZ (1990) as against the. covering of all the water column in this study including the salt wedge.

The picocyanobacteria were represented by an important population of *Cyanobium* sp. and its distribution and abundance were studied in PEREZ and CARRILLO (2005).

With respect to potentially harmful dinoflagellates, we observed two interesting species: *Dinophysis sacculus*s (Fig. 6-b), recorded as toxic in the Mediterranean Sea by ZINGONE et al. (1998, 2006), and *Prorocentrum* cf. *micans* (Fig. 6-c), a very common species in coastal and estuarine waters (STEIDINGER and TANGEN 1996). Ebridian flagellates have only two extant species, *Ebria tripartita* and *Hermesinum adriaticum*, and this latter was observed in our study (Tab. 1) in one sample from the river mouth. This flagellate species is heterotrophic and possibly mixotrophic and is restricted to warmer waters (HARGRAVES 2002).

Acknowledgemens

The authors are greatly indebted to Prof. Dr. F. Round of the University of Bristol for his valuable comments about some diatom species, to M. Rodilla, S. Falco, I. Romero and R. Martínez for their technical assistance with sampling and to the technicians of the Electronic Microscopy Service of the UPV (Valencia) for their assistance with SEM images. We thank the reviewers, who improved the quality of the manuscript. This project has been financed by European community MAS3-CT98-0170 (DG12-VOMA): PIONEER »Preparation and integration of analysis tools towards operational forecast of nutrients in estuaries of European rivers«.

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