Mallomonas retrorsa, a new species of silica-scaled Chrysophyceae with backwards orientated scales

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A new species, *Mallomonas retrorsa*, with a unique siliceous armour, is described from four slightly humic and acidic localities in Connecticut, U.S.A., each low in specific conductance. Cells of the new species have three types of siliceous scales each of which is asymmetric, domeless and arranged with their longitudinal axis parallel to the longitudinal axis of the cell. The scales are positioned such that the posterior rim of each scale faces the apical end of the cell. In addition, the new taxon has an apical whorl of very small, forward projecting paddle-shaped bristles that emerge from the rimmed ends of the apical scales, and an elongated caudal region.

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Introduction

The genus *Mallomonas* Perty (Mallomonadaceae), consists of motile, solitary cells with two flagella (one of which is usually greatly reduced), a chloroplast and a covering of siliceous scales and bristles. Upturned rims, found on most scales, are always present on the proximal border. Valid species and subspecific identifications are based on the ultrastructure of the siliceous armour (Takahashi 1978, Wee 1982, Asmund & Kristiansen 1986). As a result, approximately 50% of the species originally described with light microscopy are questionable and, to date, not considered valid (Asmund & Kristiansen 1986). In a recent taxonomic survey of the genus *Mallomonas*, Asmund & Kristiansen (1986) recognized 91 species with 15 varieties and 9 forms arranged into 16 sections. All of these taxa have been described with electron microspcopy (EM). Since this survey, several other taxa, e.g., *M. sabulosa* Croome & Tyler (Croome & Tyler 1986) and *M. portae – ferreae* var. *reticulata* Gretz, Sommerfeld & Wujek (Gretz et al. 1985) have also been described with EM.

Practically all species of *Mallomonas* have scales arranged with their longitudinal axes at oblique or right angles to the longitudinal axis of the cell and bristles associated with domed scales. The purpose of this paper is to describe a new species of *Mallomonas* with scales arranged parallel to the longitudinal axis of the cell, and will backwards orientation.

Materials and methods

Water samples and plankton net (10 μm mesh) samples were collected at 1 m from the center of the lake or at 0.5 m along the shoreline. Half of each sample was immediately fixed with Lugol's solution. Water samples were concentrated with centrifugation for 8 min at 809 χg (2000 rpm).

For scanning electron microscope observation a 1 ml aliquot from each sample was air dried onto a piece of aluminum foil, gently washed with distilled water, trimmed, and attached onto an aluminum stub with apiezon wax. Samples were coated with gold for 4.5 minutes using a Polaron model E 5100 SEM coating unit and observed with a Coates and Welter field emission scanning electron microscope. For transmission electron microscopy aliquots from each sample were air dried onto formvar/carbon coated copper grids and observed directly with a Hitachi HU11-C TEM.

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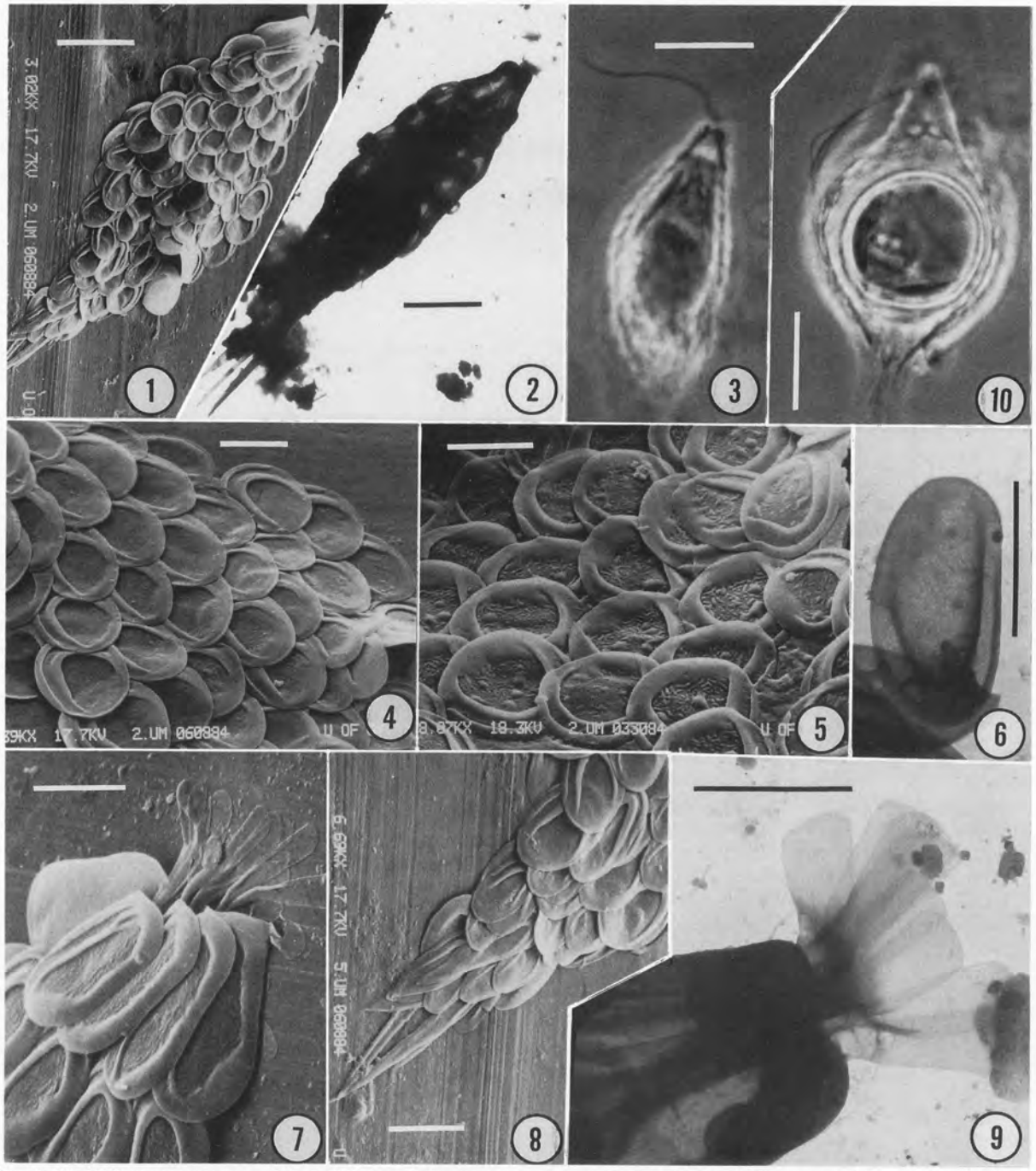
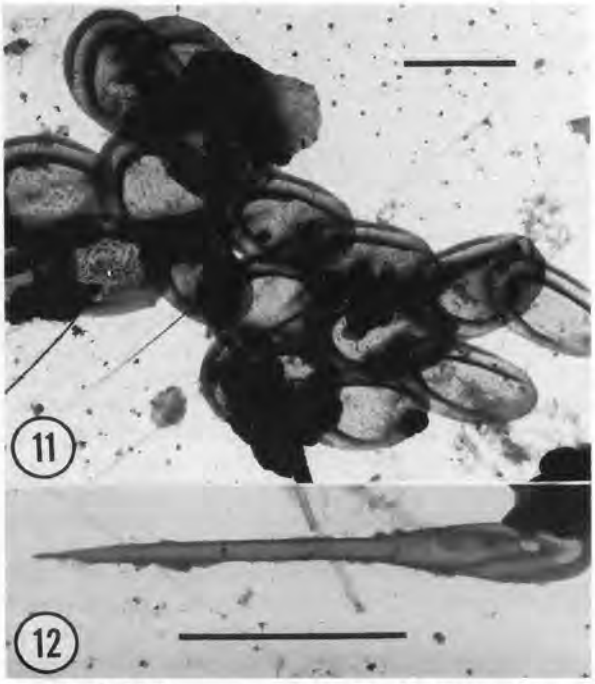


Figs 1–10. *Mallomonas retrorsa*. – Fig. 1. Whole cell. Scales are arranged with their longitudinal axes parallel to the longitudinal axis of the cell. Note the whorl of apical scales and the elongated caudal tail (SEM; bar = 5 μm). – Fig. 2. Whole intact cell showing the spindle shape of the cell (TEM; bar = 5 μm). – Fig. 3. Whole cell with a single emergent flagellum (LM, phase contrast; bar = 5 μm). – Fig. 4. Close-up of the asymmetrical body scales from the cell shown in Fig. 1. Note the overlapping pattern and spiral arrangement of the scales (SEM; bar = 2 μm). – Fig. 5. Body scales with a more elaborate series of ribs on the shield (SEM; bar = 2 μm). – Fig. 6. A single asymmetrical body scale. Note the irregularly positioned base plate pores (TEM; bar = 2 μm). – Fig. 7. Close-up of the anterior portion of a cell. Note the group of thin, paddle-shaped bristles emerging from the whorl of apical scales (SEM; bar = 2 μm). – Fig. 8. Close-up of the caudal region of the cell shown in Fig. 1. Note the elongated spined scales (SEM; bar = 2 μm). – Fig. 9. Close-up of the anterior region showing the outline of the thin paddle-shaped bristles (TEM; bar = 2 μm). – Fig. 10. Whole cell undergoing cyst formation (LM, phase contrast; bar = 5 μm).



Figs 11–12. *Mallomonas retrorsa.* – Fig. 11. Group of asymmetrical body scales. Note the base plate pores (TEM; bar = 2 μm). – Fig. 12. A single caudal spine scale (TEM; bar = 2 μm).

Results

Mallomonas sectio Retrorsae Siver sect. nov.

Cellula fusiformis, coronam apicalem setarum parvarum prorsum directarum et caudam elongatam praebens. Squamae asymmetricae, cupulis nullis, axibus longitudinalibus cum axe longitudinali cellulae parallelis, partibus posticis prorsum directis. Setae e squamis apicalibus emissae. Apices squamarum caudalium in spinas elongati.

Cells are lanceolate-spindle shaped with an apical whorl of small forward-projecting bristles and an elongated caudal tail. Scales are asymmetric, domeless, and orientated with their longitudinal axes parallel to the longitudinal axis of the cell such that the proximal ends of the scales face the anterior end of the cell. Bristles emerge from the proximal ends of apical scales. The distal end of each caudal scale is elongated into a spine.

Mallomonas retrorsa Siver sp. nov.

Cellula fusiformis, 20–35 μm longa, squamis trimorphis tecta. Partes posticae squamarum taeniis reflexis et cristis V-formibus insignes prorsum directae. Squamae mediae 2.9–3.5 × 1.9–2.3 μm magnae, quaeque e lamina basali et strato secundario tenui laevi vel paulum undulato composita, cupula nulla, taenia reflexa et crista V-formi longius in latere dextro quam in sinistro extensis. Squamae apicales 3.5–5.0 × 1.8–2.1 μm magnae, circum flagellum unicum emergens in coronam manifestam dispositae; setae 6–12, 3–4.5 μm longae, complanatae, ad apices versus dilatatae, prorsum directae.

Typus: Figura nostra 1 depictus, in Bigelow Pond, Town of Union, Connecticut, U.S.A., inventus.

Cells are lanceolate to spindle shaped, 20–35 μm long, possess an apical tuft of small paddle-like bristles that surround a single emergent flgellum, an elongated caudal tail, and three distinct types of scales arranged with their longitudinal axes parallel to the longitudinal axis of the cell (Figs 1–3). The scales are differentiated into apical, body and caudal scales and are orientated with their proximal ends (i.e., the part with the rim) facing the anterior part of the cell (Fig. 1).

Body scales (2.9–3.5 × 1.9–2.3 μm) are domeless, two-layered and have an asymmetrically positioned rim and V-rib. The V-rib is broadly U-shaped with one arm (the right-handed one) extending almost to the distal border (Figs 4–6, 11). The right-handed part of the proximal rim also extends further along the margin of the scale than the left-handed part. The base plate of the body scales consists of small irregularly positioned pores (Figs 6, 11). The secondary layer is thin, covers the base plate, and is usually smooth to slightly undulate in nature. On some scales the secondary layer may form a thumbprint like pattern of irregularly shaped ribs (Fig. 5). Since the secondary layer covers the base plate, the

Tab. 1. Environmental conditions under which *Mallomonas retrorsa* has been recorded in four lakes from Connecticut, U.S.A.

Lake or Pond	Date	Temperature	pH	Specific Conductance (μS)	Total Phosphorus (μg-P/1)
Bigelow	March 24, 1984	9	5.6	23	–
Bigelow	March 29, 1986	10	5.5	23	19
Bigelow	Feb. 22, 1987	3	5.8	22	12.7
Breakneck	Feb. 28, 1986	4.5	5.7	21	15
Breakneck	Jan. 17, 1987	3	6.2	20	19
Breakneck Swamp	May 5, 1984	14	6.0	31	–
Chamberlain	Feb. 22, 1987	3.4	5.7	37	27

pores can only be seen with TEM. The body scales are arranged in spiral rows and aligned such that the distal portion of each body scale overlaps the proximal border(s) of the scale(s) behind it (Figs 1, 4).

The apical bristle-bearing scales (3.5–5.0 × 1.8–2.1 μm) are also asymmetrical in shape, elongated, and are aligned into a distinct ring (Figs 7, 9) around the emergent flagellum. Apical scales, usually 6–8 in number, are clearly aligned with their proximal ends facing forward. As such, the bristles are attached to and emerge from the "rear" portion of the scale. Although the shield of the caudal scales is much smaller, the V-rib is extended along both distal margins forming a long spine (Figs 8, 12). The length of the spine, and hence the caudal scales, gradually increases with proximity to the posterior most portion of the cell. Thus, the caudal scales are not arranged in a single whorl like the apical scales, but rather, in a more irregular manner (Fig. 8).

Bristles are short, 3 to 4.5 μm in length, flat, and paddle-shaped with a blunt distal end (Figs 7, 9). The bristles, 6 to 12 in number, gradually increase in diameter and become widest at the distal-tip (Figs 7, 9). All bristles from a given cell are similar in length, originate from the apical whorl of scales and project forward forming an inverted cone structure around the base of the emergent flagellum. The distal portions of each bristle ends at the base of the cone. Cysts were observed with light microscopy (Fig. 10).

Type locality, Bigelow Pond, Town of Union, Connecticut, U.S.A., Iconotype Fig. 1. The epithet refers to the backwards orientation of the scales.

Mallomonas retrorsa has been found in seven collections from four water bodies (Tab. 1). Bigelow Pond is a small, slightly humic, acidic (pH range: 5.5–6.5) water body, low in specific conductance (range: 18–31 μS) and total phosphorus (range: 4–19 $\mu gP.l^{-1}$). The drainage basin is undeveloped and consists of a mixture of deciduous hardwoods and conifers. In addition to Bigelow Pond it has also been recorded in Breakneck Pond, Breakneck Swamp (Town of Union) and Chamberlain Lake (Town of Woodstock), all of which are low in specific conductance and slightly acidic in nature. Like Bigelow Pond, Breakneck Pond and Breakneck Swamp are low in total phosphorus, however, summer phosphorus levels in Chamberlain Lake are indicative of a mesotrophic to eutrophic lake. *Mallomonas retrorsa* has been most often observed during the late winter to early spring at temperatures between 3 and 14°C (Tab. 1).

Discussion

The scales of most species of *Mallomonas* are arranged such that their longitudinal axes are at oblique or right angles to the longitudinal axis of the cell (Asmund & Kristiansen 1986). Besides *M. retrorsa*, only two species, *M. akrokomos*, Ruttner in Pascher and *M. fenestrata* Cronberg & Hickel, have been described whose scales are arranged with their longitudinal axes being parallel to that of the cell.

As is described here for *M. retrorsa*, both *M. akrokomos* and *M. fenestrata* have elongated scales with spine scales on one end of the cell and a whorl of bristle-bearing scales on the other. The three species differ, however, in which end represents the apical part of the cell. The situation is similar for *M. retrorsa* and *M. akrokomos*, but differs for *M. fenestrata*. In *M. akrokomos* the whorl of bristle-bearing scales form the apical portion of the cell and the caudal most scales become gradually elongated into a posterior "tail" (see Asmund & Kristiansen 1986). An identical situation was reported here for *M. retrorsa*. Cell polarity is reversed for *M. fenestrata* (Cronberg & Hickel 1985). In *M. fenestrata* the apical end of the cell has elongated scales with spines that project forward while the posterior of the cell consists of a whorl of bristle-bearing scales (Cronberg & Hickel 1985).

In addition to the parallel orientation of the body scales, the siliceous armour of *M. retrorsa* has additional similarities to that of *M. akrokomos*. First, both taxa have a whorl of elongated apical scales with bristles, domeless body scales and caudal scales that are elongated into spines. Second, the transition from the body scales to the caudal scales is gradual; a distinct whorl of identical shaped scales is not found in the posterior region of the cell for either *M. retrorsa* or *M. akrokomos*. Lastly, the manner in which the scales are imbricated (overlapped) is similar. Despite the obvious similarities between *M. akrokomos* and *M. retrorsa*, differences in the structure and symmetry of the scales clearly serve to separate the two species. In addition, the backwards positioning of the scales on the cell is unique for *M. retrorsa*.

Evolutionarily, *M. retrorsa* is probably most closely related to M. *fenestrata*. These are the only species of *Mallomonas* with scales that are clearly asymmetric in structure and arranged with their longitudinal axes parallel to that of the cell. In addition, both species have a rather unique tuft of very short bristles that radiate from a whorl of elongated, domeless scales. In *M. retrorsa* the bristles are clearly tucked under the posterior end of the scale (i.e., the end of the scale with the rim).

M. retrorsa and *M. fenestrata* are easily separated at the species level by differences in the structure of the scales. Besides scale structure, the most obvious differences between the two species are the orientation of the scales and the polarity of the cell. However, if the bristle-bearing end of the cell in *M. fenestrata* was actually the flagellated end, then scale orientation and cell polarity would be identical to that of *M. retrorsa*. In the original description of *M. fenestrata*, Cronberg & Hickel (1985) do not make mention of the emergent flagellum. It must, therefore, be assumed that they chose the end of the cell with the spined scales to represent the apical

end. In all collections containing *M. retrorsa* live cells each with a single emergent flagellum similar to Fig. 3 were observed.

For most species of *Mallomonas* the apical portion of the cell consists of a whorl of scales that differ in shape from the body scales and surround the emerging flagellum (Takahashi 1978, Wee 1982, Asmund & Kristiansen 1986). In addition, spined scales are usually found on the posterior portion of the cell. Thus, if the anterior and posterior ends of *M. fenestrata* cells are truely represented by spine-scales and a whorl of bristle-bearing scales, respectively, it represents a rather unique situation in the genus.

Since flagella were not described, and, thus, assumed not observed, it is possible that Cronberg and Hickel reversed the apical and posterior ends of the cell in their original description of *M. fenestrata*. If Cronberg & Hickel (1985) did indeed mistake the cell polarity in *M. fenestrata* then it would differ from *M. retrorsa* only in scale structure.

Several species of *Mallomonas*, e.g., *M. insignis* Penard, can have posterior scales that are oriented backwards (Asmund & Kristiansen 1986). However, *M. retrorsa* represents the first species of *Mallomonas* where (1) the proximal portion of all the scales (i.e., that end with the rim) face the apical end of the cell and, as such, are orientated backwards, and (2) the bristles clearly emerge from the portion of the scale with the rim. In light of these unique features it is proposed that *M. retrorsa* be placed into its own section (in the sense of Asmund & Kristiansen 1986), sectio *Retrorsae*. In addition, if the cell polarity of *M. fenestrata* is found to be reversed it too should be placed into sect. *Retrorsae*. Because of similarities in the types and position of scales, the pattern of scale overlap, and the parallel arrangement of the scales, sect. *Retrorsae* is closely related to sect. *Akrokomae*.

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References

Asmund, B. & Kristiansen, J. 1986. The genus *Mallomonas* (Chrysophyceae). – Opera Bot. 85: 1–128.

Cronberg, G. & Hickel, B. 1985. Two new silica-scaled Chrysophyceae, *Mallomonas fenestrata* sp. nov. and *Mallomonas perforata* sp. nov. from tropical lakes. – Nord. J. Bot. 5: 105–110.

Crome, R. & Tyler, P. 1986. *Mallomonas sabulosa* (Chrysophyceae). A new species form Australia. – Br. phycol. J. 21: 93–96.

Gretz, M., Sommmerfeld, M. & Wujek, D. 1985. Light and electron microscopical observations of *Mallomonas portaeferreae* var. *reticulata* var. nov. (Chrysophyceae). – Phycologia 24: 478–481.

Takahashi, E. 1978. Electron microscopical studies of the Synuraceae. Taxonomy and ecology. – Tokai University Press, Tokyo.

Wee, J. L. 1982. Studies on the Synuraceae (Chrysophyceae) of Iowa. – Bibl. Phycol. 62: 1–183.