

Staurosira stevensonii sp. nov. (Bacillariophyta), a new taxon from Florida, USA

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(Received 21 May 2002; accepted 15 September 2002)

A new species, *Staurosira stevensonii*, is described from Florida, USA. This new taxon was first found during examination of depositional material from Lake Okeechobee and lately in recent collections from a number of additional localities. Light and scanning electron microscopy indicate a clear relationship with species in the genus *Staurosira*. Some of the characteristic features of the new taxon include an elegantly cruciform valve outline, slightly capitate valve poles, a constant number of 6 areolae in 1 μm , highly reduced apical pore fields, and open ends between neighbouring cells caused by the reduced size of spines at the valve apices. A higher relative abundance was recorded in bogs and marshes, which indicates the preference of this taxon for acidic environments.

Key words: Bacillariophyta, diatom taxonomy, *Staurosira stevensonii*

Introduction

Fragilaria Lyngbye is widespread and diverse and has been a taxonomic challenge for diatomists. Using morphological, cytological and ecological characters, Williams & Round (1987, 1988) recognized a narrow circumscription of this genus and assigned the remaining taxa, formerly included in *Fragilaria*, to five other genera. Although this system has been challenged by others (Lange-Bertalot, 1989, 1993a; Rumrich *et al.*, 2000), its use has become widespread, especially in ecological research. Subsequent scanning electron microscopy (SEM) data support Williams & Round's scheme to a great extent and the number of new fragilarioid genera has even increased by three (Flower *et al.*, 1996; Morales, 2001).

As more ecosystems and wider geographical areas are explored, many new species are discovered (Metzeltin & Witkowski, 1996; Moser *et al.*, 1998). Analyses of diatoms from the continental United States reveal that fragilarioids are more diverse than previously thought (Morales, 2001). Observations of periphytic material collected from different ecoregions also reveal that fragilarioid diversity tends to be higher in brackish habitats – a pattern also found in European systems

(Witkowski & Lange-Bertalot, 1993; Witkowski *et al.*, 1995, 2000). But even in areas where these diatoms are not the most abundant or diverse, new species are constantly being described (Rumrich *et al.*, 2000).

A new species is proposed in this paper based on recent and depositional material from lotic and lentic habitats in southern Florida, USA. This new taxon was first observed in a sediment core from Lake Okeechobee (Stoermer *et al.*, 1992) and subsequently was found in acidic wetlands and stream periphyton.

Materials and methods

Stream periphyton samples were collected as part of the National Water Quality Assessment Program (NAWQA) of the United States Geological Survey (USGS) (Table 1). These samples were collected and processed following the methodology presented in Porter *et al.* (1993).

Acidic wetland material was collected as part of the Wetlands Bioassessment Project conducted by the Florida Department of Environmental Protection (Florida DEP). A total of 36 acidic bogs and marshes were sampled (Table 1). Floating mats, water column and periphyton samples were collected from each site and were fixed immediately after collection using M3 fixative (Franson, 1998).

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Table 1. Wetland and stream site location information for samples collected in 1999

Site	County	Latitude	Longitude
<i>Florida DEP wetlands</i>			
Audubon	Hillsborough	29° 7' 5.8"	82° 7' 5.8"
Bear Scat	Collier	26° 11' 6.1"	81° 15' 15.9"
Big Cow	Collier	26° 13' 50.7"	81° 15' 54.7"
Cabbage	Flagler	29° 26' 26.9"	81° 22' 4.2"
Caravelle	Charlotte	29° 31' 3.6"	81° 43' 16.3"
Chuluota	Seminole	28° 37' 2.3"	81° 3' 28.1"
CMW pasture	Charlotte	26° 51' 17.5"	81° 47' 5.2"
CMW WMA	Charlotte	26° 56' 44.4"	81° 50' 41.8"
Crew site	Collier	26° 29' 23"	81° 32' 18"
Deerfly	Lake	29° 10' 12.62"	81° 37' 23.99"
Garber	Manatee	27° 12' 58.2"	82° 9' 4.6"
G-Bar-E Ranch	Okeechobee	27° 21' 32.9"	80° 50' 55.3"
Goethe	Levy	29° 9' 36.6"	82° 35' 58.9"
Green swamp	Sumter	28° 21' 16.47"	82° 1' 3.39"
H. hammock A	Highlands	27° 28' 51.6"	81° 33' 0.8" "
H. pasture B	Highlands	27° 25' 24.2"	81° 33' 39.2"
Hague 1	Alachua	29° 46' 57.6"	82° 24' 42.7"
Hague 2	Alachua	29° 47' 0.6"	82° 24' 40.8"
Half Moon	Sumter	28° 55' 7.4"	82° 15' 25.9"
Hills River	Hillsborough	28° 8' 48.56"	82° 13' 40.44"
Hunt Camp	Marion	29° 19' 21.9"	81° 44' 48.5"
IFAS one	Alachua	29° 43' 26.21"	82° 24' 24.48"
IFAS two	Alachua	29° 43' 36.4"	82° 24' 22.29"
Immokalee	Collier	26° 27' 47.4"	81° 26' 45.8"
JD 6	Martin	27° 0' 5.3"	80° 8' 46.7"
Kelly Park/Rock Cr.	Lake	28° 47' 46.92"	81° 26' 20.7"
McArthur Ranch	Highlands	27° 9' 55.3"	81° 11' 46.7"
Myakka	Sarasota	27° 14' 12.6"	82° 19' 49.5"
Pacific tomato	Lee	26° 31' 12.9"	81° 40' 25.3"
Pall-Mar	Palm Beach	26° 56' 58.9"	80° 18' 38"
Penner pond	Putnam	29° 29' 46.1"	81° 49' 29.6"
Piedmont Dairy	Gilchrist	29° 38' 44.3"	82° 49' 58.4"
Rice Creek	Putnam	29° 40' 51.1"	81° 44' 31.5"
Sandhill Crane	Palm Beach	26° 52' 0.4"	80° 13' 7.6"
Savannas SR	St Lucie	27° 18' 7.7"	80° 16' 24.5"
Wekiva	Orange	28° 44' 13.3"	81° 29' 2.3"
<i>NAWQA streams</i>			
Peace River	DeSoto	27° 13' 19"	81° 52' 34"
Caloosahatchee R.	Lee	26° 42' 48"	81° 36' 38"
Hillsboro Canal	Palm Beach	26° 28' 18"	80° 26' 46"

The three sites at which *Staurosira stevensonii* was most abundant are in **bold**.

Table 2. Selected characters considered for comparison with *Staurosira stevensonii* (in bold); taxa are presented in alphabetical order

Taxon	Characters							
	Chains	Cruciform shape	Simple spines	Uniseriate striae	Areolae	Central area	Apical pore field	Rimoportula
<i>Fragilaria construens</i> var. <i>javanica</i>	Yes	No	Yes	Yes	Circular	No	*	*
<i>Fragilaria heidenii</i>	Yes	Yes	No	Yes	Circular	No	*	*
<i>Fragilaria istvanffy</i>	Yes	Yes	No	Yes	Circular	No	*	*
<i>Staurosira construens</i>	Yes	Yes/no	Yes/no	Yes	Circular/elliptical	Yes	Yes/no	No
<i>Staurosirella leptostauron</i>	Yes	Yes/no	No	Yes	Slit-like lineate	Yes	Yes/no	No
<i>Staurosira stevensonii</i>	Yes	Yes	Yes	Yes	Oval/lineate	No	No	No

*Data not found in the literature for these taxa.

Subsamples for diatom analyses from the Florida DEP project were digested according to the methodology described by Hasle & Fryxell (1970). Clean diatom material was mounted on microscope slides using Naphrax.

Light microscopic analyses were performed at a magnification of $\times 1000$ using a Leica DMLB microscope equipped with a Spot-RT Slider digital camera. Photographic plates were assembled digitally using Adobe Photoshop 6.0. Plates incorporated specimens from both NAWQA and Florida DEP material.

Relative abundance data were calculated by enumeration of 500 valves from each Florida DEP slide. A total of 250 valves from 11 sites were utilized in the calculation of valve dimensions and stria density ranges following the methodology in Anonymous (1975).

For SEM analyses, samples were pre-digested overnight using a solution of hydrogen peroxide and potassium permanganate (Battarbee, 1986). Two consecutive digestions in concentrated nitric acid followed this pre-digestion. Samples were allowed to boil in the acid for approximately 5 min. Immediately after this step, siliceous remains were rinsed several times in distilled water. Although the latter protocol may appear drastic, it has been determined to be effective and non-damaging for even the most delicate valve structures such as closing plates (Morales, 2001; Morales *et al.*, 2001). Aliquots from each slurry were dried on pieces of aluminium foil. Smaller pieces were then trimmed and

mounted on aluminium stubs using carbon-coated double-sided tape for SEM. Then, samples were coated with gold–palladium for 30 s at 1.8 kV using a sputter coater and observed with a Leo/Zeiss DSM 982 Digital Scanning Electron Microscope at the University of Connecticut (USA). Morphological terminology follows Anonymous (1975) and Ross *et al.* (1979).

Results

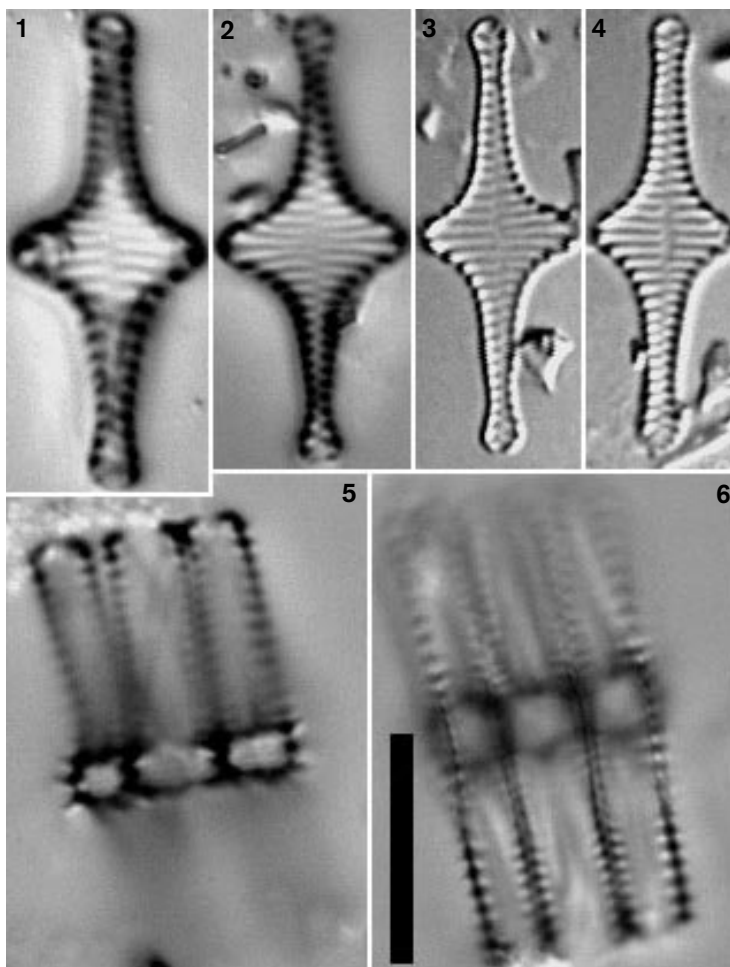
Staurosira stevensonii Manoylov, Morales *et* Stoermer, *sp. nov.* (Figs 1–12)

HOLOTYPE: Academy of Natural Sciences of Philadelphia A-GC57564.

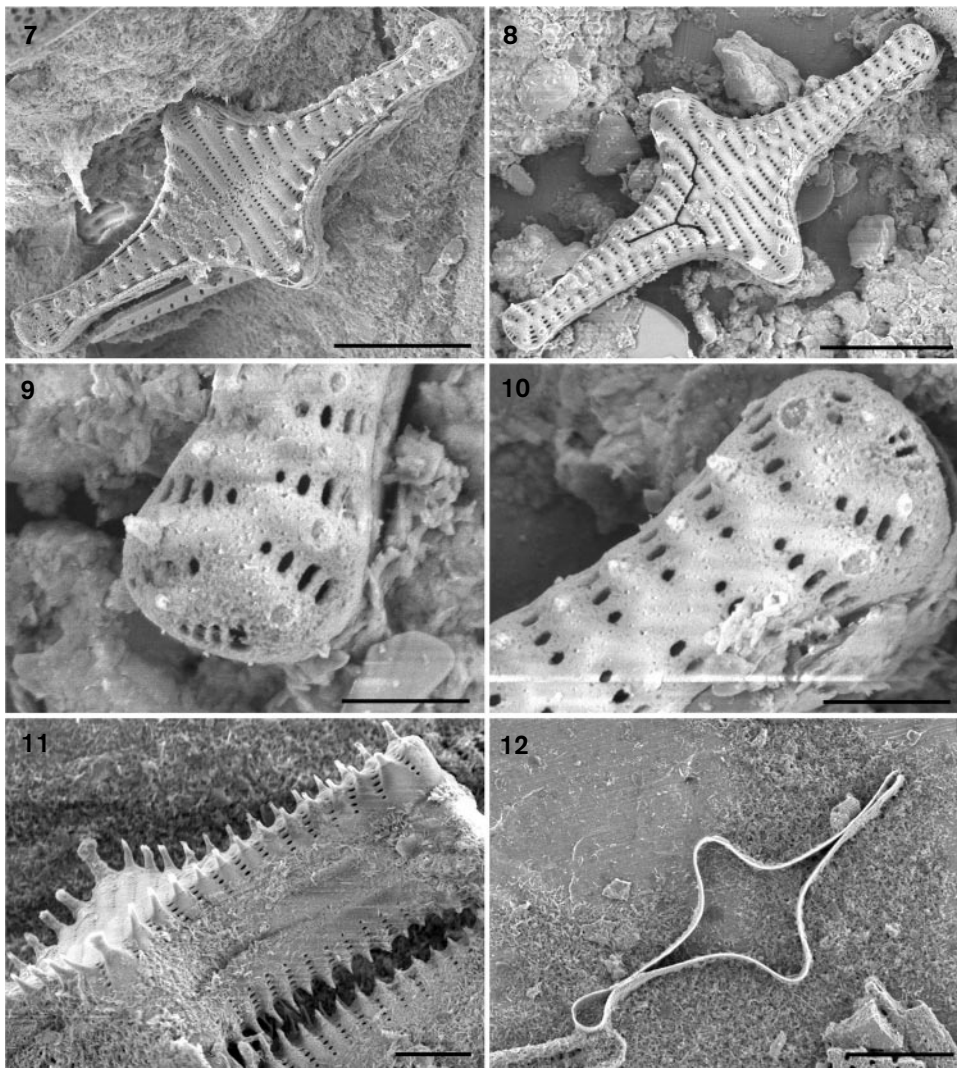
ISOTYPE: Diatom Collection, Florida wetlands; Algae laboratory, Michigan State University.

LOCUS TYPICUS: Pacific Tomato Wetland, Lee County, Florida, USA.

DESCRIPTIO: Frustula aspectu cincturae rectangularia solitaria vel in catenis (Figs 5, 6, 11) firmus spatulatus (Figs 10, 11). Spinae longae ad centrum



Figs 1–6. *Staurosira stevensonii* (LM). Figs 1, 2. Valve view of specimens from type material (A-GC57564). Figs 3, 4. Valve view of specimens from NAWQA material (Hillsboro Canal, Palm Beach Co.). Figs 5, 6. Girdle view of two different chains found in Florida DEP material. Note the open ends between neighbouring valves in Fig. 5. Scale bar represents 10 μm .



Figs 7–12. *Staurosira stevensonii* (SEM). Fig. 7. Valve view showing details of striation and spine pattern of a specimen from NAWQA material (Hillsboro Canal, Palm Beach Co.). Fig. 8. Valve view of a specimen from the type population (Pacific Tomato Wetland, Lee Co.). Figs 9, 10. Details of the apical ends of the specimen shown in Fig. 8. Note the absence of rimoportulae and the presence of reduced apical pore fields. Fig. 11. Girdle view of part of a colony showing open ends and the spatulate nature of the spines (see central area) (Hillsboro Canal, Palm Beach Co.). Also the continuation of the striae onto the valve mantle can be observed. Fig. 12. Valvocopulae showing the narrow nature of this structure in *S. stevensonii* (Hillsboro Canal, Palm Beach Co.). Scale bars represent: Figs 7, 8 and 12, 5 μm ; Figs 9 and 10, 1 μm ; Fig. 11, 2 μm .

connexus, aliter non connexus (Figs 5, 11). Superficie valvae complanata (Figs 7, 8, 11). Valvae tumidae centrae, eleganter cruciformes, congruentes (Figs 1–4, 7, 8). Fines valvae rotundi vel leviter capitati, 1.5–1.8 μm latae. Area axialis distincta, angusta. Sternum lineare, valde angustissimum (Figs 1–4, 7, 8). Areolae compositae punctis ex centro rotundis, ad marginem linearibus, 6 in 1 μm . Striae parallelae, parum radiatae ad fines, linearibus ad marginem. Striae alternis ad sternum et extendes in mantellum (Figs 7–11). Area apicalis pororum absentis vel leviter redacta. Cingulum ex taeniis apertis, valvocopulae perangusta (Fig. 12). Rimoportulae absum (Figs 9, 11). Chloroplasti par lanx, magnus. Valvae longae 12.5–21 μm , latae 7–9 μm , striae 14–19 in 10 μm .

DESCRIPTION: Frustules rectangular in girdle view, often arranged in chains (Figs 5, 6, 11) with the aid of spatulate solid spines (Figs 10, 11). Spines longer at the central area resulting in the separation of the apices of contiguous cells (Figs 5, 11). Valve surface flat (Figs 7, 8, 11). Valves swollen in the central area, elegantly cruciform (Figs 1–4, 7, 8), and very symmetrical in valve view (widest in the centre, same as valve width). Ends of the valve rounded or slightly capitate, 1.5–1.8 μm wide. Pseudoraphe distinct with a linear and very narrow central sternum (Figs 1–4, 7, 8). Areolae vary from round along the apical axis to slightly linear along the valve margins, 6 in 1 μm . Striae alternate along the sternum and continue onto the valve mantle (Figs 7–11). Apical pore fields absent or very reduced. Girdle bands open and valvocopulae narrow (Fig.

12). Rimoportulae not present (Figs 9, 11). Chloroplast plate-like and large. Valve length 18–21 μm , width 7–9 μm , and stria density 14–19 per 10 μm .

ETYMOLOGY: The new species is named after Dr R.J. Stevenson in recognition of his extensive research on diatom communities in the State of Florida.

Stream periphyton samples from NAWQA (Table 1) contained only a few representatives of this taxon and its relative abundance was never greater than 2%. In Florida DEP samples, *S. stevensonii* was observed in undigested and clean material in 35 water column samples and in two floating algae samples, but it was not present in any of the periphytic samples. Relative abundance of the new taxon was 1–8% of the total diatom assemblage. Florida DEP samples were often dominated by desmids. Among the diatoms, many species characteristic of acidic habitats were present: for example, species in the genera *Eunotia* Ehrenberg, *Pinnularia* Ehrenberg and *Frustulia* Rabenhorst. The centric diatom *Actinocyclus normanii* (Gregory) Hustedt was also found in many of the samples. The latter taxon has been reported from brackish habitats but can also tolerate lower salinity (Hohn, 1969; Hasle, 1977; Sicko-Goad *et al.*, 1989). Other fragilarioids were also present in the samples. Among them, *Staurosira construens* Ehrenberg and varieties, *Staurosirella berolinensis* (Lemmermann) Bukhtiyarova and *Fragilaria capucina* Desmazières and varieties were the most common.

Discussion

An extensive literature search was conducted in order to identify taxa with shape and spine morphology similar to those of *S. stevensonii* (Boyer, 1927; Cleve-Euler, 1953; De Toni, 1892; Ehrenberg, 1843; Frenguelli, 1941; Grunow, 1862; Habirshaw, 1881; Hustedt, 1959; Krammer & Lange-Bertalot, 1991, 1993b; Leme *et al.*, 1999; Mayer, 1937; Metzeltin & Lange-Bertalot, 1998; Patrick & Reimer, 1966; Schöenfeldt, 1913; Van-Heurck, 1880–1885; Witkowski *et al.*, 1995; Wolle, 1894; Zabelina *et al.*, 1954). This search revealed that *S. construens* Ehrenberg shares many morphological similarities with *S. stevensonii*. However, the two species have distinct morphological differences. *S. construens* has a variable shape including the cruciform outline, while the cruciform outline appears constant in *S. stevensonii*. Additionally, *S. construens* has a wider and irregular axial area. Neighbouring cells in colonies of *S. construens* are rarely disconnected at the apices, in contrast to

colonies of *S. stevensonii* in which apical separation is clearly visible. *Staurosira construens* has variable areolar density (6–8 in 1 μm), while in *S. stevensonii* this feature is constant (6 in 1 μm). Additionally *S. construens* possesses wider apices (1.8–2.2 μm) than *S. stevensonii* (1.5–1.8 μm).

Leme *et al.* (1999) found specimens similar in appearance to *S. stevensonii* in estuarine periphyton samples from Brazil. The same authors commented that in their concept *S. construens* appears to be a variable taxon and that the forms they had illustrated corresponded to transitional forms between the varieties *construens*, *pumila* and *venter*. They added that all the latter varieties should be synonyms, but did not present illustrations showing that these varieties are in fact transitional stages within a single series. As noted previously, *S. construens* was also present in samples analysed during the present study. However, our observations did not reveal transitional forms between this taxon and *S. stevensonii*, which suggests that the latter is a truly discrete entity.

Another species with morphology comparable to that of *S. stevensonii* is *Fragilaria longirostris* (Frenguelli, 1941). Photographs of this taxon appeared in a more recent publication (Metzeltin & Lange-Bertalot, 1998, pl.1, figs 7–10, p. 237). *F. longirostris* differs from *S. stevensonii* in having a wider central sternum. Additionally, the areolae in *F. longirostris* are round and similar to areolae of taxa in the genus *Pseudostaurosira* Williams & Round.

F. istvansffyi Pantocsek and *Fragilaria inflata* (Heiden) Hustedt also produce cruciform shapes that resemble *S. stevensonii*. The former two species also have a narrow central sternum and exhibit the zig-zag pattern formed by the alternation of striae along the apical axis of the valves. However, these two species differ from *S. stevensonii* in that they do not produce spines (Zabelina *et al.*, 1954).

Although the open ends between adjacent cells in colonies of *S. stevensonii* also can be observed in *Fragilaria crotonensis* Kitton, a number of features indicate that *S. stevensonii* does not belong in *Fragilaria* but in *Staurosira*. One of the most outstanding features supporting this decision is the absence of rimoportulae in *S. stevensonii*. In contrast *F. crotonensis* possesses a single rimoportula located close to one of the head poles of the valve. Comparison of *S. stevensonii* with other taxa is presented in Table 2.

Staurosira stevensonii was first reported as an unknown species in the genus *Staurosirella* Williams & Round during a palaeolimnological study in Lake Okeechobee (Stoermer *et al.*, 1992). These authors reported that this taxon was present along the entire sediment core. Although the absolute numbers of this undescribed *Staurosirella* species

increased in upper core layers, its relative abundance did not change significantly throughout the core.

The affiliations of this taxon with the genus *Staurosirella* were justified by Stoermer *et al.* (1992) based on the width of the areolae present at the cell margin. This initial identification is no longer supported. In *S. stevensonii* the striae are composed of much more reduced areolae and have smaller cross-members than in species of *Staurosirella*. Likewise, the apical pore fields, when present, are highly reduced in *S. stevensonii* and seem to be formed by a reduction in the size of the areolae composing the polar striae. In contrast, apical pore fields in *Staurosirella* are well developed and often composed of several discrete rows of poroids (Le Cohu, 1999; Round *et al.*, 1990; Williams & Round, 1987).

Spine morphology is an additional feature that supports the placement of *S. stevensonii* in the genus *Staurosira*. These structures are solid, spatulate and never branched, thus resembling spines found in other species of the mentioned genus. In those species of *Staurosirella* having well-developed spines, these structures are highly branched forming complex patterns along the contact surface between adjacent valves.

Our observations suggest that *S. stevensonii* is more abundant in acidic habitats. Its presence in much lower numbers in stream periphyton and in the more alkaline Lake Okeechobee could be explained by transport from surrounding habitats with lower pH. It is clear that additional data are needed to determine the range of distribution of this taxon and its true planktonic nature. Available data indicate that *S. stevensonii* is endemic to Florida. The true affinities of *S. stevensonii* with the taxon illustrated in Leme *et al.* (1999) remain unclear.

Acknowledgements

The authors thank the Florida DEP for supplying the bog samples and site data to Dr R.J. Stevenson's Algae Laboratory at Michigan State University. Samples from the NAWQA Program were part of a Cooperative Agreement between USGS and The Academy of Natural Sciences of Philadelphia's Patrick Center for Environmental Research. We are indebted to Dr Donald F. Charles for his support and comments during the preparation of this manuscript. We also thank Dr M.E. Cantino, J.S. Romanow and S.B. Daniels from the University of Connecticut Electron Microscopy Laboratory for help and support during SEM analyses. Comments by Dr Paul Kugrens, and four anonymous reviewers, as well

as the review of the Latin description by Dr C.W. Reimer, are gratefully acknowledged.

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