

Gyrosigma orbitum sp. nov. (Bacillariophyta) from a salt marsh in the Bay of Fundy, eastern Canada

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Abstract

An undescribed species of tube-dwelling sigmoid diatoms, *Gyrosigma orbitum* sp. nov., was found in the surface sediments of a salt marsh in Peck's Cove, Bay of Fundy, Atlantic Canada. The specimens belong to the section *Strigiles sensu* H. Peragallo and they are characterized by very fine longitudinal striation (34–45 in 10 μm), isomorphic proximal raphe endings and two large oval pits within the central area. While recorded in adjacent tidal mudflats, this species reached its highest abundances in the salt marsh, particularly within the cordgrass *Spartina patens* where it occurred in association with other epipellic taxa, including *Diploneis* cf. *smithii*, *Surirella* spp., *Gyrosigma limosum*, *Nitzschia epithemioides*, *N. ligowskii*, *N. sigma*, and a number of small sigmoid *Nitzschia* species. *Gyrosigma orbitum* is found mainly at sites with high sediment temperature and water content, but a shallow anoxic layer.

Keywords: Bay of Fundy; benthic community; *Gyrosigma*; salt marsh; tube-dwelling diatoms.

Introduction

A salt marsh is a coastal environment, usually fringed by tidal mudflats at its seaward edge, whose vegetation is adapted to regular or intermittent inundation by the tide (Jansson-Stelder 2000). Although not evident to the naked eye, diatoms and other benthic microalgae on salt marshes substantially contribute to the coastal marine food web. In a salt marsh study in the Bay of Fundy in Atlantic Canada, Hargrave et al. (1983) demonstrated that microphytobenthos primary production was comparable to primary production by the dominant macrophyte *Spartina alterniflora* Loiseleur-Deslongchamps. Furthermore, epipellic diatoms prevented erosion by producing extracellular polymeric substances, which increased the stability of cohesive sediments (Paterson 1989, Austen et al. 1999). However, while the functional role of diatoms in these habitats is relatively well known, the community composition remains little studied (McIntyre et al. 1996, Agatz et al. 1999, Trites et al. 2005).

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The distribution of epipellic diatom species on tidal flats and salt marshes throughout the world varies from year to year and still remains poorly understood (Underwood and Paterson 1993). Trites et al. (2005) suggested that the epipellic diatom community on two adjacent mudflat diatom communities in Chignecto Bay in the Bay of Fundy, Atlantic Canada may not form a natural community. They hypothesized that interannual variation in the community composition may depend on which species first re-colonizes the mudflats after the spring ice melt. The new inoculum of diatom cells may come from salt marshes, which often contain a greater diversity and abundance of diatom taxa than the mudflats (Underwood 1994, Brotas et al. 1995). Unfortunately, this hypothesis cannot be readily tested because, despite their importance, the diversity and taxonomic composition of the diatom communities on mudflats and associated marshes are very poorly known in Atlantic Canada (Trites et al. 2005).

However, studies in Western Europe have shown that epipellic diatom communities in coastal environments are often numerically dominated by small *Navicula* species, while the larger but less abundant *Gyrosigma* spp. may have importance as bloom formers, or may contribute significantly to the total biovolume of diatoms (Underwood 1994, Lucas et al. 2001, Haubois et al. 2005).

Epipellic members of the genus *Gyrosigma* Hassall are commonly observed on mudflats and salt marshes in the upper reaches of the Bay of Fundy (Trites et al. 2005, Thaler 2007). Over recent decades, several studies have contributed to a better knowledge and understanding of the most salient morphological features, allowing identification of previously overlooked species. These include the longitudinal to transapical stria ratio (Sterrenburg 1991, 1994, 1995), the deflection of the central raphe endings (Sterrenburg 1993), the structure of the central bars (Cardinal et al. 1989, Reid and Williams 2003), and the presence or absence of a crescent of pores beyond the internal apical raphe endings (Sterrenburg 1991, Reid and Williams 2003).

During a benthic diatom community study on a Bay of Fundy tidal flat (Thaler 2007), a tube-dwelling *Gyrosigma* was found that did not match the description of any known species. Here, we describe a new species, *Gyrosigma orbitum* Thaler et Kaczmarska, discuss its taxonomic position within the genus, and report biotic and abiotic conditions in its environment.

Materials and methods

Sampling was conducted in Peck's Cove on the eastern shore of the Dorchester peninsula in Chignecto Bay, Bay of Fundy, Atlantic Canada; Peck's Cove has a 10-m tidal amplitude (Dijkema and Eisma 1998). The sampling area

Table 1 Geographical coordinates of sampling sites at Peck's Cove, Bay of Fundy, Atlantic Canada.

Site	Habitat	Latitude (N)	Longitude (W)	Elevation above sea level (m)
1–3	Creek	45°44.71'	64°29.72'	14
4	Marsh	45°44.80'	64°29.58'	6
5	Marsh	45°44.48'	64°29.33'	4
6	Marsh	45°44.94'	64°29.42'	2
7–9	Mudflat	45°45.67'	64°29.05'	0

consisted of a salt marsh divided by a large tidal creek, which was fresh at low tide. On one side of the creek, *Spartina alterniflora* was the dominant macrophyte on the salt marsh, while the other side was dominated by *Spartina patens* (Aiton) Muhlenberg. A road ran through the marsh, parallel to the shore. A pioneer zone of much sparser vegetation dominated by *S. alterniflora* began on the seaward side of the road and gradually became a gently sloping mudflat without any visible macrophyte vegetation.

Sediment samples were collected in springtime on 9 and 23 April, and 17 and 31 May 2006 at sites 1–3 in the creek, sites 4–6 in the marsh and sites 7–9 in the mudflat (Table 1). Our new species was observed in all three habitats, though not in all sites or on all sampling days. Most samples were collected from site 5 in a stand of *Spartina patens*. Sediment cores, 5–10 cm deep, were collected from the salt marsh, mudflat and tidal creek by pushing down through the sediment an aluminum cylinder (10 cm internal diameter) and gently raising it. Sediment core samples were kept in plastic bags for approximately 10 h prior to further processing in the laboratory.

Five smaller surface sediment cores were extracted from the main core using pre-weighed 1.5 ml Eppendorf microtubes, which were cut off at the line designating 0.25 ml. The microtube was forced into the main sediment core until the sediment reached the line designating 0.5 ml, thereby giving all cores a uniform volume of 0.25 ml. These small surface sediment cores were weighed to a precision of 0.001 g (OHAUS TS1205, Ohaus Corp., Pine Brook, NJ, USA), preserved separately with Lugol's solution in a small quantity of distilled water and stored at 4°C in the dark. Prior to analysis, samples were pooled together in sufficient distilled water for a total volume of 150 ml.

For the identification and enumeration of epipellic diatom cells in light microscopy (LM), suspended sediment subsamples were settled in Utermöhl chambers (Hasle 1978). Due to the high density of sediment particles, only diatom cells >20 µm and present in at least two sampling sites (Table 2) were identified to the lowest possible taxonomic rank and enumerated using an inverted microscope (Zeiss Axiovert 200, Carl Zeiss, Thornwood, NY, USA) operating with phase contrast optics. Diatom cell identification was assisted by the following literature: Cleve-Euler (1952, 1953, 1955), Patrick and Reimer (1975), Germain (1981), Krammer and Lange-Bertalot (1988), Witkowski et al. (2000).

The identification and biometric measurements of our new *Gyrosigma* species were performed in LM (Zeiss AxioLab, Carl Zeiss) and scanning electron microscopy (SEM) (JEOL-5600, JEOL USA, Peabody, MA, USA) oper-

ating at 10 kV. A few drops of suspended sediment material were put on a 3-µm poly-carbonate filter (Sterlitech, Kent, WA, USA), boiled in a 50:50 nitric/sulfuric acid solution for 30 min and rinsed several times with distilled water. Permanent slides of cleaned diatom material were mounted using a high refractive index medium (ZRAX, W.P. Dailey, Philadelphia, PA, USA), while preparations for SEM observation followed Trites (2002). Terminology followed Ross et al. (1979), Schoeman and Archibald (1986), Cardinal et al. (1989) and Sterrenburg (1993).

Sediment water content and temperature, and the depth of the anoxic layer were recorded on each sampling date. Sediment cores for measuring water content were collected with a pre-weighed polyethylene transfer pipette marked to give a total volume of 0.7 ml, weighed (OHAUS TS1205), dried at 60°C until two measurements 3 h apart showed no difference in weight; the sediment water content corresponded to the difference between wet and dry weight. Sediment temperature was measured with a hand-held glass thermometer. The depth of the anoxic layer corresponded to the dark, compacted layer measured with a plastic ruler on the main sediment core.

Cell abundances of the 20 diatom taxa (Table 2) and three environmental variables were analyzed using canonical correspondence analysis (CCA) with CANOCO version 4.0 (ter Braak 1987–1992), which generates linear combinations of environmental variables that produce the best dispersion between taxa (ter Braak 1995). Thus,

Table 2 Most common epipellic diatom taxa (>20 µm) recorded in at least two sampling sites from creek, marsh, and mudflat sediments of Peck's Cove, Bay of Fundy, Atlantic Canada.

<i>Cylindrotheca closterium</i> (Ehrenberg) Reimann et Lewin
<i>Cylindrotheca gracilis</i> (Brébisson) Grunow
<i>Diploneis interrupta</i> (Kützing) Cleve
<i>Diploneis</i> cf. <i>smithii</i> (Brébisson) Cleve
<i>Entomoneis paludosa</i> (W. Smith) Reimer
<i>Gyrosigma distortum</i> (W. Smith) Griffith et Henfrey
<i>Gyrosigma fasciola</i> (Ehrenberg) Griffith et Henfrey
<i>Gyrosigma limosum</i> Sterrenburg et Underwood
<i>Gyrosigma obliquum</i> Grunow
<i>Gyrosigma orbitum</i> sp. nov.
<i>Nitzschia brevissima</i> Grunow
<i>Nitzschia epithemioides</i> Grunow
<i>Nitzschia ligowskii</i> Witkowski, Lange-Bertalot, Kociolek et Brzezinska
<i>Nitzschia sigma</i> (Kützing) W. Smith
<i>Nitzschia</i> spp. <40 µm
<i>Petrodictyon gemma</i> (Ehrenberg) Mann
<i>Pleurosigma</i> sp.
<i>Surirella</i> spp.
<i>Trachyneis aspera</i> (Ehrenberg) Cleve
<i>Tryblionella levidensis</i> W. Smith

it can provide insight into the habitat properties that correlate to species abundances. Because large diatoms were very sparse within the tidal creek sediments, it was not always feasible to count a minimum number of cells per sample. Instead, exactly half of the Utermöhl chamber was examined for each sample. The large number of zeros in the resulting dataset would be a serious problem if our statistical analysis employed a linear model; however, it is acceptable for unimodal response models, such as CCA (ter Braak and Prentice 1988). This analysis pertains to the selected species and not to the community as a whole.

Results and discussion

Gyrosigma orbitum Thaler et Kaczmarska sp. nov. (Figures 1–14)

Diagnosis *Valvae lineares parum sigmoideae, 36–110 µm longa, 6–16 µm lata. Raphe recta, ad apices ex adverso parum curvata; extremitates centrales raphes isomorphicae. Foveae duae magnae ovaes inter extremitatibus centralibus raphes, utroque latere raphes dispositae. Striae transversales 27–31 in 10 µm, striae longitudinales 34–45 in 10 µm.*

Valves linear, slightly sigmoid, 36–110 µm long, 6–16 µm wide. Raphe straight, curved slightly in opposite directions at apices; central raphe endings isomorphic. Two large oval pits located between the central raphe endings on either side of the raphe. Transapical striae 27–31 in 10 µm, longitudinal striae very fine, 34–45 in 10 µm.

Holotype Slide (CANA 80556), National Herbarium of Canada, Phycology Section, Canadian Museum of Nature, Ottawa, Canada. Holotype specimen illustrated in Figure 2.

Isotypes Slide (B 40 0040629), Botanic Gardens and Botanical Museum in Berlin-Dahlem, Berlin, Germany, specimen illustrated in Figure 4. Slide (BM 101331), Natural History Museum in London, United Kingdom, specimen illustrated in Figure 3.

Type locality Top 5 mm of sediment in a salt marsh within a patch of *Spartina patens* at site 5 (45°44.48' N, 64°29.33' W), Peck's Cove, Chignecto Bay, Bay of Fundy, New Brunswick, Canada. Collected by M. Thaler, 31 May 2006.

Etymology In reference to the two orbits of a skull.

Description Cells collected from Peck's Cove were often observed embedded in narrow mucilaginous tubes one cell wide; cells with two girdle-appressed chloroplasts (Figure 1). The valves are distinctly linear and slightly sigmoid only near the apex (Figures 2–6), with the

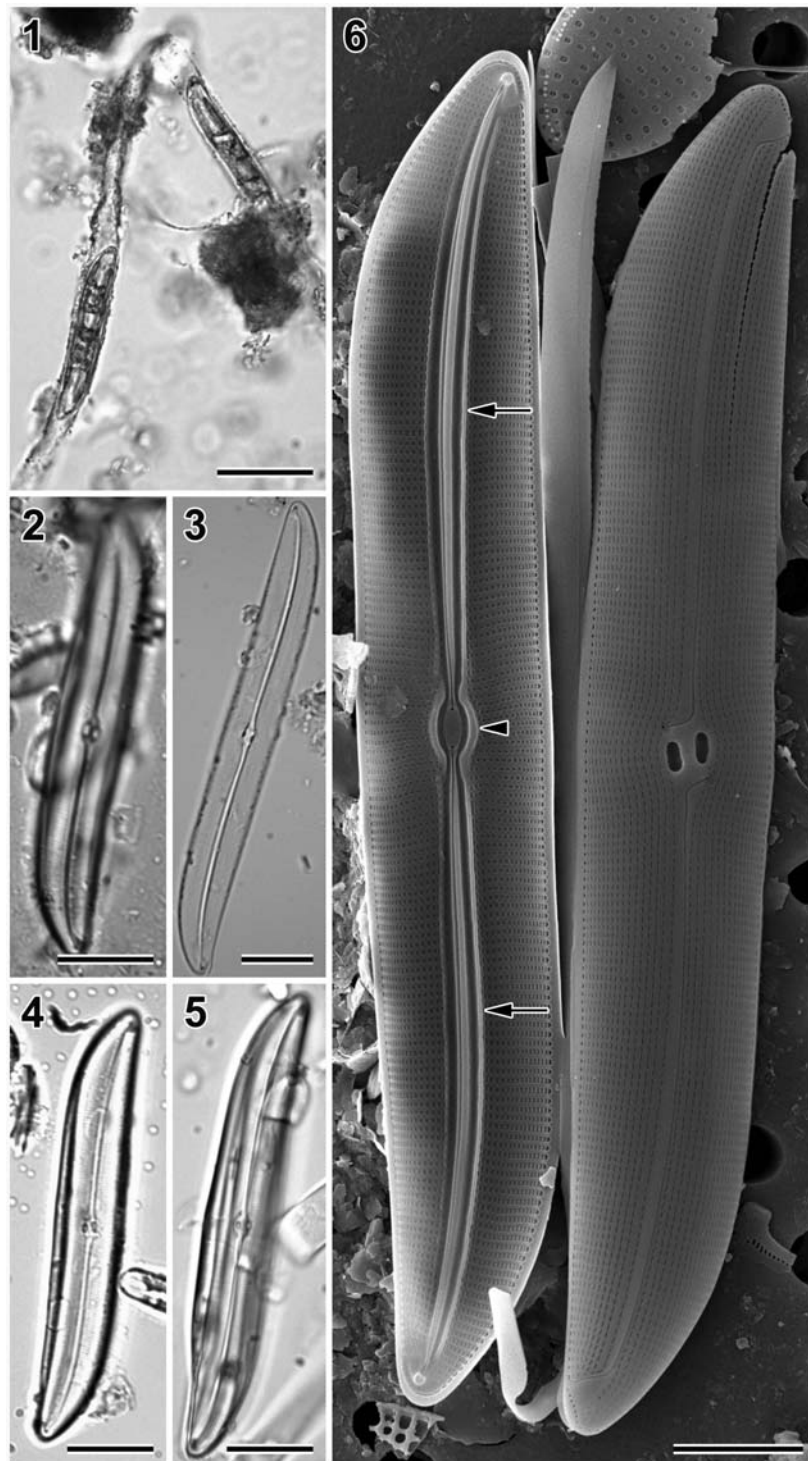
apical and transapical axes ranging from 36–110 µm and 6–16 µm, respectively (Table 3). The apices are asymmetrical, with one nearly straight margin and the other one convex, tapering to a broadly rounded end (Figures 2–6). The girdle is composed of one or two copulae, and the valvocopula is open and structureless (Figure 6).

The raphe consists of two branches centrally located and following the valve outline but displaced to the outermost side of the linear and narrow axial area (Figures 6, 7, 9). Externally, the proximal raphe ends are deflected at almost 90° towards the convex margin of the corresponding half-valve (isomorphic according to Sterrenburg 1993) stopping in a small depression at the location of an areola, while the distal raphe ends terminate in a fissure strongly deflected almost 90° in the opposite direction of the proximal raphe endings (Figures 6, 7, 9). Internally, the proximal raphe ends are co-axial, close to each other and terminate in a small T-shaped expansion while at the poles they end in a bulky and raised helictoglossa (Figures 6, 8, 10). A prominent axial costa, more developed on one side, borders the raphe throughout most of the valve length and ends near the poles (Figure 6, 8, 10, 12, long arrows point to the axial costa). In internal view, the two raphe fissures open slightly opposite the axial costa on an accessory rib, except at the center of the valve and the poles (Figure 6, 8, 10). At the center, the raphe is also bordered by distinct thick central bars with one bar merging with the prominent axial costa (Figures 6, 10, arrowheads).

The striation is characteristic of the genus *Gyrosigma* but only the transapical striae (27–31 in 10 µm) can be seen (barely) in LM; they are slightly radiate at center and parallel throughout the remaining part of the valve. They continue to the apex on one side of the raphe, though in a less organized manner (Figures 6 and 7). The longitudinal striae (34–45 in 10 µm) run linearly from pole to pole, except at mid-valve where they are gently convex around the central area (Figures 6–10). Striae consist externally of apically elongated narrow slits, which open internally in rounded to quadrangular areolae closed by featureless occlusions (Figures 6–10). A crescentic single row of rounded pores circles the apex and aligns with the outermost peripheral areolate stria (Figures 6, 7). In the internal view, the opening of some or all of these pores appears to run together in a trough (Figures 6, 8).

The frustules of this diatom are particularly sturdy and resistant to breakage; therefore, only some internal stria associated features are described here. Striae are loculate, with the external layer consisting of elongated slit-like areolae (Figures 11–14). The locula run uninterrupted longitudinally between short segments of apically oriented siliceous thickenings (Figure 12, arrowheads), which open transapically (Figures 11, 13, 14). The transapical to longitudinal stria ratio ranges from 0.64–0.89 (n=20, SEM measurements), which places this new *Gyrosigma* taxon within the section *Strigiles sensu* H. Peragallo (Sterrenburg 1991).

In SEM, a distinct linear and narrow axial area follows the raphe outline ending in a conspicuous terminal hyaline area above the distal raphe fissure (Figures 6, 7). Externally, the more or less rounded central area is distinctly characterized by the occurrence of two large,



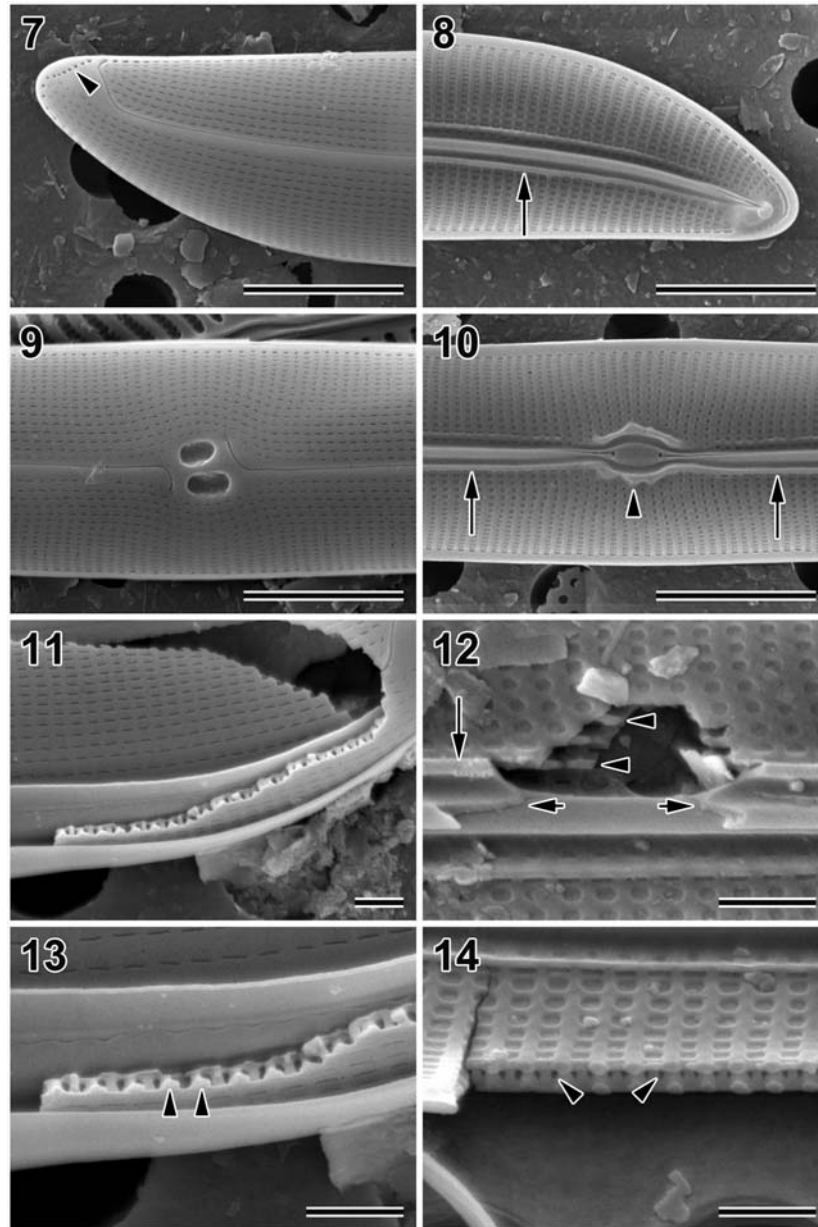
Figures 1–6 *Gyrosigma orbitum*: specimens in LM and SEM collected from a salt marsh in Peck's Cove, Bay of Fundy, Atlantic Canada.

(1) Two cells with plastids in a mucilaginous tube. (2) Holotype specimen, CANA 80556, representing a valve with the characteristic pits in the central area and the very fine transapical striation. (3) Large valve showing the linear outline and asymmetrical apices; isotype specimen (B 40 0040629). (4) Valve with oval pits and linear outline; isotype specimen (BM 101331). (5) Valve with distinct apical hyaline areas. (6) Frustule showing an internal and external view of the valves. Clear axial costa (long arrows) more developed on one side of the raphe and central bars (arrowhead) are visible internally, while distinct oval pits are present on the external valve in the central area. Figures 1–5, LM; Figure 6, SEM. Scale bars=25 μm (Figure 1); 10 μm (Figures 2–5); 5 μm (Figure 6).

elliptical to rectangular pits (approximately 0.75 μm wide by 1.00 μm long) near the striae and apically oriented, which can also be observed in LM (Figures 2–6, 9). These pits do not communicate with the internal valve surface (Figures 6, 9, 10).

Taxonomic comparison

Gyrosigma has traditionally been divided (by H. Peragallo in Peragallo and Peragallo 1897–1908) into four sections, *Attenuati*, *Acuminati*, *Strigiles*, and *Fasciolati*, based on



Figures 7–14 *Gyrosigma orbitum*: specimens in SEM collected from a salt marsh in Peck's Cove, Bay of Fundy, Atlantic Canada. (7) External view of apex showing the terminal raphe fissure, striation pattern, and crescentic row of pores (arrowhead). (8) Internal view of apex showing the helictoglossa and the more strongly developed axial costa (long arrow) on one side of the raphe system. (9) External view of central area with diagnostic oval pits. (10) Internal view of central area showing the axial costa (long arrows) more developed on one side of the raphe and central bars (arrowhead). (11) Fractured valve showing the loculate striae. (12) Fractured valve illustrating complexity of raphe-associated structures; note the apically oriented siliceous thickenings between the neighboring locula (arrowheads), a broken off fragment of the raphe ridge (short arrows) and a more strongly developed axial costa (long arrow). (13) Fractured valve showing the siliceous connections between loculae (arrowheads). (14) Broken valve showing apertures (arrowheads) in the siliceous thickenings, believed to be longitudinal locula. Limited availability of fractured valves does not allow us to say whether they are uninterrupted along the apical axis. Scale bars=5 μm (Figures 7–10); 1 μm (Figures 11–14).

the transapical to longitudinal stria ratio and for the latter two by the shape of the valve's apex. Our new taxon from Peck's Cove, *Gyrosigma orbitum*, fits within the section *Strigiles* wherein the transapical striae are noticeably coarser than the longitudinal pattern.

The linear valve outline, blunt apices, and general size of *Gyrosigma orbitum* are superficially similar to *G. eximium* (Thwaites) Boyer and *G. obliquum*, two species distinguishable from each other only by the deflection of

the central raphe endings (Sterrenburg 1993). However, the extremely fine longitudinal striation, and to some extent the transapical striation, is sufficient to clearly distinguish *G. orbitum* from the other taxa of the *Strigiles* (Table 3). The deflected external central raphe endings are an important feature for distinguishing apparently similar species within the genus, such as *G. obliquum* and *G. eximium* (Sterrenburg 1993). *G. orbitum*, similar to *G. obliquum*, has isomorphic external central raphe

Table 3 Morphometric data and some diagnostic features of *Gyrosigma orbitum* and other closely related taxa in the section *Strigiles*.

Species	Length (μm)	Width (μm)	Striae		Central raphe end	Central area	Life- style
			Longitudinal (in 10 μm)	Transapical (in 10 μm)			
<i>Gyrosigma eximium</i> ^a	55–90	7–12	27–32	22–25	Dimorphic	Unadorned	T
<i>Gyrosigma limosum</i> ^b	55–85	8.5–12.5	26–29	20–24	Dimorphic	Unadorned	F
<i>Gyrosigma obliquum</i> ^{a,c}	55–90	7–12	27–32	22–25	Isomorphic	Shallow depressions	T
<i>Gyrosigma orbitum</i>	36–110	6–16	34–45	27–31	Isomorphic	Oval pits	T
<i>Gyrosigma strigilis</i> ^d	250–380	30–39	15–16	12–14	Isomorphic	Unadorned	F
<i>Gyrosigma</i> sp. ^e	83–111	13–18	15–21	14–17	Isomorphic	Oval pits	U

^a Sterrenburg (1989), ^b Sterrenburg and Underwood (1997), ^c Sterrenburg (1993), ^d Patrick and Reimer (1975), ^e M. Loir, personal communication. T: tube-dwelling; F: free-living; U: unknown.

endings. Finally, the presence of oval pits in the central area constitutes a remarkable and stable feature found in all specimens of *G. orbitum* from Peck's Cove (Figures 2–6, 9). These pits are clearly different from the fainter and less well-defined depressions forming an arch bordering the central area in *G. obliquum*, another tube-dwelling *Gyrosigma* (Sterrenburg 1989, 1993). Similar-sized specimens have been observed from Bencia State Park salt marsh in San Francisco Bay; these specimens possessed similar pits but the striation remained unresolved (A. Witkowski, personal communication). Another unidentified specimen of *Gyrosigma* from Basse-Terre Island in the Caribbean Lesser Antilles also showed some distinctive pits in the central area, but the coarser striation easily distinguishes the Caribbean specimen from *G. orbitum* (M. Loir, personal communication; <http://www.diatomloir.eu/Site%20Diatom/Amhanav.html>).

Another species belonging to the *Strigiles*, *Gyrosigma limosum*, was very common on mudflat and salt marsh sites in this study. It is similar enough in the valve outline to *G. orbitum* that these two taxa can be confused. However, *G. limosum* has an unadorned central area, coarser striation, and dimorphic external central raphe endings (Table 3).

Habitats

Gyrosigma orbitum was observed in the surface sediments of the tidal creek, salt marsh, and mudflat in Peck's Cove in the Bay of Fundy, Atlantic Canada, but high abundances (>7000 cells ml^{-1}) were consistently found in the salt marsh with, however, one mudflat sample at site 8 containing a high number of cells (Figure 15a). The maximum abundance of 33×10^3 cells ml^{-1} was observed among *Spartina patens* in a salt marsh sample at site 5. Other common epipellic diatom taxa recorded in this last sample were *Diploneis* cf. *smithii*, *Surirella* spp., *Gyrosigma limosum*, *Nitzschia epithemioides*, *N. ligowskii*, *N. sigma* and a number of small sigmoid *Nitzschia* spp. (Table 2). Most of these taxa were either rare or absent on adjacent mudflats (Daniels and Buck's Flats) examined by Trites et al. (2005).

Previous studies have suggested that environmental variables, such as salinity, immersion period, sediment grain size, and nutrient content, may determine the distribution of microphytobenthos within and between tidal

flats (Ribeiro et al. 2003). CCA of the relationship between diatom cell counts and sediment temperature, sediment water content and depth of anoxic layer indicated that *Gyrosigma orbitum* was most likely associated with sediments that were slightly warmer, with higher moisture content, and a shallower anoxic layer than the average values of these variables in other sites at Peck's Cove in spring 2006 (Figure 15; CCA data not shown). The axes generated by CCA were significant ($p < 0.05$) and explained 29% of the variation in the abundance of *G. orbitum*.

In Peck's Cove, *Gyrosigma orbitum* was most abundant in the surface sediments from a stand of *Spartina patens* located in the salt marsh. Sullivan (1977) reported from a New Jersey salt marsh that the benthic diatom community within a stand of *S. patens* had more endemic species, a higher diversity, and a greater evenness than among a stand of *S. alterniflora*, which is the other most common cordgrass species in Peck's Cove. *S. patens* also showed a preference for areas of low salinity, 11.2 ± 2.7 psu (Sullivan 1977), but unfortunately no salinity measurement was made during our sampling.

The high water content of the sites where *Gyrosigma orbitum* is most commonly found may benefit this species by enhancing cell motility in the upper 5 mm of sediment. Epipellic diatoms have been observed to migrate vertically in response to light and tidal cycles (Round et al. 1990).

The sulfide-rich anoxic layer is sometimes closer to the surface in a salt marsh than in a mudflat because of a higher input of organic material (Peletier 1996). This was true at site 5 in Peck's Cove, where the highest cell abundance of *Gyrosigma orbitum* was recorded. Admiraal and Peletier (1980) reported that benthic diatom species from a mudflat in the Eems-Dollard Estuary in The Netherlands had different sulfide tolerances. Although not clearly established, circumstantial evidence suggests that *G. orbitum* may have such a high tolerance to sulfides.

Tube formation has been reported to occur in many diatom genera, such as *Berkeleya* Greville, *Cylindrotheca* Rabenhorst, *Haslea* Simonsen, *Navicula* Bory, *Nitzschia* Hassall and *Parlibellus* Cox (Haupt 1994). Diatom species capable of forming mucilaginous tubes are also frequently found free-living in the sediments. Sterrenburg (1989) suggested that the mucilaginous tubes in *Gyrosigma eximium* might protect the cell from desiccation or osmotic shock. Since *G. orbitum* was most abundant in the upper

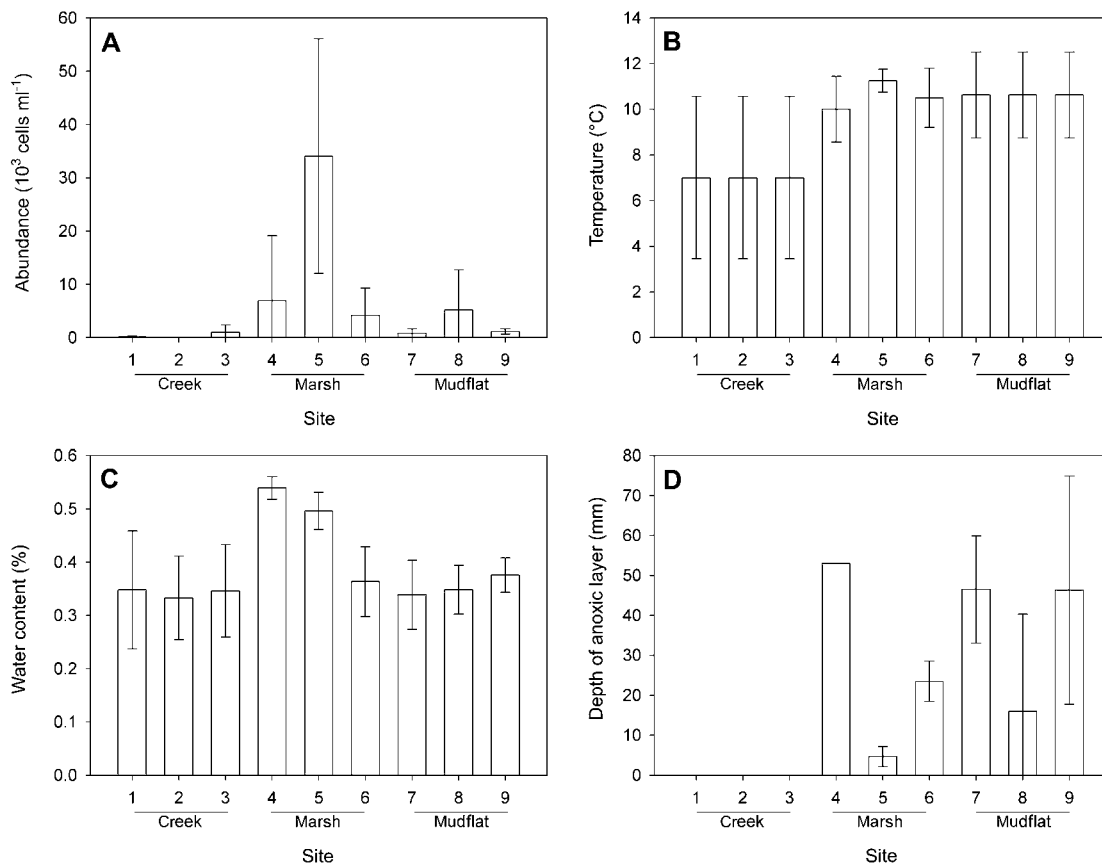


Figure 15 Variations in (A) cell abundance of *Gyrosigma orbitum*, (B) sediment temperature, (C) percent water content by weight of the sediment, and (D) depth of the anoxic layer at sites in a tidal creek, salt marsh, and mudflat of Peck's Cove in the Bay of Fundy, Atlantic Canada. Means±SD, n=4.

reach of the salt marsh, desiccation may indeed represent a challenge for this species. Houpt (1994) speculated that nutrients might be an important variable determining whether the formation of mucilaginous tubes is possible for species in the littoral zone of a variety of coastal sites in the Netherlands. At least one study by Welsh (1980) reported higher concentrations of phosphate, nitrate, nitrite, and ammonium on a salt marsh of Long Island Sound during the summer months in comparison to an adjacent mudflat. If a similar nutrient gradient exists in Peck's Cove, *G. orbitum* may take advantage of the higher nutrient concentrations on the salt marsh to offset the cost of manufacturing mucilaginous tubes, enabling them to attain higher abundances at salt marsh sites. Unfortunately, nutrients were not measured during our sampling.

It is not surprising to discover a new benthic diatom species in the intertidal zone of the Bay of Fundy. The species diversity of marsh and mudflat microorganisms, including diatoms, is virtually unexplored in Atlantic Canada. Most of the recent research effort on mudflat and salt marsh ecology has been process-oriented, with significant progress made in understanding grazing pressures (Smith et al. 1996) and biologically mediated sediment stabilization (Austen et al. 1999). However, only a broad taxonomic assessment of organisms was considered in many of these studies, so little is known about the specific composition of their communities.

Conclusion

A new diatom, *Gyrosigma orbitum*, is an epipellic, tube-dwelling species inhabiting at least one tidal flat of the Bay of Fundy and occurring most abundantly on salt marsh. It can be unambiguously recognized in both LM and SEM using several distinctive features, including two large oval pits located in the central area and the extremely fine longitudinal striation. While the autecology of *G. orbitum* is unknown, it occurs most abundantly in the surface sediments of Peck's Cove that are slightly warmer, with higher water content, and a shallower anoxic layer relative to surrounding sediments.

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