Epilithic diatoms of springs and spring–fed streams in Majorca Island (Spain) with the description of a new diatom species *Cymbopleura margalefii* sp. nov.

Cristina Delgado[1,2]*, Luc Ector[2], Maria Helena Novais[2], Saúl Blanco[3], Lucien Hoffmann[2] & Isabel Pardo[1]

[1] *Departamento de Ecología y Biología Animal, Universidad de Vigo, E–36330 Vigo, Spain; *Corresponding author e–mail: cdelgado.cristina@gmail.com*
[2] *Department of Environment and Agro–biotechnologies (EVA), Public Research Centre – Gabriel Lippmann, Rue du Brill 41, L–4422 Belvaux, Luxembourg*
[3] *Instituto de Medio Ambiente, Universidad de León, E–24071 León, Spain*

Abstract: The Island of Majorca (Spain) is characterized by a Mediterranean climate and a karstic geology that favors the formation of numerous springs and spring–fed streams on the island's Northwester zone. Water and epilithic diatom samples were collected from two springs and four spring–fed streams, located at altitudes ranging from 0 to 756 m a.s.l., in different seasons between 2005 and 2008. Water chemistry in these systems is characterized by high concentrations of dissolved calcium and pH values ranging from 6.6 to 8.4. A total of 111 diatom taxa belonging to 40 genera were found and the most abundant taxa were illustrated with LM and SEM. The diatom communities of the studied sites were dominated by species such as *Achnanthidium minutissimum*, *A. pyrenaicum*, *Amphora pediculus*, *Cymbella vulgata*, *Diploneis separanda*, *Encyonopsis minuta*, *Gomphonema lateripunctatum* and *Navicula cryptotenella*, reflecting the calcareous geological nature of Majorca Island. In the framework of the study 22 diatom taxa, which are new for Balearic Islands were recorded, such as *Achnanthidium straubianum*, *Amphora indistincta*, *Cymbella lange–bertalotii*, *Encyonopsis subminuta*, *Karayevia kolbei*, *Navicula* aff. *margalithii*, *N. reichardtiana* and *N. subalpina*. In addition, a new freshwater diatom species belonging to the genus *Cymbopleura*, *C. margalefii* was found in the Torrente of Deià. *Cymbopleura margalefii* is described as a new species based on LM and SEM observations, and compared with similar taxa. A checklist of the 309 diatom taxa recorded so far from the Balearic Islands is also presented.

Key words: Bacillariophyta, Balearic Islands, diatoms, karstic springs, Mediterranean climate, new species, Serra de Tramuntana

Introduction

Mediterranean streams are subjected to high temporal variation influenced by climatic factors (Sabater et al. 1991) with high rainfall levels occurring in autumn and spring (Pardo & Álvarez 2006). Under the Mediterranean climate, groundwater hydrology is as important as surface hydrology for the persistence and functioning of aquatic ecosystems because a high number of streams are fed by springs. Diatom assemblages are adapted to the local environmental conditions in relation to changes in water residence time and to the variations in the ionic content in water due to variations in flow volume (Aboal et al. 1996). Diatom communities inhabiting springs have been studied in several mountainous regions in Europe, including the Pyrenees (Sabater & Roca 1990, 1992), the mountains of central Germany (Werum & Lange–Bertalot 2004) and the Alps (Cantonati et al. 2006, 2012; Cantonati & Lange–Bertalot 2010; Gesierich & Kofler 2010).

Majorca is the largest of the Balearic Islands that are located in the western part of the Mediterranean Sea. The island is geologically very homogeneous, constituted by calcareous rocks where rainfall water causes karstic erosion and favours water infiltration. Topographically, it is a heterogeneous island with mountainous regions in the Northwest and lowlands in the South. The Tramuntana mountain range extends parallel to the northwest coast and presents geological structures that favour the formation of numerous springs and spring–fed streams. Around 700 springs, all with different sizes and discharge categories, can originate from the limestone rocks (Llobera & Ferriol 1994) where water mineralization is an important feature (Moyá et al. 1991). These systems are geographically isolated and their chemical characteristics and temperature make them an exceptional type of habitat for the study of algae, especially diatoms, organisms that can be considered useful indicators of spring characteristics (Sabater & Roca 1990). The spring is mainly viewed as the origin of a stream and this leads to an investigation of the physical and chemical characteristics and of the composition and structure of the communities (CANTONATI et al. 2006). Many temporary streams in the Balearic Islands have their origin in springs, and constitute refugia for the flora and fauna that colonise the streams when water flow initiates each rainy season (PARDO & ÁLVAREZ 2006). The spring systems in Majorca Island have previously been studied by MOYÁ et al. (1991) and LLOBERA & FERRIOL (1994), but none of these studies have provided information on the diatom flora composition.

Some phycological studies performed in the Balearic Islands reported only some diatom species from Majorca, Minorca and Ibiza (see references in Appendix 1). There are also taxonomic checklists available, including diatom data exclusively from the Balearic Islands (ALVAREZ COBELAS & ESTÉVEZ GARCÍA 1982; CAMBRA et al. 1991; ABOAL et al. 2003). Nevertheless, none of them illustrates the diatom species that appear in the Balearic Islands or provide information about their ecological preferences.

The objectives of this study were: i) to increase the knowledge on the epilithic diatom communities inhabiting springs and spring–fed streams in Majorca Island; ii) to illustrate their most characteristic diatom taxa under light and electron microscopy and iii) to elaborate a checklist with all the diatom taxa identified up to date in the Balearic Islands.

MATERIAL AND METHODS

Study sites. The material included in this study was collected in two springs (Font de s'Olla and Font des Pí) and in four spring–fed streams (Tte. des Prat, Tte. de Son Vic, Tte. de Deià and Son Sant Joan). All sites are located in the Northern part of Majorca Island and have water during most part of the year. Five of them (Font de s'Olla, Font des Pí, Tte. des Prat, Tte. de Son Vic and Tte. de Deià) are located in the Tramuntana mountains at elevations ranging between 55 and 732 m a.s.l. (Fig. 1; Table 1). The Son Sant Joan spring is located at sea level, beside the S'Albufera of Majorca, which is the largest and most important wetland area in the Balearic Islands. It is a former lagoon separated from the sea by a belt of dunes, which for many centuries – but especially in the last two and as a result of human influence – has been filled up with sediments converting it into an extensive flood plain.

Water and epilithic diatom samples were collected in spring–fed streams during spring, autumn and winter between 2005 and 2008. A total of 31 samples were analysed in this study. Spring samples were taken at the same time in the spring–fed streams but only when water was present in these systems (Table 1).

Sampling. Water samples for chemical analysis were collected from running water. Temperature (ºC), pH, dissolved oxygen (mg.l^{-1}) and electric conductivity (µS.cm^{-1}) were measured *in situ* with portable meters. Water temperature and dissolved oxygen were measured with a WTW Oxi 197 oxymeter, conductivity with an Orion Model 115 corrected for 25 ºC, and pH with a Termo Orion 290+. Water samples for chemical analyses were collected into polypropylene bottles and transported chilled to the laboratory. In the field, water velocity was measured using a current meter Probe (Flow probe, model FP101; Global water instrumentation, Gold River, California), as an average of three recordings in one transect of the stream. Flow was estimated multiplying this value by the transect area.

Epilithic diatoms were collected from hard natural substrata (stones), following the European Standard (CEN 2003), with a toothbrush and preserved with a formaldehyde solution (4% v/v) immediately after sampling. Ash free dry mass (AFDM) and chlorophyll *a* (Chl–*a*) were measured from epilithic samples from the upper side of three stones using a toothbrush and rinsed with distilled water. The surface areas of the stones were measured by wrapping them tightly in tin foil (for more information see DELGADO et al. 2012). The samples were stored in ice, kept in darkness and transported to the laboratory. Three samples were used to estimate epilithon biomass as AFDM and the additional three samples were used for the analysis of Chl–*a*.

Laboratory methods. Standard methods for the chemical analysis of water followed APHA (1995). Alkalinity was determined by the potentiometric method; $N–NO_3^-$, SiO_2 and PO_4^{3-} with a nutrient auto–analyzer (Auto–Analyzer 3, Bran + Luebbe, Germany), and ions Ca^{2+}, Mg^{2+}, K^+ and Na^+ with a mass spectrophotometer. Chlorides (Cl^-) and sulphates

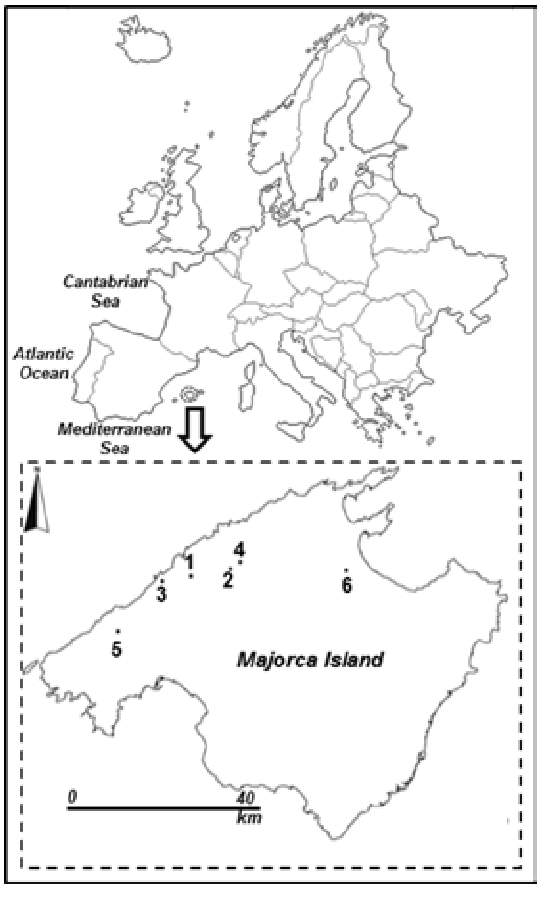


Fig. 1. Location of sampled sites in Majorca Island (Spain): (1) Font de s'Olla ; (2) Font des Pí; (3) Tte. de Deià ; (4) Tte. des Prat; (5) Tte. de Son Vic; (6) Son Sant Joan.

Table 1. Characterization and sampling period of the study sites in Majorca Island.

Site	Site location	Latitude	Longitude	Elevation (m a.s.l.)	Spring			Autumn	Winter	
					2005	2006	2008	2005	2006	2008
Font des Pì	Alaró-Escorça	39º 46‘ 14“ N	2º 48‘ 26“E	470		+	+		+	+
Font de s‘Olla	Soller	39º 45‘ 23“ N	2º 42‘ 42“E	55			+	+	+	+
Tte. des Prat	Escorça	39º 47‘ 01“ N	2º 49‘ 53“E	732	+	+	+	+	+	+
Tte. Son Vic	Puigpunyent	39º 39‘ 12“ N	2º 32‘ 08“E	356	+	+	+	+	+	+
Son Sant Joan	Muro	39º 46‘ 02“ N	3º 05‘ 17“E	0		+	+	+	+	+
Tte. de Deià	Deià	39º 44‘ 49“ N	2º 38‘ 31“E	178	+	+	+	+	+	+

(SO_4^{2-}) were measured with Inductively Coupled Plasma – Mass Spectrometry (ICP–MS).

Samples for chlorophyll–*a* (Chl–*a*) analysis were filtered through glass fiber filters and extracted with acetone for 48 h at 4 ºC in the dark. After extraction, Chl–*a* was measured spectrophotometrically (Hitachi Model U–2001 UV/Visible Spectrophotometer) and corrected (Lorenzen 1967). Three periphyton samples were filtrated and dried until constant weight (DM) at 70 ºC and ashed at 500 ºC for 2 hours to determine the ash free dry mass (AFDM).

Diatom analysis. Diatom samples were treated to obtain a suspension of clean frustules. Organic matter was eliminated using hydrogen peroxide (33%) and HCl (37%) was added to remove the calcium carbonate (Renberg 1990). Finally, after rinsing with distilled water, permanent slides were mounted using Naphrax®, a synthetic mounting medium with high refractive index. Diatoms were identified to species or subspecific levels using a Leica® DMRX light microscope (LM) with a 100× oil immersion objective and light microscopy photographs were taken with a Leica® DC500 camera. At least 400 valves were identified and counted from each slide to estimate the relative abundance of each taxon. Diatom samples for scanning electron microscopy analysis were filtered through polycarbonate membrane filters with a pore diameter of 3 µm, mounted on stubs, sputtered with gold (40 nm) with Modular High Vacuum Coating System (BAL–TEC MED 020) and studied with a Leica® Stereoscan 430i electron microscope, operated at 20 kV. Micrographs were digitally manipulated and plates containing LM and SEM pictures were mounted using CorelDRAW X5.

Diatoms were identified to the lowest taxonomical level according to usual current taxonomic literature, e.g. Krammer & Lange–Bertalot (1986–1991, 2004), Simonsen (1987), Lange–Bertalot & Krammer (1989), Lange–Bertalot (1993, 1999, 2001), Lange–Bertalot & Moser (1994), Krammer (1997a, b, 2002), Witkowski et al. (2000), Tuji & Houki (2004), Werum & Lange–Bertalot (2004), Levkov (2009), Levkov et al. (2010), Żelazna–Wieczorek (2011) and Trobajo et al. (2013).

New floristic records were determined checking the references of the phycological studies from the Balearic Islands since 1889 and also the diatom checklist with records from the Balearic Islands (Alvarez Cobelas & Estévez García 1982; Cambra et al. 1991; Aboal et al. 2003) (Appendix 1).

Results and Discussion

Physical and chemical characterization of studied sites

Benthic communities found in the Majorcan streams are influenced by different factors, such as orography, pronounced seasonal irregularity in rainfall levels and predominance of the karstic geology (Pardo & Álvarez 2006). Calcium concentrations are high in the studied streams because of the dissolution of the calcareous substratum, ranging from 22.9 to 151.4 mg.l^{-1} (Table 2). In consequence water pH was neutral to alkaline (from 6.6 to 8.4). Water temperature ranged annually between 12.5 and 19.1 ºC, indicating high temperature stability in five of these systems, except for Tte. des Prat. This site showed the largest annual fluctuation (9.4 to 25.2 ºC), attributed to its mountainous location at 732 m a.s.l. The studied sites with higher values of SiO_2 were Tte. de Son Vic and Son San Joan, with mean values around 5 mg.l^{-1} (Table 2). Son San Joan showed the highest $N–NO_3$ and chlorophyll–*a* mean values with respect to other studied sites, while SO_4^{2-} has mean values ranged between 74.0 to 139.5 mg.l^{-1} in most sites, except for Font des Pí that has the lowest mean value 28.0 mg.l^{-1}. Tte. de Deià showed the highest AFDM mean values (29.4 g.m^{-2}) with respect to other sites.

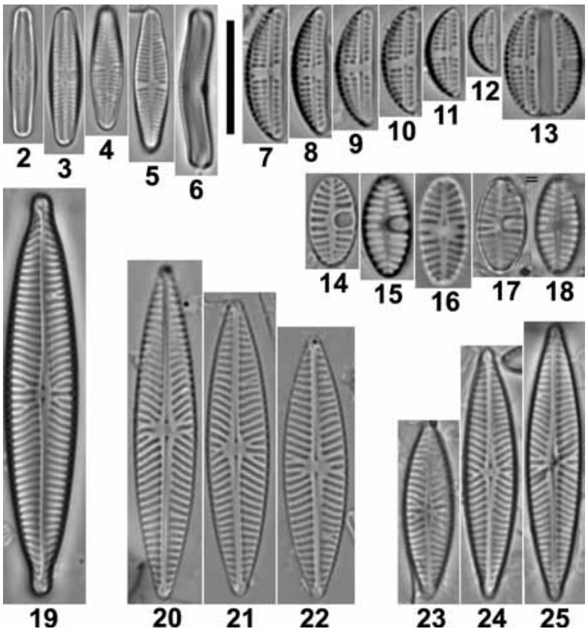
Son San Joan also showed high values of water flow, electric conductivity, Cl^-, K^+, Mg^{2+}, Na^+, $N–NO_3^-$ and SO_4^{2-} attributed to its location near to the sea and beside the S'Albufera that has a high human influence in the last two decades, with large increase of agricultural activities in the area.

Diatom assemblages

A total of 111 diatom taxa belonging to 40 genera were identified in this study, but only 19 species represented more than 5% in at least one sample (Table 3, in bold). These and other diatom taxa which characterized some sites, including new records for the Balearic Islands, were illustrated under LM and SEM (Figs 2–204). The diatom assemblages of the studied sites were characterized by high taxa richness especially within

Table 2. Range, average (AVG) and standard deviation (STD) values of physical, chemical, chlorophyll–*a* and AFDM data from the study sites. AFDM: Ass - free dry mass.

	Font des Pí (n=4)		Font de s'Olla (n=4)		Tte. des Prat (n=6)		Tte. Son Vic (n=6)		Son Sant Joan (n=5)		Tte. de Deià (n=6)	
	Range	AVG ± STD	Range	AVG ± STD	Range	AVG ± STD	Range	AVG ± STD	Range	AVG ± STD	Range	AVG ± STD
Temperature (ºC)	12.5 - 15.0	13.3 ± 1.2	15.6 - 18.8	16.5 ± 1.6	9.4 - 25.2	15.3 ± 6.4	14.4 - 17.2	15.7 ± 1.1	15.4 - 19.1	17.7 ± 1.5	14.9 - 18.3	16.6 ±1.4
Conductivity ($\mu S.cm^{-1}$)	328.5 - 495.0	406.4 ± 69.3	440 - 621.5	559.4 ± 83.5	518.3 - 817.8	635.5 ± 110.0	791.0 - 1532.1	962.1 ± 290.6	2110 - 3084	2426.8 ± 383.9	472.0 -725.1	578.2 ± 102.1
pH	6.6 - 8.1	7.4 ± 0.6	7.2 - 8.2	7.6 ± 0.4	8.0 - 8.4	8.2 ± 0.1	6.9 - 7.9	7.3 ± 0.4	6.9 - 7.4	7.2 ± 0.2	7.4 -8.4	8.1 ± 0.4
Dissolved oxygen ($mg.l^{-1}$)	8.4 - 10.5	9.3 ± 1.0	9.0 - 16.7	11.4 ± 3.7	9.2 - 10.7	9.8 ± 0.6	1.9 - 7.3	4.7 ± 2.0	7.2 - 8.5	7.7 ± 0.5	8.2 - 10.0	9.1 ± 0.7
Water flow ($l.s^{-1}$)	0 - 135.0	33.7 ± 67.5	0.0 - 42.2	26.0 ± 18.7	0.0 - 47.5	8.5 ± 19.1	0.0 - 16.6	5.7 ± 6.9	0.0 - 262.3	150.0 ± 103.1	0.0 - 110.9	20.8 ± 44.4
Chlorophyll-*a* ($mg.m^{-2}$)	1.4 - 16.6	9.2 ± 6.2	0.9 - 62.4	17.5 ± 30.0	3.5 - 18.8	7.8 ± 5.9	0.4 - 70.2	21.8 ± 25.6	10.0 - 49.3	31.4 ± 15.4	6.7 - 31.4	16.1 ± 9.3
AFDM ($g.m^{-2}$)	1.2 - 18.1	8.6 ± 7.5	1.0 - 18.9	7.8 ± 8.6	4.9 - 18.0	9.4 ± 5.0	4.5 - 43.1	14.8 ± 14.9	7.5 - 16.5	11.5 ± 4.1	4.9 - 48.8	29.4 ± 19.5
Alkalinity ($meq.l^{-1}$)	4.1 - 6.8	5.3 ± 1.2	4.3 - 6.1	5.4 ± 0.9	4.0 - 6.9	5.3 ± 1.2	6.2 - 10.1	8.2 ± 1.5	4.6 - 7.0	5.5 ± 1.0	3.5 - 6.8	4.9 ± 1.1
SO_4^{2-} ($mg.l^{-1}$)	13.6 - 38.4	28.0 ± 11	56.6 - 100.4	74.0 ± 18.8	87.0 - 183.5	139.5 ± 31.1	76.9 - 116.6	95.5 ±13.7	112.3 - 140.3	127.4 ± 11.5	21.4 - 106.1	82.3 ± 30.6
N-NO_3^- ($mg.l^{-1}$)	0.1 - 0.8	0.5 ± 0.5	0.2 - 0.4	0.3 ± 0.2	0.0- 0.7	0.2 ± 0.3	0.1 - 1.4	0.5 ± 0.6	1.7 - 20.1	9.6 ± 9.5	0.2 - 0.6	0.4 ± 0.2
SiO_2 ($mg.l^{-1}$)	1.4 - 2.5	1.9 ± 0.5	2.0 - 2.4	2.2 ± 0.2	1.9 - 3.9	2.7 ± 0.9	2.1 - 12.1	5.0 ± 3.6	2.5 - 6.2	4.6 ± 1.5	1.7 - 4.4	2.7 ± 0.9
Ca^{2+} ($mg.l^{-1}$)	43.5 - 81.2	61.3 ± 19.8	49.6 - 97.5	64.5 ± 22.2	39.1 - 128.4	93.1 ± 32.8	54.7 - 151.4	85.2 ± 35.6	61.8 -115.0	74.3 ± 22.5	22.9 - 100.7	62.1 ± 25.9
Cl^- ($mg.l^{-1}$)	15.7 - 185.7	59.9 ± 83.9	24.1 - 25.7	24.7 ± 0.8	21.4 - 57.8	30.9 ± 13.6	39.5 - 352.1	100.6 ± 123.7	156.5 - 846.5	379.9 ± 274.1	18.7 - 373.9	86.7 ± 140.9
K^+ ($mg.l^{-1}$)	0.5 - 1.0	0.8 ± 0.2	0.4 - 1.6	1.0 ± 0.5	0.4 - 1.9	1.1 ± 0.5	0.8 - 3.3	1.9 ± 0.8	7.5 -18.9	11.8 ± 5.4	0.5 - 1.8	1.1 ± 0.5
Mg^{2+} ($mg.l^{-1}$)	6.3 - 13.0	9.9 ± 3.6	8.2 - 22.5	13.4 ± 6.5	19.2 - 43.2	33.0 ± 9.3	13.2 - 39.3	29.6 ± 10.0	28.9 - 68.5	54.0 ± 17.8	11.9 - 23.4	18.6 ± 4.9
Na^+ ($mg.l^{-1}$)	9.7 - 13.2	11.0 ± 1.5	11.6 - 17.0	13.9 ± 2.5	6.6 - 24.7	15.5 ± 6.7	13.9 - 39.0	24.9 ± 9.4	163.5 - 410.7	252.6 ± 110.5	9.2 - 25.3	17.5 ± 6.5



Figs 2–25. LM: (2–6) *Achnanthidium minutissimum* (Kützing) Czarnecki. Tte. des Prat 15/05/06; (7–13) *Amphora pediculus* (Kützing) Grunow ex A. Schmidt, Son Sant Joan 25/05/06; (14–18) *Planothidium frequentissimum* (Lange–Bertalot) Lange–Bertalot, Font de s'Olla 13/12/05; (19) *Navicula subalpina* E. Reichardt, Font des Pí 13/05/06; (20–22) *Navicula cryptotenella* Lange–Bertalot, Tte. de Son Vic 19/05/05; (23–25) *Navicula wygaschii* Lange–Bertalot, Son San Joan 12/03/2006. Scale bar 10 µm.

the genera *Gomphonema*, *Navicula* and *Nitzschia* as in studies carried out in different springs in the Alps (Cantonati et al. 2006; Gesierich & Kofler 2010). Only three taxa appeared in all localities: *Achnanthidium minutissimum* (Kützing) Czar-necki *sensu lato* (Figs 2–6) showing high abundance in all samples, *Amphora pediculus* (Kützing) Grunow ex A. Schmidt (Figs 7–13) and *Navicula cryptotenella* Lange–Bertalot (Figs 20–22) (Table 3). However, the most frequent taxon found in this study was *A. minutissimum* sensu lato, which is a common cosmopolitan component of the benthic diatom communities and is also abundant in the streams of Majorca (Delgado et al. 2012) and in Alpine springs (Gesierich & Kofler 2010). *Planothidium frequentissimum* (Lange–Bertalot) Lange–Bertalot (Figs 14–18), *Gomphonema micropus* Kützing and *Nitzschia inconspicua* Grunow appeared in this study in waters with the highest values of chlorophyll *a* and AFDM, whereas *Gomphonema lateripunctatum* E. Reichardt et Lange–Bertalot, *Fragilaria* sp. and *Encyonopsis krammeri* E. Reichardt occured with values of dissolved calcium above 80 mg.l^{-1}.

Spring–fed streams

The Son Sant Joan spring had the most singular diatom community, with high abundances of *Achnanthidium minutissimum*, *Amphora pediculus* (Figs 7–13), *Navicula* aff. *margalithii* Lange–Bertalot (Figs 26–28), *Nitzschia inconspicua* (Figs 41–51) and *Rhoicosphenia abbreviata* (C. Agardh) Lange–Bertalot (Figs 29–31). Noticeable was the presence of *Navicula wygaschii* Lange–Bertalot (Figs 23–25), *Amphora indistincta* Levkov (Figs 39–40), *A. ovalis* (Kützing) Kützing, *Karayevia kolbei* (Hustedt) Bukhtiyarova (Figs 32–38), *Encyonopsis* sp. 2, *Achnanthes coarctata* (Brébisson ex W. Smith) Grunow and *A. brevipes* var. *intermedia* (Kützing) Cleve (Figs 52–57), species recorded only in this locality, usually related with brackish wetlands in Italy (Della Bella et al. 2007). These records reinforce the idea that this community is influenced by marine water, in agreement with the high conductivity values found (mean values of 2427 µS.cm^{-1}) (Table 2). According to Trobajo et al. (2013), *Nitzschia inconspicua* extends from freshwater into brackish and marine water. *Nitzschia inconspicua* and *Navicula* aff. *margalithii* appeared under high conductivities such as the waters at this site, and *N.* aff. *margalithii* and *Rhoicosphenia abbreviata* also associated with the highest values of nitrates. Son Sant Joan spring rises at sea level presenting the highest conductivity and concentrations of sodium and chlorine ions, attributed to sea proximity influence. In Son Sant Joan the value of $N–NO_3^-$ was above 20 mg.l^{-1} (Table 2), which is related to the subterranean input of nutrients from agricultural surrounding areas of the S'Albufera de Majorca. Some springs in Sardinia Island also host diatom assemblages under high to very high electric conductivities values and strong alkaline conditions (Lange–Bertalot et al. 2003). *Navicula wygaschii* (Figs 23–25) is reported for the first time out of its type locality (Thüler Moorkomplex, Germany).

Tte. de Son Vic had high percentages of *Navicula cryptotenella*, *Diploneis separanda* Lange–Bertalot (Figs 58–64), originally described from German springs by Werum & Lange–Bertalot (2004), and *Nitzschia denticula* Grunow (Figs 65–68) in autumn. The occurrence of *Brachysira vitrea* (Grunow) R. Ross (Figs 76–79), *Eunotia arcubus* Nörpel et Lange–Bertalot (Figs 69–72) and *Cymbella affinis* Kützing (Figs 73–75) is remarkable. *Cymbella affinis* is a cosmopolitan taxon particularly abundant in alkaline waters, preferring waters with high electrolyte content (Krammer 2002), that many authors have previously misidentified as *C. tumidula* Grunow. Our photographs of *C. affinis* (Figs 74, 75) fit well with the light microscope photographs from England, France, Germany and Serbia published in Krammer (2002) but not with SEM photographs from West Germany and New Zealand in Krammer (2002) where the valves have slightly radiate and finely punctuate striae (Fig. 73). In Tte. de Son Vic, dissolved oxygen concentration reached a minimum value of 1.9 mg.l^{-1} in autumn, attributed to slow water flow and high leaf litter accumulation (Table 2). *Achnanthidium straubianum* (Lange–Bertalot) Lange–Bertalot (Figs 80–91; 96–98) and *Fragilaria* sp. (Figs 92–95) are two taxa with percentages of abundance above 5% in Tte. de Son

Table 3. List of taxa identified in the studied sites. Percentage of abundance of each taxa: (1) rare, <1.5%; (2) frequent, 1.5–5%; (3) abundant, >5%. Bold: taxa with relative abundance above 5% at least in one site.

Taxa	Font des Pí	Font de s'Olla	Tte. des Prat	Tte. Son Vic	Son Sant Joan	Tte. de Deià
Achnanthes brevipes var. *intermedia* (Kützing) Cleve					1	
Achnanthes coarctata (Brébisson ex W. Smith) Grunow					1	
Achnanthes parvula Kützing					1	
Achnanthes sp. 1					1	
Achnanthes sp. 2	1				1	
***Achnanthidium minutissimum* (Kützing) Czarnecki**	3	3	3	3	3	3
***Achnanthidium pyrenaicum* (Hustedt) H. Kobayasi**	3	1	2	2		3
Achnanthidium straubianum (Lange-Bertalot) Lange--Bertalot			1	2		
Achnanthidium thermale Rabenhorst						2
Achnanthidium sp.			1			
Adlafia bryophila (J.B. Petersen) Gerd Moser, Lange--Bertalot et Metzeltin			1		1	2
Amphora indistincta Levkov					2	2
Amphora libyca Ehrenberg				1		
Amphora ovalis (Kützing) Kützing		1			2	
***Amphora pediculus* (Kützing) Grunow**	2	3	1	2	3	3
Bacillaria paxillifera (O.F. Müller) Hendey					1	
Brachysira vitrea (Grunow) R. Ross	1			2		
Caloneis lancettula (Schulz) Lange-Bertalot et Witkowski	1	2	1	1	1	2
Caloneis sp.			1	1		1
Cocconeis euglypta Ehrenberg		2		2	2	1
Cocconeis lineata Ehrenberg	1		1			
Craticula halophila (Grunow ex Van Heurck) D.G. Mann				1		
Cymbella affinis Kützing			1	2		
Cymbella lange-bertalotii Krammer			2			
***Cymbella vulgata* Krammer**	1	2	3	1	2	3
Cymbopleura margalefii sp. nov.			1			2
Denticula subtilis Grunow		1				
***Denticula tenuis* Kützing**	3	1	2			
***Diadesmis contenta* (Grunow ex Van Heurck) D.G. Mann**	3	3				
Diploneis elliptica (Kützing) Cleve				1		1

Table 3 Cont.

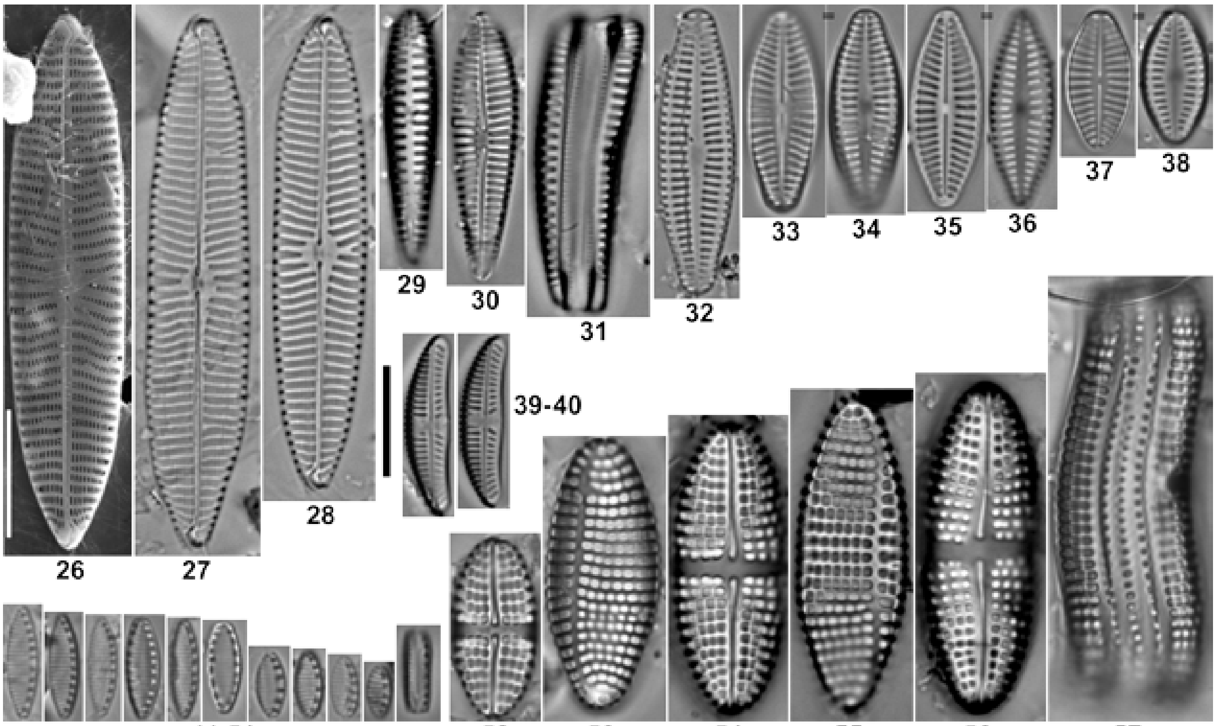
Diploneis krammeri Lange-Bertalot et E. Reichardt		1				1
Diploneis ovalis (Hilse) Cleve		1				1
***Diploneis separanda* Lange-Bertalot**	2		1	3		2
Diploneis sp.		1		1		1
Encyonema minutum (Hilse) D.G. Mann	2					
Encyonopsis cesatii (Rabenhorst) Krammer			1			
***Encyonopsis krammeri* E. Reichardt**	3		2			
***Encyonopsis minuta* Krammer et E. Reichardt**		1	3	3		3
Encyonopsis subminuta Krammer et E. Reichardt	1		1			
Encyonopsis sp. 1			1			
Encyonopsis sp. 2					2	
Eolimna minima (Grunow) Lange-Bertalot	1	2		1	1	1
Eolimna subminuscula (Manguin) Gerd Moser, Lange-Bertalot et Metzeltin		1				
Epithemia adnata (Kützing) Brébisson	1		2			
Eunotia arcubus Nörpel et Lange-Bertalot				2		
Fallacia pygmaea (Kützing) Stickle et D.G. Mann					1	
Fragilaria aff. *rumpens* (Kützing) G.W.F. Carlson	1		2	1		
Fragilaria vaucheriae (Kützing) J.B. Petersen		1	1			
***Fragilaria* sp.**				3		
Frustulia sp.			1			
Gomphonema bavaricum E. Reichardt et Lange-Bertalot			1			
Gomphonema gracile Ehrenberg	1	1		1		1
***Gomphonema lateripunctatum* E. Reichardt et Lange-Bertalot**	1		3	3		
***Gomphonema micropus* Kützing**	2	1	1	3		1
Gomphonema minutum (C. Agardh) C. Agardh	1					
Gomphonema olivaceum (Hornemann) Brébisson		1				
Gomphonema parvulum Kützing	2		1	1		1
Gomphonema pumilum (Grunow) E. Reichardt et Lange-Bertalot	2	1	2	2		2
Gomphonema rosenstockianum Lange-Bertalot et E. Reichardt		1	1	2		
Gomphonema truncatum Ehrenberg				1		
Gomphonema sp.	1	1	1	1	1	1
Halamphora coffeaeformis (C. Agardh) Levkov		1	1	1		
Halamphora montana (Krasske) Levkov	1					
Halamphora veneta Kützing				1		
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin et Witkowski					1	

Table 3 Cont.

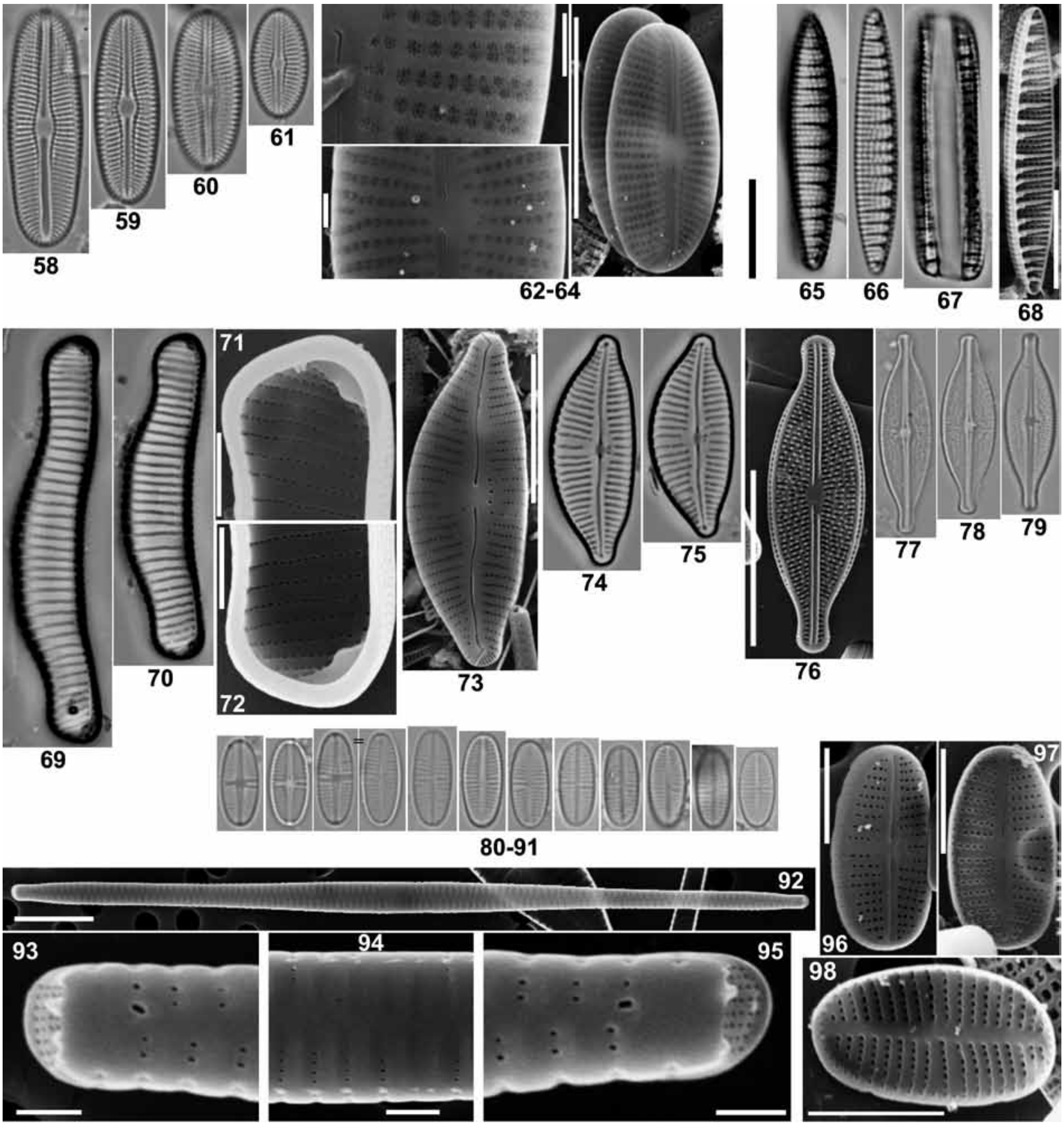
Karayevia kolbei (HUSTEDT) BUKHTIYAROVA					2	
Luticola mutica (KÜTZING) D.G. MANN		1				
Meridion circulare (GREVILLE) C. AGARDH	2	1	2	2		
Navicula antonii LANGE-BERTALOT et RUMRICH	1			1		1
***Navicula cryptotenella* LANGE-BERTALOT**	2	1	2	3	2	2
Navicula cryptotenelloides LANGE-BERTALOT	1		1			1
Navicula cryptocephala KÜTZING	1			2		
Navicula gregaria DONKIN		1		1	1	
Navicula lanceolata (C. AGARDH) KÜTZING					1	
Navicula leptostriata E.G. JØRGENSEN			1	1		
***Navicula* aff. *margalithii* LANGE-BERTALOT**					3	
Navicula radiosa KÜTZING				2		
***Navicula reichardtiana* LANGE-BERTALOT**	3					
Navicula subalpina E. REICHARDT	1					
Navicula tripunctata (O.F. MÜLLER) BORY		1	1		2	
Navicula veneta KÜTZING	1	1	1	1	1	1
Navicula wygaschii LANGE-BERTALOT					2	
Navicula sp. 1			1	1		1
Navicula sp. 2	1			1	1	2
Nitzschia amphibia GRUNOW		1		2	1	1
Nitzschia bacillum HUSTEDT	1	1				
***Nitzschia denticula* GRUNOW**				3		
Nitzschia dissipata (KÜTZING) GRUNOW	1		1			1
Nitzschia fonticola (GRUNOW) GRUNOW		1	1			
Nitzschia frustulum (KÜTZING) GRUNOW			1	1	1	
***Nitzschia inconspicua* GRUNOW**	2	1			3	1
Nitzschia lacuum LANGE-BERTALOT	1		1			
Nitzschia palea (KÜTZING) W. SMITH				1		1
Nitzschia recta HANTZSCH ex RABENHORST				1		1
Nitzschia sigmoidea (NITZSCH) W. SMITH	1					
Nitzschia tabellaria (GRUNOW) GRUNOW			1			
Nitzschia sp.					1	1
Pinnularia sp.				1		
Planothidium dubium (GRUNOW) ROUND et BUKHTIYAROVA					1	
***Planothidium frequentissimum* (LANGE-BERTALOT) LANGE-BERTALOT**	1	3		2	1	1
Planothidium lanceolatum (BRÉBISSON ex KÜTZING) LANGE-BERTALOT		1		1		
Pseudostaurosira brevistriata (GRUNOW) D.M. WILLIAMS et ROUND		1			1	

Table 3 Cont.

Reimeria sinuata (Gregory) Kociolek et Stoermer	1					
***Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot**	1	2			3	
Rhopalodia gibba (Ehrenberg) O.F. Müller			1			1
Sellaphora seminulum (Grunow) D.G. Mann		1		1		
Sellaphora stroemii (Hustedt) H. Kobayasi		1		1		3
Tabularia fasciculata (C. Agardh) D.M. Williams et Round					2	
Tryblionella apiculata W. Gregory				1		
Ulnaria acus (Kützing) Aboal			1	1		
Ulnaria ulna (Nitzsch) Compère	1	1		2		2



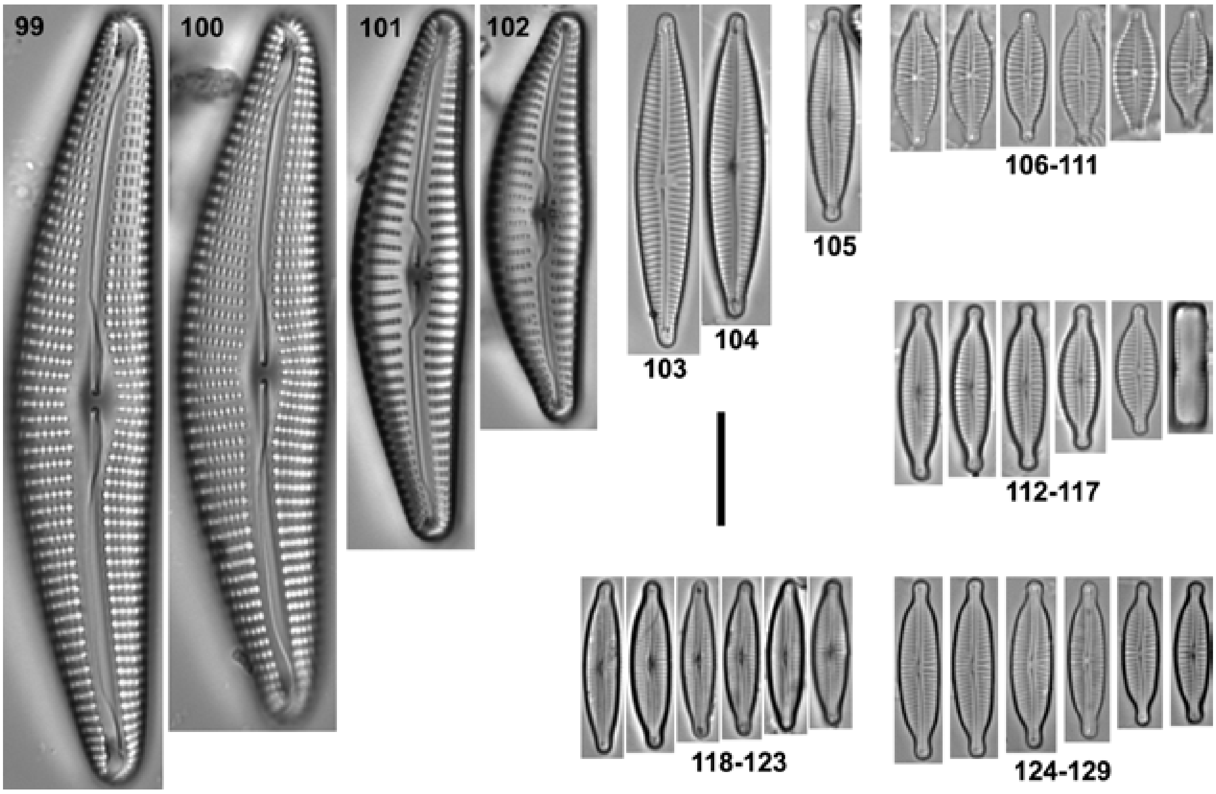
Figs 26–57. SEM and LM: (26–28) *Navicula* aff. *margalithii* Lange–Bertalot, Son Sant Joan 12/03/06; (29–31) *Rhoicosphenia abbreviata* (C. Agardh) Lange–Bertalot, Son Sant Joan 23/05/06; (32–38) *Karayevia kolbei* (Hustedt) Bukhtiyarova, Son Sant Joan 25/05/06; (39–40) *Amphora indistincta* Levkov, Son San Joan 23/05/06; (41–51) *Nitzschia inconspicua* Grunow, Son Sant Joan 13/03/06; (52–57) *Achnanthes brevipes* var. *intermedia* (Kützing) Cleve, Son Sant Joan 12/03/06. Scale bar 10 µm.



Figs 58–98. LM and SEM: (58–64) *Diploneis separanda* LANGE–BERTALOT, Tte. de Son Vic 06/11/05 ; (65–68) *Nitzschia denticula* GRUNOW, Tte. de Son Vic 6/11/05; (69–72) *Eunotia arcubus* NÖRPEL et LANGE–BERTALOT, Tte. de Son Vic 19/05/05; (73–75) *Cymbella affinis* KÜTZING, Tte. de Son Vic 19/05/05; (76–79) *Brachysira vitrea* (GRUNOW) ROSS, Tte. de Son Vic 19/05/05; (80–91, 96–98) *Achnanthidium straubianum* (LANGE–BERTALOT) LANGE–BERTALOT, Tte. de Son Vic 06/11/05; (92–95) *Fragilaria* sp., Tte de Son Vic 19/05/05. LM scale bar 10 µm, SEM scale bars 10 µm (Figs 64, 68, 73, 76, 92), 5 µm (Figs 62–63, 96–98), 1 µm (Figs 71–72, 93–95).

Vic. *Achnanthidium straubianum* also appear in Tte. des Prat and is one of the new citations for the Balearic Islands (Appendix 1).

Tte. des Prat is characterized by the presence of *Achnanthidium pyrenaicum* (HUSTEDT) H. KOBAYASI, *Cymbella vulgata* KRAMMER (Figs 101–102; 151–154), *Diploneis separanda*, *Gomphonema lateripunctatum* (Figs 130–135; 150) and different species of *Encyonopsis* (Figs 103–129). *Cymbella vulgata* was recently found also in freshwaters in Lluc, Majorca (KRAMMER 2002). Different species of the genus *Encyonopsis*, formerly grouped under the *Cymbella microcephala* GRUNOW complex, and separated by KRAMMER (1997b), were identified in this locality indicating similarity in the ecological tolerance of these species. *Encyonopsis minuta* KRAMMER et E. REICHARDT (Figs 160; 163–164) is the most abundant taxon and appeared together with *E. cesatii* (RABENHORST) KRAMMER (Figs 155–158), *E. krammeri*, *E. subminuta* KRAMMER et E. REICHARDT (Figs 142–144) and *Encyonopsis* sp. 1 (Figs 147–149). *Gomphonema lateripunctatum* is a highly alkaliphilous species of mountain and lowland watercourses and is



Figs 99–129. LM: (99–100) *Cymbella lange–bertalotii* Krammer, Tte. des Prat 25/05/05; (101–102) *Cymbella vulgata* Krammer, Tte. des Prat 15/05/06; (103–104) *Encyonopsis cesatii* (Rabenhorst) Krammer, Tte. des Prat 25/05/05; (105) *Encyonopsis subminuta* Krammer et E. Reichardt, Tte. des Prat 25/05/05; (106–111) *Encyonopsis* sp. 2, Son Sant Joan 12/03/06; (112–117) *Encyonopsis minuta* Krammer et E. Reichardt, Tte. de Son Vic 19/05/05; (118–123) *Encyonopsis krammeri* E. Reichardt, Font des Pí 13/05/06; (124–129) *Encyonopsis minuta* Krammer et E. Reichardt, Tte. des Prat 25/05/05. Scale bar 10 µm.

commonly found in calcareous Mediterranean rivers (Gomà et al. 2004; Farrés et al. 2007). *Cymbella lange–bertalotii* Krammer (Figs 99–100; 166–169) was identified in two seasons, and our photographs fit with the specimens from Austria, Germany, Hungary and Russia presented by Krammer (2002). Although this species is very similar to *Cymbella helvetica* Kützing and *C. subhelvetica* Krammer, its frustules are smaller than in *C. helvetica* and wider than in *C. subhelvetica*.

Tte. de Deià had high percentages of *Achnanthidium minutissimum*, *A. pyrenaicum* and *Encyonopsis minuta*, and had similar values of electric conductivity, calcium, potassium, chlorine and sodium to Tte. des Prat (Table 2). The most remarkable fact is the presence of an undescribed species of the genus *Cymbopleura* that also appeared in Tte. des Prat.

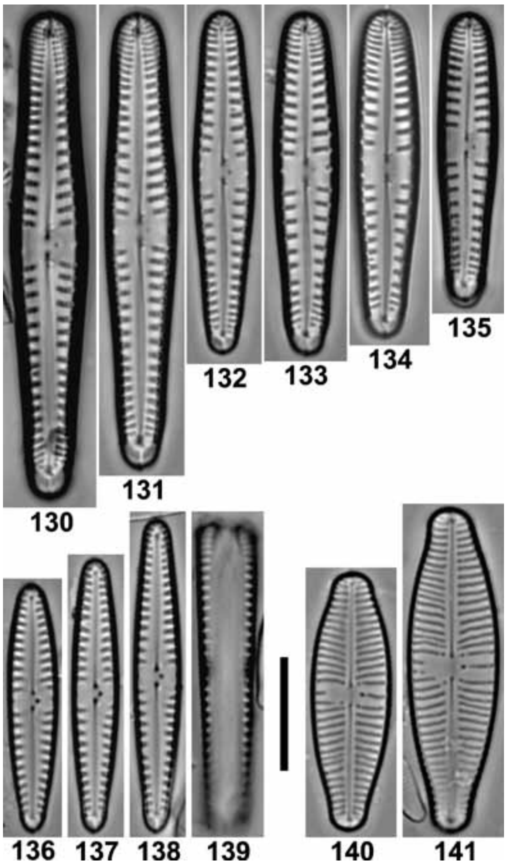
Springs

The two springs studied, Font des Pí and Font de s'Olla, were sampled in four dates (Table 1). The benthic diatom community at Font des Pí was dominated by *Denticula tenuis* Kützing, *Encyonopsis krammeri*, *Achnanthidium pyrenaicum* (Figs 170–179; 189–190), *A. minutissimum*, *Diadesmis contenta* (Grunow ex Van Heurck) D.G. Mann and *Navicula reichardtiana* Lange–Bertalot (Figs 184–188). The presence of a new species for the Balearic Islands such as *Navicula subalpina* E. Reichardt (Fig. 19) is also remarkable.

Font de s'Olla was dominated by *A. minutissimum*, *Diadesmis contenta* (Figs 180–183) and *Planothidium frequentissimum* (Figs 14–18) in November, while in March the community was dominated by *A. minutissimum*. *Diadesmis contenta*, a typical aerophilous taxon, was present in both springs indicating seasonal dryness in these systems (Cantonati et al. 2006; Gesierich & Kofler 2010).

Taxonomic section

Four species that did not fit well with the species already described in the literature were found: *Cymbopleura* sp., *Encyonopsis* sp. 1, *Encyonopsis* sp. 2 and *Fragilaria* sp., but description of new taxa, based only on one or a very few cells, has been criticized. We are also considering this approach to be unproductive and possibly erroneous by omitting the whole range of morphological variation from the population in question. For this reason we propose only one new species of the genus *Cymbopleura* in this study and we used the material of the Tte. de Deià, where this species was more abundant.



Figs 130–141. LM : (130–135) *Gomphonema lateripunctatum* E. REICHARDT et LANGE–BERTALOT, Tte. des Prat 15/05/06; (136–139) *Gomphonema pumilum* (GRUNOW) E. REICHARDT et LANGE–BERTALOT, Font de s'Olla 13/03/06 ; (140–141) *Gomphonema micropus* KÜTZING, Font de s'Olla 13/03/06; Scale bar 10 µm.

Cymbopleura margalefii C. DELGADO, NOVAIS, S. BLANCO et ECTOR sp. nov., Figs 191–199 (LM), Figs 200–204 (SEM)

Diagnosis: Valvae distincte dorsiventrales latae asymmetrice elliptico–lanceolatae, marginibuse dorsali arcuata, margine ventrali leviter convexa, apicibus late rotundatis. Longitudo 19–37 µm, latitudo 6.5–9.0 µm, ratio longitudo/latitudo circiter 2.7–4.4. Area axialis angusta curvata leviter ventraliter locata. Raphe distincte lateralis filiformis ad apices, reverse–lateralis ad aream centralem. Extrema proximalia leviter expansa ad poros centrales. Fissurae terminales dorsaliter deflexae. Striae dorsales 11–12 in 10 µm in medio, usque ad 13 ad apices. Puncta 40–45 in 10 µm. Species nova dedicata est ad honorem Prof. Dr. Ramón Margalef (1919–2004) vir illustris in scientia hydrobiologica.

Locus typicus: Deià torrentis, Maiorica Insula, Hispania (39º44'49''N; 2º38'31''E). Coll. Cristina Delgado in 22/05/2006.

Description: Valves distinctly dorsiventral, broad, asymmetrically elliptical–lanceolate, with arcuate dorsal margin and slightly convex ventral margin, ends obtusely rounded. Length 19–37 µm, width 6.5–9.0 µm, length/width ratio varying between 2.7 and 4.4; striae in the middle portion (dorsal) 11–12/10 µm, up to 13 towards the ends and puncta 40–45 in 10 µm (Table 4). Axial area narrow, curved, slightly ventrally displaced. Raphe distinctly lateral, narrowing towards the distal ends, appearing reverse–lateral near the proximal ends and terminal fissures dorsally deflected.

Etymology: The new species is dedicated to Prof. Dr. Ramón Margalef (Barcelona, 1919–2004), in recognition of his extraordinary contributions to the limnological studies in the Balearic Islands.

Holotype (hoc designatus): National Botanic Garden, Meise, Belgium (BR–4198).

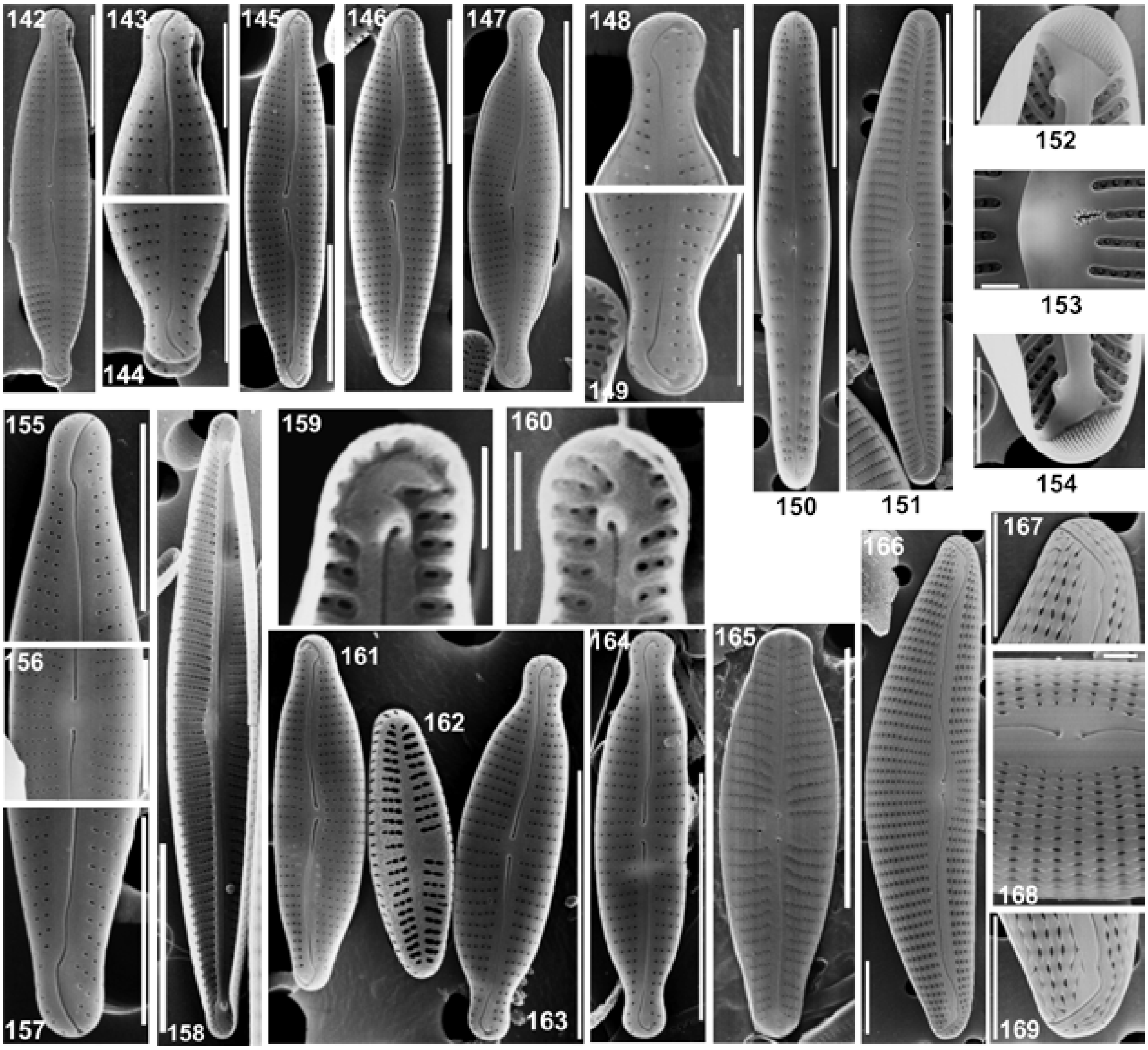
Isotype: British Museum of Natural History, London (BM–101403).

This new species was already described in DELGADO (2011). Since this dissertation does not include an ISBN, the name of any printer, publisher or distributor, or any statement that it was intended to be effectively published under the requisites of the ICN (see art. 30.8) the description provided in this paper thus validates this taxon.

Differential diagnosis: The new species is distinguished from the other taxa of the *Cymbopleura austriaca* (GRUNOW) KRAMMER group by outline, length and width (Table 4). KRAMMER (2003) defined this group as presenting smaller valves with rhomboid–lanceolate outline and strongly reverse–lateral raphe. The valves of *Cymbopleura margalefii* may be confused, in the first instance, with *C. laeviformis* KRAMMER or *C. pyrenaica* LE COHU et LANGE–BERTALOT; nevertheless these species have a different outline and size (see KRAMMER 2003; LE COHU et al. 2011). *Cymbopleura margalefii* is smaller and narrower than *C. korana* KRAMMER, *C. rhomboidea* var. *angusta* KRAMMER and *C. laeviformis*, with also denser puncta than the latter species (Table 4). Even though *C. margalefii* has a similar range of size as *C. pyrenaica*, the new species presents denser striae, coarser areolae and different shape of the areolae in both external and internal views (Table 4).

Distribution: Thus far, only reported from alkaline and eutrophic springs in Majorca Island (Spain).

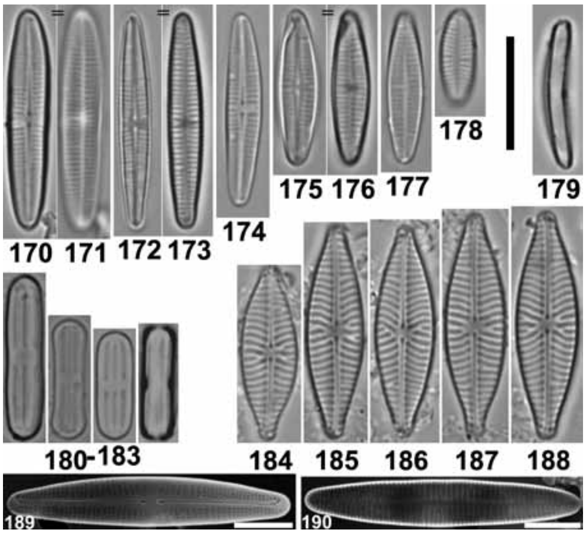
New records: According to biogeographical theories, lower taxa richness is expected in isolated ecosystems such as islands. This is the case of the Hawaiian Islands, where the freshwater diatom flora is species poor and contains only 1.3% of endemic taxa (FUNGLADDA et al. 1983). However, islands frequently exhibit unusual diatom communities (e.g. MOSER et al. 1998; METZELTIN & LANGE–BERTALOT 2000). From a biogeographical point of view, the described diatom communities show low floristic singularities with respect to those described in the Iberian Peninsula and comparable European regions. After the revision of the bibliography and with the data collected during the present study, we can state



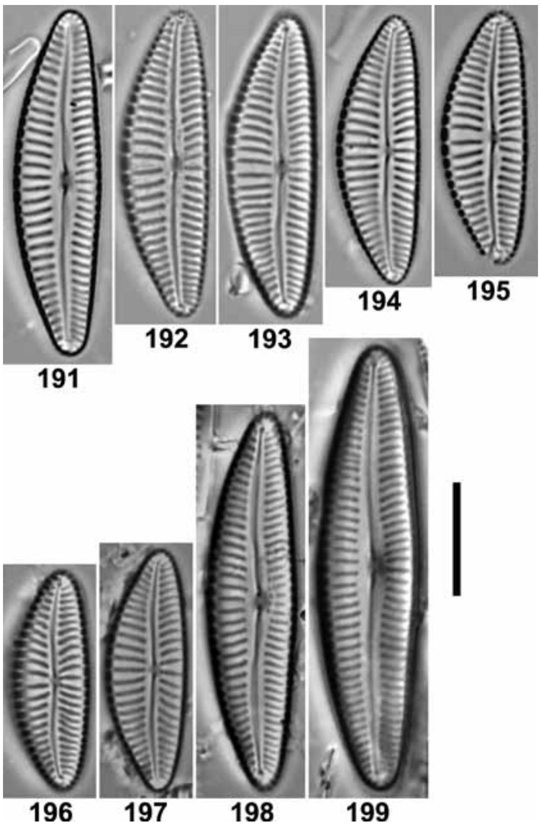
Figs 142–169. SEM : (142–144) *Encyonopsis subminuta* Krammer et E. Reichardt, Tte. des Prat 25/05/05; (145, 146, 159, 161) *Encyonopsis krammeri* E. Reichardt, Font des Pí 13/05/06; (147–149) *Encyonopsis* sp. 1, Tte. des Prat 25/05/05; (150) *Gomphonema lateripunctatum* E. Reichardt et Lange–Bertalot, Tte. des Prat 15/05/06; (151–154) *Cymbella vulgata* Krammer, Tte. des Prat 25/05/05; (155–158) *Encyonopsis cesatii* (Rabenhorst) Krammer, Tte. des Prat 25/05/05; (160, 163–164) *Encyonopsis minuta* Krammer et E. Reichardt, (160, 164) Tte. de Son Vic 19/05/05, (163) Font des Pí 13/05/06; (165) *Gomphonema micropus* Kützing, Font de s'Olla 13/03/06; *Cymbella lange–bertalotii* Krammer, Tte. des Prat 25/05/05. Scale bars 10 µm (Figs 142, 145–147, 150–151, 158, 161–166), 5 µm (Figs 143–144, 148–149, 152, 154–157, 167, 169), 1 µm (Figs 153, 159–160, 168).

that 309 diatom taxa have been reported to date from the Balearic Islands, this paper adding 22 new records for the region (Appendix 1). The relatively large amount of floristic novelties could be explained by the lack of published works on diatoms from these islands. Several common taxa for the European flora have not been previously cited in Balearic Islands due to the scarcity of studies or because some of the taxa only have been recently described or separated from older species complexes such as *Cymbella lange–bertalotii* and *C. vulgata* (Krammer 2002), *Diploneis separanda* (Werum & Lange–Bertalot 2004), *Encyonopsis krammeri*, *E. minuta*, *E. subminuta* (Krammer 1997b) and *Navicula antonii* Lange–Bertalot et Rumrich (Lange–Bertalot 1993).

To our knowledge, the present study constitutes the first record of *Navicula wygaschii* and *Diploneis krammeri* Lange–Bertalot et E. Reichardt for the Iberian Peninsula (Spain and Portugal). The photographs of *D. separanda* for Majorca Island are the first in Spain; it was first recorded in a spring of the river Schutter (Franconia/Bavaria) and found in many other oligosaprobic waters of Germany by Werum & Lange–Bertalot (2004), later also in springs of Łódź Hills (Central Poland) by Żelazna–Wieczorek (2011). *Gomphonema rosensto-ckianum* Lange–Bertalot et E. Reichardt has so far only been found in the Canary Islands (La Gomera, Tenerife), South Portugal, Balearic Islands, Duero Basin (Spain), and Cyprus (Lange–Bertalot 1993; Novais et al. 2009; Blanco et



Figs 170–190. LM: (170–179) *Achnanthidium pyrenaicum* (Hustedt) H. Kobayasi, Font des Pí 15/05/06; (180–183) *Diadesmis contenta* (Grunow ex Van Heurck) D.G. Mann, Font des Pí 18/03/06; (184–188) *Navicula reichardtiana* Lange–Bertalot, Font des Pí 18/03/06. SEM: (189–190) *Achnanthidium pyrenaicum* (Hustedt) H. Kobayasi, Font des Pí 15/05/06. LM scale bar 10 µm, SEM scale bar 5µm.



Figs 191–199. LM: (191–199) *Cymbopleura margalefii* C. Delgado, Novais, S. Blanco et Ector sp. nov.; (191–195) Tte. des Prat 25/05/05; (196–199) Tte. de Deià 22/05/06, type material (Fig. 198 designated as holotypus). Scale bar 10 µm.

al. 2010; Kermarrec et al. 2011).

According to Foged (1984), spring environments have no specific diatom floras; though taxa richness can be one of the largest within European freshwaters. The study by Werum & Lange–Bertalot (2004) in German springs reaches analogue conclusions. However, Kaczmarska & Rushforth (1983) detected several diatom taxa with disjunct geographical distribution patterns in certain North American springs. Likewise, diatoms in Sardinian springs have a remarkable degree of endemicity (Lange–Bertalot et al. 2003).

This study contributed to improve the knowledge of the diatom flora in Majorca and the Balearic Islands, also providing a recent taxonomical overview on the modern benthic diatom flora of Majorca. It also adds information related to the physical and chemical factors and diatom communities, to previous works done in the island, being the first study on epilithic diatoms from springs in the Balearic Islands.

Acknowledgments

This article covers some of the results obtained in the context of a project dealing with the application of the Water Framework Directive in Balearic Islands. The financial support for this study has been provided by Agència Balear de l'Aigua i de la Qualitat Ambiental and this also included the support of the University of Vigo (Spain) and the Centre de Recherche Public – Gabriel Lippmann (Luxembourg). We are grateful to the editor and anonymous reviewers for their criticism and comments that improved the final manuscript. We thank Liliana García for the help with the sample collection, M. Dominguez with the chemical analysis, Gabriel Moyà with the bibliography of Balearic Islands and Christophe Bouillon with the SEM micrographs. Dr. Maria Angélica Oliveira (Universidade Federal de Santa Maria, Brazil) kindly revised the English.

REFERENCES

Aboal, M.; Prefasi, M. & Asencio, M.D. (1996): The aquatic microphytes and macrophytes of the Transvase Tajo–Segura irrigation system, southeastern Spain. – Hydrobiologia 340: 101–107.

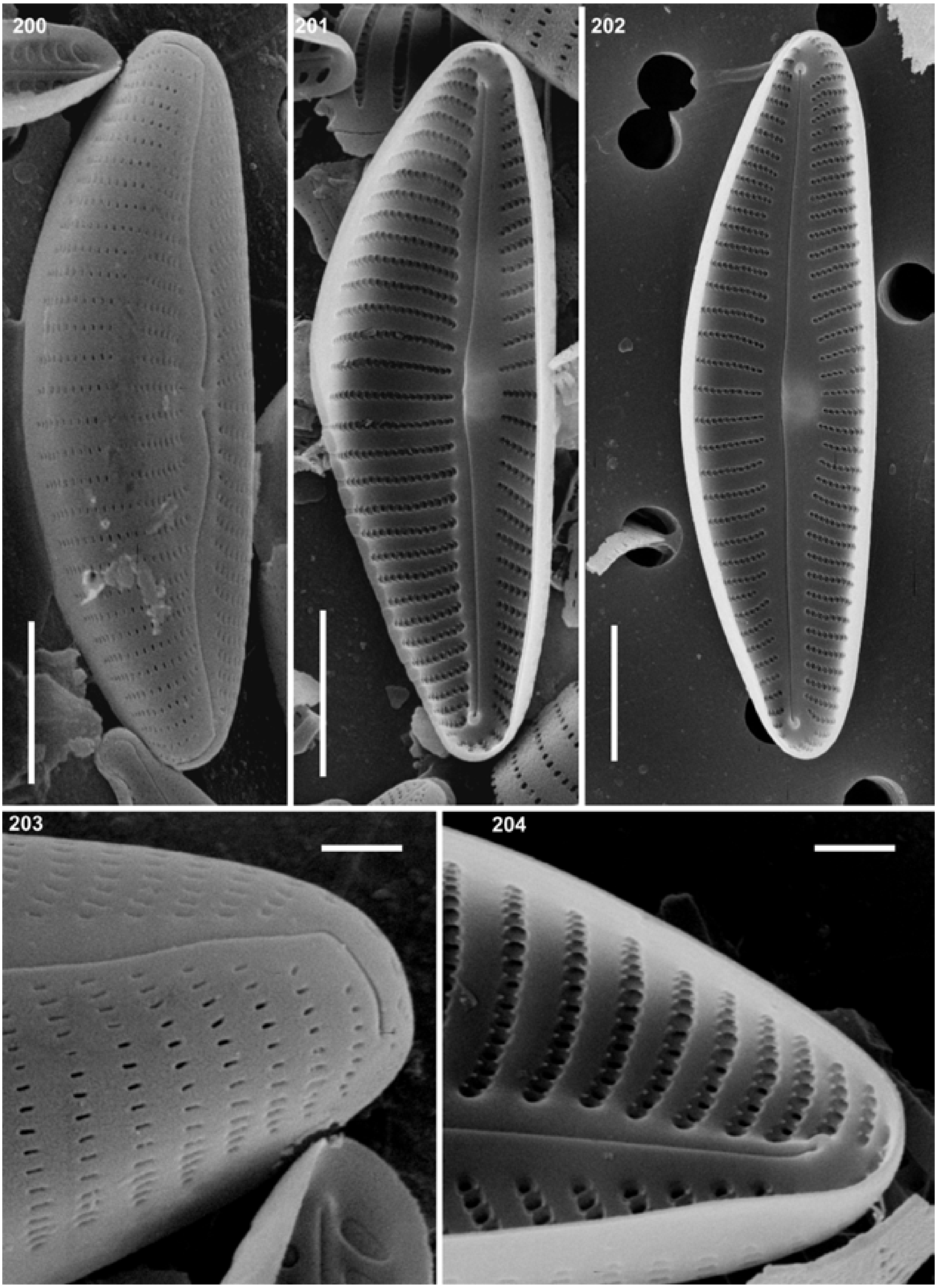
Aboal, M.; Álvarez–Cobelas, M.; Cambra, J. & Ector, L. (2003): Floristic list of the non–marine diatoms (Bacillariophyceae) of Iberian Peninsula, Balearic Islands and Canary Islands. Updated taxonomy and bibliography. – Diatom Monogr. 4: 1–639.

Alvarez Cobelas, M. & Estévez García, A. (1982): Catálogo de las algas continentales españolas. I. Diatomophyceae Rabenhorst 1864. – Lazaroa 4: 269–285.

APHA (1995): Standard methods for the examination of water and wastewater. – AWWA, WEF. 19th ed. New York, American Public Health Association.

Blanco, S.; Cejudo–Figueiras, C.; Álvarez–Blanco, I.; Bécares, E.; Hoffmann, L. & Ector, L. (2010): Atlas de las Diatomeas de la cuenca del Duero, Diatom atlas of the Duero Basin., 1a ed. – 382 pp., Área de Publicaciones, Universidad de León, León.

Cambra, J.; Sabater, S. & Tomás, X. (1991): Diatom check–list from Catalonian countries (Eastern Spain). – Bull. Inst. Catalana Hist. Nat. 59, Secc. Bot. 8: 5–39.



Figs 200–204. SEM: (200–204) *Cymbopleura margalefii* C. Delgado, Novais, S. Blanco et Ector sp. nov.; (200–201, 203–204) Tte. de Deià 22/05/06, type material, (203) Tte. des Prat 25/05/05. Scale bars 5 µm (Figs 200–203), 1 µm (Figs 204–205).

Table 4. Morphological characterization of *Cymbopleura margalefii* and closely related *Cymbopleura* taxa.

	C. margalefii **sp. nov**	***C. korana***	***C. rhomboidea*** **var.** ***angusta***	***C. laeviformis***	***C. pyrenaica***
Valve outline	distinctly dorsiventral; asymmetrically elliptical–lanceolate	distinctly dorsiventral; broadly subelliptical to elliptical–lanceolate	moderately to distinctly dorsiventral; broadly rhomboid–lanceolate	distinctly dorsiventral; asymmetrically elliptical–lanceolate	distinctly dorsiventral; semi–lanceolate to rhomboid lanceolate
Valve ends	obtusely rounded	obtusely rounded	obtusely rounded	obtusely rounded	obtusely rounded, not protracted
Length (µm)	19–37	31–59	23–58	27–46	13.8–39
Width (µm)	6.5–9	11–13	10–13	8.5–10.7	5.6–9.5
Maximum L/B ratio	4.4	4.6	4.2	4.3	4.2
Striae / 10 µm	11–12	9–10	8–10	11–13	12–17
Areolae / 10 µm	40–45	29–32	30–36	30–35	35–40
Morphology of the areolae in external view (SEM)	linear	–	–	quadrangular	reniform, cruciform, triphid
Morphology of the areolae in internal view (SEM)	quadrangular, with papillas on the top and bottom of the space between two areolae	–	–	four fine ribs surrounding each areola	fine ribs oblique over the vimines

Cantonati, M.; Gerecke, R. & Bertuzzi, E. (2006): Springs of the Alps – sensitive ecosystems to environmental change: from biodiversity assessments to long–term studies. – Hydrobiologia 562: 59–96.

Cantonati, M. & Lange–Bertalot, H. (2010): Diatom biodiversity of springs in the Berchtesgaden National Park (northern Alps, Germany) with the ecological and morphological characterization of two species new to science. – Diatom Res. 25: 251–280.

Cantonati, M.; Angeli, N.; Bertuzzi, E.; Spitale, D. & Lange–Bertalot, H. (2012): Diatoms in springs of the Alps: springs types, environmental determinants, and substratum. – Freshwater Sci. 31: 499–524.

CEN (2003): Water quality – Guidance standard for the routine sampling and pretreatment of benthic diatoms from rivers. – 14 pp., European Standard EN 13946. Brussels, European Committee for Standardization.

Delgado, C. (2011): Benthic diatoms of Atlantic and Mediterranean Spanish rivers: Ecology and bioindication [PhD thesis]. – 183 pp., University of Vigo, Vigo, Spain.

Delgado, C.; Pardo, I. & García, L. (2012): Diatom communities as indicators of ecological status in Mediterranean temporary streams (Balearic Islands, Spain). – Ecol. Indic. 15: 131–139.

Della Bella, V.; Puccinelli, C.; Marcheggiani, S. & Mancini, L. (2007): Benthic diatom communities and their relationship to water chemistry in wetlands of central Italy. – Ann. Limnol. – Int. J. Lim. 43: 89–99.

Farrés, R.; Vila, M.; Prat, N.; Gomà, J.; Ortiz, R. & Cambra, J. (2007): Efectes d'un incendi forestal sobre la comunitat de fitobentos en una riera mediterrània. – pp. 263–269, VI Trobada d'Estudiosos de Sant Llorenç del Munt i l'Obac Diputació de Barcelona.

Foged, N. (1984): The diatom floras in springs in Jutland, Denmark. – Biblioth. Diatomol. 4: 1–120.

Fungladda, N.; Kaczmarska, I. & Rushforth, S.R. (1983): A contribution to the freshwater diatom flora of the Hawaiian Islands. – Biblioth. Diatomol. 2: 1–103.

Gesierich, D. & Kofler, W. (2010): Epilithic diatoms from rheocrene springs in the eastern Alps (Vorarlber, Austria). – Diatom Res. 25: 43–66.

Gomà, J.; Ortiz, R.; Cambra, J. & Ector, L. (2004): Water evaluation in Catalonian Mediterranean rivers using epilithic diatoms as bioindicators. – Vie Milieu 54: 81–90.

Kaczmarska, I. & Rushforth, S.R. (1983): The diatom flora of Blue Lake Warm Spring, Utah. – Biblioth. Diatomol. 2: 1–123.

Kermarrec, L.; Ector, L.; Bouchez, A.; Rimet, F. & Hoffmann, L. (2011): A preliminary phylogenetic analysis of the Cymbellales based on 18S rDNA gene sequencing. – Diatom Res. 26: 305–315.

Krammer, K. (1997a): Die cymbelloiden Diatomeen. Teil 1. Allgemeines und *Encyonema* part. – Biblioth. Diatomol. 36: 1–382.

Krammer, K. (1997b): Die cymbelloiden Diatomeen. Teil 2. *Encyonema* part., *Encyonopsis* und *Cymbellopsis*. – Biblioth. Diatomol. 37: 1–469.

Krammer, K. (2002): *Cymbella*. – In: Lange–Bertalot, H. (ed.): Diatoms of Europe 3. – 584 pp., A.R.G. Gantner Verlag K.G., Ruggell.

Krammer, K. (2003): *Cymbopleura*, *Delicata*, *Navicymbula*, *Gomphocymbellopsis*, *Afrocymbella*. – In: Lange–Bertalot, H. (ed.): Diatoms of Europe 4. – 530 pp., A.R.G. Gantner Verlag K.G., Ruggell.

Krammer, K. & Lange–Bertalot, H. (1986–1991): Bacillariophyceae, 1–4. – In: Ettl, H.; Gerloff, J.; Heynig, H. & Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa. – 876+596+576+437 pp., VEB Gustav Fisher Verlag, Jena, Germany.

Krammer, K. & Lange–Bertalot, H. (2004): Bacillariophyceae. 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. – In: Ettl, H.; Gerloff J.; Heynig, H. & Mollenhauer, D. (eds): Süsswasserflora von Mitteleuropa 2/3. – 599 pp., Spektrum Akademischer Verlag Heidelberg, Berlin.

Lange–Bertalot, H. (1993): 85 neue Taxa und über 100 weitere neu definierte Taxa ergänzend zur Süsswasserflora von Mitteleuropa 2/1–4. – Biblioth. Diatomol. 27: 1–454.

Lange–Bertalot, H. (1999): Neue Kombinationen von Taxa aus *Achnanthes* Bory (sensu lato). – Iconogr. Diatomol. 6: 276–289.

Lange–Bertalot, H. (2001): *Navicula* sensu stricto. 10 genera separated from *Navicula* sensu lato. *Frustulia*. – In: Lange–Bertalot, H. (ed.): Diatoms of Europe 2. – 526 pp., A.R.G. Gantner Verlag K.G., Ruggell.

Lange–Bertalot, H.; Cavacini, P.; Tagliaventi, N. & Alfinito, S. (2003): Diatoms of Sardinia. Rare and 76 new species in rock pools and other ephemeral waters. – Iconogr. Diatomol. 12: 1–433.

Lange–Bertalot, H. & Krammer, K. (1989): *Achnanthes*, eine Monographie der Gattung mit Definition der Gattung *Cocconeis*. – Biblioth. Diatomol. 18: 1–393.

Lange–Bertalot, H. & Moser, G. (1994): *Brachysira*. Monographie der Gattung. – Biblioth. Diatomol. 29: 1–212.

Le Cohu, R.; Lange–Bertalot, H. & Azemar, F. (2011): *Cymbopleura pyrenaica* sp. nov. (Bacillariophyceae) et d'autres espèces du même genre rarement recensées dans quelques lacs des Pyrénées françaises. – Cryptogamie Algol. 32: 337–349.

Levkov, Z. (2009): *Amphora* sensu lato. – In: Lange–Bertalot, H. (ed.): Diatoms of Europe 5. – 916 pp., A.R.G. Gantner Verlag K.G., Ruggell.

Levkov, Z.; Caput Mihalič, K. & Ector, L. (2010): A taxonomical study of *Rhoicosphenia* Grunow (Bacillariophyceae) with a key for identification of selected taxa. – Fottea 10: 145–200.

Llobera, M. & Ferriol, A. (1994): Seasonal fluctuations in the chemistry of limestone springs from the Tramuntana Mountain Range (Mallorca, Spain). – Verh. Internat. Verein. Limnol. 25: 1445–1448.

Lorenzen, C.J. (1967): Determination of chlorophyll and phaeopigments: spectrophotometric equations. – Limnol. Oceanogr. 12: 342–346.

Metzeltin, D. & Lange–Bertalot, H. (2000): Diatoms from the "Island Continent" Madagascar. – Iconogr. Diatomol. 11: 1–286.

Moser, G.; Lange–Bertalot, H. & Metzeltin, D. (1998): Insel der Endemiten. Geobotanisches Phänomen Neukaledonien. – Biblioth. Diatomol. 38: 1–464.

Moyá, G.; Ferriol, A. & Llobera, M. (1991): Chlorophyll contents in the freshwater vegetation of Serra de Tramuntana springs (Mallorca, Spain). – Verh. Internat. Verein. Limnol. 24: 2002–2006.

Novais, M.H.; Blanco, S.; Hlúbiková, D.; Falasco, E.; Gomà, J.; Delgado, C.; Ivanov, P.; Àcs, E.; Morais, M.; Hoffmann, L. & Ector, L. (2009): Taxonomic revision and biogeography of the *Gomphonema rosenstockianum* and *G. tergestinum* species complex. – Fottea 9: 257–274.

PARDO, I. & ÁLVAREZ, M. (2006): Comparison of resource and consumer dynamics in Atlantic and Mediterranean streams. – Limnetica 25: 271–286.

RENBERG, I. (1990): A procedure for preparing large sets of diatom slides from sediment cores. – J. Paleolimnol. 4: 87–90.

SABATER, S. & ROCA, J.R. (1990): Some factors affecting distribution of diatom assemblages in Pyrenean springs. – Freshwater Biol. 24: 493–507.

SABATER, F.; ARMENGOL, J. & SABATER, S. (1991): Physico–chemical disturbances associated with spatial and temporal variation in a Mediterranean river. – J. N. Am. Benthol. Soc. 10: 2–13.

SABATER, S. & ROCA, J.R. (1992): Ecological and biogeographical aspects of diatom distribution in Pyrenean springs. – Br. Phycol. J. 27: 203–213.

SIMONSEN, R. (1987): Atlas and catalogue of the diatom types of Friedrich Hustedt. –Vol. 1, Catalogue, 525 p.; Vol. 2, Atlas, pl. 1–395; Vol. 3, Atlas, pl. 396–772. J. Cramer, Berlin/Stuttgart.

TROBAJO, R.; ROVIRA, L.; ECTOR, L.; WETZEL, C.E.; KELLY, M. & MANN, D.G. (2013): Morphology and identity of some ecologically important small *Nitzschia* species. – Diatom Res. 28: 37–59.

TUJI, A. & HOUKI, A. (2004): Type examination of *Synedra delicatissima* W. Sm. and its occurrence in Japan. – Bull. Natl. Sci. Mus., Tokyo, Ser. B, 30: 151–154.

WERUM, M. & LANGE–BERTALOT, H. (2004): Diatoms in springs from central Europe and elsewhere under the influence of hydrogeology and anthropogenic impacts. – Iconogr. Diatomol. 13: 1–417.

WITKOWSKI, A.; LANGE–BERTALOT, H. & METZELTIN, D. (2000): Diatom flora of marine coasts. – Iconogr. Diatomol. 7: 1–925.

ŻELAZNA–WIECZOREK, J. (2011): Diatom flora in springs of Łódź Hills (Central Poland). Biodiversity, taxonomy, and temporal changes of epipsammic diatom assemblages in springs affected by human impact. – Diatom Monogr. 13: 1–419.

Supplementary material

the following supplementary material is available for this article:

Appendix 1. Diatom checklist of Balearic Islands (*new record for Balearic Islands and **new record for Spain). Underlined the taxa identified in the present study.

This material is available as part of the online article (http://fottea.czechphycology.cz/contents)

Received November 30, 2012
Accepted February 12, 2013