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Macroalgae newly recorded, rare or introduced to the French Mediterranean coast

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Abstract – During the past century dramatic changes in the composition and structure of species assemblages have been observed worldwide. These changes took a sharp increase in recent years. Global changes such as climatic changes and species introductions are superimposed on more or less local habitat degradation, pollution and overexploitation. A detailed knowledge of the taxonomic composition of the flora and fauna at a local scale is important because it represents the only mean to assess subtle changes in the distribution and abundance of species, in particular of rare species. The present study discusses 15 interesting macroalgal species from the French Mediterranean coast. Among them, *Antithamnion amphigeneum*, *A. piliferum*, *Cordylecladia guiryi*, *Goniotrichiopsis sublittoralis*, *Jania adhaerens*, *Laurencia chondrioides* and *Phyllophora sicula* are reported and described for the first time from the region and 7 species are considered as introduced. For each species, the geographical distribution and the ecology are discussed.

Acrothamnion* / *Antithamnion* / *Antithamnionella* / *Calliblepharis* / *Cordylecladia* / *Dasyella* / *Goniotrichiopsis* / *Gontrania* / *Jania* / *Laurencia* / marine algae / Mediterranean / *Phyllophora* / *Solieria

Résumé – Macroalgues de la côte française de Méditerranée : nouvelles signalisations, taxons rares ou introduits. Durant le siècle dernier et dans le monde entier, des changements importants ont été observés dans la composition et la structure des écosystèmes. Le rythme de ces changements s'accélère depuis ces dernières années. Les changements globaux tels que les changements climatiques et les introductions d'espèces se surimposent aux dégradations plus ou moins étendues, à la surexploitation et à la pollution des habitats. Une connaissance approfondie et à une échelle locale de la composition floristique et faunistique des peuplements est importante car elle est le seul moyen qui permette d'appréhender des changements subtils de l'abondance et de la distribution des espèces, en particulier des espèces rares. Cette étude répertorie 15 espèces intéressantes de macroalgues de la côte méditerranéenne française. Parmi celles-ci, *Antithamnion amphigeneum, A. piliferum, Cordylecladia guiryi, Goniotrichiopsis sublittoralis, Jania adhaerens, Laurencia chondrioides* and *Phyllophora sicula* sont signalées pour la première fois dans la région et 7 espèces sont considérées comme étant introduites. Pour chaque espèce, la distribution géographique et l'écologie sont discutées.

Acrothamnion* / algues marines / *Antithamnion* / *Antithamnionella* / *Calliblepharis* / *Cordylecladia* / *Dasyella* / *Goniotrichiopsis* / *Gontrania* / *Jania* / *Laurencia* / Méditerranée / *Phyllophora* / *Solieria

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INTRODUCTION

The marine flora of a given region is in constant compositional change. A species' range may extend, retract or shift. The main driving forces of these changes are climatic fluctuations, dramatic meteorological events (e.g. major storms), pollution, habitat degradation/destruction and species introductions. Urbanised areas are particularly concerned, because they coincide with several disturbance sources.

It is estimated that the Mediterranean Sea harbours around 1,500 macrophyte species (Boudouresque, 2004) and a total of approximately 17,000 marine species (Coll *et al.*, 2010). The Mediterranean thus shows very high species richness comparable to major hotspots of biodiversity of the world including the central Indo-Pacific (Philippines, Indonesia), the South African coast and the southern part of Australia. There also is a high amount of endemism, around 20% for macroalgae (Giaccone, 1974; Coll *et al.*, 2010).

Besides being a hotspot for native species diversity, the Mediterranean Sea has also become a hotspot of species introductions (Ribera Siguan, 2003; Boudouresque & Verlaque, 2005). A total of 600-630 marine species are considered to be introduced (Boudouresque & Verlaque, 2005; Coll *et al.*, 2010) among them between 80 and 110 (+ 7 debatable) macrophytes (Verlaque, 1994; Ribera Siguan, 2003; Cormaci *et al.*, 2004; Zenetos *et al.*, 2005; Verlaque *et al.*, 2010). Between 10 and 19 introduced macrophytes can be considered as being invasive according to the criteria established by Boudouresque & Verlaque (2002).

The importance of the different introduction vectors vary between the eastern and western Mediterranean basin. In the north-western Mediterranean certain coastal lagoons (e.g. Venice Lagoon in Italy, Thau and Salses-Leucate Lagoons in France) are highly colonised by macrophytes introduced principally by oyster aquaculture. In Thau lagoon, the introduced macrophytes coming from Japan represent the large majority of the biomass produced by the hard bottom communities and 32% of the total flora (Verlaque, 2001; Boudouresque *et al.*, 2010).

Besides the considerable number of introduced species, there are several rare species whose distribution and ecology are poorly known. The majority of studies consider common species and studies on rare macrophytes remain an exception. The definition of rarity depends on the organism studied; however, the term is usually associated with small abundances, a small geographic range and/or very restricted habitat-specificity (Chapman, 1999). According to this definition, the majority of species are in fact rare and not common (Kunin & Gaston, 1993; Chapman, 1999). It is supposed that rare species are more susceptible to become extinct than common species (Simberloff, 1988). In order to sustain species diversity, it is very important to increase the knowledge about the distribution and ecology of rare species.

The aim of the present study is to report, with a brief description, the species newly recorded, rare or introduced to the French Mediterranean coast, in particular the Bay of Marseille, to contribute to the knowledge of their morphology, distribution and ecology.

MATERIAL AND METHODS

Sampling was conducted between 2002 and 2008 at various locations along the French Mediterranean coast (Fig. 1) focussing on the eastern Provence, from Marseille to the Port-Cros National Park. Sampling was carried out by

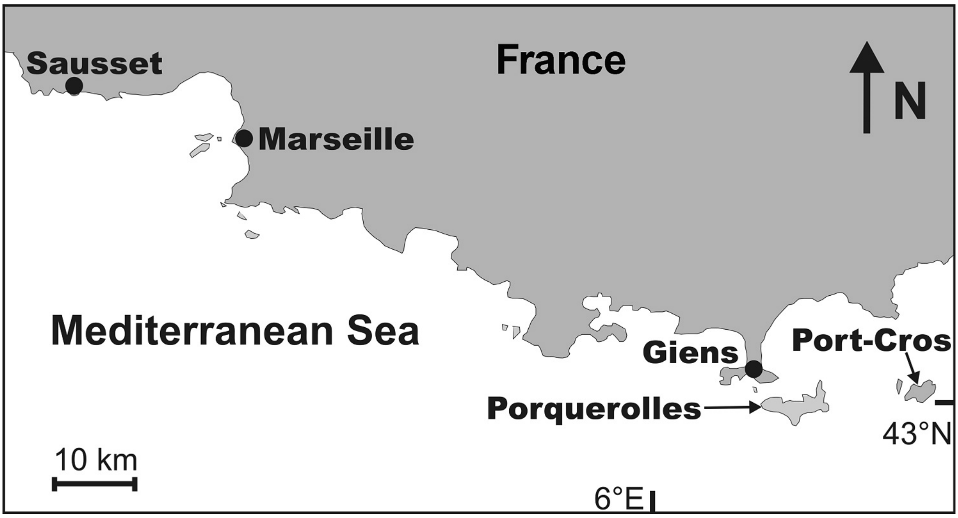


Fig. 1. Map of the study sites.

SCUBA diving. Specimens were preserved in 4% formaldehyde seawater. Herbarium specimens noted “HXXXX” have been deposited in the Verlaque Herbarium, HCOM, Marseille, France. The Herbarium abbreviation follows Thiers (2009).

For nomenclature purposes the taxonomic database *AlgaeBase* (Guiry & Guiry, 2010) was used. The geographical distribution of each species was based on Guiry & Guiry (2010), the following Mediterranean checklists: Athanasiadis (1987), Ballesteros (1990), Ribera *et al.* (1992), Aleem (1993), Gómez Garreta *et al.* (2001), Benhissoune *et al.* (2001, 2002a,b, 2003), Furnari *et al.* (2003), Cormaci *et al.* (2004), Taşkin *et al.* (2008), Verlaque *et al.* (2010) and regional works.

RESULTS

The present study has allowed identifying 15 species of marine macroalgae newly recorded, rare or introduced to the French Mediterranean coast. Among the species showing range extensions, 7 were new to the French Mediterranean coast. As far as species introductions are concerned, 7 exotic species reported during this study showed considerable range extensions. One of these 7 species can be considered as an invasive species (*Acrothamnion preissii*).

Acrothamnion preissii **(Sonder) E.M. Wollaston**

(Ceramiales, Rhodophyta)

Basionym: *Callithamnion preissii* Sonder, 1845.

Distribution: Worldwide: Species originally described from Western Australia, Indian Ocean (Sonder, 1845), successively recorded in South Africa, Indian Ocean; W Pacific Ocean (South Australia, Japan, Korea). **Mediterranean:** Introduced species recorded first in 1969 from Italy, Livorno (Cinelli & Sartoni, 1969);

successively recorded in Capraia, Elba, Gorgona, Liguria, Sicily and Ustica; Balearic Islands; France (Alpes-Maritimes, Var); Monaco (see Verlaque *et al.*, 2010); Spain (C. Pena Martín, pers. comm.). Since its first report from France in the Alpes-Maritimes (Boillot *et al.,* 1982), *Acrothamnion preissii* has become common all along the French Riviera. The species is illustrated for the first time from Marseille, which constitutes its present western limit of distribution along the French Mediterranean coast.

Material studied: Marseille: June, Sept. & Dec. 2002, March & June 2003, March 2005, Oct. & Nov. 2006, March 2007, 17 m depth, dead *Posidonia oceanica* (L.) Delile rhizomes. Les Embiez & Hyères (Var): July 2002, 4-8 m depth, photophilous assemblages.

Other collections examined: Monaco: Sept. 1996 (H4657-4658), 3 m depth, photophilous assemblages; April 1997 (H4659-4660), 20 m depth, *P. oceanica* meadows; June 1997 (H4652), 12 m depth, *P. oceanica* meadows. Villefranche-sur-Mer (Alpes-Maritimes): Oct. 1981 (H4653-4655), 35 m depth, coastal detritic bottoms. Les Lecques (Var): Sept. 1996 (H4656), 30 m depth, coralligenous assemblages. Cavalaire (Var): Jan. 1997 (H4651), 35 m depth, coastal detritic bottoms. Saint-Tropez (Var): June 1999 (H4661), 38 m depth, *Cystoseira spinosa* Sauvageau assemblage. Levant Island (Var): April 2000 (H4662), 20 m depth, *P. oceanica* meadows.

Note. The branching arrangement of the thallus and the gland cells terminal on the rachis of whorl-branches of our material are distinctive (Fig. 2). Reproductive structures have not been observed. *Acrothamnion preissii* preferably colonises the living and dead *Posidonia oceanica* rhizomes but it has also been observed epiphytic on *P. oceanica* leaves, macroalgae and in coastal detritic bottoms (down to 40 m depth). In many parts of the Mediterranean Sea, *A. preissii* has negative impacts on the native flora and can be considered as an invasive species (Piazzi *et al.,* 1996; Piazzi & Cinelli, 2000, 2001; Boudouresque & Verlaque, 2002). In the Bay of Marseille, *A. preissii* is present all year round on living and dead *P. oceanica* rhizomes but without reaching high biomasses.

Antithamnion amphigeneum A.J.K. Millar

(Ceramiales, Rhodophyta)

Synonym: *Antithamnion algeriense* M. Verlaque *et* Seridi.

Distribution: Worldwide: Species originally described from New South Wales, SW Pacific Ocean (Millar, 1990); successively recorded in the NE Atlantic Ocean (introduced) (Norway, Spain). **Mediterranean:** Introduced species recorded first in 1989 from Algeria (Verlaque & Seridi, 1991, as *A. algeriensis*); successively recorded at Alboran Island; Italy (Liguria); Monaco; Morocco, Spain (see Verlaque *et al.*, 2010). *Antithamnion amphigeneum* is reported and described for the first time from the French Mediterranean coast.

Material studied: Marseille: June 2002, 4-8 m depth, photophilous assemblages; June, Sept., Nov. & Dec. 2002, March & June 2003, March 2005 (H8099), 17 m depth, dead *P. oceanica* rhizomes; March 2005 (H8097-8098), 0.5 m depth, sciaphilous assemblages; March & June 2007, 28 m depth, coastal detritic bottoms. Port-Cros Island (Var): May 2008, 35 m depth, coralligenous assemblages.

Other collections examined: Monaco: April 1997 (H2890 & F1396), 1 m depth, sciaphilous assemblages.

Note. The branching of the whorl-branches, the gland-cells touching 2-3 branch cells, the primary indeterminate lateral axes single on axial cells (without any whorl-branch), and the terminal cells blunt of our material are distinctive (Figs 3-4). Reproductive structures have not been observed. In the Bay of Marseille, *Antithamnion amphigeneum* was found on dead *Posidonia oceanica* rhizomes, breakwaters and coastal detritic bottoms at depths ranging from 0.5 to 35 m. On breakwaters, *A. amphigeneum* was associated with three other introduced species: *Antithamnionella boergesenii, A. spirographidis* and *A. ternifolia*.

Antithamnion piliferum Cormaci *et* G. Furnari

(Ceramiales, Rhodophyta)

Distribution: Mediterranean: Endemic species originally described from Sicily, Ionian Sea (Cormaci & Furnari, 1987); successively recorded in the Adriatic Sea; Balearic Islands; France; Greece (Kephallinia Island, Ionian Sea); Spain (Alicante); western and southern Italy (Toscana, Puglia) (see Gómez Garreta *et al.*, 2001). *Antithamnion piliferum* is reported and described for the first time from the French Mediterranean coast.

Material studied: Port-Cros (Var): May 2008 (H8060-8061), 35 m depth, coralligenous assemblages.

Other collections examined: Monaco: Sept. 1996 (H2892 & F1379-1381) & Sept. 1997 (H2894-2896), 2 m depth, photophilous assemblages; June 1997 (H2893), 12 m depth, photophilous assemblages.

Note. The whorl-branches alternately branched in one plane, without basal pairs of opposite branchlets, the gland-cells on reduced branchlets, 2 cells long and the terminal hair cells in pairs of our material are distinctive (Figs 5-6). Reproductive structures have not been observed. In the southern Mediterranean, *Antithamnion piliferum* grows between 10 and 25 m depth. In France, it is found in coralligenous assemblages.

Antithamnionella boergesenii (Cormaci *et* G. Furnari) Athanasiadis

(Ceramiales, Rhodophyta)

Basionym: *Antithamnionella elegans* (Berthold) J.H. Price *et* D.M. John var. *boergesenii* Cormaci *et* G. Furnari.

Distribution: *Antithamnionella boergesenii*, *A. elegans* and *A. sublittoralis* (Setchell *et* Gardner) Athanasiadis have previously been subsumed in a single species *A. elegans* (and more recently recognized as separate varieties of *A. elegans*) (Athanasiadis, 1996), so the distribution of each species requires to be updated. **Worldwide:** Species described from the Canary Islands, NE Atlantic (Cormaci & Furnari, 1988), successively recorded at Madeira, Salvages Islands, Spain, western tropical Africa; W Atlantic Ocean (Caribbean Sea, Florida). **Mediterranean:** Introduced species recorded first in 1937 from Algeria (Mazoyer & Feldmann, 1937, as *Antithamnion elegans*); successively recorded in Italy (Lampedusa); Spain (Valencia); in France it was only reported from Banyuls-sur-Mer (Athanasiadis, 1996) (see Verlaque *et al.*, 2010). Contrarily to Cormaci *et al.* (2004) we consider the species as introduced into the Mediterranean Sea. The Marseille collection constitutes the second record of *Antithamnion boergesenii* on the French Mediterranean coast.

Material studied: Marseille: June 2002, 4-8 m depth, photophilous assemblages; March 2005 (H8104), 0.5 m depth, sciaphilous assemblages.

Note. The sub-equal whorl-branches, simple or distichously-alternately ramified, in whorls of 4-5, and the lens-shaped gland cells produced on terminal branches of our material are distinctive (Figs 7-8). Reproductive structures have not been observed. In the Bay of Marseille, *A. boergesenii* was found on breakwaters, associated with *Antithamnion amphigeneum, Antithamnionella spirographidis* and *A. ternifolia*.

Antithamnionella spirographidis (Schiffner) E.M. Wollaston (Ceramiales, Rhodophyta)

Basionym: *Antithamnion spirographidis* Schiffner.

Distribution: Worldwide: E Atlantic Ocean (introduced) (from Scotland to Spain); SE Atlantic Ocean (South Africa); Indian Ocean (South Africa); W Pacific Ocean (Australia, Japan, Korea and Vietnam); NE Pacific Ocean (from Alaska to Baja California). **Mediterranean:** Species originally described from the Adriatic Sea (Italy, Trieste) (Schiffner, 1916); successively recorded in the Balearic Islands; Corsica; France (Banyuls-sur-Mer, Nice, Toulon); Greece; Italy (Naples, Venice, Puglia); Morocco; Sardinia; Sicily (see Verlaque *et al.*, 2010). Since its first report from France (Nice, Ollivier, 1929, as *Antithamnion spirographidis*), it was recorded all along the French Mediterranean coast.

Material studied: Marseille: April 2005 (H8108), 0.5 m depth, sciaphilous assemblages.

Other collections examined: Nice (Alpes-Maritimes): Oct. 1968 (H1529), 30 m depth, coralligenous assemblages. Port of Marseillan (Hérault): May 1998 (H4712), 0.3 m depth, dockside.

Note. The un-equal or sub-equal whorl-branches in whorls of 1 - 2 (3), the whorl-branches simple or sparsely and unilaterally ramified, the apices of axes sinusoidal, the periaxial cells as long as the next branch cell and the gland cells single per whorl-branch of our material are distinctive. Reproductive structures have not been observed. In the Bay of Marseille, *A. spirographidis* was found on break-waters, associated with *Antithamnion amphigeneum, Antithamnionella boergesenii* and *A. ternifolia*.

Antithamnionella ternifolia (J.D. Hooker *et* Harvey) Lyle (Ceramiales, Rhodophyta)

Basionym: *Callithamnion ternifolia* J.D. Hooker *et* Harvey.

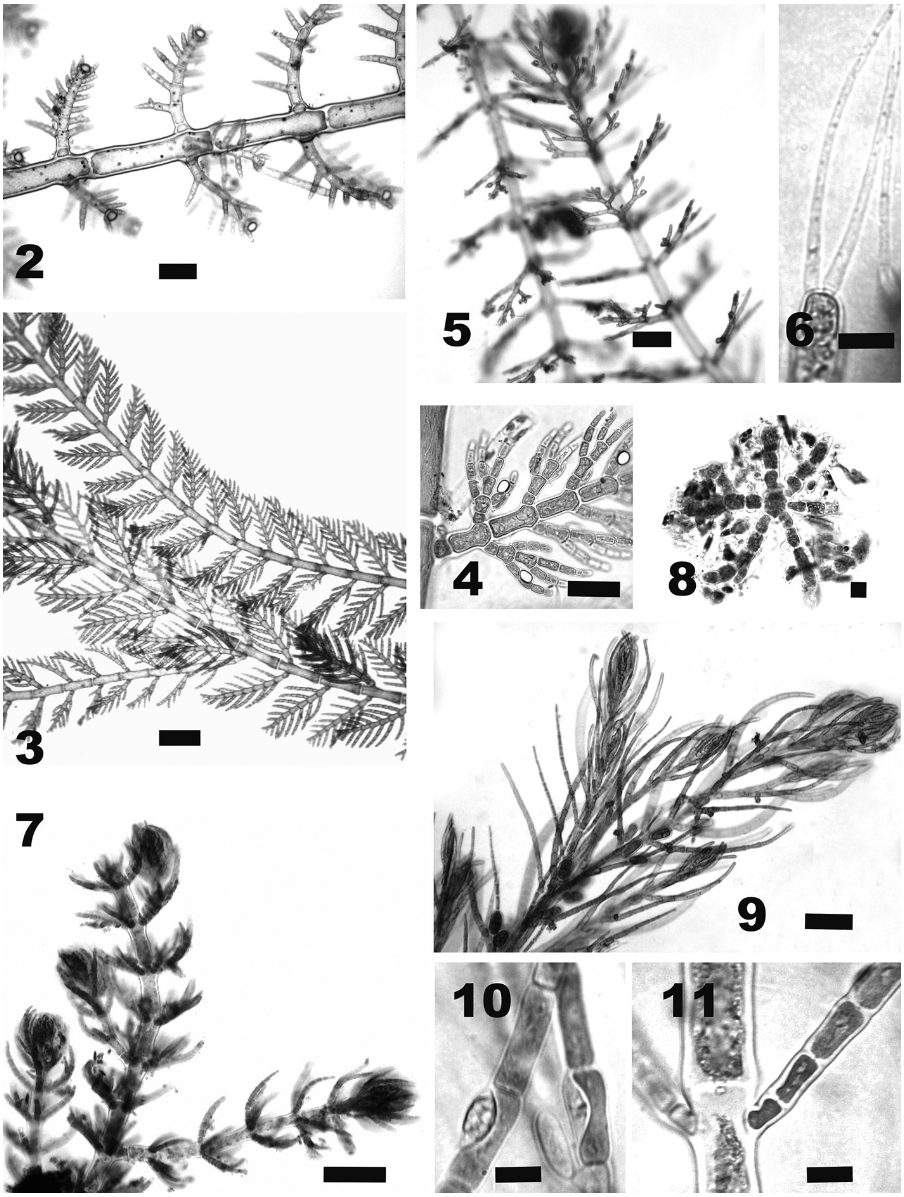
Synonyms: *Antithamnion ternifolium* (J.D. Hooker *et* Harvey) De Toni; *Antithamnionella sarniensis* Lyle; *Antithamnion sarniensis* (Lyle) Feldmann-Mazoyer.

Distribution: Worldwide: Species originally described from the Cap Horn, S Pacific Ocean (Hooker & Harvey, 1845); successively recorded in the Pacific Ocean (Australia, Chile, Japan, New Zealand, Tasmania); NE Atlantic Ocean (from Holland to Portugal); SW Atlantic Ocean (Argentina); Indian Ocean (Chagos Islands, South Africa). **Mediterranean:** Introduced species recorded first in 1926 from France (Nice and Villefranche-sur-Mer, Ollivier, 1926), successively recorded at Cassis, Toulon; Monaco (see Verlaque *et al.*, 2010). Marseille constitutes its present western limit of distribution along the French Mediterranean coast.

Material studied: Marseille: March 2005 (H8105), 0.5 m depth, sciaphilous assemblages.

Other collections examined: Marseille: March 1982 (H4710), 0.4 m depth, photophilous assemblages. Cassis (Bouches-du-Rhône): March 1993 (H4711), 0.5 m depth, on *Mytilus galloprovincialis,* Lamarck, 1819.

Note. The simple sub-equal whorl-branches in whorls of 2-4, the terminal cells pointed, the periaxial cells shorter than the contiguous branch cell, and the gland cells single per whorl-branch of our material are distinctive (Figs 9-11). Reproductive structures have not been observed. In the Bay of Marseille, *A. ternifolia* was found on breakwaters, associated with *Antithamnion amphigeneum, Antithamnionella boergesenii* and *A. spirographidis*.



Figs 2-11. **2.** *Acrothamnion preissii* (Marseille, May 2006), detail of an axis. Scale bar = 50 µm. Figs 3-4. *Antithamnion amphigeneum* (Marseille, March 2007). **3.** Detail of axes. Scale bar = 200 µm. **4.** Detail of the insertion of a primary indeterminate lateral axe. Scale bar = 100 µm. Figs 5-6. *Antithamnion piliferum* (Port-Cros Island, H8060, May 2008). **5.** Detail of axes. Scale bar = 50 µm. **6.** Apical cell of a whorl-branch bearing two hairs. Scale bar = 10 µm. Figs 7-8. *Antithamnionella boergesenii* (Marseille, H8104, March 2005). **7.** Detail of axes. Scale bar = 100 µm. **8.** Transverse section of axis showing a primary lateral axis and the sub-equal whorl-branches in whorl of 5. Scale bar = 10 µm. Figs 9-11. *Antithamnionella ternifolia* (Marseille, H8105, March 2005). **9.** Detail of a tetrasporophyte with tetrasporangia. Scale bar = 100 µm. **10.** Detail of gland cells. Scale bar = 10 µm. **11.** Detail of basal portion of whorl-branches. Scale bar = 10 µm.

***Calliblepharis jubata* (Goodenough *et* Woodward) Kützing (Gigartinales, Rhodophyta)**

Basionym: *Fucus jubatus* Goodenough *et* Woodward.

Synonym: *Calliblepharis lanceolata* Batters

Distribution: Worldwide: Species originally described from England, NE Atlantic Ocean (Goodenough & Woodward, 1797); successively recorded from Ireland to Mauritania; SW Atlantic (Brazil); Indo-Pacific Ocean (India, Pakistan). **Mediterranean:** Algeria; Balearic Islands; France (Marseille); Italy (Calabria, Naples as *C. ciliata*, Puglia); Morocco; Sicily; Spain (Catalonia). *Calliblepharis jubata* is described for the first time from the French Mediterranean coast.

Material studied: Marseille: March 2006, 39 m, coralligenous assemblages; Sept. 2006, June 2007, 29 m depth, coastal detritic bottoms; Port-Cros Island (Var): May 2008 (H8063), 35 m depth, coralligenous assemblages.

Other collections examined: Marseille, 23 April 1853, 1860 (without month) and 24 August 1862 (specimens no 266, 264-265 and 263, Huvé Herbarium, HCOM), drifted to the coast. Port-Cros Island (Var): Oct. 1968 (H1874), 45 m depth, coastal detritic bottoms. Sausset-les-Pins (Bouches-du-Rhône) : August 1982 (H3347-3350), 8 m depth, sciaphilous assemblages. Banyuls-sur-Mer (Pyrénées-orientales) : August 1985 (H3351), 23 m depth, coralligenous assemblages.

Note. Our material is in good agreement with previous descriptions (Preda, 1908-1909; Dixon & Irvine, 1977). Erect fronds, cartilaginous, 9-11 cm high and up to 3.5 mm broad, arise from a branched holdfast. Axes are flattened, dichotomously or pinnately branched in one plane, with apices acute and margins beset with simple or branched narrow proliferations, up to 3 cm long (Fig. 12). The structure of the thallus is pseudoparenchymatous with a medulla composed of large cells intermixed with smaller cells and a 2-3 cell layers thick cortex. Outer cortical cells, polygonal, not uniform in size, from 8×10 µm to 16×18 µm. Reproductive structures have not been observed. In the Mediterranean Sea, *Calliblepharis jubata* was found to be usually restricted to deep assemblages: coralligenous and deep detritic bottoms, 25-40 m depth. The shallowest population (8 m depth, Sausset-les-Pins) grew in an upwelling area where the water is frequently colder than at the other localities.

***Cordylecladia guiryi* Gargiulo, G. Furnari *et* Cormaci (Rhodymeniales, Rhodophyta)**

Distribution: Worldwide: Since its first description in Italy (Sicily) (Gargiulo *et al.,* 1990), *Cordylecladia guiryi* was only reported without description from the Canary Islands in the NE Atlantic Ocean (John *et al.,* 2004) and Linosa Island (Straits of Sicily) in the Mediterranean Sea (Serio *et al.*, 2006). *Cordylecladia guiryi* is reported and described for the first time from the French Mediterranean coast.

Material studied: Marseille: Sept., Nov. & Dec. 2002, March 2003, March 2005, April 2007 (H8101, tetrasporophytes and female gametophytes), 17 m depth, dead *P. oceanica* rhizomes; Sept. & Dec. 2006, Feb., March & June 2007 (H8102-8103, tetrasporophytes and female gametophytes), 29 m depth, coastal detritic bottoms.

Other collections examined: Marseille : March 1990 (H3289, tetrasporophytes and female gametophytes), 12 m depth, dead *P. oceanica* rhizomes.

Note. Our material is in good agreement with the original diagnosis (Gargiulo *et al.,* 1990). Plants are epiphitic on dead *P. oceanica* rhizomes and free-living Corallinales (Rhodoliths). Erect fronds, 0.9-1.3 mm high and 200-250 µm in diameter, arise single or in small groups of 2-3 on a creeping encrusting basis (Fig. 13).

Axes are unbranched or with a subdivision near the basis. Apices are acuminate. Transverse sections of axis are subcylindrical and show an abrupt transition between the 1-2 cell-layers thick cortex and the parenchymatous medulla composed of rounded cells, 35-40 µm in diameter. Mature cystocarps are spherical, 558-580 µm in diameter, and crowded in groups of 2-3, near the apices of the erect fronds (Fig. 14). Transverse sections of cystocarps show a thick pericarp with a small ostiole, a gonimoblast occupying almost the totality of the cavity, and large basal columnar gonimoblast cells (Fig. 15). Tetrasporangia are differentiated in swollen pod-like apices, up to 1-2 mm long and 300 µm in diameter (Fig. 16). Tetrasporangia are formed in an intercalary position in the cortex (Fig. 17).

In Italy, *C. guiryi* was found epiphytically on *Posidonia oceanica* leaves at 10 m depth (Gargiulo *et al.*, 1990) and in macroalgal assemblages with dominance of Udoteaceae at 40 m depth (Serio *et al.*, 2006). In the Bay of Marseille it was found on dead *Posidonia oceanica* rhizomes and deep detritic bottoms between 17 and 30 m of depth.

Dasyella gracilis Falkenberg

(Ceramiales, Rhodophyta)

Distribution: Mediterranean: Endemic species originally described from the Gulf of Naples (Italy) (Falkenberg, 1901); successively recorded from France (Banyuls-sur-Mer) (Coppejans & Boudouresque, 1984); Spain (Tossa de Mar) (Ballesteros, 1984). *Dasyella gracilis* is illustrated for the first time from Marseille, which constitutes its second locality on the French Mediterranean coast.

Material studied: Marseille: March 2002 (H8104), March 2003, March 2005, Nov. 2006, 17 m depth, dead *Posidonia oceanica* rhizomes; Sept. 2006, June 2007, 29 m depth, coastal detritic bottoms.

Note. The uncorticated axis with a sympodial growth, the monosiphonous pigmented pseudolaterals, dichotomously branched and alternately arranged on the axis at intervals of 2-9 segments (Fig. 18), and the axial cells giving 4 periaxial cells subsequently transversally divided in three cells of our material are distinctive (Fig. 19). Reproductive structures have not been observed.

According to Funk (1955), at Naples, *Dasyella gracilis* is probably growing between 10 and 20 m depth. At Banyuls-sur-Mer, it was found forming a short turf on gravel at 35 m depth (Coppejans & Boudouresque, 1984). In Tossa de Mar, it grew in an assemblage dominated by *Cystoseira zosteroides* C. Agardh at 18 m depth (Ballesteros, 1984, 1992). In the Bay of Marseille, it grew as isolated individuals on dead *Posidonia oceanica* rhizomes as well as on deep detritic bottoms.

Goniotrichiopsis sublittoralis G.M. Smith

(Porphyridiales, Rhodophyta)

Distribution: Worldwide: Species originally described from California, E Pacific (Smith & Hollenberg, 1943); successively recorded in Alaska, British Columbia, Oregon, Washington; Pacific Islands (Fiji); NE Atlantic (France, Brittany). **Mediterranean:** Introduced species recorded first in 1989 from Majorca (Balearic Islands) (Magne, 1992); successively recorded in Monaco (see Verlaque *et al.*, 2010). Contrarily to Cormaci *et al.* (2004) we consider the species as introduced into the Mediterranean Sea. The Hyères collection constitutes the first record of *Goniotrichopsis sublittoralis* on the French Mediterranean coast.

Material studied: Hyères (Var): July 2002, 4 m depth, photophilous assemblages.

Other collections examined: Monaco: Feb. 1998 (F1432), 44-46 m depth, coastal detritic bottoms.

Note. The very small size, the branching arrangement and the cells with numerous discoid plastids without pyrenoid of our material are distinctive. Reproductive structures have not been observed. *Goniotrichiopsis sublittoralis* is usually epiphytic on other Rhodophyta species (Magne, 1992). In the Balearic Islands, the species was found epiphytic on *Bonnemaisonnia asparagoides* between 10 and 20 m depth (Magne, 1992). At Hyères, we found it on *Laurencia microcladia* in photophilic shallow assemblages.

***Jania adhaerens* J.V. Lamouroux**

(Corallinales, Rhodophyta)

Distribution: Worldwide: Widespread in all the oceans, in warm temperate and tropical zones. **Mediterranean:** Type stated by Lamouroux (1816) to be from the Mediterranean Sea, but with some uncertainty; species successively recorded all around the Mediterranean: Adriatic Sea; Algeria; Balearic Islands; Corsica; Egypt; Greece; Italy; Israel; Libya; Malta; Morocco; Sardinia; Sicily; Spain; Tunisia; except for the coldest regions (Gulf of Lion and north Aegean Sea). *Jania adhaerens* is described and illustrated for the first time from the Gulf of Lion and the French Mediterranean coast.

Material studied: Marseille: May 2008 (H8062), 28 m depth, *Posidonia oceanica* meadows.

Other collections examined: Monaco: Sept. 1996 (H3817), 10 m depth, photophilous assemblages; Sept. 1997 (H3820), 5 m depth, photophilous assemblages; Porquerolles Island (Var): Oct. 2001 (H7459), 35 m depth, coralligenous assemblages.

Note. Our material is in good agreement with the numerous descriptions from the literature. Erect calcified fronds, up to 3.5 cm high, are pink and regularly dichotomously branched. The angle of ramifications is conspicuously wide (greater than 30°) (Fig. 20). Segments are cylindrical, (75-)100-125(-175) µm in diameter. The branches develop characteristic secondary discoidal holdfasts (Fig. 21). Reproductive structures have not been observed. Along the Mediterranean French coast, *Jania adhaerens* has a seasonal development from spring to autumn. In the Bay of Marseille, it was found epiphytic on deep *P. oceanica* meadows.

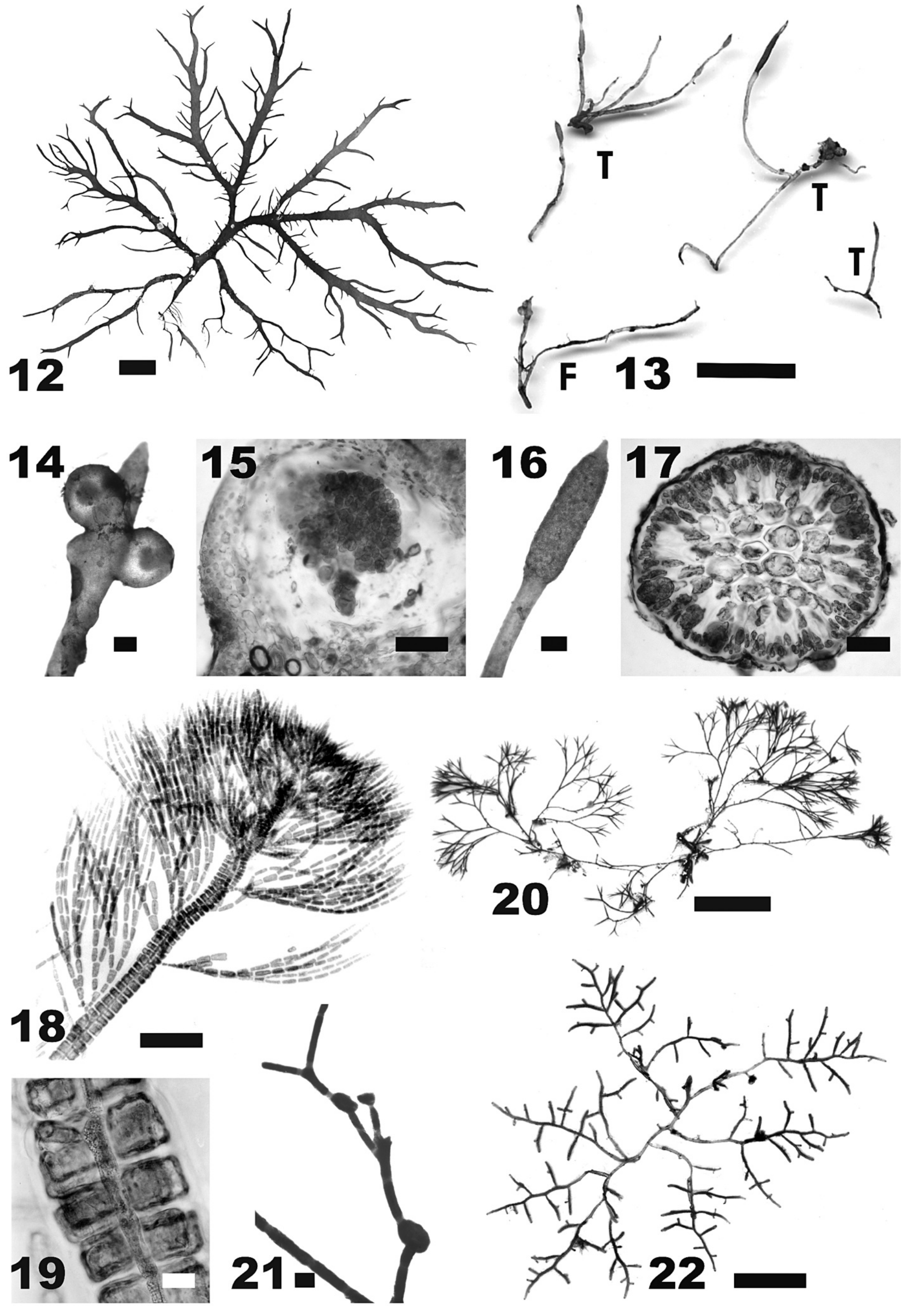
***Laurencia chondrioides* Børgesen**

(Ceramiales, Rhodophyta)

Distribution: Worldwide: Species originally described from Saint John Island, Virgin Islands, W Atlantic (Børgesen, 1918); successively recorded from the Caribbean Islands, Cuba, Puerto Rico; NE Atlantic, Canary Islands; SE Asia (Philippines). **Mediterraean:** Recorded first in 1990 from the Aeolian Islands, Balearic Islands, Columbretes (Spain) and Lachea Island (Italy) (Boisset *et al.*, 1998); successively recorded in the Adriatic Sea (Tremiti Islands) (Cormaci *et al.*,

Figs 12-22. **12.** *Calliblepharis jubata* (Port-Cros Island, H8063, May 2008), habit. Scale bar = 1 cm. Figs 13-17. *Cordylecladia guiryi* (Marseille, H8101, April 2007). **13.** Habit, T: tetrasporophytes with tetrasporangia, F: Female gametophyte with cystocarps. Scale bar = 5 mm. **14.** Detail of Cystocarps. Note large columnar gonimoblast cells. Scale bar = 200 µm. **15.** Longitudinal section through a cystocarp. Scale bar = 100 µm. **16.** Swollen pod-like branch apex with tetrasporangia. Scale bar = 200 µm. **17.** Transverse section through a tetrasporangial sorus. Scale bar = 50 µm. Figs 18-19. *Dasyella gracilis* (Marseille, H8104, March 2002). **18.** Habit. Scale bar = 250 µm. **19.** Longitudinal optical section of an axis showing the axial cell with periaxial cells subdivided in three cells. Scale bar = 20 µm. Figs 20-21. *Jania adhaerens* (Marseille, H8062, May 2008). **20.** Habit. Scale bar = 1 cm. **21.** Detail of a branch with secondary discoidal holdfasts. Scale bar = 200 µm. **22.** *Laurencia chondrioides* (Hyères, H4402, Oct. 1978), habit. Scale bar = 1 cm.

▶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2000), western Italy (Tuscany) (Rindi *et al.*, 2002), Sicily (Furnari *et al.*, 2003), Greece (Tsirika & Haritonidis, 2005). *Laurencia chondrioides* is reported and described for the first time from the French Mediterranean coast.

Material studied: Porquerolles Island (Var): Dec. 2005, 10 m depth, *Posidonia oceanica* meadows.

Other collections examined: Hyères (Var): Oct. 1978 (H4402), 10 m depth, *Posidonia oceanica* meadows.

Note. Our material is in good agreement with descriptions from the literature (Børgesen, 1918; Boisset *et al.*, 1998; Furnari *et al.*, 2001). The plants rosy-red, up to 4 cm high, are soft in texture. The axes, erect or prostrate, flexuous and entangled, 350-500 µm in diameter, have a sparse, irregularly alternate, rarely subopposite branching with up to 3 orders of branching. The branches and branchlets are often inserted at a right angle (Fig. 22). The cortical cells have their outer walls projecting near the apices. Secondary pit-connections are present between adjacent cortical cells. There are four periaxial cells per axial cell. On transverse sections of the median portion of axes, the cortical cells are isodiametric subquadrate, medullary cells usually lack lenticular thickenings and the axial filament is distinguishable. Reproductive structures have not been observed. According to Boisset *et al.* (1998) *L. chondrioides* is a deep water species that is growing at around 30 m depth in the Caribbean Sea and on rocks and epiphytic on macroalgae and leaves of *Posidonia oceanica* between 15 and 40 m depth in the Mediterranean Sea. On the French Mediterranean coast *Laurencia chondrioides* was found in *Posidonia oceanica* meadows where it formed large intermingled tufts at 6 m depth. The tufts have often been observed floating at the edge of the seagrass meadows.

Phyllophora sicula (Kützing) Guiry *et* L.M. Irvine
(Gigartinales, Rhodophyta)

Basionym: *Phyllotylus siculus* Kützing.

Synonym: *Phyllophora palmettoides* J. Agardh.

Distribution: Worldwide: NE Atlantic Ocean (including the Azores). **Mediterranean:** Species originally described from Sicily, Italy (Kützing, 1847), successively recorded all around the Mediterranean Sea: Adriatic; Greece; Italy; Morocco; Sardinia; Sicily; Spain; Turkey, except for France (Guiry & Guiry, 2010). *Phyllophora sicula* is described and illustrated for the first time from the French Mediterranean coast.

Material studied: Marseille: June, Sept., Nov. & Dec. 2002, March 2003, March 2005 (H8100), Nov. 2006, March 2007, 17 m depth, dead *Posidonia oceanica* rhizomes; Sept, Nov. & Dec. 2006, Feb., March & June 2007, 29 m depth, coastal detritic bottoms.

Other collections examined: Roscoff, March 1966 (specimens 746-749, Boudouresque Herbarium, HCOM), as *P. palmettoides*.

Note. Our material is in good agreement with the previous descriptions of the species (Schotter, 1968; Dixon & Irvine, 1977) and the material collected in the NE Atlantic. Plants are epiphitic on dead *Posidonia oceanica* (L.) Delile rhizomes and free-living Corallinales (Rhodoliths). Erect fronds, 15-61 mm high, arise in small groups on an encrusting basal disc (Fig. 23), and are composed of a cylindrical stipe, 400-410 µm in diameter (Fig. 26), and a cuneate blade, up to 7 mm broad. The structure is multiaxial. In transverse section, the blade consists of a medulla of large cells, 80-100 µm x 50-80 µm, intermixed with groups of smaller cells, and a continuous, 1-2 cell-layers thick cortex (Figs 24, 25, 27). Outer cortical cells are small, 4-8 µm by 4-8 µm in surface view (Fig. 24). Tetrasporangia are grouped in a central sorus on the blade. Sexual organs have not been observed. According to Dixon & Irvine (1977), gametangial plants are unknown and the generic assignment of this species must be regarded as provisional. *Phyllophora sicula* differs from *Rhodymenia ardissonei* (Kuntze) Feldmann and *Schottera nicaeensis* (J.V. Lamouroux *ex* Duby) Guiry *et* Hollenberg by the encrusting basal disc, the continuous cortex and the particular arrangement of medullar cells, which gives a very distinctive pattern on tangential optical sections of the blades (Fig. 25). The ecology of the Mediterranean populations of *P. sicula* is poorly known. In the Bay of Marseille, this perennial species was rather abundant on dead *Posidonia oceanica* rhizomes and deep detritic bottoms where it was frequently associated with *Rhodymenia ardissonei*. On Porquerolles Island, it grew in *Posidonia oceanica* meadows at 6 m depth.

***Solieria filiformis* (Kützing) P.W. Gabrielson**

(Gigartinales, Rhodophyta)

Basionym: *Euhymenia filiformis* Kützing

Distribution: Worldwide: Species originally described from Antigua, Caribbean, W Atlantic Ocean (Kützing, 1863); successively recorded from Brazil to North Carolina; NE Atlantic Ocean, Britain, Canary Islands, Cape Verde Islands, Gabon, Ghana, Mauritania, Senegal; Indian Ocean, Persian Gulf; S Pacific, Australia (as *Solieria tenera*); **Mediterranean:** Introduced species found first in the Gulf of Taranto in 1922 (see Cecere, 1990); successively recorded in Mar Piccolo lagoon, Venice, South Italy; Israel; France, recorded first in 1999 at Salses-Leucate (see Verlaque *et al.,* 2010).

The Marseille collection constitutes the second record of *Solieria filiformis* on the French Mediterranean coast and the first description based on a marine population.

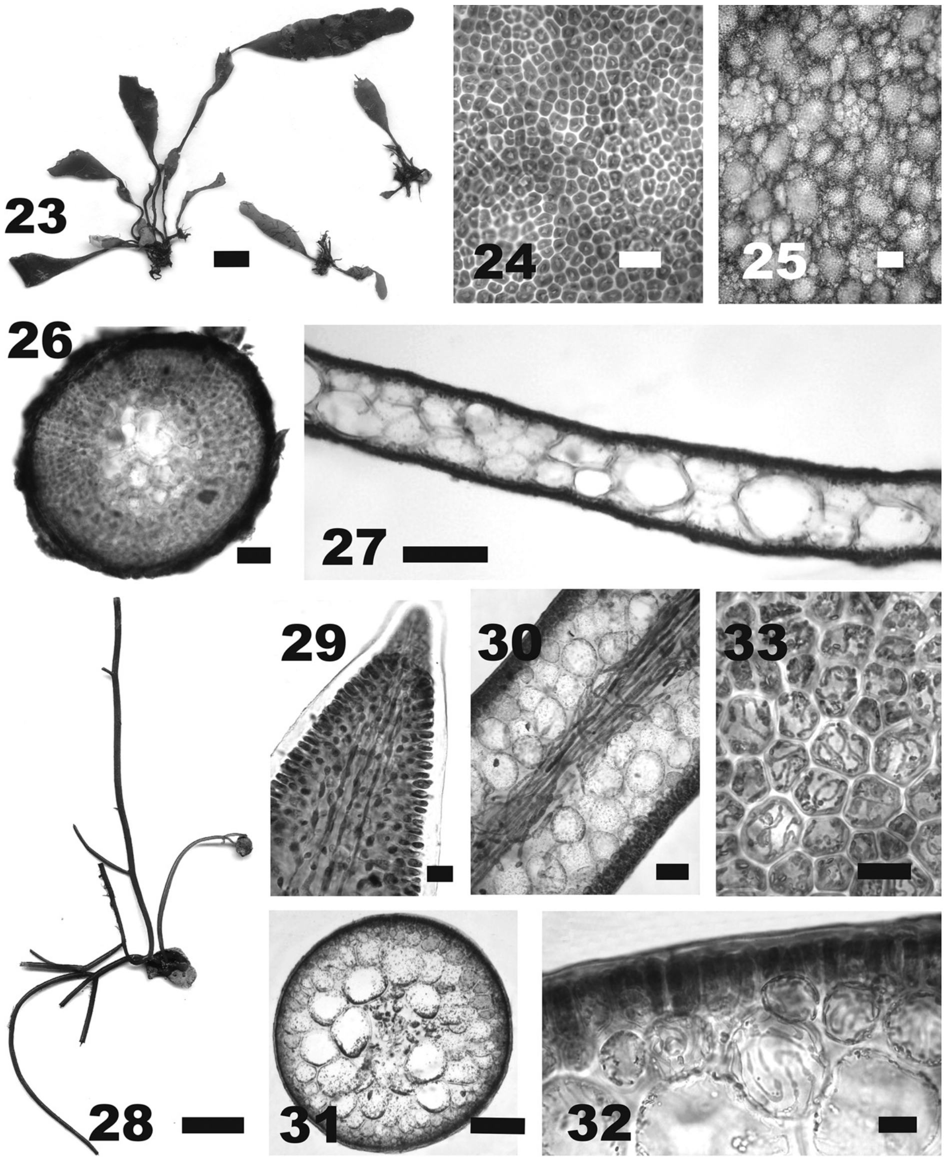
Material studied: Marseille: Feb. 2006 (H8106), 35 m depth, coastal detritic bottoms; Sept. 2006, June 2007, 29 m depth, coastal detritic bottoms.

Note. Plants from Marseille are small, 5-6 cm high, deep pink to purplish-red, and sparsely branched. They are attached by an encrusting holdfast and sometimes secondary holdfasts differentiated on recurved axes (Fig. 28). Axes are cylindrical throughout, ranging from 0.5 to 1.0 mm in diameter. Apices are acute and long. In a longitudinal section, the structure is multiaxial with periaxial cells rotated about each axial filament (Fig. 29). The medulla is broad and composed of lax entangled longitudinal filaments surrounded by large cells, grading into a cortex of small pigmented cells (Figs. 30-31). Plastids which are numerous and long in outer cortical cells become slender to homogeneously filiform, forming delicate parietal loops in inner cortical cells (Figs 32-33). In spite of the absence of reproductive structures our material is in good agreement with the description given by Perrone & Cecere (1994). In the Mar Piccolo, *S. filiformis* was found largely as drifting thalli and only exceptionally attached to the substrate (Perrone & Cecere, 1994). By contrast in the Bay of Marseille, it grew attached to shell debris and small stones on deep detritic bottoms invaded by *Caulerpa racemosa* var. *cylindracea* at depths of around 30-35 m.

***Gontrania lubrica* Sauvageau**

(Ectocarpales, Ochrophyta)

Distribution: Mediterranean: Endemic species originally described from Villefranche-sur-Mer, France (Sauvageau, 1936); successively recorded at Banyuls-sur-Mer; Corsica (Calvi); Greece (Aegean Sea) (see Ribera *et al.*, 1992); Monaco (Verlaque, unpublished data). *Gontrania lubrica* is described and illustrated for the first time from Marseille.

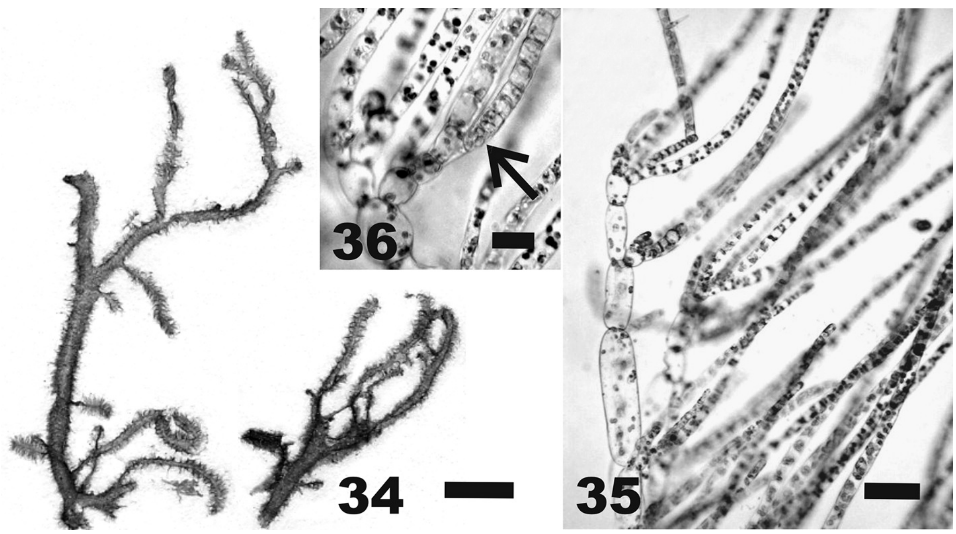


Figs 23-33. **Figs 23-27.** *Phyllophora sicula* (Marseille, Feb. 2007). **23.** Habit. Scale bar = 5 mm. **24.** Surface view of cortical cells. Scale bar = 20 µm. **25.** Tangential optical section of a blade showing the arrangement of medullary cells. Scale bar = 50 µm. **26.** Transverse section of a stipe. Scale bar = 50 µm. **27.** Transverse section of a blade. Scale bar = 100 µm. **Figs 28-33.** *Solieria filiformis* (Marseille, H8106, Feb. 2006). **28.** Habit. Scale bar = 1 cm. **29.** Longitudinal section of an apex. Scale bar = 20 µm. **30.** Longitudinal section of an axis. Scale bar = 100 µm. **31.** Transverse section of an axis. Scale bar = 200 µm. **32.** Detail of cortex. Scale bar = 20 µm. **33.** Surface view of cortical cells showing the elongated plastids. Scale bar = 20 µm.

Material studied: Marseille: June 2007 (H8107), 29 m depth, coastal detritic bottoms.

Other collections examined: Giens (Var): May 1979 (H6398-6399), photophilous subtidal assemblages; Monaco: June 1997 (H6402), 31 m depth, coralligenous assemblages.

Note. Our specimens are in good agreement with the original diagnosis (Sauvageau, 1936). Plants are erect, soft, mucilaginous, cylindrical, 1-5 cm high, 2-3 mm in diameter, irregularly branched, attached with a minute discoid holdfast (Fig. 34). The multiaxial medulla is composed of elongated unpigmented, sympodially branched filaments that end by a young assimilatory filament and bear simple cortical assimilatory filaments, 600-700 (-900) µm long and 10-12 µm in diameter, and phaeophycean hairs, 10-20 µm in diameter, without basal sheath. Each cell contains several discoid chloroplasts (Figs 35-36). In spite of the absence of reproductive structures, the material from Marseille is well characterised in having primary filaments with sympodial growth, axial cells without secondary division, and phaeophycean hairs without basal sheath. *Gontrania lubrica* was found between 20 and 35 m depth on coastal detritic bottoms and coralligenous assemblages.



Figs 34-36. *Gontrania lubrica* Sauvageau (Marseille, H8107, June 2007). **34.** Habit. Scale bar = 5 mm. **35.** Upper part of a primary filament showing the sympodial growth pattern. Scale bar = 50 µm. **36.** Detail showing the basal portion of a hair without basal sheath (arrow). Scale bar = 20 µm.

DISCUSSION AND CONCLUSIONS

Since the mid-20th century, changes observed in marine floras and faunas worldwide took a sharp increase. The Mediterranean Sea is one of the most impacted seas in the world, since climate change interacts synergistically with the introduction of species and many other disturbances (Lejeusne *et al.*, 2010).

In the present study, seven macroalgal species, *Antithamnion amphigeneum, A. piliferum, Cordylecladia guiryi, Goniotrichopsis sublittoralis, Jania adhaerens, Laurencia chondrioides* and *Phyllophora sicula,* are reported and described for the first time from the French Mediterranean coast and we provide new information about the distribution of several species that we consider as introduced: *Acrothamnion preissii, Antithamnion amphigeneum, Antithamnionella boergesenii, Antithamnionella spirographidis, Antithamnionella ternifolia, Goniotrichiopsis sublittoralis* and *Solieria filiformis.*

In contrast to Cormaci *et al.* (2004), we range *Antithamnionella spirographidis* and *Goniotrichiopsis sublittoralis* among the introduced species. Although originally described and widely distributed in the Mediterranean Sea, *A. spirographidis* is considered as introduced because (i) the species belongs to an Indo-Pacific group, (ii) it has often been found in harbours and on breakwaters associated with other introduced species (present study), and (iii) Athanasiadis (1996) obtained several successful crosses between isolates from the E Atlantic and N Pacific. Similarly, *G. sublittoralis* is considered as introduced because (i) it was first described from the NE Pacific, (ii) its discovery in the E Atlantic and the Mediterranean is recent, and (iii) the species is still rare in the Mediterranean contrarily to similar Rhodophyta like *Stylonema* spp. and *Chroodactylon ornatum* (C. Agardh) Basson, which have a worldwide distribution and are considered as native. In the case of *Antithamnion piliferum,* the recent northward expansion of its distribution does not allow any definite conclusions. According to Athanasiadis (1996), *A. piliferum* is either a sister-taxon of *A. compactum* (Grunow) Schiffner or *A. diminuatum* Wollaston, which both occur in nearby regions (Gibraltar and the Azores, respectively), or represents an introduction from the Indo-Pacific Ocean where the majority of its relatives are distributed. Consequently it may be either a southern Mediterranean species boosted by global warming or an exotic species first introduced in the Sicily region.

Similar to nearly 50 Mediterranean warm-water fishes and several sessile organisms (Azzurro, 2008; Lejeusne *et al.*, 2010), the two native macroalgae, *Jania adhaerens* and *Laurencia chondrioides*, appear as good candidates to illustrate the recent northward expansion of thermophilic species. *Jania adhaerens* is widely distributed in warm temperate and tropical seas and *L. chondrioides* is a common species of the western tropical Atlantic Ocean. According to Boisset *et al.* (1998) and Cormaci *et al.* (2004), the presence of *L. chondrioides* in the Canary Islands deep-water flora, which is closely related to the western Mediterranean flora, makes a recent introduction of the species into the Mediterranean Sea unlikely.

By contrast to warm-water species, a parallel decline of cold-water Mediterranean species can be expected if the global warming trend is confirmed in the future. In such a case, *Calliblepharis jubata* appears as a good candidate to follow this decline. The species is already rare in the W Mediterranean Sea and always restricted to cold waters (deep assemblages and upwelling zones).

Among the other Mediterranean species, *Cordylecladia guiryi*, *Dasyella gracilis*, *Phyllophora sicula*, and *Gontrania lubrica*, only *D. gracilis* is probably a true rare species. The others are certainly less rare than it might seem from the literature. The apparent rarity of *Cordylecladia guiryi* results most likely from (i) its small size, (ii) the difficulties of identification when sterile, and (iii) its location at relatively great depths. According to Gargiulo *et al.* (1990) and Furnari *et al.* (2003), the small form of *Cordylecladia erecta* (Greville) J. Agardh, reported on maerl between 40 and 60 m depth from Algeria (Feldmann & Feldmann, 1943), the Balearic Islands (Ballesteros, 1989) and France (Pyrénées-Orientales) (Feldmann, 1967; Cabioch, 1969), could correspond to misidentifications of *C. guiry*;

however, further investigations are needed to confirm this hypothesis. As far as *Phyllophora sicula* is concerned, its absence on the French coast was surprising in view of the fact that it is widely distributed in the Mediterranean. It is likely that the species was already present but confused with other species like *Rhodymenia ardissonei* or *Schottera nicaeensis*. Finally, the apparent rarity of the Mediterranean endemic brown alga *Gontrania lubrica* is certainly due to (i) a very short growth period in spring (May-June), (ii) a location in deep assemblages (20-30 m), and (iii) misidentification with other Mediterranean mucilaginous Ectocarpales like *Cladosiphon* spp. and *Sauvageaugloia griffithsiana* (Hooker) Kylin.

In conclusion, in spite of the huge mass of data hitherto published on the Mediterranean marine flora, our study illustrates still existing gaps in the knowledge of the native flora and highlights the on-going changes in the north-western basin. Among the species listed here, *Calliblepharis jubata*, *Cordylecladia guiryi*, *Jania adhaerens*, *Laurencia chondrioides* and *Phyllophora sicula* have an Atlantico-Mediterranean distribution; therefore it would be interesting to investigate, through molecular analyses, the taxonomical link between the populations of these two regions.

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