Achnanthidium druartii sp. nov. (Achnanthales, Bacillariophyta), a new species invading European rivers.

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ACHNANTHIDIUM DRUARTII SP. NOV. (ACHNANTHALES, BACILLARIOPHYTA), A NEW SPECIES INVADING EUROPEAN RIVERS

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ACHNANTHIDIUM DRUARTII SP. NOV.
DIATOMS
ECOLOGY
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ABSTRACT. – Since 2004, an unknown diatom taxon has been spreading through an increasing number of French watercourses. Our findings led us to describe it as a new species, *Achnanthidium druartii* sp. nov. This taxon can easily be differentiated from other morphologically closely related species like *A. convergens*, *A. deflexum*, *A. japonicum*, *A. latecephalum*, *A. pyrenaicum* and *A. rivulare* with both light and electron microscopy since its valve is longer, its stria density is lower and it has a lanceolate shape with subrostrated apices (never capitated). The assessment of its ecology was made through physicochemical analyses carried out on sites that are part of the river monitoring quality networks. The new taxon is an epilithic taxon, often observed in well mineralized waters running through sedimentary rock and of quite low trophic and saprobic levels. Many of the sites are large rivers and navigation channels. Considering the increasing number of stations where it was recorded and since it is only recently recorded in rivers, this taxon can be considered as invasive.

INTRODUCTION

Every year since 2004, an unknown diatom taxon has been regularly observed during routine diatom analyses by technicians of the French river monitoring networks. The first years (2004-2006), the species was only present in few rivers and always in low abundances. But in later years (2007, 2008), the same taxon appeared in an increasing number of rivers and canals, with sometimes high abundances. We present here different techniques we used to detail the study of the new taxon described as a new species of *Achnanthidium* Kützing.

The genus *Achnanthidium* was redefined by Round & Bukhtiyarova (1996). Since then, its number of species has increased remarkably. As an alternative view to that of Round & Bukhtiyarova (1996), Monnier *et al*. (2007) working on *Psammothidium* Bukhtiyarova & Round concluded that several species in the latter genus should be transferred to *Achnanthidium*. In 2008, the latter genus encompassed more than 80 taxa (Lecointe *et al*. 1993). As far as diatom indices are concerned, it is of biomonitoring importance. The new taxon described here is also included in the genus *Achnanthidium*. It is less than 30 µm long and about 5 µm wide, has uniseriate striae becoming denser at the apices and fulfills the genus protologue in every other respect.

The new taxon was recognized as an outstanding diatom during routine monitoring studies in France because it showed rather different features compared to morphologically closely related taxa that are also abundant in French rivers and which sometimes show features only discernible with the scanning electron microscope. This early distinction was not the case of other taxa from French rivers known to have been misidentified. For instance, *Achnanthidium atomoides* Monnier, Lange-Bertalot & Ector, was called *Achanthidium atomus* (Hustedt) Monnier, Lange-Bertalot & Ector before its description by Monnier *et al*. (2004). Another example of a misidentified taxon is *Reimeria uniseriata* Sala, Guerrero & Ferrari which was mistaken for *R. sinuata* (Gregory) Kociolek & Stoermer by routine diatom research technicians in France, until the publication of Sala *et al*. (1993). The distinctive features of the unknown *Achnanthidium* provided the opportunity to follow its interannual geographical distribution in French rivers. It also enables to assess its ecological preferences versus physical and chemical parameters which are usually measured by the French Water Agencies for monitoring purposes.

MATERIAL AND METHODS

Samples used in the present investigation were collected as part of the river monitoring networks framework by several Regional Environmental Agencies in France (Direction Régionale de l'Environnement), consulting agencies (Asconit, Aquascop) and our institute (INRA, Institut National de Recherche Agronomique). The geographical area includes the main French hydrographical basins (Rhône, Loire, Meuse, Seine and Dordogne river basins). The samplings were carried out following

Table I. – Sampling dates and location of the observations of *Achnanthidium druartii* sp. nov. in France from 2004 to 2008 and in the Ebro basin from 2005 to 2006.

Country	River name	Town	Sampling date	Institution	Observer name
France	Ailette	Neuville-sur-Ailette	16/07/2008	Asconit	Ponton Etienne
France	Ailette	Neuville-sur-Ailette	16/07/2008	Asconit	Monnier Olivier
France	Anglin	Mérigny	22/08/2006	Diren Centre	Imbert Edith
France	Ariège	Montoulieu		Asconit	Garcia Fabien
France	Armançon	Cheny	10/07/2007	Diren Bourgogne	Peteers Valérie
France	Armançon	Cheny	30/07/2008	Diren Bourgogne	Peteers Valérie
France	Armançon	Tronchoy	10/07/2007	Diren Bourgogne	Peteers Valérie
France	Armançon	Tronchoy	30/07/2008	Diren Bourgogne	Peteers Valérie
France	Aude	Salles-d'Aude	24/07/2007	Asconit	Monnier Olivier
France	Beuvron	Ouagne	17/07/2007	Diren Bourgogne	Peteers Valérie
France	Boutonne	Champdolent	31/07/2008	Aquascop	Migaud Julie et Vizinet Jessica
France	Canal de Brouage	Beaugeay	31/07/2008	Aquascop	Migaud Julie et Vizinet Jessica
France	Canal de jonction de la Marne au Rhin	Troussey	23/07/2008	Diren Lorraine	Heudre David
France	Canal de l'est, Branche Nord	Génicourt sur Meuse	30/07/2008	Diren Lorraine	Heudre David
France	Canal de l'est, Branche Nord	Sampigny	09/09/2008	Diren Lorraine	Heudre David
France	Canal de l'est, Branche Nord	Vacherauville	23/07/2008	Diren Lorraine	Heudre David
France	Canal de Saint-Quentin	Lesdins	06/09/2007	Asconit	Monnier Olivier
France	Canal de Saint-Quentin	Saint-Simon	14/08/2008	Asconit	Monnier Olivier
France	Canal de Saint-Quentin	Cantaing/Escaut	25/08/2006	Asconit	Monnier Olivier
France	Canal des Ardennes	Seuil	26/09/2008	Asconit	Ponton Etienne
France	Canal du midi	Labastide d'Anjou	30/06/2008	INRA	Rimet Frédéric
France	Canal du midi	Labastide d'Anjou	03/06/2009	Becq'eau	Rolland Anne
France	Canal du midi	Marseillette	09/07/2008	INRA	Rimet Frédéric
France	Canal latéral Marne	Juvigny	25/09/2008	Asconit	Ponton Etienne
France	Charente	Saint Simeux	29/08/2007	Asconit	Ponton Etienne
France	Charente	Saint-Yrieix-sur-Charente	28/08/2007	Asconit	Ponton Etienne
France	Clain	Poitiers	21/07/2006	Asconit	Monnier Olivier
France	Clain	Saint Benoît	06/08/2007	Asconit	Ponton Etienne
France	Doubs	Saunières	25/09/2007	Diren Bourgogne	Peteers Valérie
France	Doubs	Saunières	02/07/2008	Diren Bourgogne	Peteers Valérie
France	Drac	Gua	11/09/2007	Diren Rhône-Alpes	Bey Maurice
France	Garonne	Aiguillon	25/07/2007	Asconit	Monnier Olivier
France	Garonne	Couthures-sur-Garonne	28/07/2008	Asconit	Ponton Etienne
France	Garonne	Lamagistère		Asconit	Garcia Fabien
France	Garonne	Toulouse		Asconit	Garcia Fabien
France	Grande Baise	Nérac	24/07/2007	Asconit	Monnier Olivier
France	Grande Baise	Nérac	24/07/2008	Asconit	Ponton Etienne
France	Grande Baise	Vianne	24/07/2008	Asconit	Ponton Etienne
France	Isle	Neuvic	30/07/2007	Asconit	Monnier Olivier
France	Isle	Sablons	25/07/2007	Asconit	Monnier Olivier
France	Isle	Trélissac	20/08/2005	IPL	Heudre David
France	Loing	Moret-sur-Loing	23/07/2008	Asconit	Ponton Etienne
France	Loire	Saint-Mathurin sur Loire	12/08/2008	Diren Pays de la Loire	Guillard Didier
France	Lot	Casseneuil	24/07/2008	Asconit	Ponton Etienne
France	Lot	Clairac	24/07/2008	Asconit	Ponton Etienne
France	Marne	Jaulgonne	18/07/2008	Asconit	Ponton Etienne
France	Marne	La Ferté sous Jouarre	18/07/2008	Asconit	Ponton Etienne
France	Meuse	Givet	09/08/2006	Diren Lorraine	Rimet Frédéric

Country	River name	Town	Sampling date	Institution	Observer name
France	Mignon	Grève-sur-Mignon	08/08/2007	Asconit	Ponton Etienne
France	Orbieu	Raissac-d'Aude	24/07/2007	Asconit	Monnier Olivier
France	Orbieu	Ribaute	30/07/2008	Asconit	Monnier Olivier
France	Rhône	Avignon	29/07/2008	Aquascop	Migaud Julie et Vizinet Jessica
France	Rhône	Saint Pierre de Bœuf	15/03/2007	INRA	Rimet Frédéric
France	Rhône	Saint Vallier	12/10/2004	Diren Rhône-Alpes	Bey Maurice
France	Rhône court-circuité	Serrières	26/09/2007	Diren Rhône-Alpes	Bey Maurice
France	Rhône court-circuité	Serrières	06/10/2008	Diren Rhône-Alpes	Bey Maurice
France	Roubion	Montelimar	25/09/2008	INRA	Rimet Frédéric
France	Salon	Autet		Asconit	Gassiole Gilles
France	Saône	Auxonne	27/05/2008	Diren Bourgogne	Peteers Valérie
France	Saône	Gergy	02/07/2008	Diren Bourgogne	Peteers Valérie
France	Somme canalisée	Camon	10/09/2007	Asconit	Monnier Olivier
France	Yonne	Armeau	23/07/2008	Asconit	Monnier Olivier
France	Yonne	Bassou	10/07/2007	Diren Bourgogne	Peteers Valérie
France	Yonne	Bassou	30/07/2008	Diren Bourgogne	Peteers Valérie
France	Yonne	Montereau Fault-Yonne	23/07/2008	Asconit	Ponton Etienne
France	Yonne	Prégilbert	11/07/2007	Diren Bourgogne	Peteers Valérie
France	Yonne	Prégilbert	30/07/2008	Diren Bourgogne	Peteers Valérie
France	Yonne	Vaux	12/09/2008	Asconit	Ponton Etienne
Spain	Alpartir	Alpartir	29/08/2005	Asconit	Ortiz Roser
Spain	Aragon	Caparroso	21/09/2006	Asconit	Ortiz Roser
Spain	Cinca	Puente de las Pilas, Estada-Estadilla	30/09/2006	Asconit	Ortiz Roser
Spain	Ebro	Conchas de Haro	10/09/2006	Asconit	Ortiz Roser
Spain	Ebro	Miranda de Ebro	07/09/2006	Asconit	Ortiz Roser
Spain	Ebro	Sartaguda	13/09/2006	Asconit	Ortiz Roser
Spain	Ebro	Miranda	19/08/2005	Asconit	Ortiz Roser
Spain	Ebro	Rincon de Soto	27/08/2005	Asconit	Ortiz Roser
Spain	Ega	Estella	24/08/2005	Asconit	Ortiz Roser
Spain	Jiloca	Daroca	27/09/2006	Asconit	Ortiz Roser
Spain	Noguera Ribagorzana	Puente de Montañana	31/08/2005	Asconit	Ortiz Roser
Spain	Noguera Ribagorzana	Puente de Montañana	30/09/2006	Asconit	Ortiz Roser
Spain	Omecillo	Espejo	19/08/2005	Asconit	Ortiz Roser
Spain	Omecillo	Espejo	11/09/2006	Asconit	Ortiz Roser
Spain	Ribera Salada	Altès	10/10/2006	Asconit	Ortiz Roser
Spain	Rudron	Tablada de Rudron	08/09/2006	Asconit	Ortiz Roser

the French (Afnor 2007) and European standards (Afnor 2003) for benthic diatom samplings. Diatoms were collected from natural hard substrates such as stones using clean toothbrushes in riffle or run sections. The diatom valves were cleaned using 40 % hydrogen peroxide to eliminate organic matter and hydrochloric acid to dissolve calcium carbonate. Clean diatom frustules were mounted in synthetic resin (Naphrax©). Diatom lists were produced following the French standard (Afnor 2003) for the Biological Diatom Index calculation. Up to 400 valves were counted and identified in each sample using a light microscope with a 1000 × magnification. The identifications were carried out with available descriptions (Krammer & Lange-Bertalot 1986, 1988, 1991a, b). The lists were then managed using the Omnidia software (Lecointe *et al*. 1993).

The sample containing the largest population of the unknown *Achnanthidium* described here as a new species was collected in September 2009 from the Roubion River in Montélimar (position in Lambert II étendu: Latitude 774189, Longitude 2102648). A Zeiss AxioImager A1 © (1600x magnification) and an AxioCam HRc Camera were used for morphometric measurements and light photography. Images and plates were prepared using the PowerPoint software.

Morphometric measurements were carried out on 128 valves. The list of the sampling sites and dates is given in Table I with the number of analyzed valves for each sample. Mann Whitney rank sum tests were carried out on the different morphometric

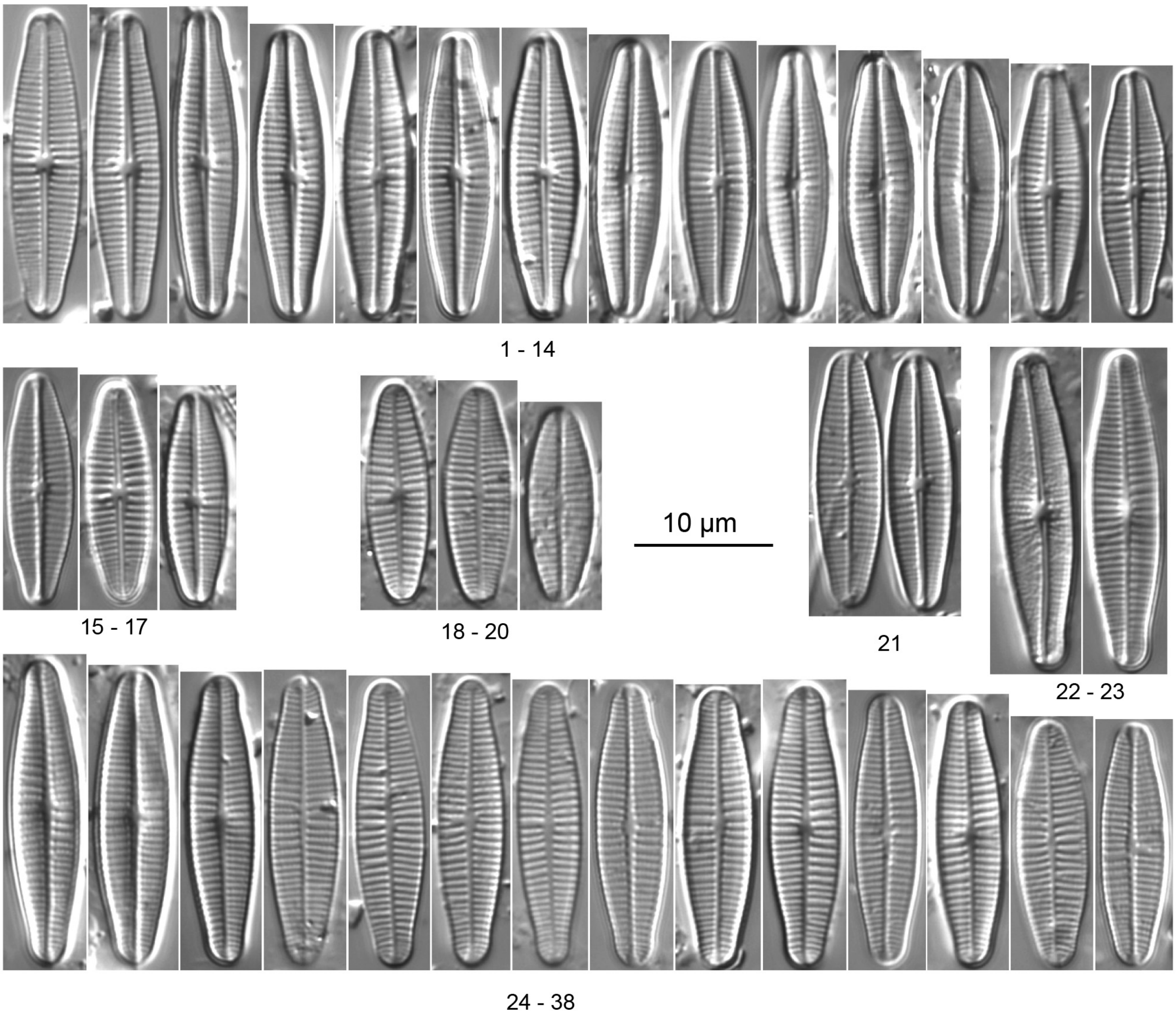

Plate I. – *Achnanthidium druartii* sp. nov. from Roubion River in Montélimar (sampled 25/09/2008). L.M. Figs 1-17 : raphe valves; Figs 18-20 and 24-38: rapheless valves; Fig. 21: rapheless and raphe valve of a single individual; Figs 22-23: teratological raphe valve and normal rapheless valves of a single individual.

data with the SigmaStat software (v. 3.10).

For scanning electron microscopy (SEM) examination, dried cleaned sub-samples of the Roubion River at Montélimar were coated with gold using a Cressington 108 auto sputter coater© and subsequently examined with a Zeiss DSM940A ©.

Taxonomical papers were used to compare the new species to morphologically closely related taxa: *A. deflexum, A. pyrenaicum* and *A. rivulare* in Potapova & Ponader (2004), *A. latecephalum* in Kobayasi (1997), *A. convergens* and *A. japonicum* in Kobayasi *et al*. (1986).

The data resulting from the regular monitoring performed by the French Water Agencies (chemical analyses of watercourses) were used to determine the ecological preferences of the new taxon. For each sample containing the new taxon, the corresponding physical and chemical data were gathered in the database. The ecological preferences were calculated using the weighted average and standard deviation.

OBSERVATIONS

Achnanthidium druartii Rimet & Couté sp. nov.

Diagnosis: Valva lanceolata cum apicibus leviter subrostris sed nunquam capitatis. Longitudo : 12-29 μm (medietas : 21 μm) ; latitudo : 3,9-5,5 μm (medietas : 5 μm).

Valva cum raphe concava ; raphe recta cum in externo visu centralibus apicibus guttularum elongatarum similibus prope 0,8 μm remotis ; in interno visu centrales apices breves et curvati ad opposita latera. Raphei sternum latius in media parte quam in apicibus. Valva sine raphe

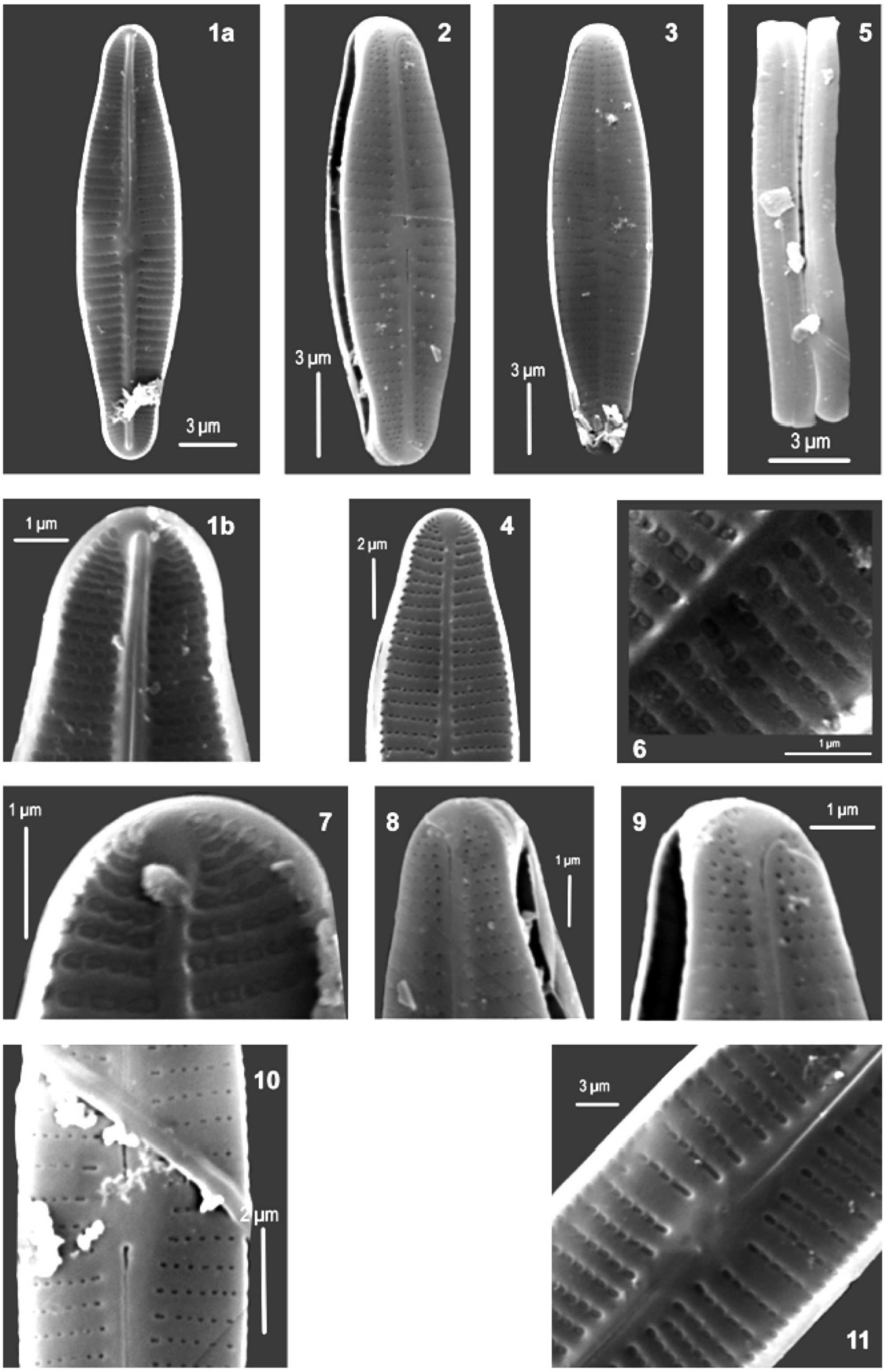

Plate II. – *Achnanthidium druartii sp. nov.* from Roubion River in Montélimar (sampled 25/09/2008). SEM. Scale bars : 1 μm. Fig. 1a: internal view of raphe valve; Fig. 1b: detail of the internal apical view; Fig. 2 external view of raphe valve; Fig. 3: external view of rapheless valve; Fig. 4: internal view of rapheless valve; Fig. 5: girdle view; Fig. 6: internal view of raphleless valve, detail of punctuation structure; Fig. 7: internal view of rapheless valve, detail of the apex; Figs 8-9: external view of raphe valves, detail of both apices; Fig. 10 : external view of the central part of the raphe; Fig. 11: internal view, details of the central part of the raphe.

convexa et cum angusto et recto sterno in media parte valde leviter dilatato.

Striae valde leviter radiantes secus valvam, aliquando angustiores in media valvae parte. In media valvae parte

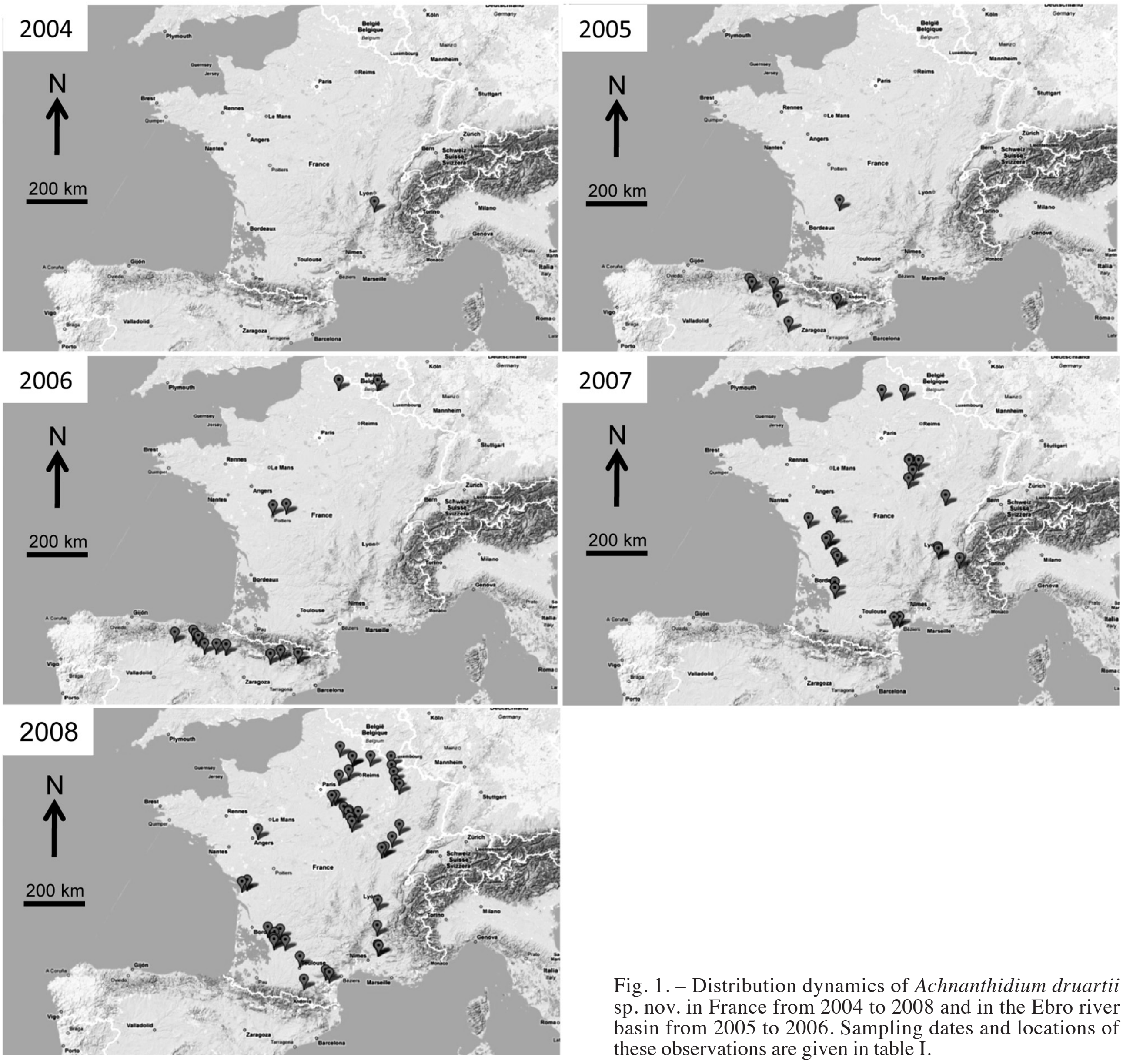

Fig. 1. – Distribution dynamics of *Achnanthidium druartii* sp. nov. in France from 2004 to 2008 and in the Ebro river basin from 2005 to 2006. Sampling dates and locations of these observations are given in table I.

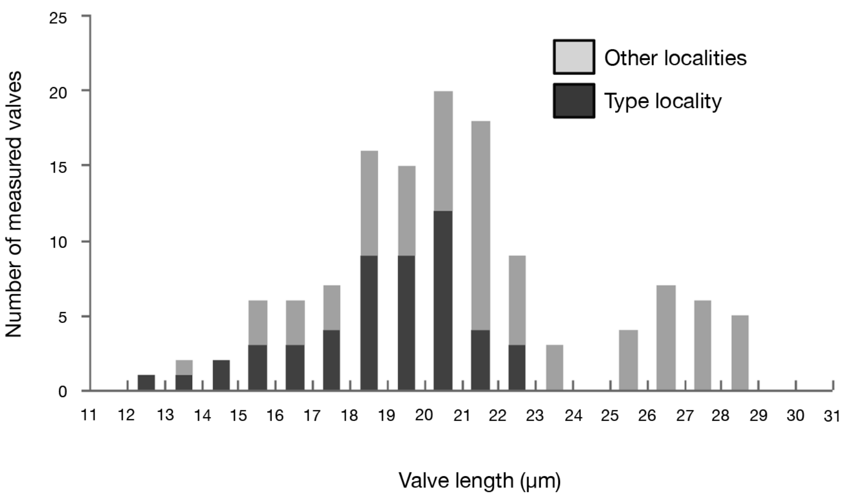

Fig. 2. – Distribution of valve length in *Achnanthidium druartii* sp. nov. populations.

15-22 striae in 10 μm (medietas: 18-19) et 40-50 striae in 10 μm in apicibus. In media valvae parte striae cum 6-7 areolis; in apicibus 3-4 areolae per striam. Areolarum externa foramina rotundata vel leviter elongata. Areolarum interna foramina occulta rectangularibus hymenibus et in media parte in lineis disposita interius tenui depressione et coalescentia in apicibus. Areolarum lineae in apicibus interruptae in quaque valva.

Diagnosis: Valves lanceolate with slightly subrostrate ends never capitate. Valve length 12-29 μm (average 21 μm), valve width 3.9-5.8 μm (average 5 μm). Raphid valve is presenting proximal ends in the shape of tapered drops in external view which are distant by about 0.8 μm. Central endings in internal view are short and curved to opposite sides. The raphe sternum is larger in the middle of the valve than in the extremities. Rapheless valve is convex, with narrow straight sternum very slightly enlarged in the middle.

Striae are very weakly radiate throughout on both valves. Occasionally there are short striae inserted near the middle of the valve. For both valves, stria density is 15-22 in 10 μm (average 18) at the valve center and about 40-50 in 10 μm near the apices.

Striae in the middle part of the valve are composed of 6 to 7 areolae, whereas striae in the extremities are only composed of 3 to 4 areolae. External foramina of areola are round to slightly elongated. Internal foramina of areola are closed by a rectangular hymen. The internal foramina are forming lines inside a shallow depression and foramina are separated from each other except near the apex where they are coalescent. On both valves, the rows of areola are interrupted at the apex.

Holotype: sample number PC0157974 (Naphrax slide) and PC0157975 (untreated sample) deposited in the National Museum of Natural History, Paris, France. Plate I, Fig. 21

Isotype: sample number G00298069 (untreated sample) deposited in the Conservatoire et Jardins Botaniques, Geneva, Switzerland.

Type locality: Montélimar, River Roubion, tributary of River Rhône (position 44°33’20.8”N and 4°44’42,3”E). Epilithon from riffle, 25/09/2008.

Etymology: this new species is dedicated to Jean-Claude Druart, French phycologist who worked on diatoms and on the phytoplankton of large French lakes.

Morphology: looking at the whole spectrum of variation, the smallest valves are slightly elliptical (Plate I, Figs 17 and 20, Plate III, Fig. 29). Medium-sized and largest valves show this typical lanceolate shape with subrostrated apices.

Location of the river Roubion in Montélimar and other sites where *Achnanthidium druartii* sp. nov. has been observed since 2004 are given in Fig. 1. Table I provides the name of the river and town of each observation. The results of the morphometric measurements carried out on the valves of the type locality (river Roubion in Montélimar) and on the other sites are given in Figs 2 to 4. These results clearly show that the valves observed in the type locality present only a part of the morphological variability. Mann Whitney rank sum tests were carried out between the lengths, widths and stria densities of the valves, comparing the valves of the type locality with the

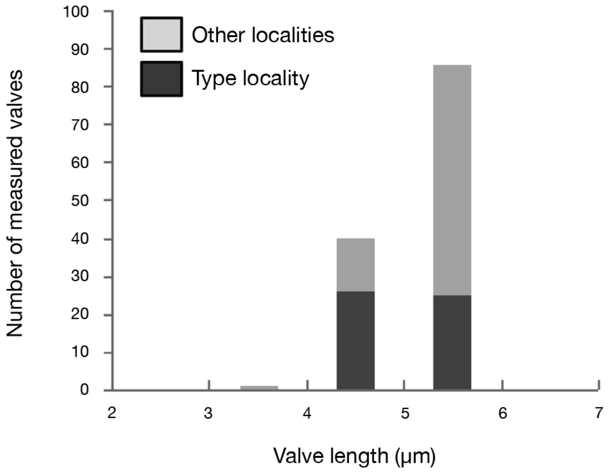

Fig. 3. – Distribution of valve width in *Achnanthidium druartii* sp. nov. populations.

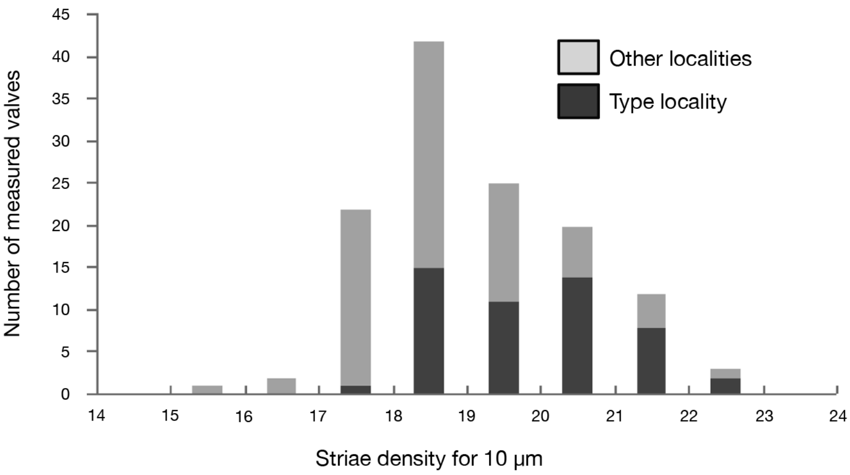

Fig. 4. – Distribution of striae density in *Achnanthidium druartii* sp. nov. populations

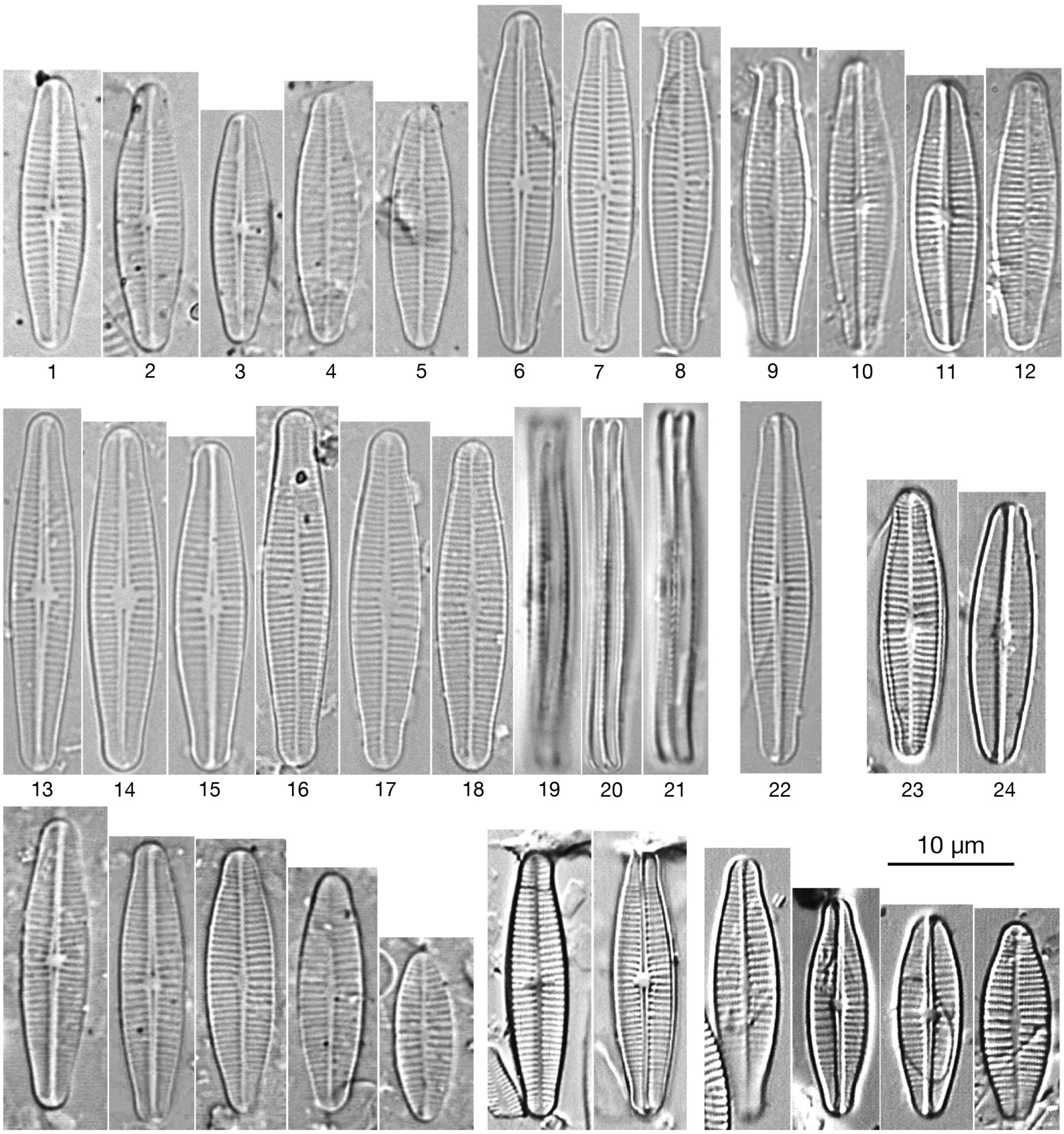

Plate III . – *Achnanthidium druartii* sp. nov. from various sites. LM. Figs 1-5: Meuse River in Givet (9/08/06); Figs 6-8: Anglin River in Mérigny (22/08/06); Figs 9-12: Rhône River in Saint Pierre de Bœuf (15/03/07); Figs 13-21: Isle River in Tréllissac (20/08/05); Fig. 22: Drac river in Gua (11/09/07); Figs 23-24: Saône River in Auxonne (2008); Figs 25-29: Loire River in Saint-Mathurin (12/08/08); Figs 30-31: Armançon River in Tronchoy (10/07/2007); Figs 32-34: Armançon River in Cheny (10/07/2007).

valves of the other sites. All tests show significant differences.

The frustules of three locations, Isle river in Trelissac (Figs 13-21 in Plate III), Anglin river in Merigny (Figs 6-8 in Plate III) and Drac in Gua (Fig. 22 in Plate III) present longer valves than the ones of the other sites. Mann Whitney rank sum tests show significant differences with average value of 26.9 μm in the rivers mentioned above compared to 19.4 μm for the other sites. Although the Mann Whitney tests show significant differences for valve length, the widths (5.3 μm in the rivers mentioned above compared to 5.1 μm for the other sites) and stria density (17.8 stria for 10 μm compared to 18.8 stria for 10 μm for the other sites) have average values compa-

Table II. – Comparison of the morphological features of selected *Achnanthidium* species. Median values are given in brackets, striae density = number in 10 µm.

Morphological features	*A. druartii* sp. nov.	*A. convergens*	*A. deflexum*	*A. japonicum*	*A. latecephalum*	*A. pyrenaicum*	*A. rivulare*
valve shape	lanceolate with slightly subrostrated ends never capitated	linear lanceolate	linear-elliptical to elliptical with subrostrate ends	linear lanceolate	linear-lanceolate with broadly capitates or rostrated ends	linerar-lanceolate to narrowly elliptical with rostrate ends	linear-elliptical to elliptical with rounded, sometime slightly drawn-out ends
valve length (µm)	13-29 (21)	10-25 (17)	7.4-27.1 (14.1)	9-23 (16)	10-18 (14)	8.4-18.4 (12.8)	6.2-18.3 (9.5)
valve width (µm)	3.9-5.8 (5)	4-4.5 (4.2)	3.5-5.2 (4.2)	4-5 (4.5)	4.0-4.5 (4.2)	2.7-4.6 (3.2)	2.7-4.4 (3.4)
striae orientation at apices	slightly radiate	convergent near the ends on the raphe valve, slightly radiate near the ends on the araphid valve	parallel	strongly radiate on the raphid valve, almost parallel on the araphid valve	almost parallel	parallel	slightly convergent to Parallel
striae density at center (raphe valve)	15-22 (18 to 19)	18-20 (19)	18.8-26 (22.5)	16-20 (18)	18-20 (19)	20-28 (22.5)	20-25 (22)
striae density at apices (raphe valve)	40-50	36-40	35-40	30 : denser in the end on the araphid valve	ca. 34	35-45	45-55
striae density at center (rapheless valve)	15-22 (18)	18-20 (19)	20-26 (22.5)	18	ca. 22	18-28 (22.5)	20-25 (22.5)
striae density at apices (rapheless valve)	40-50	36-40	30-35	18 : equidistantly spaced on raphe valve	ca. 34	35-45	ca. 40
number of observations (LM)	128	no data	109	no data	no data	101	100

rable to the one of the other sites. Fig. 5 shows the correlation between valve length and valve width and stria density. On this figure, the three locations with the longer valves clearly show no significant deviation in terms of widths and stria densities. Moreover, their outline shape is similar to those observed in the type locality (see figures in Plate III). For this reason, we considered that these individuals belong to *Achanthidium druartii* sp. nov.

DISCUSSION

Comparison with morphologically closely related taxa

This new species belongs to the group of taxa around *A. pyrenaicum* based on the stria density which is around 20 µm and the linear-lanceolate valve shape. There are six morphologically closely related taxa to be found in the literature: *A. convergens* (Kobayasi) Kobayasi, *A. deflexum* (Reimer) Kingston, *A. japonicum* (Kobayasi) Kobayasi, *A. latecephalum* Kobayasi, *A. pyrenaicum* (Hustedt) Kobayasi and *A. rivulare* Potapova & Ponader. Table II summarizes the main morphological features of these taxa.

In light microscopy, the easiest way to distinguish *A. druartii* from these taxa is the average valve size. Even if there are some overlaps in the valve lengths *A. druartii* sp. nov. is the only taxon showing the highest average length. It also shows the highest average width. Secondly, the striae orientation near the apices is slightly radiate in *A. druartii* sp. nov. whereas in four other taxa the striae orientation at apices is different, i.e. slightly convergent to parallel for *A. rivulare*, parallel to almost parallel for *A. deflexum, A. latecephalum, A. pyrenaicum*. The other two, *A. convergens* and *A. japonicum* present a striae orientation which is radiate for only one of their valves (raphe valve for *A. japonicum* and rapheless valve for *A. convergens*) and share a different feature for the other valve (convergent for raphe valve for *A. convergens*, parallel for rapheless valve for *A. japonicum*).

Stria density near the valve center is also a good distinctive feature revealed by light microscopy. *A. druartii* sp. nov. has fewer striae in the center than four of the other taxa (*A. deflexum, A. latecephalum, A. pyrenaicum, A. rivulare*). *A. convergens* and *A. japonicum* show a similar stria density in the center, but their valve shape is very different since it is linear lanceolate whereas in *A. druartii* it is lanceolate.

Another interesting characteristic to differentiate *A. druartii* sp. nov., is that it shows an important stria density difference between the center and the apices, which is about 25-28 stria per 10 μm, similar to *A. rivulare* (25-30) but very different from *A. convergens* (18-20), *A. deflexum* (14-16), *A. japonicum* (10-14), *A. latecephalum* (14-16) and *A. pyrenaicum* (15-17).

Table III. – Abundance-weighted averages and weighted standard deviation of the water physico-chemical parameters in the sites where *Achnanthidium druartii* sp. nov. was registered.

Physicochemical parameters	Weighted average	Weighted standard deviation	Number of data
water temperature (°C)	19.06	1.50	7
pH	7.99	0.10	7
conductivity at 25°C (μS.cm^{-1})	390.28	114.90	7
suspended matter (mg.L^{-1})	26.3	11.8	11
dissolved oxygen (mg.L^{-1})	9.08	0.56	7
oxygen saturation (%)	97.8	5.1	7
chemical Oxygen Demand (mg.L^{-1} O_2)	9.66	5.20	6
biological oxygen demand (mg.L^{-1} d'O_2)	0.63	0.29	11
dissolved organic carbon (mg.L^{-1} C)	2.1	1.0	11
Nkj (mg.L^{-1})	0.9	0.2	6
NH_4^+ (mg.L^{-1} NH_4^+)	0.09	0.03	11
NO_2^- (mg.L^{-1} NO_2-)	0.07	0.03	11
NO_3^- (mg.L^{-1} NO_3-)	8.4	2.8	11
PO_4^{2-} (mg.L^{-1} PO_4^2-)	0.130	0.057	11
total phosphorus (mg.L^{-1} P)	0.06	0.03	11
Ca^{2+} (mg.L^{-1})	74	8	8
Mg^{2+} (mg.L^{-1})	5.3	0.9	8
Na^+ (mg.L^{-1})	12.0	7.7	8
K^+ (mg.L^{-1})	2.1	0.6	8
CO_3^{2-} (mg.L^{-1})	0.9	0.2	4
HCO_3^- (mg.L^{-1})	183.3	31.1	4
Cl^- (mg.L^{-1})	18.2	15.1	8
SiO_2 (mg.L^{-1} SiO_2)	7.4	3.1	4
SO_4^{2-} (mg.L^{-1} SO_4^{2-})	44.1	10.4	5

Ecology and distribution dynamics

Achnanthidium druartii sp. nov. is a freshwater epilithic taxon usually sampled on stones. Its type locality is the confluence of the middle sized river Roubion with the much larger river Rhône. At this sampling site, the river is more than 200 m wide. The river Rhône hardly influences this sampling site, since the main current at the sampling point was mostly coming from the Rhône river. Several other sampling sites present on analogous context as the type locality: the river Meuse in Givet, the river Garonne in Toulouse, the river Doubs in Saunières, the river Rhône in Avignon and the river Loire in Saint-Mathurin are likewise large rivers. Several other sampling sites are navigation channels.

Table III summarizes the ecological preferences of *A. druartii* sp. nov. Water conductivity and pH values clearly indicate that this species is typical for relatively high conductivities and calcium contents. It is present on sedimentary substrates and therefore can be considered as alkaliphilous. This taxon prefers well oxygenated waters, with relatively low trophic and very low saprobic levels.

In the river Roubion (type locality, sampled in 2008), *A. druartii* sp. nov. was dominant (47 %) accompanied by *Amphora pediculus* (Kützing) Grunow (16 %) and *Achnanthidium minutissimum* (Kützing) Czarnecki (11 %). Other taxa with lower abundances include *Sellaphora minima* (Grunow) Mann (8 %), *Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot (5 %) and *Nitzschia palea* (Kützing) W. Smith (3 %). The average abundances of the main taxa observed in the other samples were: *A. minutissimum* (13 %), *Amphora pediculus* (11 %), *Achnanthidium straubianum* (7 %), *A. druartii* sp. nov. (6 %), *A. eutrophilum* (5%), *Staurosira venter* (Ehrenberg) Cleve & Moeller (5 %), *Navicula cryptotenella* Lange-Bertalot (4 %).

Achnanthidium druartii seems to spread quickly in France (Fig. 1). This observation does not seem to be related to a higher sampling effort since the river networks for quality monitoring have been established with the same sampling stations several years before 2004 when this new taxon was first mentioned. It was observed in only one site in 2004 and 2005, 4 sites in 2006, 21 in 2007 and 40 in 2008 (Fig. 6). In view of this expansion rate, this taxon can probably be considered as an invasive species similar to several other taxa in France such as *Eolimna comperei* Ector, Coste & Iserentant, *Achnanthes subhudsonis* Hustedt and *Gomphoneis minuta* (Stone) Kociolek & Stoermer (Coste & Ector 2000). The dynamics of the geographical distribution of this species shows how fast microalgae can be disseminated over long distances.

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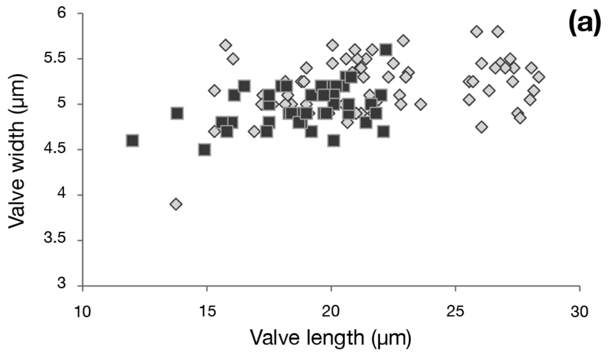

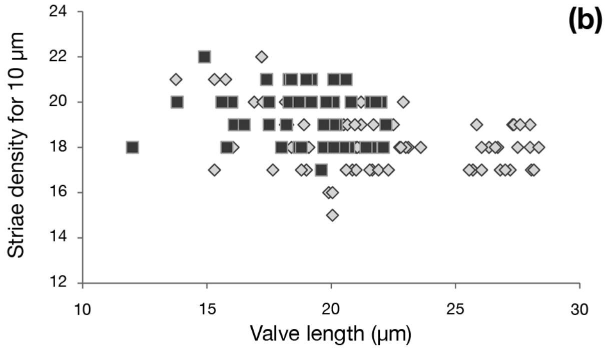

Fig. 5. – Correlation between valve length and valve width (a) valve length (b) and striae density in *Achnanthidium druartii* sp. nov. cells. Black squares correspond to type locality and grey diamonds to other sites.

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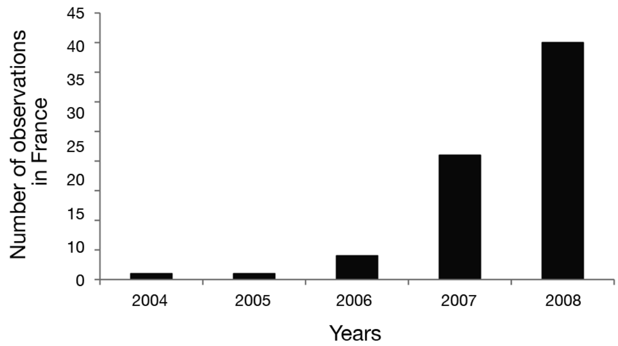

Fig. 6. – Number of sampling sites evolution where *Achnanthidium druartii* sp. nov. was observed in France from 2004 to 2008.

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