Tracking down biofoulers: a survey of freshwater bryozoans around Dunedin, New Zealand

A.M. Smith & P.B. Batson

Abstract: At the Southern Reservoir water treatment station, Dunedin, New Zealand, freshwater bryozoans *Paludicella articulata* and *Plumatella repens* infest hard surfaces throughout the microstrainers as well as the Reservoir itself, intermittently affecting normal operation of the plant since 1996. In order to determine the geographic scope of the infestation, and to assist the Dunedin City Water Department in managing the problem, a survey of the bryozoan fauna at Southern Reservoir and in nearby freshwater streams and reservoirs in Dunedin was undertaken. Twenty-two sites were each visited three times over the summer of 2002, with a minimum of six person-hours spent searching for bryozoans at each site. Sixteen of the 22 sites surveyed, all shady fast-flowing streams, had no bryozoans present in all three surveys. All four reservoirs and both wide rivers did have some bryozoans. *Plumatella emarginata* was the most widespread of the freshwater bryozoans in Dunedin, occurring at all 6 sites where any bryozoans were found. *Fredericella sultana* was most abundant in the Waipori River, and commonly found at Outram Glen and Southern Reservoir. *Plumatella repens* (both forms *P. r. typica* and *P. r. rugosa*) and *Paludicella articulata* were found only at Southern Reservoir and nowhere else in the survey. We note that open sunny eutrophic reservoirs appear to produce conditions conducive for bryozoan proliferation, resulting in biofouling problems such as occur at Southern Reservoir.

Key words: Bryozoa, *Paludicella articulata*, *Plumatella repens*, fouling, Dunedin.

Introduction

Freshwater bryozoans, bushy colonies of minute tentacle-bearing clones (zooids) that feed upon microscopic plankton, are usually found in ponds, lakes and rivers, forming a cryptic but often abundant part of the fauna (Bushnell 1966). When they colonise artificial structures such as equipment at water treatment plants or aquaculture facilities, bryozoans can become a nuisance (Baily-Brock & Hayward 1984; Aprosi 1988; Wood et al. 1998, Wood & Marsh 1999). In Dunedin's Southern Reservoir water treatment station, *Paludicella articulata* and *Plumatella repens* grow on hard surfaces in water intake pipes, floats, microstrainer chambers as well as in the Reservoir itself. Their presence has become a severe problem since 1996, intermittently affecting normal operation of the plant. The main impact of freshwater bryozoans at Southern Reservoir occurs when dead clumps are torn off the sides of pipes and walls, clogging microstrainers and causing considerable damage. Bryozoans living in pipes may also reduce effective pipe bore diameter and thus slow water velocities. The presence of fouling bryozoans increases staff workloads, reduces efficiency, and may impede the delivery of drinking water to Dunedin residents. In addition, decaying bryozoan fragments may adversely affect water quality (Harmer 1913).

Any investigation into methods of controlling or managing bryozoan populations at Southern Reservoir requires the identification of bryozoan species. Knowledge of the local bryozoan fauna is essential because biofouling control strategies will be heavily influenced by the biology of the pest species. Freshwater bryozoans are easily overlooked and there is little information available on identification or distribution of species in southern New Zealand.

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A survey of freshwater bryozoans in New Zealand (WOOD et al. 1998) found 5 species. The most common species, *Fredericella sultana*, was found on rocks and aquatic plants throughout the North and South Islands. *Plumatella repens*, the second most common species found was also widespread. It was divided into two subspecies, *P. repens typica* and *P. repens rugosa*, distinguished solely by microscopic features of their statoblasts. *Plumatella emarginata* was widely distributed in fast-flowing water but not abundant at any site. *Paludicella articulata* was found only in Dunedin, its only record in Australasia, and possibly the southern hemisphere. An undescribed and unnamed plumatellid was also found in the Manawatu region. The survey of WOOD et al. (1998), conducted in January and February of 1995, found the first four of these species (including both subspecies of *P. repens*) in South Island, New Zealand.

Hence, the present study aims to establish which freshwater bryozoan species occur now around Dunedin, how widespread they are, whether the fouler *Paludicella articulata* has spread to any other parts of the Dunedin water supply, and the likely environmental controls on distribution of freshwater bryozoans. Dunedin City Council Water Department and Dunedin consultants AMS Research have devised a multi-staged research approach to the problem of fouling by freshwater bryozoans. As part of that programme, surveys were carried out in the microstrainer hall at Southern Reservoir (where fouling is most severe) as well as in Dunedin's water reservoirs and intake streams. The long-term goal of the overall research programme is to allow the Dunedin City Council Water Department to determine the scope of the infestation, the potential for further colonisation by other species, and the possibilities for controlling the problem.

Methods

Survey of the microstrainer hall, Southern Reservoir

In order to survey the bryozoan fauna at Southern Reservoir water treatment plant, samples were collected from five locations in the microstrainer hall on 28th March 2001. Collection sites included ropes, floats, experimental settlement plates, microstrainer housings, and the chamber walls immediately below the access hatches. Entire colonies were recovered using a long-handled scraper, to a maximum water depth of about one metre. Wall scrapes in areas without visible colonies yielded enormous numbers of bryozoan statoblasts (resting stages), some of which were collected. All samples were taken alive to the laboratory for identification.

All living bryozoan colonies collected were examined under a dissecting microscope. The specimens were identified using the keys of ROGICK (1959), MUNDY (1980), RICCIARDI & REISWIG (1994) and WOOD et al. (1998). Several colonies were preserved as an archive. Statoblasts were examined under the light microscope, but it was clear that scanning electron microscopy (SEM) was necessary to identify bryozoan statoblasts to the sub-species level. SEM samples were dehydrated in ethanol and allowed to air-dry over a 24-hour period. The samples were then mounted on stubs, gold-coated, and examined using a SEM.

Survey of Dunedin City freshwaters

Twenty-four sites from five areas were chosen in consultation with the Dunedin City Council Water Department. They included five reservoirs, two wide rivers, and 16 smaller streams, most of which contributed to Dunedin's urban water supply. The Outram borefield pump was also added to the list. In the summer of 2002, two sites in upper Sawyers Bay were clogged by a massive mud-slide, and it was decided not to include them in the survey. The 22 sites visited are listed in Table 1 and their locations marked on Figure 1. Several are pictured in Figure 2.

Three separate surveys were made at each site. The first survey of all sites occurred between 31 January and 25 February 2002 (it was delayed by prolonged rainfall). The second survey was carried out between 12 March and 10 April 2002, and the third between 18 May and 1 June 2002. During the first survey, each site was visited, photographed, and described. All available surfaces were examined, and many samples of substrate were removed to be studied under the microscope.

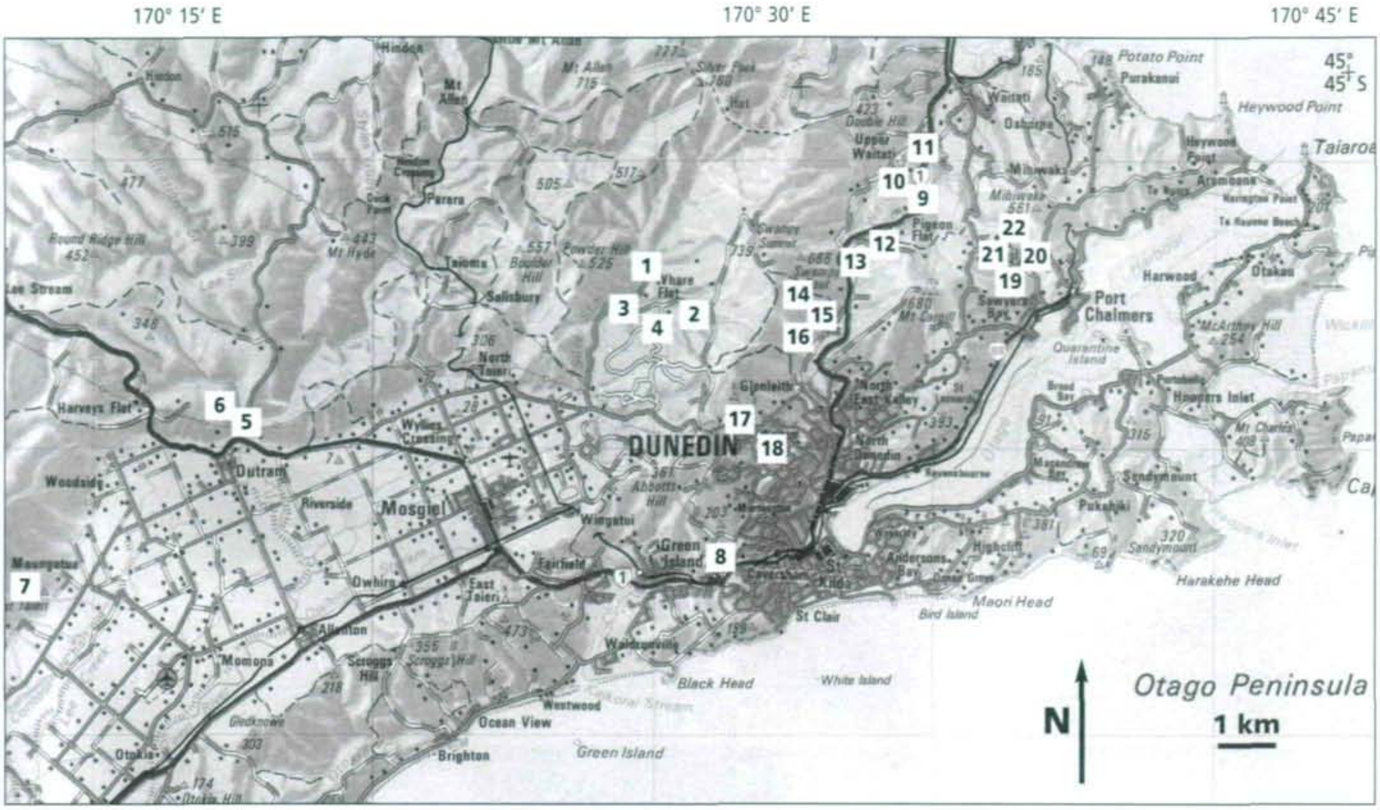
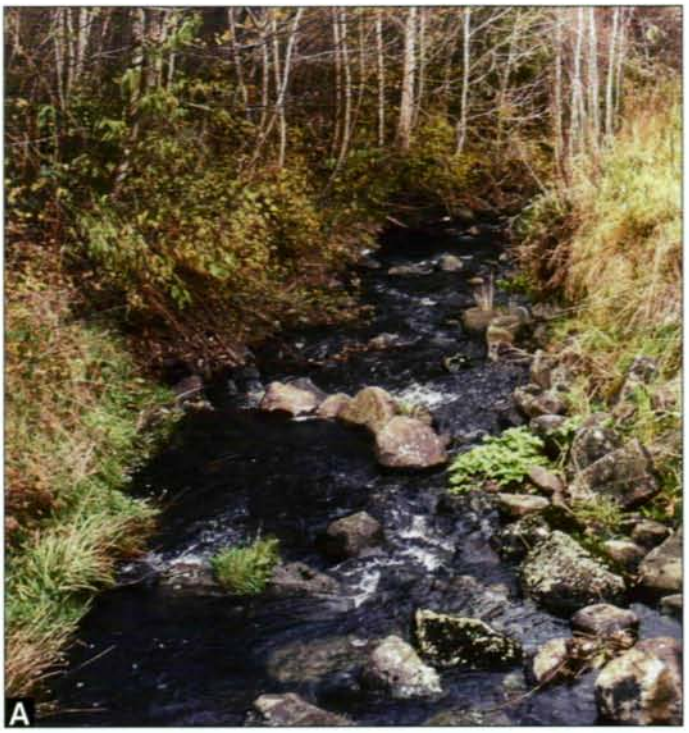


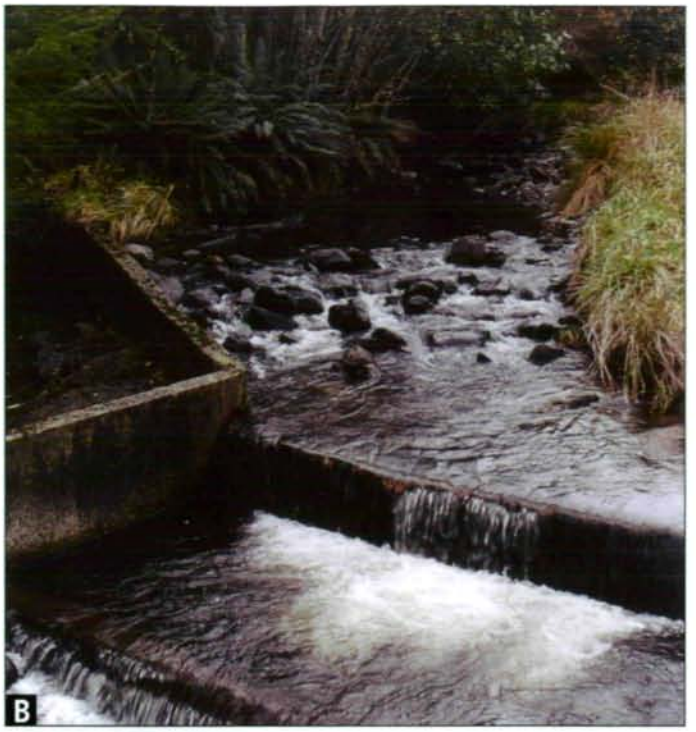
Fig. 1: Locations of survey sites around Dunedin, New Zealand (see also Tab. 1).

Tab. 1: Freshwater survey sites, Dunedin, New Zealand, as shown in Figures 1 and 2.

Site	Site Name	Longitude	Latitude	Description	Fig
1	Silverstream pump	170° 26′ E	45° 49′ S	Open stream, wide, clean water of variable velocity	
2	McKenzie's Creek	170° 27′ E	45° 50′ S	Shallow stream, shady, narrow, fast flowing clean water	
3	Sligo's Creek	170° 26′ E	45° 50′ S	Deep stream, shady, clean water of variable velocity	2 B
4	McQuilkan's Creek	170° 26′ E	45° 50′ S	Stream, shady, fast-flowing clean water	2 A
5	Outram Borefield	170° 15′ E	45° 52′ S	Borefield pump, water strained to find statoblasts	2 I
6	Outram Glen	170° 15′ E	45° 51′ S	Shallow wide river, slow backwaters and faster riffles	2 D
7	Waipori River	170° 6′ E	45° 57′ S	Shallow wide green river, slow flowing, deep pools	2 E
8	Southern Reservoir	170° 28′ E	45° 54′ S	Reservoir with concrete walls, 2 intakes, green water	2 G
9	Williams Creek	170° 32′ E	45° 48′ S	Small creek, shady, fast flowing clean water	
10	Burns Creek	170° 31′ E	45° 48′ S	Steep stream, shady, fast flowing clean water	
11	Jeffersons Creek	170° 31′ E	45° 49′ S	Narrow stream, shady, fast flowing clean water	
12	Sullivan's Dam Res	170° 32′ E	45° 49′ S	Reservoir with rocky walls, turbid, greenish water	
13	West Branch Creek	170° 31′ E	45° 50′ S	Wide shallow stream, clean, shady, some deep pools	
14	Upper Morrisons	170° 30′ E	45° 50′ S	Steep creek, shady, fast flowing clean water	
15	Lower Morrisons	170° 30′ E	45° 51′ S	Steep creek, shady, fast flowing clean water	
16	Nicholls Creek	170° 30′ E	45° 51′ S	Stream, shady, fast-flowing clean water, some deep	
17	Ross Creek	170° 29′ E	45° 52′ S	Stream, very shady, fast-flowing clean water	2 F
18	Ross Creek Reservoir	170° 31′ E	45° 52′ S	Reservoir with rocky walls, turbid, greenish water	
19	Rossville Reservoir	170° 35′ E	45° 49′ S	Reservoir with rocky walls, turbid, greenish water	2 H
20	Cedar Creek	170° 36′ E	45° 49′ S	Small stream, shady, fast-flowing clean water	2 C
21	Brosnahan's Creek	170° 36′ E	45° 49′ S	Stream, shady, silty water of variable velocity	
22	Thompson's Creek	170° 35′ E	45° 50′ S	Stream, shady, silty fast-flowing water	

All bryozoans and other organisms were recorded. Every effort was made to check all available habitats: deep pools, submerged rock walls, intake pipes (inside and out), boulders, rocks (including some buried rocks) gravel, sand and mud, logs, twigs and leaves, and rubbish. To standardize sampling effort at the sites, at least an hour was spent searching (by 2-3 people) at each site, allowing a very comprehensive picture of each area. The smaller





streams were easier to sample, however, than the steep-sided reservoir walls. In the second and third surveys, two people each spent half an hour searching.

At the Outram borefield site, the pump was opened and water was sieved through several layers of fine cloth, collecting many fine particles. The collected material was analysed later for bryozoan statoblasts.

Rocks, sticks, leaves, and sediment samples were examined under dissecting microscopes in the laboratory. Bryozoans present were identified using the keys of ROGICK (1959), MUNDY (1980), RICCIARDI & REISWIG (1994) and WOOD et al. (1998). Relative abundance was estimated using the scale: abundant – common – rare – absent. Dead colonies, too, were noted. Sediment taken from each site was washed into a white bucket and statoblasts were extracted and dehydrated in ethanol and allowed to air-dry over a 24-hour period. The samples were then mounted on stubs, gold-coated, and examined using a SEM.

Results

Southern Reservoir

Colonies and reproductive structures of two bryozoan species (*Paludicella articulata* and *Plumatella repens*) were found in the mi-

crostrainer hall at Southern Reservoir (Fig. 3A). Both species had been recorded in Southern Reservoir prior to this survey, although the precise identification of the plumatellid species was uncertain (SMITH & BATSON 2001). Two distinct varieties of *Plumatella repens* were present: *P. r. typica* and *P. r. rugosa*. Later analysis of statoblasts suggested that *P. vaihiriae* could also be present, though no colonial material was identified.

Dunedin freshwaters

Sixteen of the 22 sites surveyed had no bryozoans present in all three surveys. Most of them were shady, fast-flowing streams with clear water. All four reservoirs and both wide rivers did have some bryozoans. All four species previously recorded were found in our survey of Dunedin, although only one site on one visit had all four present (Tab. 2).

Plumatella emarginata (Fig. 3B) was the most widespread of the freshwater bryozoans in Dunedin, occurring at all six sites where any bryozoans were found. At Sullivan's Dam, it was the most abundant bryozoan present, and it was common at Rossville Reservoir and Waipori River. While no living *P. emarginata* was found at Ross Creek Reservoir, the statoblasts were found in increasingly large numbers as the summer turned to autumn. *Plumatella emarginata* was rare or absent at Outram Glen and Southern Reservoir. While *P. emarginata* was widespread from January to April (in the first two rounds of sampling), colonies were found only at Sullivan's Dam in the later (May to June) sampling, suggesting its growth season was ending.

Fredericella sultana was most abundant at Waipori River, and commonly found at Outram Glen and Southern Reservoir. It was mostly found on rocks (Fig. 3C). Like *Plumatella emarginata*, *Fredericella sultana* abundance declined as autumn arrived.

Paludicella articulata and *Plumatella repens* (and possibly *P. vaihiriae*) were found in Southern Reservoir and nowhere else in the survey. *Plumatella repens* was rare, but *Paludicella articulata* was quite abundant in places. WOOD et al. (1998) found *Plumatella repens* (as well as *P. emarginata*) at Ross Creek, but there was no sign of it at this time. No bryozoans were found at Southern Reservoir in the second round of sampling, possibly due to the water level being very high, such that some previously occupied substrates were too deep to reach or observe. Live colonies of *Paludicella articulata* were still common in late autumn at Southern Reservoir (despite having mostly died out in the microstrainer hall; see SMITH 2001).

Fig. 2: Photographs of some of the survey sites around Dunedin, New Zealand.
A: McQuilkan's Creek, Silverstream, site 4.
B: Sligo's Creek, Silverstream, site 3.
C: Cedar Creek, Sawyers Bay, site 20.
D: Outram Glen, Taieri River, site 6.
E: Waipori River, West Taieri, site 7.
F: Ross Creek, Dunedin City, site 17.
G: Southern Reservoir, Dunedin City, site 8.

Fig. 2: Photographs of some of the survey sites around Dunedin, New Zealand.
H: Rossville Reservoir, Sawyers Bay, site 19.
I: Outram borefield pump, site 5.

Discussion

One of the main reasons for studying the small streams was to see if these intakes were sources of freshwater bryozoans, carrying them or their statoblasts into the reservoirs. It appears that the opposite is the case – reservoirs (and slow turbid rivers) clearly provide an excellent environment for the growth of freshwater bryozoans, whereas clean shady streams do not. The sites without bryozoans in this survey were characterized by clear water, steepness, fast water flow, and shade. Sites with bryozoans, on the other hand, tended to have turbid water, often greenish-coloured, at least some areas where flow was quite slow, and open, sunny aspects.

SMITH (2002) found, in an experimental setting, that high water velocity did not inhibit growth of freshwater bryozoans. Others have found that freshwater bryozoans prefer strong flows, and indeed the populations in the reservoirs are often concentrated near the intake and outlets, where water flow is the highest. It seems unlikely that relatively high water velocity in streams limits the distribution of bryozoans.

Bryozoans are suspension-feeders (SMITH & BATSON 2000, 2001), consuming organic particles they are able to gather from the water column. If the sunny open reservoirs have provided a setting conducive to phytoplankton blooms, they have also provided plenty of food for freshwater bryozoans. The greenish colour of the water, along with observations of foam at the banks, suggest that planktonic primary productivity in the reservoirs was high during the summer and autumn.

Almost all sites contained a wide variety of other freshwater invertebrates. Caddisfly, stonefly, and mayfly larvae were common in many locations, as were other aquatic insects such as water boatman. Snails, crayfish and worms were seen at some locations. Freshwater sponges were observed at Sullivan's Dam Reservoir (in association with the bryozoan *Plumatella emarginata*), and eels were noted at Southern Reservoir. This abundance of life suggests that none of the sites studied have a pollution, siltation, or persistent oxygenation problem that would inhibit the growth of invertebrates.

Freshwater bryozoans inhabited all the reservoirs studied, but Southern Reservoir had two species found nowhere else, and was the only site where all four species were found. While freshwater bryozoans may have inhabited Southern Reservoir for a long time, excessive fouling by *Paludicella articulata* and *Plumatella repens* has only occurred since about 1996. At about the same time, the pine forest around Southern Reservoir was logged. It is worth considering whether a change in environment associated with the removal of trees may have resulted in the sudden enhancement in bryozoan growth and settlement. Removing the trees could have raised the pH of the water as pine needles ceased to fall in, thus promoting growth. *Paludicella articulata* colonies do not thrive in water with pH less than 5.9 (ØKLAND & ØKLAND 2000). Experimental lowering of pH (SMITH 2002), however, did not control or limit settlement of these

bryozoans. Increasing amounts of sunlight and/or nutrients reaching the reservoir, too, may well have produced phytoplankton blooms and enhanced the food supply for bryozoans so much that they were able to grow prolifically.

In summary, four (or possibly five) species of freshwater bryozoans live in the Dunedin freshwaters surveyed. *Plumatella emarginata* and *Fredericella sultana* are the most widespread, but are not at present acting as biofoulers. *Paludicella articulata*, *Plumatella repens* and possibly *P. vaihiriae* are important foulers, only found at Southern Reservoir. This survey found no bryozoans in any of the small, shady creeks that flow into the water system, nor were any statoblasts found in Outram borefield water. Bryozoans and their statoblasts were only found in reservoirs and larger, turbid rivers, open to the sun; and none of these environments were free of bryozoans. Eutrophic waters with considerable phytoplankton production may be able produce enough food for freshwater bryozoans to survive and even to grow excessively, becoming biofoulers.

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Tab. 2: Distribution and abundance of freshwater bryozoans in Dunedin, New Zealand. A = abundant, C = common, R = Rare, Statob. = statoblasts only found, all others indicate colonies present.

Site	Site Name	31 January to 25 February 2002			12 March to 10 April 2002				18 May to 1 June 2002				All Visits
		Paludicella articulata	*Plumatella emarginata*	*Plumatella repens*	*Fredericella sultana*	*Paludicella articulata*	*Plumatella emarginata*	*Plumatella repens*	*Fredericella sultana*	*Paludicella articulata*	*Plumatella emarginata*	*Plumatella repens*	*Fredericella sultana*	Other taxa
1	Silverstream pump													Algae, fly larvae
2	McKenzie's Creek													Algae, fly larvae
3	Sligo's Creek													Many insects
4	McQuilkan's Creek													Fly larvae, crayfish
5	Outram Borefield	pump not running, water not sampled												
6	Outram Glen		R - dead		C - live		R - live		C - live				R - live	Algae, others
7	Waipori River		C - live		A - live		C - live		A - live					Algae
8	Southern Reservoir	A - live	R - live	R - live	C - live					C - live		R - live		Snails, larvae, eels
9	Williams Creek													Fly larvae, worms
10	Burns Creek													Larvae, crayfish
11	Jeffersons Creek													Larvae, worms
12	Sullivan's Dam Res.		A - live				A - live				C - live			Algae, ?sponges
13	West Branch Creek													Many larvae, crayfish
14	Upper Morrisons													Insect larvae
15	Lower Morrisons													Insect larvae, snails, crayfish
16	Nicholls Creek													Insect larvae
17	Ross Creek													Insect larvae, worms, crayfish
18	Ross Creek Reservoir		R - statob.				C - statob.				A - statob.			Algae
19	Rossville Reservoir		C - live				C - live							Insects, snails, others
20	Cedar Creek (lower)													Insect larvae, snails, crayfish
21	Brosnahan's Creek													Insects, crayfish
22	Thompson's Creek													Insect larvae

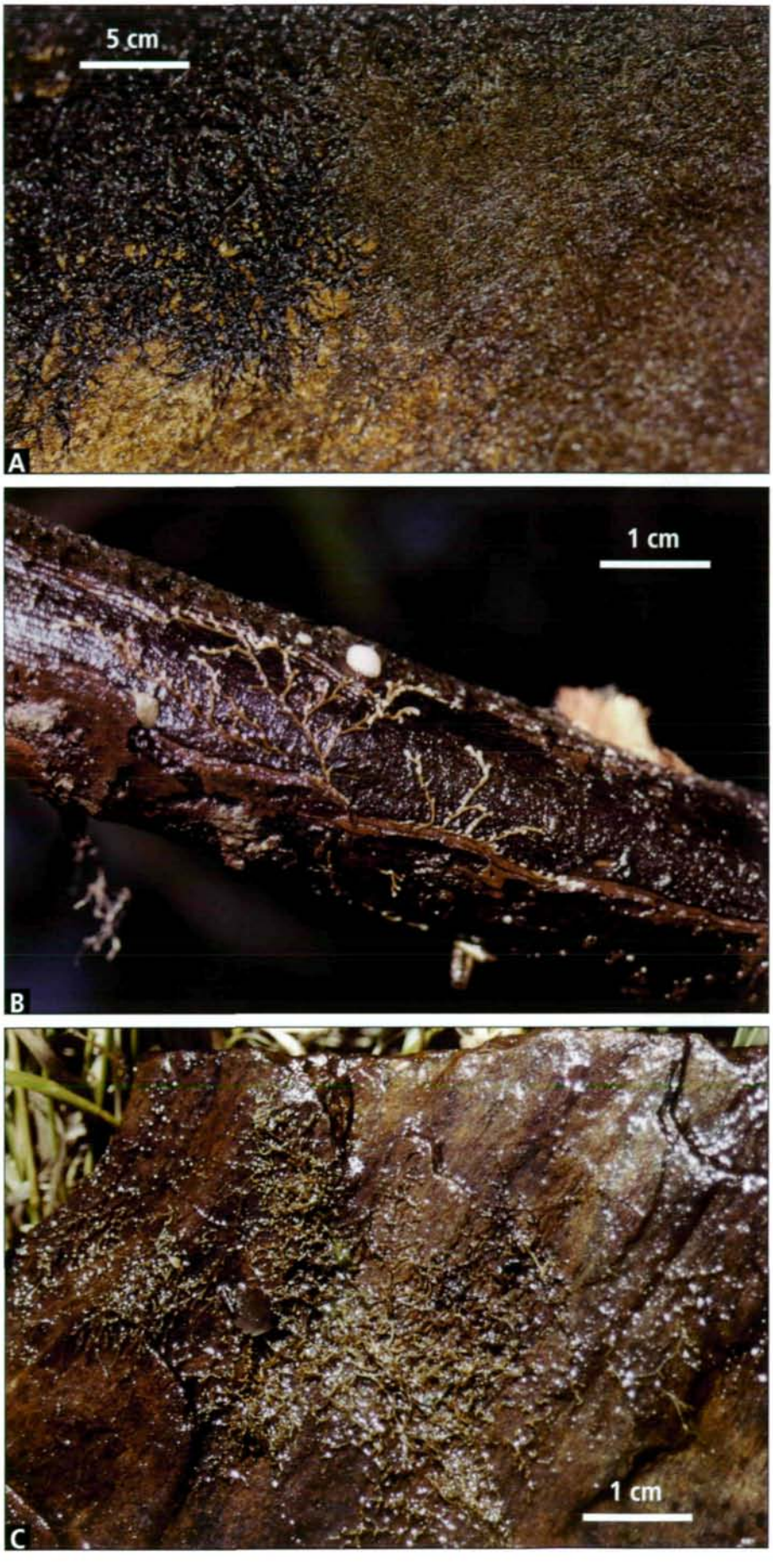

Fig. 3: Freshwater bryozoan species found in Dunedin, New Zealand. **A**: *Paludicella articulata* (right, pale brown) and *Plumatella repens* (left, dark brown) growing on a concrete wall, Southern Reservoir. **B**: *Plumatella emarginata* on a branch from Outram Glen. **C**: *Fredericella sultana* on a rock from the Waipori River.

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