

Four new *Navicula* (Bacillariophyta) species from Swedish rivers

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Abstract – During an extensive survey of the diatoms of Swedish rivers, four new *Navicula* species (Bacillariophyceae) were found: *Navicula antoniooides* sp. nov., *N. ireneae* sp. nov., *N. scaniae* sp. nov. and *N. ceciliae* sp. nov. The new species are described formally using light and scanning electron microscopy. All four species possess a unique set of morphological characters including the structure of the central raphe endings, the striation pattern, the valve dimensions and outline, which make it possible to separate them from similar *Navicula* taxa such as *N. cryptocephala*, *N. radiosafallax* or *N. antonii*. The ecological preferences of each species are briefly discussed. Finally, the distribution of *Navicula* s.s. taxa in European inland waters is briefly discussed.

Bacillariophyta / Freshwater diatoms / *Navicula* / New species / Rivers / Sweden / Taxonomy

Résumé – Quatre nouvelles espèces de *Navicula* (Bacillariophyta) provenant de rivières en Suède. Durant une analyse des diatomées lotiques des rivières en Suède, plusieurs nouvelles espèces de *Navicula* (Bacillariophyceae) ont été trouvées : *Navicula antoniooides* sp. nov., *N. ireneae* sp. nov., *N. scaniae* sp. nov. et *N. ceciliae* sp. nov. Les nouvelles espèces sont décrites à partir d'observations en microscopie optique et à balayage. Chaque nouvelle espèce présente une combinaison unique de caractères morphologiques comme la structure des terminaisons centrales du raphé, la striation, les dimensions des valves et la forme générale des valves qui permet de les séparer d'autres espèces semblables du genre *Navicula* comme *N. cryptocephala*, *N. radiosafallax* ou *N. antonii*. Les préférences écologiques de chaque espèce sont brièvement discutées. Enfin, la distribution des *Navicula* s.s. dans les eaux continentales d'Europe est brièvement discutée.

Bacillariophyta / Diatomées des eaux douces / *Navicula* / Nouvelles espèces / Rivières / Suède / Taxinomie

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INTRODUCTION

In 1822, Bory de St. Vincent described the diatom genus *Navicula*. Almost 150 years later, the initial – rather broad – species concept was modified several times (Patrick 1959, Cox 1979, Round et al. 1990) and, after elimination of all other sections of this formerly very heterogeneous collective genus based on the neotypus generis *Navicula tripunctata* (O.F. Müller) Bory, only members of the section ‘Lineolatae’ were included within *Navicula s.s.* In 2001, Lange-Bertalot produced a revision of the majority of European *Navicula* species, which resulted in the publication of an iconographic atlas for the European taxa belonging to this genus. To date, more than 125 described taxa (including subspecies and varieties) of *Navicula s.s.* have been recorded from freshwater (excluding brackish-water) habitats of Europe (Lange-Bertalot, 2001; Werum & Lange-Bertalot, 2004; Levkov et al., 2007; Van de Vijver & Lange-Bertalot, 2009). In the past, due to force-fitting (Tyler, 1996) and lumping the actual diversity has been underestimated. In temperate and tropical regions, *Navicula* species form a dominant and often highly diverse component of aquatic benthic diatom communities (Rumrich et al., 2000; Lange-Bertalot, 2001; Werum & Lange-Bertalot, 2004; Metzeltin & Lange-Bertalot, 2009). New species are regularly being described (Levkov et al., 2007; Van de Vijver & Lange-Bertalot, 2009). Moreover, *Navicula s.s.* is a dominant constituent of the European river diatom flora forming often important populations and hence plays a major role in the European biomonitoring of rivers.

A recent survey of the freshwater diatom flora of Swedish rivers has already resulted in the description of *Navicula suecicarum* Van de Vijver et al. and the new taxonomic combination *Navicula neomundana* (Lange-Bertalot) Van de Vijver et al. (Van de Vijver & Lange-Bertalot, 2009). During the analysis of new material from Swedish rivers, four hitherto undescribed *Navicula* taxa were found. Whether the description of these four species reflects the correct biological reality can only be tested using molecular analysis comparing all *Navicula* taxa. This is practically impossible to perform for every single population. Recent studies suggest that due to semicryptic or cryptic diversity, the true diversity within *Navicula s.s.* is almost certainly underestimated (Vanellander et al., 2009; Pouličková et al., 2010). Nevertheless, it is sometimes important to recognize populations as separate (morphological) entities, especially when their presence may indicate different environmental conditions, allowing for a finer discrimination of water quality. Therefore, in this paper, we present data on the morphology, ecology and distribution together with the formal description of all four (morpho)-species. A comparison is made with the most similar taxa to facilitate the distinction of these four species.

MATERIAL AND METHODS

Samples of benthic diatoms used in this study were collected during the course of the ongoing floristic survey and water quality monitoring programs in Sweden. Three river localities were selected for this paper, since their diatom communities contained previously undescribed *Navicula* species. These were Bergunda kanal (province of Småland; X/Y 6304710/1435250), Skräbeån

(province of Skåne; X/Y 6213507/1416637) and Vasslan (province of Härjedalen; X/Y 6881709/1378823).

Diatom samples were taken from the upper surface of stones or from submerged water plants. The samples were prepared following the method described in Van der Werff (1955). Small parts of the samples were cleaned by adding 37 % H₂O₂ and heated to 80°C for about 1h after which the reaction was completed by addition of KMnO₄. Following digestion and centrifugation (3 times 10 minutes at 3500 rpm), the material was diluted with distilled water to avoid excessive concentrations of diatom valves which could hinder reliable observations. Cleaned diatom valves were mounted in Naphrax. The samples and slides were deposited at the National Botanic Garden of Belgium (BR), Department of Bryophytes and Thallophytes. Light microscope (LM) observations were carried out using an Olympus BX51 microscope equipped with Nomarski optics. For scanning electron microscopy (SEM), part of the suspension was filtered through polycarbonate membrane filters with a pore diameter of 3 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with 50 nm of Au and studied in a JEOL-5800LV at 20 kV.

Terminology of valve morphology is based on Barber & Haworth (1981), Ross *et al.* (1979), Round *et al.* (1990) and Lange-Bertalot (2001).

RESULTS

During our floristic survey of the freshwater diatoms from Sweden, more than 40 different taxa (including species, varieties and formas) belonging to the genus *Navicula* s.s. were found (Appendix 1). Four taxa could not be identified based on the available literature and after a thorough morphological analysis, they were considered to be new to science: *Navicula antonioides* sp. nov., *Navicula ireneae* sp. nov., *Navicula scaniae* sp. nov. and *Navicula ceciliae* sp. nov.

Navicula antonioides sp. nov.

Figs 1-9, 12-15

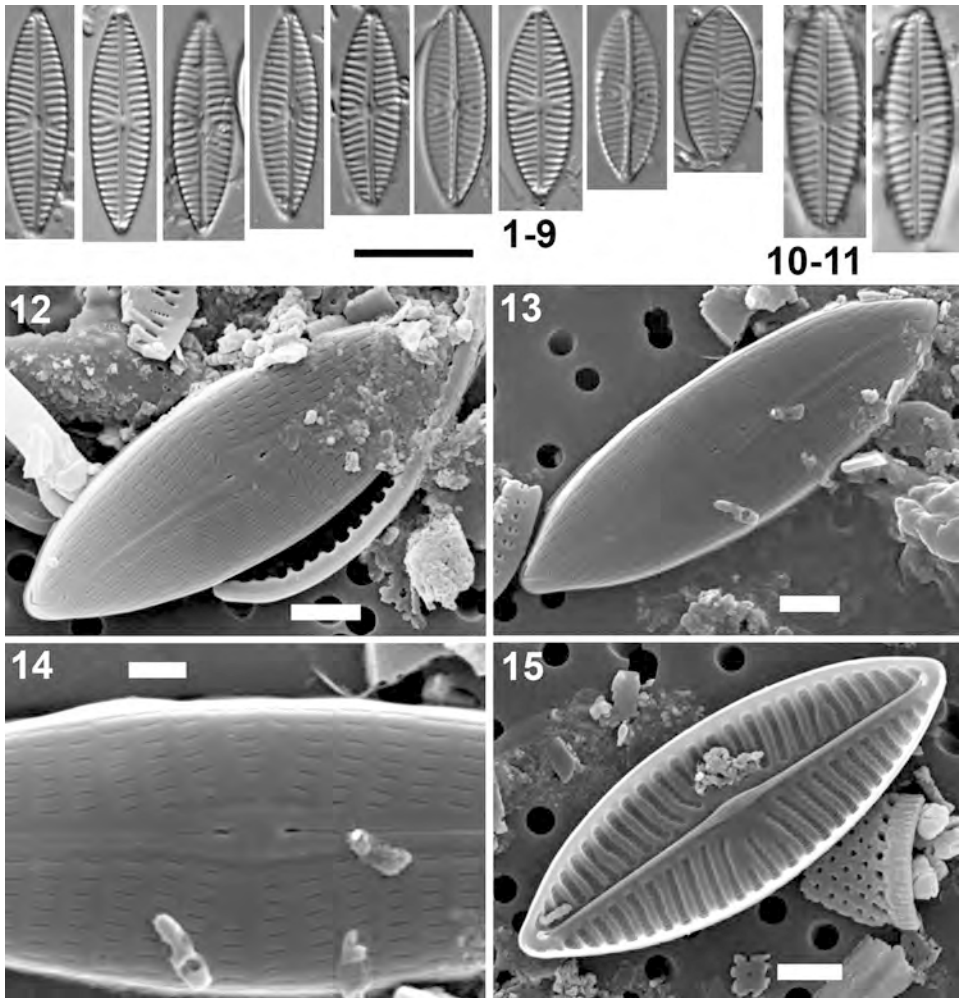
Holotype: BR-4186 (National Botanical Garden of Belgium, Meise)

Isotypes: PLP-149 (UA, University of Antwerp), BRM-ZU7/33 (Hustedt Collection, Bremerhaven)

Typelocality: Bergundakanal (province of Småland, Sweden; X/Y 6304710/1435250) (coll. date 20/10/2005)

Etymology: the specific epithet refers to the close similarity with *Navicula antonii* Lange-Bertalot.

Diagnosis: *Valvae elliptico-lanceolatae ad lanceolatae apicibus cuneatim attenuatis et fere acute rotundatis non protractis. Longitudo 12-19 µm, latitudo 4.9-5.8 µm. Raphe filiformis recta poris centralibus punctiformibus. Area axialis angustissima linearis. Area centralis parva aliquid transapicaliter dilatata variabilis ad instar. Striae transapicales modice radiantibus sed sub apices subparallelae vel minime convergentes, fere constanter 14-15 in 10 µm. Lineolae difficulter discernendae microscopio photonico. Aspectus ultramicroscopicus externus internusque (vide Figs 12-15). Sternum externum in media parte valvae distincte formatum. Pori centrali raphis parum dilati sed apicaliter elongati paene recti vel minime deflexi ad latus secundum valvae. Foramina areolarum 35-38 in 10 µm.*



Figs 1-9, 12-15. *Navicula antonioides* sp. nov. Light and Scanning Electron micrographs. **1-9**. LM views of the type population. **10, 11**. *Navicula antonii* Lange-Bertalot. **12, 13**. SEM external views of an entire valve. **14**. SEM detail of the central area. **15**. SEM internal view of an entire valve. Scale bars represent 10 μm for Figs 1-11, 2 μm for Figs 12, 13 & 15 and 1 μm for Fig. 14.

Unica species vero similis, *N. antonii* Lange-Bertalot differt valvis latoribus (6.0-7.5 μm), striis plerumque distantius sitis inter se (10.5-15 in 10 μm) etiam lineolis (28-32 in 10 μm).

LM observations (Figs 1-9): Valves lanceolate to elliptic-lanceolate in smaller specimens with convex margins and cuneately to almost acutely rounded, non protracted valve apices. Valve dimensions (n=15): valve length 12-19 μm , valve width 4.9-5.8 μm . Axial area very narrow, linear, hardly widening towards the central area. Central area rather variable, small, somewhat asymmetric, weakly transapically widened with one rounded and one rectangular side, never forming

a fascia due to the presence of irregularly shortened central striae. Raphe filiform with expanded external central pores, weakly deflected to the secondary side. Transapical striae radiate in the middle, becoming subparallel and even slightly convergent towards the apices, 14-15 in 10 μm . Lineolae rather difficult to observe in the LM.

SEM observations (Figs 12-15): External valve surface raised around the central raphe endings, coincident with the internal raphe sternum thickenings, but flattened towards the pole so only the extent of the central area is visible (Figs 12-14). External central raphe endings weakly expanded, elongated apically, almost straight or slightly deflected to the secondary valve side (Fig. 14). Striae composed of lineolae as long as the virgae are wide, 35-38 in 10 μm (Figs 12-13). Internally, lineolae openings rounded, occluded by raised hymenes, in grooves below the internal surface of the virgae (Fig. 16).

Ecology and associated diatom taxa: The species is described from Bergunda kanal, a small brook in southern Sweden (close to the city of Växjö), which is eutrophic (mean total P 0,12 mg/l) with an IPS index of 13,0 and with a circumneutral to alkaline pH (7.0-9.4). The species has been found in several other rivers in Sweden, but was identified as *Navicula antonii*. The IPS values of some of the rivers varied between 11,8-14,0 and the diatom assemblages were dominated by *Achnantheidium minutissimum* (Kützing) Czarnecki (group III = mean width > 2,8 μm), *Amphora pediculus* (Kützing) Grunow, *Cocconeis placentula* Ehrenberg (including varieties), *Eolimna minima* (Grunow) Lange-Bertalot, *Fistulifera saprophila* (Lange-Bertalot et Bonik) Lange-Bertalot, *Gomphonema parvulum* (Kützing) Kützing, *Nitzschia amphibia* Grunow, *N. paleacea* (Grunow) M. Peragallo and *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot.

***Navicula ireneae* sp. nov.**

Figs 16-30

Holotype: BR-4187 (National Botanical Garden of Belgium, Meise)

Isotypes: PLP-150 (UA, University of Antwerp), BRM-ZU7/34 (Hustedt Collection, Bremerhaven)

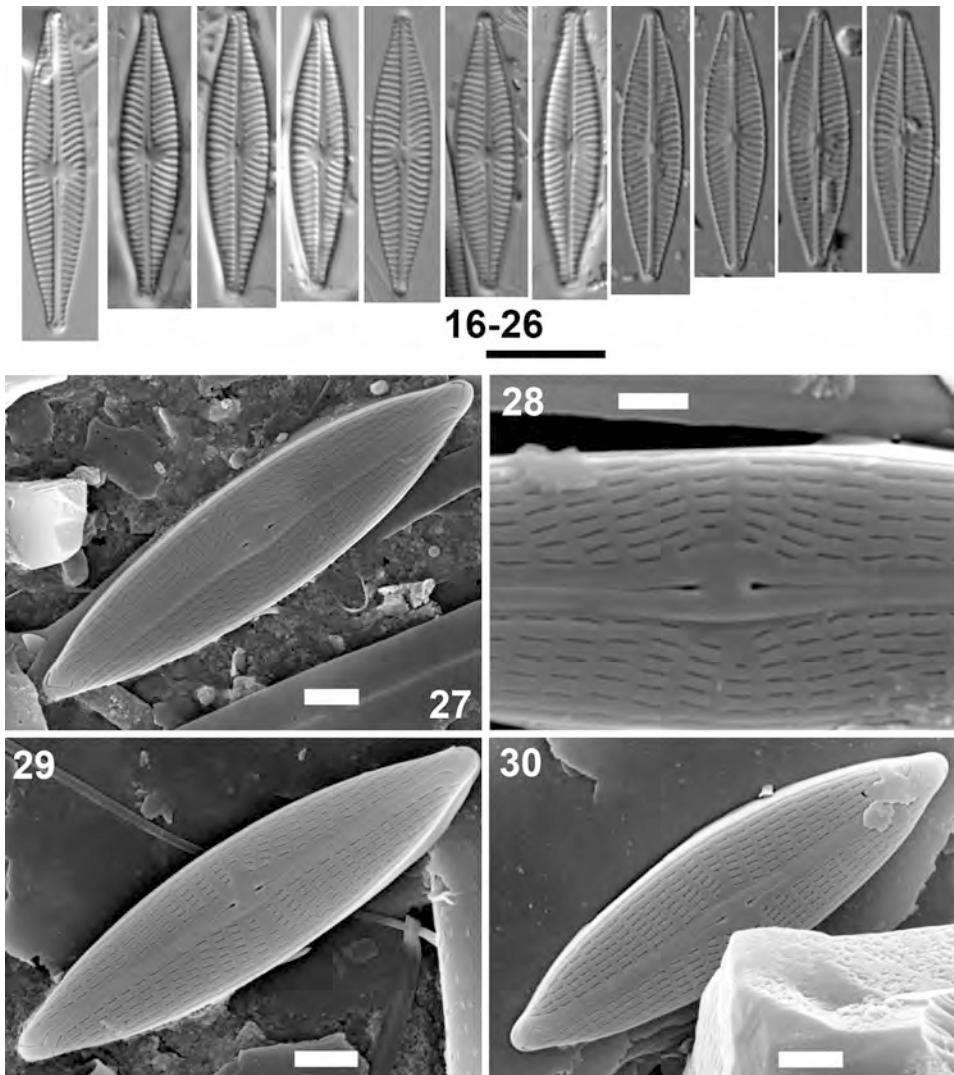
Typelocality: Skräbeån (province of Skåne, Sweden; X/Y 6213507/1416637) (coll. date 04/09/2008)

Etymology: The taxon is named after our dear friend and colleague Iréne Sundberg (Medins Biologi AB, Mölnlycke, Sweden), who independently of us recognized this taxon as an undescribed species.

Diagnosis: *Valvae lanceolatae apicibus curte protractis circiter subrostratis. Longitudo 20-26 μm , latitudo 4.5-5.0 μm . Raphe filiformis fere recta apprens poris centralibus parvis. Area axialis angustissima linearis. Area centralis circiter tertium ad dimidium latitudinis valvae extendens variabiliter formata. Striae transapicales radiantibus sed subparallelas vel modice convergentes sub apices, 15-17 in 10 μm , aliquid irregulariter abbreviatae ad aream centralem. Areolae inaspectabiles. Aspectus ultramicroscopicus externus (vide Figs 27-30). Pori centrales raphis apicaliter elongati fere recti parum expansi non distincte deflexi ad latus primum vel secundum valvae. Foramina areolarum 40-45 in 10 μm . Sternum externum conspicue formatum in media parte valvae.*

Species plus minusve similes ut N. cryptocephala Kützing, N. caterva Hohn & Hellerman, N. aquaedurae Lange-Bertalot omnes differunt complexione signorum typicum (vide descriptiones in Lange-Bertalot 2001).

LM Observations (Figs 16-26): Valves lanceolate to elliptic-lanceolate with shortly protracted, almost subrostrate valve apices. Valve dimensions (n=15):



Figs 16-30. *Navicula ireneae* sp. nov. Light and Scanning Electron micrographs. 16-26. LM views of the type population. 27, 29-30. SEM external valve of entire valves. 28. SEM detail of the central area. Scale bars represent 10 μm for Figs 16-26, 2 μm for Figs 27, 29-30 and 1 μm for Fig. 28.

valve length 20-26 μm , valve width 4.5-5.0 μm . Axial area very narrow, linear, hardly widening near the central area. Central area extending to 1/3-1/2 of the valve width, variable in shape and clearly asymmetrical. Raphe filiform, almost straight with small, rather distant external central endings. Transapical striae radiate but becoming subparallel to moderately convergent near the apices, 15-17 in 10 μm . Striae irregularly shortened near the central area. Lineolae not discernible in LM.

SEM observations (Figs 27-30): Raphe sternum distinctly developed near the central area (Figs 27-28). External central raphe endings apically elongate, only

weakly expanded (Fig. 28), very slightly undulate and not deflected to either the primary nor secondary side (Figs 29-30). Striae composed of rather large lineolae, longer than the virgae are wide, 40-45 in 10 μm . The internal valve structure was not observed due to the rarity of the species in the material.

Ecology and associated diatom taxa: The largest population of *Navicula ireneae* was found in Skråbeån, a small shallow, mesotrophic river in southern Sweden (IPS 15,6), with a slightly alkaline pH (max. 7.9). The diatom assemblage was dominated by *Achnanthydium minutissimum*, and subdominant species were *Fragilaria gracilis* Østrup, *Navicula cryptotenella* Lange-Bertalot, *Nitzschia sociabilis* Hustedt and *Pseudostaurosira brevistriata* (Grunow) Williams *et* Round. *Navicula ireneae* has been found in several other mesotrophic to slightly eutrophic rivers in Sweden.

***Navicula scaniae* sp. nov.**

Figs 31-45

Holotype: BR-4188 (National Botanical Garden of Belgium, Meise)

Isotypes: PLP-151 (UA, University of Antwerp), BRM-ZU7/35 (Hustedt Collection, Bremerhaven)

Type locality: Skråbeån (province of Skåne, Sweden; X/Y 6213507/1416637) (coll. date 04/09/2008)

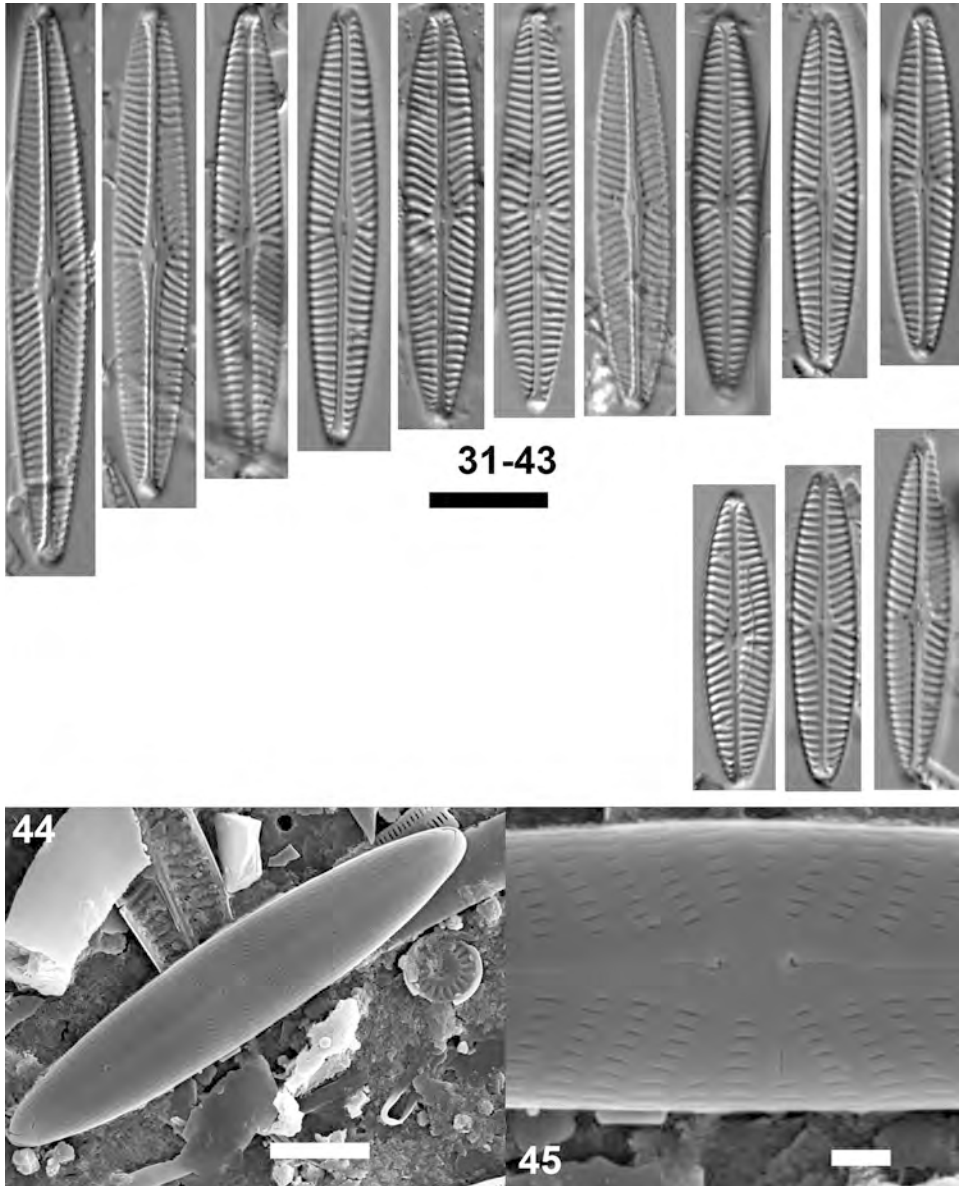
Etymology: The specific epithet refers to the Swedish province of Skåne (latin: Scania) from where the species was described.

Diagnosis: *Valvae lineari-lanceolatae ad anguste lanceolatae apicibus obtuse rotundatis numquam protractis. Longitudo 25-50 μm , latitudo 5.5-6.5 μm . Raphis filiformis recta in partibus distalibus tum sensim deflexis ad latus secundum valvae. Area axialis angustissima. Area centralis aliquid variabilis sed semper parva parum dilatata circiter rhombica ad margines versus irregulariter formata striis mediis alternantibus curtioribus longioribusque. Striae transapicales fortius radiantes in mediis partibus sed ab disordinatione Voigtii usque ad apices fere abrupte convergentes, 11-13 in 10 μm . Areolae difficulter discernendae microscopio photonico. Aspectus ultramicroscopicus externus (vide Figs). Raphis cum extremis centralibus externis conspicue undulatis denique distincte hamatis ad poros centrales. Foramina areolarum modice elongata apicaliter, 35-38 in 10 μm .*

Species similissima, Navicula radiosafallax Lange-Bertalot syn. N. radiosa var. parva Wallace differt proprie striis transapicalibus densius sitis inter se (13-14 in 10 μm) etiam lineolis (33-35 in 10 μm). Alterae species adhuc cognitae ut N. seibigiana Lange-Bertalot, N. cariocincta Lange-Bertalot, N. hintzii Lange-Bertalot magis differunt complexione signorum typicorum.

LM observations (Figs 31-43): Valves linear-lanceolate to narrowly lanceolate with almost parallel to weakly convex margins and broadly rounded, never protracted valve apices. Valve dimensions (n=25): valve length 25-50 μm , valve width 5.5-6.5 μm . Axial area very narrow, linear, gradually widening near the central area. Central area rather variable in shape due to alternating longer and shorter striae around the central area, but always small and only slightly widened. Raphe filiform, straight near the distal endings but slightly undulate near the central area with external central endings deflected towards the secondary side. Transapical striae strongly radiate in the middle part of the valves, abruptly becoming convergent distal to the Voigt discordance, 11-13 in 10 μm . Lineolae difficult to resolve in LM.

SEM observations (Figs 44-45): Central external raphe fissures distinctly undulated with slightly expanded external central endings. External central endings hooked towards the valve secondary side (Fig. 45). Striae composed of rather large lineolae, never longer than the virgae are wide, 35-38 in 10 μm (Fig. 44). The valve interior has not been observed.



Figs 31-45. *Navicula scaniae* sp. nov. Light and Scanning Electron micrographs. **31-43**. LM views of the type population. **44**. SEM external valve view clearly showing the course of the raphe and the structure of the striae and lineolae. **45**. External SEM detail of the central area. Scale bars represent 10 μm except for Fig. 45 where scale bar = 1 μm .

Ecology and associated diatom taxa: *Navicula scaniae* is described from Skräbeån, a small mesotrophic river in southern Sweden (IPS 15,6), with a slightly alkaline pH (max. 7.9). The diatom assemblage was dominated by *Achnanthydium minutissimum*, and subdominant species were *Fragilaria gracilis*, *Navicula cryptotenella*, *Nitzschia sociabilis* and *Pseudostaurosira brevistriata*. This species was also found in several other Swedish rivers with an IPS-range of 12-15 indicating moderately polluted, eutrophicated waters.

***Navicula ceciliae* sp. nov.**

Figs 46-59

Holotype: BR-4189 (National Botanical Garden of Belgium, Meise)

Isotypes: PLP-152 (UA, University of Antwerp), BRM-ZU7/36 (Hustedt Collection, Bremerhaven)

Type locality: Vasslan (=Djursvasslan) (province of Härjedalen; X/Y 6881709/1378823) (coll. date 10/09/2005)

Etymology: The taxon is dedicated to Cecilia Andrén, who introduced the analysis of diatoms in the ISELAW (Integrated studies of the effects of liming acidified waters) programme in Sweden, and from the results constructed an acidity index for diatoms, called ACID, which is now used in riverine waters monitoring in Sweden.

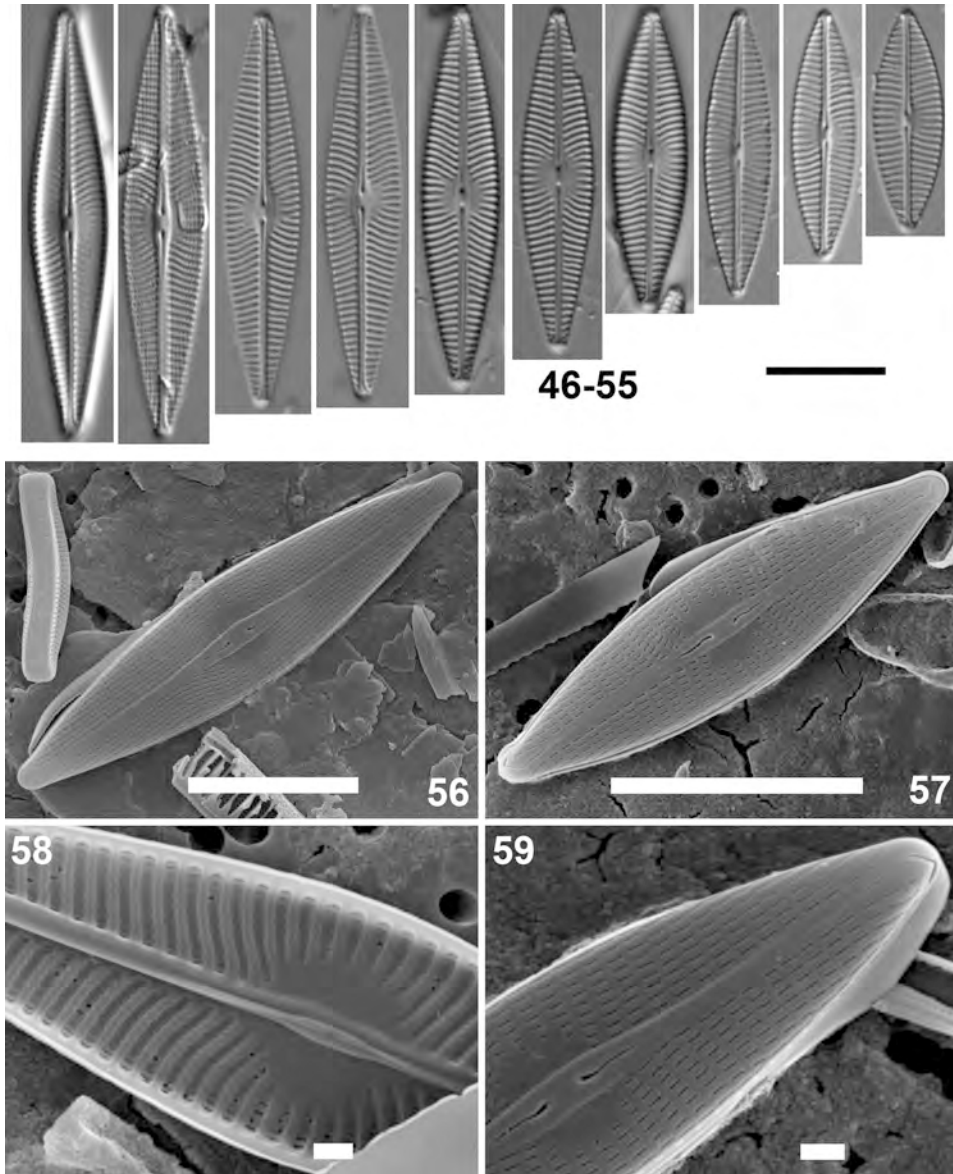
Diagnosis: *Valvae omnes lancolatae apicibus acute rotundatis non protractis. Longitudo 18-40 µm, latitudo 4.8-6.5 µm. Raphe linearis recta poris centralibus distinctis. Area axialis angustissima linearis. Area centralis ampla plus minusve circularis circiter dimidium latitudinis valvae extendens. Striae transapicales radiantes sed sub apices subparallelae ad paulo convergentes, 16-17 in 10 µm. Areolae aspectabiles cum illuminatione aliquid obliqua, 35 in 10 µm. Aspectus ultramicroscopicus externus internusque (vide figs 56-59). Sternum externum in media parte valvarum distincte formatum. Raphe cum extremis centralibus externis undulata denique leviter hamatis ad latus primum valvae.*

Species simillissimae quoad lineamentum et dimensiones, N. cryptocephala Kützing, N. phyllepta Kützing et N. wygaschii Lange-Bertalot etiam aliae minus similes differunt proprie extremis centralibus raphis deflexis ad latus secundum valvae, praeterea N. phyllepta vivat in aquis marinis.

LM observations (Figs 46-55): Valves typically lanceolate to elliptic-lanceolate in smaller specimens with convex margins and acutely rounded, non-protracted valve apices. Valve dimensions (n = 20): valve length 18-40 µm, valve width 4.8-6.5 µm. Axial area very narrow, linear, not widening towards the central area. Central area more or less circular, rather large, occupying almost half the valve width, but never forming a fascia, having several, regularly arranged shortened striae around the central area. Raphe filiform, almost straight with expanded central pores. Transapical striae radiate but subparallel to weakly convergent near the valve apices, 16-17 in 10 µm. Lineolae visible in LM using oblique lighting, ca. 35 in 10 µm.

SEM observations (Figs 56-59): External raphe sternum clearly raised and widened in the middle of the valve, less developed towards the apices (Figs 56-57). Central raphe endings undulate with expanded central pores that are weakly deflected towards the primary side (Fig. 59). Striae composed of rather long lineolae, clearly longer than the virgae are wide (Figs 56-57). Internally, asymmetrically developed raphe sternum with the raphe slit opening on the side, but with central raphe endings in the middle of the central area (Fig. 58).

Ecology and associated diatom taxa: This new species has so far only been found at the type locality. Vasslan is a circumneutral to slightly acidic (minimum



Figs 46-59. *Navicula ceciliae* sp. nov. Light and Scanning Electron micrographs. 46-55. LM views of the type population. 56-57. SEM external valve views clearly showing the course of the raphe and the structure of the striae and lineolae. 58. SEM internal detail view of the central area. 59. External SEM detail of the central area and the valve apex. Scale bars represent 10 μm except for Figs 58-59 where scale bar = 1 μm .

pH 6,3), oligotrophic river in central Sweden. The diatom assemblage at the type locality is composed of *Achnantheidium minutissimum*, *Encyonopsis krammeri* Reichardt, *Fragilaria gracilis*, *Gomphonema exilissimum* (Grunow) Lange-Bertalot et Reichardt and *Rossithidium pusillum* (Grunow) Round et Bukhtiyarova.

DISCUSSION

The *Navicula* flora in Sweden is rather diverse. Based on Lange-Bertalot (2001) and others (Werum & Lange-Bertalot, 2004; Levkov *et al.*, 2007; Van de Vijver & Lange-Bertalot, 2009) the entire European diatom flora contains almost 130 (non-marine) *Navicula* taxa. Of these, more than 50 % have been found so far in Swedish rivers. Many of the missing taxa have only a very limited distribution in Europe. For instance, eleven taxa are only known from the ancient lakes of Ohrid and Prespa (Levkov *et al.*, 2007), others, such as *Navicula cancellata* Donkin, have a preference for brackish environmental conditions or, like *Navicula arkona* Lange-Bertalot et Witkowski are only known from fossil assemblages.

The four new *Navicula* species from Sweden all present unique sets of characters that distinguish them from all previously described *Navicula* species. At present, most have a restricted distribution in Sweden. However, it is possible that in the past they have been confused with well-known species, such as *Navicula cryptocephala* Kützing. Better delimitation of these taxa will enhance our knowledge, not only of the northern, but also of the central and western European diatom flora.

Only one species, *Navicula antonii* Lange-Bertalot (Figs 10-11) can be confused with *Navicula antonioides*. However, *Navicula antonii*, has wider valves (6.0-7.5 μm vs 4.9-5.8 μm) with more distantly spaced striae (10.5-15 vs constantly 14-15 in 10 μm in *N. antonioides*) and a lower number of lineolae in 10 μm (28-32 vs 35-38) so that the lineolae are clearly discernible in LM. Other taxa such as *Navicula menisculus* Schumann, *N. upsaliensis* (Grunow) Peragallo and *N. catalanogermanica* Lange-Bertalot have larger valves.

Navicula ireneae is similar to *N. cryptocephala*, *N. leistikowii* Lange-Bertalot, *N. caterva* Hohn et Hellerman and *N. aquaedurae* Lange-Bertalot. *Navicula cryptocephala* is usually larger (valve width 5-7 μm vs 4.5-5.0 μm in *N. ireneae*), has a larger, more circular central area and hooked external central raphe endings unlike *N. ireneae* in which external central raphe endings are straight. *Navicula aquaedurae* and *N. leistikowii* have a more linear-lanceolate valve outline with less radiate and more distant striae and a larger central area. *Navicula caterva* is smaller (10.4-17 μm vs 20-24 μm) with a less radiate, longer striae near the central area. Taxa such as *N. cryptotenella* Lange-Bertalot or *Navicula lundii* Reichardt have very different valve outlines with for instance more obtusely rounded, less protracted valve apices, and can therefore hardly be confused with *N. ireneae*. The asymmetric central area of *N. lundii* differs from the smaller central area in *N. ireneae* (Lange-Bertalot, 2001).

Navicula scaniae can be confused with several *Navicula* species such as *N. radiosafallax*, *N. seibigiana* Lange-Bertalot, *N. cariocincta* Lange-Bertalot and *N. hintzii* Lange-Bertalot. *Navicula radiosafallax* has more acutely rounded valve apices and can also be separated based on its more densely striated valves (13-14 vs 11-13 in 10 μm) with fewer lineolae (33-35 vs 35-38 in 10 μm). *Navicula seibigiana* is smaller (25-35 vs 25-50 μm) with a different valve outline showing typical rostrate

apices and more convex margins contrary to *N. scaniae* that is more elongate with more parallel margins and non-protracted apices. Likewise, there are differences in striation pattern with less radiate, more distant (9-11 vs 11-13 in 10 µm) striae and a different pattern of shortened striae near the central area showing a more regular alternation of longer and shorter striae. *Navicula cariocincta* has a larger central area due to more shortened central striae. *Navicula hintzii* has wider valves (6.5-8.5 µm vs 5.5-6.5 µm in *N. scaniae*), a more clearly lanceolate to elliptic-lanceolate outline. In *N. hintzii*, the external central raphe endings are distinctly expanded but never hooked as is the case in *N. scaniae* (Lange-Bertalot, 2001).

Finally, based on the deflection of the central raphe endings towards the primary side, *Navicula ceciliae* belongs to the Alinea-section of the genus *Navicula* s.s. (Lange-Bertalot, 2001) and all species presenting a large similarity in valve outline and valve dimensions, such as *N. cryptocephala*, *N. phyllepta* and *N. wygaschii*, belong to the section *Navicula* based on their central raphe endings being curved towards the secondary side. *Navicula cryptocephala* also shows weakly but still detectably protracted valve apices that are always absent in *N. ceciliae*. The striation pattern in *N. cryptocephala* shows a much more abrupt change in direction near the Voigt discordance than in *N. ceciliae*, where this change is gradual. *N. phyllepta* is so far only known from brackish and marine conditions (Lange-Bertalot, 2001; Van Elslander *et al.*, 2009) whereas *N. ceciliae* is found in oligotrophic conditions with mean conductivity of 35,5 µS/cm and low phosphorus content (0.013 mg/l). *Navicula phyllepta* is also wider than *N. ceciliae* (6.6-8.5 µm vs 4.8-6.5 µm) with a higher number of striae (17-20 vs 16-17 in 10µm). Finally, *N. wygaschii* is lanceolate with very acutely rounded valve apices and a very small, barely developed central area.

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Appendix 1. List of species of the genus *Navicula* s.s. Bory de Saint-Vincent recorded from Swedish rivers.

<i>Navicula amphiceropsis</i> Lange-Bertalot et Rumrich	<i>Navicula peregrina</i> (Ehrenberg) Kützing
<i>Navicula angusta</i> Grunow	<i>Navicula perminuta</i> Grunow
<i>Navicula antonii</i> Lange-Bertalot	<i>Navicula phyllepta</i> Kützing
<i>Navicula antonioides</i> sp. nov.	<i>Navicula pseudolanceolata</i> Lange-Bertalot
<i>Navicula aquaedurae</i> Lange-Bertalot	<i>Navicula pseudotenelloides</i> Krasske
<i>Navicula</i> cf. <i>arctotenelloides</i> Lange-Bertalot et Metzeltin	<i>Navicula praeterita</i> Hustedt
<i>Navicula associata</i> Lange-Bertalot	<i>Navicula radiosa</i> Kützing
<i>Navicula capitatoradiata</i> Germain	<i>Navicula radiosafallax</i> Lange-Bertalot
<i>Navicula cari</i> Ehrenberg	<i>Navicula recens</i> (Lange-Bertalot) Lange-Bertalot
<i>Navicula catalanogermanica</i> Lange-Bertalot	<i>Navicula reichardtiana</i> Lange-Bertalot
<i>Navicula caterva</i> Hohn & Hellerman	<i>Navicula reinhardtii</i> (Grunow) Grunow
<i>Navicula ceciliae</i> sp. nov.	<i>Navicula rostellata</i> Kützing <i>sensu</i> Germain
<i>Navicula</i> cf. <i>cincta</i> (Ehrenberg) Ralfs	<i>Navicula rhynchocephala</i> Kützing
<i>Navicula cryptocephala</i> Kützing	<i>Navicula rhynchotella</i> Lange-Bertalot
<i>Navicula cryptotenella</i> Lange-Bertalot	<i>Navicula salinarum</i> Grunow
<i>Navicula cryptotenelloides</i> Lange-Bertalot	<i>Navicula scaniae</i> sp. nov.
<i>Navicula densilineolata</i> (Lange-Bertalot) Lange-Bertalot	<i>Navicula slesvicensis</i> Grunow
<i>Navicula erifuga</i> Lange-Bertalot	<i>Navicula streckeriae</i> Lange-Bertalot et Witkowski
<i>Navicula escambia</i> (Patrick) Metzeltin et Lange-Bertalot	<i>Navicula striolata</i> (Grunow) Lange-Bertalot
<i>Navicula exilis</i> Kützing	<i>Navicula subalpina</i> Reichardt
<i>Navicula germainii</i> Wallace	<i>Navicula suecicarum</i> Van de Vijver, Jarlman et Lange-Bertalot
<i>Navicula gottlandica</i> Grunow <i>sensu</i> Hustedt	<i>Navicula tenelloides</i> Hustedt
<i>Navicula gregaria</i> Donkin	<i>Navicula tripunctata</i> (O. F. Müller) Bory
<i>Navicula heimansioides</i> Lange-Bertalot	<i>Navicula trivialis</i> Lange-Bertalot var. <i>trivialis</i>
<i>Navicula ireneae</i> sp. nov.	<i>Navicula trophicatrix</i> Lange-Bertalot
<i>Navicula lanceolata</i> (Agardh) Ehrenberg	<i>Navicula upsaliensis</i> (Grunow) Peragallo
<i>Navicula leptostriata</i> Jørgensen	<i>Navicula vandamii</i> Schoeman et Archibald
<i>Navicula libonensis</i> Schoeman	<i>Navicula vandamii</i> var. <i>mertensiae</i> Lange-Bertalot
<i>Navicula longicephala</i> Hustedt	<i>Navicula venerabilis</i> Hohn et Hellerman
<i>Navicula</i> cf. <i>moskalii</i> Metzeltin, Witkowski et Lange-Bertalot	<i>Navicula veneta</i> Kützing
<i>Navicula namibica</i> Lange-Bertalot et Rumrich	<i>Navicula vilaplani</i> (Lange-Bertalot et Sabater) Lange-Bertalot et Sabater
<i>Navicula neomundana</i> (Lange-Bertalot et Rumrich) Lange-Bertalot, Jarlman et Van de Vijver	<i>Navicula viridula</i> (Kützing) Ehrenberg
<i>Navicula notha</i> Wallace	<i>Navicula viridulacalcis</i> Lange-Bertalot
<i>Navicula oblonga</i> (Kützing) Kützing	<i>Navicula vulpina</i> Kützing
<i>Navicula oppugnata</i> Hustedt	<i>Navicula witkowskii</i> Lange-Bertalot, Iserentant et Metzeltin
