Neidium pseudodensestriatum sp. nov., a new epiphytic diatom from Florida (U.S.A.) and comparison with N. densestriatum (Østrup) Krammer

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Abstract

Populations of a Neidium taxon from lakes in Ocala National Forest, Florida, U.S.A., were studied in terms of its valve morphology and taxonomic placement. The valves are elliptical-lanceolate, with a rectangular central area, proximal raphe ends deflected in opposite directions, and a single large longitudinal canal along each valve's margin. Observations in scanning electron microscopy show the arrangement of areolae to be disorganized and the valve face/mantle junction to be sharply delineated, with the mantle height to be relatively deep. These Florida populations resemble N. densestriatum in outline, size range and number of striae, but differ in several other morphological features, such as the proximal raphe ends, the striae arrangement, the number of the areolae forming rows on the mantle and the structure of the central nodule. The Florida specimens are described as a new species, Neidium pseudodensestriatum.

Introduction

The freshwater diatom flora of Florida is not well known. Early taxonomic work was carried out by Bailey (1850, 1853). Additional studies by Hanna (1933) and Hohn (1961) focused on freshwater fossil and recent diatoms, respectively, while Patrick & Reimer (1966, 1975) and Camburn et al. (1984–1986), included treatment of Florida samples in their works. Florida freshwater diatom material was included in the exsiccata of H.L. Smith (1874; slide 193). At the time of Hanna's work, he remarked (pp. 73–74), "I have made as intensive a search as was possible for previous records of individual species of freshwater diatoms from Florida... but I was not successful in finding any..." The situation on the literature of freshwater diatoms from Florida has not changed much since Hanna's time.

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In a survey of the diatoms from lakes in Ocala National Forest, we encountered populations of a *Neidium* species whose identity was difficult to determine. In this study we detail valve features of this *Neidium* taxon and compare it to a species that appears closely related and occurs in similar habitats along the east coast of North America. Special attention is drawn to features that refer them to *Neidium* and are discussed in detail by Hamilton et al. (1990, 1995, 1996) and Siver et al. (2003). We discuss the taxonomic status of the Florida taxon and present it as a new species.

Materials and Methods

Periphyton samples were taken from 31 different seepage, freshwater, acid lakes in Ocala National Forest, Florida, U.S.A. In addition we investigated holotype of *Neidium densestriaatum* (Östrup) Krammer – slide No 3942, type material of species described as *Caloneis ladogensis* var. *densestriaatum* Hustedt – slide No Ne 1/13 and populations of *Neidium densestriaatum* (Östrup) Krammer from Ryder Pond, Cape Cod, Massachusetts, U.S.A. and Jones Lake, North Carolina, U.S.A. Samples were cleaned in H₂O₂ and K₂Cr₂O₇. They were subsequently washed several times and air-dried onto coverslips. Slides for optical microscopy were mounted in Naphrax®. Light microscope (LM) observations were made with a Leica DMRB. For scanning electron microscopy (SEM), coverslips were mounted onto aluminum stubs, sputter-coated with gold-palladium, and observations were made with Leo 1450VP. Samples are archived at the Diatom Collection of the California Academy of Sciences, San Francisco (CAS).

Results and Discussion

*Neidium pseudodensestriaatum* Stachura-Suchoples & Kociolek, sp. nov. (Figs 1–23)


*Description:* Valves elliptical-lanceolate to elliptical, with apices acute to rounded, length 18–52 μm, breadth 10.5–17 μm. Striae straight, 21–26/10 μm, parallel to slightly radiate except at the apices where they are slightly arched and parallel. Axial area straight, narrow. Central area rectangular. External proximal raphe ends deflected in opposite directions. Longitudinal canals marginal. Distal raphe ends appear forked.

*Holotype:* CAS slide 539047.
*Type material:* Cleaned sediment, CAS 620642, collector P.A. Siver, March 2000.
*Type locality:* Wildcat Lake, Ocala National Forest, Florida, U.S.A. (N 29°10′13″; W 81°37′34″). It grows as an epiphyte on aquatic plants.
Neidium pseudodensestriatum specimens from Florida are elliptical-lanceolate to elliptical in shape, with acute to rounded apices (Figs 1–11). Striae are straight and parallel to slightly radiate throughout most of the length of the valve, becoming arched and parallel at the apices. The axial area is narrow and straight, widening to form a rectangular central area. The external proximal raphe ends are deflected in opposite directions. The degree of deflection of the proximal raphe ends is variable, and focusing through specimens produces the image of the ends being straight. There is only one longitudinal canal along each valve margin. The distal raphe ends appear forked.

Figs 1–11. Neidium pseudodensestriatum from Ocala National Forest lakes (Florida, U.S.A.), LM, size range series. Fig. 2. Specimen showing proximal raphe ends deflected in opposite directions (arrow a), marginal position of longitudinal canal (arrow b), parallel to slightly arched striaion (arrows c). Scale bar = 10 μm.
In SEM, the external proximal raphe ends are clearly hooked or deflected in opposite directions (Figs 12, 14); a character state that was observed consistently in the Florida specimens. The external openings of the areolae vary widely from round to slit-like and are often positioned irregularly within a stria (Figs 12, 14, 15). The valve face/mantle junction is acute, with the longitudinal canal positioned along the valve margin (Figs 12, 15). The mantle contains striae composed of 4–5 areolae along the vertical face (Figs 12, 13). Lacinia, a term recently described by Siver et al. (2003), at the apices give the impression of bisected distal raphe ends (Figs 12, 13, 16).

Figs 12–16. *Neidium pseudodensestriatum* from Ocala National Forest lakes (Florida, U.S.A.). SEM, external views. **Fig. 12.** Whole valve showing proximal raphe ends deflected in opposite directions, broad longitudinal canals, sharp valve face/mantle junction and irregular organization of areolae. Note mantle striae with 4–5 rows of areolae. **Fig. 13.** Apex showing the lacinia giving the impression of a bisected distal raphe fissure and the rows of areolae on the mantle. **Fig. 14.** Central area showing deflected proximal raphe ends. **Fig. 15.** Fractured valve showing longitudinal canal and key and slot raphe type (arrow). **Fig. 16.** Apex showing the distal raphe end and the lacinia. Scale bars = 1 μm.
A small and raised central nodule and helicotoglossae are prominent on the valve interior (Figs 17, 19, 22, 23). Hymenate pore occlusions cover the internal openings of the areolae (Figs 17, 21–23). The raphe is of the key and slot type (Fig. 20). A longitudinal canal is visible at each valve's margin (Fig. 17). Recently described by Siver et al. (2003), the renilimbi are scattered across the valve interior, but concentrated along the raphe sterna (Figs 17, 22, 23). Numerous pleurae, each with a single row of rounded poroids, are present (Fig. 18).

Figs 17–23. Neidium pseudodensestriatum from Ocala National Forest lakes (Florida, U.S.A.), SEM, internal views. Fig. 17. Entire valve showing marginal longitudinal canals and prominent central nodule and helicotoglossae. Fig. 18. Numerous pleurae, each with a single row of rounded poroids. Fig. 19. Raised central nodule with co-axial proximal raphe ends. Areolae lack hymenate pores. Note renilimbi (single renilimbus mark by arrow). Fig. 20. Fragmented valve showing the raphe to be of a key and slot type. Fig. 21. Single areola with hymenate pore occlusions and renilimbi (arrows). Figs 22, 23. Helicotoglossae, renilimbi and areolae with hymenate pore occlusions (single renilimbus mark by arrows). Scale bars = 1 μm (Figs 17–19, 22, 23), 200 nm (Fig. 20), 100 nm (Fig. 21).
The Florida specimens are similar to *Neidium densestriatum* (Ostrup) Krammer, described originally as *Caloneis ladogensis* var. *densestriata* Ostrup 1910. However, a separate species described by Hustedt (1930) also was named *Caloneis ladogensis* var. *densestriata* Hustedt. The nomenclatural situation is clear, as *C. ladogensis* var. *densestriata* Ostrup (1910) is a valid published name and is the basionym of *N. densestriatum* (Krammer & Lange-Bertalot 1985). However, Ostrup (1910) and Hustedt (1930) drawings differ in the shape and size of the central area, the pattern of striae in the central part of the valve and the location of the longitudinal canal. So far, the question as to whether both scientists described the same or different species has been raised, but never resolved (e.g. Simonsen 1987).

Here, we compare specimens investigated by Ostrup (1910) from Råbjerg Mile, Denmark (Figs 24–28) with specimens studied by Hustedt (1930) from the Wollingster Lake, Germany (Figs 29–33). Both populations share the same features of valve shape, size range (length: 18 to 40 μm, width: 11.5 to 16.5) and number of striae (22–26/10 μm). Other features including arrangement of striae, straight proximal raphe ends and the appearance of submarginal position of the longitudinal canal are also the same. No material for SEM investigation is available. Based on LM observations we conclude that Hustedt (1930) investigated the same taxon described previously by Ostrup (1910).

Figs 24–33. *Neidium densestriatum*, LM. Figs 24–28. Specimens from Ostrup’s holotype slide 3942, size range series. Figs 29–33. Specimens from Hustedt’s slide Ne 1/13, size range series. Figs 26, 31. Specimens showing proximal raphe ends slightly curved in opposite directions (arrows a), impression of submarginal position of longitudinal canals (arrows b), and radiate striae (arrows c). Scale bar = 10 μm.

In the U.S.A. diatom flora, *Neidium densestriatum* has previously been reported from New York, New Jersey, North Carolina (Camburn & Charles 2000, Patrick & Reimer 1966), and we have recorded specimens conforming to this description in samples from North
Carolina and Massachusetts (Siver et al. 2004). It is these latter specimens on which our detailed observations have been made.

*Neidium densestriatum* is elliptical-lanceolate to elliptical in shape, 20–60 µm long, 10.5–17 µm broad (Figs 34–48) (see also Foged 1952, Krammer & Lange-Bertalot 1985, 1986). The striae are radiate throughout, 23–27/10 µm. The axial area is straight, narrow, and widens to form a rectangular central area. The external proximal raphe ends are straight, only rarely suggesting a slight deflection (Fig. 35). The longitudinal canals seem to be submarginal, as rows of areolae can be seen to border the lines at the valve margin (e.g. Figs 35–37). A forked appearance to the external distal raphe ends is given.

Figs 34–48. *Neidium densestriatum*, LM, size range series. Figs 34, 38, 40, 41, 43–48. Specimens from Ryder Pond (Massachusetts, U.S.A.). Figs 35–37, 39, 42. Specimens from Jones Lake (North Carolina U.S.A.). Fig. 35. Specimen showing proximal raphe ends slightly curved in opposite directions (arrow a), impression of submarginal position of longitudinal canals (arrows b), and radiate striae (arrows c). Scale bar = 10 µm.
The external morphology of valves of *Nelidium densestriatum* is shown in Figs 49–57. The valves are ornamented with rounded to slit-like areolae, which are arranged in distinct striae. The lacinia at the apices create the image of bisected distal raphe ends (Figs 49, 50, 52), but in a rare instance the lacinia flap was missing and the raphe fissure is shown to be straight and terminating prior to the valve apex (Fig. 51). The proximal raphe ends are straight (Fig. 53), though one (Fig. 54) or both (Fig. 55) raphe ends may be asymmetrically enlarged. Due to the rounded nature of the valve margin, the longitudinal canal appears to be bordered by areolae around the periphery (Fig. 49). The valve face/mantle junction is rounded, and the mantle has striae composed of 2–3 vertical rows of areolae (Figs 49, 52). The tube-like longitudinal canal is bordered by areolae (Figs 56, 57).

Figs 49–57. *Nelidium densestriatum* from Ryder Pond (Massachusetts, U.S.A.) and Jones Lake (North Carolina, U.S.A.), SEM, external views. Fig. 49. Whole valve showing roundish valve face/mantle junction, which may give the impression of a submarginal longitudinal canal (arrows). Note the straight proximal raphe ends and small flaps at apices. Striae are organized into distinct rows. Mantle striae with 2–3 rows of areolae. Figs 50, 52. Apices with the lacinia. Fig. 51. Apex without the lacinia showing the straight distal raphe end. Figs 53–55. Variation in the proximal raphe ends showing slight deflection in none, one or both ends. Figs 56, 57. Longitudinal canal is shown to be an ovoid tube and is bordered by areolae (arrows). Scale bars = 1 μm.
Internally, the central nodule and helictoglossae are prominent (Figs 58–61, 64). The central nodule has the appearance of being comprised of two abutting "helictoglossa-like" structures (Fig. 60). The areolae are occluded by hymenate pores (Figs 59–61), which may be lacking in some specimens due to an apparent physical destruction (Fig. 64). The longitudinal canal is tube-like and perforated by a single row of areolae (Fig. 62). The renilimbi are scattered across the valve face, being more dense along the raphe sternum (Figs 58–61). The raphe is of the key and slot type (Fig. 63).

Figs 58–64. Neidium densestriatum from Ryder Pond (Massachusetts, U.S.A.) and Jones Lake (North Carolina, U.S.A.), SEM, internal views. Fig. 58. Whole valve showing longitudinal canals and prominent central nodule and helictoglossae. Figs 59, 61. Apices with helictoglossae. Note areolae with hymenate pore occlusions and renilimbi (arrows) dispersed, but aligned along the raphe and longitudinal canal. Fig. 60. Rectangular central area with raised central nodule that appears to be comprised of two "helictoglossa-like" structures (arrows). Fig. 62. Fractured valve showing the marginal longitudinal canal with hymenate pore occlusions (arrow). Fig. 63. Fractured valve with the key and slot raphe (arrow). Fig. 64. Whole valve exhibiting shallow mantle, prominent longitudinal canals and areolae without hymenate pore occlusions. Scale bars = 1 µm.
Specimens of *Neidium pseudodensestriatum* from Florida and *N. densestriatum* share many similarities, including those that refer them to *Neidium* (longitudinal canals, lacinia, striaion, to name a few; see Hamilton et al. 1990, 1995, 1996, Siver et al. 2003). In LM, these two taxa may appear conspecific, having in common a similar valve shape, size range and number of striae. However, a closer examinations revealed differences between the two taxa, such as the arrangement of the areolae (irregular in the Florida specimens, regular in *N. densestriatum*), the structure of the valve face/mantle junction and the resulting appearance of the longitudinal canal junction acute in the Florida specimens giving the impression of a marginal canal versus the junction more rounded and sloped in *N. densestriatum*, giving the impression of a submarginal canal), the valve mantle structure (deeper, more vertical with 4–5 rows of areolae in the Florida specimens versus more shallow, rounded with 2–3 rows of areolae in the other), deflected external, proximal raphe ends in opposite directions (present in the Florida specimens, lacking in the other), and different structure of raised central nodule (that appears to be comprised of two "helictoglossa-like" structures at the proximal ends in the case of *N. densestriatum*). Additionally, in the case of *N. pseudodensestriatum*, the pleurae each with a single row of rounded poroids were noted. Similar observation was also made for *N. cape-codii* Siver & Hamilton (Siver et al. 2003). However, Round et al. (1990) stated that one of the circumscribing characteristics for the genus *Neidium* are the pleurae without poroids, but it does not hold true for all members of the genus.

*Neidium pseudodensestriatum* shares a superficial resemblance to *N. apiculatum* Reimer, including the short, deflected proximal raphe ends, but it lacks the pronounced and characteristic apiculate apices (Reimer 1959). *Neidium apiculatum* is also bigger in size, with a higher number of striae. Additionally, the striae are radiate throughout most of the valve and become parallel to convergent at the ends. Another *Neidium* species with short proximal raphe ends curved in opposite directions is *N. demerariense* Krammer & Metzeltin (Metzeltin & Lange-Bertalot 1998). However, in the case of *N. demerariense*, the striae are less dense and the central area is smaller.

The resemblance between *Neidium pseudodensestriatum* and *N. densestriatum* suggests that the two taxa may be closely related, though closer observations indicate otherwise (especially the differences in the proximal raphe ends). These two species have not been found as co-occurring in our samples. *Neidium pseudodensestriatum* is restricted to Florida's lakes, and *N. densestriatum* was observed in lakes from Massachusetts and North Carolina. So far, there is no record of *N. densestriatum* in Florida. However, both species prefer similar conditions. They occur in freshwater, acid lakes and are associated with taxa belonging to *Frustulia* Ehrenberg and *Brachysira* Kützing. It is clear that the diatom flora of the United States is far from being well understood, and the complex distribution patterns found there need to be taken into account in future taxonomic work. Potapova & Charles (2002) suggested that there is a geographical separation of diatoms species in the U.S.A., a point made previously by Ehrenberg (1849). Kociolek & Kingston (1999) noted the southeastern United States has unique species of gomphonemoid diatoms. Despite over 150 years of work, the number and kinds of freshwater diatom species in the U.S.A. is still a relative mystery, as is their distribution across time and space.

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