Chinese Journal of Oceanology and Limnology
Vol. 35 No. 4, P. 815-820, 2017
http://dx.doi.org/10.1007/s00343-017-6052-2

Pectinatella magnifica (Leidy, 1851) (Bryozoa, Phylactolaemata), a biofouling bryozoan recently introduced to China*

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Received Feb. 22, 2016; accepted in principle Mar. 30, 2016; accepted for publication Apr. 26, 2016

Abstract Freshwater biofouling threatens a variety of human activities, from the supply of water and energy to recreation. Several species of freshwater bryozoans are notorious for clogging pipes and filters but have been relatively poorly studied to date. We report, for the first time, a biofouling species of freshwater bryozoan, *Pectinatella magnifica* (Leidy, 1851), from several freshwater rivers, lakes and ponds in China. A complete description, national distribution and the fouling problems are provided. Exactly how *Pectinatella magnifica* arrived in China remains unclear, but anthropochory and zoochory are considered to be important dispersal pathways.

Keyword: *Pectinatella magnifica*; Bryozoa; Phylactolaemata; new record species; taxonomy; China

1 INTRODUCTION

Biofouling animals accumulate on underwater substrates and adversely affect human infrastructure and activities. Freshwater biofoulers are much less well-known than their marine counterparts, but can have an important economic impact (Callow, 1993). Nakano and Strayer (2014) estimate the potential global cost of freshwater biofouling to be ~277US$ million per year. As one of the most important groups of freshwater biofoulers, bryozoans have the ability to accumulate in large masses of living and non-living materials on submerged surfaces, which can seriously damage artificial equipment and disrupt human activity (Wood, 2010).

Bryozoans are tiny coelomate animals. They can form coherent colonies which often grow to a surprisingly large size. Most freshwater species belong to the class Phylactolaemata, and we here report an exotic bryozoan, *Pectinatella magnifica*, which has caused serious biofouling problems in aquaculture systems in several freshwater lakes and ponds in China. Due to its large size (sometimes exceeding 0.5 m in diameter), *P. magnifica* also has a history of clogging water intake structures in North America (Geiser, 1937). Although seldom acknowledged publically, it is capable of causing serious damage to irrigation and other water supply systems.

Our primary intent in this paper was to document *P. magnifica* occurrence in China, giving the first full description of the species. We also summarized the fouling problems and discussed the dispersal mode of *P. magnifica*. Although we discuss several possible methods for suppressing bryozoan populations, thorough studies on the effectiveness of such measures are still under way.

2 MATERIAL AND METHOD

2.1 Collection and preservation

We used a sharp knife to remove colonies, along with the underlying substratum to keep them intact. Living colonies were put in a standard 1-L wide-

* Supported by the National Natural Science Foundation of China (Nos. 31100407, 31471962)

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mouth polyethylene bottle and taken to the laboratory for further observation and final identification. Specimens were narcotized with menthol, then fixed and preserved in 75% ethanol.

2.2 Treatment of statoblast

Statoblasts were measured with a compound microscope fitted with an ocular micrometer. For scanning electron microscopy, we removed the close-fitting membranous envelope of the statoblasts and dried them in a household freezer, sputtered them in gold, and examined and photographed them through a Hitachi S-4800 microscope (Wood, 2005).

2.3 Data sources and analysis

Data on the distribution and biofouling of *P. magnifica* in China were collected from author's field investigations, literature (Wang et al., 2009) and news report (http://news.163.com/05/0929/21/1URLF3BU0001122C.html).

3 RESULT

3.1 General description and identification of *Pectinatella magnifica*

Colonies are globular and gelatinous, ranging from a small flat sheet to a large mass the size of a rugby ball (sometimes exceeding 0.5 m in diameter). They can be free floating or attached to submerged solid materials in freshwater rivers and lakes (Fig.1). They consist of a single layer of zooids attached to a thick substratum of firm, transparent, colorless jelly. Zooids are arranged in clusters, or "rosettes", with many slender, radiating lobes, each bordered by a double row of actively-contracting polypides (Fig.1). The mouth area of each zooid is red, and each tip of a lophophore arm bears a single white glandular organ.

The free statoblast of *P. magnifica* is discoidal, laterally asymmetrical and about 1 mm in diameter (Fig.1c). Hooked spines radiate from the annulus periphery, each spine composed of fused extensions of the dorsal periblast (Fig.2a, b, c, and d). There is a single large tubercle in the center of the ventral fenestra (Fig.2b). The surface of dorsal and ventral periblasts are both reticulated with a raised net-like pattern (Fig.2a, b, c, and d), but ventral valve's reticulation becomes weak in the center of the fenestra (Fig.2b). No sessile statoblasts are produced.

A pair of conspicuous white spots on the lophophore is diagnostic for this species. Red pigmentation around the mouth is much more pronounced and consistent than in any other phylactolaemate species. The statoblast bears a superficial resemblance to that of *Cristatella mucedo*, but the spines of *P. magnifica* originate at the periphery of the annulus, not at the periphery of the fenestra.

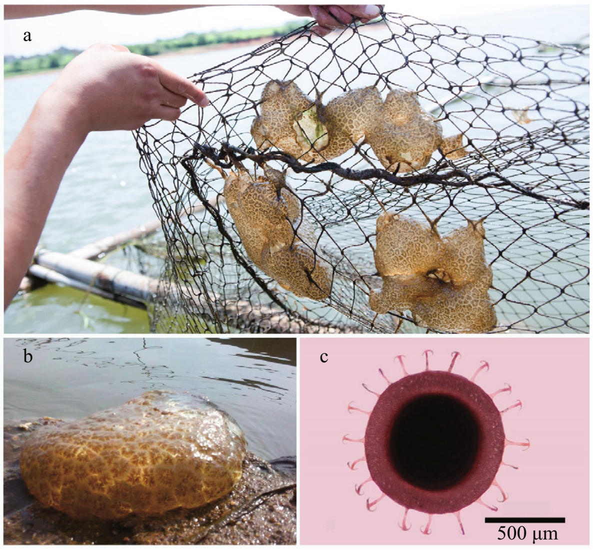

Fig.1 *Pectinatella magnifica* found in Poyang Lake in June 2012

a. habitat; b. colonies; c. statoblast.

3.2 Distribution of *Pectinatella magnifica* in China

In September 2005, *P. magnifica* was recorded on leaves and stems of aquatic plants in Human Reservoir (28°21′38″N, 121°24′56″E) on the eastern coast of Zhejiang Province. This is the first record of *P. magnifica* from China. Within a short period of time, the presence of this species was also confirmed in Poyang Lake, Zuohai Lake and the Wujiang River. In addition, *P. magnifica* was also found in Dianbai Pond, where colonies grow to a giant size of up to 2 m in diameter. Until now, *P. magnifica* had been found in 8 localities, including 5 different provinces in China (Table 1, Fig.3).

The known distribution so far suggests the species prefers a sluggish lentic habitat and flourished from the early summer to the late autumn. The colony substrate included long-submerged wood, bamboo, aquaculture cage, dangling ropes and dock pilings.

3.3 The fouling problems of *Pectinatella magnifica*

Although a single bryozoan species fouled all eight sites, the problems they caused were somewhat different at each site (Table 1). In the Human Reservoir and Wujiang River, the colonies were a nuisance and a worrisome presence, but they did not noticeably

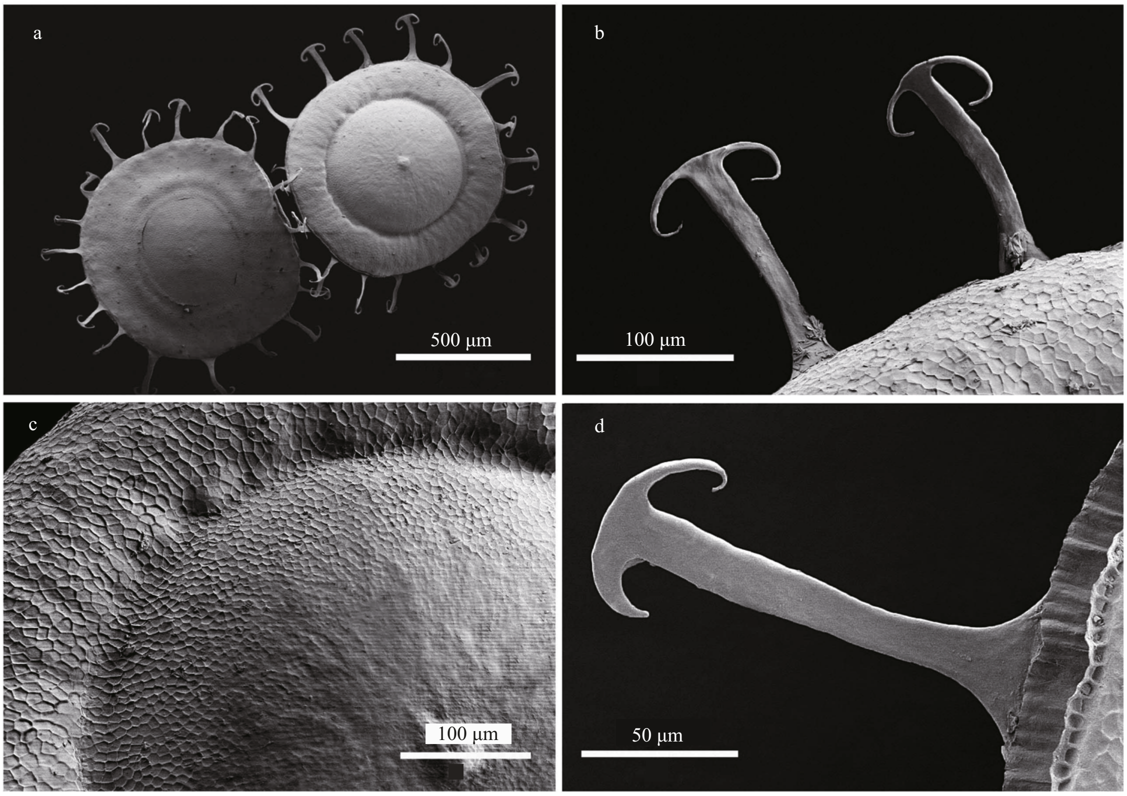

Fig.2 Scanning electron Microscopy of *Pectinatella magnifica*

a. statoblast, dorsal views (left), ventral views (right); b. higher magnification enlargement of ventral statoblast; c. hooked spines; d. higher magnification enlargement of spine.

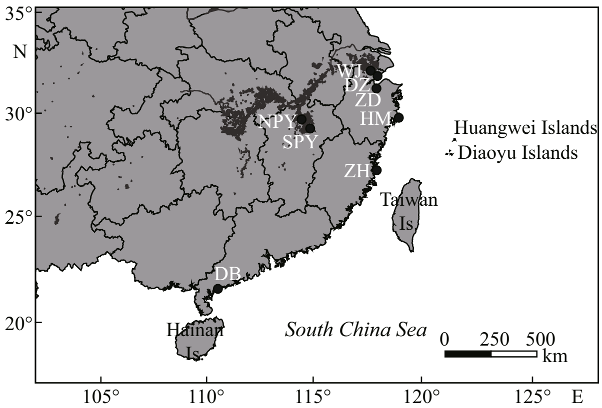

Fig.3 Localities (black dots) of *Pectinatella magnifica* in China from 2005 to 2012

HM: Human Reservoir; SPY: Southeast of Poyang Lake; ZH: Zuohai Lake; WJ: Wujiang River; ZD: Zhudong Lake; DB: Dianbai Pond; NPY: Northeast of Poyang Lake; DZ: Dingzha Pond.

impair any human activity. In Poyang Lake (2012), Zuohai Lake, Zhudong Lake, Dianbai Pond and Dingzha Pond the fouling problems were more serious. Thousands of colonies were attached to fish cages, which can reduce interstitial water flow, with consequent effects on water oxygen and chemistry causing adverse impacts on aquaculture and ecosystems. In a mussel farm of Poyang Lake (2007), the fouling problem was the most serious case occurring in China. Vigorous colonies of *P. magnifica* on mussel cages had lethal and sublethal effects on *Cristaria plicata*, because of the strong competition for space. Moreover, they belong to the same functional feeding group, and thus probably compete for food as well as space. Large accumulations of *P. magnifica* attached on mussel cage can generate a hypoxic environment, which would lead to a fall in production and even widespread death of *C. plicata* for lacking of food and oxygen.

Due to its large size (sometimes exceeding 0.5 m in diameter), *P. magnifica* can block water intake structures. Although not reported in China, *P. magnifica* is capable of causing serious damage to irrigation and other water supply systems.

4 DISCUSSION

Leidy found and described *Pectinatella magnifica* in 1851 near Philadelphia. He placed it in the genus *Cristatella* and called this new species *Cristatella magnifica* (Leidy, 1851a). However, he soon discovered that this new species differs from others in

Table 1 Basic information of *Pectinatella magnifica* found in China

Date	September, 2005	November, 2007	June, 2008	November, 2008	June, 2010	June, 2011	July, 2012	September, 2012
Code	HM	SPY	ZH	WJ	ZD	DB	NPY	DZ
Location	Human Reservoir, Zhejiang Province	Southeast of Poyang Lake, Jiangxi Province	Zuohai Lake, Fujian Province	Wujiang River, Jiangsu Province	Zhudong Lake, Zhejiang Province	Dianbai Pond, Guangdong Province	Northeast of Poyang Lake, Jiangxi Province	Dingzha Pond, Zhejiang Province
Latitude	28°21′38″N	28°37′35″N	26°06′03″N	30°59′38″N	29°48′33″N	21°30′57″N	29°10′37″N	30°59′32″ N
Longitude	121°24′56″E	116°12′48″E	119°16′48″E	120°38′30″E	120°52′59″E	111°00′51″E	116°00′34″E	120°57′03″E
Diameter of the largest colony	20 cm	60 cm	100 cm	50 cm	40 cm	180 cm	30 cm	160 cm
Picture						Not given		
Substrata	Aquatic plants	Mussel cages	Fish cages	Ships/boats	Fish cages	Fish cages	Channels	Fish cages

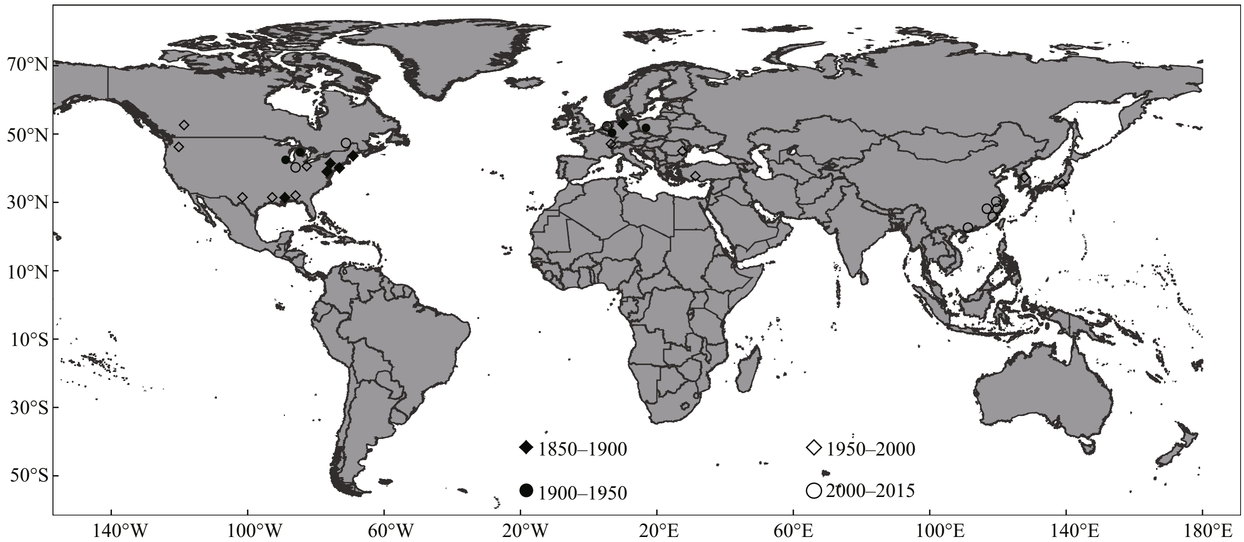

Fig.4 Historical global records of *Pectinatella magnifica*

the genus *Cristatella* and established a new genus for this species: *Pectinatella* (Leidy, 1851b). Early records of *P. magnifica* mainly focused on the east of the Mississippi River, and the northeastern coast of the Atlantic Ocean (Leidy, 1851a; Kellicott, 1882; Jullien, 1885; Kraepelin, 1887; Davenport, 1898). Subsequently it was found in a relatively wide area from the Great Lakes on the border with Canada to Florida, and from the Mississippi to the Atlantic Ocean (Davenport, 1904; Dendy, 1963; Bushnell, 1965; Everitt, 1975; Wood, 1989; Joo et al., 1992). It now appears to be well established across North America, except in some cold areas (Wood, 2001; Rodriguez and Vergon, 2002; Barnes and Lauer, 2003). In addition to its occurrence in the United States and Canada, *P. magnifica* had been recorded in scattered sites in Europe, including Germany, Poland, Luxemburg, Turkey, Romania, France, the Czech Republic and the Netherlands (Kraepelin, 1887; Lacourt, 1968; Bernauer and Jansen, 2006; Balounová et al., 2013), Japan (Mawatari, 1973; Oda, 1974) and Korea (Seo, 1998; Jo et al., 2014) (Fig.4). Since 2005, this species had been found in several areas of China, including Jiangxi, Jiangsu, Zhejiang, Fujian and Guangdong Provinces.

According to many authors, *P. magnifica* originated from the east of North America. Its occurrence outside this area is very likely only a result of being introduced (Bushnell, 1965; Everitt, 1975; Wood, 1989; Barnes and Lauer, 2003). The origin of *P. magnifica* in China remains unclear, but historical records of this species indicate that anthropochory is the most probable and coherent reason. Some researchers had reported statoblasts of *P. magnifica* in the stomach contents of fish, which were largely unharmed by the digestive system. This provides the most likely possibility for the introduction of *P. magnifica*; its association with imported commercial fish, clams, and aquatic plants (Osburn, 1921; Seo, 1998). *P. magnifica* was first introduced in Zhejiang Province and then spread to nearby provinces over the next few years. The principal pathway for dispersal of this invasive species is likely to be anthropochory. The big anchors on the statoblasts enable them to attach to different objects in the water, such as ships and fishing equipment (Lacourt, 1968, Seo, 1998). Zoochory is considered to be another important pathway for its dispersal (Oda, 1974; Wood, 2001). Waterfowling carries viable bryozoan statoblasts on their feathers, feet and even in their digestive tracts, and this may be especially important vectors of dispersal (Brown, 1933; Wood et al., 2006). Apart from anthropochory and zoochory, water flow may be another important agent in the dispersal of *P. magnifica* (Rodriguez and Vergon, 2002).

Freshwater biofouling threatens a number of human activities, from the supply of water and energy to recreation. Several species of freshwater bryozoans are notorious for clogging pipes and filters and there is no effective method for prevention (Wood, 2010). Spraying hot water and thorough drying of fouled surfaces are suitable methods for temporarily reducing the living biomass of bryozoans. However, these physical methods require high labor and time costs. Various chemicals, including chlorine and BOD, can prevent the accumulation of bryozoans by means of their toxic effects (Wood and Marsh, 1999). However, this is not a long-term solution, since dormant statoblasts remain and can instigate a new generation. Canning et al. (1997) used microsporidium or myxosporidium parasites to disable bryozoans, which suggests biological control could be a future possibility, but further research is needed. Although we suggest several possible methods for suppressing bryozoan populations, detailed studies on the effectiveness of measures are still under way.

5 ACKNOWLEDGEMENT

We acknowledge the efforts of reviewers for their helpful comments on this manuscript. The authors are much indebted to Prof. Timothy S. Wood (Bryo Technologies LLC, USA), whose comments greatly improved the manuscript.

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