Phytotaxa 13: 40–48 (2010)
www.mapress.com/phytotaxa/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

Aulacoseira coroniformis sp. nov., a new diatom (Bacillariophyta) species from Highlands Hammock State Park, Florida

CHRISTOF PEARCE[1], HOLGER CREMER[2] & FRIEDERIKE WAGNER-CREMER[1]

[1]*Department of Palaeoecology, Laboratory of Palaeobotany and Palynology, Institute of Environmental Biology, Utrecht University, Budapestlaan 4, 3584 CD, Utrecht, the Netherlands*
[2]*TNO Built Environment and Geosciences, Geological Survey of the Netherlands, Princetonlaan 6, 3584 CB, Utrecht, the Netherlands*
Email: holger.cremer@tno.nl (corresponding author)

Abstract

Aulacoseira coroniformis sp. nov. is described from a short peat core recovered in Highlands Hammock State Park, Florida, U.S.A. The morphology of the new diatom species is documented by light and scanning electron micrographs and discussed in detail, including a comparison with related species in the genus *Aulacoseira*.

Introduction

Highlands Hammock State Park is situated 6 km west of Sebring in Highlands County, Florida, U.S.A. (Fig. 1). The park, now encompassing over 9250 acres, was established in 1931 by local citizens in order to preserve the 690 acres of hydric hammock hardwood forest, the central vegetation unit and main attraction of the park. The park is located on the western edge of the Lake Wales Ridge, a relict Pleistocene shoreline. The edge of the ridge forms the highest elevation (46 m.a.s.l.) from where the land slopes gradually down to around 24 m.a.s.l. in the western, flatter area of the park. Within the framework of a multi-proxy palaeoenvironmental reconstruction of the Highlands Hammock area, several sediment cores were drilled in 2008. The freshwater diatom flora of the Highlands Hammock State Park, which has not been documented so far, is studied with the goal of reconstructing the hydrology of Highlands Hammock State Park during the past approximately 3000 years. Core Highlands Hammock 3 (HHA3) was taken from a seasonally inundated forest dominated by maple and magnolia trees with a fern undergrowth. In the present paper, subsamples of core HHA3 were studied for the diversity of sub-recent and fossil diatoms. We describe the new species *Aulacoseira coroniformis* Pearce & Cremer *sp. nov.*, and document its morphological variability with high-quality light (LM) and scanning electron (SEM) microscope images.

Materials and methods

Sediment core HHA3 (27°27’47.45’’N, 81°32’21.48’’W; Fig. 1) was drilled in April 2008 south of the road bordering South Canal in Highlands Hammock State Park (Fig. 1) from a seasonally inundated forest dominated by maple trees and a fern undergrowth. A 78 cm long peat sequence was retrieved at the coring site and subsequently stored at 2 °C. Diatom subsamples taken at 1 cm intervals were freeze-dried and approximately 1 gram dry weight was used for further analysis. Samples were treated subsequently with 30 % hydrogen peroxide (1.5 hours at 100 °C), 10 % hydrochloric acid and 65 % nitric acid (2 hours at 120 °C) for the removal of organic matter and carbonate. Excess acid was removed by repeated sedimentation procedures in demineralized water. Microscopic slides were prepared by using evaporation trays (Battarbee 1973) and the

Accepted by D. Williams: 1 Nov. 2010; published: 6 Dec. 2010

high refraction mountant Naphrax®. Diatom slides were examined using a Leica DM2500 microscope equipped with a ×63 oil immersion lens and differential interference contrast at a magnification of ×945. Diatom valves were generally well-preserved and abundant in the studied peat sequence HHA3. Digital images were taken with a Leica DFC320 camera. For SEM analysis, cleaned material was mounted on a stub, sputter-coated with 12 nm platinum and examined using a Philips XL30S FEG SEM operating at 10kV.

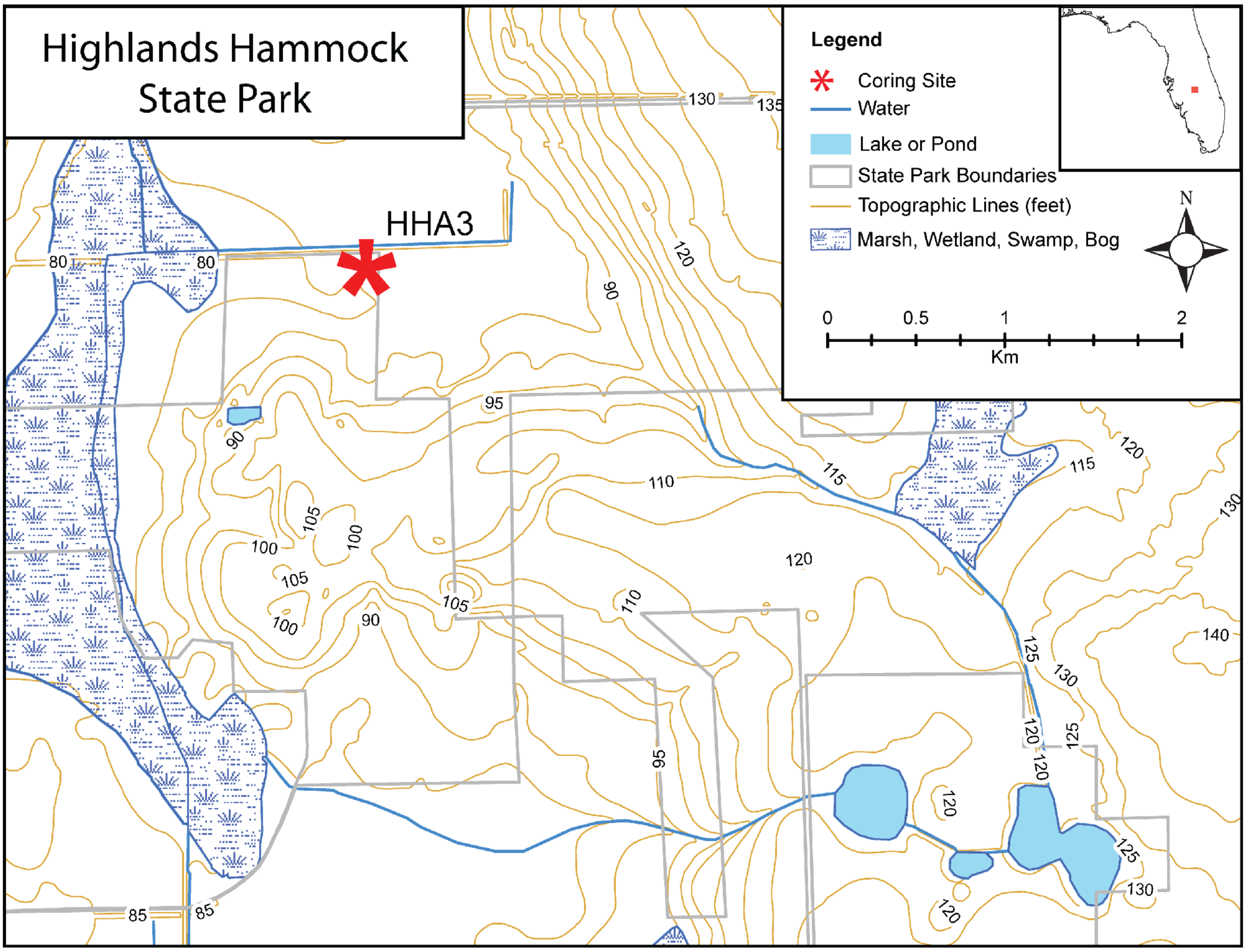


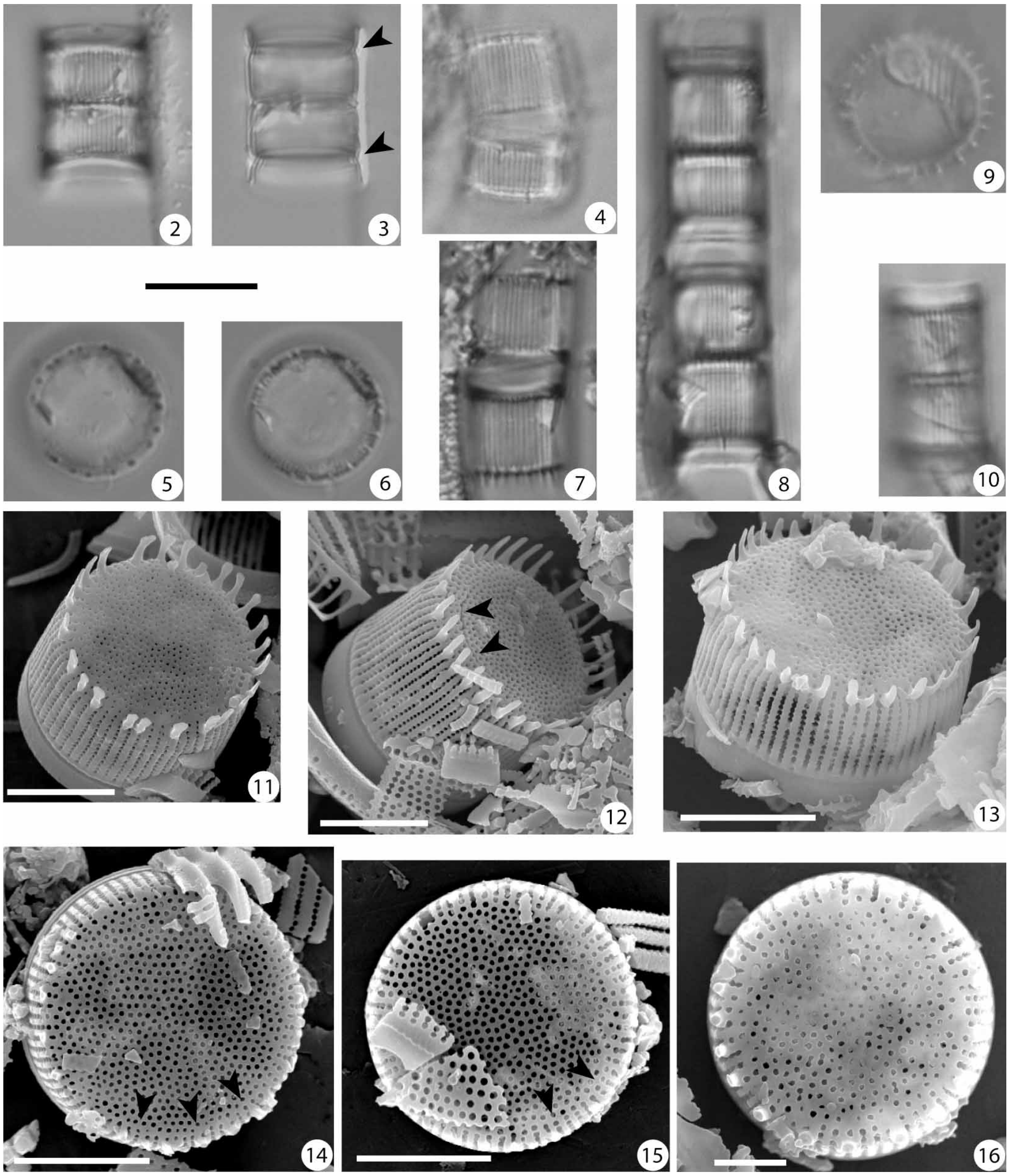
FIGURE 1: Geographical location of Highlands Hammock State Park, Highlands County, Florida, USA. Asterisk: drill site of sediment core HHA3.

New species description

Division Bacillariophyta
Sub-division Coscinodiscophytina Medlin & Kaczmarska 2004
Class Coscinodiscophyceae F.E. Round et R.M. Crawford in Round *et al.* 1990 emend. Medlin & Kaczmarska 2004
Subclass Coscinodiscophycidae F.E. Round et R.M. Crawford in Round *et al.* 1990
Order Aulacoseirales R.M. Crawford in Round *et al.* 1990
Family Aulacoseiraceae R.M. Crawford in Round *et al.* 1990
Genus *Aulacoseira* Thwaites 1848

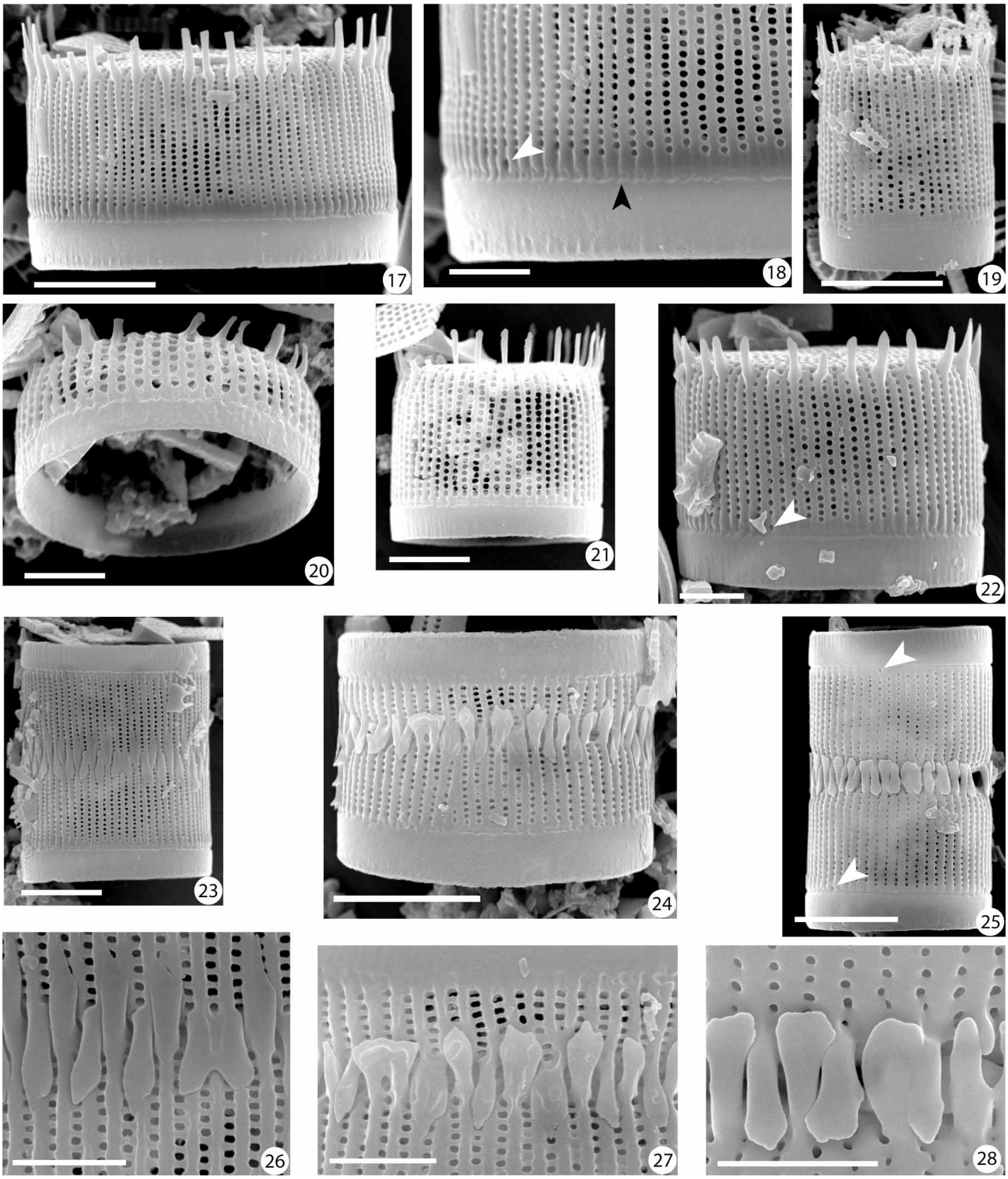
Aulacoseira coroniformis **Pearce & Cremer,** ***sp. nov.*** (Figs 2–37)

Frustula cylindrica, rectangularis in aspectu cinguli. Valvae circulares. Dimensiones valvarum: diameter discorum 6–15 µm, limbus valvarum 4–8 µm. Discus planus, tectus areolis aequaliter dispersis. Iunctura faciei valvae limbique leviter curvata. Striae limbi, 22–28 in 10 µm, parallelae, continuantes in peripheriam faciei valvae. Areolae 35–45 in 10 µm. Collum latum, sulcus distinctus, pseudoseptum latum praesens interius in limbo. Spinae marginales positae in iunctura faciei valvae limbique, in terminali omni vel fere omni costae pervalvaris. Rimoportula una observata in parte interna pseudosepti.

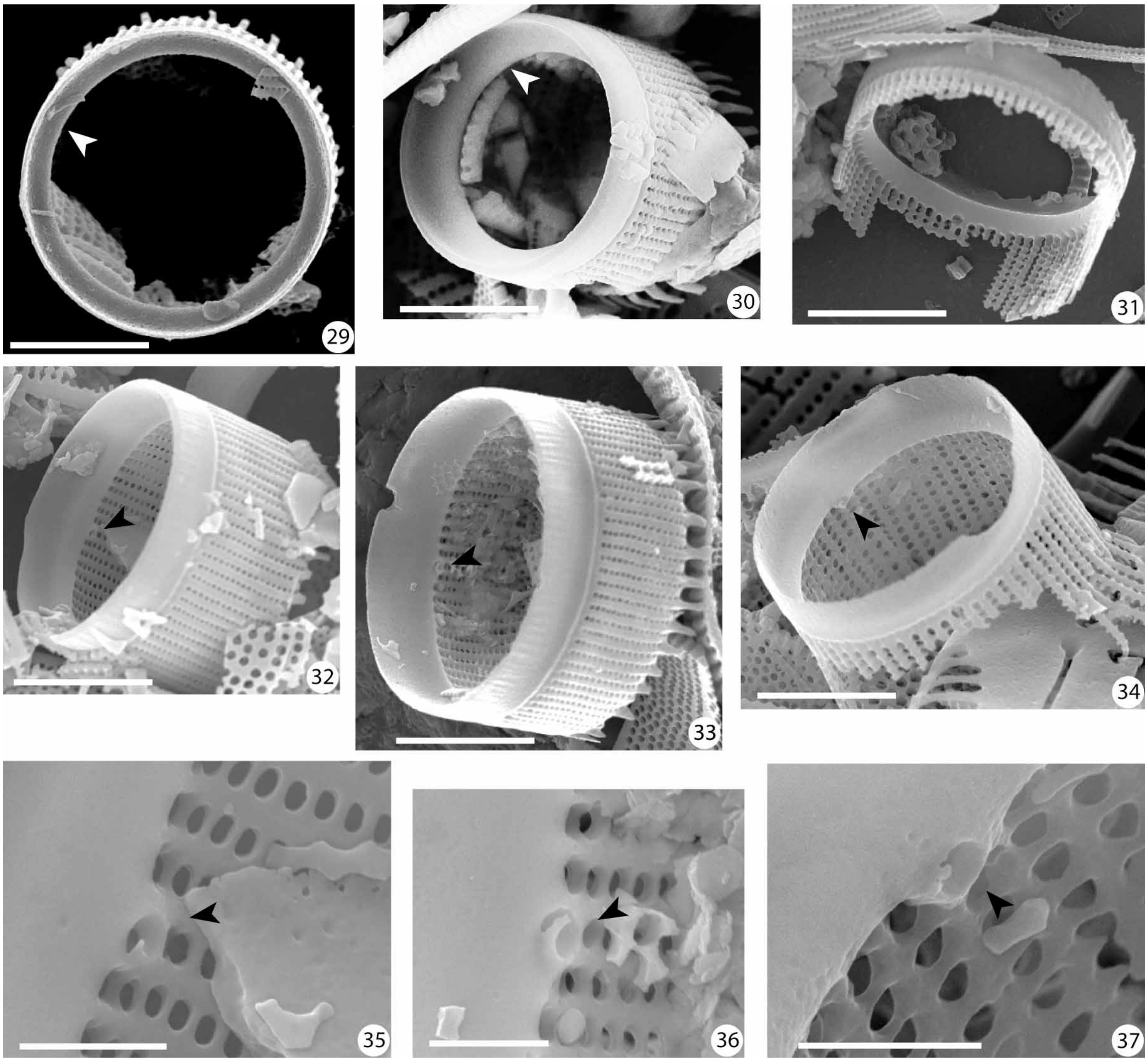


FIGURES 2–16: *Aulacoseira coroniformis*. Figs 2–10: LM images, all in girdle view apart from Figs 5, 6 & 9 which are in valve face view. Figs 2–6: Specimens from the holotype slide. Figs 2 & 3: Two spine-linked valves belonging to two frustules shown in two different foci. Arrows in Fig. 3 indicate the sulci of both valves. Figs 5 & 6: Two different foci of a valve in face view. Fig. 5 emphasizes the marginal ring of spines, Fig. 6 the areolae on the valve face periphery. Figs 4 & 7: Two complete frustules in girdle view. Fig. 8: Chain of four valves in girdle view, the middle two forming one frustule, with clearly visible, closely spaced pervalvar striae. Figs 11–16: SEM images documenting variation of discus areolation and spine morphology. The arrows in Figs 12, 14 & 15 indicate the border between discus areolae and peripheral striae belonging to the mantle. Scale bars: Figs 2–10: 10 µm; Figs 11–15: 5 µm; Fig. 16: 2 µm.

Frustules cylindrical, rectangular in girdle view. Valves circular, 6–15 µm in diameter. Pervalvar axis (mantle) 4–8 µm in length. Discus flat with evenly arranged areolae. Valve face-mantle junction gently curved. Mantle areolae arranged in parallel rows (22–28 in 10 µm), continuing onto the periphery of the valve face, 35–45 in 10 µm. Collum broad, sulcus distinct, thick ringleiste present inside the mantle. Linking spines on each to every third mantle costa. One rimoportula at the inner side of the ringleiste.



FIGURES 17–28: *Aulacoseira coroniformis*. SEM images, all in girdle view. Figs 17–25: variability of habitus, size and height-to-diameter ratio in selected valves. The black arrow in Fig. 18 points to the sulcus. White arrows in Figs 18, 22 & 25 point to possible external rimoportula openings. Figs 26–28: close-ups of Figs 23–25, respectively, showing the spine linkages between two valves of two different frustules. Scale bars: Figs 17, 19, 21, 23, 24, 25: 5 µm; Figs 18, 20, 22, 26, 27, 28: 2 µm.



FIGURES 29–37: *Aulacoseira coroniformis*. SEM images. Figs 29–31: size and position of the ringleiste (arrows in Figs 29 & 30). Figs 32-34: position of the rimoportula near the inner ringleiste (arrows). Figs 35–37: close-ups of Figs 32–34, respectively, showing the shape, size and positioning of the rimoportula (arrows). Scale bars: Figs 29–34: 5 µm; Figs 35–37: 1 µm.

Type:—Highlands Hammock State Park, Sebring, Florida, U.S.A., 27°27'47.45''N, 81°32'21.48''W, Cleaned sediment from 74 cm depth from a 78 cm long sediment core (HHA 3), drilled on the 1st of April 2008. Slide BR–4199 (holotype BR, Figs 2–6).

Habitat:—Epiphytic in modern swamps; fossil in Holocene lake sediments.

Distribution:—Central Florida, U.S.A.

Etymology:—From the Latin *corona* (crown) and *forma* (form), referring to the crown-shaped appearance of the valve.

Observations:—*Valve outline and dimensions*: The valve face is generally flat with a gentle transition towards the mantle (Figs 11–13). The discus-mantle boundary is difficult to recognize but usually characterized by a predetermined breaking line (arrows in Figs 12, 14 and 15) along which the discus regularly breaks (Fig. 12). The valve diameter is 6–15 µm (mean 9 µm; N = 48), the mantle height is 4–8 µm (mean 5.5 µm; N = 35) and the ratio of mantle height to diameter varies between 0.3 and 1.1 (mean 0.6; N =

35). *Mantle*: Approximately one quarter of the mantle height consists of the collum which possesses no areolae or other ornamentation. The boundary between the areolated mantle and the collum, the sulcus, is indicated as a local narrowing of the valve (arrows in Figs 3, 18). *Areolae*: The mantle striae consist of relatively small round (Figs 17, 18) to more or less rectangular (Figs 26, 27) areolae that are arranged in rows parallel to the pervalvar axis. The mantle striae density is 22–28 in 10 µm (N = 18) and the areola density per stria varies between 35 and 45 in 10 µm (N = 16). The striae continue over the mantle-valve face edge onto the periphery of the valve face (Fig. 11, 13). The discus itself is covered with mostly circular, evenly distributed areolae (Figs 14–16). The areola density on the discus is 98–108 areolae per 10 µm^2 (N = 8). On the valve face, the line between the peripheral striae and the evenly arranged areolae in the centre marks the boundary between the discus and the mantle (Figs 11, 12, 14, 15; see also Krammer 1991a, p. 91). Vela, which are rather common in the genus *Aulacoseira* (Crawford & Likhoshway 2002) were not observed in the examined specimens of *A. coroniformis*. This could mean that the vela in *A. coroniformis* are too delicate to be preserved after acid-cleaning of the raw material. *Ringleiste*: The ringleiste is a thick bulge-like broadening (Figs 29–31) located inside the valve opposite from the sulcus, at the junction between the areolated mantle and the collum. The width of the ringleiste is approximately 10–15 % of the valve diameter (N = 6). *Spines*: At the junction of the mantle and the valve face, linking spines arise usually from a single pervalvar costa and are present on each to every third costa (Figs 17–22). Spines are usually straight, lacking any side spines and run parallel to the pervalvar axis. Spines vary considerably in shape being relatively long with blunt or pointed distal ends (Figs 17, 21, 22) or comparably shorter and club-shaped (Figs 26–28). Also spines having anchor-shaped distal ends were observed (Fig. 11). The spine length ranges from 1.1–2.0 µm (mean 1.6 µm; N = 16). Separation valves with characteristic separation spines were not observed. *Rimoportula*: The labiate process is often difficult to recognize in *Aulacoseira*. A few valves of *Aulacoseira coroniformis* were observed having a rimoportula near the inner side of the ringleiste (Figs 32–37). The rimoportula is circular, stalk-less and surrounded by a thickened rampart-like siliceous wall (Figs 35, 37). Valves with more than one rimoportula were not observed. The external opening of the rimoportula which very often resembles a regular areola is difficult to recognize in *A. coroniformis*. The enlarged and somewhat isolated pores next to the sulcus visible in many valves (for example Figs 18, 22, 25) might correspond with the external rimoportulae openings. Likhoshway & Crawford (2001) provide an excellent overview on the variability of the morphology and position of rimoportulae in *Aulacoseira*.

Comparison with related taxa

Aulacoseira coroniformis may be confused with two other species in *Aulacoseira*: *A. nygaardii* (Camburn) Camburn & Charles (2000) and *A. lacustris* (Grunow) Krammer (1991b). Detailed SEM examination, however, revealed a number of distinctive features between the three taxa (Table 1). The original description of *A. nygaardii* by Camburn in Camburn & Kingston (1986) was solely based on LM and an emended description of *A. nygaardii* based on detailed SEM examination of the type material was provided by Siver & Hamilton (2005) almost 20 years later. The most obvious difference between *A. coroniformis* and *A. nygaardii* is the lack of areolae on the discus in the latter species. A further difference is the presence of vela in *A. nygaardii* which were not observed in *A. coroniformis*. Furthermore, no rimoportulae were described so far in *A. nygaardii*.

Aulacoseira lacustris and *A. coroniformis* are distinguished by both morphological and morphometric characters. The valve face of *A. coroniformis* is flat whereas in *A. lacustris* it is more or less flat to convex (Krammer & Lange-Bertalot 1991, Houk 2003). Valve face areolae are invisible in LM in *A. coroniformis* whereas in *A. lacustris* they are large and distinct in LM. Spines in *A. lacustris* are short, spatulate and have anchor-shaped distal ends compared to long and pointed, blunt or club-shaped spines in *A. coroniformis*. *Aulacoseira lacustris* has a diameter of 10–28 µm and a mantle height of 6–11 µm (Krammer & Lange-Bertalot 1991, Houk 2003) and is clearly larger than *A. coroniformis*. The number of pervalvar striae in *A.*

lacustris is distinctly lower with 13–16 in 10 µm and the width of the ringleiste is larger in *A. lacustris* (20% of valve diameter) compared to *A. coroniformis* (10–15%).

TABLE 1: Comparison between *Aulacoseira coroniformis*, *A. nygaardii* and *A. lacustris*, after Siver & Hamilton (2005), Krammer & Lange-Bertalot (1991) and Houk (2003)

	A. coroniformis	***A. nygaardii***	***A. lacustris***
Valve diameter (µm)	6–15	7–11	10–28
Mantle height (µm)	4–8	7–17	6–11
Discus	flat	flat	flat to slightly convex
Areola density on discus (in 10 µm^2)	98–108	no areolae	not reported
Valve face areolae	evenly distributed over entire valve face	only present on valve face periphery	irregularly scattered on valve face
Velum	not observed	two bars, most often form a cross	not reported
Orientation of pervalvar striae	parallel to pervalvar axis	parallel to pervalvar axis	parallel to pervalvar axis
Number of pervalvar striae (in 10 µm)	20–24	20–30	13–16
Number of areolae on pervalvar striae (in 10 µm)	35–45	25–48	13–14
Spine shape	long, straight to slightly bent, distal ends pointed, blunt, club- or anchor-shaped	short, tapered, with anchor-shaped ends	short, spatulate, with anchor-shaped ends
Spine frequency	on each to every third mantle costa	on every 2–3 (rarely 4) mantle striae	every few striae
Length of spines (µm)	1.1–2.0	0.7–1.5	not reported
Width of ringleiste	10–15 % of valve diameter	slight swelling of the valve	20 % of valve diameter
Rimoportulae	one per valve near the inner ringleiste	not reported	not reported

Aulacoseira coroniformis has most likely been overlooked and misidentified in the past. Siver & Hamilton (2005) in their re-evaluation of *A. nygaardii* suggest that SEM micrographs of diatom valves from Okefenokee Swamp, Georgia, published by Scherer (1988), were erroneously identified as *Aulacoseira nygaardii* (as *Melosira nygaardii* in Scherer 1988). Images of the specimens in question (Figs 62–64 in Scherer 1988) show a very close resemblance to *A. coroniformis*, including the presence of areolae on the discus in their micrographs. We therefore propose that they likely belong to *Aulacoseira coroniformis*. Scherer (1988) described his specimens from sites associated with increased hydrological flow and silica input and with slightly higher nutrient content.

Quillen presented images of valves identified as *A. nygaardii* from Highland County, Florida, which are probably *A. coroniformis* (Quillen 2009). Quillen's LM images do not differ from those of *A. coroniformis* and further SEM study may justify a transfer of this taxon to *A. coroniformis* (Quillen 2009, Figs 70–73). *Aulacoseira coroniformis* is also similar to *Aulacoseira 'occulta'* (provisional name proposed by Siver & Hamilton 2011, written communication), a taxon distributed in regions along the east coast of North America. Both *Aulacoseira coroniformis* and *A. 'occulta'* are barely distinguishable in LM but SEM reveals a number of significant taxonomic characters for *A. 'occulta'*, among them the presence of a distinct secondary siliceous layer (Siver & Hamilton 2010, 2011, and written comm.) that has never been observed in *A. coroniformis*.

Ecology and geography

Since *A. coroniformis* is here described for the first time, little ecological and geographical information is available other than that from Highlands Hammock State Park, where it is described from. *Aulacoseira coroniformis* was the dominant diatom species in Holocene lake sediments deposited between 550 B.C. and 1200 A.D. A total of 22 additional diatom taxa representing 10 genera were identified in the core sediments. Diatoms mainly co-occurring with *A. coroniformis* are: *Eunotia zygodon* Ehrenberg (1843), *Eunotia carolina* Patrick (1958), *Eunotia tautoniensis* Hustedt *ex* Patrick (1945) and *Pinnularia viridis* (Nitzsch) Ehrenberg (1843). These species are acidophilous, with pH optima around 5.0 (Siver *et al.* 2005, Gaiser & Johansen 2000). *Aulacoseira coroniformis* was also recognized in a modern environment with a water depth of 50 cm and pH 5.1, attached to leaves of *Nuphar lutea* (yellow water-lily), sampled nearby the coring location in Highlands Hammock State Park. *Aulacoseira nygaardii sensu* Quillen (2009) has a reconstructed TP optimum of 13.0 ± 1.8 µg/L and a pH optimum of 7.01 ± 0.72, thus being a weakly mesotrophic and circumneutral species. In summary, it can be assumed that *A. coroniformis* is an acidophilous taxon.

Taking into account the misidentifications discussed above, *Aulacoseira coroniformis* occurs in the southeastern regions of the U.S.A.

Acknowledgements

We greatly appreciate the cooperation of State Park District 4 staff and the support of Ken Alvarez during fieldwork. Jan van Tongeren is acknowledged for assisting with SEM sessions and slide preparation in the lab. Bart van de Vijver (National Botanical Gardens of Belgium) assisted with the Latin diagnosis. This study is part of the Hurricanes and Global Change Program funded by Utrecht University. This paper is Netherlands Research School of Sedimentary Geology publication no 20101002.

References

Battarbee, R.W. (1973) A new method for the estimation of absolute microfossil numbers, with reference especially to diatoms. *Limnology and Oceanography* 18: 647–653.

Camburn, K.E. & Charles, D.F. (2000) *Diatoms of low-alkalinity lakes in the Northeastern United States*. Academy of Natural Sciences of Philadelphia, Philadelphia, 152 pp.

Camburn, K.E. & Kingston, J.C. (1986) The genus *Melosira* from soft-water lakes with special reference to northern Michigan, Wisconsin and Minnesota. *In*: Smol, J.P., Battarbee, R.W., Davis, R.B. & Meriläinen, J. (Eds), *Diatoms and Lake Acidity.* Dr W. Junk Publishers, Dordrecht, pp. 17–34.

Crawford, R.M. & Likhoshway, Y.V. (2002) The velum of species of the diatom genus *Aulacoseira* Thwaites. *In:* John, J. (Ed.), *Proceedings of the 15th International Diatom Symposium, Perth, Australia, 28 September–2 October, 1998.* A.R.G. Gantner Verlag K.G., Ruggell, pp. 275–287.

Ehrenberg, C.G. (1843) Verbreitung und Einfluss des mikroskopischen Lebens in Süd-und Nord-Amerika. *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin* 1841: 291–445.

Gaiser, E. & Johansen, J. (2000) Freshwater diatoms from Carolina Bays and other isolated wetlands on the Atlantic coastal plain of South Carolina, USA, with descriptions of seven taxa new to science. *Diatom Research* 15: 75–130.

Houk, V. (2003) Atlas of freshwater centric diatoms with a brief key and descriptions. Part I. Melosiraceae, Orthoseiraceae, Paraliaceae and Aulacoseiraceae. *Czech Phycology*, Supplement 1: 1–111.

Krammer, K. (1991a) Morphology and taxonomy of some taxa in the genus *Aulacoseira* Thwaites (Bacillariophyceae). I. *Aulacoseira distans* and similar taxa. *Nova Hedwigia* 52: 89–112.

Krammer, K. (1991b) Morphology and taxonomy in some taxa of the genus *Aulacoseira* Thwaites (Bacillariophyceae). II: Taxa in the A. *granulata*-, *italica*-and *lirata*-groups. *Nova Hedwigia* 53: 477–496.

Krammer, K. & Lange-Bertalot, H. (1991) Bacillariophyceae: Teil 3: Centrales, Fragilariaceae, Eunotiaceae. *In*: Ettl, H., Gerloff, J., Heynig, H. and Mollenhauer, D. (Eds), *Süßwasserflora von Mitteleuropa, Bd. 02/3*. VEB Gustav Fisher Verlag, Jena, pp. 1–576.

Likhoshway, Y.V. & Crawford, R.M. (2001) The rimoportula - a neglected feature in the systematics of *Aulacoseira*. *In*: Economou-Amilli, A. (Ed.), *Proceedings of the 16th International Diatom Symposium, Athens & Aegean Islands, 25 August – 1 September*, 2000. Amvrosiou Press, Athens, pp. 33–47.

Medlin, L.K. & Kaczmarska, I. (2004) Evolution of the diatoms: V. Morphological and cytological support for the major clades and a taxonomic revision. *Phycologia* 43: 245–270.

Patrick, R.M. (1945) A taxonomic and ecological study of some diatoms from the Pocono Plateau and adjacent regions. *Farlowia* 2: 143–221.

Patrick, R. (1958) Some nomenclatural problems and a new species and a new variety in the genus *Eunotia* (Bacillariophyceae). *Notulae Naturae of the Academy of Natural Sciences of Philadelphia* 312: 1–15.

Quillen, A.K. (2009) *Diatom-based Paleolimnological Reconstruction of Quaternary Environments in a Florida Sinkhole Lake, PhD- Dissertation*. Florida International University, Miami, 131 pp.

Round, F.E., Crawford, R.M. & Mann, D.G. (1990) *The Diatoms. Biology & Morphology of the Genera*. Cambridge University Press, Cambridge, 747 pp.

Scherer, R.P. (1988) Freshwater diatom assemblages and ecology/palaeoecology of the Okefenokee swamp/marsh complex, Southern Georgia, U.S.A. *Diatom Research* 3: 129–157.

Siver, P.A. & Hamilton, P.B. (2005) A reevaluation of *Aulacoseira nygaardii* (Camburn) Camburn & DF Charles (Bacillariophyceae): based on scanning electron microscopy of type material. *Nova Hedwigia* 81: 257–266.

Siver, P.A., Hamilton, P.B., Stachura-Suchoples, K. & Kociolek, J.P. (2005) Diatoms of North America: the freshwater flora of Cape Cod, Massachusetts, U.S.A. *In*: Lange-Bertalot, H. (Ed.), *Iconographia Diatomologica. Vol. 14. Diatoms of North America*. A.R.G. Gantner Verlag K.G., Ruggell, pp. 1–463.

Siver, P.A. & Hamilton, P.B. (2010) Six new freshwater diatom species and their autecology from acidic lakes and ponds along the eastern coast of North America. 21st *International Diatom Symposium, St. Paul, Minnesota, U.S.A., 29-Aug. to 3-Sep., 2010, Abstract volume*, p. 143.

Siver, P.A. & Hamilton, P.B. (2011, in press) Diatoms of North America. An introduction to the Atlantic Coastal Plain from North Carolina to New Jersey. Freshwater wetlands, ponds and lakes. *In*: Lange-Bertalot, H. (Ed.), *Iconographia Diatomologica.* A.R.G. Gantner Verlag K.G., Ruggell.

Thwaites, G.H.K. (1848) Further observations on the Diatomaceae with descriptions of new genera and species. *Annals and Magazine of Natural History* 1: 161–172.