Taxonomy, distribution, and ecology of the freshwater bryozoans (Ectoprocta) of eastern Canada

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The freshwater Bryozoa (Ectoprocta) are one of the most poorly known faunal groups in Canada. A recent survey of 80 freshwater habitats in eastern Canada (from Ontario to Newfoundland) revealed 14 species of bryozoans, representing 56% of described species in North America. The greatest numbers of species and specimens were found in alkaline waters (pH 7.0–9.8) near lake outflows, wherever hard substrates were present. *Paludicella articulata*, *Cristatella mucedo*, *Fredericella indica*, and *Plumatella fungosa* are among the most frequently encountered, widely distributed, and eurytopic species. *Pottsiella erecta* and *Plumatella fruticosa* are rare, and new to eastern Canada. *Lophopodella carteri*, an exotic Asian species discovered in Lake Erie in the early 1930s, has become firmly established in the lower Ottawa and upper St. Lawrence rivers. Detailed notes on taxonomy, morphology, distribution, and ecology are given for each bryozoan. New limits of tolerance to water temperature, pH, and calcium and magnesium hardness are established for several species. A taxonomic key to the freshwater bryozoans of eastern Canada, including a key to statoblast types, is presented for the first time.

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Les bryozoaires d'eau douce (Ectoprocta) constituent l'un des groupes fauniques les plus mal connus au Canada. Un inventaire récent de 80 habitats dulcicoles de l'est du Canada (de l'Ontario à Terre-Neuve) a révélé la présence de 14 espèces de bryozoaires, ce qui représente 56% des espèces connues en Amérique du Nord. C'est dans les eaux alcalines (pH 7,0–9,8) aux abords des tributaires, là où se trouvent des substrats durs, que la plupart des espèces et le plus grand nombre d'individus ont été trouvés. *Paludicella articulata*, *Cristatella mucedo*, *Fredericella indica* et *Plumatella fungosa* comptent parmi les espèces les plus communes, les plus répandues et les plus eurytopes. *Pottsiella erecta* et *Plumatella fructicosa* sont rares et c'ést la première fois qu'elles sont mentionnées dans l'est du Canada. *Lophopodella carteri*, une espèce exotique asiatique trouvée dans le lac Érié au début des années '30, a colonisé avec succès la partie basse de l'Outaouais et la partie haute du Saint-Laurent. On trouvera ici des notes détaillées sur la taxonomie, la morphologie, la répartition et l'écologie de chaque espèce de bryozoaire. De nouvelles limites de tolorérance à la température, au pH, à l'eau dure forte en calcium et en magnésium ont été enregistrées chez plusieurs espèces. Une clé taxonomique des bryozoaires d'eau douce de l'est du Canada, qui comprend une clé des types de statoblastes, est proposée pour la première fois.

[Traduit par la Rédaction]

Introduction

Freshwater bryozoans (Ectoprocta) are sessile, filter-feeding organisms commonly found attached to submerged surfaces in a broad range of inland water habitats. As a group, they are widely distributed (Bushnell 1973) and may dominate epibenthic and littoral communities in biomass (Raddum and Johnsen 1983; Bushnell et al. 1987), contribute significantly to the recycling of nutrients in small lentic habitats (Job 1976; Sorensen et al. 1986), constitute a common food source for several species of fish (Osburn 1921; Mann 1964; Dendy 1963; Applegate 1966), form microhabitats and refugia for smaller invertebrates (Kaminski 1990), and serve as indicators of chemical pollutants in inland waters (Malchow 1978; Pardue and Wood 1980; Mundy 1981). Most bryozoans produce sclerotized resting buds (statoblasts) that are well preserved in lake sediments, thus they have potential value in paleolimnological studies (Kuc 1973; Crisman et al. 1986).

Bryozoans are often among the dominant organisms in a freshwater fouling community. Occasionally, encrusting colonies grow so profusely that they become a serious nuisance, e.g., by fouling boats and fish nets (Jonasson 1963), reducing water exchange and fish growth in aquaculture cages (Greenland et al. 1988), obstructing municipal water supplies (Bushnell 1974; Shrivastava and Rao 1985), and causing operating problems in power installations (Pourcher and d'Hondt 1987; Aprosi 1988; Pennak 1989).

Despite their common occurrence and potential ecological and economic impacts, freshwater bryozoans have received very little attention and are among the poorest known faunal groups in Canada. They have been neglected in most limnological studies and faunal surveys; consequently, published information on their taxonomy, distribution, and ecology is very scarce. Difficulties in species identification and taxonomic confusion are two probable factors that have discouraged attention to these organisms. Proper species identification of bryozoans, coupled with an understanding of their ecology, is essential for their effective use in water quality and bioassay studies, and for controlling their profuse growth. Unfortunately, the taxonomy of freshwater bryozoans has been historically problematic, largely due to the morphological plasticity of several species. The available identification keys and checklists of North American freshwater bryozoans (e.g., Pennak 1989; Wood 1989, 1991) are based entirely on specimens collected in the United States, therefore detailed information concerning the distribution, ecology, and ecophenotypic variation of Canadian species has been largely unavailable to aquatic biologists.

There are 25 described species of ectoproct bryozoans in North American fresh waters (Wood 1991; Smith 1992). We predicted that the majority of these species would be found in eastern Canada, owing to the diversity and abundance of freshwater habitats and the wide range of ecological conditions within the region. We obtained specimens from various parts of Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland, to attempt a general survey of the freshwater bryozoans of eastern Canada. This paper presents a detailed examination of the morphology, taxonomy, distribution, and ecology of each identified species. It also presents the first taxonomic key to eastern Canadian freshwater bryozoans, including a key to statoblast types.

Materials and methods

We collected specimens from May to November 1989–1993, from 50 localities in southern Quebec (35), eastern Ontario (10), and Nova Scotia (5). Additional specimens (including those from New Brunswick and Newfoundland) were obtained from colleagues and from the following collections of museums and universities (subsequently referred to by the abbreviations in parentheses): Canadian Museum of Nature (formerly National Museums of Canada) (NMC), New Brunswick Museum (NBM), and Royal Ontario Museum (ROM). Specimens in our own collection (assigned the prefix AR or RMI) are located in the Redpath Museum of McGill University. In total, 500 specimens from 80 localities in eastern Canada (Ontario to Newfoundland) were examined.

We measured water quality parameters of most collection sites in Quebec, Ontario, and Nova Scotia. Temperature and pH were measured on site, using a Fisher mercury thermometer and a Cole–Parmer digital pH meter (model 05941-20), respectively. Hardness due to calcium ($CaCO_3$) and magnesium ($MgCO_3$) was determined using a chemical test kit (LaMotte Chemical Products Co., Chestertown, Maryland). Water quality data from New Brunswick were obtained from Dr. D.F. McAlpine, New Brunswick Museum, Saint John.

Methods of specimen preservation and preparation generally follow Wood (1989). Materials collected in this study were preserved in either 10% formalin or 70% ethanol.

Bryozoan taxonomy depends almost exclusively upon colonial and (in the case of the phylactolaemate species) statoblast morphology (Lacourt 1968). Many species are phenotypically variable and may be identified by means of only a few reliable features. In most cases, statoblasts are required for species identification. Statoblasts are environmentally resistant, encapsulated buds that are produced asexually by all bryozoans of the class Phylactolaemata (Mukai 1982); freshwater gymnolaemate bryozoans produce irregularly shaped resting buds called hibernacula (Fig. 13*b*). A sample of statoblasts, when present, was teased out of each of our specimens, using fine needles. Statoblast and zooecial measurements were made through a camera lucida using a Numonics 2200 digitizing tablet connected to a personal computer and SigmaScan (version 3.92, Jandel Scientific) software.

Some remarks on specimen collection

Bryozoans are found in a wide variety of lentic and lotic habitats during the summer and early autumn months. They often occur on macrophytes, stones, buoys, bridge supports, woody debris, bivalve shells, larval caddisfly cases, and a variety of other firm substrates; some species may grow on hard-packed mud and even on sand. Luxuriant tube-like colonies (Figs. 1, 7, 8*a*) with erect branches resemble filamentous algae, and gelatinous colonies (e.g., Fig. 10*a*) may be mistaken for the egg masses of gastropods. Examination of living colonies with a hand lens allows them to be easily identified as bryozoans, especially while the specimen is still immersed in water. Colonies should be carefully removed with a knife, preferably leaving them intact by removing a piece of the substrate on which they are attached.

The occurrence of statoblasts within a habitat is a useful indicator of the presence of many species. Sessoblasts (Figs. 3*c*, 4*b*, 5*d*, 8*e*) may be found in groups attached to the substrate even in the absence of colonies. Floatoblasts (e.g., Figs. 2*c*, 3*b*, 4*a*) are frequently found drifting in the surface waters of lakes and rivers, and become entrained in backpools, weedy areas (e.g, under the leaves of water lilies), and along shorelines, where they may be collected with a fine net. They often are found caught within the silk nets of hydropsychid and polycentropodid caddisfly larvae.

Results and discussion

We collected 14 species (2 classes and 6 families) of freshwater ectoproct bryozoans from various regions in eastern Canada.

Phylum Ectoprocta
  Class Phylactolaemata
    Family Fredericellidae
      1. *Fredericella indica* Annandale, 1909
    Family Plumatellidae
      2. *Plumatella casmiana* Oka, 1907
      3. *Plumatella emarginata* Allman, 1844
      4. *Plumatella fruticosa* Allman, 1844
      5. *Plumatella fungosa* (Pallas, 1768)
      6. *Plumatella orbisperma* Kellicott, 1882
      7. *Plumatella repens* (Linnaeus, 1758)
      8. *Plumatella reticulata* Wood, 1988
      9. *Hyalinella punctata* (Hancock, 1850)
    Family Lophopodidae
      10. *Lophopodella carteri* (Hyatt, 1866)
    Family Pectinatellidae
      11. *Pectinatella magnifica* (Leidy, 1851)
    Family Cristatellidae
      12. *Cristatella mucedo* Cuvier, 1798
  Class Gymnolaemata
      Order Ctenostomata
    Family Paludicellidae
      13. *Paludicella articulata* (Ehrenberg, 1831)
      14. *Pottsiella erecta* (Potts, 1884)

These represent 56% of the total number of described species in North America (cf. Wood 1991; Smith 1992) and about 23% of all species described worldwide (Wood 1991). This species richness is likely correlated with the abundance and diversity of aquatic habitats and ecological conditions within the study region. The relatively few bryozoans recorded in New Brunswick, Nova Scotia, and Newfoundland (Table 1) reflect a lack of intensive sampling in these regions rather than a locally depauperate bryozoan fauna. Given annual and seasonal population fluctuations, as well as large areas whose aquatic invertebrate fauna have generally been poorly surveyed, further investigation of lakes and rivers in eastern Canada would likely reveal more species.

Over 90% of the aquatic habitats surveyed contained one or more species. The greatest numbers of species and specimens were found in alkaline waters and near lake outflows, wherever firm substrates were available. Peak abundances typically occurred in late summer. Most colonies degenerated in late autumn or at the onset of winter, although at least one species (*Fredericella indica*) may be perennial.

TABLE 1. Recorded distribution of freshwater bryozoans from eastern Canada

	Species codes*													
Ontario	1	2	3	—	5	6	7	8	9	—	11	12	13	—
Quebec	1	2	3	4	5	—	7	8	9	10	11	12	13	14
New Brunswick	—	—	—	4	5	—	7	—	—	—	11	12	13	—
Nova Scotia	1	—	—	—	—	—	—	—	9	—	—	—	13	—
Prince Edward Island	—	—	3	—	5	—	—	—	—	—	—	—	13	—
Newfoundland	—	—	—	—	—	—	—	—	—	—	—	12	—	—

* Numbers refer to species listed in Table 1.

Bryozoans were often found in association with an assemblage of filter feeders (e.g., other bryozoans, sponges, hydroids, hydropsychid and polycentropodid caddisfly larvae). The interstitial spaces between zooids and around the edges of colonies were commonly occupied by a diverse Aufwuchs community consisting primarily of ciliate protozoans (*Vorticella*), tubicolous rotifers, ostracods, naidid oligochaetes, nematodes, and chironomids. Bryozoan colonial structure may provide microscopic spaces where deposits of seston and the bryozoan's own fecal discharges accumulate and enrich Aufwuchs communities (Bushnell and Rao 1979). Bryozoan predators observed during this study included leptocerid caddisfly larvae (particularly *Ceraclea nepha*), turbellarians, gastropods, and crayfish (*Orconectes virilis*).

Detailed descriptions of each species, including notes on taxonomy, ecology, and distribution in eastern Canada, are presented below. Distribution records for a province, if reported previously, are provided, with references; otherwise, the species is reported for the first time. Synonyms are limited to those published for eastern Canada and follow Lacourt (1968), with some exceptions (Wood and Backus 1992; Ricciardi and Wood 1992). Water quality data are provided for active, living colonies rather than for the more resistant statoblast phase. Measurements are presented in this paper as minimum-(mean)-maximum. The number of measurements (n) and standard deviations of the mean (SD) are indicated by SD_n. A key to eastern Canadian species and a glossary of terms follow the species descriptions. Since statoblasts are often found in water samples or attached to substrates in the absence of colonies, we also provide an illustrated key to the floatoblasts and sessoblasts of phylactolaemate bryozoans.

CLASS Phylactolaemata
FAMILY Fredericellidae
Fredericella indica Annandale, 1909
Figs. 1, 15*v*, 15*w*

Fredericella regina Odell, 1899
Fredericella sultana Huntsman, 1913; White 1915; Rogick 1937
Fredericella indica Ricciardi and Lewis, 1991

Description of eastern Canadian specimens

Colony dendritic with either adherent or free, erect, antler-shaped branches; adherent branches are keeled, erect branches are without a keel. Ectocyst brown or grey, lightly to heavily encrusted. Extended lophophore circular in outline. Statoblasts without annulus, nonbuoyant, elongate-oval or kidney-shaped in outline (Figs. 15*v*, 15*w*); surface of both valves marked extensively with a uniform pattern of small hexagonal pits (resembling the surface of a golf ball), clearly visible when a dried valve is examined under a light microscope; in some specimens, the pitting is reduced in size and depth, or (rarely) is replaced by a light reticulation. Statoblasts occur in both free and adherent branches; 1–3 statoblasts may be present in each zooid; statoblast length = 413-(500)-550 μm (SD_{25} = 38.6), width = 149-(204)-278 μm (SD_{25} = 33.8).

Taxonomy

Wood and Backus (1992) presented morphological and genetic evidence that North American and European forms earlier assigned to *Fredericella sultana* are different species. These two forms are separated by the surface patterning of the statoblast; *Fredericella indica* has a pitted or reticulated statoblast, where *F. sultana* has a smooth statoblast lacking any distinct surface marking. The surface pattern of the *F. indica* statoblast is best observed on a dried valve, since the valve may appear smooth when wetted. Some specimens from Ile Perrot, Quebec (e.g., AR21B, AR32B, AR122B), have lightly reticulated valves without any pitting, and may be found in the same habitat as (and even growing adjacent to) colonies with pitted statoblasts. All known Canadian specimens of *Fredericella* have pitted or reticulated statoblasts and are therefore assignable to *F. indica*.

Habitat and general ecology

Fredericella indica may dominate the epibenthic community in the littoral region and outflows of lakes (Raddum and Johnsen 1983; Bushnell et al. 1987). Dense, luxuriant colonies are commonly found on the underside of "permanent" substrates (e.g, large stones, submerged logs). The free, erect, branching growth form of *F. indica* minimizes competition for space and food, alleviates the effects of siltation, and allows colonization of the muddy bottom sediments of lakes (Bushnell 1966). Fragmentation of loose branches allows passive dispersal of zooids by water current (Wood 1973). The disadvantage of the erect growth form is that it facilitates predation by fish (Dendy 1963; Applegate 1966); extensive predation of *Fredericella* sp. colonies by bluegill and longear sunfish has been reported in which the bryozoan contributed to 70–75% of the food volume (Applegate 1966).

We collected *F. indica* from lentic and lotic habitats in the following water quality conditions: temperature 4–26°C, pH 6.1–9.4, calcium hardness 0–78 mg/L, magnesium hardness 2–70 mg/L. The species can colonize a wide range of habitats including alpine lakes (Bushnell et al. 1987), marl lakes (Bushnell 1966), dystrophic lakes (Raddum and Johnsen 1983), temporary ponds (Mozley 1932), and acidic streams (Everitt 1975). It is usually the dominant bryozoan in oligotrophic lakes at high elevations or high latitudes (Rawson 1953; Raddum and Johnsen 1983; Bushnell et al. 1987). In Canada, *Fredericella* have been collected at depths of more than 30 m (Rawson 1953), while European specimens have been found at 214 m depth and in alpine lakes at an altitude of 3480 m (Lacourt 1968). Living colonies can tolerate temperatures of 32°C in Louisiana lakes (Everitt 1975), and 1.5–2°C under an ice-covered Michigan lake throughout the winter (Bushnell 1966). Although *F. indica* may flourish in acidic waters (pH 4.7, Everitt 1975; pH 5.0–6.1, Raddum and Johnsen 1983), we found living colonies abundant in highly alkaline water (pH 9.4, a new tolerance limit for the species) in the upper St. Lawrence River.

Fredericella indica is commonly associated (i.e., shares substrate or grows in contact) with the bryozoans *Plumatella reticulata* and *Paludicella articulata* and the sponge *Eunapius fragilis*. It is one of the most common epizoic species on bivalves (Bushnell 1966; Curry et al. 1981), and occurs on the shells of up to 70% of living unionid mussels (*Elliptio complanata* and *Lampsilis radiata*) in southwestern Quebec lakes.

Distribution in eastern Canada

Ontario (Odell 1899; Huntsman 1913; White 1915; Rogick 1937), Quebec (Ricciardi and Lewis 1991), Nova Scotia.

Fredericella indica is a common eurytopic bryozoan that probably occurs throughout eastern Canada. A specimen (AR168B) from Warren Lake, Cape Breton Highlands National Park, Nova Scotia, represents the first record of *F. indica* from that province.

FAMILY Plumatellidae

Plumatella casmiana Oka, 1907

Figs. 2, 15*a–d*, 15*u*

Plumatella casmiana Rogick, 1943

Description of eastern Canadian specimens

Colony flat, compact, dendritic, entirely adherent, without any upright branches; colonial branches tend to radiate from a common point of origin. Ectocyst brown or grey, semi-translucent or opaque, normally heavily encrusted and brittle, strongly keeled and furrowed near the zooecial tips (Figs. 2*a*, 2*b*). Zooids crowded, often partially fused; septa usually present.

Floatoblasts are of two types: the first type is thick-walled and buoyant, and usually has a pointedly convex ventral capsule (Figs. 2*c*, 15*a*–15*b*). The second type, termed a leptoblast, is thin-walled and nonbuoyant, has a uniformly thin annulus, and is twice as long as wide (Figs. 15*c*, 15*d*); it is fragile and the valves are easily separated. Both types are symmetrical in lateral outline and have extensive oval fenestrae; the fenestral length is at least 1.5 times its width. Measurements of the thick-walled floatoblast are as follows: length = 297-(323)-340 μm (SD_{15} = 14.3), width = 184-(202)-222 μm (SD_{15} = 9.0), dorsal fenestra length = 167-(191)-213 μm (SD_{15} = 13.0), width = 114-(127)-140 μm (SD_{15} = 8.3); ventral fenestra length = 179-(235)-271 μm (SD_{15} = 23.0), width = 138-(158)-177 μm (SD_{15} = 12.0). Leptoblasts were not found in the few eastern Canadian specimens that were obtained. Bushnell (1965) gives the following size ranges for *P. casmiana* leptoblasts in Michigan: length = 340–430 μm, width = 160–220 μm.

Sessoblasts round or oval (Fig. 15*u*); frontal valve fairly smooth, but sometimes bears a conspicuous raised tubercle at its center; lamella typically very thin, normally less than 40 μm in width, and oriented perpendicularly to the substrate; sessoblast length (including lamella) = 441-(463)-478 μm (SD_{15} = 19.8), width (including lamella) = 272-(321)-366 μm (SD_{15} = 47.1), lamella width = 24-(35)-47 μm (SD_{19} = 8.0).

Taxonomy

The extensive oval fenestrae of the floatoblasts, with an average length/width ratio of at least 1.5, is a key feature of the species (Wood 1989). The presence of leptoblasts, which are found in no other bryozoan, insures correct identification of *P. casmiana*.

Bushnell and Wood (1971) described honeycomb-like *P. casmiana* colonies derived from the fusion of erect, densely crowded zooids. Honeycomb-like colonies of *P. casmiana* have not been found in eastern Canadian specimens, although the growth form occurs in *P. fungosa* and (rarely) *P. emarginata*.

Habitat and general ecology

Luxuriant colonies of *P. casmiana* have been reported to foul fish culture cages, resulting in impeded water flow and reduced fish growth (Greenland et al. 1988). The species grows in both lentic and lotic habitats, with a preference for alkaline waters (Bushnell 1968), and occurs on limestone channel markers in the upper St. Lawrence River (Quebec) in water of pH 8.0–9.0.

In most plumatellid bryozoans, floatoblasts serve as dispersal agents and sessoblasts have both overwintering and recruitment functions (Raddum 1981; Pourcher and d'Hondt 1987; Karlson 1991). However, *P. casmiana* sessoblasts are formed only in response to adverse environmental conditions; they often complete development when the parent colony has deteriorated, and during unfavorable periods, conserve favorable substrate for future generations (Wood 1973). The functions of dispersal and recruitment are divided among both types of *P. casmiana*'s floatoblasts. The thick-walled, buoyant floatoblast has dispersal capability. The thin-walled nonbuoyant leptoblast is produced in the early part of the growing season (Rogick 1943) and germinates immediately after release from the colony (Mukai et al. 1983), thus serving as a mechanism of colonial recruitment during favorable environmental periods.

Distribution in eastern Canada

Ontario (Rogick 1943), Quebec.

In Ontario, *P. casmiana* is known from Lake Erie (Rogick 1943) and the Grand River at Caledonia (ROM K-5). Previously unrecorded in Quebec, *P. casmiana* is rare and known only from the upper St. Lawrence River near the Island of Montréal (AR11B, AR25B).

Plumatella emarginata Allman, 1844

Figs. 3, 15*j*–15*l*

Plumatella diffusa Osler, 1883
Plumatella princeps var. *emarginata* Davenport, 1904
Plumatella repens var. *emarginata* Rogick, 1937
Plumatella emarginata Huntsman, 1913; White 1915

Description of eastern Canadian specimens

Colony dendritic, zooids, recumbent or erect; ectocyst brown or grey, translucent to opaque, lightly to heavily encrusted; recumbent branches normally keeled; septa present at the junction of every branch; branches may be partially fused; in rare cases the upright tips of many branches are fused together to form a compact, honeycomb-like mass. Floatoblasts oval, each with a distinctly flattened dorsal valve,

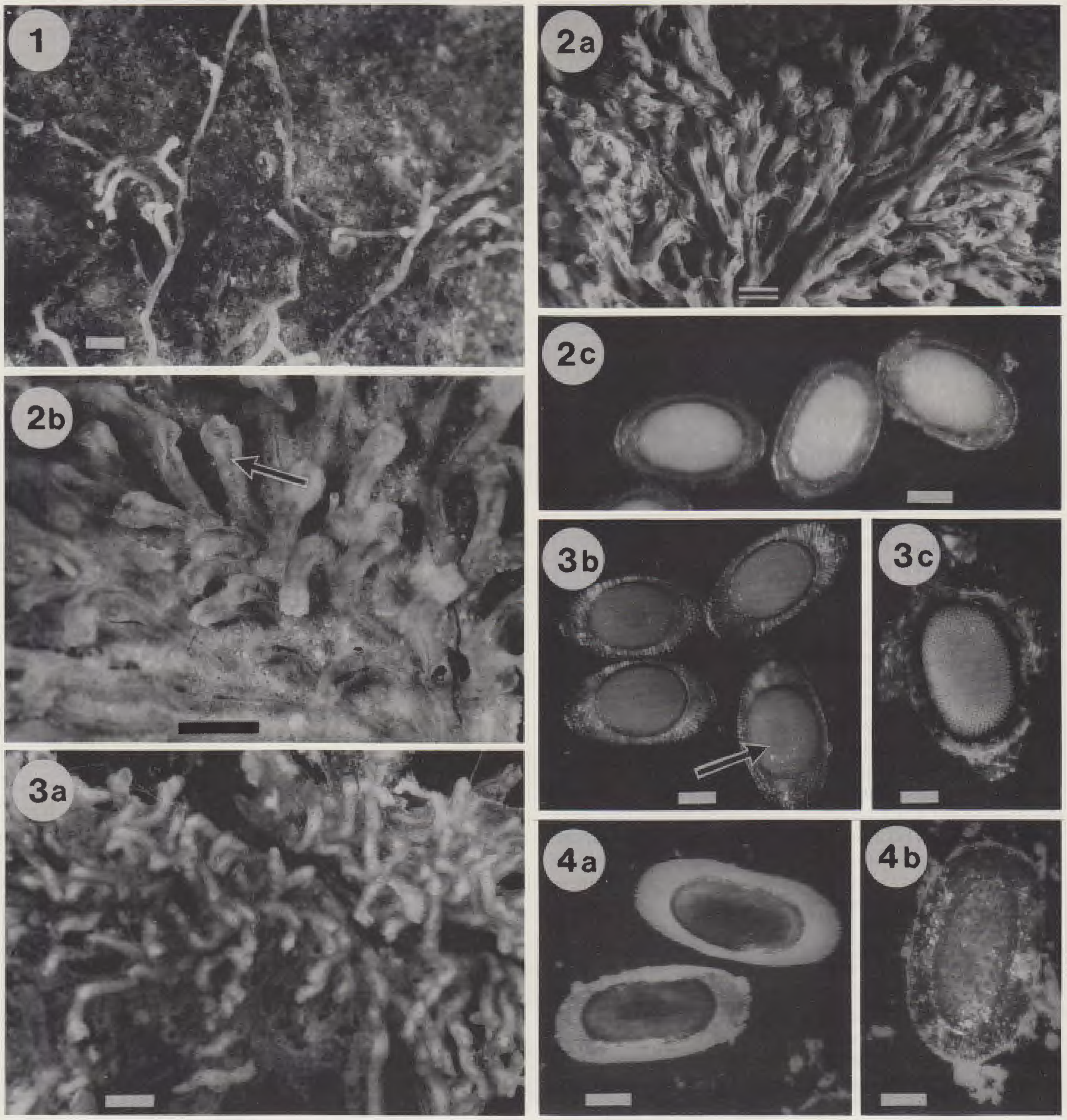


FIG. 1. *Fredericella indica.* FIG. 2. *Plumatella casmiana* (*a*) Colony on rock. (*b*) Close-up of zooids (arrow points to furrow on one zooid). (*c*) Thick-walled floatoblasts. FIG. 3. *Plumatella emarginata* (*a*) Colony. (*b*) Floatoblasts (arrow points to reduced dorsal fenestra). (*c*) Sessoblast. FIG. 4. *Plumatella fruticosa.* (*a*) Floatoblasts. (*b*) Sessoblast. Scale bars: 1 mm for Figs. 1, 2*a*, 2*b*, 3*a*; 0.1 mm for all others.

giving it a strongly asymmetrical lateral outline (Figs. 3*b*, 15*j*–15*l*); dorsal annulus extensive, leaving only a small fenestra uncovered; maximum width of dorsal annulus at least as great as length of dorsal fenestra; annulus often with a silvery sheen, less commonly with a bronze sheen; floatoblast length = 382-(422)-460 μm (SD_{25} = 18.3), width = 200-(237)-258 μm (SD_{25} = 13.7); dorsal fenestra length = 84-(126)-150 μm, width = 58-(95)-123 μm (SD_{25} = 16.2); ventral fenestra length = 196-(223)-250 μm (SD_{25} = 13), width = 169-(188)-210 μm (SD_{25} = 11.4).

Sessoblasts round or oval (Fig. 3*c*); frontal valve uniformly granular, densely covered with large dorsal tubercles visible with light microscopy (40×); sessoblast length (including lamella) = 401-(453)-513 μm (SD_{10} = 52.3), width (including lamella) = 264-(354)-414 μm (SD_{10} = 52.3); lamella width = 33-(52)-60 μm (SD_{10} = 10.7).

Taxonomy

Plumatella emarginata closely resembles its congener *Plumatella reticulata*, but *P. emarginata*'s strongly asymmetrical floatoblast and smooth sessoblast (lacking the network of ridges present on *P. reticulata*'s sessoblast) clearly distinguish the species.

Habitat and general ecology

Plumatella emarginata is found in streams, lake outflows, and waveswept areas of lakes. It grows luxuriantly on rocks in shallow, riffle streams. In calm, lentic habitats, *P. emarginata* grows on the underside of submerged surfaces, even when in shaded areas. Conversely, colonies usually occupy upper, exposed surfaces in running water (with fecal wastes and other debris being washed away by the current). The preferred position on the substrate is likely designed to avoid fouling or siltation rather than to avoid light or competition with periphyton.

Eastern Canadian specimens of *P. emarginata* were collected from the following water quality conditions: temperature 14–21°C, pH 7.0–8.4, calcium hardness 20–68 mg/L, magnesium hardness 20–28 mg/L. *Plumatella emarginata* is apparently tolerant of organic and chemical pollution (Bushnell 1966, 1974; Shrivastava and Rao 1985) and is often found in highly colored waters (A. Ricciardi, personal observation). Bushnell (1966) reported dense colonies where tubificid oligochaetes were present in abundance, less than 100 m downstream of a point source of industrial waste discharge. Shrivastava and Rao (1985) reported *P. emarginata* in an organically polluted river (PO_4 = 1.3 mg/L, NO_3 = 1.2 mg/L). Luxuriant growths of *P. emarginata* occur on stones in woodland streams (north of Montréal, Quebec) where the water is turbid and brown from iron seepage. In one such stream, the bryozoan was intimately associated with larvae of the hydropsychid caddisfly *Macronema zebratum* (Hagen), a lotic filter feeder which constructs specialized shelters that direct current and food particles through a silken capture net; the caddisfly larvae were abundant and had constructed their shelters interstitially among the bryozoan's colonial branches (A. Ricciardi, personal observation).

Distribution in eastern Canada

Ontario (Davenport 1904; Huntsman 1913; White 1915; Rogick 1937), Quebec, Prince Edward Island.

Plumatella emarginata was not previously recorded from Quebec or Prince Edward Island. In Quebec, the species was found in lake outflows in the Laurentian region near Morin Heights, and as far south as the Chateauguay River near Huntington. A specimen was obtained from a pond at Southport, P.E.I. (AR 141B, mixed with *Plumatella fungosa* and *Paludicella articulata*).

Plumatella fruticosa Allman, 1844
Fig. 4

Description of eastern Canadian specimens

Colony dendritic; zooecial branches adherent with upright tips, or growing free of the substrate (similar to Fig. 1); ectocyst lightly to moderately encrusted; adherent branches with keel; no visible septa; zooecial diameter = 250-(339)-460 μm (SD_{14} = 59.0). Floatoblasts (Fig. 4*a*) and sessoblasts (Fig. 4*b*) long and narrow, and strongly asymmetric in lateral view; length of statoblast usually greater than twice the width. Dorsal surface of floatoblast flattened or slightly concave, dorsal fenestra very narrow; ventral surface convex, ventral fenestra long and oval; length/width ratio of both dorsal and ventral fenestrae greater than 2. Annulus covered with either a bronze or a silvery sheen. Statoblast length = 385-(443)-563 μm (SD_{20} = 51), width = 179-(200)-226 μm (SD_{20} = 42.9); dorsal fenestra length = 191-(232)-349 μm (SD_{16} = 35.5 μm), width = 54-(78)-128 μm (SD_{16} = 18); ventral fenestra length = 277-(290)-378 μm (SD_{20} = 39), width 96-(138)-163 μm (SD_{20} = 17.3).

Sessoblasts broadly oval, almost rectangular (Fig. 4*b*); frontal valve covered with irregular tubercles, sometimes appearing reticulated; lamella sclerotized, distinctly reticulated, and with wavy, serrated margins; sessoblast length (including lamella) = 445-(504)-582 μm (SD_{20} = 30.7), width (including lamella) = 236-(273)-315 μm (SD_{20} = 20.3); lamella width = 32-(67)-97 μm (SD_{20} = 11.2).

Taxonomy

The zooecia of *P. fruticosa* resemble those of *Fredericella indica*, but both species are easily distinguished by statoblast morphology. The combined statoblast characteristics (large length/width ratio, strong asymmetry of floatoblast and sessoblast, narrow fenestra on dorsal floatoblast valve) distinguish *P. fruticosa* from all other plumatellid species.

Some authors (e.g., Bushnell 1965; Smith 1991) consider the presence of serrated zooecial branches in *P. fruticosa* to be taxonomically important; the serrations result from the budding and successive shedding of newly formed zooids. This feature is not found in Quebec specimens, and is apparently uncommon in North America (Bushnell 1968).

Habitat and general ecology

Plumatella fruticosa was collected from the outflows of two Quebec lakes (water temperature 10°C, pH 6.1–6.3), where it was associated with other bryozoans, *Cristatella mucedo* and *F. indica*, and sponges *Spongilla lacustris* and *Trochospongilla pennsylvanica*. It was also found in a northern New Brunswick lake (Mecormack Lake) subjected to the following summer water quality conditions: temperature 18.5–21.5°C, pH 7.7–8.5, calcium hardness 7.7–8.1 mg/L, magnesium hardness 1.0–1.2 mg/L, potassium 0.3 mg/L, sodium 1.6–1.7 mg/L; also occurring in this lake were *Plumatella fungosa* and *P. repens*.

Plumatella fruticosa occurs predominantly in cold, Holarctic lakes and streams, especially in montane regions (Bushnell 1968), in slightly acidic and often highly colored waters (Bushnell 1966, 1968).

Distribution in eastern Canada

Quebec, New Brunswick.

Plumatella fruticosa is recorded in eastern Canada for the first time. The only other Canadian record of this species is from Vancouver Island (Carl 1943). *Plumatella fruticosa* likely occurs throughout the Great Lakes region; it has been reported from Green Island (U.S. possession) in the southwestern basin of Lake Erie (Rogick 1935), and from scattered locations in northern Michigan (Bushnell 1965). The species is known from Lac Demarest (AR145B) and Lac Minette, Parc Mastigouche, Quebec (46°26′N, 73°09′W), and from Mecormack Lake (AR162B), Restigouche Co., New Brunswick (48°00′N, 66°52′W).

Plumatella fungosa Pallas, 1768
Figs. 5, 15*i*, 15*r*, 15*s*

Plumatella fungosa White, 1915

Description of eastern Canadian specimens

Mature colony compact (Fig. 5*a*); branches fused throughout their length; often growing as an erect honeycomb-like or fungoid mass, sometimes reaching 6 cm in thickness (White 1915). Ectocyst brown or colorless, transparent to opaque, typically only lightly encrusted; conspicuous dark septa usually present; adherent branches may be weakly keeled. Floatoblasts (Figs. 5*c*, 5*e*, 15*i*) are round to oval, and strongly asymmetric in lateral view because of an inflated ventral capsule, which is often pointedly convex (Fig. 15*i*); floatoblast length = 270-(327)-388 μm (SD_{40} = 17.5), width = 211-(240)-273 μm (SD_{40} = 11.6); dorsal fenestra length = 106-(154)-202 μm (SD_{40} = 11.9), width = 100-(147)-183 μm, (SD_{40} = 13.8); ventral fenestra length = 167-(216)-252 μm (SD_{40} = 12.0), width = 139-(182)-227 μm (SD_{40} = 13.3).

Sessoblasts are round to oval (Figs. 5*d*, 15*s*), normally with a wide lamella; sessoblast length (including lamella) = 391-(445)-502 μm (SD_{14} = 23.3), width (including lamella) = 277-(335)-411 μm (SD_{14} = 30.2), lamella width = 29-(46)-64 μm (SD_{14} = 6.0). The surface of both the sessoblast and the floatoblast is covered with a raised reticulation and intersitial tubercles (Mundy 1980; Geimer and Massard 1986), very similar to those that occur on the statoblasts of *Plumatella repens* and *P. orbisperma* (Ricciardi and Wood 1992), which are discernible only under high magnification.

Taxonomy

The conspicuous fungoid mass of adherent zooids is a characteristic feature of *P. fungosa*; only *P. casmiana* and *P. emarginata* occasionally produce similar colonies. In such cases, statoblast features may easily distinguish the species.

Habitat and general ecology

Plumatella fungosa is found in stagnant, eutrophic waters (Bushnell 1966; Geimer and Massard 1986; Wood 1989), primarily in shaded areas. Eastern Canadian specimens were found in the following water quality conditions; temperature 15–23°C, pH 7.1–8.6, calcium hardness 7.7–78.0 mg/L, magnesium hardness 1.0–70.0 mg/L. *Plumatella fungosa* grows very prolifically, with recorded biomasses of up to 1600 g/m^2 (Jonasson 1963; Job 1976), and plays a significant role in the removal of nitrogen (Job 1976) and the release of phosphorus (Sorensen et al. 1986) in the water column of small lakes. It can tolerate highly polluted conditions, including exposure to extensive heavy metal and PCB contamination (Henry et al. 1989).

The dense and rapid growth of encrusting colonies of *P. fungosa* obstruct the cooling circuits of power stations, where they may cause significant operating problems (Pourcher and d'Hondt 1987; Aprosi 1988). Bryozoans colonize the cooling circuits when the pumps are not operating, particularly when water temperatures are 25–30°C; intensive production of statoblasts leads to widespread proliferation and accumulation of colonies within the circuits (Aprosi 1988). In controlled experiments, Aprosi (1988) found that colonies detach from pipes when subjected to a water velocity of 0.9 m/s.

In lentic areas of the St. Lawrence River, *P. fungosa* is often found growing in close contact with zebra mussels (*Dreissena polymorpha*).

Distribution in eastern Canada

Ontario (White 1915), Quebec, New Brunswick, Prince Edward Island.

The only published record of *Plumatella fungosa* in eastern Canada is from Georgian Bay, Ontario (White 1915) but this in no way reflects the actual distribution of the species. We have obtained a specimen (AR161B) from Wolf Island (St. Lawrence River) near Kingston, Ontario. In Quebec, we collected specimens from the following locations: Lac Macdonald and Lac Carruther (AR60B), near Lachute; Ile Perrot (AR105B, AR106B) and Lac St-Louis (AR128B, AR129B), near the Island of Montréal; Lac Hertel (AR139B) near Mont St-Hilaire; and Parc d'Avignon (AR154B) near Huntington. The species was particularly abundant in Lac St. Louis (St. Lawrence River). Elsewhere, *P. fungosa* occurs in Mecormack Lake, Restigouche Co., N.B. (AR163B), and in ponds at Southport, P.E.I. (AR141B).

Plumatella orbisperma Kellicott, 1882
Figs. 6, 15*e*, 15*f*

Plumatella orbisperma Ricciardi and Wood, 1992

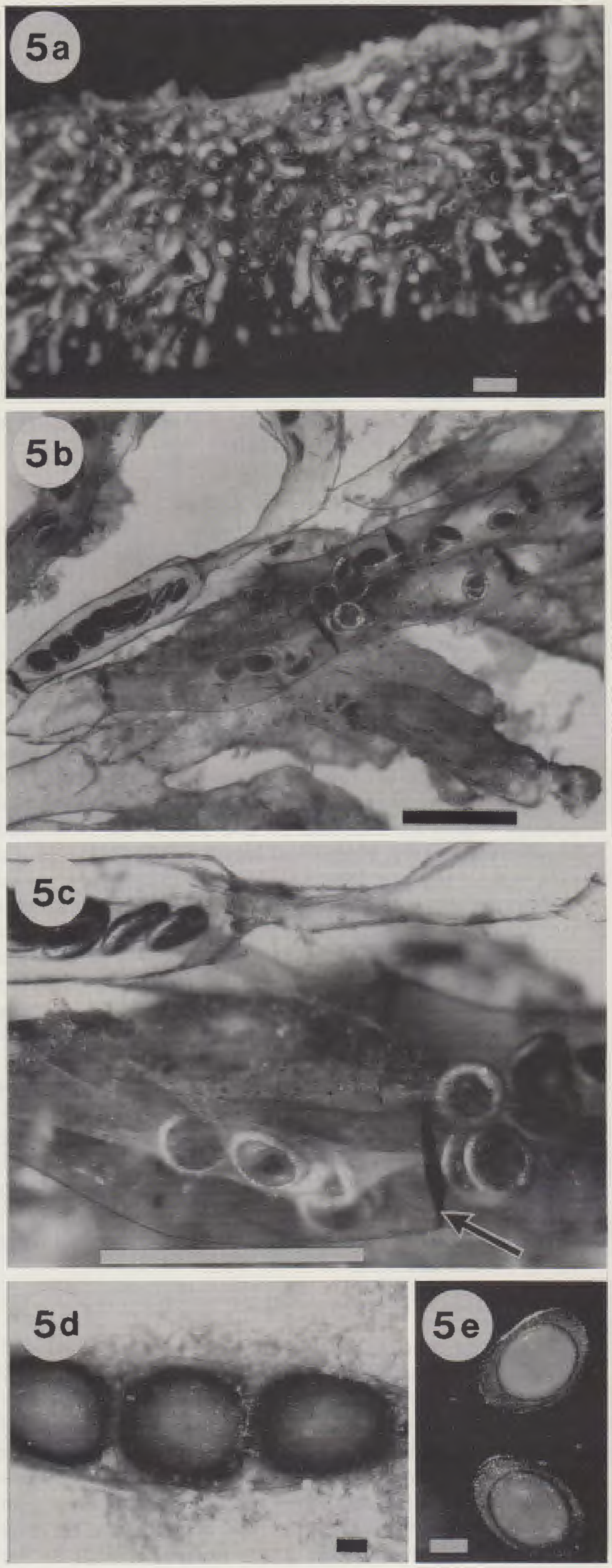
Description of eastern Canadian specimens

Colony dichotomously branched and mostly recumbent; polypides in erect clusters of 2–7, usually connected by only a narrow stolon. Ectocyst soft, gelatinous, transparent, swollen, without keeling or encrustation; septa absent. Floatoblasts circular (length/width ratio = 1.07–1.11), biconvex, and generally symmetrical in lateral view; ventral capsule inflated and pointed (Figs. 6*c*, 15*e*, 15*f*). Annulus is thin on both the dorsal and ventral surfaces; average dorsal and ventral annulus widths are less than 18 and 11% of the floatoblast length, respectively. Floatoblast length = 320-(332)-336 μm (SD_6 = 6.1), width = 288-(300)-304 μm (SD_6 = 6.1); dorsal fenestra length = 192-(213)-240 μm (SD_6 = 17.7), width = 192-(203)-208 μm (SD_6 = 7.5; ventral fenestra length = 240-(257)-272 μm (SD_6 = 9.7), width = 224-(232)-256 μm (SD_6 = 12.2). Sessoblasts circular; sessoblast length (including lamella) = 528-(549)-576 μm (3 counts), width (including lamella) = 410-(429)-448 μm (3 counts); average length/width ratio = 1.2.

The dorsal and ventral fenestrae of the floatoblast and the frontal valve of the sessoblast are covered with tubercles, which are prominent near the periphery but disappear toward the center. Tubercles on the fenestrae are enclosed in a lightly raised reticulation visible with scanning electron microscopy (Ricciardi and Wood 1992), very similar to that which occurs on the statoblasts of certain other *Plumatella* species (Wood 1979; Geimer and Massard 1986; Smith 1992).

Taxonomy

Plumatella orbisperma appears to be closely allied with *Plumatella repens*, *P. fungosa*, *P. recluse*, and *Hyalinella vaihiriae* (Ricciardi and Wood 1992; Smith 1992). The soft, swollen ectocyst resembles that of *Hyalinella punctata*, but the round floatoblasts are distinctive, and sessoblasts are absent in *H. punctata*. The lateral symmetry of the floatoblast and lack of zooecial septa easily separate *P. orbisperma* from hyaline forms of *P. fungosa*. The combination of erect, clustered polypides and the round floatoblast with its thin annulus and pointedly convex ventral capsule distinguish *P. orbisperma* from hyaline forms of *P. repens*. The recently described *P. recluse* has round floatoblasts, but differs from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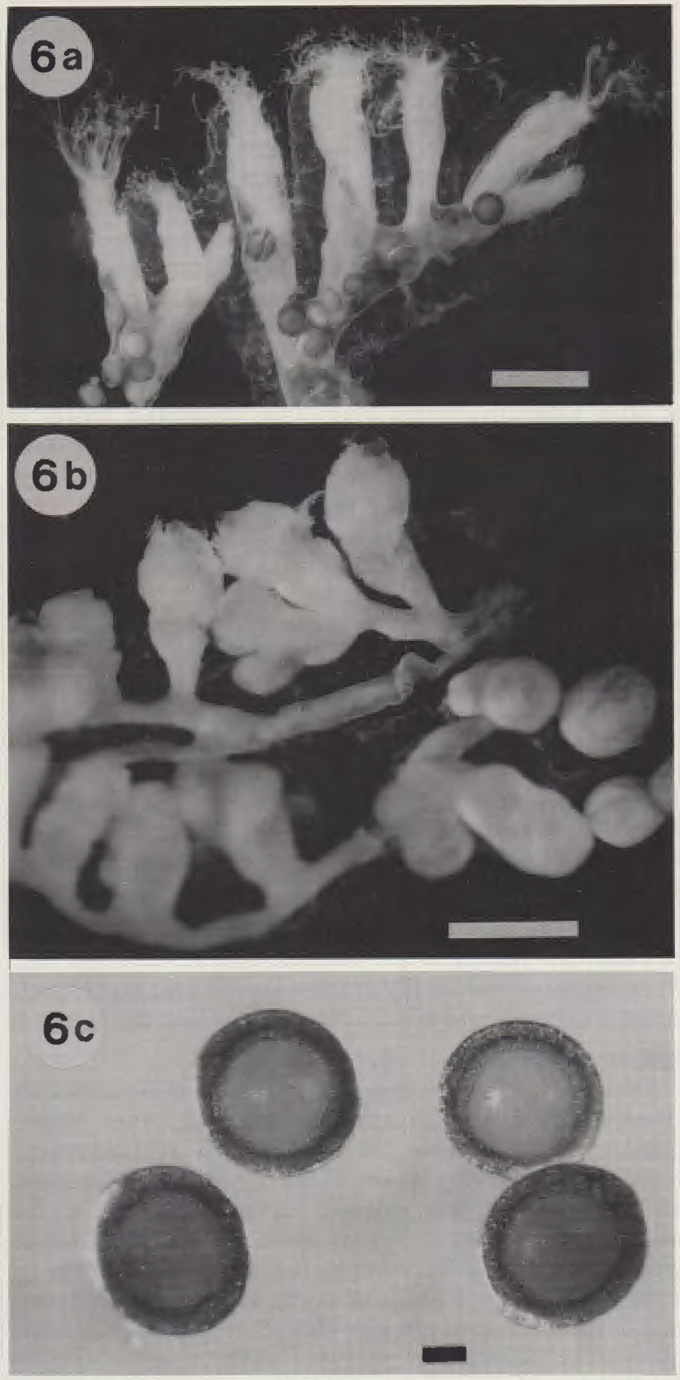
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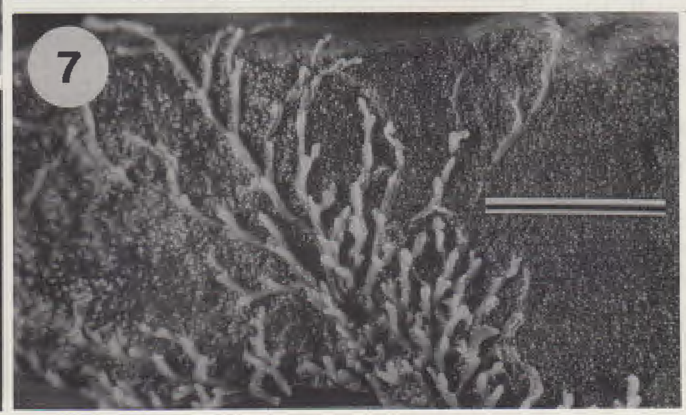
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P. orbisperma primarily by its broadly oval sessoblast (mean length/width ratio = 1.3) and its restricted occurrence in weakly acidic (pH 5.5–6.0) habitats (Smith 1992).

A plumatellid bryozoan (ROM K-4) collected at Lake Nipissing, Ontario, had sessoblasts and a colonial form quite similar to that of *P. orbisperma*, but no floatoblasts were present for confirmation.

Habitat and general ecology

Plumatella orbisperma has thus far only been found in calm, standing waters (primarily ponds) rich in macrophytes, algae, and organic material, with a mean pH of 7.3 (Bushnell 1966, 1974).

Distribution in eastern Canada

Ontario (Ricciardi and Wood 1992).

In Canada, *Plumatella orbisperma* is known only from Go Home Lake, Georgian Bay, Ontario (ROM K-13), but the species may occur in eutrophic ponds and lakes scattered throughout the Great Lakes region.

Plumatella repens (Linnaeus, 1758)
Figs. 7, 15*g*, 15*h*

Plumatella arethusa Osler, 1883; Davenport 1904
Plumatella repens Odell, 1899; Huntsman 1913; White 1915; Rogick 1937; Ricciardi and Lewis 1991

Description of eastern Canadian specimens

Colony recumbent and dendritic (Fig. 7), forming large, flat, spreading masses; in rare cases, branches closely appressed and partially fused; ectocyst translucent to opaque, colorless or reddish brown, normally unencrusted, sometimes lightly (never heavily) encrusted; a faint keel may be present; zooids normally filled with numerous floatoblasts. Floatoblasts round to broadly oval (Figs. 15*g*, 15*h*); valves symmetric in lateral view; minute tubercles interstitially enclosed in a raised reticulation (visible under high magnification) cover the dorsal and ventral fenestrae, and prominent where annulus and fenestra meet (Wood 1979; Geimer and Massard 1986). Dorsal fenestra round or slightly truncated; its size varies considerably among specimens. Ventral fenestra circular and relatively large. Floatoblast length = 312-(367)-391 μm (SD_{20} = 21.5), width = 237-(251)-270 μm (SD_{20} = 7.4); dorsal fenestra length = 128-(147)-157 μm (SD_{20} = 10.3), width = 137-(149)-165 μm (SD_{20} = 10.0); ventral fenestra length = 206-(227)-241 μm (SD_{20} = 13.3), width = 191-(199)-209 μm (SD_{20} = 7.0).

Sessoblasts round to oval (identical to Figs. 15*r*, 15*s*); lamella wide and usually parallel to the substrate; tubercles on the frontal valve are enclosed in a faint reticulation similar to that which appears on the floatoblast, but only discernible under scanning electron microscopy. Sessoblast length (including lamella) = 347-(462)-474 μm (SD_{10} = 16.8), width (including lamella) = 336-(364)-392 μm (SD_{10} = 40.0); lamella width = 49-(52)-54 μm (SD_{10} = 2.4).

Taxonomy

The absence of septa, the generally unfused branches, and the symmetric floatoblast valves of *Plumatella repens* distinguish it from *P. fungosa*. Hyaline forms of *P. repens* have a clear transparent ectocyst, and may produce a round floatoblast with a thin dorsal and ventral annulus. These forms of *P. repens* are distinguished from *P. orbisperma* by the following differences: (*i*) the polypides of *P. repens* are not arranged into erect clusters, unlike those of *P. orbisperma*; (*ii*) the ventral floatoblast capsule is not inflated and pointed as in *P. orbisperma*; (*iii*) the floatoblast annulus, especially on the dorsal surface, is not as thin as that of *P. orbisperma*. On average, the dorsal annulus width is greater than 20% of the floatoblast length in *P. repens* but less than 18% in *P. orbisperma* (Ricciardi and Wood 1992).

Habitat and general ecology

Colonies of *Plumatella repens* occurred primarily in lentic habitats, from early May until late October, and were collected from the following water quality conditions: temperature 16–23°C, pH 7.2–8.5, calcium hardness 7.7–120.0 mg/L, magnesium hardness 1.0–90.0 mg/L. *Plumatella repens* is most often found associated with the bryozoans *P. fungosa P. emarginata*, and *P. reticulata* and the sponge *Eunapius fragilis*, as well as larval caddisflies *Ceraclea nepha* (Trichoptera: Leptoceridae), which are common predators of *P. repens* in southern Quebec (Ricciardi and Lewis 1991). Spreading colonies of *P. repens* are found growing on a variety of substrates, including macrophytes, *Vallisneria americana*, *Nymphaea tuberosa*, *Nuphar variegatum*, *Pontederia* sp., and *Potamogeton* sp. Like most bryozoans, *P. repens* grows preferentially on the underside of submerged surfaces, and thus escapes fouling from periphyton, seston, and its own fecal wastes (Raddum 1981).

Malchow (1978) determined that minute concentrations of chemical pollutants (heavy metals, pesticides, dyes) cause enzyme deactivation and cell damage in *P. repens*, and advocated the use of this bryozoan as an indicator of such pollutants in the laboratory and the field.

Distribution in eastern Canada

Ontario (Odell 1899; Davenport 1904; Huntsman 1913; White 1915; Rogick 1937), Quebec (Ricciardi and Lewis 1991), New Brunswick.

We have identified a specimen of *P. repens* from Mecormack Lake, Restigouche Co., New Brunswick (AR164B), which represents the first collection of this species from the province.

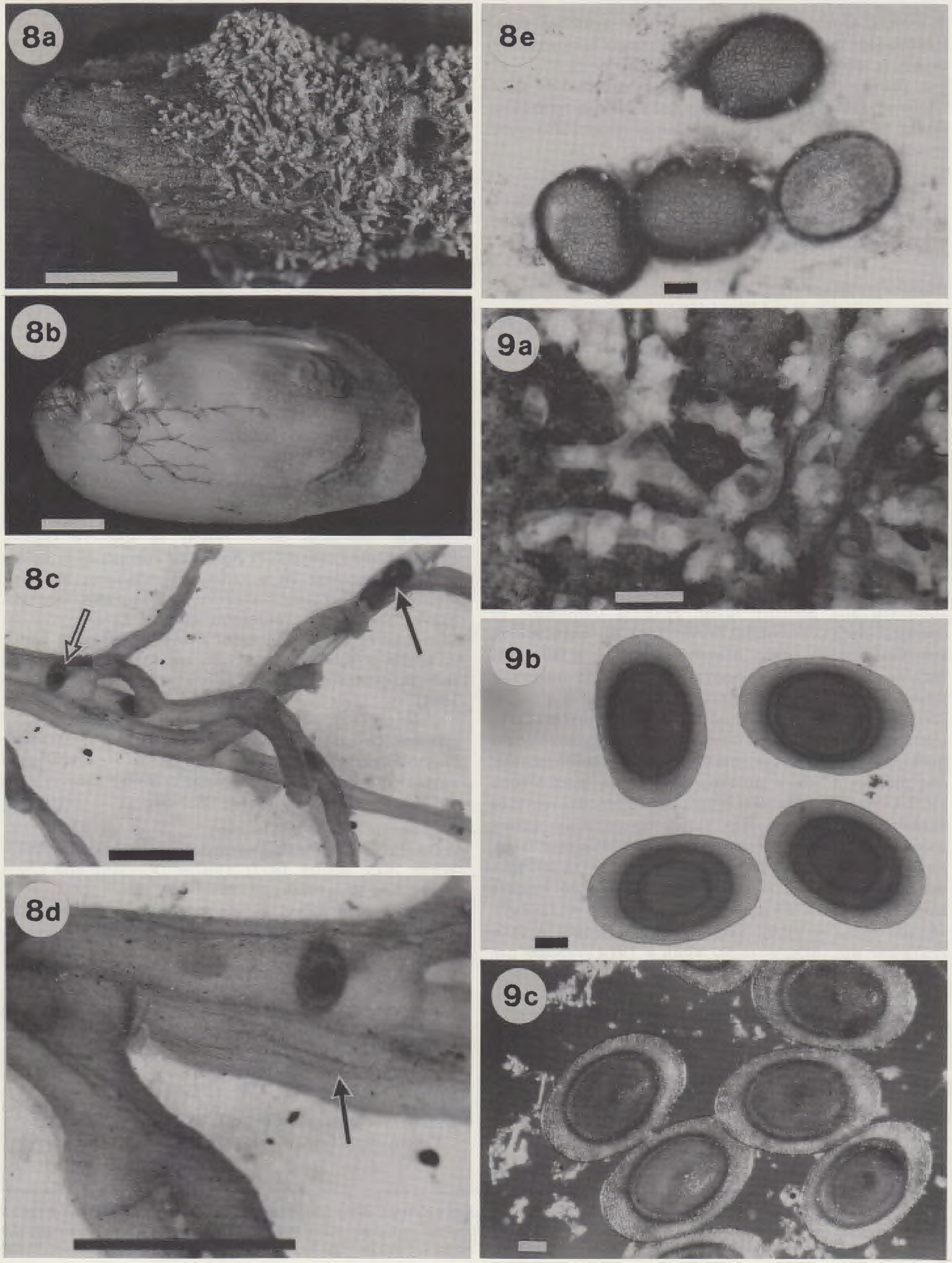
Plumatella repens is widespread and common in North America (Bushnell 1973), and is expected to occur throughout eastern Canada.

Plumatella reticulata Wood, 1988
Figs. 8, 15*m* 15*n*, 15*t*

Description of eastern Canadian specimens

Colony recumbent, with upright zooecial tips (Figs. 8*a*-8*d*).

FIG. 5. *Plumatella fungosa*. (*a*) Colony on twig. (*b*) Hyaline colony packed with floatoblasts. (*c*) Close-up of zooids, showing floatoblasts (arrow points to septum). (*d*) Sessoblasts. (*e*) Floatoblasts. FIG. 6. *Plumatella orbisperma*. (*a*) Colony with floatoblasts. (*b*) Colony, showing erect polypides connected by stolon. (*c*) Floatoblasts. FIG. 7. *Plumatella repens* colony. Scale bars: 1 mm for Figs. 5*a*–5*c*, 6*a*, 6*b*; 0.1 mm for Figs. 5*d*, 5*e*, 6*c*; 10 mm for Fig. 7.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8e
8b
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9b
8d
9c

Ectocyst dark brown, heavily sclerotized, translucent to opaque, lightly to heavily encrusted, distinctly keeled. Dark, conspicuous septa occur at the junction of each branch. Zooecial tips are furrowed. Crowded branches may be fused along a portion of their length. Floatoblasts oval to broadly oval, valves approximately symmetrical in lateral view, float coverage on dorsal surface far more extensive than on ventral surface (Figs. 15*m*, 15*n*). Floatoblast length = 273-(348)-389 μm (SD_{34} = 17.0), width = 177-(209)-225 μm (SD_{34} = 22); dorsal fenestra length = 67-(123)-136 μm (SD_{34} = 17.3), width = 55-(103)-125 μm(SD_{34} = 20.8); ventral fenestra length = 112-(146)-211 μm (SD_{17} = 31.0), width = 108-(127)-156 μm (SD_{34} = 21.0).

Sessoblasts oval; frontal valve of mature sessoblasts is marked by thick, dark reticulating ridges (Figs. 8*e*, 15*t*), clearly visible under low magnification (40×). Sessoblast length (including lamella) = 340-(397)-460 μm, (SD_{10} = 31.5), width (including lamella) = 208-(278)-328 μm (SD_{10} = 33.0), lamella width = 23-(33)-40 μm (SD_{10} = 6).

Taxonomy

The distinctly reticulated sessoblast and the symmetric floatoblast valves clearly distinguish *Plumatella reticulata* from its congener *P. emarginata*, which is otherwise similar in appearance. Identification may be complicated in that the reticulation is not always visible on immature sessoblasts, i.e., its development is apparently a function of age; young colonies will usually have smooth or only faintly reticulated sessoblasts. A few unreticulated sessoblasts are often found in the extremities (the younger portion) of a mature colony, whereas typical reticulated sessoblasts are found near the central (older) portion of the colony.

A previously undescribed form of *P. reticulata* (AR104B) found in the lower Ottawa River (Quebec) has floatoblasts that are laterally curved or bent and therefore appear asymmetrical in lateral view; in this colony there are no floatoblasts of the normal type, but typical sessoblasts are present in abundance. Normal *P. reticulata* colonies occur in the same habitat.

Habitat and general ecology

Plumatella reticulata occurs primarily in calm alkaline waters. It has been collected from the following range of water quality conditions: temperature 20–26°C, pH 7.5–9.4, calcium hardness 16–63 mg/L, magnesium hardness 30–65 mg/L. Colonies of *P. reticulata* are sometimes overgrown by freshwater sponges (*Eunapius fragilis*, *Spongilla lacustris*), are often associated with other bryozoans (*Fredericella indica*, *Paludicella articulata*), and have Aufwuchs communities predominantly composed of attached tubicolous rotifers (*Limnias* spp.) and ciliate protozoans (*Vorticella* sp.).

Distribution in eastern Canada

Ontario (Wood 1988), Quebec.

In Ontario, this species has been found at East Sister Island in the western basin of Lake Erie (Wood 1988) and in the Grand River, Caledonia (ROM K-5). In Quebec, this species is abundant in the Ottawa and St. Lawrence rivers; it is also found in Lac Carruthers (ca. 45°40′N, 74°20′W) in the Laurentian region, which represents the northern limit of its known range.

Hyalinella punctata (Hancock, 1850)
Figs. 9, 15*o*–15*q*

Plumatella punctata Davenport, 1904; Huntsman 1913; White 1915

Hyalinella punctata Ricciardi and Lewis, 1991

Description of eastern Canadian specimens

Young colonies consist of adherent stoloniferous strings of contiguous zooids; mature colonies consist of flat, compact, gelatinous masses formed by the agglutination of zooecial branches; compact colonies may have at least one long, linear branch. Ectocyst soft, swollen, gelatinous, transparent, colorless or yellowish, unencrusted, without septation or keeling; minute white spots (present in over 50% of Quebec specimens) are often visible on the ectocyst of younger portions of the colony. Floatoblasts (Figs. 9*b*, 9*c*, 15*o*–15*q*) are large, broadly oval, rounded or truncated at the poles, and asymmetrical in lateral view; dorsal and ventral fenestrae are broadly oval; the outline of the floatoblast capsule is clearly visible through the annulus; a conspicuous central nodule (Fig. 9*c*) occurs on the floatoblast ventral fenestra in about 80% of Quebec specimens and in a specimen from Warren Lake, Nova Scotia, but not all floatoblasts in a specimen may bear it. Floatoblast length = 542-(586)-617 μm (SD_{40} = 15), width = 315-(408)-411 μm (SD_{40} = 13); capsule length = 365-(382)-403 μm (SD_{10} = 12), width = 270-(281)-295 μm (SD_{10} = 8). Sessoblasts are absent.

Taxonomy

Sessoblasts are generally not produced by *Hyalinella* colonies (Massard and Geimer 1991; Ricciardi and Wood 1992). Some European authors (e.g., Lacourt 1968) report sessoblasts in *H. punctata*, but no confirmed specimens bearing sessoblasts are known to exist. These reports are probably based on erroneous identifications of hyaline forms of *Plumatella repens* (Toriumi 1972; Massard and Geimer 1991).

The occurrence of a central nodule on the ventral floatoblast capsule is of unknown taxonomic significance and may simply be ecophenotypic. A similar structure has been observed in only one other eastern Canadian species: 10% of the floatoblasts in a single specimen of *P. repens* (AR42B) from a creek on Ile Perrot, Quebec, had a similar nodule. Rogick (1940) did not indicate such a structure in her detailed drawings of *H. punctata* statoblasts from New York State. Smith (1988) mentioned a "centrally located circular region" on the floatoblast capsules of *H. punctata* and *P. fungosa*, and Wood (1979) illustrated a small raised central tubercle on the ventral capsular valve of *P. emarginata*, but these structures are rare and apparently not as pronounced as those in specimens of *H. punctata* from Quebec.

Habitat and general ecology

In southern Quebec, *H. punctata* has been collected from the following water quality conditions: temperature 14–26°C,

FIG. 8. *Plumatella reticulata*. (*a*) Colony on wood. (*b*) Colony on inner surface of valve of unionid clam. (*c*) Close-up of zooids occupied by statoblasts (white arrow points to floatoblast; dark arrow points to sessoblasts). (*d*) Close-up of keel (arrow). (*e*) Sessoblasts. FIG. 9. *Hyalinella punctata*. (*a*) Close-up of colony. (*b*) Floatoblasts. (*c*) Floatoblasts with central nodule on fenestra. Scale bars: 10 mm for Figs. 8*a*, 8*b*; 1 mm for Figs. 8*c*, 8*d*, 9*a*; 0.1 mm for Figs. 8*e*, 9*b*, 9*c*.

pH 7.4–9.0, calcium 20–78 mg/L, magnesium 20–70 mg/L. Bushnell (1974) describes *H. punctata* as having a preference for alkaline, mesotrophic, or eutrophic habitats, and sometimes occurring in highly alkaline waters (pH > 9.0). Wood (1991) associates *H. punctata* with very still waters; however, luxuriant colonies occur in great abundance in several rapid streams in southern Quebec. The species is abundant in lake outflows and tributaries of the Chateauguay River, where colonies blanket the underside of rocks and submerged tree branches in densities exceeding 900 cm^2/m^2 of hard substrate. In southern Quebec, colonies first appear in early June when the water temperature exceeds 20°C. In late July, small (<1 cm) linear strings of zooids are found in sudden abundance (20–30 colonies/m^2) on the underside of rocks and branches when water temperatures range from 23 to 26°C. These colonies consistently lack the statoblast valves that are normally present at the point of origin of a colony, suggesting that the colonies (often too spatially separated to have resulted from fission) are derived from larvae and that sexual reproduction and larval release occur in early July. Statoblasts are formed in August.

Distribution in eastern Canada

Ontario (Davenport 1904; Huntsman 1913; White 1915), Quebec (Ricciardi and Lewis 1991), Nova Scotia.

We have collected a specimen (AR167B) at Warren Lake, Cape Breton Highlands National Park, Nova Scotia. This species is widely distributed in eastern North America (Bushnell 1973) and should occur throughout eastern Canada.

FAMILY Lophopodidae
Lophopodella carteri (Hyatt, 1866)
Fig. 10

Lophopodella carteri Ricciardi and Lewis, 1991

Description of eastern Canadian specimens

Colony yellow, gelatinous, transparent, globular and lobate, loosely attached to the substrate, rarely greater than 1 cm in diameter (Fig. 10*a*). Ectocyst soft, without any encrustation. Polypides withdraw into a common coelomic cavity.

Only one type of statoblast is produced (Fig. 10*b*). It is broadly oval and saddle-shaped, with a series of 8–13 spiny marginal projections at both poles; statoblast length (with spines) = 1150-(1121)-1126 μm (SD_{20} = 30), width = 904-(948)-979 μm (SD_{20} = 20); spine length = 200-(264)-357 μm (SD_{20} = 20).

Taxonomy

As Wood (1989) noted, the unpigmented mouth region of the *L. carteri* lophophore distinguishes young colonies (without statoblasts) from those of *Pectinatella magnifica*, which has a conspicuous red pigment. The yellowish coloration and lobate form of *L. carteri* colonies separate them from similar young colonies of *Cristatella mucedo*.

Habitat and general ecology

Lophopodella carteri is apparently restricted to alkaline waters (Bushnell 1966). In southern Quebec the species has been recorded from the following water quality conditions: temperature 9–26°C, pH 7.4–9.4, calcium hardness 18–30 mg/L, magnesium hardness 20–30 mg/L. Colonies are often found in association with *C. mucedo* and *P. magnifica*, and occur in abundance on the stems and leaves of macrophytes (e.g., *Ceratophyllum demersum*, *Elodea canadensis*, *Najas flexilis*, *Nuphar variegatum*, *Nymphaea tuberosa*, *Vallisneria americana*) in greater frequency than any other bryozoan.

The coelomic fluid of *L. carteri* colonies is highly toxic to certain fish (Tenney and Woolcott 1964) and larval salamanders (Collins et al. 1966); the fluid damages the gill epithelium. The toxin may somehow be discharged into the water to discourage predation by fish. However, several mature *L. carteri* statoblasts were found in the stomach of a 23-g living yellow perch (*Perca flavescens*) collected from the St. Lawrence River (A. Ricciardi, unpublished data). In southern Quebec, the major predators of *L. carteri* include larval caddisflies *Ceraclea nepha* and *C. submacula*, and probably turbellarians (*Dugesia tigrina* and *Procotyla fluviatilis*). Extensive predation of laboratory colonies by the microturbellarian *Stenostomum* sp. (Turbellaria: Catenulida) has been observed (Ricciardi and Lewis 1991).

The Ottawa River population of *L. carteri* typically forms statoblasts in early July when water temperatures exceed 20°C. Colonies reach their greatest abundance in midsummer in water temperatures of 23–25°C. A population density of 230 colonies/m^2 occurred in a stagnant pool (temperature 25°C, calcium 20 mg/L, magnesium 20 mg/L, pH 9.4) that formed between Ile Claude and Ile Bellevue in July 1991 when a branch of the lower Ottawa River was interrupted during a period of bridge construction.

Several living lophopodid colonies were found on unionid mussels (*Elliptio complanata*) collected from the St. Lawrence River (at Iles de Boucherville, near the Island of Montréal), at a water temperature of 9°C, on November 3, 1991. These small (<5 mm diameter), yellowish, lobate colonies had features typical of *L. carteri*, but lacked statoblasts. The lowest recorded temperature at which living colonies have been collected is 8°C (Tenney and Woolcott 1962).

Distribution in eastern Canada

Quebec (Ricciardi and Lewis 1991).

Lophopodella carteri is uncommon and known from scattered locations in eastern North America, in which its range has been steadily expanding (Bushnell 1973; Smith 1985; Wood 1989; Ricciardi and Lewis 1991). The species has a wide distribution in southeast Asia (Lacourt 1968) and was apparently introduced to the North American continent with imported aquatic plants in the early 1930s (Masters 1940). Statoblasts of *L. carteri* are capable of germination after being kept dry for up to 6 years (Oda 1959), or after passing through the digestive tracts of amphibians and ducks (Brown 1933). Transport of statoblasts by migratory birds (e.g, on feathers, in mud on the feet or bill, or in the gut) has been implicated as a dispersal mechanism for this and other bryozoan species (Abricosov and Kosova 1963; Bushnell 1973).

In eastern Canada, *L. carteri* is known only from the lower Ottawa River (Ricciardi and Lewis 1991) and St. Lawrence River, near the Island of Montréal; this area represents the northern limit of its North American range. Previously unidentified specimens collected from the lower Ottawa River (by D.J. Lewis, McGill University) indicate that the species has been present there since at least 1982.

FAMILY Pectinatellidae
Pectinatella magnifica (Leidy, 1851)
Fig. 11

Pectinatella magnifica Goadby and Bovell, 1855; Osler 1883;

Odell 1899; Huntsman 1913; White 1915; Geiser 1934; Tanton 1935; Judd 1950; Ricciardi and Lewis 1991

Description of eastern Canadian specimens

Colony gelatinous, transparent; young colonies small (1–3 cm diameter), irregular and lobed in outline; mature colonies occur as contiguous rosettelike patches over a common gelatinous base, and may grow into a large slimy gelatinous mass several centimetres in diameter. Lophophore bears a conspicuous red pigment around the mouth region. Statoblasts are of one type only, roughly circular, with a single row of 12–20 flattened, hooked spines around entire periphery (Fig. 11); statoblast diameter (including spines) = 1209-(1275)-1322 μm (SD_{20} = 32.6).

Taxonomy

No other bryozoan produces large, compound gelatinous colonies reaching several centimetres in diameter; Tanton (1935) and Judd (1950) reported colonies measuring 30–50 cm in diameter from various localities in Ontario. Young, individual colonies of *P. magnifica* may be distinguished from all other bryozoans by the red pigment on the mouth region of the lophophore.

Habitat and general ecology

Colonies of *P. magnifica* occur in lentic areas and lake outflows in eastern Canada from June to late October, normally produce statoblasts in July, and have been recorded from the following water quality conditions: temperature 9–26°C, pH 6.8–9.4, calcium hardness 10–130 mg/L, magnesium hardness 20–150 mg/L. *Pectinatella magnifica* is considered to be a warm-water species (Bushnell 1974). It has been reported that most colonies disintegrate at 12°C, and colonies with immature statoblasts are more resistant to lower temperatures (Brown 1933), but can endure a temperature of 10°C for only a "very brief time" (Brooks 1929). In general, large colonies decay in autumn with decreasing water temperatures. However, we have found small, active colonies abundant in water of 9°C at Lac Papineau (near Lachute, Quebec), which is the lowest recorded temperature at which the species has been collected. Every colony examined had mature statoblasts, and many had green material in their digestive tract, which suggested that they were still actively feeding. The adaptation of these colonies to low temperatures may indicate a speciation trend in northern populations of *P. magnifica*.

Pectinatella magnifica grows prolifically near impoundments (Davenport 1904; Geiser 1937; Wood 1989; Smith 1991) and in oxbow lakes (Geiser 1937; Joo et al. 1992). Large, compound colonies occur in warm, lentic habitats, predominantly in shallow, shaded areas. They are generally absent from turbid water, possibly because their larger surface area is more exposed to siltation (Cooper and Burris 1984). Occasional summer outbreaks of massive floating colonies are a nuisance, since they clog the intake screens of hydroelectric plants (Geiser 1937; Pennak 1989); these outbreaks appear to be correlated with hot, dry conditions in early summer (Geiser 1937).

Colonies of *P. magnifica* are commonly associated with *Cristatella mucedo* and the freshwater sponge *Eunapius fragilis*. They are preyed upon by the larval caddisfly *Ceraclea submacula* (Trichoptera: Leptoceridae). Crayfish (*Orconectes virilis*) feed upon *P. magnifica* colonies in the laboratory (A. Ricciardi, personal observation). Bushnell (1974) reports yellow perch predation of *Pectinatella* colonies and statoblasts.

In a tributary of the St. Lawrence River, massive *Pectinatella* colonies have been observed overgrowing and killing zebra mussels on rocky substrates, presumably by preventing normal feeding and gas exchange (D. B. Conn, Department of Biology, University of the South, Sewanee, Tennessee, personal communication).

Distribution in eastern Canada

Ontario (Goadby and Bovell 1855; Osler 1883; Odell 1899; Huntsman 1913; White 1915; Geiser 1934; Tanton 1935; Judd 1950), Quebec (Osler 1883; Ricciardi and Lewis 1991), New Brunswick (Osler 1883).

Pectinatella magnifica is very common and widely distributed in the eastern Canadian region.

FAMILY Cristatellidae

Cristatella mucedo Cuvier, 1798

Fig. 12

Cristatella ophidoidea Osler, 1883

Cristetella idae Odell, 1899

Cristatella mucedo Davenport, 1904; Hunstman 1913; White 1915; Rogick 1937; Ricciardi and Lewis 1991

Description of eastern Canadian specimens

Colony soft, transparent, gelatinous, smooth in outline, without lobes or branches, round when young, elongate and caterpillarlike when mature; usually no more than 1 cm in width and 2–5 cm in length, but occasionally much longer; attached loosely to the substrate by a flat base. Individual colonies sometimes share a thin gelatinous base. Mature colonies have 3 marginal rows of polypides enclosing a clear central space. Statoblasts are of one type (Fig. 12), circular, with a complete row of slender, cylindrical, hooked spines (18–38) on the periphery of each capsule; statoblast diameter (without spines) = 995-(1085)-1143 μm (SD_{25} = 56), spine length = 279-(373)-489 μm (SD_{15} = 54).

Taxonomy

Young, round colonies of *C. mucedo* are normally distinguished from those of *P. magnifica* by the red coloration on the *P. magnifica* lophophores. In some instances, this coloration is not clearly seen or has not yet developed in young colonies of *P. magnifica*, and an alternative method of identification must be used. The radially symmetrical arrangement of polypides in *C. mucedo* colonies separates them from the random arrangement of *P. magnifica* polypides (Smith 1993); colonies of *C. mucedo* consist of marginal rows of polypides enclosing a clear central space, which is discernible even in young colonies.

Habitat and general ecology

Cristatella mucedo was collected from the following water quality conditions: temperature 4–26°C, pH 5.9–9.4, calcium hardness 2–60 mg/L, magnesium hardness 10–64 mg/L. The species is clearly eurytopic with respect to temperature and pH tolerance. We found colonies in a pH of 5.9 in Lake Sir John (near Lachute, Quebec, September 15, 1990), and in a temperature of 4°C and pH of 6.1 at the outflow of Lac St. Bernard, in Parc Mastigouche, Quebec (November 10, 1991). To our knowledge, these lower limits of temperature (4°C) and pH (5.9) are the lowest recorded for the species (cf. Bushnell 1966, 1968, 1974). Bushnell (1966) collected colonies in water temperatures of 6–32°C, and pH as high as 9.8.

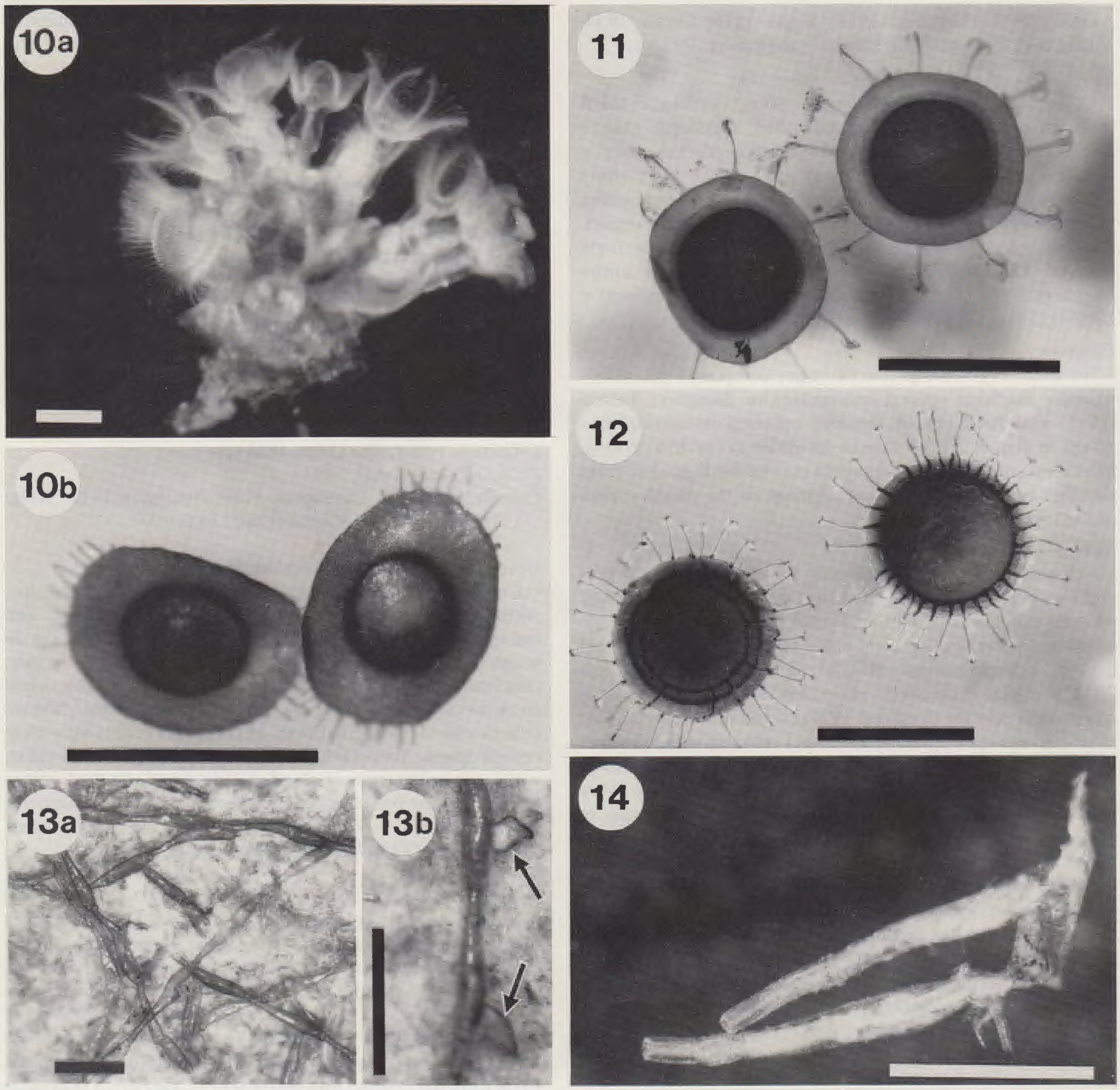

FIG. 10. *Lophopodella carteri*. (*a*) Colony, showing expanded lophophores. (*b*) Statoblasts. FIG. 11. *Pectinatella magnifica* statoblasts. FIG. 12. *Cristatella mucedo* statoblasts. FIG. 13. *Paludicella articulata*. (*a*) Colony. (*b*) Hibernacula (arrows). FIG. 14. Two zooids of *Pottsiella erecta*. Scale bars = 1 mm.

In southern Quebec, *C. mucedo* is found from late May until mid-November; statoblasts are usually produced in late June. Colonies of *C. mucedo* are most often associated with *P. magnifica* and the sponges *Eunapius fragilis* and *Ephydatia muelleri*. The larval caddisfly *Ceraclea nepha* (Trichoptera: Leptoceridae) is a predator of *C. mucedo* and uses its statoblasts as case-building material (Ricciardi and Lewis 1991). Snails (e.g., *Amnicola limosa*, *Gyraulus circumstriatus*, *Helisoma* spp.) commonly graze among colonies and may also be important predators. Stomachs of channel catfish (*Ictalurus punctata*) from the St. Lawrence River have been found to contain statoblasts of *C. mucedo*, but these may have been ingested with plant material (A. Ricciardi, unpublished data).

Cristatella mucedo is sensitive to micromolar concentrations of copper ions (Mundy 1981). However, we have found several mature colonies growing on corroded iron plates. The relatively thick ectocyst on the flat colony base may allow this bryozoan to occupy substrates that are inhospitable to other colonial organisms.

Distribution in eastern Canada

Ontario (Osler 1883; Odell 1899; Huntsman 1913; White 1915; Rogick 1937), Quebec (Osler 1883; Ricciardi and Lewis 1991), New Brunswick, Newfoundland.

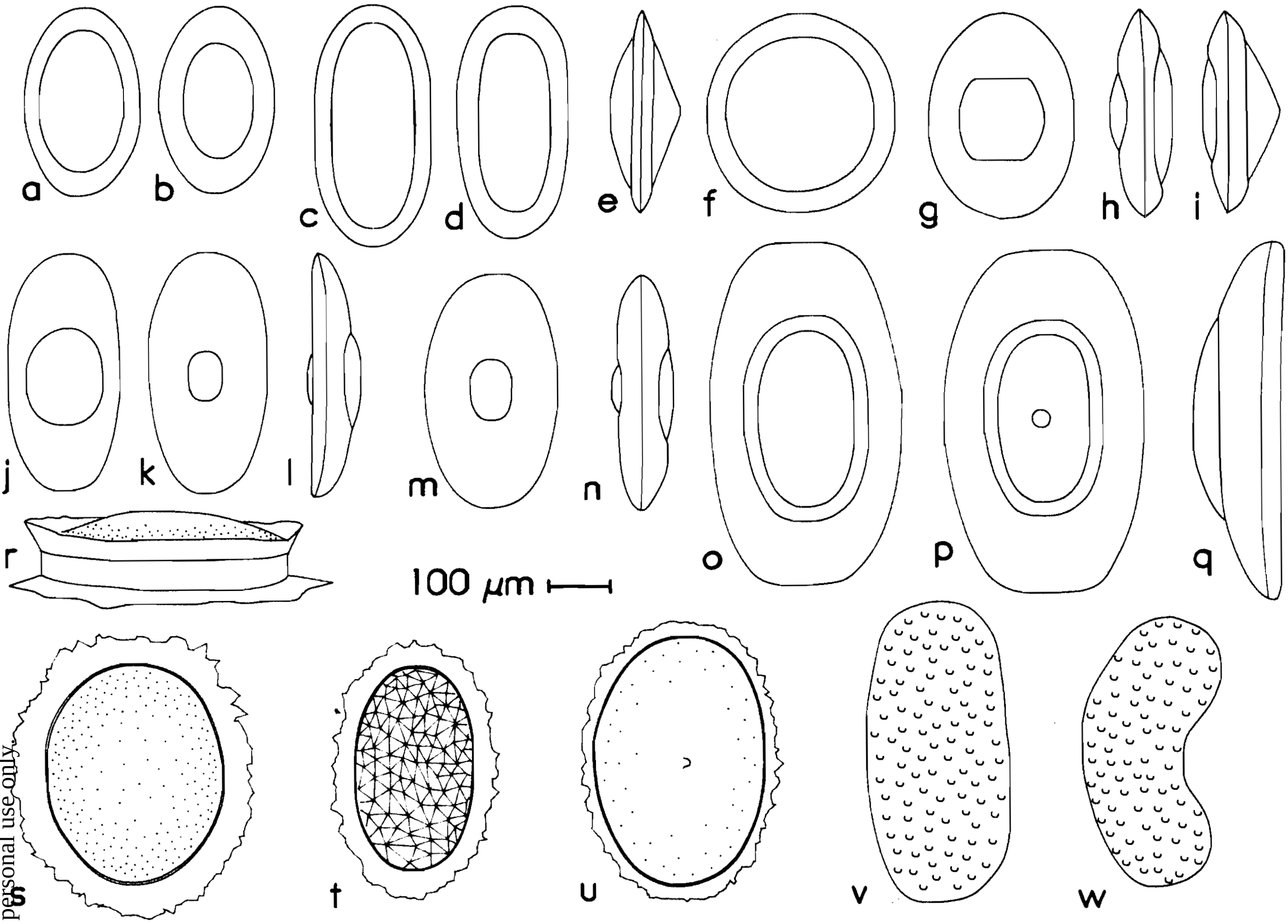

FIG. 15. Bryozoan statoblasts. (*a*) *Plumatella casmiana* floatoblasts, ventral view. (*b*) *P. casmiana* floatoblast, dorsal view. (*c*) *P. casmiana* leptoblast, ventral view. (*d*) *P. casmiana* leptoblast, dorsal view. (*e*) *Plumatella orbisperma* floatoblast, side view. (*f*) *P. orbisperma* floatoblast, ventral view. (*g*) *Plumatella repens* floatoblast, dorsal view. (*h*) *P. repens* floatoblast, side view. (*i*) *Plumatella fungosa* floatoblast, side view (*j*) *Plumatella emarginata* floatoblast, ventral view. (*k*) *P. emarginata* floatoblast, dorsal view. (*l*) *P. emarginata* floatoblast, side view. (*m*) *Plumatella reticulata* floatoblast, dorsal view. (*n*) *P. reticulata* floatoblast, side view. (*o*) *Hyalinella punctata* floatoblast, ventral view. (*p*) *H. punctata* floatoblast, showing central nodule on ventral fenestra. (*q*) *H. punctata* floatoblast, side view. (*r*) *P. repens* sessoblast, side view. (*s*) *P. repens* sessoblast, frontal valve. (*t*) *P. reticulata* sessoblast, frontal valve. (*u*) *P. casmiana* sessoblast, frontal valve. (*v*) *Fredericella indica* sessoblast, normal form. (*w*) *F. indica* sessoblast, kidney-shaped form.

This Holarctic species is common and widely distributed throughout eastern Canada. Statoblasts from White Point Pond in Terra Nova National Park, Newfoundland (NMC 1977-0501B), and from the Hammond River, New Brunswick (NBM, uncatalogued), represent the first records of this species from these provinces.

CLASS Gymnolaemata
FAMILY Paludicellidae
Paludicella articulata (Ehrenberg, 1831)
Figs. 13, 16*a*, 16*b*

Paludicella ehrenbergii Odell, 1899
Paludicella articulata Huntsman, 1913; White 1915; Rogick 1937; Ricciardi and Lewis 1991

Description of eastern Canadian specimens

Colony threadlike, with both free and adherent branches (Figs. 13, 16*a*); zooids club-shaped, growing contiguously, divided by septa, branching from lateral buds; ectocyst yellow or brown, firm, often shiny, with little or no encrustation; zooecial orifice square (Fig. 16*b*), located subterminally; extended lophophore circular. Zooecial length = 1384-(1652)-1974 μm (SD_{20} = 141), maximum width = 179-(229)-355 μm (SD_{20} = 40.1).

External sclerotized buds, termed hibernacula, are produced instead of statoblasts; these are highly variable and often irregular in outline, although club-shaped forms resembling zooids often occur (Figs. 13*b*, 16*a*).

Taxonomy

Because of its small size, this species is easily overlooked or mistaken for filamentous algae. Close examination reveals a colonial form that is distinct from all other North American bryozoans. The contiguous arrangement of the zooids and the subterminal 4-sided zooecial orifice readily distinguish the species from its closest relative, *Pottsiella erecta*.

Habitat and general ecology

Paludicella articulata is a eurytopic species found in both lentic and lotic habitats, but occurs predominantly in rivers

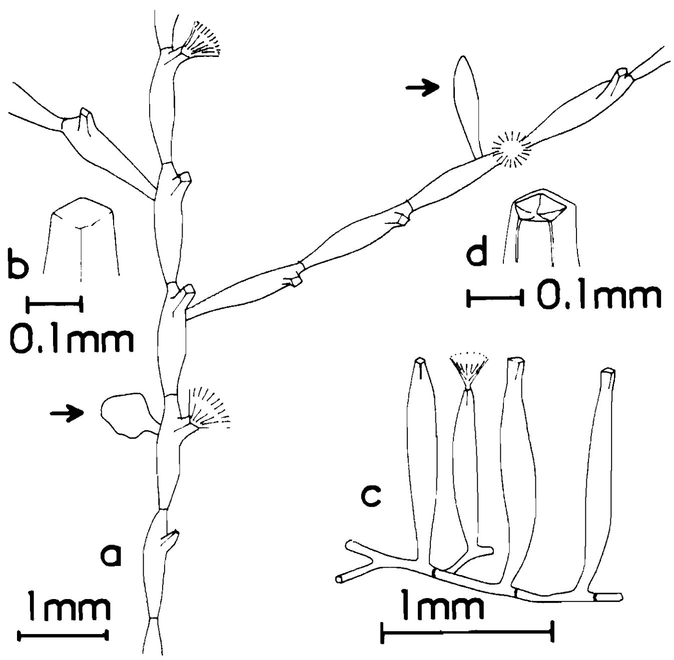

FIG. 16. Gymnolaemate bryozoans. (*a*) *Paludicella articulata* colony (arrows point to hibernacula). (*b*) Orifice of *P. articulata* zooid. (*c*) *Pottsiella erecta* colony, showing upright zooids (after Wood 1991). (*d*) Orifice of *P. erecta* zooid.

and in wave-swept areas of lakes. The species may form thick, weedy colonies on stones and other hard substrates along the shoreline of lakes (A. Ricciardi, personal observation), in the outflows of impoundments (Smith 1991), inside water pipes (Davenport 1904), and on intake grates (A. Ricciardi, personal observation). It is most frequently associated with *Plumatella reticulata*, *Fredericella indica*, and the sponge *Eunapius fragilis* which often overgrows the bryozoan colony. Active colonies were found in the following range of water quality conditions: temperature 5–26°C, pH 5.9–9.4, calcium hardness 10–130 mg/L, magnesium hardness 22–150 mg/L. Bushnell (1974) states that 5°C is the lower limit of temperature tolerance for the species.

Although *P. articulata* was found on one occasion in a lake of pH 5.9 (Lake Sir John, Quebec), it was otherwise collected from alkaline habitats of pH >7.0.

Distribution in eastern Canada

Ontario (Odell 1899; Huntsman 1913; White 1915; Rogick 1937), Quebec (Ricciardi and Lewis 1991), New Brunswick, Nova Scotia, Prince Edward Island.

This species is common in the Great Lakes region and southern Quebec. It occurs in the Hammond River, N.B. (associated with freshwater sponges; uncatalogued NBM specimens), and in ponds at Southport, P.E.I. (AR 141, mixed with *P. fungosa* and *P. emarginata*). In Nova Scotia, we have found it in Brierly Brook at Antigonish on the undersides of stones, and in Warren Lake (Cape Breton Highlands National Park) and Lower Egmont Lake (Halifax Co.); in both lakes it was growing in contact with sponges (*Eunapius fragilis* and *Spongilla lacustris*).

Paludicella articulata is cosmopolitan (Bushnell 1973), and is perhaps the most ubiquitous bryozoan in eastern Canada, but its diminutive size may cause it to be overlooked.

Pottsiella erecta (Potts, 1884)
Figs. 14, 16*c*, 16*d*

Description of eastern Canadian specimens

Colony consisting of individual erect cylindrical zooids joined by a narrow recumbent stolon (Figs. 14, 16*c*). Ectocyst firm, translucent, unencrustred. Extended lophophore circular. Zooecial orifice, located terminally, takes on a 5-sided shape when lophophore is retracted (Fig. 16*d*); lightly sclerotized ridges, extending from the apices of the orifice down to about a one-third of the length of the zooid, support the pentagonal shape of the orifice. Zooids are slightly constricted at the base. Branching and hibernacula occur only from the stolon.

Material for this study (AR147B) consisted of only four zooids attached to fragments of stolon removed from the basal portion of a freshwater sponge (*Eunapius fragilis*). Zooid length = 1680-(1780)-1900 μm (SD_4 = 98); maximum orifice width = 109-(125)-151 μm (SD_4 = 19.5); stolon width = 50-(51)-53 μm (SD_4 = 1.4).

Taxonomy

This gymnolaematous species is easily distinguished from its closest relative, *Paludicella articulata*, by its growth form (zooids are connected by a stolon, rather than joined contiguously) and the form and position of its zooecial orifice (located terminally rather than subterminally, and by being 5-sided rather than 4-sided).

Habitat and general ecology

Relatively little ecological information exists for *Pottsiella erecta*. It occurs in lentic and lotic habitats, frequently growing in close association with other suspension feeders including sponges, rotifers, cnidarians, bivalves, and other bryozoans (Potts 1884; Maciorowski 1974; Curry et al. 1981; Smith 1985). In some areas, *P. erecta* is a common epibiont on the shells of living unionid clams (Curry et al. 1981; Smith 1985), and this intimate association with freshwater sponges (Potts 1884; Davenport 1904; this study) may also be common. Colonies grow preferentially on the upper surfaces of substrates (Wood 1989) and in flowing water (Potts 1884; Davenport 1904; Smith 1985). Water quality data are very scarce, but indicate that *P. erecta* is a eurytopic species: temperature 12–35°C, pH 6.4–8.6, conductivity 38–3400 μmho/cm (Everitt 1975).

Distribution in eastern Canada

Quebec.

Recorded in Canada for the first time, *Pottsiella erecta* was collected from a single location in the lower Ottawa River, at the southwestern tip of the Island of Montréal; this location represents the northern limit of its known range (cf. previous limit given by Smith 1985, 1991). The species was reported from South Bass Island, western Lake Erie, Ohio (Maciorowski 1974), but its general distribution in the Great Lakes region is unknown.

Key to the freshwater ectoproct bryozoans of eastern Canada

1*a*. Colony gelatinous, translucent, globular, smooth or lobed in outline, never dendritic (e.g., Fig. 10*a*); statoblasts with peripheral spines (Figs. 10*b*, 11, 12) 2

1*b*. Colony translucent to opaque, tubular, dendritic, with distinct zooecial branches (e.g., Figs. 1, 2*a*, 2*b*, 3*a*, 5*a*, 6*a*, 7, 8*a*–8*d*, 13*a*, 13*b*, 14); statoblasts without spines (e.g., Figs. 2*c*, 3*b*, 3*c*, 4*a*, 4*b*, 5*c*–5*e*, 6*c*, 8*e*, 9*b*, 9*c*) 4

2*a*. Lophophore with red pigment around mouth region; young colony lobate and rosettelike; mature colonies occurring as contiguous patches on a thick gelatinous base, sometimes growing into large slimy gelatinous masses several centimetres in diameter; statoblasts with a single row of flattened, hooked spines around entire periphery (Fig. 11) . . . . . *Pectinatella magnifica*

2*b*. Lophophore without red pigment; colonies and statoblasts not as above 3

3*a*. Mature colony smooth in outline, elongated and caterpillarlike, averaging 2–5 cm in length but occasionally much longer; polypides in marginal rows enclosing a clear central area; statoblasts circular, with two rows of slender cylindrical hooked spines, one row projecting from the periphery of each capsule (Fig. 12) . . . . . *Cristatella mucedo*

3*b*. Colony globular, lobate, yellowish, less than 1.5 cm in diameter (Fig. 10*a*); statoblasts broadly oval and saddle-shaped, with broad, serrated spines that project only from the margins of the poles (Fig. 10*b*) . . . . . *Lophopodella carteri*

4*a*. Extended lophophore circular or elliptical in outline; statoblasts, if present, are sessoblasts only (Figs. 15*v*, 15*w*) 5

4*b*. Extended lophophore U-shaped in outline; both floatoblasts and sessoblasts (e.g., Figs. 3*c*, 4*b*, 5*d*, 8*e*) may be present . . . . . Plumatellidae, 7

5*a*. Zooecial orifice round; colonial branches antlerlike, often shrubby and erect (Fig. 1); adherent branches bearing a dorsal keel; sessoblasts (Figs. 15*v*, 15*w*) are produced . . . . . *Fredericella indica*

5*b*. Zooecial orifice square or pentagonal (when lophophore is retracted); zooids club-shaped (Figs. 13, 14, 16); colonial branches thin, threadlike or stoloniferous, never keeled; colony producing external buds (hibernacula; Figs. 13*b*, 16*a*) rather than statoblasts . . . . . Gymnolaemata, Paludicellidae, 6

6*a*. Orifice terminal, pentagonal when lophophore is retracted (Fig. 16*d*); zooids upright and separate, connected by a narrow stolon (Figs. 14, 16*c*, 16*d*) . . . . . *Pottsiella erecta*

6*b*. Orifice subterminal, square (Fig. 16*b*); zooids growing contiguously and branching laterally from each other; no stolons (Figs. 13, 16*a*, 16*b*) . . . . . *Paludicella articulata*

7*a*. Ectocyst soft, swollen, gelatinous, translucent to pale yellow, never encrusted, occasionally covered with minute white spots; keel and septa absent; colony entirely adherent, forming either a flat, compact mass of densely packed branches or a long dendritic string of adherent zooids; floatoblasts broadly oval, rounded or truncated at the poles, asymmetric in lateral view, average length greater than 500 μm, ventral capsule often bearing a conspicuous central nodule (Figs. 9*b*, 9*c*, 15*o*–15*q*); sessoblasts absent . . . . . *Hyalinella punctata*

7*b*. Ectocyst firm, not gelatinous, translucent to dark brown, often encrusted, very rarely covered with white spots (e.g., Figs. 2*a*, 2*b*, 3*a*, 5*a*–5*c*, 6*a*, 6*b*, 7, 8*a*–8*d*); keel and (or) septa may be present (e.g, Fig. 8*d*); colony dendritic, occasionally erect; floatoblasts round to oval, symmetric or asymmetric in lateral view, average length usually less than 500 μm, ventral capsule rarely bearing a central nodule (e.g., Figs. 2*c*, 3*b*, 4*a*, 5*c*, 6*c*, 5*e*); sessoblasts may be present (e.g., Figs. 3*c*, 4*b*, 5*d*) . . . . . *Plumatella*, 8

8*a*. Floatoblast capsule covered by annulus much more dorsally than ventrally, maximum width of dorsal annulus greater than or equal to length of dorsal fenestra (Figs. 3*b*, 15*j*–15*n*) 9

8*b*. Floatoblast capsule covered by annulus only slightly more dorsally than ventrally, maximum width of dorsal annulus less than length of dorsal fenestra (e.g., Figs. 2*c*, 4*a*, 5*c*, 5*e*, 6*c*, 15*g*–15*i*) 10

9*a*. Dorsal and ventral floatoblast valves nearly equally convex, symmetric in lateral view (Figs. 15*m*, 15*n*); frontal valve of mature sessoblast covered with a dark netlike pattern of ridges (Figs. 8*e*, 15*t*) . . . . . *Plumatella reticulata*

9*b*. Floatoblast dorsal surface flattened, valves strongly asymmetric in lateral view (Figs. 3*b*, 15*j*, 15*l*); frontal valve of mature sessoblast (Fig. 3*c*) not as above . . . . . *Plumatella emarginata*

10*a*. Average length of floatoblast *and* sessoblast more than twice width (Figs. 4*a*, 4*b*); floatoblast asymmetric in lateral view; colonial branches never fused . . . . . *Plumatella fruticosa*

10*b*. Floatoblast *or* sessoblast length less than twice width; floatoblast either symmetric or asymmetric in lateral view; colonial branches may be fused along a portion of their length 11

11*a*. Floatoblast dorsal fenestra length greater than 1.5 times width (Figs. 2*c*, 15*a*–15*d*); more than one type of floatoblast may be present; ectocyst generally opaque, encrusted, strongly keeled and furrowed near zooecial tips (Figs. 2*a*, 2*b*); sessoblast lamella width normally less than 40 μm; frontal valve may bear a conspicuous central raised tubercle (Fig. 15*u*) . . . . . *Plumatella casmiana*

11*b*. Floatoblast dorsal fenestra length less than 1.5 times width; floatoblasts of one type only; ectocyst translucent (e.g., Figs. 5*b*, 5*c*) or opaque (Figs. 5*a*, 6*a*, 6*b*, 7), seldom encrusted or keeled; sessoblast lamella width normally greater than 40 μm (Figs. 5*d*, 15*s*), frontal valve not as above 12

12*a*. Floatoblast strongly asymmetric in lateral view (Fig. 15*i*); colonial branches (Figs. 5*a*–5*c*) fused along most of their length, usually forming thick erect masses in mature colonies; conspicuous dark septa normally present (Fig. 5*c*) . . . . . *Plumatella fungosa*

12*b*. Floatoblast roughly symmetric in lateral view (Figs. 15*e*, 15*h*); colonial branches (Figs. 6*a*, 6*b*, 7) seldom fused, never in an erect mass; septa absent 13

13*a*. Average width of dorsal annulus less than 18% floatoblast length; floatoblast round, length to width ratio less than 1.1, ventral capsule pointedly convex (Figs. 6*c*, 15*e*, 15*f*); ectocyst swollen, transparent, never encrusted or keeled (Figs. 6*a*, 6*b*); polypides in erect clusters of 2–7 and connected by a narrow stolon in recumbent colonies (Fig. 6*b*) . . . . . *Plumatella orbisperma*

13*b*. Average width of dorsal annulus greater than 18% floatoblast length; floatoblast (Fig. 15*g*) round to oval, length to width ratio normally greater than 1.1, ventral capsule not pointed (Fig. 15*h*); ectocyst transparent to opaque, not swollen, sometimes lightly encrusted and keeled; polypides not as above (Fig. 7) . . . . . *Plumatella repens*

Key to the statoblasts of eastern Canadian freshwater bryozoans

1*a*. Statoblast with hooked spines (Figs. 10*b*, 11, 12) 2
1*b*. Statoblast without hooked spines 4

2*a*. Statoblast with a single peripheral row of broad, dorsoventrally flattened, hooked spines (Figs. 10*b*, 11) 3
2*b*. Statoblast with two rows of slender, cylindrical, hooked spines, one row on each valve (Fig. 12) .... *Cristatella mucedo*

3*a*. Spines with serrated edges, confined to the margins at the poles; statoblast saddle-shaped and broadly oval in outline (Fig. 10*b*) .... *Lophopodella carteri*
3*b*. Spines with smooth edges, arranged around entire periphery; statoblast roughly circular in outline (Fig. 11) .... *Pectinatella magnifica*

4*a*. Statoblast annulus air-filled; statoblast buoyant when dried, never cemented to the substrate (e.g., Figs. 2*c*, 4*a*, 5*c*, 5*e*, 6*c*, 15*g*–15*i*) .... floatoblasts, 5
4*b*. Statoblast annulus reduced to a thin lamella, or absent; statoblast cemented to the substrate or colony wall (e.g., Figs. 3*c*, 4*b*, 5*d*, 15*v*, 15*w*) .... sessoblasts, 13

5*a*. Average floatoblast length at least twice width (Figs. 4*a*, 15*c*, 15*d*) 6
5*b*. Average floatoblast length less than twice width 7

6*a*. Floatoblast symmetric in lateral view, average length less than 400 μm (Figs. 2*c*, 15*a*–15*d*); dorsal fenestra broadly oval; floatoblast may be thin-walled and transparent .... *Plumatella casmiana*
6*b*. Floatoblast asymmetric in lateral view, thick-walled and opaque; dorsal fenestra very narrow (Fig. 4*a*); average floatoblast length more than 400 μm .... *Plumatella fruticosa*

7*a*. Floatoblast capsule covered by annulus disproportionately more dorsally than ventrally; maximum width of annulus on dorsal surface greater than or equal to length of dorsal fenestra (Figs. 3*b*, 15*j*–15*n*) 8
7*b*. Floatoblast capsule covered by annulus only slightly more dorsally than ventrally; maximum width of annulus on dorsal surface less than length of dorsal fenestra 9

8*a*. Dorsal floatoblast surface flattened, floatoblast strongly asymmetric in lateral view (Fig. 15*l*); annulus with a silvery or bronze sheen .... *Plumatella emarginata*
8*b*. Dorsal and ventral floatoblast surfaces nearly equally convex, floatoblast symmetric in lateral view (Fig. 15*n*); annulus with a bronze sheen .... *Plumatella reticulata*

9*a*. Floatoblast large and broadly oval, rounded or truncated at the poles, average length greater than 500 μm (Figs. 9*b*, 9*c*, 15*o*–15*q*); ventral capsule often bearing a conspicuous central nodule (Figs. 9*c*, 15*p*); fenestra (viewed under high magnification) covered with large tubercles, without any raised reticulation .... *Hyalinella punctata*
9*b*. Floatoblast round to oval, average length less than 500 μm; ventral capsule normally without a central nodule; fenestra (viewed under high magnification) having a raised reticulation with interstitial tubercles 10

10*a*. Dorsal fenestra length less than 1.5 times width 11
10*b*. Dorsal fenestra length more than 1.5 times width (Figs. 2*c*, 15*a*–15*d*) .... *Plumatella casmiana*

11*a*. Floatoblast symmetric in lateral view 12
11*b*. Floatoblast strongly asymmetric in lateral view (Fig. 15*i*) .... *Plumatella fungosa*

12*a*. Average width of dorsal annulus less than 18% floatoblast length; floatoblast round, length/width ratio less than 1.1; ventral capsule pointed (Figs. 6*c*, 15*e*, 15*f*) .... *Plumatella orbisperma*
12*b*. Average width of dorsal annulus greater than 18% floatoblast length; floatoblast round to oval, length/width ratio greater than 1.1; ventral capsule rarely pointed (Figs. 15*g*, 15h) .... *Plumatella repens*

13*a*. Lamella present; capsule covered with raised ridges or tubercles (Figs. 3*c*, 4*b*, 5*d*, 8*e*, 15*r*–15*u*) .... *Plumatella* sessoblasts, 14
13*b*. Lamella absent; capsule normally covered with hexagonal pits; sessoblast often kidney-shaped (Figs. 15*v*, 15*w*) .... *Fredericella indica*

14*a*. Sessoblast length at least twice width (Fig. 4*b*) .... *Plumatella fruticosa*
14*b*. Sessoblast length less than twice width 15

15*a*. Frontal valve of mature sessoblast with a dark netlike pattern of ridges clearly visible under low (50×) magnification (Figs. 8*e*, 15*t*) .... *Plumatella reticulata*
15*b*. Sessoblast not as above 16

16*a*. Sessoblast lamella normally less than 40 μm in width, oriented perpendicularly to the substrate; frontal valve mostly smooth, sometimes bearing a conspicuous central raised tubercle (Fig. 15*u*) .... *Plumatella casmiana*
16*b*. Sessoblast lamella normally greater than 40 μm in width, oriented at variable angles to the substrate; frontal valve (viewed under high magnification) distinctly tuberculated to varying degrees, with or without a lightly raised reticulation; central raised tubercle absent* (Figs. 3*c*, 5*d*, 15*r*, 15*s*) .... *Plumatella emarginata*, *P. repens*, *P. fungosa*, *P. orbisperma*

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* These species cannot be confidently separated on the basis of sessoblast morphology alone.

Glossary

Annulus	The peripheral ring of the periblast that surrounds a statoblast capsule. In floatoblasts, the annulus consists of air-filled cells; in sessoblasts, the annulus is reduced to a thin flange (lamella).
Ectocyst	The secreted outer layer of the body wall, of variable thickness, texture, and flexibility.
Fenestra	The clear central portion of the periblast not covered by the annulus (Fig. 3*b*).
Floatoblast	Statoblasts with a peripheral ring (annulus) of air-filled cells (e.g., Figs. 2*c*, 3*b*, 4*a*, 6*c*); most floatoblasts are immediately buoyant upon release, others (e.g., those of *H. punctata* and *L. carteri*) are buoyant only when dried.
Furrow	A thin transparent seam running along the top of the keel in certain plumatellid bryozoans (Fig. 2*b*).
Hibernacula	Irregularly shaped sclerotized resting buds attached to the substratum; produced asexually by freshwater bryozoans of the class Gymnolaemata (Figs. 13*b*, 16*a*).
Keel	A raised longitudinal ridge running along the outer surface of adherent zooids (Fig. 8*d*); characteristic of *Fredericella indica* and certain *Plumatella* species.
Lamella	The thin transparent flange-like annulus of a sessoblast.
Leptoblast	A thin-walled statoblast (produced only by *P. casmiana*) with loosely joined valves (Figs. 15*c*, 15*d*); it has no buoyancy and does not undergo diapause, but germinates almost immediately upon release from the colony.
Lophophore	The elliptical or U-shaped structure on the polypide bearing ciliated tentacles used for capturing suspended food particles.
Orifice	The opening in a zooid through which the polypide extends.
Periblast	The cellular shell formed around the paired statoblast valves.
Polypide	The retractable portion of a zooid.
Septum	In certain plumatellid species, a portion of the body wall that grows inward, forming incomplete internal partitions (Fig. 8*d*).
Sessoblast	Adherent, nonfloating statoblasts with a thin lamella, cemented through the colony wall to a firm substrate (e.g., Fig. 3*c*).
Statoblast	Sclerotized, encapsulated, asexually produced, resistant buds consisting of a yolky germinal mass enclosed by two chitinous valves joined together by a peripheral suture and surrounded by an outer periblast; produced by freshwater bryozoans of the class Phylactolaemata.
Stolon	A thin string of tissue that connects polypides in certain tubular colonies (Figs. 6*b*, 16*c*).
Zooid	An individual of a bryozoan colony, composed of a polypide and surrounding colony wall.

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Abricosov, G.G., and Kosova, A.A 1963. A finding of tropical fresh water Bryozoa, *Lophopodella carteri* (Bryozoa, Phylactolaemata). Zool. Zh. **42**: 1724–1726.

Allman, G.J. 1844. On *Plumatella repens*. Br. Assoc. Adv. Sci. Rep. **13**: 74–76.

Annandale, N. 1909. A new species of *Fredericella* from the Indian lakes. Rec. Indian Mus. (Calcutta), **3**: 373–374.

Applegate, R.L. 1966. The use of a bryozoan, *Fredericella sultana*, as food by sunfish in Bull Shoals reservoir. Limnol. Oceanogr. **11**: 129–130.

Aprosi, G. 1988. Bryozoans in the cooling water circuits of a power plant. Verh. Int. Verein. Limnol. **23**: 1542–1547.

Brooks, C.M. 1929. Notes on the statoblasts and polypids of *Pectinatella magnifica*, Proc. Acad. Nat. Sci. Phila. **81**: 427–441.

Brown, C.J.D. 1933. A limnological study of certain fresh-water Polyzoa with special reference to their statoblasts. Trans. Am. Microsc. Soc. **52**: 271–313.

Bushnell, J.H. 1965. On the taxonomy and distribution of freshwater Ectoprocta in Michigan. III. Trans. Am. Microsc. Soc. **84**: 529–548.

Bushnell, J.H. 1966. Environmental relations of Michigan Ectoprocta and dynamics of natural populations of *Plumatella repens*. Ecol. Monogr. **36**: 95–123.

Bushnell, J.H. 1968. Aspects of architecture, ecology, and zoogeography of freshwater Ectoprocta. Atti Soc. Ital. Sci. Nat. Mus. Civ. Stor. Nat. Milano, **108**: 129–151.

Bushnell, J.H. 1973. The freshwater Ectoprocta: a zoogeographical discussion. *In* Living and fossil Bryozoa: recent advances in research. *Edited by* G.P. Larwood and M.B. Abbott. Academic Press, London. pp. 503–521.

Bushnell, J.H. 1974. Bryozoans (Ectoprocta). *In* Pollution ecology of freshwater invertebrates. *Edited by* C.W. Hart and S.L.H. Fuller. Academic Press, New York. pp. 157–194.

Bushnell, J.H., Foster, S.Q., and Wahle, B.M. 1987. Annotated inventory of invertebrate populations in an alpine lake and stream chain in Colorado. Great Basin Nat. **47**: 500–511.

Bushnell, J.H., and Rao, K.S. 1979. Freshwater Bryozoa: microarchitecture of statoblasts and some aufwuchs animal associations. *In* Advances in bryozoology. *Edited by* G.P. Larwood and M.B. Abbott. Academic Press, London. pp. 75–92.

Bushnell, J.H., and Wood, T.S. 1971. Honeycomb colonies of *Plumatella casmiana* Oka (Ectoprocta: Phylactolaemata). Trans. Am. Microsc. Soc. **90**: 229–231.

Carl, G.C. 1943. Natural history of the Forbidden Plateau area, Vancouver Island, British Columbia. Rep. Prov. Mus. Nat. Hist. Anthropol. B.C. 1943: 18–40.

Collins, E.J., Tenney, W.R., and Woolcott, W.S. 1966. Histological effects of the poison of *Lophopodella carteri* (Hyatt) in the gills of *Carassius auratus* (Linnaeus) and larval *Ambystoma opacum* (Gravenhorst). Va. J. Sci. (n.s.), **17**: 155–161.

Cooper, C.M., and Burris, J.W. 1984. Bryozoans—possible indicators of environmental quality in Bear Creek, Mississippi. J. Environ. Qual. **13**: 127–130.

Crisman, T.L., Crisman, U.A.M., and Binford, M.W. 1986. Interpretation of bryozoan microfossils in lacustrine sediment cores. Hydrobiologia, **143**: 113–118.

Curry, M.G., Everitt, B., and Vidrine, M.F. 1981. Haptobenthos on shells of living freshwater clams in Louisiana. Wasmann J. Biol. **39**: 56–62.

Cuvier, G. 1798. Tableau élémentaire de l'histoire naturelle des animaux.

Davenport, C.B. 1904. Report on the fresh-water Bryozoa of the United States. Proc. U.S. Natl. Mus. **27**: 211–221.

Dendy, J.S. 1963. Observations on bryozoan ecology in farm ponds. Limnol. Oceanogr. **8**: 478–482.

Ehrenberg, C.G. 1831. Phytozoa polypi. Symbolae physicaem, etc. Animalia Evertebrata, **1**: 831.

Everitt, B. 1975. Freshwater Ectoprocta: distribution and ecology of five species in southeastern Louisiana. Trans. Am. Microsc. Soc. **94**: 130–134.

Geimer, G., and Massard, J.A. 1986. Les bryozoaires du Grand-Duché de Luxembourg et des régions limitrophes. Trav. Sci. Mus. Hist. Nat. Luxemb. No. 7.

Geiser, S.W. 1934. The distribution of *Pectinatella magnifica* in the United States. Field Lab. **2**: 56–59.

Geiser, S.W. 1937. *Pectinatella magnifica* Leidy. An occasional river-pest in Iowa. Field Lab. **5**: 65–76.

Goadby, D., and Bovell, J. 1855. Passing visits to the Rice Lake, Humber River, Grenadier's Pond, and the Island. Can. J. **3**: 201–203.

Greenland, D.C., Newton, S.H., and Faucette, Jr. R.F. 1988. Effects of cage encrustation by the bryozoan *Plumatella casmiana* on production of channel catfish. Prog. Fish-Cult. **50**: 42–45.

Hancock, A. 1850. On the anatomy of the fresh-water Bryozoa, with descriptions of three new species. Ann. Mag. Nat. Hist. Serv. 2, **5**: 175–202.

Henry, V., Bussers, J.C., Bouquegneau, J.M., and Thomé, J.P. 1989. Heavy metal and PCB contamination of bryozoan colonies in the River Meuse (Belgium). Hydrobiologia, **202**: 147–152.

Huntsman, A.G. 1913. Invertebrates other than insects and mollusks. *In* The natural history of the Toronto region. *Edited by* J.H. Faull. Toronto Canadian Institute, Toronto. pp. 272–287.

Hyatt, A. 1866. Observations on polyzoan suborder Phylactolaemata. Proc. Essex Inst. **4**: 107–228.

Job, P. 1976. Intervention des populations de *Plumatella fungosa* (Pallas) (Bryozoaire Phylactolème) dans l'autoépuration des eaux d'un étang et d'un ruisseau. Hydrobiologia, **48**: 257–261.

Jonasson, P.M. 1963. The growth of *Plumatella repens* and *P. fungosa* (Bryozoa Ectoproctoa). Oikos, **14**: 121–137.

Joo, G.-J., Ward, A.K., and Ward, G.M. 1992. Ecology of *Pectinatella magnifica* in an Alabama oxbow lake: colony growth and association with algae. J. N. Am. Benthol. Soc. **11**: 324–333.

Judd, W.W. 1950. *Pectinatella magnifica* Leidy (Bryozoa) in the Dundas Marsh, Hamilton, Ontario. Can. Field-Nat. **64**: 191–192.

Kaminski, M. 1990. Fauna inhabiting the colonies of freshwater bryozoan *Plumatella fungosa* Pall. (Phylactolaemata). Pol. Arch. Hydrobiol. **37**: 495–502.

Karlson, R.H. 1991. Recruitment and local persistence of a freshwater bryozoan in stream riffles. Hydrobiologia, **226**: 119–128.

Kellicott, D.S. 1882. Polyzoa. Observations on species detected near Buffalo, N.Y. Proc. Am. Soc. Microsc. **4**: 217–229.

Kuc, M. 1973. Fossil statoblasts of *Cristatella mucedo* Cuvier in the Beaufort Formation and in interglacial and postglacial deposits of the Canadian arctic. Geol. Surv. Can. Pap. No. 72–28.

Lacourt, A.W. 1968. A monograph of the freshwater Bryozoa—Phylactolaemata. Zool. Verh. (Leiden) No. 93.

Leidy, J. 1851. On *Cristatella magnifica* n.sp. Proc. Acad. Nat. Sci. Phila. **5**: 265–266.

Linnaeus, C. 1758. Systema naturae. 10th ed. J. Cramer, Weinheim.

Maciorowski, A.F. 1974. The occurrence of the freshwater bryozoan *Pottsiella erecta* (Potts) 1884 (Gymnolaemata: Paludicellidae) in Lake Erie. Ohio J. Sci. **74**: 245–247.

Malchow, C.P. 1978. Der Verdauungstrakt von *Plumatella repens* (L) (Bryozoa, Phylactolaemata). I. Ultrastruktur und funktionelle Zusammenhange. II. Strukturveranderungen als Indikator für Wasserverschmutzung. Zool. Beitr. **24**: 365–394.

Mann, K.H. 1964. The pattern of energy flow in the fish and invertebrate fauna of the River Thames. Verh. Int. Verein. Limnol. **25**: 485–495.

Massard, J.A., and Geimer, G. 1991. Note sur les Bryozoaires d'eau douce trouvés en diverses stations luxembourgeoises et belges, avec des considérations sur la bryozoofaune de la Sûre et des remarques concernant les statoblastes de *Hyalinella punctata* (Hancock, 1850). Bull. Soc. Nat. Luxemb. **92**: 131–148.

Masters, C.O. 1940. Notes on subtropical plants and animals in Ohio. Ohio. J. Sci. **25**: 67–70.

Mozley, A. 1932. A biological study of a temporary pond in western Canada. Am. Nat. **66**: 235–249.

Mukai, H. 1982. Development of freshwater bryozoans (Phylactolaemata). *In* Developmental biology of freshwater invertebrates. *Edited by* F.W. Harrison and R.R. Cowden. Alan R. Liss, Inc., New York. pp. 535–576.

Mukai, H., Niwa, T., Tsuchiya, M., and Nemoto, T. 1983. The growth of colonies and the production of statoblasts in a freshwater bryozoan, *Plumatella casmiana*. Sci. Rep. Fac. Educ. Gunma Univ. **32**: 55–75.

Mundy, S.P. 1980. Stereoscan studies of phylactolaemate bryozoan statoblasts including a key to the statoblasts of the British and European Phylactolaemata. J. Zool. (1965–1984), **192**: 511–530.

Mundy, S.P. 1981. Some effects of low concentrations of copper ions on *Cristatella mucedo* (Bryozoa: Phylactolaemata). *In* Recent and fossil Bryozoa. *Edited by* G.P. Larwood and C. Nielsen. Olsen and Olsen, Fredensborg, Denmark, pp. 177–184.

Oda, S. 1959. Germination of statoblasts in freshwater Bryozoa. Sci. Rep. Tokyo Kyoiku Daigaku Sect. B, **9**: 90–131.

Odell, W.S. 1899. Notes on fresh-water Polyzoa. Ottawa Nat. **13**: 107–113.

Oka, A. 1907. Zur Kenntinis der Süsswasserbryozoen von Japan. Annot. Zool. Jpn. **6**: 117–123.

Osburn, R.C. 1921. Bryozoa as food for other animals. Science (Washington, D.C.), **53**: 451–453.

Osler, W. 1883. On Canadian fresh-water Polyzoa. Can. Nat. **10**: 399–406.

Pallas, P.S. 1768. Descriptio Tubulariae-fungosae prope Wolo mense Julio 1768 observatae. Nov. Comment. Acad. Sci. Imp. Petropol. **12**: 565–572.

Pardue, W.J., and T.S. Wood, 1980. Baseline toxicity data for freshwater Bryozoa exposed to copper, cadmium, chromium and zinc. J. Tenn. Acad. Sci. **55**: 27–31.

Pennak, R.W. 1989. Fresh-water invertebrates of the United States. Protozoa to Mollusca. 3rd ed. John Wiley and Sons. New York.

Potts, E. 1884. On *Paludicella erecta*. Proc. Acad. Nat. Sci. Phila. **36**: 213–214.

Pourcher, A.-M., and d'Hondt, J.-L. 1987. Étude ultrastructurale du sessoblaste et du flottoblaste chez *Plumatella fungosa* (Pallas, 1768) (Bryozoaires, Phylactolaemates). Ann. Sci. Nat. Zool. 13[e] Ser. **8**: 209–216.

Raddum, G.G. 1981. Life strategy of *Plumatella repens* (Bryozoa). Fauna (Oslo), **34**: 162–166.

Raddum, G.G., and Johnsen, T.M. 1983. Growth and feeding of *Fredericella sultana* (Bryozoa) in the outlet of a humic acid lake. Hydrobiologia, **101**: 115–120.

Rawson, D.S. 1953. The bottom fauna of Great Slave Lake. J. Fish. Res. Board Can. **10**: 486–520.

Ricciardi, A., and Lewis, D.J. 1991. Occurrence and ecology of *Lophopodella carteri* (Hyatt) and other freshwater Bryozoa in the lower Ottawa River near Montréal, Quebec. Can. J. Zool. **69**: 1401–1404.

Ricciardi, A., and Wood, T.S. 1992. Statoblast morphology and systematics of the freshwater bryozoan *Hyalinella orbisperma* (Kellicott 1882). Can. J. Zool. **70**: 1536–1540.

Rogick, M.D. 1935. Studies on the freshwater Bryozoa II. The Bryozoa of Lake Erie. Trans. Am. Microsc. Soc. **54**: 245–263.

Rogick, M.D. 1937. Studies on the freshwater Bryozoa V. Some additions to Canadian fauna. Ohio J. Sci. **37**: 99–104.

Rogick, M.D. 1940. Studies on the freshwater Bryozoa IX. Additions to New York Bryozoa. Trans. Am. Microsc. Soc. **59**: 187–204.

Rogick, M.D. 1943. Studies on freshwater Bryozoa XIII. Additional *Plumatella casmiana* data. Trans. Am. Microsc. Soc. **62**: 265–270.

Shrivastava, P., and Rao, K.S. 1985. Ecology of *Plumatella emarginata* (Ectoprocta: Phylactolaemata) in the surface waters of Madhya Pradesh with a note on its occurrence in the protected waterworks of Bhopal (India). Environ. Pollut. Ser. A Ecol. Biol. **39**: 123–130.

Smith, D.G. 1985. *Lophopodella carteri* (Hyatt), *Pottsiella erecta* (Potts) and other freshwater Ectoprocta in the Connecticut River (New England, U.S.A.). Ohio J. Sci. **85**: 67–70.

Smith, D.G. 1988. *Stephanella hina* (Ectoprocta: Phylactolaemata) in North America, with notes on its morphology and systematics. J. N. Am. Benthol. Soc. **7**: 253–259.

Smith, D.G. 1991. The colonial hydras and moss animals. *In* Keys to the freshwater macroinvertebrates of Massachusetts. Massachusetts Department of Environmental Quality and Engineering, Division of Water Pollution Control, Westborough. pp. 34–64.

Smith, D.G. 1992. A new freshwater moss animal in the genus *Plumatella* (Ectprocta: Phylactolaemata: Plumatellidae) from New England (U.S.A.). Can. J. Zool. **70**: 2192–2201.

Sorensen, J.P., Riber, H.H., and Kowalczewski, A. 1986. Soluble reactive phosphorus release from bryozoan dominated periphyton. Hydrobiologia, **132**: 145–148.

Tanton, T.L. 1935. *Pectinatella* in Rainy River District, Ontario. Can. Field-Nat. **49**: 127–129.

Tenney, W.R., and Woolcott, W.S. 1962. First report of the bryozoan, *Lophopodella carteri* (Hyatt), in Virginia. Am. Midl. Nat. **68**: 247–248.

Tenney, W.R., and Woolcott, W.S. 1964. A comparison of the responses of some species of fishes to the toxic effect of the bryozoan *Lophopodella carteri* (Hyatt) Va. J. Sci. (n.s.), **15**: 16–20.

Toriumi, M. 1972. Additional observations of *Plumatella repens* (L.) (a fresh-water bryozoan). VII. Re-examination on the materials labelled *Plumatella punctata*. Bull. Mar. Biol. Stn. Asamushi, **14**: 155–167.

White, H.T. 1915. Bryozoa of the Georgian Bay region. Contrib. Can. Biol. (1911–1914), **2**: 195–199.

Wood, T.S. 1973. Colony development in species of *Plumatella* and *Fredericella* (Ectoprocta: Phylactolaemata). *In* Development and function of animal colonies through time. *Edited by* R.S. Boardman, A.H. Cheetham, and W.A. Oliver, J. Dowden, Hutchinson and Ross, Stroudsburg, Pa. pp. 395–432.

Wood, T.S. 1979. Significance of morphological features in bryozoan statoblasts. *In* Advances in bryozoology. *Edited by* G.P. Lawrood and M.B. Abbott. Academic Press, London, pp. 59–74.

Wood, T.S. 1988. *Plumatella reticulata* sp.nov. in Ohio (Bryozoa: Phylactolaemata). Ohio J. Sci. **88**: 101–104.

Wood, T.S. 1989. Ectoproct bryozoans of Ohio. Bull. Ohio Biol. Surv. (n.s.), **8**(2).

Wood, T.S. 1991. Bryozoans. *In* Ecology and classification of North American freshwater invertebrates. *Edited by* J.H. Thorp and A.P. Covich. Academic Press, New York. pp. 95–124.

Wood. T.S., and Backus, B.T. 1992. Differentiation of North American and European forms of *Fredericella sultana* (Blumenbach) (Ectoprocta: Phylactolaemata). Hydrobiologia, **237**: 185–193.