

**First report of *Lomentaria hakodatensis*  
(Lomentariaceae, Rhodophyta) from the lagoon of Venice  
(Adriatic Sea, Mediterranean)**

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*Lomentaria hakodatensis* Yendo, known from China, Japan, Korea, and the Pacific coasts of North America, was recorded for the first time in the lagoon of Venice on the Adriatic Sea in 2000. Specimens in the reproductive stage had tetrasporophytes, male, and female gametophytes. Morphological, anatomical, and reproductive features of the thalli are described and the occurrence of the species in the lagoon is discussed. Data on associated algae are presented. This species was recently found in France, Spain, Russia, the Hawaiian Islands, and Australia.

**Key words:** marine algae, Rhodophyta, *Lomentaria hakodatensis*, Venice Lagoon, Adriatic Sea

## INTRODUCTION

*Lomentaria hakodatensis* Yendo was originally recorded in the East China Sea, Japan, Korea (HOWE, 1924; OKAMURA, 1932; KANG, 1966), and the Pacific coasts of British Columbia, Washington and southern California (DAWSON, 1944; ABBOTT & HOLLENBERG, 1976; HAWKES & SCAGEL, 1986).

This species has been reported as an alien species in Europe on the Atlantic shores of France (CABIOCH & MAGNE, 1987) and Spain (ICES, 1992; BÁRBARA & CREMADES, 1996), in the Mediterranean Sea (VERLAQUE & RIOUALL, 1989; ROMAGNOLI & SOLAZZI, 2003), in Russia (PERESTENKO, 1994), in the Hawaiian Islands (ABBOTT, 1999), and in Australia (PHILLIPS, 1997).

Thalli of a Rhodophyta determined to be *L. hakodatensis* were found on Chioggia Island (southern basin) during a survey of marine benthic flora of the hard substrata of the lagoon of Venice in spring and autumn 2000. The first vegetative and reproductive anatomy of Mediterranean specimens is described in the present work.

## DESCRIPTION

The brownish-purple thalli are spherical or hemispherical, formed by cylindrical, gelatinous, flaccid, hollow, and somewhat flattened branches. Ramifications occur three to five times, in opposite or occasionally alternate or verticillate directions (Fig. 1).



Fig. 1. Typical *Lomentaria hakodatensis* Yendo from the lagoon of Venice (scale bar = 2 cm)



Fig. 2. Septa in the apical branches (scale bar = 400  $\mu$ m)

The thalli are intertangled, 5-10 cm high and 0.8-1.3 mm wide, and attached to the substratum by a stoloniferous discoid holdfast. The lower branches are longer than the upper ones, giving a pyramidal appearance to the mature thalli. Branches rise with a divergence of about 45°. The constrictions and septa in the main axis, primary, and secondary branches

are indiscernible but in the branchlets or young branches are distinct and evident (Fig. 2). The inter-septa in the lower part of the thalli are much longer than in the upper.

The main branches in the transverse section consist of a single external layer of isodiametric or slightly oblong pigmented cells (diameter 5-13  $\mu$ m) and a medulla of 3-5 layers of round



Fig. 3. Vegetative anatomy in transverse section with tube cavity (arrow) and axial filaments in section (double arrows; scale bar = 50  $\mu$ m)

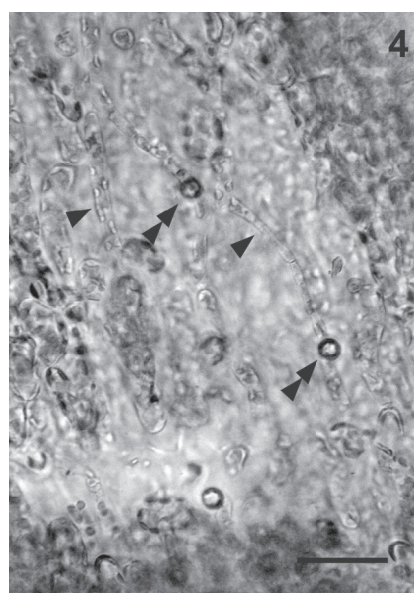


Fig. 4. Inner wall of cavity with axial filaments of elongated cells (arrows) and gland cells (double arrows; scale bar = 40  $\mu$ m)

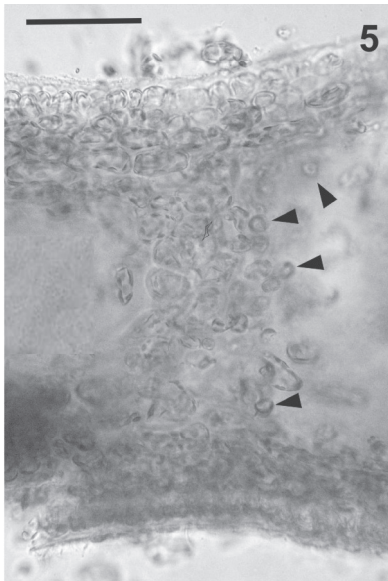


Fig. 5. Longitudinal section at the multi-cellular septum level with gland cells (arrows; scale bar = 100  $\mu$ m)



Fig. 6. Anastomosis of two branches (scale bar = 350  $\mu$ m)

to elliptical cells which become larger inwards (diameter 30-38  $\mu$ m; Fig. 3). The outer medullary cells are slightly pigmented, the inner are hyaline and elongated in a longitudinal section. The medullary cells have scattered filamentous longitudinal rows of cells (diameter 5-7  $\mu$ m) and gland cells (diameter 9-12  $\mu$ m; Fig. 4).

The transverse septa of the branches and branchlets are composed of 3-4 irregular rows

of polygonal cells with several gland cells (Fig. 5). The anastomosis among the thalli or branches of a thallus are numerous and originate from the resumption of growth of the cortical cells (Fig. 6).

Fertile tetrasporophytes and female and male gametophytes were found from April to September. The tetrasporophytes are similar to sterile specimens and tetrasporangia (60-68  $\mu$ m in length) and borne in small swollen branchlets

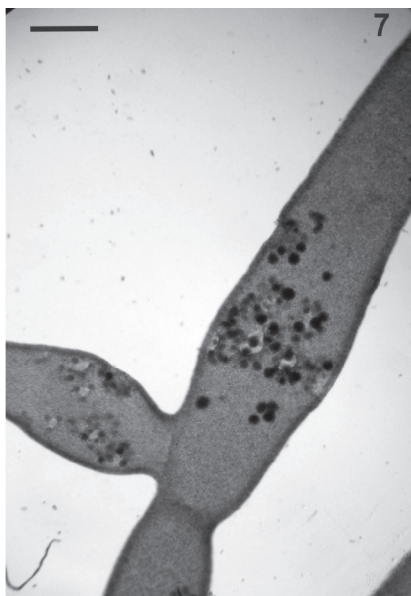


Fig. 7. Tetrasporangia (scale bar = 150  $\mu$ m)



Fig. 8. Mature cystocarp (scale bar = 600  $\mu$ m)

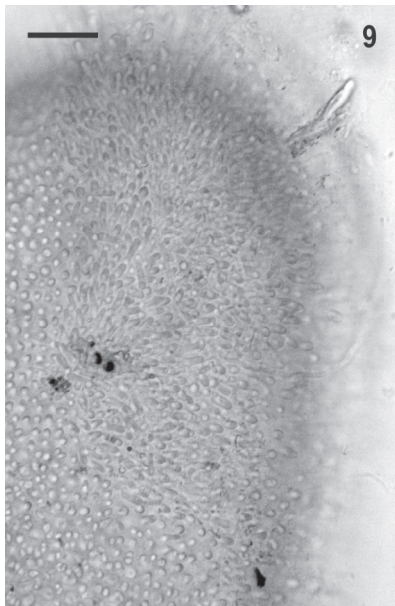


Fig. 9. Spermatangia in surface view (scale bar = 40  $\mu\text{m}$ )

deep in the cortex (Fig. 7). The elliptical to round tetrasporangial sori are dispersed on branch intersepta in the middle portions of secondary and tertiary branches. Procarps were not observed. Female gametophytes bear cystocarps

in the upper portions of the lateral branches (diameter 300-850  $\mu\text{m}$ ) and appear to be solitary or in groups of two or three (Fig. 8). The sessile cystocarps are spherical to pear-shaped, with prominent pores (diameter 150-300  $\mu\text{m}$ ). The spermatangia extend over the whole surface of the gametophytes except for the basal part of the axis. Mature spermatangia are elliptical, 4-6  $\mu\text{m}$  high, and 3  $\mu\text{m}$  wide (Fig. 9).

## ECOLOGY

*Lomentaria hakodatensis* was found from March to October in the lower intertidal and upper subtidal zones from 0.20 m above sea level to 1.0 m below, on the vertical canal banks of Chioggia Island. They were more common and had higher coverage and biomass values in autumn samples than in spring. *Lomentaria hakodatensis* is associated with the dominant alien brown algae *Sargassum muticum* (Yendo) Fensholt and *Undaria pinnatifida* (Harvey) Suringar. The main algae occurring on the hard vertical banks where *L. hakodatensis* was collected are presented in Table 1.

Table 1. Coverage and biomass of the main algae species in Chioggia Island

	Coverage (%)	Biomass
<b>Rhodophyta</b>		
<i>Antithamnion pectinatum</i> (Montagne) Brauner ex Athanasiadis et Tittley	0.3 - 0.8	0.7 - 75.5
<i>Ceramium diaphanum</i> (Lightfoot) Roth	0.1 - 2.0	0.7 - 1.4
<i>Ceramium virgatum</i> Roth	0.01 - 0.4	0.03 - 0.2
<i>Polysiphonia denudata</i> (Dillwyn) Greville ex Harvey	0.2 - 3.0	0.9 - 1.9
<i>Polysiphonia morrowii</i> Harvey	0.3 - 0.5	0.1 - 0.3
<i>Rhodymenia ardissoni</i> J. Feldmann	0.5 - 10.0	0.7 - 47.5
<i>Lomentaria hakodatensis</i> Yendo	0.5 - 2.0	2.3 - 4.01
<i>Lomentaria clavellosa</i> (Turner) Gaillon	0.01 - 3.0	1.4 - 5.1
<b>Phaeophyta</b>		
<i>Sargassum muticum</i> (Yendo) Fensholt	0.5 - 13.0	7.3 - 39.6
<i>Undaria pinnatifida</i> (Harvey) Suringar	8.0 - 25.0	4.9 - 75.3
<b>Chlorophyta</b>		
<i>Bryopsis plumosa</i> (Hudson) C. Agardh	0.1 - 2.0	2.1 - 7.2
<i>Chaetomorpha linum</i>	0.05 - 0.1	0.04 - 2.3
<i>Cladophora sericea</i>	0.1 - 0.5	0.06 - 0.4
<i>Ulva intestinalis</i> Linnaeus	0.5 - 9.0	0.4 - 35.1
<i>Ulva laetevirens</i> Areschoug	0.9 - 8.0	5.8 - 64.3

The limited local distribution of *L. hakodatensis* may indicate a recent introduction, possibly associated with shellfish culture since aquaculture farms on Chioggia Island import mollusks and fish. The spread of alien species along the Atlantic and Mediterranean coasts of Europe has been linked with aquaculture farming and intensive shipping (ICES, 1992; VERLAQUE, 1994; OCCHIPINTI, 2000), so it is of no surprise that *L. hakodatensis*, like *U. pinnatifida*, *S. muticum*, and *Antithamnion pectinatum*, was first reported in the shellfish raising lagoons Thau (France) and Venice (Italy).

A recent survey (SFRISO & LA ROCCA, 2005) found *L. hakodatensis* in the southern lagoon of Venice, 2-10 km from Chioggia Island, but not in the central lagoon or canals. Similarly *S. muticum*, introduced in the lagoon near Chioggia (GARGIULO *et al.*, 1992), required several years to spread into the central lagoon (MARZOCCHI *et al.*, 2003). If the ecological requirements of *L. hakodatensis* are similar to those of other species of the same genus that exist in the lagoon (marine water, low turbidity, good hydrodynamics), it could gradually spread to areas with seawater inflow but not to more interior areas where the water turbidity is high.

*Lomentaria hakodatensis* joins the list of alien algae recently recorded in the Venice Lagoon (GARGIULO *et al.* 1992; RISMONDO *et al.* 1993; CURIEL *et al.* 1996ab, 1999, 2002; BELLEMO *et al.* 2001). The abundance of *L. hakodatensis* in Chioggia is low. The most abundant species are the alien *U. pinnatifida* and *S. muticum*, though their biomass is lower in Chioggia than in other parts of the lagoon (400-1200 g dry wt/m<sup>2</sup> for *U. pinnatifida* and 200-1100 g dry wt/m<sup>2</sup> for *S. muticum* (CURIEL *et al.*, 1995, 1998, 2001).

## DISCUSSION

The organization of the thalli was similar to the recent description of the genus *Lomentaria*: (a) terete or slightly flattened thalli with hollow branches and multilayered cellular septa at intervals, (b) septa identified by constriction only in young branchlets, (c) cortical layers and rows of medullary cells bearing gland cells, and (d) tetrahedrally-divided tetrasporangia in

sori in the cortex (ABBOTT & HOLLENBERG, 1976; LEE, 1978; IRVINE, 1983; HAWKES & SCAGEL, 1986). These thalli are distinct from others of the same genus that exist in Venice lagoon, namely, *Lomentaria clavaeformis* Ercegovic, *L. chylocladiella* Funk, *L. ercegovicii* Verlaque, Boudouresque, Meinesz, Giraud et Marcot-Coqueugnot, *L. clavellosa* (Turner) Gaillon, *L. articulata* (Hudson) Lyngbye (DE TONI & LEVI, 1888, as *L. phalligera* J. Agardh), and *L. uncinata* Meneghini ex Zanardini.

The only species from the Venice lagoon with similar morphological characteristics is *L. firma* (J. Agardh) Falkenberg (SCHIFFNER & VATOVA 1937, VATOVA 1940). In common with *L. firma*, *L. hakodatensis* sometimes has flattened cylindrical axes, anastomosed intricate branches, and well-developed cortication formed of a single layer of pigmented cells and 3-4 inner layers of polygonal subcortical cells. The original description of *L. firma* as *Chrysymenia firma* (AGARDH, 1842) and subsequent publications as *Chondrosiphon mediterraneus* Kützting (KÜTZING, 1865) and *C. firma* J. Agardh and *C. polycarpa* Zanardini (ZANARDINI, 1871) do not correspond to *L. hakodatensis*, as these species are reported to have irregular branching (alternate, opposite, or unilateral) rather than the strictly opposite, verticillate, or rarely alternate branching in *L. hakodatensis*. In addition, branchlets are apically thin and flexuous rather than slightly curved inwards and tapering as in *L. hakodatensis*. The description of *L. firma* by ERCEGOVIĆ (1956) resembles the figures of *L. firma* of KYLIN (1931; Tables 13, 14; Figs. 31, 32) and are quite different from the specimens illustrated by ZANARDINI (1871; Table 110a).

The above authors failed to report the constrictions in young branches and septa so typical of *L. hakodatensis*. In fact, ZANARDINI (1871) placed his material in the genus *Chylocladia* and not in *Lomentaria* because of its continual tubular structure without septa.

In his description of Japanese specimens, YENDO (in LEE, 1978) noted that his species was intermediate between *L. linearis* Zanardini and *L. articulata* (Hudson) Lyngbye, but mentioned species currently considered synonymous with *L. firma*: *C. polycarpa* Zanardini, *C.*

*firma* J. Agardh, and *C. compressa* (Kützinger) Zanardini. A comparison between *L. firma* and *L. hakodatensis* is needed to resolve the question of possible synonymy.

The morphological, anatomic, and reproductive features of the species collected in the Venice lagoon correspond well with *L. hakodatensis* Yendo in Japan (LEE, 1978), British Columbia and Washington (HAWKES & SCAGEL, 1986), California (ABBOTT & HOLLENBERG, 1976), and along the Atlantic coast of France (CABIOCH & MAGNE, 1987).

The Chioggia survey targeted areas with low coverage of aliens, as large algae successfully

compete with smaller species. The occurrence of reproductive specimens in the lagoon of Venice, as in Brittany (CABIOCH & MAGNE, 1987), suggests that the lagoon has appropriate environmental conditions for reproduction of the species. In other locations, introduced populations maintain themselves primarily by vegetative propagation (SOUTH, 1968; HAWKES & SCAGEL, 1986; MILTON *et al.*, 2002).

## ACKNOWLEDGEMENTS

The authors would like to thank Professor M. CORMACI for his observations and suggestions.

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Received: 19 July 2005

Accepted: 7 March 2006

## Prvo izvješće o algi *Lomentaria hakodatensis* (Lomentariaceae, Rhodophyta) u venecijanskoj laguni (Jadran, Sredozemlje)

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### SAŽETAK

*Lomentaria hakodatensis* Yendo nalazimo u Kini, Koreji i na obalama Tihog oceana u Sjevernoj Americi. Po prvi puta je zabilježena u reproduktivnom stadiju u venecijanskoj laguni, Jadransko more.

U 2000. godini pronađene su tetrasporofite i muške i ženske gamete *L. hakodatensis*. Opisana su morfološka, anatomska i reproduktivna svojstva talusa i njihova učestalost u venecijanskoj laguni. Također su izneseni podaci o vegetaciji algi. Nalazi ove vrste se u posljednje vrijeme javljaju u Francuskoj, Španjolskoj, Rusiji, na Havajskom otočju i Australiji.

**Ključne riječi:** morske alge, Rhodophyta, *Lomentaria hakodatensis*, venecijanska laguna, Jadransko more