

***Laurencia caduciramulosa* Masuda *et* Kawaguchi (Ceramiales, Rhodophyceae), first record on the Mediterranean coast of France**

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Abstract – The first record of *Laurencia caduciramulosa* Masuda *et* Kawaguchi from the northwestern Mediterranean is reported. The hypothesis that this species, known to date from Vietnam, Malaysia and only two stations in southern Italy, has been recently introduced into the Mediterranean Sea is discussed.

France / introduced species / *Laurencia caduciramulosa* / marine macroalgae / Mediterranean Sea / Rhodophyceae

Résumé – *Laurencia caduciramulosa* Masuda *et* Kawaguchi est signalé pour la première fois en Méditerranée nord-occidentale. L'hypothèse que cette espèce, connue à ce jour du Viêt-Nam, de Malaisie et de seulement deux stations du Sud de l'Italie, ait été récemment introduite en Méditerranée est discutée.

Espèces introduites / France / *Laurencia caduciramulosa* / macroalgues marines / Mer Méditerranée / Rhodophyceae

INTRODUCTION

Laurencia caduciramulosa Masuda *et* Kawaguchi (Masuda *et al.*, 1997) was described from Vietnam (Type locality: Hon Tre Island, Tien Hai Islands, Hatien, Kien Giang Province). In 2001, it was recorded for the first time close to Sicily (Southern Italy) in the southern central Mediterranean Sea (Furnari *et al.*, 2001). During a study of the invasiveness of the shallow photophilic subtidal Mediterranean macrophyte communities (Klein *et al.*, 2005), *L. caduciramulosa* was discovered at seven sites on the Mediterranean coast of France. The morphology and distribution of the populations are described and the hypothesis of a recent introduction of this species into the Mediterranean is discussed.

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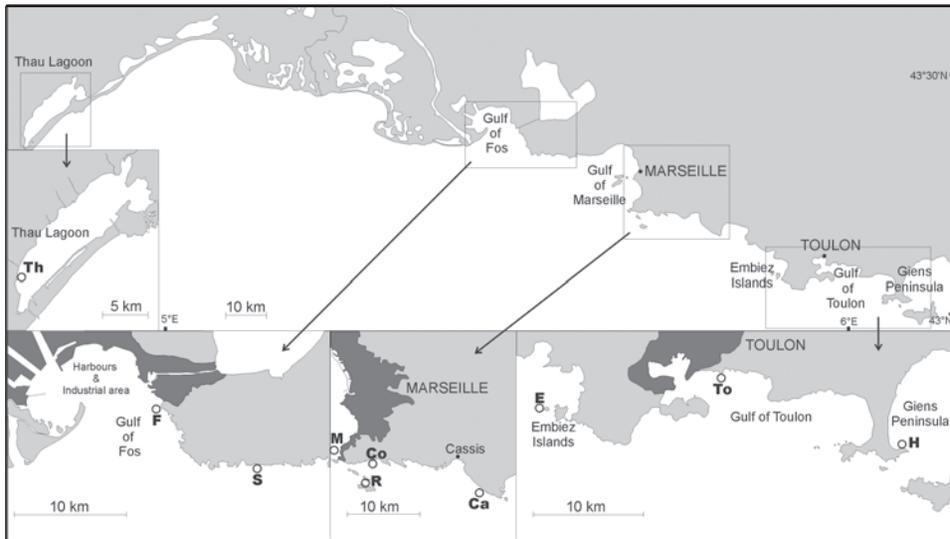


Fig. 1. Map of the study sites. Th: Thau; F: Fos; S: Sausset; M: Marseille; Co: Cortiou; R: Riou; Ca: Cassis; E: Embiez; To: Toulon; H: Hyères.

MATERIAL AND METHODS

Study area and sampling

This study was carried out, in the framework of the EU project “Algal Introductions to European Shores” (ALIENS), between June and July 2002 at ten different sites on the Mediterranean coast of France. From east to west, the ten sites are the following: Thau (Languedoc: Hérault), Fos, Sausset-les-Pins, Marseille, Riou and Cassis (western Provence: Bouches-du-Rhône), and Embiez Islands, Toulon and Hyères (eastern Provence: Var) (Fig. 1). A natural calcareous substrate characterizes all sites, except for Thau where it is artificial (calcareous rockfill), and the Embiez Islands and Hyères where the natural substrate is siliceous.

Randomly distributed 15 cm × 15 cm quadrats were sampled by SCUBA diving in the shallow photophilic communities of the subtidal zone, at depths between 4 and 8 m. Rocks with approximately the same inclination (0-20°) were chosen. Material was preserved in buffered 5 % formaldehyde-seawater until further treatment.

Sample analysis

The fixed material was studied using dissecting and light microscopes. Specimens of *Laurencia caduciramulosa* were sectioned manually with a razor blade. Transverse sections were stained in 1% aqueous Aniline Blue, washed, and then acidified by adding a drop of 1 N HCl. Photomicrographs were made using a Coolpix 995 Nikon® digital camera and an Optiphot-2 Nikon® light microscope.

Material studied

The following material was preserved in buffered 5 % formaldehyde-seawater and deposited in the Herbarium Verlaque, Centre d'Océanologie de Marseille (COM), Marseille, France:

WESTERN PROVENCE- H7190, Fos, 24.vi.2002, 4-5 m deep; H7191, Sausset-les-Pins, 1.vii.2002, 5-6 m deep; H7192, Marseille, 19.vi.2002, 7-8 m deep; H7193, Riou Island, 28.vi.2002, 5-6 m deep; H7194, Cassis, 26.vi.2002, 5 m deep.

EASTERN PROVENCE – H7195, Embiez Islands, 8.vii.2002, 4-5 m deep; H7196, Toulon, 10.vii.2002, 5-6 m deep.

The dried and fresh Mediterranean specimens of *Laurencia* spp. collected since the 19th century and deposited at the Centre d'Océanologie de Marseille were re-examined.

RESULTS

Laurencia caduciramulosa (Figs 2-8) was present in low abundance at the sites of Fos, Sausset-les-Pins, Marseille, Riou, Cassis, in the western Provence, and Toulon and Embiez Islands, in the eastern Provence. It was absent at Thau, Cortiou, and Hyères (Fig. 1). The species was not found in the old collections of Mediterranean *Laurencia* specimens deposited at the Centre d'Océanologie de Marseille (COM).

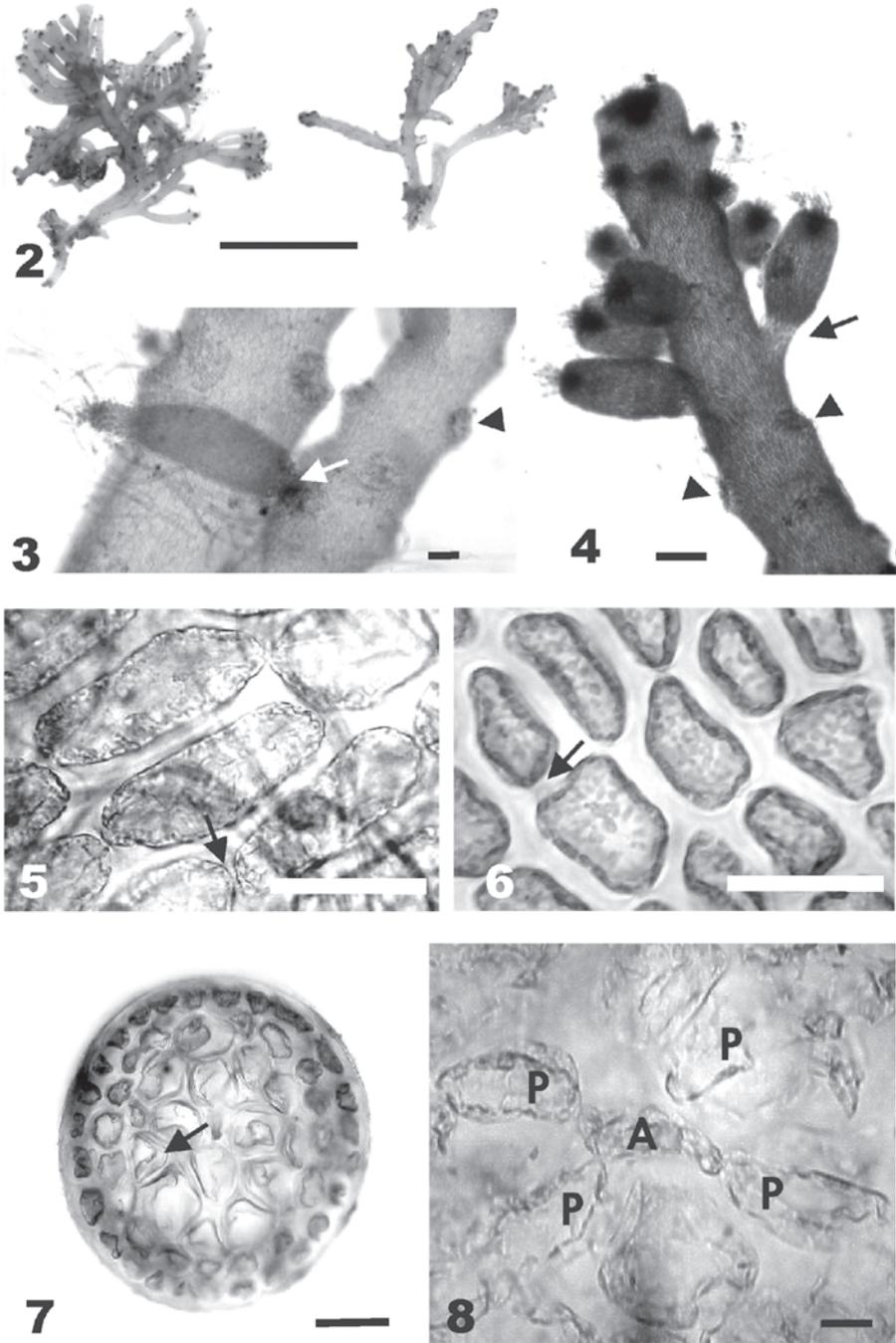
Description

Axes up to 1.0-1.5 cm high, terete, arising from a stoloniferous holdfast, branched up to four orders, with branches and branchlets irregularly alternate and spirally arranged (Fig. 2); main axes 360-440 µm in diameter in the lower to middle portions, to 340-400 µm in the uppermost portions; small deciduous branchlets, up to 500-560 µm long and 240-260 µm wide at the tips, developed near apices, leaving after their fall peculiar scars on the axis (Figs 3, 4); epidermal cells in basal to median portions of axes longitudinally elongated, 50-80 µm long and 30-40 µm wide, and rounded, slightly projecting but never palisade-like, near apices; secondary pit connections linking the epidermal cells longitudinally present (Figs 5, 6); medullary cells with lenticular thickenings (Fig. 7); four vegetative periaxial cells per axial cell (Fig. 8); reproductive structures not observed.

Wet-preserved material did not allow the observation of *corps en cerise* in epidermal cells and the germination potential of propagules as described in Masuda *et al.* (2001).

Distribution

So far *Laurencia caduciramulosa* has only been reported in the Mediterranean Sea from southern Italy. Sterile specimens were collected at Lachea Island (Ionian Sea, Sicily) and at Linosa Island (Pelagean Islands) in October 1991 and September 1998, respectively (Furnari *et al.*, 2001). This is the first report for the Mediterranean coast of France, where the species was found



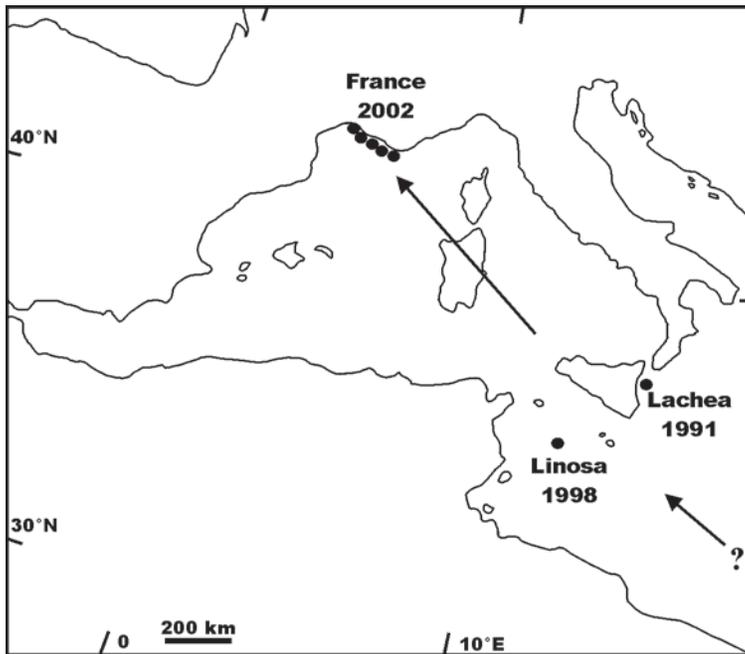


Fig. 9. Distribution of *Laurencia caduciramulosa* in the Mediterranean Sea (arrows: hypothetical direction of spread; '?': unknown introduction source).

close to three major harbours, the cargo harbour and oil tanker terminal of Fos, the passenger and cargo harbour of Marseille and the naval and passenger harbour of Toulon. It was also collected from four natural species-rich sites (Saussetles-Pins, Riou, Cassis and Embiez Islands).

Ecology

The host communities are the photophilic shallow subtidal communities of sheltered places. As far as the structural organization is concerned, during the sampling period (late spring and early summer), dominant erect species belonged



Figs 2-8. *Laurencia caduciramulosa* Masuda et Kawaguchi (H7193, Riou Island, 28.vi.2002, 5-6 m deep). **2.** Habit. Scale bar = 5 mm. **3.** Portion of branch bearing a small deciduous branchlet (arrow: constricted basal part of branchlet; arrowhead: scar of shed branchlet). Scale bar = 100 μ m. **4.** Ultimate branch with small deciduous branchlets (arrow) and scars of shed branchlets (arrowheads). Scale bar = 200 μ m. **5-6.** Epidermal cells in surface view near base and apex of an axis, respectively (arrows: secondary pit connections). Scale bar = 50 μ m. **7.** Transverse section of a branch showing lenticular thickenings in the walls of medullary cells (arrow). Scale bar = 100 μ m. **8.** Transverse section of branch near the apex showing an axial cell (A) with four periaxial cells (P). Scale bar = 10 μ m.

to the Bryopsidales (*Codium* spp.), Dictyotales [*Dictyota* spp., *Padina pavonica* (L.) J.V. Lamouroux and *Taonia atomaria* (Woodward) J. Agardh], and Sphacelariales [*Halopteris filicina* (Grateloup) Kützinger and *Stypocaulon scoparium* (Linnaeus) Kützinger]. The Rhodophyceae (Peyssonneliaceae and Corallinaceae) represented the dominant constituent of the highly differentiated encrusting algal layer. The photophilic communities of the sites from Fos to Toulon were characteristic of the northwestern biogeographical zone (Gulf of Lion) of the western Mediterranean Sea where cold-water species, as *Aphanocladia stichidiosa* (Funk) Ardré, *Ceramium virgatum* Roth, *Chondracanthus acicularis* (Roth) Fredericq, *Lithophyllum dentatum* (Kützinger) Foslie, *Ophidocladus simpliciusculus* (Crouan frat.) Falkenberg, *Phyllophora heredia* (Clemente) J. Agardh, *Polyisiphonia flexella* (C. Agardh) J. Agardh and *Radicilingua thysanorhizans* (Holmes) Papenfuss, are encountered. On the other hand, at the easternmost site (Embiez Islands), the occurrence of *Cystoseira brachycarpa* J. Agardh and the lack of the above cold-water species are characteristic of the photophilic shallow communities of the central biogeographical zone (French Riviera, Balearic Islands and Corsica) of the western Mediterranean Sea (Verlaque, 1987; Ballesteros, 1990).

DISCUSSION AND CONCLUSIONS

The northwestern Mediterranean specimens of *Laurencia caduciramulosa* are in good agreement with the protologue (Masuda *et al.*, 1997) and the description of the southern Italian populations (Furnari *et al.*, 2001). The main characteristics of *L. caduciramulosa* are: (1) the presence of short deciduous branchlets (up to 560 µm long), that function as propagules; (2) a stoloniferous holdfast; (3) densely branched main axes 360-440 µm in diameter; and (4) epidermal cells slightly projecting near apices (Masuda *et al.*, 1997, 2001).

So far, there are four discontinuous records of *Laurencia caduciramulosa* worldwide: two in the Pacific Ocean, Vietnam (Masuda *et al.*, 1997) and Malaysia (Masuda *et al.*, 2001), and two in the Mediterranean Sea, Italy (Furnari *et al.*, 2001) and France (the present study). Furnari *et al.* (2001) did not consider the hypothesis of a recent introduction into the Mediterranean Sea on the basis that some Mediterranean specimens were collected in 1991 (Lachea Island), while the species described from Vietnam was collected in 1993 only. However, an introduced species may well first be described from the region of introduction before being discovered in the native area, as was probably the case for the following Indo-Pacific species described from the Mediterranean or NE Atlantic: *Asparagopsis taxiformis* (Delile) Trevisan de Saint-Léon (Delile, 1813-1826, as *Fucus taxiformis*, type locality: Alexandria, Egypt), *Codium fragile* (Suringar) Hariot subsp. *tomentosoides* (van Goor) P.C. Silva (van Goor, 1923, as *C. mucronatum* J. Agardh var. *tomentosoides*, type locality: The Netherlands) and *Colpomenia peregrina* Sauvageau 1927 (Syntype locality: various in Atlantic Europe) (Eno *et al.*, 1997; Andreakis *et al.*, 2003; Murphy *et al.*, 2003). In agreement with the criteria proposed by Ribera & Boudouresque (1995), the introduction hypothesis is highly probable because (1) in the Mediterranean Sea, the species was only discovered in 1991; (2) the first Mediterranean population was very localised and close to a potential introduction zone (the small island Lachea lies close to the harbour of Catania); (3) afterwards it was found next to a potential introduction zone (the

harbours of Fos, Marseille, Toulon) or in proximity to it (Sausset-les-Pins, Riou, Cassis and Embiez) (Fig. 1); (4) the chronology and discontinuity of the pattern of distribution in the Mediterranean agree well with a north-westward spread model, as for other introduced species as *Acrothamnion preissii* (Sonder) E.M. Wollaston (Verlaque, 1994) or *Caulerpa racemosa* (Forsskål) J. Agardh var. *cylindracea* (Sonder) Verlaque, Huisman *et* Boudouresque (Verlaque *et al.*, 2000); and (5) so far, in France, the species appears at low abundances, contrasting with the native *Laurencia* species, which usually form well developed populations. After a probable primary introduction from the Pacific to southern Italy, we may assume a secondary introduction from Italy to France (Fig. 9). Its occurrence close to harbours is in good agreement with the hypothesis of an introduction by ships, either through fouling (attached thalli) or ballast water (free-floating propagule-like branchlets).

In the Pacific, *Laurencia caduciramulosa* grows on bedrock in the lower intertidal zone on exposed coasts, like in Southern Italy where it was encountered between -0.2 m and 0.2 m. On the French Mediterranean coast, *L. caduciramulosa* was found at depths of 4 to 8 m, both in warm-water (Embiez Islands) and cold-water photophilic communities (the other sites). In the western Mediterranean, coldest seawater temperatures are found at Marseille (10.5 °C, Verlaque *et al.*, 2000). Consequently, *L. caduciramulosa* seems to be capable of colonizing the whole of the Mediterranean Sea, except perhaps for the coldest waters of the northern Adriatic.

So far, *Laurencia caduciramulosa* does not show invasive behaviour. However, its mode of vegetative reproduction by propagules might facilitate its further spread in the Mediterranean. Most introduced and invasive species in the Mediterranean are known to possess high vegetative reproduction capacities: *Acrothamnion preissii*, *Asparagopsis armata* Harvey, *Caulerpa* spp., *Codium fragile* subsp. *tomentosoides*, *Womersleyella setacea* (Hollenberg) R.E. Norris (Boudouresque & Verlaque, 2002). There is often a lag time between the introduction and the proliferation of an exotic species. Therefore, any prediction about the further development of the species in the Mediterranean would be premature.

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