

The Scaled Chrysophyte Flora in Freshwater Ponds and Lakes from Newfoundland, Canada, and their Relationship to Environmental Variables

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Abstract – The distributions of scaled chrysophytes in 22 waterbodies from the eastern portion of Newfoundland, Canada, are described relative to environmental gradients. A rich and diverse flora of scaled chrysophytes was recorded that included 47 species from six genera, *Mallomonas* (n = 29), *Synura* (n = 7), *Neotessella* (n = 1), *Chrysosphaerella* (n = 2), *Spiniferomonas* (n = 7) and *Paraphysomonas* (n = 1). Combined with previous works, 57 species of scaled chrysophytes are now known from Newfoundland. On average, 15 species were recorded from each site, and 34 of the taxa were found in more than 10% of the sites. The most widely distributed species were *Mallomonas duerrschmidtiae*, *M. galeiformis*, *Synura echinulata*, *S. sphagnicola*, and *S. petersenii* sensu lato, each found in over 75% of the study sites. Seven additional species were found in over 50% of the localities indicating the rich diversity of the flora. One site is of particular significance as it represents the type locality for three species, including *Mallomonas newfoundlandicus* sp. nov. described in this communication, and represents the northern-most site harboring the marker taxon, *M. binocularis*. Expanded descriptions of *M. maculata* and *Spiniferomonas abei* are given, and evidence is presented that *Synura synuroidea* represents two distinct species. Overall, the flora reflects habitats that are acidic, dilute and contain moderate to high concentrations of humic substances. Since many of the species are diagnostic bioindicators, these organisms would provide a valuable resource for future paleolimnological studies aimed at understanding impacts from environmental stressors on Newfoundland lakes.

Acid lakes / Chrysophyceae / *Mallomonas newfoundlandicus* / Newfoundland / scaled chrysophytes / Synurophyceae

INTRODUCTION

Members of the Synurophyceae and Chrysophyceae bearing siliceous scales (hereafter referred to as the scaled chrysophytes), are unicellular or colonial planktonic flagellates composed of species-specific overlapping scales. Many species of scaled chrysophytes are restricted along various environmental gradients making them excellent bioindicators (Kristiansen, 1986; Siver, 1995), and since scales remain in sediments these organisms are useful in reconstructing historical conditions and tracking changes in lakewater conditions over time (e.g. Siver *et al.*, 1999; Arseneau *et al.*, 2016).

Newfoundland is a large island situated in the North Atlantic just to the south of Labrador that abounds with lakes, ponds and bogs. Given the sparse

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population of the island, many of these waterbodies experience little direct human influence. In a study of 15 localities situated in western and north-central Newfoundland, Wawrzyniak and Andersen (1985) recorded 32 scaled chrysophytes with a mean of seven taxa per sample. Interestingly, in another study of Newfoundland lakes, Kristiansen (2005) reported very few scaled chrysophytes in pristine and remote sites, but noted that these organisms were abundant in waterbodies that experienced even the slightest human influence. This observation supported the conclusion by Siver (1995) that ultra oligotrophic lakes often support only a few, if any, scaled chrysophytes.

A goal of our research program is to document and inventory siliceous algae, including scaled chrysophytes and diatoms, in freshwaters along the eastern coast of North America relative to physical and chemical attributes. To date, we have analyzed collections from over 300 waterbodies with scanning electron microscopy (SEM) (Siver & Lott, 2012). The primary purpose of this contribution is to expand our knowledge of scaled chrysophyte biodiversity relative to water chemistry in Newfoundland freshwaters. Twenty-two waterbodies located in the eastern portion of the island, and all to the east of those surveyed by Wawrzyniak and Andersen (1985), are included in the study. In addition, a new species, *Mallomonas newfoundlandicus* is described and new details of several rare species are discussed.

MATERIALS AND METHODS

Study Sites

Twenty-two sites on the Island of Newfoundland were included in the study (Table 1). Newfoundland is located in the North Atlantic Ocean, east of the Gulf of Saint Lawrence and south of Labrador. It extends between latitudes 46°36'N and 51°38'N, covers approximately 111,390 km², and forms the eastern-most portion of the Boreal Shield Ecozone (Canadian Geographic). The island is dominated by boreal forest trees, including balsam fir and spruce, and contains numerous lakes, ponds, shallow bogs and wetlands. The climate of Newfoundland is highly influenced by the ocean, yielding a somewhat mild winter and cool summer given its latitudinal position. Based on the GHCN Global Climate database published by EarthInfo Inc. (Huntington Beach, CA, U.S.A.), and using stations closest to the study sites, the mean minimum and maximum temperature for January were – 9.4°C and – 1.7°C, respectively. Likewise, the mean minimum and maximum temperature for July were 10.6°C and 20.8°C, reflecting cool summer conditions. The study sites were situated in three regions, on the Avalon Peninsula, along the east coast in Terra Nova National Park, and around Gander towards the northeastern end of the island. Maps, images, and attributes for all sites can be found at the web site, http://fmp.conncoll.edu/Silicasecchidisk/Newfoundland_Lakes_Frameset_New.html.

Field and Laboratory Methods

Plankton and surface sediment samples were collected from each study site during the summer of 2006. Plankton samples were made with a 10 µm mesh net from along shore and from the center of each waterbody. A sediment core was taken

Table 1. Physical and chemical data for 22 waterbodies from Newfoundland, Canada. Lakes are from three major regions: AV = Avalon Peninsula, TN = Terra Nova National Park, and NE = Northeast Newfoundland. Lakes names marked with an asterisk are not official names recognized by the Government

Name	Code	Region	Latitude	Longitude	pH Epi	SC µS	Color Pt-Co	TP µg L ⁻¹	TN µg L ⁻¹	Chl-a µg L ⁻¹	NA (meq L ⁻¹)	CA (meq L ⁻¹)	CL (meq L ⁻¹)	SO ₄ (meq L ⁻¹)
Burnt Point	BU	AV	N 47 23' 56"	W 53 10' 12"	6.04	34	21.3	13	376	0.64	0.136	0.098	0.184	0.037
Butter Pot	BP	AV	N 47 23' 41"	W 53 06' 19"	5.83	36	27.5	12	261	1.3	0.165	0.057	0.213	0.058
Charlie's	CA	AV	N 47 25' 03"	W 53 09' 12"	6.72	73	17.5	4	439	0.82	0.218	0.268	0.285	0.052
Cochrane	CO	AV	N 47 28' 24"	W 52 52' 20"	5.78	26	23.8	25	282	0.83	0.130	0.036	0.186	0.053
Deer Park	DP	AV	N 47 16' 42"	W 53 16' 17"	6.06	40	30	12	261	1.48	0.180	0.078	0.286	0.057
Goose	GO	AV	N 47 15' 46"	W 53 16' 39"	5.85	44	38.8	4	187	1.42	0.198	0.084	0.302	0.056
*Lily Pond Bog	LP	AV	N 47 14' 31"	W 53 18' 36"	5.75	107	150	25	524	1.87	0.972	0.030	0.707	0.056
*Orchid Bog	OR	AV	N 47 14' 46"	W 53 18' 18"	3.9	29	212.5	21	731	5.16	0.099	0.004	0.105	0.019
Paddy's	PA	AV	N 47 28' 18"	W 52 53' 00"	5.85	67	27.5	26	279	1.83	0.553	0.062	0.501	0.058
Grassy	GR	TN	N 48 29' 34"	W 54 04' 01"	5.9	33	72.5	13	300	0.89	0.131	0.085	0.161	0.032
Minchins	MI	TN	N 48 33' 33"	W 53 52' 55"	5.98	24	50	4	201	0.84	0.092	0.061	0.104	0.027
Ochre	OC	TN	N 48 30' 29"	W 53 57' 59"	5.18	16	100	14	609	0.54	0.072	0.032	0.080	0.018
Park Harbour	PK	TN	N 48 31' 36"	W 53 48' 32"	5.69	20	36.3	2	148	0.54	0.095	0.043	0.108	0.027
Pine Hill	PH	TN	N 48 36' 15"	W 53 58' 28"	6.49	275	23.8	15	335	0.85	1.932	0.282	2.087	0.133
*Pita	PI	TN	N 49 06' 30"	W 53 45' 37"	4.66	27	81.3	9	319	1.55	0.150	0.004	0.196	0.025
Round	RO	TN	N 48 57' 08"	W 53 57' 00"	5.16	68	65	10	317	2.08	0.453	0.046	0.488	0.037
*Screech	SC	TN	N 49 07' 21"	W 53 43' 60"	4.56	24	81.3	8	422	3.07	0.127	0.007	0.150	0.025
Trout	TR	TN	N 48 27' 09"	W 54 00' 50"	5.36	50	75	4	404	2.35	0.270	0.054	0.354	0.036
*Charger	CH	NE	N 49 09' 28"	W 55 03' 56"	6.26	57	62.5	9	389	1.12	0.241	0.152	0.360	0.030
*Harry's Bog	HB	NE	N 49 06' 43"	W 55 04' 46"	6.18	60	287.5	8	545	1.14	0.136	0.345	0.176	0.058
Otter	OT	NE	N 49 10' 10"	W 55 05' 27"	6.4	32	75	10	502	1.1	0.107	0.164	0.103	0.018
*Windy	WI	NE	N 49 06' 40"	W 55 04' 41"	6.03	25	75	15	400	1.5	0.086	0.128	0.095	0.024
Minimum					3.9	16	17.5	2	148	0.54	0.072	0.004	0.080	0.018
Maximum					6.72	275	287.5	26	731	5.16	1.932	0.345	2.087	0.133

from the deep point of each lake using a Glew gravity corer (Glew, 1988) and sectioned on site with a mechanical extruder (Glew, 1989). Water samples for chemical analysis were taken at a depth of 1 m from the center of each waterbody. Geographic coordinates were made with a Trimble Geoexplorer GPS unit.

Chemical analyses followed the procedures of Ahrens and Siver (2000) and Siver and Lott (2012), and are briefly summarized herein. The pH was measured on the same day of collection with a Fisher Accumet 640-A pH meter, and conductivity in the field with a Hydrolab DataSonde 4A. Alkalinity was measured using the Gran titration method (Wetzel & Likens, 1991) with Fisher reagent-grade 0.02N acid titrant. Chlorophyll-*a* was extracted in acetone and measured using the trichlorometric method (APHA, 1985). Total phosphorus was determined using the stannous chloride-ammonium molybdate colorimetric assay after a persulfate digestion (APHA, 1985). Total nitrogen samples were digested using the alkaline persulfate oxidation method (D'Elia *et al.*, 1977) and then analyzed using the N-(1-naphthyl)-ethylenediamine dihydrochloride method (U.S. EPA method 353.2, 1983). Sulfate and chloride were estimated with anion chromatography (U.S. EPA, 1983), and concentrations of sodium and calcium were measured using flame atomic absorption spectroscopy with a Perkin Elmer 2380 spectrophotometer. Water color was determined using the platinum-cobalt method as Pt-Co units (APHA, 1985), and used as a measure of colored dissolved organic matter (CDOM).

A few ml of each plankton sample were air dried directly onto heavy duty aluminum foil the day of collection. Approximately 0.5 g of surface sediment was oxidized with a sulfuric acid-potassium dichromate solution according to Marsicano and Siver (1993), and aliquots from the resulting slurry air dried onto both glass coverslips and aluminum foil. The aluminum foil samples containing live plankton, and those with surface sediment, were used to record and identify all scaled chrysophytes with scanning electron microscopy (SEM) according to the procedures of Siver (1987). Samples were secured onto an aluminum stub with Apiezon® wax, coated with a gold and palladium mixture for one minute with a Polaron model E5100 sputter coater, and observed with a Leo 982 SEM or a Leo 435V SEM. Glass coverslips containing oxidized surface sediment were mounted onto glass slides with Naphrax mounting medium and used to quantify the scaled chrysophyte taxa. A minimum of 300 scales were enumerated for each sample using the surface sediment glass slide preparations with light microscopy (LM) after the sample was first thoroughly examined with SEM. In this manner identifications were initially confirmed with SEM before enumeration with LM. Scales from *Paraphysomonas* and *Spiniferomonas* were not included in the counts, but their presence was confirmed with SEM.

RESULTS

Environmental Conditions of Study Sites

As a group, the study lakes were acidic, dilute, with low to moderate nutrient concentrations and moderate to high colored dissolved organic matter (CDOM). All of the study lakes had a pH below 7, the mean pH was 5.7, and 14 sites had pH below 6.0 (Table 1). The mean specific conductance for the suite of waterbodies was 53 $\mu\text{S cm}^{-1}$, and 15 of the sites were below this value. Removing

Pine Hill, which had a significantly higher level of specific conductance than all other sites, the mean value for the remaining lakes is $42 \mu\text{S cm}^{-1}$. Mean total phosphorus (TP) and total nitrogen (TN) concentrations were $12 \mu\text{g L}^{-1}$ and $374 \mu\text{g L}^{-1}$, respectively (Table 1). Eleven sites had TP levels below $10 \mu\text{g L}^{-1}$. Many of the sites had relatively high concentrations of humic substances, ranging from 17.5 – 288 Pt-Co units, with a mean of 74 Pt-Co units. Bog localities had the highest CDOM concentrations. The relatively low concentrations of nutrients, coupled with high CDOM levels, resulted in low levels of chlorophyll-*a*. The mean concentration of chlorophyll-*a* was only $1.5 \mu\text{g L}^{-1}$, and 18 sites were less than $2 \mu\text{g L}^{-1}$.

In eighteen of the sites, sodium was the dominant base cation, with concentrations ranging from $0.072 - 1.932 \text{ meq L}^{-1}$ and a mean of 0.297 meq L^{-1} (Table 1). Except for Lily Pond Bog (0.972 meq L^{-1}) and Pine Hill (1.932 meq L^{-1}), situated along a road and downhill from a highway, respectively, all other sites had sodium concentrations below 0.553 meq L^{-1} . Calcium levels exceeded sodium in only four waterbodies, Charlie's, Harry's Bog, Otter and Windy (Table 1). Chloride was the dominant anion in most sites, with a range of 0.08 (Öchre) – 2.087 (Pine Hill) meq L^{-1} and a mean concentration of 0.329 meq L^{-1} . Sulfate concentrations were low at all sites, ranging from $0.018 - 0.133 \text{ meq L}^{-1}$.

Scaled Chrysophyte Flora

A total of 47 scaled chrysophytes, representing six genera, were identified with SEM from the 22 study sites (Tables 2-3; Figs 1-54). These included 37 species from the synurophyte genera *Mallomonas* ($n = 29$), *Synura* ($n = 7$) and *Neotessella* ($n = 1$), and 10 taxa from the chrysophyte genera *Chrysosphaerella* ($n = 2$), *Spiniferomonas* ($n = 7$) and *Paraphysomonas* ($n = 1$). The number of species per site ranged from 7 (Pine Hill) to 24 (Butter Pot), with a mean of 15 (Table 3). Eighteen of the sites had 11 or more species, and in addition to Butter Pot, Deer Park, Goose and Pita each had 20 or more taxa. Twenty-three of the species were found in 25 percent of the sites, 11 in over 50% of the sites, and five taxa were present in over 75% of the sites.

The most abundant and widely distributed species included *Mallomonas duerrschmidtiae* (Figs 8-9), *M. galeiformis* (Fig. 11), *Synura echinulata* (Fig. 30), *S. petersenii* sensu lato (Fig. 32) and *S. sphagnicola* (Fig. 33), each present in $\frac{3}{4}$ or more of the study sites. In fact, *S. echinulata* was present in each site and accounted for more than 10% of the scales in 17 sites. We note that scales of *S. echinulata* can be difficult to separate from those of *S. mamilliosa*. In this study, scales identified as *S. echinulata* all had a series of straight or curved, and parallel, ribs on the anterior end. Likewise, *M. duerrschmidtiae* accounted for more than 20% of the scales in nine localities. Seven additional species, including *Chrysosphaerella longispina* (Fig. 25), *M. hamata* (Fig. 12), *M. punctifera* var. *brasiliensis* (Fig. 22), *Paraphysomonas vestita* (Fig. 24), *S. synuroidea* (Figs 28-29), *S. spinosa* and *Spiniferomonas trioralis* (Fig. 42) were recorded from 50% or more of the sites (Tables 2-3). Species from the genus *Spiniferomonas* were recorded in 16 of the 22 localities with highest diversities in Burnt Point, Butter Pot, Cochrane, Goose, Grassy and Paddy's.

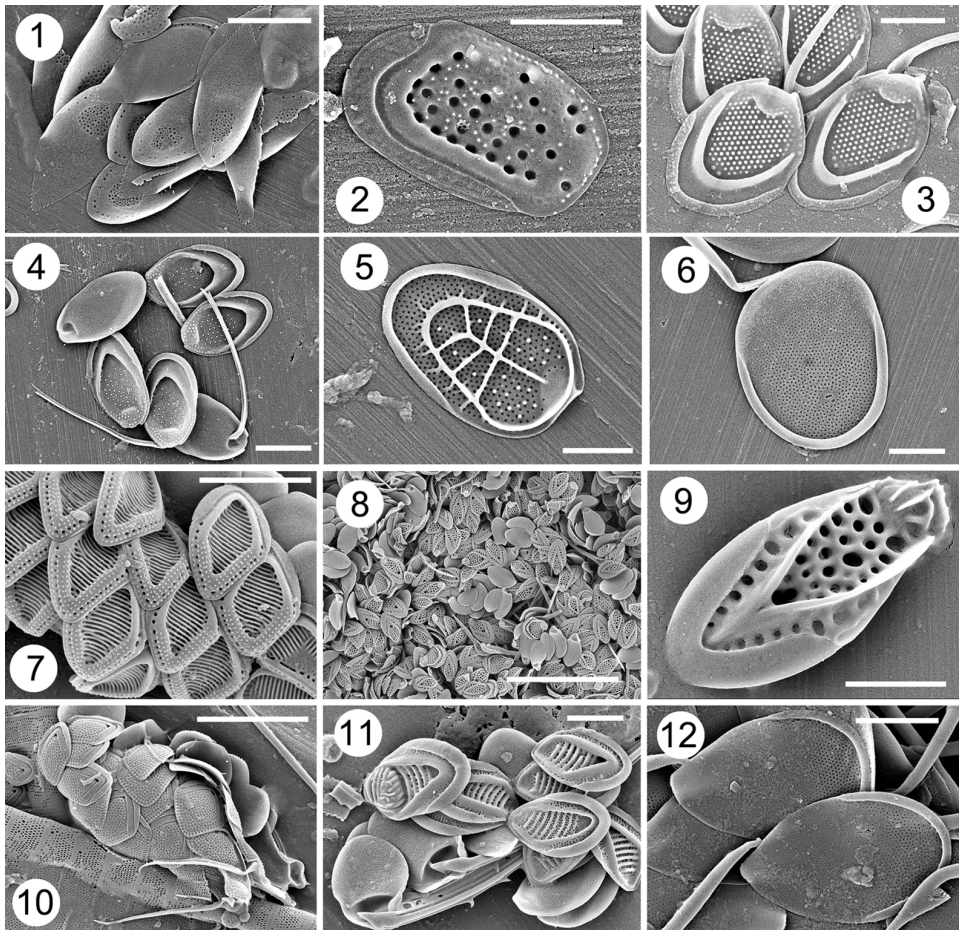
Several of the sites had extensive numbers of scales, but with low overall diversity due to dominance of one species. Especially high scale concentrations were found in Pine Hill samples, with over 90% belonging to *Mallomonas duerrschmidtiae*

Table 2. The number of occurrences and maximum relative abundances (%) for scaled chrysophyte taxa found in 22 Newfoundland waterbodies. An “X” indicates the taxon was observed with SEM, but not included in the counts

<i>Taxon Name</i>	<i>Number of occurrences</i>	<i>Maximum abundance (%)</i>
<i>Chrysosphaerella brevispina</i> Korshikov	2	0.9
<i>C. longispina</i> Lauterborn	14	8.0
<i>Mallomonas akrokomos</i> Ruttner in Pascher	7	7.2
<i>M. baskettei</i> Siver & Lott	1	21.1
<i>M. binocularis</i> Siver	1	4.7
<i>M. calceolus</i> Bradley	2	1.5
<i>M. canina</i> Kristiansen	4	1.9
<i>M. caudata</i> Ivanov	9	19.4
<i>M. crassisquama</i> (Asmund) Fott	4	2.0
<i>M. dickii</i> Nicholls	3	1.6
<i>M. duerschmidtiae</i> Siver, Hamer & Kling	19	91.4
<i>M. favosa</i> Nicholls	2	0.6
<i>M. galeiformis</i> Nicholls	17	26.0
<i>M. guttata</i> var. <i>simplex</i> Nicholls	1	1
<i>M. hamata</i> Asmund	14	11.8
<i>M. hindonii</i> Nicholls	1	0.2
<i>M. lelymene</i> Harris & Bradley	8	8.6
<i>M. lichenensis</i> Conrad	3	2.6
<i>M. maculata</i> Bradley	1	1.0
<i>M. matvienkoe</i> Asmund & Kristiansen	3	14.8
<i>M. multisetigera</i> (Matvienko) Asmund & Kristiansen	2	2.8
<i>M. muskokana</i> (Nicholls) Siver	9	15.5
<i>M. newfoundlandicus</i> Siver	1	1.0
<i>M. paludosa</i> Fott	6	18.8
<i>M. papillosa</i> Harris & Bradley	7	7.1
<i>M. pillula</i> Harris	3	0.5
<i>M. pseudocoronata</i> Prescott	4	7.4
<i>M. pugio</i> Bradley	4	5.9
<i>M. punctifera</i> var. <i>brasiliensis</i> Kristiansen & Menezes	13	9.7
<i>M. striata</i> Asmund	8	5.1
<i>M. torquata</i> Asmund & Cronberg	4	2.6
<i>Neotessella lapponica</i> (Skuja) Jo, Kim, Shin, Škaloud & Siver	6	35.4
<i>Paraphysomonas vestita</i> (Stokes) De Saedelee	14	X
<i>Synura echinulata</i> Korshikov	22	71.0
<i>S. kristiansenii</i> Siver & Lott	1	0.5
<i>S. petersenii</i> Korshikov	19	15.5
<i>S. sphagnicola</i> (Korshikov) Korshikov	17	33.3
<i>S. spinosa</i> Korshikov	15	18.4
<i>S. synuroidea</i> (Prowse) Pusztai, Certnerová, Škaloudová & Škaloud	14	8.3
<i>S. uvella</i> Stein em. Korshikov	10	17.6
<i>Spiniferomonas abei</i> Takahashi	1	X
<i>Sp. bilacunosa</i> Takahashi	9	X
<i>Sp. bourrellyi</i> Takahashi	4	X
<i>Sp. coronacircumspina</i> (Wujek & Kristiansen) Nicholls	6	X
<i>Sp. serrata</i> Nicholls	2	X
<i>Sp. takahashii</i> Nicholls	3	X
<i>Sp. trioralis</i> Takahashi	11	X

(Fig. 8). A similar situation was found in Trout Lake with over 70% of the scales assigned to *Synura echinulata*. The scale assemblages in Pita and Ochre contained over 33% *Neotessella lapponica* (Fig. 27) and *S. sphagnicola*, respectively.

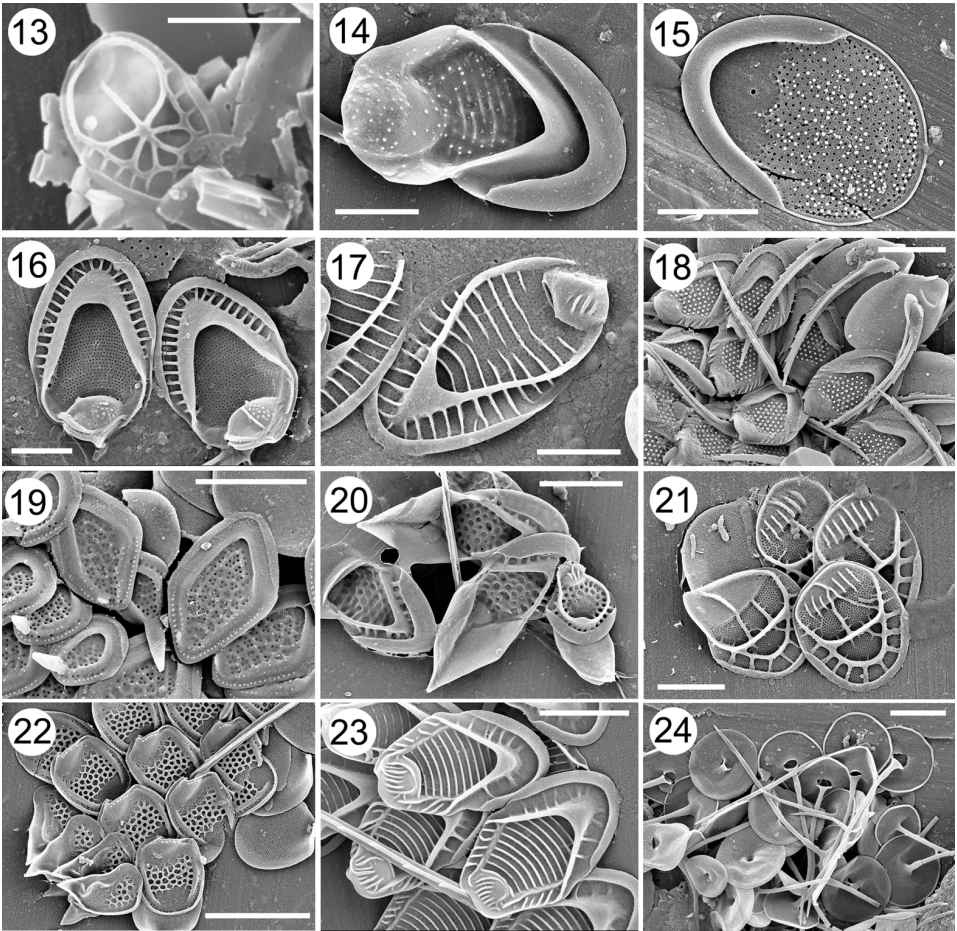
Eighteen of the 47 taxa were rare, found in three or fewer sites. Several species, including *M. matvienkoae* (Fig. 15), *M. pseudocoronata* (Fig. 20), and *Chrysosphaerella brevispina* (Fig. 26) were among the rare species in the Newfoundland lakes, each restricted to the more eutrophic sites or ones with higher pH or specific conductance.



Figs 1-12. Scaled chrysophytes from Newfoundland. 1. *Mallomonas akrokomos*. 2. *M. baskettei*. 3. *M. binocularis*. 4. *M. calceolus*. 5. *M. canina*. 6. *M. caudata*. 7. *M. dickii*. 8. *M. duerrschmidtiae*. 9. *M. duerrschmidtiae*. 10. *M. favosa*. 11. *M. galeiformis*. 12. *M. hamata*. Scale bars = 1 μm (3, 5), 2 μm (1-2, 4, 6-7, 9, 11-12), 5 μm (10) and 20 μm (8).

Table 3. Relative abundances of sealed chrysophytes in 22 waterbodies from Newfoundland. Site codes and region designations are given in Table 1. Organisms marked with an “X” were observed in samples from these localities, but not included in the counts

Site Code	BU	BP	CA	CO	DP	GO	LP	OR	PA	GR	MI	OC	PK	PH	PI	RO	SC	TR	CH	HB	OT	WI
Region	AV	AV	AV	AV	AV	AV	AV	AV	AV	TN	TN	TN	TN	TN	TN	TN	TN	TN	NE	NE	NE	NE
<i>Chrysosphaerella brevispina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.34	0	0	0	0	0	0.92	0
<i>C.longispina</i>	0	0.32	0	0	0.61	2.55	2.59	0.7	0	1.79	0.58	0	8	0	0.67	0.46	0	0	0.79	6.41	4.59	2.72
<i>Mallomonas akrokomos</i>	0.91	0	1.32	0	0	0	2.59	0	7.22	0	0	0	0	0	2.36	0	0	1.26	0	0.64	0	0
<i>M.baskettei</i>	0	0	0	0	0	0	0	21.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>M.binocularis</i>	0	0	0	0	0	0	0	4.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>M.calceolus</i>	0	0	0	0	0	1.53	0	0	0	0	0	0	0	0	0.34	0	0	0	0	0	0	0
<i>M.canina</i>	0	0	0	1.94	0	0	0	0	0.26	0	0	0	0	0	0.34	0	0.91	0	0	0	0	0
<i>M.caudata</i>	4.55	0	0	0	3.07	0	0	0	6.7	1.79	19.36	9.26	0	0	2.69	3.21	7.27	0	0	0	0	0
<i>M.crassisquama</i>	0	0	0	0	1.84	2.04	0	0	0	0	0	0	0	0	0	0	0	0.32	0	1.28	0	0
<i>M.dickii</i>	0	0.32	0	0	0	0	0	0	1.55	0	0	0	0	0	0.34	0	0	0	0	0	0	0
<i>M.duerrschmidtiae</i>	14.55	16.83	22.37	44.66	33.13	5.1	0	2.56	23.97	2.24	38.15	0	58	91.37	16.5	61.7	0	0.95	5.51	0.64	26.61	62.5
<i>M.favosa</i>	0	0	0	0	0.61	0	0	0	0	0.45	0	0	0	0	0	0	0	0	0	0	0	0
<i>M.galeiformis</i>	0	1.62	0	0.97	9.2	4.08	3.17	0	7.47	26.01	9.83	3.7	8	1.78	18.52	0.46	9.09	0.95	3.15	0	0	3.8
<i>M.guttata f.simplax</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>M.hamata</i>	0.91	0.32	0	6.8	4.29	0.51	0	0	3.35	0	3.47	0	0	0.51	4.38	2.29	11.82	0.63	0	1.92	0	2.72
<i>M.hindonii</i>	0	0	0	0	0	0	0	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>M.lelymene</i>	0	0.65	0	0	8.59	1.02	2.02	0	0	0	1.45	0	0	0	1.35	2.29	3.64	0	0	0	0	0
<i>M.lychenensis</i>	0.91	0	0	0	0	2.55	0	0	0	0	0	0	0	0	1.01	0	0	0	0	0	0	0
<i>M.maculata</i>	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>M.marvienkoe</i>	0	0	0	0	0	0	0	0	0	14.8	0	0	0	0	0	0	0	0.32	4.72	0	0	0
<i>M.multisetigera</i>	0	0	0	0	1.84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.75	0
<i>M.muskokana</i>	3.64	0	0	0	0	4.08	0	0	2.84	2.24	0	5.56	9	0	5.72	0	15.45	1.58	0	0	0	0

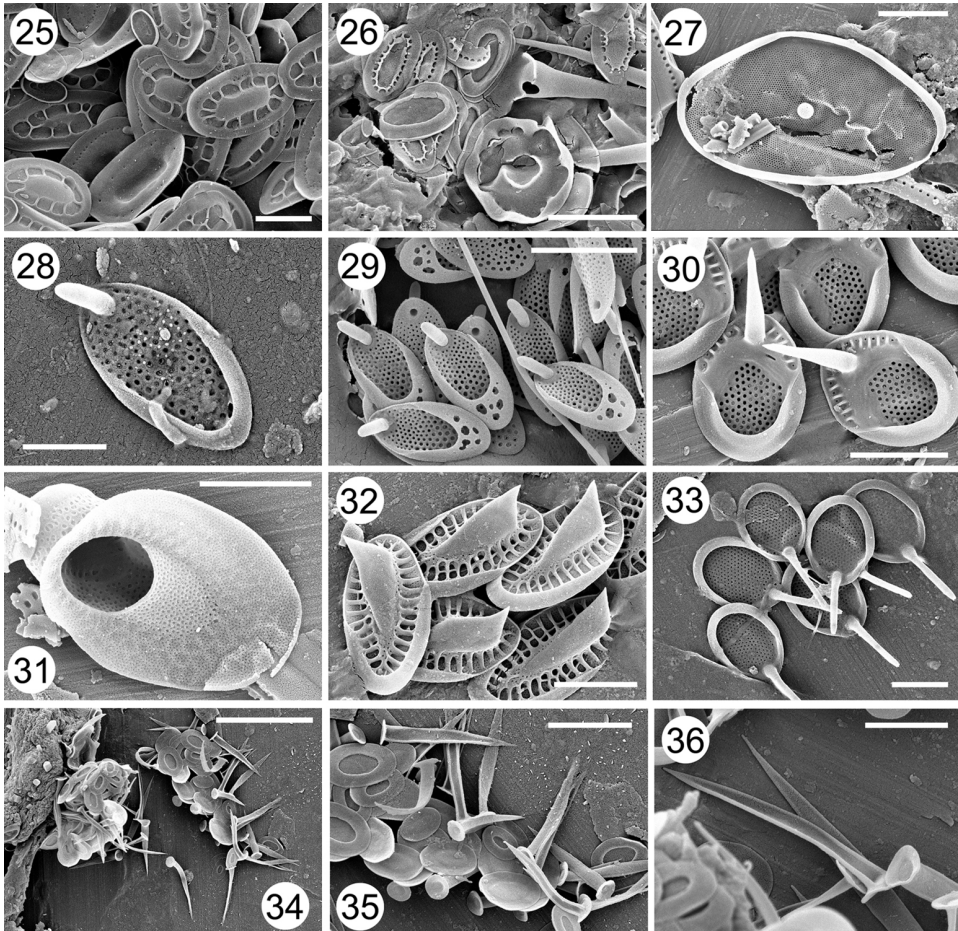


Figs 13-24. Scaled chrysophytes from Newfoundland. 13. *Mallomonas hindonii*. 14. *M. lelymene*. 15. *M. matvienkoae*. 16. *M. muskokana*. 17. *M. paludosa*. 18. *M. papillosa*. 19. *M. pillula*. 20. *M. pseudocoronata*. 21. *M. pugio*. 22. *M. punctifera* var. *brasiliensis*. 23. *M. striata*. 24. *Paraphysomonas vestita*. Scale bars = 2 μ m (13-19, 21, 23-24) and 5 μ m (20, 22).

Comments on Other Taxa and New Species

Mallomonas baskettei was originally published as “*Mallomonas basketii*.” According to Article 60.12 (in association with Rec 60C.1) of the ICN the correct spelling of this species should be *Mallomonas baskettei*.

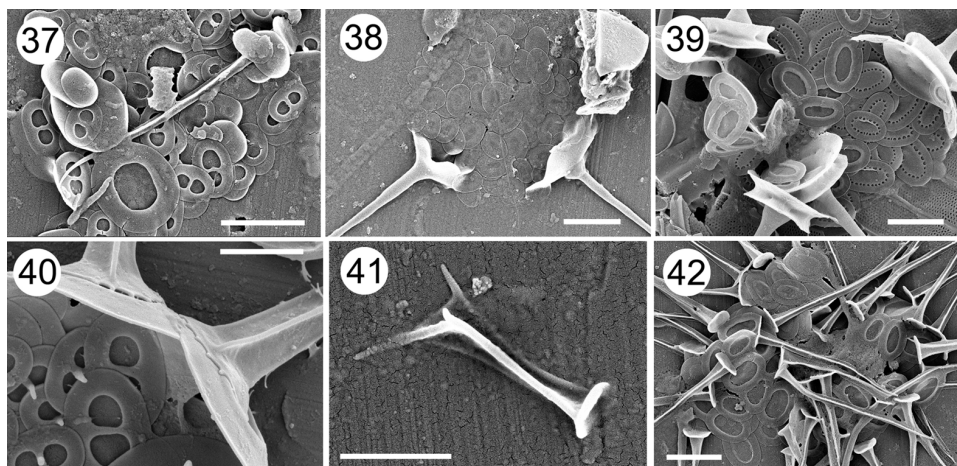
Five rare species were only recorded from Orchid Bog. Two of the species, *Mallomonas baskettei* (Fig. 2) and *Synura kristiansenii* (Fig. 31), were recently described from this site (Siver & Lott, 2016), and are only known from this locality. *Mallomonas baskettei* has highly asymmetric body and apical scales, caudal scales with very long spines, and belongs in section *Retrorsae*. *Synura kristiansenii*, a taxon in section *Petersenianae*, has scales with a large and variable-shaped median



Figs 25-36. Scaled chrysophytes from Newfoundland. **25.** *Chrysosphaerella longispina*. **26.** *C. brevispina*. **27.** *Neotessella lapponica*. **28.** *Synura synuroidea* (form without holes in the posterior rim). **29.** *Synura synuroidea* (form with holes in the posterior rim). **30.** *S. echinulata*. **31.** *S. kristiansenii*. **32.** *S. petersenii* sensu lato. **33.** *S. sphagnicola*. **34-36.** *Spiniferomonas abei*. Scale bars = 1 µm (29, 36), 2 µm (25-28, 30-33, 35) and 5 µm (34).

keel, and an exceptionally large foramen pore on the base plate. Two other rare species found only at this locality included *Mallomonas binocularis* (Fig. 3) and *M. maculata* (Figs 43-48). The fifth taxon represents a new species, *M. newfoundlandicus*, described below.

Four new characteristics of *Mallomonas maculata* based on our SEM observations are noteworthy and enhance the description of this species (Figs 43-48). First, base plate pores are of two types. A series of 4-6 rows of pores with wider diameters align the anterior perimeter of the scales between the ends of the posterior rim (Fig. 46, double arrows). The remainder of the base plate is covered with distinctively smaller pores (Fig. 46, single arrow). Second, small papillae are scattered over the scale surface. Third, bristles are smooth, slightly curved, with a



Figs 37-42. Scaled chrysophytes from Newfoundland. 37. *Spiniferomonas bilacunosa*. 38. *S. bourrellyi*. 39. *S. coronacircumspina*. 40. *S. serrata*. 41. *S. takahashi*. 42. *S. trioralis*. Scale bars = 1 µm (40-41) and 2 µm (37-39, 42).

groove along the shaft and an elongate foot (Figs. 44, 48). Fourth, bristles are distributed on both ends of the cell (Fig. 43).

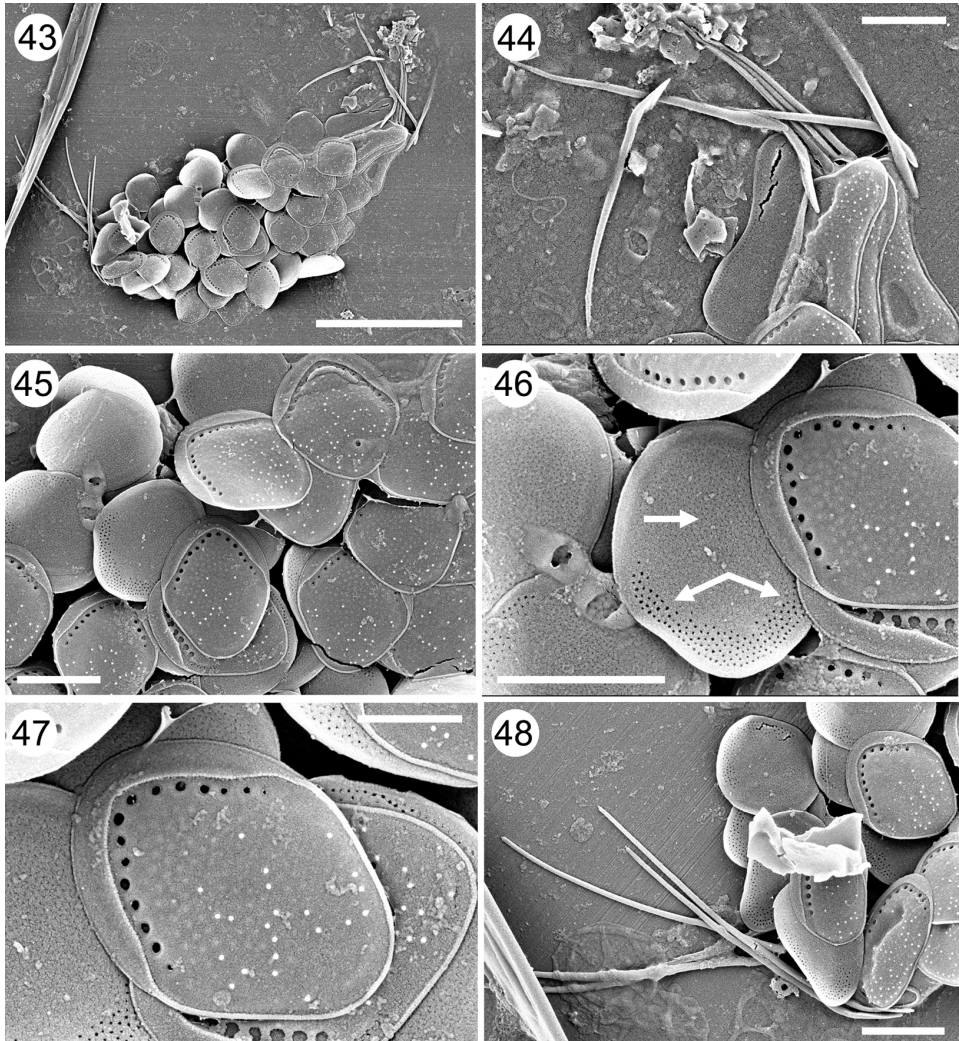
Populations of *Synura synuroides* expressed one of two different types of scales (Figs 28-29). Some populations had scales with large base plate pores on the proximal end, becoming smaller towards the distal end, a very wide posterior rim with a series of large holes of varying size, and lacked surface papillae (Fig. 29). Other populations had scales of similar size and spine type, but with large and reinforced base plate pores, a shallow posterior rim lacking holes, and surface papillae (Fig. 28). Scales with the wide posterior rim were common in the plankton samples and often found in large piles reflecting the presence of active populations, whereas those with the smaller posterior rims were more abundant as single specimens in the surface sediment samples.

The population of the rare taxon, *Spiniferomonas abei*, uncovered in Lily Pond Bog allows for a more complete description of the spine scales (Figs 34-36). The base plate of the spine scales is circular, much smaller than the elliptical scales with a central lacuna, and with a mean diameter of 0.55 µm. As noted by Takahashi (1973; 1978), the spine shaft is broad and flat on one side with clearly thickened margins (e.g. Fig. 255, Takahashi, 1978). What is clear in our material is that the proximal portion of the shaft is broadly U-shaped in cross section, and the margins of the shaft remain parallel for approximately two-thirds the length of the spine maintaining a similar width before tapering to a sharp point (Figs 35-36).

Mallomonas newfoundlandicus P.A.Siver sp. nov.

Figs 49-54

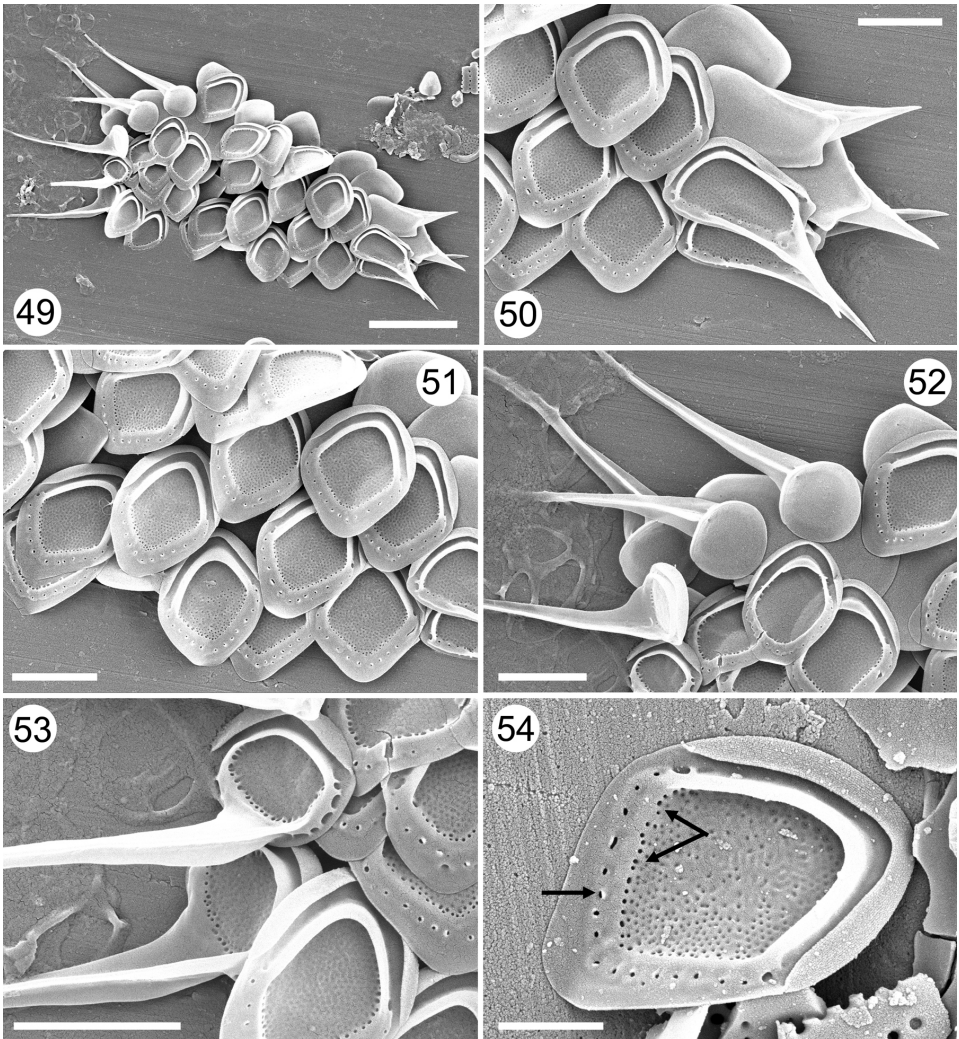
Description: Cell are ellipsoidal, 23-31 × 6-8 µm (n = 6; includes projecting spines), and with scales arranged in spiral rows where each scale is overlapped by the scale positioned behind it in the same row, and by scales in the row above it (Fig. 49). Cells with three types of scales, collar scales with forward projecting



Figs 43-48. *Mallomonas maculata*. **43.** Remains of a whole cell showing bristles on both ends of the cell. **44.** Close-up of the anterior end of the cell denoting the structure of the collar scales and bristles. Note the sunken region on the collar scales. **45.** Body scales. Note the scattered papillae on the scale surface and the ring of pores lining the posterior rim. **46.** Undersurface of a body scale showing the larger base plate pores aligning the distal end of the scale (double arrows) and the smaller pores covering the middle portion of the scale (single arrow). **47.** Body scale. **48.** Posterior end of the cell denoting bristles. Note the sunken pits and asymmetric nature of the caudal scales that possess the bristles. Scale bars = 1 μm (47), 2 μm (44-46, 48) and 10 μm (43).

spines, body scales, and posterior scales with long spines (Figs 50-54). Collar scales and body scales are aligned with their longitudinal axes parallel and perpendicular, respectively, with the longitudinal axis of the cell (Fig. 50). Body scales range in size from $3\text{-}3.6 \times 2.2\text{-}2.7 \mu\text{m}$ ($n = 15$), are slightly rhombic in outline, possess a well-defined V-rib, posterior upturned rim, and anterior submarginal ribs. Body

scales lack domes and any extensive secondary structures on the shield. The shield is covered with evenly-spaced base plate pores that continue up onto the interior margin of the anterior submarginal ribs (Fig. 54, double arrows). A small reticulation of ribs may be present on some scales in the center of the shield. A single row of pores sits atop of the anterior submarginal ribs (Fig. 54, single arrow). The pores in



Figs 49-54. *Mallomonas newfoundlandicus*. **49.** Whole cell depicting collar scales with forward projecting spines, body scales, and posterior scales with long spines. This specimen is from the type. **50.** Close-up of collar scales surrounding the flagellar pore. **51.** Group of body scales. Note the slightly rhombic outline, V-rib, posterior upturned rim, and anterior submarginal ribs. **52.** Posterior scales with spines. Note the circular outline of the scales and the three-ribbed nature of the spines. **53.** Close-up of the posterior spine-bearing scales. **54.** Body scale depicting the base plate pores that continue up onto the anterior submarginal ribs (double arrow), and the single row of pores, each with a partially thickened rim, on the anterior submarginal ribs (single arrow). Scale bars = 1 μm (54), 2 μm (50-53) and 5 μm (49).

this row are widely spaced, of uneven diameters, and each is lined with a partially thickened rim. Other than the row of pores, the anterior submarginal ribs are unornamented. The V-rib is positioned close to the posterior rim forming a small posterior flange, has a shallow hood, and arms that extend to the mid-section of the scale where they connect to the anterior submarginal ribs. The posterior rim encircles approximately $\frac{1}{2}$ the scale perimeter. The posterior flange is lacking of base plate pores or any secondary structures. Collar scales, which form a ring around the flagellar pore, are 5.3-5.7 μm long (including the spine), asymmetric with a broadly rounded proximal end tapering slightly towards the distal end (Fig. 50). The posterior rim and V-rib are also asymmetric extending the length of the dorsal margin, but not along the ventral margin. The arms of the V-rib on the collar scales connect with the anterior submarginal ribs, which extend to form the forward projecting spine (Fig. 50). The spines on the collar scales are long, range in length from 2.4-2.7 μm , and project out from the cell at an angle of approximately 30° . The posterior scales are small, circular in outline, range in diameter from 1.8-2.1 μm , and with anterior submarginal ribs that extend into a long three-ribbed spine that ranges in length from 5.0-7.1 μm (Figs 52-53). The base of the spine is triangular-shaped and it tapers to a sharp point. Bristles and cysts are unknown.

Holotype Specimen: Portion of a single gathering of cells on SEM stub deposited at the Canadian Museum of Nature, CANA (# 126425). Material is from a phytoplankton sample collected by P.A. Siver on June 16, 2006. Figure 49 is a representative whole cell from the specimen.

Type locality: A small bog, unofficially referred to as Orchid Bog Pond, situated at N 47° 14' 46.1", W 53° 18' 18.2" in Newfoundland, Canada. The pond is located on the north side of Route 90, 13.5 km SW of the junction with Hwy 1.

Epithet: *Mallomonas newfoundlandicus* is named after the Island, Newfoundland.

DISCUSSION

Although scaled chrysophytes can be found over a wide range of environmental conditions, the most diverse floras are usually observed in waterbodies that are slightly acidic, low in dissolved salts, oligotrophic to mesotrophic, and with moderate amounts of dissolved humic matter (Eloranta, 1995; Siver, 1995; Kristiansen, 2005). The importance of these variables in shaping scaled chrysophyte floras was supported by findings from an extensive study of 264 waterbodies from nine regions along the east coast of North America (Siver & Lott, 2012). In that study, pH, the minimum mean July temperature, water clarity and color, specific conductance, and total nitrogen were all found to be important variables determining the structure of scaled chrysophyte floras. Given these generalizations, especially since the study lakes were acidic and dilute, with high humic content and low in nutrient content, it is not surprising that the Newfoundland waterbodies harbored a rich and diverse scaled chrysophyte flora.

Numerous species known to be narrowly distributed over environmental gradients and therefore excellent bioindicators for pH, specific conductance, trophic condition and temperature are abundant in the Newfoundland sites. As a whole, the study lakes were slightly to highly acidic, and all had pH values below 7. Thus, it is not unexpected that many of the most abundant species uncovered in the lakes are known acidophilic or acidobiontic forms. Siver and Smol (1993) identified and

classified many scaled chrysophyte species into four categories along a pH gradient: (1) low-pH; (2) mid-pH; (3) pH-indifferent and; (4) high-pH. These groupings were reviewed and updated by Siver (2015). The most acidic group, the low-pH group, included nine species typically found below pH 6 and with average weighted mean pH (AWMpH) values less than 6. All nine of the species included in this category, *Mallomonas canina*, *M. hindonii*, *M. paludosa*, *M. pugio*, *M. hamata*, *M. muskokana*, *Synura sphagnicola*, *S. echinulata* and *S. synuroidea*, were present in the study lakes reflecting the current acidic nature of the sites. The preferences of *S. sphagnicola* and *S. echinulata* for acidic conditions were also confirmed by Němcová *et al.* (2008). The mid-pH group includes species typically growing between pH 5 and 7 that are best classified as acidophilic (Hustedt, 1932). Species in the mid-pH group that are common and often abundant in Newfoundland include *M. galeiformis*, *M. duerrschmidtiae*, *M. punctifera* var. *brasiliensis*, *M. dickii*, *M. torquata* and *S. spinosa*. On the other hand, only one of the many species in the high-pH group, *M. pseudocoronata*, was recorded from the study lakes.

Likewise, many of the species found in Newfoundland waters have been reported from localities low in specific conductance (Siver & Hamer, 1989; Siver, 1995; Němcová *et al.*, 2003) and low in nutrients (Siver & Marsicano, 1996). Siver and Hamer (1989) reported the maximum number of species per site from waterbodies with specific conductance close to or below $40 \mu\text{S cm}^{-1}$, and that this number dropped significantly as values climbed above $200 \mu\text{S cm}^{-1}$. Němcová *et al.* (2003) also found the highest diversity in dilute waters. Since 15 of the study sites had specific conductance values less than $50 \mu\text{S cm}^{-1}$, the high numbers of species is not surprising. Similarly, nine of the ten taxa reviewed by Siver (2015) as being diagnostic for oligotrophic to mesotrophic conditions were present, and often abundant, in Newfoundland sites. In contrast, none of the species known to thrive in eutrophic or highly eutrophic conditions were uncovered in the study lakes, except for *Mallomonas matvienkoeae*, present in three lakes.

Two species, *Synura sphagnicola* and *S. synuroidea*, known to grow during the warmer summer months (Dürschmidt & Croome, 1985; Siver & Hamer, 1992; Kristiansen, 2005) were found in 77% and 64% of the sites, respectively. In contrast, four species considered cold water forms, *Chrysosphaerella longispina* (Němcová, 2010), *Neotessella lapponica* (Siver & Hamer, 1992; Němcová, 2010; Pichtová *et al.*, 2011), *S. echinulata* (Asmund, 1968; Siver & Hamer, 1992) and *S. spinosa* (Kristiansen, 1975; Roijackers & Kessels, 1986), were also common components of the scaled chrysophyte flora. It is possible that shifts in these organisms over time could be used to examine impacts of climate warming.

Combining our findings with those of Wawrzyniak and Andersen (1985), there are now 57 scaled chrysophytes reported from Newfoundland freshwaters. Sites in our study representing the eastern portion of the island had, on average, over twice the number of species per site ($n = 15$) compared with the more western sites ($n = 7$) investigated by Wawrzyniak and Andersen (1985). A few additional comments regarding taxonomic issues are noteworthy. Reports of *M. trummensis* by Wawrzyniak and Andersen (1985) most likely represent the abundant and widespread species, *M. galeiformis*. This latter taxon, widely distributed in the northeastern part of North America and bearing similarities with *M. trummensis*, had not yet been described at the time of the Wawrzyniak and Andersen (1985) study. Second, since *M. duerrschmidtiae* was also described after Wawrzyniak and Andersen (1985), records of this species were most likely reported by these authors as *M. crassisquama* or possibly *M. pseudocoronata*. Third, *M. elliptica* reported by Wawrzyniak and Andersen (1985) has since been combined with *M. matvienkoeae*. Lastly, although

we believe the records of *M. matvienkoae* reported in this study best fit this taxon, care must be exercised to distinguish it from the closely related species, *M. pseudomatvienkoae* Jo, Shin, Kin, Siver & Andersen, recently described by Jo *et al.* (2013). Our specimens fit the scale illustrated by Kristiansen (2002, Fig. 7C) for *M. matvienkoae*, which was also collected from Newfoundland, however, the scale represented in Fig. 7D (Kristiansen, 2002) may represent a different species. Scales of *M. pseudomatvienkoae* differ from those of *M. matvienkoae* in that the base plate pores are restricted to the distal end of the scale and lacking in the proximal portion of the scale. Thus, given the species diversity now evident in the *M. matvienkoae* complex, care needs to be exercised in order to distinguish between species.

The diversity of scaled chrysophytes in Newfoundland waters is comparable to those reported from other regions along the east coast of North America, and the compliment of species most similar to ones from Nova Scotia and coastal Maine (Siver & Lott, 2012). The similarities between Newfoundland, Nova Scotia and coastal Maine make sense since lakes in these regions were most closely clustered based on a suite of 14 physical and chemical characteristics (Siver & Lott, 2012). Several findings from the Siver and Lott (2012) study are of further interest to this study. First, 90 scaled chrysophyte species (including 15 belonging to *Spiniferomonas* and *Paraphysomonas*) were documented from all nine regions along coastal North America. Fifty-two percent of these taxa were found in our study of Newfoundland, and 63% when also including the Wawrzyniak and Andersen (1985) study. Many of the 90 species not present in Newfoundland were largely restricted to more southern and non-glaciated regions of the continent. Second, four of the five most abundant scaled chrysophytes in the Siver and Lott (2012) survey of lakes along the east coast of North America, *Synura echinulata*, *Mallomonas duerrschmidtiae*, *S. petersenii* sensu lato and *S. sphagnicola*, were also among the top five in Newfoundland waters.

Although the Newfoundland flora was found to be most similar to that from Nova Scotia, significantly fewer taxa were reported in a study by Ginn *et al.* (2010) of Nova Scotia lakes compared to the Siver and Lott (2012) study. Ginn *et al.* (2010) recorded 25 taxa from 52 lakes, considerably fewer than reported by Siver and Lott (2012) for Nova Scotia and in this study for Newfoundland. This is even more surprising since the Ginn *et al.* (2010) study included more lakes. There are a number of possible reasons for this discrepancy. First, since the Ginn *et al.* (2010) survey was based only on light microscopy it would not be possible to identify all of the taxa. Indeed, Ginn *et al.* (2010) lumped some scales into a category referred to as "*Mallomonas* sp. small" which likely included multiple species. For example, this category probably included *Mallomonas galeiformis*, one of the most abundant species in both Newfoundland and Nova Scotia. Second, although water chemistry is similar in many respects, the mean alkalinity and calcium concentrations were lower for Nova Scotia sites which could impact the number of species found. For example, many of the waterbodies included in the Ginn *et al.* (2010) study from Cape Breton Island had negative alkalinity and lacked *Synura* species altogether. Lakes from Cape Breton Island were not included in the Siver and Lott (2012) study which could account for some of the differences observed.

A few additional comments are noteworthy regarding the Ginn *et al.* (2010) study. First, as was the case for Newfoundland lakes, *M. duerrschmidtiae* was also the dominant taxon in Nova Scotia sites where it was present in 43 lakes with a mean relative abundance of 53%. Second, as was also the situation for Newfoundland lakes, *Synura echinulata* was the most common species from the genus *Synura* in Nova Scotia habitats. Third, Ginn *et al.* (2010) reported *S. petersenii* as rare in Nova

Scotia, found in only three sites. Given that this taxon was observed in 86% of the Newfoundland sites, and is typically one of the most common taxa reported throughout North America (Siver, 2015), its paucity in Nova Scotia lakes warrants further investigation. Fourth, Ginn *et al.* (2010) reported the second most abundant species as *M. acaroides*, found in 25 Nova Scotia lakes with a mean abundance of 16%. In contrast, *M. acaroides* was not reported from either Nova Scotia, coastal Maine (Siver & Lott, 2012) or Newfoundland (this study). Ginn *et al.* (2010) did note that their records for *M. acaroides* could include both the type and a variety, *M. acaroides* var. *muskokana*. They further state that these two taxa are “difficult to separate with a light microscope,” citing Kristiansen (2002). However, Kristiansen (2002) did not include records based on light microscopy for *M. acaroides* in his monograph on *Mallomonas* because he deemed them “unreliable.” Based on a suite of characters, *Mallomonas acaroides* var. *muskokana* was elevated to the rank of species, *M. muskokana* (Nicholls) Siver (Siver *et al.*, 2009). In addition, since *M. acaroides* and *M. muskokana* are found under very different environmental conditions (Siver, 1989), both are independently valuable bioindicators. Reporting both species under the name “*M. acaroides*” limits their usefulness in paleolimnological and biogeographical studies, especially since both species are rarely, if ever, found in the same samples, and yields invalid environmental information that could be used by other researchers.

The most unique site in terms of its scaled chrysophyte flora was Orchid Bog, a small highly acidic (pH = 3.9), dilute, and highly colored bog pond. Orchid Bog is the type locality for three new scaled chrysophytes, including *Synura kristiansenii*, *Mallomonas baskettei* (Siver & Lott, 2016) and *M. newfoundlandicus* (this paper). It is also the only site where *M. binocularis* and *M. maculata* were found. Orchid Bog remains the only known locality for *S. kristiansenii*. Interestingly, another species that is closely related to *M. baskettei*, *M. fimbriata* Gusev was recently described from a dilute, acidic bog in Vietnam (Gusev, 2015). These two species, both belonging to the section *Retrorsae*, are clearly related and may actually best represent two varieties. Nonetheless, since the primary feature used to describe *M. fimbriata*, the lobate-shaped structures separated by distinct pits found along the scale margin, is lacking on *M. baskettei* scales, it is our conclusion that until additional populations can be examined that these two taxa should remain separate species. Regardless, it is intriguing that although the environmental conditions of the two type localities are very similar, they are geographically widely separated.

Except for the presence in Orchid Bog in Newfoundland, *Mallomonas binocularis* is only known from non-glaciated sites along the Atlantic Coastal Plain, including ones in Florida, North Carolina and southern New Jersey (Siver, 2002, Lott & Siver, 2005; Siver & Lott, 2006; 2010). In fact, since this is a useful organism for distinguishing between glaciated and non-glaciated sites (Siver & Lott, 2012), its presence in Newfoundland was unexpected. Along the Atlantic Coastal Plain, *M. binocularis* has previously been reported from 11 sites low in alkalinity (-92 to $42 \mu\text{eq L}^{-1}$), acidic (pH ranging from 4.1 to 5.3), and dilute (32 to $130 \mu\text{S cm}^{-1}$). In addition, the sites are small, shallow waterbodies, and high in CDOM, with 11 sites above 37 Pt-Co units. Thus, *M. binocularis* is best classified as an acidobiontic species largely restricted to shallow sites with high levels of CDOM.

The presence of *M. maculata* in Newfoundland is not surprising since it was originally described from northern Iceland (Bradley, 1964), found in Russia (Kristiansen & Preisig, 2007), and previously reported from Newfoundland by Wawrzyniak and Andersen (1985). What is interesting is the fact that other than these reports from cold north temperate localities and a few additional reports from Europe (Němcová, 2010), it is also known from the Southern Hemisphere in New

Zealand (Asmund & Kristiansen, 1986), yielding a potential bipolar distribution. Our findings for *M. maculata* also provide new details of scale and cell structure that are valuable in understanding the evolutionary history of the genus. In addition to noting the distinct pattern of base plate pores and the presence of surface papillae, the fact that the cell has bristles restricted to both ends and that the bristles are of the rolled type suggest that *M. maculata* may be closely aligned with *Mallomonas splendens* and *M. pseudobronchartiana* Gusev, Siver & Shin (Gusev *et al.*, 2017). Based on a detailed molecular phylogeny, Siver *et al.* (2015) found that *M. splendens* and *M. pseudobronchartiana* (as *Mallomonas* sp.1), other species with bristles restricted to the ends of the cell, formed a clade that likely represented a second and independent evolution of the rolled type of bristle. The overall structure of *M. maculata* scales, coupled with the presence of rolled bristles on both ends of the cell, suggests it also aligns with these two species. Future molecular work will be helpful to confirm this hypothesis.

The combination of characters for *Mallomonas newfoundlandicus* is unique and warrants description of this organism as a new species. Given the presence of collar scales and overall structure of the cell, this species belongs in section *Torquatae*. There are several species in this section, including *Mallomonas clavus* Bradley, *M. eoa* Takahashi and *M. doignonii* Bourrelly em. Asmund & Cronberg, that also possess long spines on the posterior scales similar to cells of *M. newfoundlandicus*. However, in each case the structure of the body scales is very different, and none have collar scales with extended spines similar to those on *M. newfoundlandicus*. In addition, the shield on scales of *M. newfoundlandicus* is simple and lacking any extensive secondary layers. In contrast, the shields of the other three species have distinct secondary designs consisting of a series of roughly circular meshes (*M. clavus* and *M. eoa*) or transverse ribs (*M. doignonii*).

Although the characteristics of *Mallomonas newfoundlandicus* indicate placement in section *Torquatae*, this taxon also has similarities with *M. insignis* that are worth noting. We were not able to find any specimens of *M. newfoundlandicus* with bristles and it is unknown if these structures are present or not. Although we suspect the collar scales have bristles, if they do not this means *M. newfoundlandicus* is one of only a few species in the genus, including *M. insignis*, known to lack these siliceous structures. In addition, as is found on *M. newfoundlandicus*, cells of *M. insignis* have spines projecting from both ends of the cell.

The genus *Chrysodidymus* was formally described by Prowse (1962), in part, based on the presence of distinctive two-celled colonies. Prowse (1962) further described two species, *C. synuroideus* Prowse and *C. gracilis* Prowse, on the basis of cell and colony shape and size. As noted by Pusztai *et al.* (2016), Prowse did not illustrate the siliceous scales and details of these structures for each species remain unknown. Because Wujek and Wee (1983) observed a high degree of phenotypic plasticity within individual colonies of *Chrysodidymus* that encompassed both species descriptions made by Prowse (1962), they synonymized both species to *C. synuroideus*, and observations of *Chrysodidymus* have been reported under this epithet ever since. More recently, *Chrysodidymus synuroideus* was transferred to *Synura synuroidea* since it was found to be deeply nested within the *Synura* clade based on molecular evidence, and most closely related to *S. sphagnicola* (Pusztai *et al.*, 2016). The cultures used in the Pusztai *et al.* (2016) work had cells with scales equivalent to those reported in our study with wide posterior rims, holes on the rim, and progressively smaller base plate pores moving from the proximal to distal ends of the scale. It is most likely that organisms possessing the other scale type noted in our study (Fig. 28) represents a separate species. We have observed

two-celled colonies with this scale type in other localities along the eastern seaboard of North America (Siver & Lott, 2012), and they have also been reported from Asia (Gusev, personal communication). Work is underway to fully characterize both taxa. Perhaps Prowse (1962) was correct when he described two distinct species.

We suspect that our records of *Synura petersenii* sensu lato may represent multiple species. Molecular phylogenetic works, first by Wee *et al.* (2001) and later by Kynčlová *et al.* (2010) and Boo *et al.* (2010), have revealed ever increasing levels of cryptic diversity within the *S. petersenii* complex. More recently, Škaloud *et al.* (2012; 2014) and Jo *et al.* (2016) have described many of these cryptic taxa as new species. Based on images taken when we originally worked on the samples, we believe that *Synura truttiae* was also present in several waterbodies in addition to *S. petersenii*. However, further study and verification would be needed before making this conclusion. Nonetheless, future analyses of this cryptic species complex, as well as others, will only enhance our understanding of scaled chrysophyte diversity.

Sixteen species of *Spiniferomonas* have been reported from North America (Nicholls, 1981; 1984a; 1984b; Siver, 1987; 1988a; 1988b). The genus has been found to be particularly common and widespread in Ontario and Connecticut lakes where 13 (Nicholls, 1981; 1984a; 1984b) and 14 (Siver, 1987; 1988a; 1988b) species have been reported. *Spiniferomonas* was less common and with fewer species reported in regions surveyed along the Atlantic Coastal Plain (Siver & Lott, 2006; 2010; Lott & Siver, 2005). Seven species were found in Newfoundland waterbodies, and active populations were recorded in 16 of the 22 sites, with particularly high concentrations in Burnt Point, Butter Pot, Cochrane, Grassy and Paddy's. The broadly U-shaped structure of the spine shaft on *Spiniferomonas abei* scales is noteworthy as it is the only known species within the genus where the shaft has two, not three, ridges.

In summary, Newfoundland waterbodies harbor a rich and diverse flora of scaled chrysophytes, and one that reflects habitats that are acidic, low in nutrients and dissolved salts, and with moderate concentrations of humic substances. Since many of the species found in this region are diagnostic bioindicators, scaled chrysophytes would provide a valuable resource for future paleolimnological studies aimed at understanding impacts from environmental stressors on Newfoundland lakes. The high diversity of scaled chrysophytes in this suite of lakes is reflected in the high number of species ($n = 47$), the high number of species per site (mean = 15), and the fact that 34 of the taxa were found in more than 10% of the sites. Sites are especially rich in populations of *Mallomonas duerrschmidtiae*, *M. galeiformis*, *S. echinulata*, *S. sphagnicola*, and specimens from the *S. petersenii* complex. The high number of lakes harboring *Spiniferomonas*, and the low number of *Paraphysomonas* species are both noteworthy, as is the unique flora from Orchid Bog that serves as the type locality for three scaled chrysophyte species and the sole site for other rarely reported taxa.

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