Limnologica 33, 258–270 (2003)
© Urban & Fischer Verlag
http://www.urbanfischer.de/journals/limno

LIMNOLOGICA

Rare and new small-celled taxa of *Navicula* s. str. in the Gulf of Gdansk and in its freshwater affluents

H. Lange-Bertalot[1,2], A. Witkowski[2,*], B. Bogaczewicz-Adamczak[1], A. Zgrundo[1]

[1] Institute of Oceanography, University of Gdansk, Al. Pilsudskiego 46, 81-378 Gdynia, Poland
[2] Institute of Marine Sciences, University of Szczecin, Waska 13, PL-71-415 Szczecin, Poland

Received October 7, 2003 · Accepted October 20, 2003

Abstract

Presented are results of morphological (LM and SEM) and taxonomical investigations on very small-sized *Navicula* spp. from the brackish waters of the Gulf of Gdansk and some freshwater affluents. Detailed studies revealed that most of the taxa in question are either new for science or previously described but rather poorly known. Dominant in that assemblage of extraordinarily small-celled *Navicula* species, specimens mostly below 10 µm in length, are *Navicula germanopolonica* WITKOWSKI & LANGE-BERTALOT and *Navicula paul-schulzii* WITKOWSKI & LANGE-BERTALOT as established taxa. New for science are *Navicula aleksandrae*, *Navicula bozenae* and *Navicula viminoides* ssp. *cosmomarina*. From common freshwater habitats no species are known that could be confused with the new taxa.

Key words: Diatoms (Bacillariophyceae) – *Navicula* – new taxa – Gulf of Gdansk – littoral zone

Introduction

Surface sediments were collected in the course of ecological studies directed towards the use of diatoms as bioindicators of environmental conditions in brackish waters in the Gulf of Gdansk (the southern Baltic Sea). The sediment samples originated from the littoral and sublittoral zones and from some freshwater affluents (BOGACZEWICZ-ADAMCZAK & KOŹLARSKA 1999; BOGACZEWICZ-ADAMCZAK et al. 2001). Light microscopic studies revealed the presence of several taxonomically problematic taxa which were selected for a detailed study. All of them resemble, to a certain extent, *Navicula germanopolonica* WITK. & LANGE-BERT., *Navicula paul-schulzii* WITK. & LANGE-BERT. and *Navicula viminoides* GIFFEN, altogether taxa which are known to have a very broad distribution also outside of the Baltic Sea (WITKOWSKI et al. 2000).

The increasing number of ecological studies in the Baltic Sea reveals the occurrence of numerous uncommonly small-celled taxa belonging to *Navicula* s. str. In the past they have either been identified only to the generic level or assigned erroneously to one of the known taxa. Usually such problematic forms were included in e.g. *Navicula perminuta* GRUNOW, *N. germanopolonica* or *N. viminoides*. Recently BUSSE & SNOEIJS (2002), based on detailed LM and SEM examination, described two new small-sized species, namely *N. sjoersii* and *N. bossvikensis* from the Bothnian Sea and from the northern part of the Baltic Proper respectively.

***Corresponding author:** Prof. Andrzej Witkowski, Institute of Marine Sciences, University of Szczecin, Waska 13, PL - 71-415 Szczecin, Poland; e-mail: witkowsk@univ.szczecin.pl

Sampling of the marine and brackishwater littoral zone sediments for diatom studies faces the diatomologists with numerous taxa of minute cell dimensions. Their size and morphological features frequently reach the limits of the light microscopy resolution. In this respect especially interesting is the diatom flora inhabiting the littoral sediments of the Gulf of Gdansk (e.g. WITKOWSKI 1991; WITKOWSKI & LANGE-BERTALOT 1993; WITKOWSKI 1994; BOGACZEWICZ-ADAMCZAK et al. 2001; STACHURA-SUCHOPLES 2001). The problem of correct identification becomes particularly important when the study of the diatom flora aims at using the taxa as bioindicators, and various indices have been developed as a result of such studies (e.g. DENYS 1991/92; VAN DAM et al. 1994; PRYGIEL et al. 1999).

In the course of diatomological research on surficial bottom sediments several taxa of *Navicula* s. str. of minute size and difficult to identify in LM were encountered and considered worthy of a detailed comparing study. The purpose of this paper is to report results of the research on their general morphology, ultrastructure, and geographical distribution that may serve to avoid errors in comparable investigations of other marine coasts.

Research area

The material studied originated from the sublittoral sampled at the seaside resort Sopot situated along the coastal zone of south-western part of the Gulf of Gdansk. Six streams and three creeks discharge directly into the gulf here. The streams Karlikowski, Haffnera, Kamienny and Swelinia in their upper courses flow through the forested area, allotments and housing estates. All streams and creeks flow partly, particularly in their middle and lower course, in the underground as artificial canals collecting water polluted by municipal sewage. This results in different degrees of sanitary conditions (WALKOWIAK 1999, 2000). The nutrient load and organic pollutants affect the water quality in the streams and therefore the state of the environment in the coastal zone of the gulf. Nevertheless, the waters in the mouths of the streams and creeks on the basis of chemical parameters were classified as I (II) class of purity (BOGACZEWICZ-ADAMCZAK et al. 2001).

Material and Methods

The samples of the littoral sediments and from the streams were collected once a month, from March 1999 to February 2002 from 7 sites situated in the mouths of streams (5) and creeks (2) of the Gulf of Gdansk. The superficial 1 cm sediment layer from the littoral zone was collected by means of a sterile glass pipette. The freshwater samples were scraped with knife from stones and other submerged objects surface.

The sediment samples were boiled in 30% H_2O_2 at temperatures between 60 °C and 90 °C in a water bath for three days and washed twice in distilled water. Diatom slides were prepared using Naphrax as a mounting medium. Light microscopic studies were carried out with Leitz Diaplan and Leica DMLB microscopes equipped with ×64/1.4 and 100/1.4 PlanAPO oil immersion objectives respectively. SEM examinations involved a Hitachi S 4500. SEM stubs have been deposited in the Botanical Institute of J.-W. Goethe University, Frankfurt am Main in Coll. LANGE-BERTALOT.

The diatoms were identified according to KRAMMER & LANGE-BERTALOT (1986, 1988, 1991a, 1991b), SNOEIJS (1993), SNOEIJS & VILBASTE (1994), SNOEIJS & POTAPOVA (1995), SNOEIJS & KASPEROVICHENE (1996), SNOEIJS & BALASHOVA (1998), WITKOWSKI (1993), WITKOWSKI & LANGE-BERTALOT (1993), WITKOWSKI (1994), WITKOWSKI et al. (1995a), and WITKOWSKI et al. (1995b).

Description and observations

The results of the ecological investigations are published in BOGACZEWICZ-ADAMCZAK & KOŹLARSKA (1999) and BOGACZEWICZ-ADAMCZAK et al. (2001). In the following section only results of that part of taxonomical studies which is based on detailed morphological and ultrastructural examination are presented.

Navicula aleksandrae LANGE-BERTALOT, BOGACZEWICZ-ADAMCZAK & WITKOWSKI nov. spec. (Figs. 1–20)

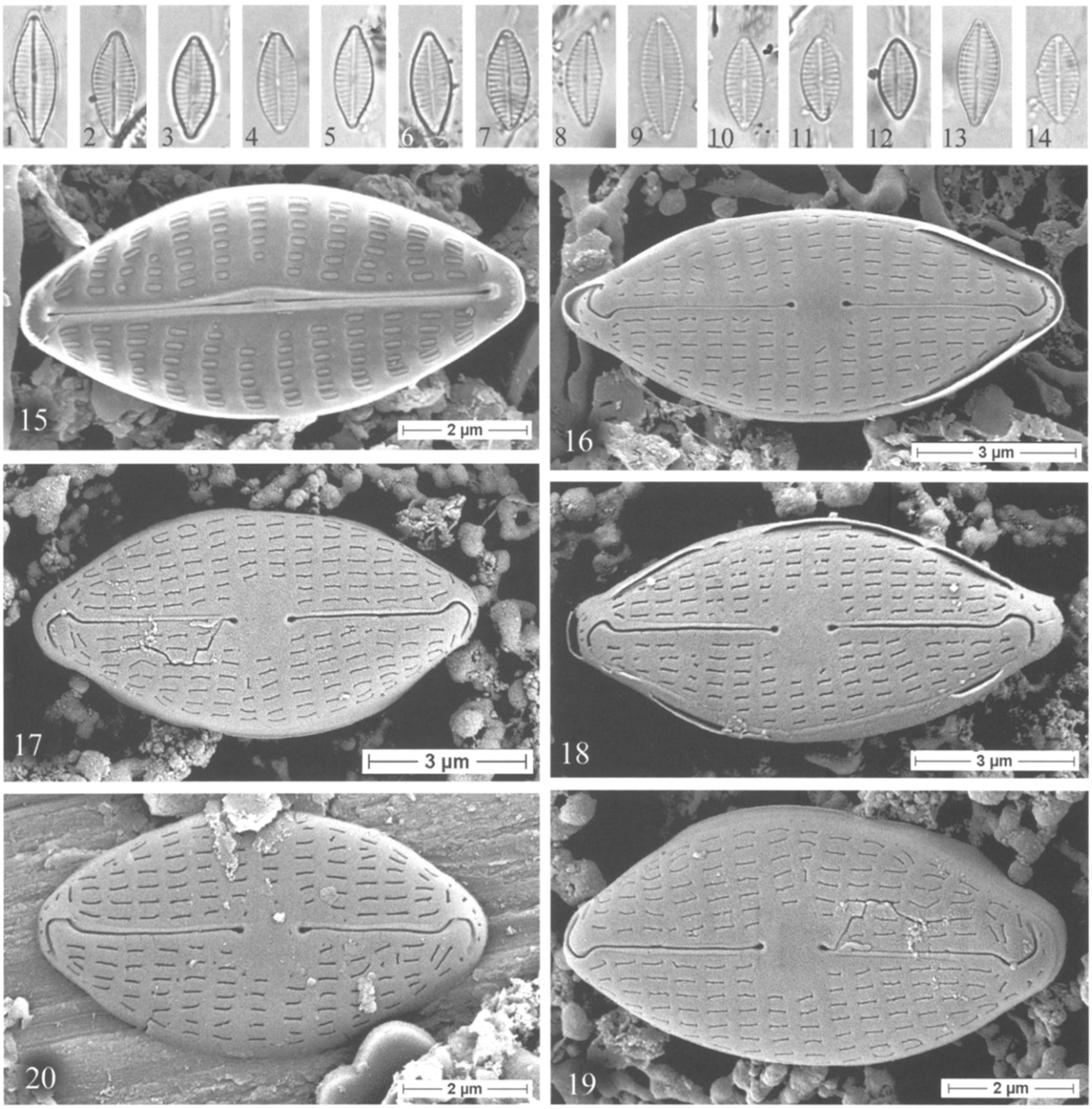
Diagnosis differens versus *Navicula germanopolonica*
Valvae elliptico-lanceolatae vel curte lateque lanceolatae apicibus cuneatis denique acute (numquam obtuse) rotundatis interdum curtissime protractis. Longitudo 8.5–12 µm, latitudo 4–4.6 µm. Raphe filiformis rectaque apparens extremis centralibus nec distanter nec dense sitis inter se. Area axialis angustissima, area centralis parva quia striae mediae parum abbreviatae (numquam dilatata plus minusve quadratarea ad instar). Striae transapicales non curvatae sed simpliciter subparallelae vel parum radiatae omnino etiam sub apices (ibi non distincte convergentes), 18–20 in 10 µm. Aspectus ultramicroscopicus externus vide Figs. 16–20. Raphe paene recta poris centralibus plus minusve circularibus curte declinatis ad latus secundum valvae aequaliter fissuris terminalibus hamiformibus curvatis. Foramina areolarum comparate longa id est longiora quam interstriae latae sunt, circiter 40 (nec 25–30) in 10 µm itaque non aspectabilia microscopio photonico.

Similes sunt etiam *Navicula paul-schulzii* (vide infra) et *Navicula biskanterae* HUSTEDT sed striis transapicalibus tenuioribus et distinctissime curvatis, 21–24 plerumque 23–24 in 10 µm. *N. paul-schulzii* est assiociata in loco typico et faciliter discernanda.

Typus: Praep. no. Eu-PL-66 in Coll. Lange-Bertalot, Botanical Institute, University Frankfurt a. Main (Figs. 1–20).

Locus typicus: Prope ostium rivi Haffnera in urbe Sopot, Mare Balticum, sinus Gedanensis (legit ALEKSANDRA ZGRUNDO, January 2000).

Diagnosis: Valves elliptical-lanceolate or shortly broad-lanceolate; ends cuneate, finally acutely (never obtusely) rounded, often shortly protracted. Length 8.5–11 µm, breadth 4.0–4.6 µm. Raphe filiform and straight with central endings that are although not close-standing even less appearing far-standing (unlike *N. ger-*

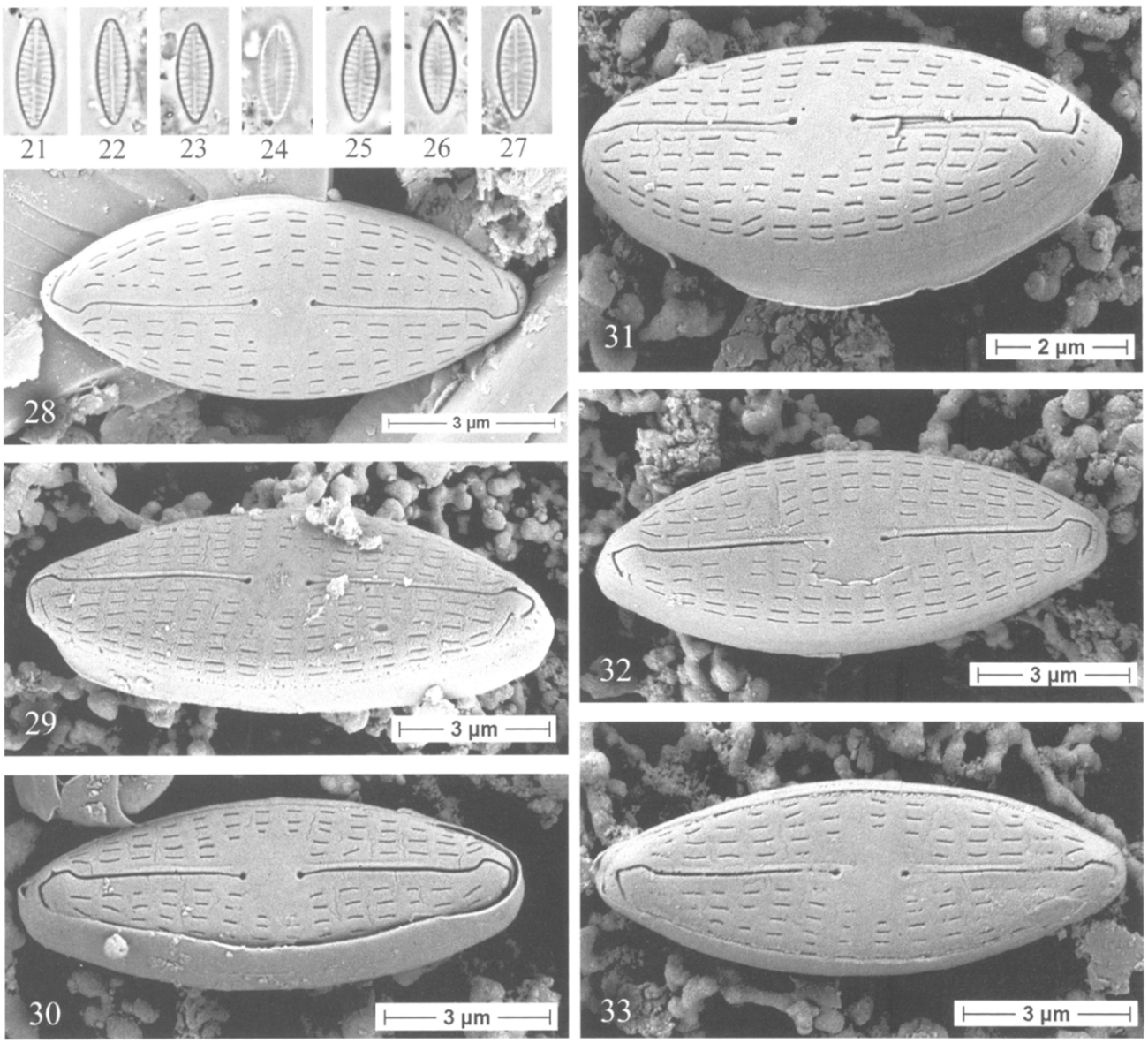


Figs. 1–20. *Navicula aleksandrae* sp. nov.
Figs. 1–8. Haffnera stream, type locality, freshwater. Figs. 9–14. Sopot sea coast of the Gulf of Gdansk, brackishwater. Scale bar = 10 µm (×1500). Fig. 15. Internal view of a valve with intact hymenes occluding the areolae. Figs. 16–19. External view of valves from the type locality. Fig. 20. From the sea coast. Independent of brackish or freshwater the pattern of fine structure of the raphe system remains consistent, central pores of the raphe are drop-like expanded, slightly deflected, and the terminal fissures are simply hooked.

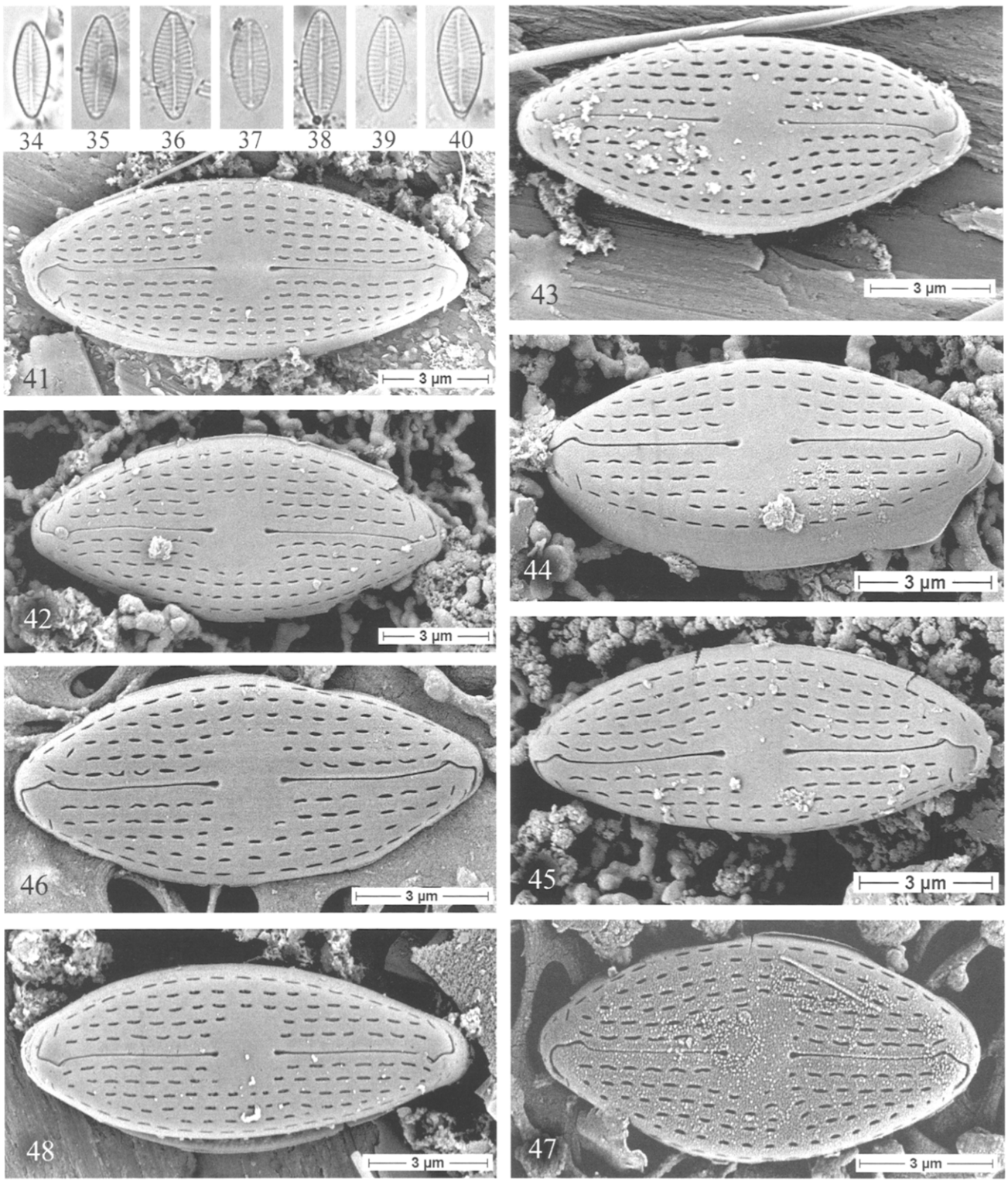
manopolonica). Axial area very narrow; central area consistently small (never more or less expanded) rectangular. Striae subparallel or moderately radiate and not curved, also at the ends subparallel (rather than distinctly convergent), 18–20 in 10 µm. SEM (external view see Figs. 16–20): raphe branches almost straight, central pores expanded more or less circular, shortly declined to the secondary valve side like the hooked terminal fissures. Foramina of the areolae form comparatively long apical slits, commonly longer than the breadth of the interstriae, ca. 40 in 10 µm, hence not to discern in LM (unlike the 25–30 in 10 µm of *N. germanopolonica*).

Distribution: So far identified in freshwater of the type locality and in brackishwater of the Puck Bay.

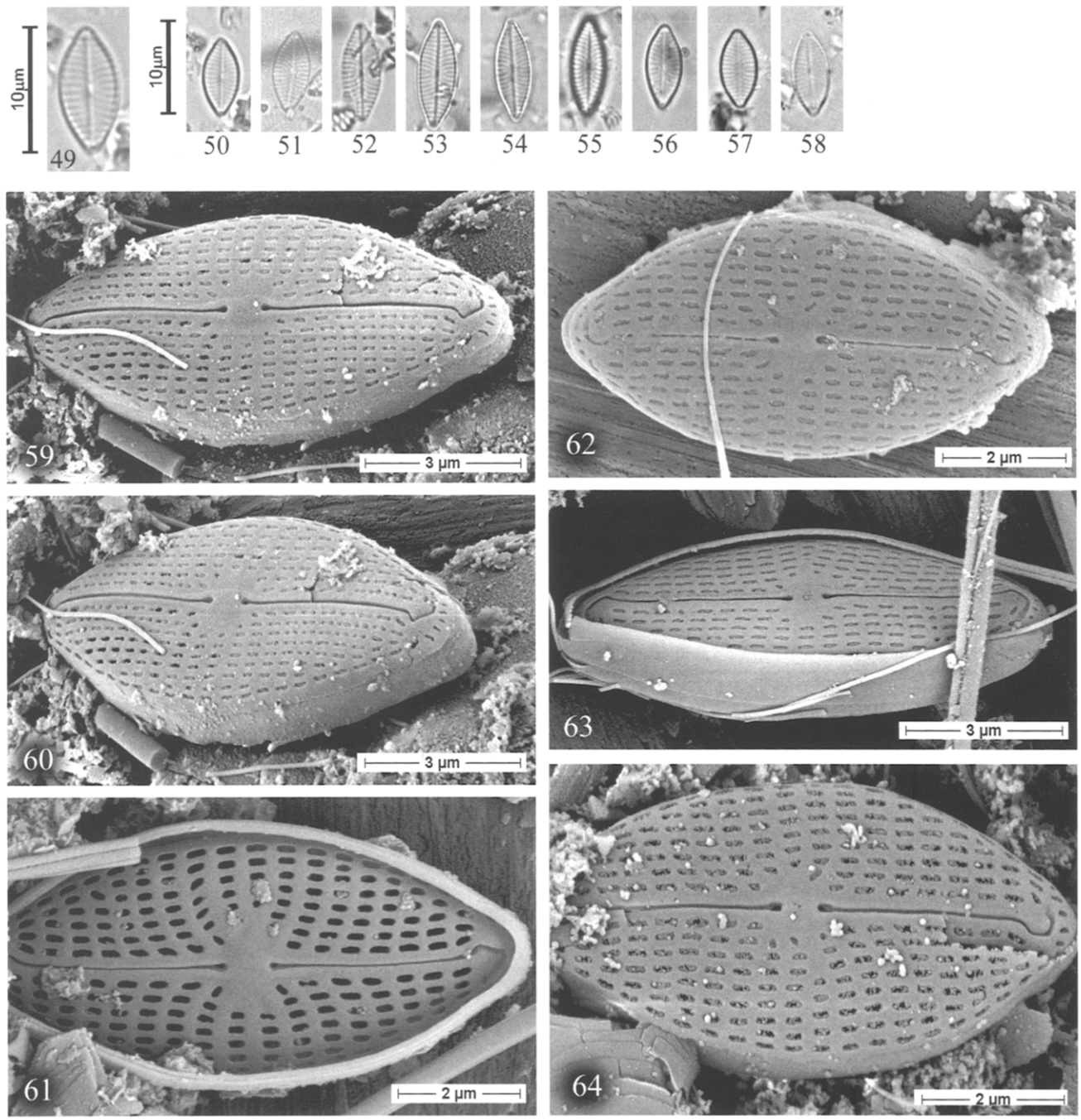
This taxon is dedicated to Msc ALEKSANDRA ZGRUNDO, University of Gdansk, Faculty of Biology, Geography and Oceanology, Institute of Oceanography who has collected the type material for her PhD thesis.



Figs. 21–33. *Navicula bozenae* sp. nov.
Figs. 21–26. Haffnera stream, type locality, freshwater. Fig. 27. Sopot sea coast of the Gulf of Gdansk. Scale bar = 10 µm (×1500). Figs. 28–33. External view of valves at different angle; compared to *N. aleksandrae* the terminal raphe fissures appear more geniculate than simply rounded hook-like, the transapical costae (= interstriae) are broader. All specimens (SEM) from the type locality, but the pattern of fine structures of specimens from the sea coast do not differ at all.



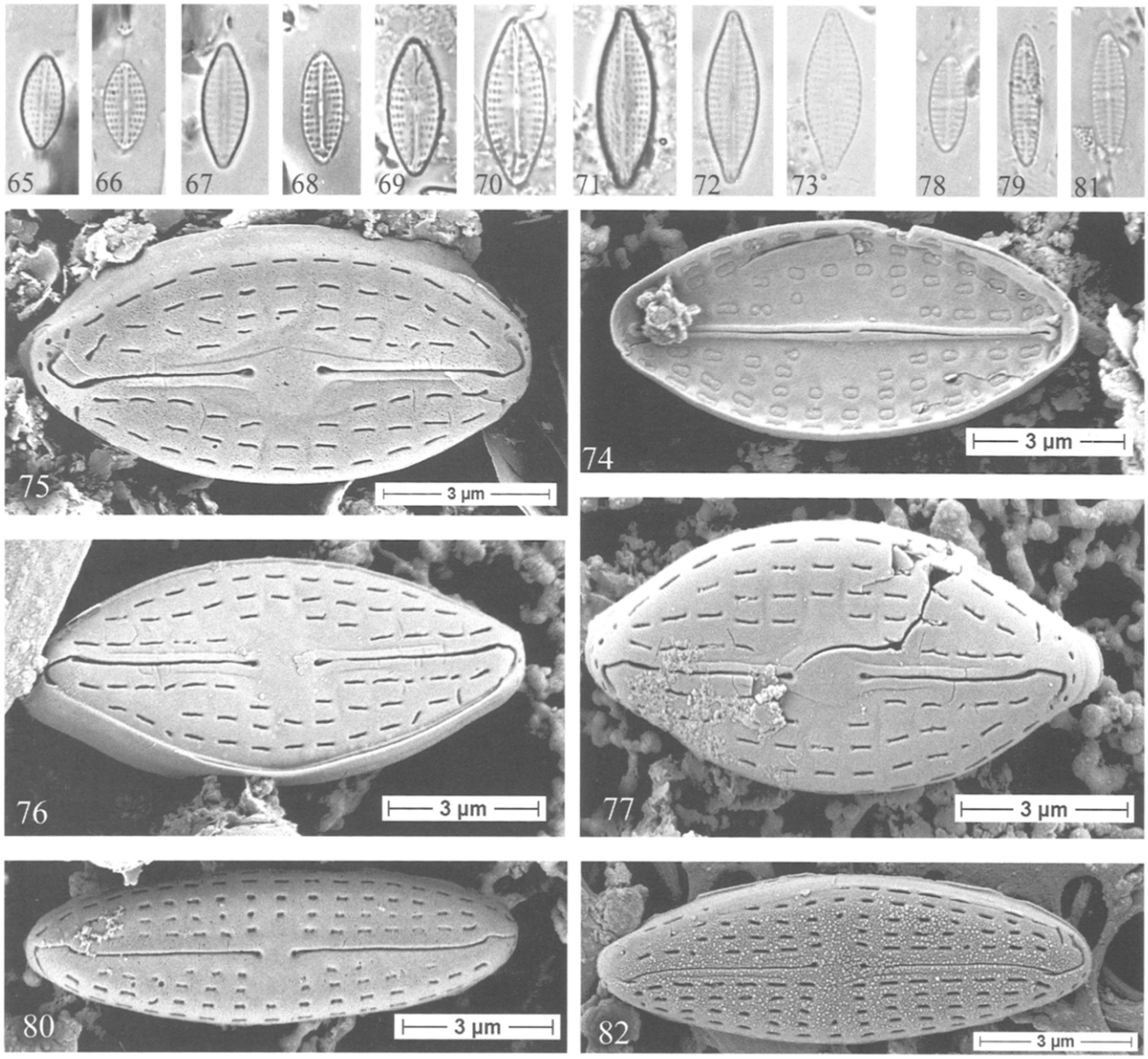
Figs. 34–48. *Navicula germanopolonica* Witkowski & Lange-Bertalot.
Figs. 34–38. Haffnera stream, freshwater. Figs. 39–40. Sopot sea coast. Scale bar = 10 µm (×1500). Figs. 41–48. External view of valves at different angle; the terminal raphe fissures are more complicated geniculate than in *N. bozenae*, the central pores less expanded and not circular and the raphe system as a whole lies plain in the valve face, not in a relief-like elevated external sternum as in the case of *N. bozenae*, *N. aleksandrae* and *N. viminoides* ssp. *cosmomarina*. The areolae lying adjacent to the raphe are comma-like curved and not straight, independent of the locality where the specimens originate from. Figs. 41–45. Haffnera stream. Figs. 46–47. Sopot sea coast. Fig. 48. Puck Bay, type locality.



Figs. 49–64. *Navicula paul-schulzii* Witkowski & Lange-Bertalot.
Figs. 49–53. Haffnera stream, freshwater. Figs. 54–56. Puck Bay. Figs. 57–58. Sopot sea coast. Scale bars = 10 µm (Fig. 49 ×2400, Fig. 50–58. ×1500). Fig. 49/50, 54/55, 59/60 are photographs of the same specimens under different focus or different tilting (SEM respectively). Figs. 59–64. External view of valves showing very close-standing central pores of the raphe and densely spaced and apically comparatively short areola foramina characteristic of this species. The occluding hymenes internally can also be seen from the valve exterior since lying closely below the surface, except of Fig. 61 where they are destroyed.

***Navicula bozenae* Lange-Bertalot, Witkowski & Zgrundo nov. spec.** (Figs. 21–33)

Valvae simpliciter lanceolatae (nec elliptico- nec linearilanceolatae) apicibus cuneatis denique acute rotundatis non protractis. Longitudo 8.1–10.5 (13) µm, latitudo 3.1–4.3 µm. Raphe filiformis rectaque apparens extremis centralibus nec distanter nec dense sitis inter se poris centralibus fere inconspicuis. Area axialis angustissima, area centralis parva sed satis formata plus minusve circularis ad instar. Striae transapicales modice radiantes sed parum convergentes vel subparallelae sub polos, 15–18 in 10 µm. Aspectus ultramicroscopicus externus internusque vide Figs. 28–33. Rami raphis vix curvati poris centralibus distinctissime dilatatis ad instar circiter



Figs. 65–77. *Navicula viminoides* ssp. *cosmomarina* ssp. nov.
Figs. 65–67. Haffnera stream, freshwater. Figs. 68, 71–73. Gulf of Gdansk. Figs. 69–70. Mouth of the Mississippi, USA. Scale bar of all LM Fig. = 10 µm (×1500). Figs. 71–73. The taxonomic identity of such extremely rare specimens is not yet completely out of doubt. Fig. 74. Internal view of a valve with intact hymenes occluding the areolae. Figs. 75–77. External view of specimens originating like Fig. 74 from Haffnera stream. The raphe slits lie in a prominent externally elevated raphe sternum, unlike Figs. 80 and 82 (see below).

Figs. 78–82. *Navicula perminuta* auct., none is necessarily identical with *N. perminuta* Grunow.
Fig. 78. Conforms to *N. hansenii* M. Moeller. Figs. 79–80. Originate from freshwater of the Haffnera stream and certainly represent the same taxon. Figs. 81–82. Represent another uncertain taxon from the Sopot sea coast (see more details in the „Discussion").

circularibus et declinatis ad latus secundum valvae aequaliter fissuris terminalibus valde hamatis. Area centralis fere symmetrica. Foramina areolarum (id est lineolae) 35–40 in 10 µm apicaliter comparate valde elongata ita costae transapicales alias interstriae angustiores apparentes externe. Interne disordinatio Voigtii distincte aspectabilis.

Complures species similes sunt. Associata in loco typico sunt: *Navicula paul-schulzii*, *Navicula germanopolonica*, *Navicula perminuta*, *Navicula cryptotenelloides*, *Navicula viminoides* ssp. *cosmomarina* nov. ssp., *Navicula aleksandrae* nov. spec. Omnes satis differunt combinatione signorum typicorum singularium.

Aliquid similes sunt etiam *Navicula vekhovii* LANGE-BERTALOT & GENKAL cum striis crassioribus et longitudine superiore, habitat in Siberia et *Navicula "jeffreyi"* HALLEGRAEFF & BURFORD cum valvis ad instar linearibus vel lineari-lanceolatis habitat in Australia.

Nomen rectum est *Navicula jeffreyae* quia persona honorata feminina est.

Typus: Praep. no. Eu-PL-66 in Coll. LANGE-BERTALOT, Botanical Institute, University Frankfurt a. Main (Figs. 21–26).

Locus typicus: Prope ostium rivi Haffnera in urbe Sopot, Mare Balticum, sinus Gedanensis (legit ALEKSANDRA ZGRUNDO, January 2000).

The species is dedicated to our colleague, BOŻENA BOGACZEWICZ-ADAMCZAK, Professor at the University of Gdansk, Faculty of Biology, Geography and Oceanology, Institute of Oceanography.

Valves simply lanceolate (neither elliptical- nor linear-lanceolate), ends cuneate, finally acutely rounded, not protracted. Length 8.1–10.5 (13) µm. The 13 µm in brackets means that only a single specimen was found longer than 10.5 µm, however there is almost no doubt to identify it belonging to the same species, breadth 3.1–4.3 µm. Raphe filiform appearing straight in the LM, central endings neither distinctly narrow nor far to each other. Axial area very narrow; central area small but well developed by 1–3 shortened striae at each side. Transapical striae are not curved, moderately radiate except of one or two near the poles being subparallel to convergent, 15–18 in 10 µm. SEM (see Figs. 28–33): raphe branches outside at most slightly curved with comparatively large central pores almost circular in shape declined to the secondary valve side. Terminal fissures hooked to the same side. The raphe system is contoured by shallow depressions (apical lines) forming a very narrow external raphe rib or sternum. Central area almost symmetrical, circular or apically elliptic. Foramina of the areolae 35–40 in 10 µm, moderately longer apically than the interstriae when uncorroded. The Voigt fault is well developed internally and externally.

Distribution: so far only found at the type locality, a small freshwater river near its mouth into the Baltic Sea, Sopot, and in brackishwater of the Puck Bay.

Navicula viminoides ssp. *cosmomarina* nov. ssp.

(Figs. 65–77)

Syn.: *Navicula viminoides* sensu auct. nonnull.

Diagnosis differens versus *Navicula viminoides* GIFFEN ssp. *viminoides*

Valvae elliptico-lanceolatae ad lanceolatas (potius quam simpliciter ellipticae) apicibus cuneatis denique acute rotundatis interdum paulo protractis. Longitudo 8–17 µm, latitudo 4.0–6.0 µm (circumcirca minus quam 5.5–6 µm). Rami raphis filiformes extremis centralibus quam non distanter sitis inter se tamen numquam dense sitis ita ut iconismi subspeciei *viminoides* demonstrant (vide in protologo; figurae 99–101 in GIFFEN 1975). Area axialis fere angustissima, area centralis semper distincte adest quamvis ad instar fere variabilis (numquam abest ita ut in speciminibus inferioribus quoad protologum subspeciei *viminoides*). Striae transapicales subparallelae in media parte et minime radiantes ad apices versus sed interdum parallelae plerumque modice convergentes directe sub polos (nec ad polos modice radiantes quoad protologum subspeciei *viminoides*), conspicue constanter 14–16 (nec 12) in 10 µm. Puncta striarum distinctissime aspectabilia microscopio photonico, 20–22 (nec 15–16) in 10 µm. Aspectus ultramicroscopicus externus internusque vide Figs. 74–77. Habitat ad multa litora mundi in aquis submarinis etiam distincte marinis. *Navicula viminea* Hustedt, habitat ad litus insularum Seychellarum Oceano Indica tropica, differt omnino quoad signa typica, ita valde dissimilis apparens.

Typus: Praep. no. Eu-PL-66 in Coll. LANGE-BERTALOT, Botanical Institute, University Frankfurt a. Main (Figs. 65–67).

Locus typicus: Prope ostium rivi Haffnera in urbe Sopot, Mare Balticum, sinus Gedanensis (legit ALEKSANDRA ZGRUNDO, January 2000).

Differential diagnosis compared with ssp. *viminoides*

Valves elliptic-lanceolate concerning the smallest specimens to distinctly lanceolate (rather than simply elliptical). Ends cuneate and finally acutely rounded, commonly very slightly protracted. Length 8–17 µm, breadth 4.0–6.0 (5.5–6.0 µm, this is less on the average than given in the protologue of the nominate ssp. (GIFFEN 1975). Raphe filiform, the central endings comparatively somewhat widely spaced (rather than close standing). Axial area very narrow, central area consistently well developed although somewhat variable shaped (never absent). Failure of the ends of some of the middle striae (as reported for the nominate subspecies) lacking.

Transapical striae subparallel in the central part of the valve becoming slightly radiate distally, but the apical pairs of striae parallel to distinctly convergent (not radiate), consistently 14–16 in 10 µm (12 were never counted). Puncta or lineolae respectively 20–22 (never 15–16) in 10 µm. SEM, valve externally and internally see Figs. 74–77. The central pores of the raphe are clearly declined to the secondary side of the valve lying in a distinct external sternum elevated over the valve surface.

Distribution: Widespread in brackish- and marine waters along the sea coasts of different continents, e.g. Indian Ocean, the Baltic Sea or the mouth of the Mississippi River and a coastal lagoon connected with the Atlantic Ocean in Uruguay. The type locality of the subspecies *cosmomarina* is, however, in freshwater of a small river in Sopot not far from the mouth into the Gulf of Gdansk. The diatom assemblage here indicates commonly freshwater under slight influence of brackish conditions. Highly predominantly occur typical freshwater taxa.

Discussion

The newly described taxa *Navicula bozenae*, *Navicula aleksandrae* and *Navicula viminoides* ssp. *cosmomarina* show more or less resemblance to *Navicula paul-schulzii*, *Navicula germanopolonica*, *Navicula perminuta*, *Navicula cryptotenelloides*, *Navicula sjoersii* and *Navicula bossvikensis*. The characteristics of new taxa and the taxa showing the highest degree of resemblance (i.e. *Navicula viminoides* ssp. *viminoides*, *Navicula germanopolonica*, *Navicula paul-schulzii*, *Navicula biskanterae*) are given in Table 1. The other very small-celled species of *Navicula* sensu stricto which are principally similar and may be confused to the newly described ones are also characterized. To make the identification of the new taxa easier a determination key including new and already existing taxa was prepared (see Table 2). However, all of them are clearly to distinguish by comparison of the combination of their LM and SEM characters. Less similar is *Navicula vekhovii* LANGE-BERTALOT & GENKAL by coarser striae and much larger valves on average; it was only found in Siberia so far under similar ecological conditions as the new species. *Navicula jeffreyi* (sic) HALLEGRAEFF & BURFORD is significantly linear-lanceolate to linear in outlines, and also the central pores and striae differ. It was described from a culture originating from the subtropical Australian sea coast. The name given by the authors should be corrected to *N. jeffreyae* since the dedication concerns a lady. Thus also *Navicula biskanteri* Hustedt was corrected later on by the author consequently to *N. biskanterae*. This species from the coast of the North Sea is also similar, but possesses more striae in 10 µm which are distinctly curved and not straight.

Table 1. Comparison of the main characters of the most similar taxa (from 17 taxa concerned in the determination key, cf. Table 2).

	N. aleksandrae sp. n.	*N. bozenae* sp. n.	*N. viminoides* ssp. *cosmomarina*	*N. viminoides* ssp. *viminoides*	*N. germanopolonica*	*N. paul-schulzii*	*N. biskanterae*
Shape	elliptic-lanceolate, ends acute	lanceolate, ends acute	elliptic-lanceolate to lanceolate ends cuneate, acute	elliptic-lanceolate to lanceolate ends cuneate, acute	elliptic-lanceolate ends obtuse	lanceolate ends acute	elliptic-lanceolate ends obtuse
Length (µm)	8,5–11	8,1–10,5	8–17	10–14	9–13	7–16	7–8
Breadth (µm)	4,0–4,6	3,1–4,3	4–6	5,5–6	4–5,2	3,5–5,5	3,5–4,5
Stria/10 µm	18–20	15–18	14–16	12	16–22	21–24	23–25
Stria orientation middle of the valve	slightly radiate	moderately radiate	subparallel	subparallel	radiate	radiate, curved	radiate, curved
Stria orientation near the ends	subparallel	subparallel to slightly convergent	subparallel to slightly convergent	slightly radiate	convergent	subparallel	slightly radiate
Lineolae/10 µm	ca 40	35–40	20–22	15–16	25–30	40–42	>40
Central area	very small, almost circular	small, almost circular	moderately large, variable in shape	lacking (or see in the text)	rel. large, transapically expanded	small, variable in shape	lacking, or hardly differentiated
Other considerable characters	terminal fisures, simply curved (SEM)	central pores distinctly expanded, cricular (SEM)	central pores rather far-standing	central pores rather close-standing	raphe terminal fissures particularly complicated (SEM), lineolae near the raphe comma-like	central pores rather close-standing (SEM)	

Table 2. Determination key for 17 very small-celled taxa of *Navicula* sensu stricto being more or less similar to the new taxa: *N. aleksandrae*, *N. bozenae*, *N. viminoides* ssp. *cosmomarina*.

The established taxa in comparison are: *Navicula viminoides* GIFFEN 1975 ssp. *viminoides*, *Navicula viminea* HUSTEDT 1934, *Navicula biskanterae* HUSTEDT 1939, *Navicula paul-schulzii* WITKOWSKI & LANGE-BERTALOT 1994, *Navicula germanopolonica* WITKOWSKI & LANGE-BERTALOT 1993, *Navicula perminuta* GRUNOW 1880, *Navicula perminuta* auct. non GRUNOW, *Navicula hansenii* MOELLER 1950, *Navicula jeffreyae* HALLEGRAEF & BURFORD 1996, *Navicula sjoersii* BUSSE & SNOEIJS 2002, *Navicula bossvikensis* BUSSE & SNOEIJS 2002, *Navicula tropicoidea* WITKOWSKI, METZELTIN & LANGE-BERTALOT 1996, *Navicula celinei* WITKOWSKI, METZELTIN & LANGE-BERTALOT 1996, *Navicula vekhovii* LANGE-BERTALOT & GENKAL 1999, *Navicula cryptotenelloides* LANGE-BERTALOT 1993.

1a	Lineolae conspicuously coarse comparatively with respect to the small valve sizes, about 20 in 10 µm or less	18
1b	Lineolae more densely spaced, from c. 25 up to 56 in 10 µm	2
2a	Freshwater species, lanceolate with acutely rounded ends, length only exceptionally less than 11 µm, striae clearly radiate becoming convergent near the ends, lineolae more than 40 in 10 µm	*N. cryptotenelloides*
2b	Set of characters different	3
3a	Valves linear-ellipic, ends broadly rounded	6
3b	Valve outlines different, more or less lanceolate	4
4a	Lineolae discernible in LM, easily using oblique lighting, 25–30 in 10 µm	8
4b	Lineolae more densely spaced, difficult to discern, even with oblique lighting, 33 or more in 10 µm	5
5a	Valve outlines linear to linear-lanceolate or narrow-lanceolate	9
5b	Valve outlines lanceolate or elliptic-lanceolate	12
6a(3)	Lineolae easy to resolve in LM, ca. 26 in 10 µm	*N. tropicoidea*
6b	Lineolae much more densely spaced	7
7a	Striae parallel to slightly convergent at the ends, lineolae 47–53 in 10 µm	*N. bossvikensis*
7b	Striae parallel to radiate throughout, lineolae 36–42 in 10 µm	*N. sjoersii*
8a(4)	Valve outlines broadly elliptic, central area very small, one pair of striae shortened here or none	*N. tropicoidea*
8b	Valve outlines elliptic-lanceolate, central area delimited by more than one pair of striae	*N. germanopolonica*
8c	Valve outlines more linear, central area rectangular, one pair of striae shortened	*N. perminuta* auct.
9a(5)	Valves commonly more than 14 up to 24 µm long and 4.5–6 µm broad, central area delimited by two or more shortened striae	*N. celinei*
9b	Valves commonly smaller, central area delimited by only one pair of short striae	10
10a	Valves comparatively broad, 4–5 µm	*N. hansenii*
10b	Valves narrower	11
11a	Valves 2.2–4 µm broad, ends obtusely rounded (the very similar *N. perminuta* was not mentioned in the list of similar taxa given by the authors; but it is not unlikely that this taxon belongs to the genus *Hippodonta* because of conforming central and terminal raphe ends shown in the TEM)	*N. jeffreyae*
11b	Valves 2.4–2.8 µm broad, ends acutely rounded	*N. perminuta* (lectotype)
12a(5)	Striae comparatively coarse, 12–13 in 10 µm	*N. vekhovii*
12b	Striae more densely spaced	13
13a	Valves narrow-lanceolate, 2.4–2.8 µm broad	*N. perminuta* (lectotype)
13b	Valves broader	14
14a	Stria density high, 21–25 distinctly curved striae in 10 µm, lineolae about 40 and more in 10 µm	17
14b	Less striae and lineolae in 10 µm	15
15a	Valve ends obtusely rounded, central area moderately large rather than small, 25–30 lineolae in 10 µm	*N. germanopolonica*
15b	Combination of characters different	16
16a	Valves strictly lanceolate with cuneately rounded, non-protracted ends, 15–18 moderately radiate striae in 10 µm	*N. bozenae*
16b	Valves elliptic-lanceolate with more or less shortly protracted and acutely rounded ends, 18–20 slightly radiate striae in 10 µm	*N. aleksandrae*
17a(14)	Species known from tidal flats of the North Sea, valves lanceolate with obtuse rather than acute ends, 7–8 µm long	*N. biskanterae*
17b	Species known from the Baltic Sea and Arctic Ocean so far, valves lanceolate with distinctly acute even pointed ends, 7–17 µm long	*N. paul-schulzii*
18a(1)	Lineolae 15–16 in 10 µm	19
18b	Lineolae 20–22 in 10 µm	*N. viminoides* ssp. *cosmomarina*
19a	Breadth 7.5 µm, striae 9 in 10 µm (only the holotype specimen is known)	*N. viminea*
19b	Breadth 5.5–6 µm, striae 12 in 10 µm (only known from the protologue)	*N. viminoides* ssp. *viminoides*

Navicula aleksandrae resembles very closely *Navicula germanopolonica*. However, the new species differs from the latter with respect to the valve ends which are cuneate, finally acutely (never obtusely) rounded, often shortly protracted. The raphe central endings of *N. aleksandrae* are closer each to other and the central area is consistently small (never more or less expanded) rectangular. The striae in *N. aleksandrae* are subparallel or only slightly radiate but not curved, also at the ends subparallel (rather than distinctly convergent), 18–20 in 10 µm. The foramina of the areolae form comparatively long apical slits, not discernible in LM, unlike in *N. germanopolonica* (see Figs. 34–84).

Similar are also *Navicula paul-schulzii* (see below and Figs. 49–64) and *Navicula biskanterae* Hustedt, both are distinguished by more densely spaced and curved striae, mostly 23–24 in 10 µm. The first taxon is associated in the type locality and elsewhere in the Gulf of Gdansk, it is always to separate easily in the LM.

Navicula viminoides ssp. *cosmomarina* differs from ssp. *viminoides* with respect to the valve shape which is elliptic-lanceolate concerning the smallest specimens to distinctly lanceolate rather than simply elliptical as given for GIFFEN's taxon (GIFFEN 1975).

The type of the nominate subspecies was not yet found and could not be compared so far, hence the very distinct and detailed protologue of GIFFEN (op. cit.) is the basis for comparison. Since GIFFEN (1975) states that his taxon is "very closely allied to *N. viminea* HUSTEDT" it is not unlikely that the new taxon is not so closely allied to GIFFEN's taxon and may merit the rank of an independent species. The reason to prefer provisionally the infraspecific rank is the indisputable resemblance to the "iconotypes" of GIFFEN's taxon, whereas any similarity to HUSTEDT's taxon must be excluded definitely. Other authors, e.g. SUNDBÄCK in SNOEIJS & POTAPOVA (1995, no. 261) or WITKOWSKI et al. (2000) have determined the taxon in question here without restriction as *Navicula viminoides*. However, after a more subtle comparison several considerable distinguishing characters from GIFFEN's taxon cannot be neglected: mainly the more widely spaced central endings of the raphe, the distinct central area, the slightly convergent subapical striae, the more densely spaced lineolae (ca. 20 instead of 15–16), and, calculated on the average, a significantly lower width of the valves (4–6 instead of 5.5–6 µm). All these criteria coincide much more in HUSTEDT's and GIFFEN's taxa than in GIFFEN's and the new taxon. Finally a type study of GIFFEN's taxon will decide whether it is allied with HUSTEDT's *N. viminea* (see the photographical documentation of SIMONSEN 1987, Figs. 397: 10–11) rather than with ssp. *cosmomarina*. In the first case our provisional decision to prefer the intraspecific rank has to be revised.

Some larger specimens being ca. 16–17 µm long, 4–6 µm broad with about only 20 puncta in 10 µm were found to be extremely rare in brackishwater of the Gulf of Gdansk and rare in the Gulf of Mexico, USA, but could not be observed in the SEM. This example of moderately small but individual-poor groups of forms (populations?) and some other examples of extremely minute *Navicula* s. str. (Figs. 71–73) demonstrate general problems of identification without coinciding SEM fine structure analyses. It is also very difficult to confirm coincidence in the LM and SEM when numerous taxa – including assumed unknown species – occur associated in the same sample as it is the case here.

Since its complex of characters is different *Navicula perminuta* GRUNOW may not easily be confused with the new taxa although it belongs into the grouping of extremely small-celled *Navicula* s. str. species occurring abundantly and frequently in brackish waters (see Figs. 78–82). Only one pair of the weakly radiate striae is significantly shortened, and hence the central area appears transversely rectangular. The problem with *N. perminuta* is that the common concept of this taxon encompasses a wider range of populations than the lectotypified one from Collection GRUNOW 2106. The specimens there have narrow-lanceolate outlines with acutely rather than obtusely rounded ends. The dimensions are ca. 6–16 µm long and 2.6–2.8 µm broad. The stria density is about 14–16 in 10 µm. Lineolae could not be resolved. This could be due to the low refraction of the embedding medium from the 19-th century, for the case that the number is comparatively low, about 30/10 µm. On the other hand the number could be really higher than ca. 35 in 10 µm, and then it would be also very difficult or impossible to resolve the lineolae even with a modern embedding medium of higher refraction in the LM. This means that the identity of *Navicula perminuta* remains unclear and comparisons with supposed synonyms and other similar taxa will be problemaceous until the type material will be observed in the SEM. A supposed synonym of *N. perminuta* is *N. hansenii* M. MOELLER (MOELLER 1950). According to the protologue this taxon encompasses individuals with linear-lanceolate to linear outlines, ends cuneate with pointed poles being 10–20 µm long, 2.5–4 µm broad, and a stria density about 16 in 10 µm. The central area is transversely rectangular like in *N. perminuta*, but somewhat larger. After investigation of the type material of *N. hansenii* KUYLENSTIERNA (1989–1990) could show that apparently two populations have been mixed up in the diagnoses of *N. hansenii*. KUYLENSTIERNA (op. cit.) keeps the population with larger specimens for *N. hansenii* (LM Figs. 712–714) which are 13–17.5 µm long, 4–4.5 µm broad with 13–16 striae in 10 µm. The other population (LM Figs. 715–717), 10–13 µm long, 2.5–3.5 µm, 18–20 striae in 10 µm, may or may not represent *N. perminuta* s. str. as already supposed by KUYLENSTIERNA (1989–1990). At least they do conform to the lectotypified specimens of GRUNOW. It

seems necessary now to select formally, in a second-step lectotypification, *N. hansenii* s. str. from other similar specimens lying in the type slide of A XIIa no 1 in the M. MOELLER collection, housed in the Botanical Museum, Copenhagen. LANGE-BERTALOT & WITKOWSKI therefore designate figure number 712 (on plate 58, photographed by M. KUYLENSTIERNA) as a lectotype specimen. It conforms to Figs. 713–714, but not to Figs. 715–717. Lineolae could not be resolved in the DIC photographs; that means their number should be considerably higher than 30–34 in 10 µm.

As a result of these reflections we can exclude that our SEM figures 80 and 82 coincide with *N. hansenii* in the restricted sense since the combination of outlines, valve breadth and lineolae density is different. More likely one of them conforms either to *N. perminuta* or both represent a third and a fourth species in this group of problematic taxa. Because of the different pattern and number of lineolae it is very unlikely that both belong to the same species. Specimens illustrated in Figs. 79 and 80 living associated with the three new taxa in a freshwater stream possesses 4 apically rather short lineolae (areola foramina) on either side proximally, i.e. 29 in 10 µm, whereas those in Figs. 81–82 from brackish water in the Gulf of Gdansk, seaside of Sopot, 5 apically longer foramina, i.e. 35 in 10 µm.

This part of the discussion shows once more how difficult it is to identify appropriately recently found species of small-sized *Navicula* species with established taxa even if LM photographs of the types are available for comparison. The full set of characters is necessary to distinguish between a range of more or less similar taxa.

The question is left open, why these brackish water taxa can live in freshwater creeks. Any direct influence of the seawater must be excluded, since tides are inconspicuous at this part of the Baltic coasts and even the higher tides coming up with eastern winds will never reach the sampling site ca. 1000 m upstream and 30 m above sea level. Influence of street salt sprinkling during snowfall periods is not very likely. More convincing is a certain capacity of these taxa to live outside of their normal habitats, in the marine littoral. This could be found at least, concerning other brackish water taxa, in some rivers flowing into the Mediterranean Sea, several hundred meters upstream of the mouth (unpublished records). No auxospores or ascertained initial or post-initial cells could be observed neither in freshwater nor in the marine habitats. On the other hand no reduced or larger cell sizes respectively can be noted in the different habitats.

Acknowledgements

The authors are grateful to Frithjof Sterrenburg and Malgorzata Bak for the assistance with manuscript preparation. The contribution of Horst Lange-Bertalot was possible through the Alexander von Humboldt Award for German Scientists granted by the Polish Science Foundation.

References

BOGACZEWICZ-ADAMCZAK, B. & KOŹLARSKA, I. (1999): The evaluation of water quality in the Swelinia Stream on the basis of diatom analysis. Oceanol. Stud. **27**: 59–71.

BOGACZEWICZ-ADAMCZAK, B., KŁOSIŃSKA, D. & ZGRUNDO, A. (2001): Diatoms as indicators of water pollution in the coastal zone of the Gulf of Gdansk (Southern Baltic Sea). Oceanol. Stud. **30**: 59–75.

BUSSE, S. & SNOEIJS, P. (2002): *Navicula sjoersii* sp. nov., *N. bossvikensis* sp. nov. and *N. perminuta* GRUNOW from the Baltic Sea. Diatom Research **17** (2): 271–282.

DENYS, L. (1991/92): A check-list of the diatoms in the Holocene deposits of the Western Belgian coastal plain with a survey of their apparent ecological requirements, I. Introduction, ecological code and complete list. Prof. Paper, Belg. Geol. Surv. **246**: 1–41.

GIFFEN, M. (1975): An account of the littoral diatoms from Langebaan, Saldanha Bay, Cape Province, South Africa. Botanica Marina **18**: 71–95.

KRAMMER, K. & LANGE-BERTALOT, H. (1986): Süßwasserflora von Mitteleuropa, Bacillariophyceae 2/1. Gustav Fischer Verlag, Jena, Stuttgart.

KRAMMER, K. & LANGE-BERTALOT, H. (1988): Süßwasserflora von Mitteleuropa, Bacillariophyceae 2/2. Gustav Fischer Verlag, Jena, Stuttgart.

KRAMMER, K. & LANGE-BERTALOT, H. (1991a): Süßwasserflora von Mitteleuropa, Bacillariophyceae 2/3. Gustav Fischer Verlag, Jena, Stuttgart.

KRAMMER, K. & LANGE-BERTALOT, H. (1991b): Süßwasserflora von Mitteleuropa, Bacillariophyceae 2/4. Gustav Fischer Verlag, Jena, Stuttgart.

KUYLENSTIERNA, M. (1989–1990): Benthic algal vegetation in the Nordre Älv estuary (Swedish West Coast). Doctoral Thesis, University of Goeteborg. Vol. 1 (Text 1990), 244 pp.; Vol. 2 (Plates 1–76).

MOELLER, M. (1950): The diatoms of Praestø Fiord. Fol. Geogr. Danica **3/7**: 187–237.

PRYGIEL, J., WHITTON, B. A. & BUKOWSKA, J. (eds.) (1999): Use of algae for monitoring rivers III. Agence de l'Eau Artois-Picardie.

SIMONSEN, R. (1987): Atlas and catalogue of the diatoms types of FRIEDRICH HUSTEDT (1–3). **1**: 1–525; **2**: Pl. 1–395; **3**: Pl. 396–772. Cramer Verlag, Berlin-Stuttgart.

SNOEIJS, P. (1993): Intercalibration and distribution of diatom species in the Baltic Sea. The Baltic Marine Biologist Publication 1. 16a. Opulus Press. Uppsala.

SNOEIJS, P. & VILBASTE, S. (1994): Intercalibration and distribution of diatom species in the Baltic Sea. The Baltic Marine Biologist Publication 2. 16b. Opulus Press. Uppsala.

SNOEIJS, P. & POTAPOVA, M. (1995): Intercalibration and distribution of diatom species in the Baltic Sea. The Baltic Marine Biologist Publication 3. 16c. Opulus Press. Uppsala.

SNOEIJS, P. & KASPEROVICHIENE, J. (1996): Intercalibration and distribution of diatom species in the Baltic Sea. The Baltic

Marine Biologist Publication 4. 16d. Opulus Press. Uppsala.

SNOEIJS, P. & BALASHOVA, N. (1998): Intercalibration and distribution of diatom species in the Baltic Sea. The Baltic Marine Biologist Publication 5. 16e. Opulus Press. Uppsala.

STACHURA-SUCHOPLES, K. (2001): Bioindicative values of dominant diatom species from the Gulf of Gdansk, Southern Baltic Sea, Poland. In: R. JAHN, J.P. KOCIOLEK, A. WITKOWSKI & P. COMPÈRE (eds.), Studies on diatoms, pp. 477–490. A.R.G. Gantner Verlag Kommanditgesellschaft, Ruggell.

VAN DAM, H., MERTENS, A. & SINKELDAM, J. (1994): A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Neth. J. Aquat. Ecol. **28** (1): 117–133.

WALKOWIAK, A. (ed.) (1999): Report on the environmental state of the Pomeranian province. Biblioteka Monitoringu Środowiska, Gdansk.

WALKOWIAK, A. (ed.) (2000): Report on the environmental state of the Pomeranian province. Biblioteka Monitoringu Środowiska, Gdansk.

WITKOWSKI, A. (1991): Diatoms of the Puck Bay coastal shallows (Poland, Southern Baltic). Nord. J. Bot. **11**: 689–701.

WITKOWSKI, A. (1993): *Fragilaria gedanensis* sp. nov. (Bacillariophyceae), a new epipsammic diatom species from the Baltic Sea. Nova Hedwiga **56** (3–4): 497–503.

WITKOWSKI, A. (1994): Recent and fossil diatom flora of the Gulf of Gdansk, Southern Baltic Sea. J. Cramer, Berlin.

WITKOWSKI, A. & LANGE-BERTALOT, H. (1993): Established and new diatom taxa related to *Fragilaria schulzii* BROCKMANN. Limnologica **23** (1): 59–70.

WITKOWSKI, A., LANGE-BERTALOT, H. & METZELTIN, D. (1995a): The diatom species *Fragilaria martyi* (HERIBAUD) LANGE-BERTALOT. Identity and ecology. Arch. Protistenkd. **146**: 281–292.

WITKOWSKI, A., LANGE-BERTALOT, H. & WITAK, M. (1995b): Diatom taxa of unusual frustule belonging to the genus *Fragilaria*. Fragm. Flor. Geobot. **40** (2): 729–741.

WITKOWSKI, A., LANGE-BERTALOT, H. & METZELTIN, D. (2000): Diatom flora of marine coasts I. In: H. LANGE-BERTALOT (ed.), Iconographia Diatomologica 7, pp. 925. Gantner, Ruggell, Liechtenstein.