

First discovery of *Bugula stolonifera* Ryland, 1960 (Phylum Bryozoa) in Japanese waters, as an alien species to the Port of Nagoya

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Abstract

Samples taken in 1997 from the Port of Nagoya, Japan, revealed the first record of the cheilostome bryozoan, *Bugula stolonifera* Ryland in Japanese waters. The species, which has been reported within the last years from several localities over the world, has probably been imported by ships coming to the Port of Nagoya. The species record illustrates the changes to which the Japanese bryozoan communities are subjected due to neozoan immigration.

1. Introduction

Bryozoans represent a phylum of colonial, suspension feeding animals. They are abundantly found in both cool waters and tropical reefs, silicoclastic shelves, polar regions, and even in the deep sea realm. The phylum is the only major group of exclusively clonal animals. Colonies are formed by repeated budding of genetically (but not always morphologically) identical, physically connected, intercommunicating member zooids (McKinney and Jackson, 1989; Cook, 1988).

The modular construction of their fixosessile, mostly calcifying colonies makes it possible to reconstruct life histories and interactive relationships on substratum surfaces. Skeletal growth modifications of both single units (zooids) and colonies (zoaria) preserve the influence of the outside environment at the time of growth.

The large percentage of surface occupied by laminar bryozoans despite the small biomass makes them important in any biological interactions on hard substrata (Riedl, 1966). Bryozoans are frequently the dominant biota covering the surfaces of dead coral reef colonies. This suggests that bryozoans serve as a major frame-binding agent for maintaining the integrity of the reefs, in opposition to bioeroding biota (Soule and Soule, 1972).

Fouling bryozoa are an economic problem since for example in boats and ships, a 1 mm thick layer of slime can cause a 15% loss in ship speed compared to values obtained for a clean hull (Lewthaite *et al.*, 1985). Bryozoans are frequently overgrowing and suffocating marine oyster beds, and fresh-water bryozoans may foul water system distribution pipes (Cuffey, 1970).

Today, the arrival of fouling bryozoans settling e.g. on ship hulls is rapidly altering the species composition of bryozoans on a world wide scale, occasionally with dramatical impacts (see Gordon

and Mawatari, 1992). Bryozoans may even be distributed by aeroplanes, such as probably happened during the Second World War, when European *Conopeum seurati* were introduced to the remote Chatham island lagoon by allied “Sunderland” flying boats (Scholz, 2001). As early as 1971, J. Ryland cited the number of 54 species of bryozoans known to colonize ship’s hulls, and 139 fouling bryozoans from ships, buoys, wrecks, and harbour installations. For fouling bryozoans it is typical that they do not have a competitive advantage over less-generalist species, but may thrive in the particular conditions of ports and harbours since the mature colonies are more tolerant of the wider ranges of the prevailing temperature, salinity, turbidity, and pollution (literature reviewed by Gordon and Mawatari, 1992).

For the Japanese islands, little is known on the magnitude of this event, although it is readily evident that for example harbour sites or floating piers are heavily colonized by dense clusters of fouling species of *Watersipora subovoidea*, *Bugula neritina* and some other species (Nandakumar *et al.*, 1993). Aside from this comparatively recent contribution, we have to rely on data that record the state of the art as it has been several decades ago (A. Grischenko, Sapporo, pers. comm.), such as the articles of Yanagi and Okada (1918) and S. Mawatari (1953), and a consideration of the neozoan impact must be part of any new taxonomic inventory of the Japanese seas. Every species counts, and in the following, we report on the arrival of a new fouling bryozoan to Japan. Furthermore, a state of the art of biodiversity research of Japanese bryozoans is given.

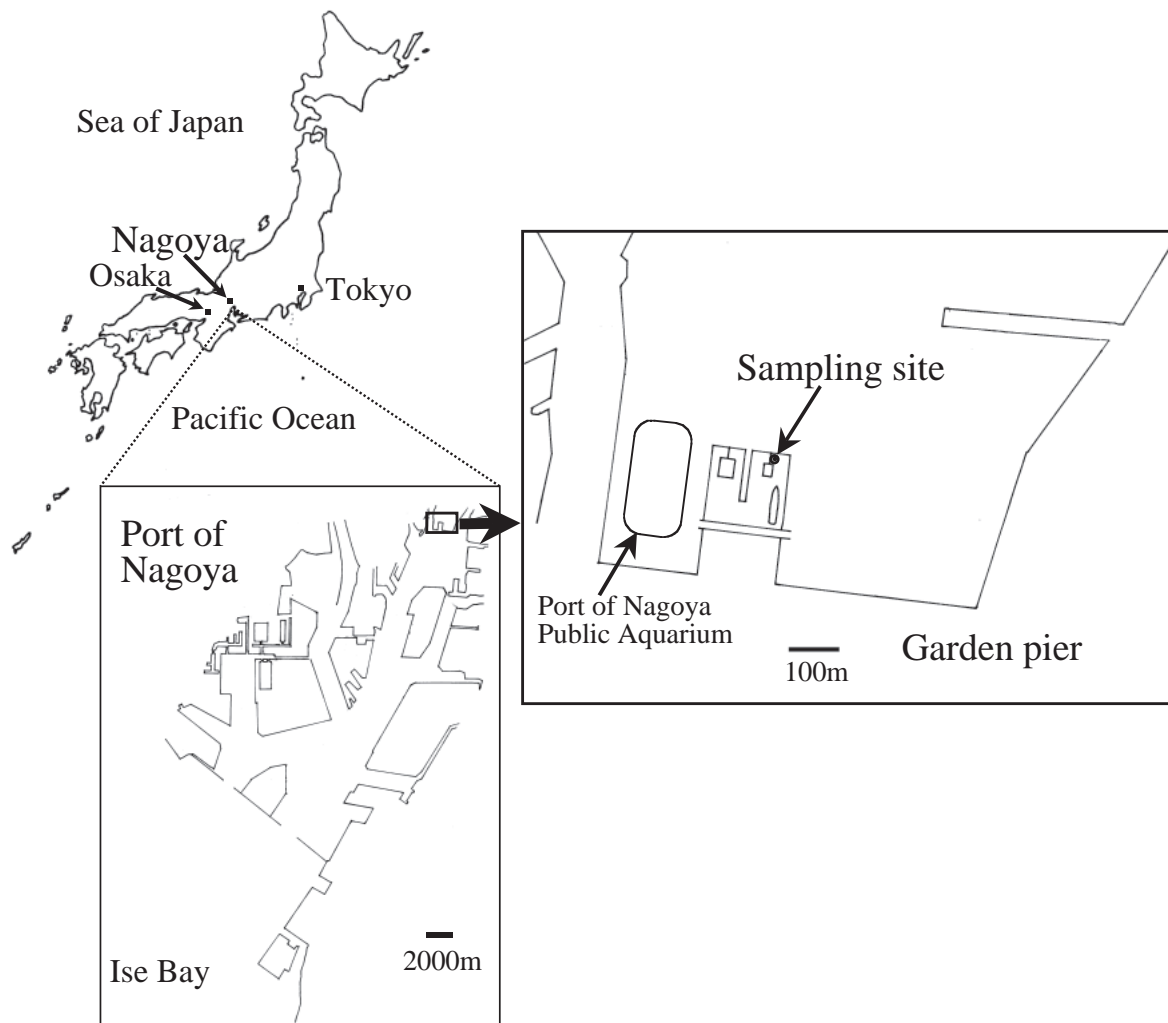


Fig. 1: Map showing the sampling site in the Port of Nagoya, Middle Japan.

2. Material and Methods

The specimen, registered as NUM-Az 0363 in The Nagoya University Museum, was collected on 15 Nov. 1997 from a vinyl-chloride panel set in a launch harbour in front of the Port of Nagoya Public Aquarium, northern end of Ise Bay on the Pacific coast of Middle Japan (Fig. 1). The Port of Nagoya is one of the biggest harbours in Japan, with arrivals of 9,231 (in 2001) and 9,132 (in 2002) foreign vessels (data from www.port-of-nagoya.jp).

The panel had been set subtidally from 5 July 1997, just below the mean low water of spring tide. Water temperature and salinity at the sampling site were 21.8°C on an average (ranging from 11.3 to 31.6°C), and 31‰ (from 20 to 37‰), based on the daily data throughout 2000 and 2002, respectively. The specimen was fixed and preserved in 10% formalin.

The sample was transferred to ethanol in a dehydration series, critical-point-dried and sputtered for SEM observation.

3. On the genus *Bugula* Oken, 1815

Species of *Bugula* have intrigued biologists for more than 100 years, due to their abundance and to the presence of spectacular, strange bird head avicularia (Fig. 2). For example, in the first 1969 edition of Ricketts' famous account on the intertidal fauna of California, he states: "The avicularia ('bird beaks') of *Bugula*, thought to be defensive in function, are classic objects of interest to the invertebrate zoologist. It is a pity that these ... can be seen only with a microscope. If the movable beaks of avicularia were a foot or so long, instead of a fraction of a millimeter, newspaper photographers and reporters would flock to see them. The snapping process would be observed excitedly, some enterprising cub would certainly have one of his fingers snapped off, and the crowds would amuse themselves by feeding stray puppies into the pincers."

Bird head avicularia are one of most useful features to identify *Bugula* species. This is important since the genus is diverse, and the ERMS (European Register of Marine Species) report (Hayward, 2001) cites 20 species of *Bugula* for European waters alone.

The function of bird head avicularia, and avicularia in general is still obscure. The function was discussed in Darwin's "Origin of Species", but Darwin and his successors provided inconclusive evidence on the evolutionary significance of avicularia. Defense against predators, cleaning, locomotion, nutrient storage, respiration, chemical defense, current flow modifications, or larval inoculation are among the functions possible for the diverse type of bryozoan avicularia (literature reviewed in Winston, 1984).

For bird head avicularia, a very early observation may be the most probable explanation, pointing out a peculiar way of agriculture in invertebrates: "On one occasion I saw one with the mandibles closed, grasping a tuft of confervoid-like substance, just like a bird with a wisp of hay in its beak. This is retained for some days, while the peculiar waving motion was still kept up. The only explanation seemed to be that the decaying conferva would attract minute infusoria, which would thus be brought within easy reach of the tentacles of the Polyzoon" (Goldstein, 1880).

Aside from the presence of bird head avicularia in most but not all species, the following description can be given for bryozoans of the genus *Bugula*: Colony are erect and branched, growing from an upright ancestrula (first zooid). The colony may be attached by rhizoids which issue from the autozooidal surfaces. Zooids arranged unilaminar in two or more series, alternating, the proximal end being forked. The basal and lateral walls are lightly calcified, and the membrane occupies most of the frontal surface. Spines are usually present. The ovicells (brood chambers) are hyperstomial and globular (summarised from Ryland and Hayward, 1977: p.150).

4. Results

Bugula stolonifera Ryland, 1960

(Fig. 2)

Bugula stolonifera Ryland, 1960, p.78; Ryland, 1962, p.50; Gordon and Mawatari, 1992, p.3.

Colonies are greyish-buff. in a compact and non-spiral tuft 3-4 cm high. Branches with zooids in two series, with long and narrow zooids. Frontal membranes occupying 2/3 to 3/4 of the length of the zooid. the length of the avicularia not exceeding the length of the zooid, and avicularian beak is shorter than the head. Spines are rather slender (see Ryland, 1960; Ryland and Hayward, 1977; Zabala and Mauquer, 1988). The slender spines are important to distinguish the species from *Bugula*

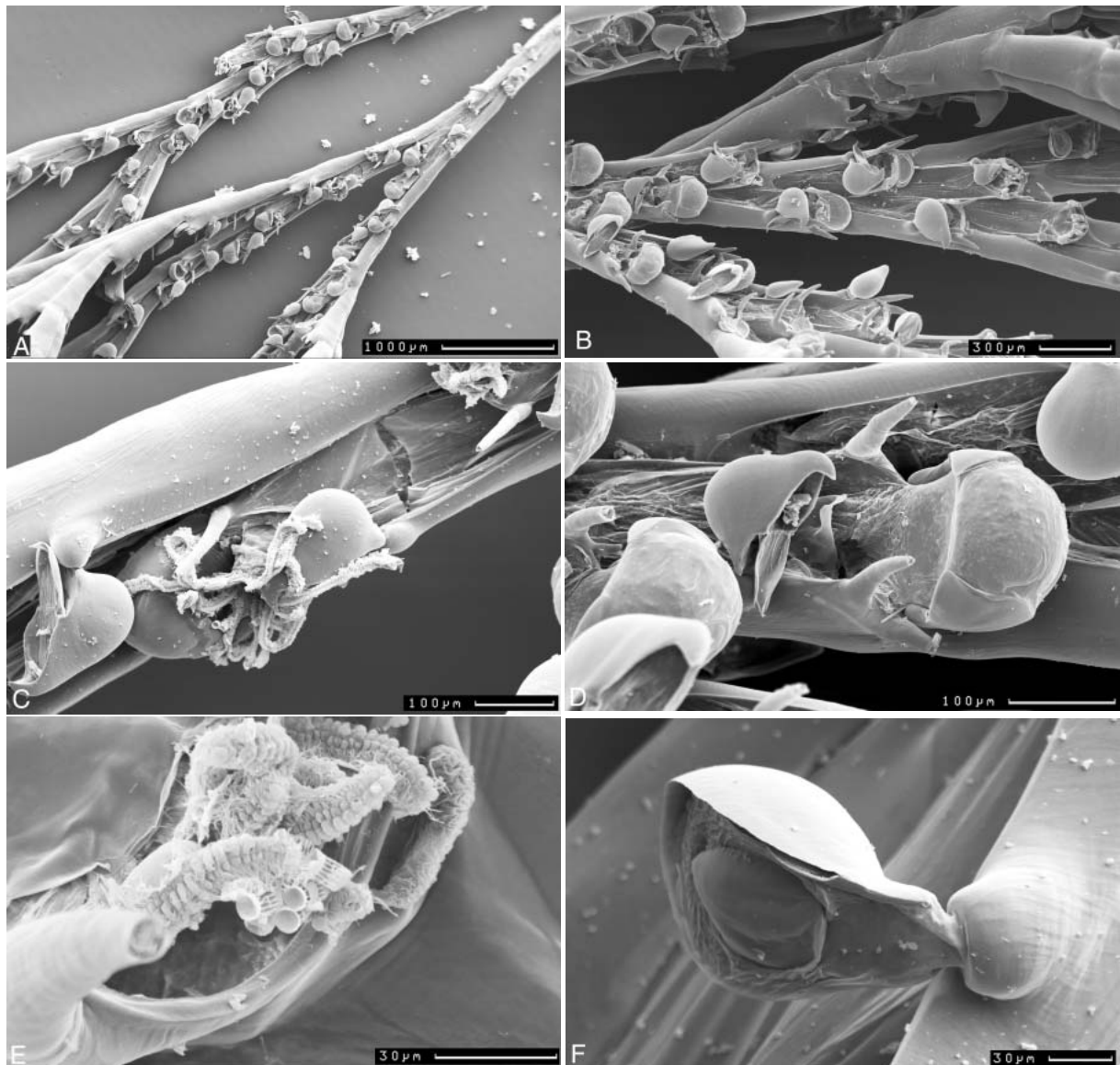


Fig. 2: *Bugula stolonifera* Ryland from the Port of Nagoya, Japan.

A: Frontal and lateral surfaces of the erect colony. SEM Image, Critical-point-dried sample. **B:** Biserial row of zooids, bifurcating; surfaces are nearly free of microbial fouling, thus indicating the presence of secondary metabolites. **C:** Lateral view of autozooids and sections of the parent and daughter zooid, showing tentacles and bird head avicularia. **D:** Autozooid and part of neighboring zooids, showing orificial spines, frontal membranes, lateral walls, ovicells (brood chambers), and a bird head avicularium with mandible opened. **E:** Tentacle sheet, showing multiciliate cells and phytoplankton (diatoms), which is a food source of bryozoans. **F:** Single bird head avicularium with closed rounded mandible.

californica Roberston (1905) which was reported from Japan already, but judging from Soule *et al.* (1995), has more stout finger-like spines.

Like many species of *Bugula*, *B. stolonifera* is a widely distributed neozoan. The type locality is Swansea, Wales. In the 1960's and 70's, it arrived in Australia and New Zealand. The report of Gordon and Mawatari (1992) does not mention any occurrence in Japan. The species is not mentioned in the PhD thesis of S. Mawatari (1958) that focussed e.g. on the genus *Bugula* in Japan.

SEM-images (Fig. 2) show that the colony surface is very clean. This phenomenon has been observed for many fouling bryozoans, which may probably be attributable to some anti-fouling chemicals produced by the colony.

5. Discussion

Bugula stolonifera Ryland has been reported from the docks in the Southwest of the British Isles (Ryland, 1960). It settles between early summer to mid-autumn and is well known as a fouling species. It has been introduced to other countries, for example to New Zealand (Harger 1964, Gordon & Mawatari 1992), by ships. It has been recorded also from the Mediterranean sea, Ireland, Ghana, Massachusetts to Florida, Brazil and South Australia (Winston, 1982; Cook, 1985; Ryland and Hayward, 1991).

Studies on bryozoans and bryozoan diversity have implications in very diverse fields of basic and applied research, four of them being listed below:

- 1) Bryozoans have been well established as biological indicators of anthropogenic influences in coastal waters (e.g. Soule and Soule, 1981; Scholz, 1991; Hillmer and Scholz, 1991; Winston, 1995). Thus, the contribution of bryozoans and other suspension feeding benthos to the management equation cannot be ignored.
- 2) The development of molecular methods has led to the recognition of high marine microbial diversity, which can be used as a resource for the detection of novel marine natural products. Since the 1980's, Bryozoans and their cultivatable bacterial associates have become a focal point for marine natural product research (e.g. Newman, 1996; Shellenberger and Ross, 1998; Pukall *et al.*, 2001, 2003).
- 3) Bryozoans are excellent tools for paleoecological studies (e. g. Voigt, 1930; Hageman *et al.*, 1998) since they commonly die in such a way that their relations to one another are preserved as they were in life (McKinney and Jackson, 1989). Presence or absence, zooid size, colonial form and integration of bryozoans contain conclusions about substrate, sedimentation, environmental stability and conditions, food supply and temperature (Smith, 1995).
- 4) Accordingly, bryozoans have become an example for the study of functional morphology (Schäfer, 1991), evolution (McKinney and Jackson, 1989, with review of literature) and zoogeographical aspects of speciation (Hayward, 1983; Soule and Soule, 1985a; Moyano, 1996). Data on bryozoans have significantly contributed the punctuated equilibrium theory (Gould, 2002 with review of literature), and biological individuality (Beklemishev, 1958-1960; Scholz and Levit, 2003).

Yet, "the use of bryozoan growth forms in the interpretation of paleocology without adequate taxonomic classification is probably meaningless" (Kelly and Horowitz, 1987), and non- or ill-classified organisms cannot be as a subject used in other fields of biology (Mawatari and Kajihara, 2003). Likewise, the utilisation of bryozoan data depends on continuous geographical coverage in collections. However, even in a comparatively well studied region such as the European coastal waters, monitoring activities have been subject to great variation through the last decades (Hayward, 2001). The aspect of fragmentary documentation is ever the more true for the modern Indo-

Pacific province were bryozoan communities constitute a considerable part of the sessile, benthic biomass, and thus achieve conspicuous presence over a huge ocean area. Especially the Western Pacific is considered to be the hot spot of bryozoan biodiversity (Gordon, 1984). With such a large number of regional bryozoan occurrences, and small numbers of systematists it would not be surprising if information about living specimens is rather insufficient (Winston, 1988), and what appears to be a simple request for the name of a bryozoan might be difficult or impossible to provide.

Most of the taxonomical bryozoan monographs are several decades or a century old, and the old-fashioned style of descriptions and illustrations (for example in Ortmann 1890, Waters, 1909, or Canu and Bassler, 1929) precludes their reliable use in species identification. Therefore, the Grant-in-aid projects for Monbusho International Scientific Research Programms have already supported re-descriptions of Japanese Bryozoa and other Japanese taxa (see Mawatari and Suwa, 1998). What has successfully been started for the Japanese fauna should now be applied on the whole Indo-Pacific.

How biotas are affected by geographical isolation and environmental change is a question fundamental to ecology, historical biogeography, and phylogeography. A re-evaluation of types from Indo-Pacific collections (e.g. Waters, 1909, Red Sea; Ortmann, 1890, Japan; Harmer, 1915-1957, Indonesia; Canu and Bassler, 1929, Philippines), and modern state-of-the-art re-illustration of type material has now become necessary to have a new data base about the comparative morphology of Indopacific bryozoans.

We should carefully consider both re-illustration of morphology, and geographical range. Specimens may not always be assigned unequivocally to a known species based on the holotype only. There is a need to understand morphological plasticity of species throughout their range of distribution. One of the first important achievements outlining regionalism and a high degree of speciation in tropical bryozoans is represented by the monograph of the Smittinidae of Hawaii (Soule and Soule, 1973), a family of ascophorine bryozoans that accordingly became known as “marine Darwin Finches”.

During the past years, molecular biology has become a powerful tool in contribution to bryozoan taxonomy, on the grounds of combination with methods of traditional morphology (Levington *et al.*, 2001). Meanwhile, studies on genetic relatedness have revealed metapopulations (Okamura, 2000), identified the presence of cryptic species in alleged cosmopolitan bryozoans (Hoare *et al.*, 2001), and started to contribute to revised classifications of gymnolaemate bryozoans (Dick *et al.*, 2000, 2003). It has been found out that morphological differences are often, but not always consistent with taxonomical differences (Mackie *et al.*, 2002). Accordingly, the statement made by McKinney and Jackson in 1989 that “most descriptions of living bryozoans with calcified skeletons do not differ substantially from descriptions of fossil species in the same class” is only partly true today.

Despite of the increasing demand for research in molecular biology and taxonomy of bryozoans, traditional morphology still has its values. Important regions of the Indo-Pacific like, for example, the Arabian (Persian) Gulf is still a terra incognita in terms of bryozoology. Aside from a brief account of Soule and Soule (1985b) on epiphytic bryozoans, nothing is known on the bryozoan fauna off the northern coast of Saudi Arabia. Recently, Azis *et al.* (2001) observed that bryozoans belong to the most important fouling organisms in the Persian Gulf region, but they did not provide a list of species that occur. The very diverse bryozoan fauna of Socotra (Yemen) is virtually unknown aside from a very preliminary account by Scholz *et al.* (2001), and a more extensive report is under way. The eastern coast of Africa is poorly studied, and aside from the report of Brood (1976) on certain taxa, and the Mauritius report of Hayward (1988), we still wait for an overview on the regional biodiversity of the phylum. Fortunately, for the Japanese bryozoans, the situation is not

so bad and there are numerous reports prepared by one of the authors (S. F. M.) and by his father Shizuo Mawatari. Some bryozoan studies have been conducted within the scope of the comparative survey “Natural History Researches of northern Hokkaido” of the National Science Museum, Tokyo, that outlined zoogeographical connections of the Hokkaido fauna to Russia (Mawatari *et al.*, 1991), and triggered new research on comparative views of bryozoans from Northern Japan, Okhotsk, and the Kuril Arc (Grischenko *et al.*, 2002). Previously, an inventorization of Recent marine Bryozoa living along Hokkaido Island was carried out by the efforts of Mawatari, S. (1957, 1973a, b, 1974), Mawatari, S.F. (1971, 1972), and by their collaborative researches (Mawatari and Mawatari, 1973, 1974; 1979, 1980, 1981a, b) with 22 cyclostome, 4 ctenostome and more than 130 cheilostome species reported, giving about 170 species in total. However, this is very preliminary number and more work needs to be done to receive a reliable data on bryozoan diversity of this region. Henceforth, a bryozoology PhD study (A. Grischenko, Hokkaido University, Sapporo) has been launched, and one of the goals of this study is to list all species of the bryozoans, that occur off the Oshoro Marine Biology Station, and other coastal areas of Hokkaido. Aside from the links to Russia that are evident in the bryozoans or the northern Japanese latitudes, there are surprising links of Recent Japanese bryozoans to the Southern Ocean (Gordon *et al.*, 2002) that are also indicated by the fossil record (Brown, 1952: p.128). Compared with the bryozoans in Northern Japan, the warm water bryozoans of Japan that are influenced by the Kuroshio current are not so well known. The Bryozoa fauna of the cool temperate northern latitudes of Japan is strikingly different in both taxonomy, and growth morphologies. Therefore, for the bryozoans dwelling in the coastal seas off Honshu and Kyushu, we still have to rely on the historical accounts such as prepared by Ortmann (1890), Okada (1923), Saito (1931), and Sakakura (1935).

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名古屋港で発見されたコケムシ類の外来種 *Bugula stolonifera*
Ryland, 1960 (日本初記録)

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名古屋港水族館前の船だまりに垂下していた塩ビ試験板から1997年に採集されたコケムシ類は、日本初記録の *Bugula stolonifera* Ryland, 1960 であることが判った。本種は最近、世界各地でその新たな出現が記録されている。おそらく名古屋港にも外国船によって到来したものと思われる。あわせて、コケムシ類の生物多様性研究が持つ意義と将来展望、そこでの形態情報の重要性について論じた。