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The Pipeline Menace of Freshwater Bryozoans

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Abstract. Under certain conditions, conduits carrying unfiltered water from lakes or rivers eventually become lined with bryozoans, hydroids, sponges, and many other organisms. By blocking the conduit or clogging end use devices, these nuisance animals impose serious economic costs. Bryozoans are probably the most common among the fouling animals. Three factors hinder control efforts: (1) dormant bodies (statoblasts or hibernaculae) that tolerate harsh physical and chemical treatments; (2) regeneration of bryozoan colonies from pockets of living tissue; (3) easy dispersal of bryozoans through air and water. Control measures must take into account the species involved, their source, their accessibility, the end use of the water, and the seasonal conditions in which the problem occurs.

Key words. Bryozoa, biofouling

Introduction.

Whenever a pipeline or waterway carries untreated water from a lake or river it soon becomes home to a variety of invertebrate animals. This point was graphically illustrated by HASSALL (1850) in his classic color plates published in “Microscopical Examination of the Water Supplied to the Inhabitants of London and Suburban Districts” **(Fig 1).** The drawings, showing an abundance of rotifers, nematodes, protists and microcrustaceans enlarged 250x, contributed to a heated debate in England over the quality of water supplied by public utilities.

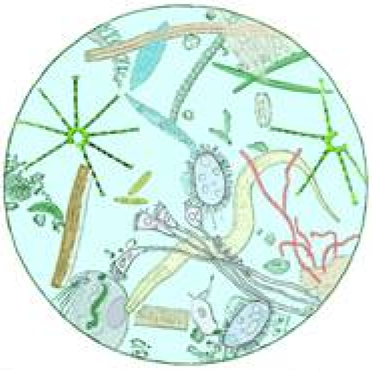

Fig. 1. Representation of microscopic organisms appearing in the water lines in the City of London to alert residents to the poor quality of the public water supply, from a color plate by Hassall (1850).

Pipeline residents are not always so microscopic. Hydroids and bryozoans are among the invertebrate animals that thrive in dark places where continuously flowing water brings an unlimited supply of particulate food **(Fig 2).** Free branches of the tubular colonies may become tangled and intertwined, filling the pipeline interior with a dense meshwork that impedes or blocks water flow. Pieces of colonies are eventually carried off by the water until they clog a filter, water sprinkler orifice, or other end-use device. The colonies leave behind dormant, resistant structures attached to the pipeline interior, which are the “seeds” to start new colony growth.

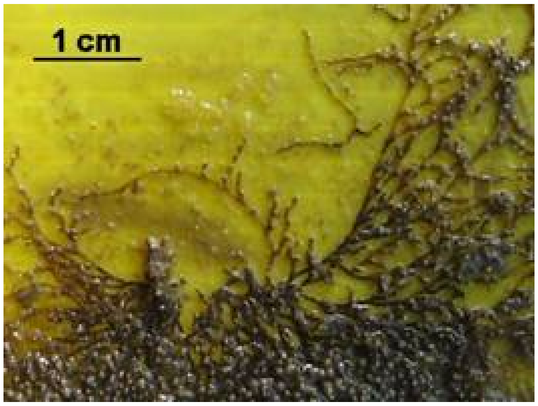

Fig. 2. Colony of the bryozoan, *Plumatella bombayensis*, growing on a plastic substratum in eutrophic waters of Thailand.

Before the widespread use of sand filtration, “pipeline animals” were discharged regularly from household faucets. One bryozoan species was discovered in New Zealand for the first time after “...specimens had come through the ordinary (Dunedin) town water-supply tap, about a mile and a half from the reservoir, and were floating in a white earthenware basin” (HAMILTON 1902). Today colonies of that same species still plague water lines in the City of Dunedin, clogging filters and microstrainers, often causing considerable damage and impeding the supply of drinking water (SMITH et al. this volume).

The situation in Dunedin is unique only in that the cause is recognized. Typically, seasonally clogged filters are tolerated as an unknown nuisance. For example, filters for the water piped from Lake Springfield (Illinois) are frequently burdened by what waterworks operators term “moss and turds,” actually living bryozoans and sponges. During peak seasons these are laboriously scooped out by hand, and the old cement conduit bringing water from lake depths remains a large source of the fouling animals. Throughout the world, bryozoans grow on filters, fountains, irrigation systems, cooling tower grids, water supply and wastewater facilities (WOOD & MARSH 1999). Typically known as “moss” or “algae,” they are seldom recognized as animals **(Fig. 3)**. Fouled surfaces are usually ineffectively cleaned and then returned to service.

Fig. 3. Handful of plumatellid bryozoans (*Plumatella vaihiriae*) from the wall of a secondary clarifier of a municipal wastewater treatment plant in Phoenix, Arizona, USA. They look more like plants than animals.

The economic costs of bryozoan fouling is probably high. In 1997 a wastewater treatment plant in Phoenix, Arizona had bryozoans removed by the truckload until an engineering firm recognized the problem and took steps to eliminate it (MARSH & WOOD 1997). At Florida golf courses entire clogged irrigation systems sometimes have to be dug up and replaced. The chronic fouling of decorative fountain pumps causes the motors to burn out prematurely **(Fig 4).** Because the cause is so seldom recognized there is no uniform reporting, and the economic cost is impossible to estimate. Information about bryozoan fouling is scanty at best in scientific, popular, or commercial literature. Even the internet is practically silent on the issue.

Good summary information on the biology of freshwater bryozoans is provided by WOOD (2001) and WOOD & OKAMURA (2005). This paper will present basic information about bryozoans that may be useful to anyone trying to solve a problem of bryozoan fouling.

Fig. 4. Bryozoans (*Plumatella rugosa*) growing on a submersible pump for a decorative fountain in a pond in Centerville, Ohio, USA.

Bryozoan dormancy.

It is an axiom of aquatic biology that freshwater invertebrates include in their life cycle a dormant structure specialized in surviving adverse conditions (BARNES et al. 2001). These may be thick-walled eggs or cysts, encapsulated germinal tissue, or even entire organisms that undergo long-term aestivation. For various lengths of time such structures may be unaffected by desiccation, freezing temperatures, toxic chemicals, lack of oxygen, and other suboptimal conditions.

Bryozoans have evolved several types of dormant structures. Those species classified in the exclusively freshwater Class Phylactolaemata (such as *Plumatella*) produce asexual statoblasts that are either attached firmly to the substratum or else released freely into the water. Sessile statoblasts, called sessoblasts, adhere firmly to the substratum **(Fig. 5b)**. No larger than a period on this page, they are easily overlooked by

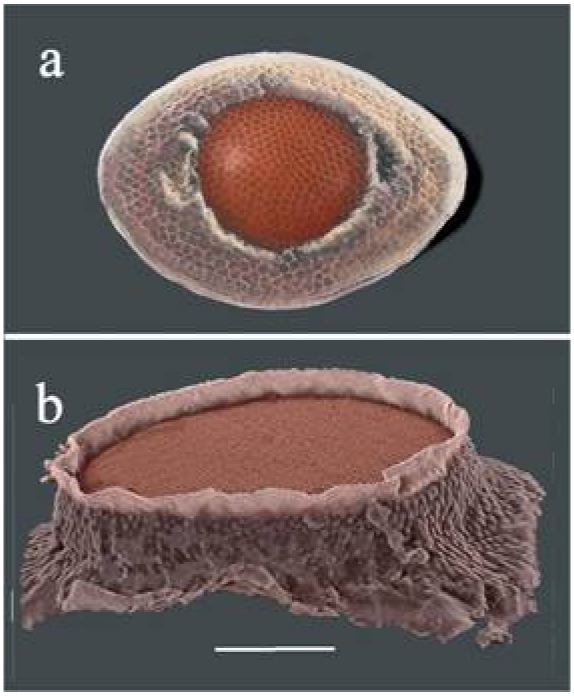

Fig. 5. Typical bryozoan statoblasts. (a) buoyant statoblast (floatoblast) of *Plumatella vaihiriae*; (b) attached statoblast (sessoblast) of *Plumatella emarginata*. Scale bar = 100 µm

workers cleaning away bryozoan colonies. Sessoblasts can lie dormant for months, either wet or dry, and then germinate to form new colonies. The free types of statoblast are termed floatoblasts because they are usually buoyant **(Fig. 5a)**. Far more numerous than sessoblasts but just as small, floatoblasts are the form most likely to gain entry to pipelines.

Not all freshwater bryozoans produce statoblasts. In the Class Gymnolaemata a few species, such as *Paludicella*, isolate a small part of the colony, thicken the walls, and fill it with yolk and germinal tissue (Harmer 1913). There are apparently two types of these so-called hibernacula: one is dark, spindle-shaped, and occurring within the normal zooid walls; the other is a yellowish, irregularly shaped body attached to the substratum. Both of these are too small to be examined without magnification. Virtually nothing is known about the tolerance of hibernacula to adverse conditions. However, like statoblasts, they are capable of overwintering in a dormant state and then germinating whenever suitable conditions return.

Being dormant, statoblasts and hibernaculae are unresponsive to treatments that would normally kill a living colony. Bryozoans may be removed from a fouled surface, but if dormant structures are left behind the fouling problems will continue to recur.

The problem of resilience.

Bryozoans respond to unfavorable conditions by withdrawing deeply into the colony interior. In this position they may withstand exposure to low levels of heavy metals and other toxins for hours or even days. In a toxicity bioassay it is not uncommon for such an apparently dead colony to “revive” when it is returned to clean water. The same observation has been made for hydroid colonies of *Cordylophora* (Folino-Rorem & Indelicato 2005).

Death does not overtake the entire colony at once, but occurs instead one zooid at a time, depending on zooid age, condition, position within the colony, and possibly other factors. It is even possible for a dead zooid to be replaced by an entirely new zooid derived from a small reservoir of germinal tissue (Wood 1973). Exactly how this occurs and under what circumstances are questions not yet resolved.

Because of these resilient mechanisms, it requires surprisingly high concentrations of biocides to kill live bryozoan colonies. Often this cannot be done without inflicting serious damage on nontarget organisms. For example, low concentrations of copper sulfate may have little long-term impact, while higher concentrations would create unacceptable consequences in irrigation or public water supply systems.

The problem of dispersal.

Freshwater bryozoans are common in freshwater habitats worldwide. Species such as *Plumatella casmiana* are reported from every continent except Antarctica (Wood & Wood 2000), while others, such as *Plumatella mukaii*, have widely distributed but highly disjunct populations (Wood 2002). It is clear from distribution data that freshwater bryozoans have little difficulty getting around.

Buoyant floatoblasts are responsible for much of bryozoan dispersal. Produced in large numbers by most species, they are effectively transported in flowing water. Flood waters also distribute statoblasts over wide areas where they find new places to germinate. Terrence Marsh (personal communication) has reported plumatellid colonies growing at the highwater line on homes submerged for several weeks during spring flooding of the Mississippi River. Similar scenes are common during the rainy season in Southeast Asia **(Fig. 6)**. Floatoblasts are easily drawn from rivers or lakes into irrigation systems where they may lodge and germinate. Because of their small size the floatoblasts are difficult and expensive to remove from incoming water.

Those bryozoan species lacking free statoblasts (*Fredericella*, *Paludicella*) are probably distributed either by drifting fragments of colonies or by substrata (eg. aquatic plants) bearing colonies or other dormant structures. Bryozoan statoblasts are also carried passively by migrating animals. Microsatellite data suggest that waterfowl are likely vectors for ongoing dispersal of *Cristatella mucedo* in Europe (FREELAND et al. 2000). In some instances, species distribution often seems to follow routes of bird migration (WOOD 2002). In a series of experiments, BROWN (1933) and CHARALAMBIDOU et al. (2003) have determined that floatoblasts can survive passage through the digestive tract of ducks, suggesting that these and other waterfowl could disperse bryozoans even during long distance migration. Not surprisingly, wastewater treatment plants reporting bryozoans in their secondary clarifiers also note frequent visits by ducks that may be carrying viable statoblasts from natural habitats.

Fig. 6. Bryozoan colonies left behind when flood waters retreated from a house along the Bang Pakong River in central Thailand. Colonies appear on the neck and body of the decorative ceramic goose as well as on some of the woodwork.

Control of bryozoan fouling.

Successful control strategies must be tailored to each fouling situation. Important considerations should include the source of water, the source of fouling bryozoans, the species of bryozoans involved, and the end use of water. Also important are the nature of the fouled surfaces, access to those surfaces, whether they can be taken out of service, and for how long.

The first step of effective control is to determine whether bryozoans are generated within the system or entering with the water source. If the bryozoans are the type that produce buoyant statoblasts it may be possible to find the source by setting out a series of statoblast traps: small blocks of rough plastic foam (expanded polystyrene, such as Styrofoam®). Smooth foam, as in some fast food containers or construction panels, is not as effective as rough, sandpapery material from hobby shops. Small blocks of foam are tethered in the water at appropriate sites and allowed to remain for several days or weeks to see where statoblasts accumulate. Unmagnified, the statoblasts appear as uniform black specks; with a 10x lens it is possible to distinguish the outer buoyant cells and the darker central capsule.

Technically, statoblasts and colony fragments entering an irrigation system from surface waters can be removed by filtration. Products such as the self-cleaning filters made by Orival, Inc. (Englewood, New Jersey) claim to remove statoblasts and other particles larger than 200 microns from a 11 cm line with a flow rate up to 1500 liters/minute.

However, once a fouling problem has developed other treatment becomes necessary. Unfortunately, the most effective toxins for controlling bryozoans also kill fish and other nontarget organisms. Sodium hypochlorite (commercial bleach) is probably the least offensive chemical for effectively killing bryozoan colonies. For heavy growths in clean water a single static exposure to 1 mg/l for at least 5 hours is normally sufficient. Occasional maintenance treatments of 0.3 mg/l over 24 hours should keep bryozoans under control. For a highly organic environment it may be necessary to increase either the hypochlorite concentration or the exposure time. Note that these treatments will kill colonies but not statoblasts.

Among heavy metals, copper is widely used to control algae, and in higher concentrations it can also control bryozoans. However, in most instances the necessary concentrations are ecologically unacceptable and the results are only temporary. The effective concentration will vary with water hardness. Additives and formulations to make the copper more toxic to algae have little apparent effect on bryozoans. For *Plumatella emarginata* a 96-hour LC_{50} in moderately hard water has been calculated at 0.14 mg/l (PARDUE 1980); in soft water the 24-hour LC_{50} for *Plumatella bombayensis* is established at 0.17 mg/l (WOOD et al. 2004).

Antifouling paints have so far proven ineffective against freshwater bryozoans (APROSI 1988). Zinc galvanized surfaces appear not to support bryozoan growth (COLLINS 1978), but plastic and aged wood present very favorable substrata. Data from GREENLAND et al. (1988) suggest that polyethylene is more attractive to bryozoan colonization than vinyl, but virtually all known plastics, rubber, stone, glass and even corroding iron will support bryozoan growth to some degree.

Although all bryozoans thrive in quiet water, the most rapid and luxuriant growth occurs in lotic conditions. Experimental studies of *Plumatella fungosa* in pipelines showed that germinating statoblasts can take hold most easily in currents of less than 0.2 m/s; colony growth is inhibited at 0.6 m/s and at 0.9 m/s the mound-shaped colonies are swept away (APROSI 1988). Species that form a flatter colonies, such as *P. emarginata* and *P. reticulata*, tolerate much greater water velocities under natural conditions.

Few reliable experimental data are available to guide the practitioner on methods to control bryozoan fouling. Moreover, the wide range of situations where bryozoans are a serious nuisance places a heavy reliance on improvisation. Colonies can usually be killed by 3 hours of anoxic conditions or water temperatures above 35^o C. Brief exposures of high ammonia levels have successfully killed colonies in some wastewater treatment plants. No species can survive complete desiccation, although dense colonies, like a thick carpet, will retain water for a surprisingly long time.

Probably none of the above treatments will affect the dormant stages, although so far nothing is known about the tolerances of hibernaculae. Sometimes the simplest option is to wait for statoblasts to germinate and then treat the young colonies. If statoblasts cannot be observed directly, it should be sufficient to conduct treatments once in the early and late spring and in early fall. Most colonies stop growing at temperatures below 20^o C., or below 15^o C in the case of *Fredericella* species. Another possible option is to pressure-spray fouled surfaces with very hot water, which will blast away colonies and kill the dormant stages.

Sometimes it is possible to apply more creative strategies. For example, a golf course in Indiana (USA) took water from a small retention pond to irrigate the turf. During spring and fall the sprinklers were often seriously clogged with fragments of bryozoan colonies dislodged from inside the irrigation lines. The lake itself had a large population of bryozoans (*Plumatella casmiana*) growing on rocky rubble that lined the lakeshore. Masses of buoyant statoblasts formed what appeared to be a brown scum nearly a meter wide along the windward shore. The solution was not to treat the water, but to remove the rubble. With no substrate on which to grow, bryozoans disappeared from the lake. The irrigation system was treated only once with hypochlorite and thereafter the fouling problem was resolved.

References.

APROSI, G. (1988): Bryozoans in the cooling water circuits of a power plant. Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie 23: 1542-1547.

BARNES, R.S.K., P, CALOW, P.J.W. OLIVE, D.W. GOLDING, & J.J. SPICER (2001): The Invertebrates: A Synthesis, Third Ed. Blackwell Science, Oxford: 1-497.

BROWN, C.D. (1933): A limnological study of certain fresh-water Polyzoa with special reference to their statoblasts. Transactions of the American Microscopical Society 52: 271-316.

CHARALAMBIDOU, I., L SANTAMARIA, & J. FIGUEROLA (2003): *Cristatela mucedo* Cuvier 1798 (Bryozoa: Phylactolaemata) statoblasts survive duck gut passage. Archiv für Hydrobiologie **157**: 547-554.

COLLINS, C.M. (1978): Catfish cage culture, fingerlings to food fish. $Kerr Foundations, Inc. Publication 13, Poteau, Oklahoma.

FOLINO-ROREM, N.C. & J. INDELICATO (2005): Controlling biofouling caused by the colionial hydroid *Cordylophora caspia*. Water Research 39: 2731-2737.

FREELAND, J.R., L.R. NOBLE & B. OKAMURA (2000): Genetic consequences of the metapopulation biology of a facultatively sexual freshwater invertebrate. Journal of Evolutionary Biology 13: 383-395.

GREENLAND, D.C., S.H. NEWTON & R.F. FAUCETTE, JR. (1988): Effects of cage encrustation by the bryozoan *Plumatella casmiana* on production of cannel catfish. The Progressive Fish Culturist 50: 42-45.

HARMER, S.F. (1913): The Polyzoa of waterworks. Proceedings of the Zoological Society of London 1913: 426-457.

HASSALL, A.H. (1850): Microscopical examination of the water supplied to the inhabitants of London and suburban districts. Samuel Highley, London.

HAMILTON, A. (1902): On the occurrence of *Paludicella* in New Zealand. Transactions and Proceedings of the New Zealand Institute 35: 262-264.

MARSH. T.G. & WOOD, T.S. 1997. Report to Carollo Engineers regarding biofouling organisms at the 23rd Avenue Wastewater Treatment Plant (Carollo Project No. 4300A.10 510). (Unpublished).

PARDUE, W.J. (1980): Baseline toxicity data for freshwater bryozoa exposed to copper, cadmium, chromium, and zinc. Journal of the Tennessee Academy of Science 55(1): 27-31.

SMITH, A.M. (2005): Growth and development of biofouling freshwater bryozoans, Southern Reservoir, Dunedin, New Zealand, November 2000 to June 2004. (This volume).

WOOD, T. (1973): Colony development in species of *Plumatella* and *Fredericella* (Ectoprocta: Phylactolaemata). $In: R.S. Boardman, A.H. Cheetham, W.A. Oliver, Jr. (Eds.). Animal Colonies. Development and Function through Time. Dowden Hutchinson and Ross, Stroudsburg, Pennsylvania: 395-432.

WOOD, T. (2001): Bryozoans. $In: THORP, J. & A. COVICH, (Eds.). Ecology and Classification of North American Freshwater

Invertebrates, 2nd Edition. Academic Press, London: 505-525.

WOOD, T. (2002): Freshwater bryozoans: a zoogeographical reassessment. $In: WYSE JACKSON, P.N., C.J. BUTTLER & M. SPENCER JONES (Eds). Bryozoan Studies 2001: Proceedings of the 12th International Bryozoology Association. Balkema: Rotterdam & Brookfield: 339-345.

WOOD, T.S. & T.G. MARSH (1999): Biofouling of wastewater treatment plants by the freshwater bryozoan, *Plumatella vaihiriae* (Hastings, 1929). $Water Research 33(3): 609-614.

WOOD, T. & B. OKAMURA (2005): A new key to the freshwater bryozoans of Britain, Ireland and Continental Europe, with notes on their ecology. Freshwater Biological Association Publication 63, Ambleside, UK:

WOOD, T. S. & L. J. WOOD (2000): Statoblast morphology in historical specimens of phylactolaemate bryozoans. In: HERRERA CUBILLA, A. & J. B. C. JACKSON (Eds.) Proceedings of the 11th International Bryozoology Association Conference. Panama: Smithsonian Tropical Research Institute, Panama: 432-430.

Wood, T., Anurakpongsatorn P., Mahujchariyawong J., Satapanajaru T., Chaichana R. & Intorn N (2004). Guidebook on the use of bryozoans as bioindicators in the Mae Klong River Basin. Kasetsart University, Bangkok, Thailand: 1-39 {in Thai}.

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