Mallomonas nieringii sp. nov., a new species of Synurophyceae from a suite of ponds on Cape Cod, Massachusetts, U.S.A.

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A new species of *Mallomonas*, *M. nieringii* sp. nov., is described from a small, poorly buffered, acidic locality on Cape Cod, Massachusetts, U.S.A. Cells are covered with uniquely sculptured scales, each scale of which may possess a single bristle. Cell, scale and bristle morphology all indicate that this new species should be placed within the series Punctiferae of the section Punctiferae, which now has four recognized species and one variety. Scales of the apical ring are highly asymmetric in design, each with a forward projecting triangular shaped spine. Collectively, the triangular shaped extensions of the apical ring of scales surround a single emergent flagellum. Body scales resemble those of *Mallomonas punctifera* and *M. transsilvanica* in shape and general morphology, but differ in lacking distinct secondary ribbing on the shield. *Mallomonas nieringii* was found in six waterbodies all situated within a small geographic area on the outer tip of the Cape Cod peninsula.

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Introduction

The genus *Mallomonas* Perty in the class Synurophyceae (Andersen, 1987), consists of solitary motile cells with two flagella, one or two lobed chloroplasts and a highly organized layer of siliceous scales and bristles. Identification of species and sub-specific taxa are based on the ultrastructure of the siliceous cell covering, and in particular the morphology of the scales, as determined using electron microscopy (Asmund & Kristiansen 1986; Siver 1991). Over 135 taxa of *Mallomonas* have been described (Asmund & Kristiansen 1986; Siver & Marsicano 1993; Péterfi & Momeu 1996). The purpose of this paper is to describe a new species with a unique type of scale in the series Punctiferae of the section Punctiferae (Asmund & Kristiansen 1986; Siver 1991).

Methods

Water samples, plankton net tows, and surface sediment samples were taken from 60 lakes and ponds on Cape Cod, MA and analyzed for silica-bearing synurophytes. Three water samples and three plankton net tows were taken from each lake between 1996 and 1998, and surface sediments were obtained from each lake using a Glew (1988) gravity corer during the same time period. Water samples were taken from a depth of 1 m from the center of each waterbody, fixed in Lugol's preservative and concentrated with centrifugation. Plankton net samples were also collected from the center of the lake using a 10 μm net, kept cool, and processed within a few hours as outlined below.

Portions of each concentrated water sample and plankton net tow were air dried onto a piece of
heavy duty aluminum foil and used for observation with scanning electron microscopy (SEM). The pieces of aluminum were trimmed and attached to SEM stubs using Apiezon wax, coated with a mixture of gold and palladium for 1 minute using a Polaron model E sputter coater and observed with either a Leo 982 field emission or a Leo 435 VP SEM.

Location information and chemical characteristics of all study lakes are listed in Ahrens & Siver (2000).

Results

*Mallomonas nieringii* Siver sp. nov.

Cellula parva, 18-26 × 8-11 μm, ellipsoida vel ovoidea, parte anteriori protracta, parte posteriori saepe cauda brevi provisa. Squamae anticae triangulara spina protinus procurrenti instructae. Squamae corporis paene quadratae, distaliter rotundatae, 3.5-4.0 × 2.7-3.2 μm, costa submarginali instar litterae U ornatae, sine ornamentis secundariis; lamina basalis poris minutis perforata. Setae notacanthae, dentibus in tres series longitudinales dispositis ornatis. Setae apicales 6-8 μm, setae corporis 10-14 μm longitudine.

Type Locality, Spectacle Pond, Town of Wellfleet, Cape Cod National Seashore, Cape Cod, Massachusetts, U.S.A.. Iconotype Fig 1. The epithet is named in honor of Professor William A. Niering, noted wetland ecologist and environmental scientist, for his inspiration and friendship.

Cells are relatively small, ellipsoidal to ovoid with a slightly protruding anterior region, and range in size from 18 to 26 μm × 8 to 11 μm (Fig. 1). The posterior end is often extended or tapered to form a short tail (Fig. 1). Except for the extreme posterior region of the cell, all scales possess a single bristle. The anterior-most, or apical, scales on the cell are asymmetric, triangular-shaped and situated in a ring around the flagellar pore with their longitudinal axes parallel to that of the cell (Figs 1, 3). The distal left side of each apical scale is extended forward forming a short triangular-shaped spine; the end of each spine has a series of small teeth (Fig. 3). The forward projecting spines on all apical scales form the pore through which a single flagellum emerges. Each apical scale in the anterior ring is overlapped by the scale to its left, and overlaps the scale to its right. In addition, the proximal end of each apical scale is sandwiched between two body scales. The apical ring consists of six to eight scales, each of which possesses a bristle that is morphologically similar to those associated with body scales, but shorter in length (Fig. 1).

Body scales are aligned in spiral rows with their longitudinal axes perpendicular to the axis of the cell (Figs 1-2). Body scales are more or less quadrate with a broadly rounded proximal end, a more squared distal end (Figs 5-6), and range in size from 3.1 to 4.0 μm × 2.7 to 3.2 μm. Each body scale has a shallow posterior rim that encircles half to two-thirds of the perimeter of the scale, and a shallow dome with a U-shaped opening on the right side from which a single bristle emerges (Fig. 6). Body scales also possess a U-shaped submarginal rib (Figs 5-6). The distal ends, or arms, of the U-shaped submarginal rib broadly connect to the sides of the dome, run parallel with the longitudinal axis of the scale and attach in the proximal region. The basal or proximal portion of the submarginal rib is usually thinner and not raised as high from the base of the scale as are the arms. The dome and submarginal rib complex lack ornamentation, including base plate pores (see undersurfaces of scales in Fig. 6).

The area of each scale between the proximal rim and submarginal rib, and that delimited by the submarginal rib, contain only small pores, and lack additional secondary structures (Figs 1-3; 5-6). On the distal portions of a few scales there were thicker and more silicified areas where the distribution of pores was more irregular (Fig. 5). Most often there are only approximately two rows of pores between the proximal rim and the submarginal rib (Fig. 6). Bristles associated with body scales are 10 μm to 14 μm long and composed of three equally spaced and serrated ribs (Figs 1, 4). Bristles associated with apical scales are shorter, 6 μm to 8 μm, but otherwise
Table 1. Chemical characteristics of the six lakes on Cape Cod, MA where *Mallomonas nieri ngii* has been reported. Key: Alk = alkalinity; Spec. Cond. = specific conductivity; SD = Secchi disk depth; TP = total phosphorus; TN = total nitrogen.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Town</th>
<th>pH</th>
<th>Alk. (μeq L⁻¹)</th>
<th>Spec. Cond. (μS)</th>
<th>SD (m)</th>
<th>TP (μg L⁻¹)</th>
<th>TN (μg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duck</td>
<td>Wellfleet</td>
<td>4.8</td>
<td>-47</td>
<td>114</td>
<td>7.1</td>
<td>5</td>
<td>57</td>
</tr>
<tr>
<td>Great</td>
<td>Truro</td>
<td>5.9</td>
<td>1</td>
<td>131</td>
<td>5.5</td>
<td>9</td>
<td>195</td>
</tr>
<tr>
<td>Higgins</td>
<td>Brewster</td>
<td>6.4</td>
<td>11</td>
<td>85</td>
<td>6.2</td>
<td>8</td>
<td>161</td>
</tr>
<tr>
<td>Horseleech</td>
<td>Wellfleet</td>
<td>6.3</td>
<td>27</td>
<td>206</td>
<td>3.8</td>
<td>8</td>
<td>222</td>
</tr>
<tr>
<td>Slough</td>
<td>Wellfleet</td>
<td>5.1</td>
<td>-22</td>
<td>144</td>
<td>6</td>
<td>8</td>
<td>68</td>
</tr>
<tr>
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<td>Wellfleet</td>
<td>4.9</td>
<td>-31</td>
<td>178</td>
<td>5</td>
<td>9</td>
<td>169</td>
</tr>
</tbody>
</table>

Morphologically similar to those associated with body scales.

*Mallomonas nieri ngii* was found in six of sixty waterbodies sampled (Ahrens & Siver 2000) on the peninsula of Cape Cod, Massachusetts (Table 1). Although the sixty waterbodies were geographically spread over the 105-km long peninsula, the localities that harbored *M. nieri ngii* were all localized along a 19-km stretch in the eastern-most arm of the peninsula, primarily in a section referred to as the “forearm” (Ahrens & Siver 2000). In general, the waterbodies were acidic with pH values ranging from 4.8 to 6.4, poorly buffered, oligotrophic, and with specific conductivities ranging from 85 μS to 222 μS (Table 1). Sodium and chloride were the dominant ions in the six localities. Total phosphorus and total nitrogen concentrations were all below 10 μg L⁻¹ and 222 μg L⁻¹, respectively, and Secchi disk depths ranged from 3.8 m to 7.1 m.

Discussion

There is no doubt that *Mallomonas nieri ngii* belongs in the series Punctiferae of the section Punctiferae in the genus *Mallomonas* (Asmund & Kristiansen 1986; Siver 1991). The shape, structure and orientation of anterior, body and posterior scales, bristle morphology, and the distribution of siliceous components on the cell are all indicative of taxa in the series Punctiferae. However, the distinctive design of the scales on *M. nieri ngii* is clearly different from all other taxa in this series and the taxon should be recognized at the species level.

With the inclusion of *Mallomonas nieri ngii* there are now at least four recognized species and one variety within the series Punctiferae. *Mallomonas punctifera* and *M. transsylvanica*, the two most common species in this series, have been found in many studies representing a wide geographic distribution (e.g. Asmund & Kristiansen 1986; Siver 1991). A third species, *Mallomonas connensis* Siver & Marsicano, is another taxon with very uniquely sculptured scales that Siver & Marsicano (1993) argued was best placed in the section Punctiferae. *Mallomonas connensis* clearly belongs in the series Punctiferae and not the series Vannigerae. Unlike *M. punctifera* and *M. transsylvanica*, *M. connensis* is known from only a single eutrophic lake in Connecticut, U.S.A. A fifth species, *Mallomonas plumosa* Croome & Tyler, was also placed in the series Punctiferae by Asmund & Kristiansen (1986), but in the series Hamatace by Péterfi & Momoe (1996).

Although he did not give taxonomic status to scales of different sizes, Siver (1991) noted that there were two forms of *Mallomonas punctifera* that differed in their ecological tolerances. One form had smaller scales and was found primarily in moderately acidic lakes in North America that were oligotrophic and of low specific conductivity. The other form had larger scales and was especially common in alkaline and eutrophic waters in Europe. Recently, Kristiansen & Menezes (1998) described a second variety of *Mallomonas punctifera*, var. *brasiliensis*, that appears to represent the taxon with smaller scales noted by Siver (1991). Kristiansen & Menezes (1998) commented that most of the previous observations of *Mallomonas punctifera* made in North and South America are probably of var. *brasiliensis*.

Like *Mallomonas connensis*, it appears that *M. nieri ngii* is also geographically quite limited. Despite considerable efforts aimed at describing scaled chrysophytes in northeastern North America (e.g. Nicholls 1982; 1988; Siver 1988; 1989; 1991; Siver & Lott 2000) cells of *M. nieri ngii* have not been found other than on the eastern-most section of the Cape Cod peninsula. This is of further interest because *M. nieri ngii* was quite common in six ponds situated in a very small geographic area on the outer arm of Cape Cod (Siver, 2000), but was not found in
waterbodies situated a short distance away from this suite of ponds. Based on a thorough survey of the literature, scales of *M. nieringii* may have been previously reported from Finnish waters by Hällfors & Hällfors (1988) and Ikävälko (1994), but to my knowledge this taxon has not been previously reported from North America. Hällfors & Hällfors (1988) referred to *M. nieringii*-like scales as “blank” scales due to their lack of secondary reticulation. Neither Hällfors & Hällfors (1988) nor Ikävälko (1994) specified if they found whole cells with only *M. nieringii*-like scales and therefore it is difficult to assess if *M. nieringii* has actually been observed in Europe.

It could be possible that *M. nieringii* is a form of *M. punctifera* where the scales simply lack the shield reticulation. However, several lines of evidence support the hypothesis that *M. nieringii* is indeed a separate species. First, of the many cells of *M. nieringii* observed in Cape Cod lakes, none possessed scales with a definitive reticulation on the shield similar to scales of *M. punctifera*. A few scales of *M. nieringii* appeared to have some additional thickenings on the shield (see Fig. 5). However, these thickenings appeared to possess pores and were not distinctly raised above the base plate as is the case for ribs on scales of *M. punctifera*. Second, in the two ponds with populations of both *M. nieringii* and *M. punctifera*, no body scales on cells of *M. punctifera* were observed to lack shield reticulation like those of *M. nieringii*. In fact, all scales on *M. punctifera* cells were heavily ribbed. Third, the submarginal rib complex connects in the proximal region on scales of *M. nieringii*, but not on scales of *M. punctifera*. As a result, scales of *M. punctifera* often possess base plate pores in the proximal region of the scale between the ends of the submarginal ribs, whereas they are lacking on scales of *M. nieringii*.

Both *Mallomonas punctifera* and *M. transsydvanica* have distinctive scales that can usually be differentiated with light microscopy. The secondary reticulation of ribs found on scales of *M. punctifera* is clearly observed with a light microscope, whereas the series of closely spaced transverse ribs on scales of *M. transsydvanica* are usually not. Because secondary ribbing is lacking on scales of *M. nieringii*, they can be distinguished from *M. punctifera* with a light microscope, but possibly not from scales of *M. transsydvanica*. However, since scales of *M. nieringii* are smaller than those of *M. transsydvanica* (see Siver 1991), this characteristic could be potentially used to help separate scales with light microscopy.

*Mallomonas nieringii* was found in 10% of the lakes and ponds examined on the Cape Cod peninsula (Siver 2000). The lakes were similar in chemical composition in being acidic, poorly buffered, oligotrophic, and compared to many poorly buffered acidic lakes in northeastern North America, high in specific conductivity. The higher specific conductivity values were caused by elevated concentrations of sodium chloride due to close proximity to the ocean (Ahrens & Siver 2000). All of the waterbodies harbouring this species were located within a small geographic region near the end of the peninsula at least 60 km from the mainland. More interesting, is the fact that this taxon was not found in the 35 waterbodies examined to the west of this suite of lakes. It is unclear why the geographic distribution of *M. nieringii* appears to be restricted to ponds situated on the outer portion of Cape Cod, but perhaps it is related to the higher concentrations of dissolved salts, especially sodium chloride.

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References


