

## Epitypification and redescription of *Corallina officinalis* L., the type of the genus, and *C. elongata* Ellis et Solander (Corallinales, Rhodophyta)

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**Abstract** – *Corallina* L. is the type genus of the subfamily Corallinoideae (Aresch.) Foslie and *Corallina officinalis* L. is the type species of the genus. This name has been applied worldwide, particularly in temperate waters. An attempt to obtain sequence data from the lectotype specimen was not successful. In order to establish a species concept for *C. officinalis* based on molecular sequence data as well as morphology, an epitype was selected from Devon, England within the vague type locality ‘in *O* [Oceano] *Europaeo*’, and from which mitochondrial (*cox1*) and plastid (*rbcL*) data were obtained. A second species, *Corallina elongata* Ellis et Solander (type locality Cornwall, England), was shown previously to include at least two species based on DNA sequences. The lectotype of *C. elongata* is an illustration and therefore an epitype was selected to provide molecular sequence data, using the same markers as for *C. officinalis*. These molecular sequences for *C. officinalis* and *C. elongata* are compared with those of a third, recently described species from Great Britain, *Corallina caespitosa* R.H. Walker, J. Brodie et L.M. Irvine: these data provide an example for studying *Corallina* species taxonomy and diversity in other parts of the world. The implications of this work are discussed in relation to concepts of species distribution.

***Corallina caespitosa* | *Corallina elongata* | *Corallina officinalis* | epitype**

**Résumé** – Epitypification des *Corallina officinalis* L., le type de la genre, et *C. elongata* Ellis & Solander (Corallinales, Rhodophyta). *Corallina* L. est le genre type de la sous-famille des Corallinoideae (Aresch.) Foslie et *Corallina officinalis* L. est l'espèce type du genre. Le nom d'espèce est couramment utilisé pour dénommer des spécimens provenant du monde entier, principalement de zones tempérées. Les tentatives de séquençage du spécimen type sont restées infructueuses. Dans le but de définir l'identité spécifique de *C. officinalis*, basée sur des données moléculaires ainsi que morphologiques, un épitype a été sélectionné. Celui-ci était originaire du Devon (Angleterre) au sein de la localité (ou région) type ‘in *O* [Oceano] *Europaeo*’, et a été séquençé pour des marqueurs mitochondriaux (*cox1*) et chloroplastiques (*rbcL*). Les séquences d'ADN avaient aussi mis en évidence, dans une étude précédente, l'existence d'au moins deux espèces correspondant à *Corallina elongata* Ellis et Solander (localité type : Cornouailles, Angleterre). Le lectotype de *C. elongata* est une illustration, et par conséquent, un épitype a aussi été sélectionné afin de réaliser des analyses moléculaires similaires. Les séquences de *C. officinalis* et *C. elongata* sont comparées avec celles d'une troisième espèce décrite plus récemment en Grande Bretagne, *Corallina caespitosa* R.H. Walker, J. Brodie et

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L.M. Irvine : ces données constituent un exemple d'étude de la taxonomie et de la diversité des espèces du genre *Corallina* dans différentes régions du monde. Les implications de ce travail sont discutées en parallèle avec les concepts de distribution des espèces.

***Corallina caespitosa* / *Corallina elongata* / *Corallina officinalis* / épitype**

## INTRODUCTION

*Corallina* L. is the type genus of the subfamily Corallinoideae (Aresch.) Foslie and the oldest name in coralline literature (Irvine & Johansen, 1994). The number of species in *Corallina* is uncertain: Guiry & Guiry (2012) list 16 although approximately 272 species and infraspecific names have been recorded. Despite a long history of study, concepts of species delimitation in *Corallina* remain ambiguous.

The most commonly recorded species worldwide has been *C. officinalis sensu lato*, which, according to distribution records from herbarium collections (BM) and literature records (Guiry & Guiry, 2012), has a supposed cosmopolitan distribution largely in temperate waters. It has also been the most studied species in the genus and research includes development (Colthart & Johansen, 1973; Andrade & Johansen, 1980), cytology (Peel, 1985), ultrastructure (Borowitzka & Veski, 1978), calcification (Digby, 1977a, 1977b; Pentecost, 1978) and biogeography (Munda, 1977). *Corallina officinalis* has also been used as a representative species for the Corallinales in molecular studies (Bailey and Chapman 1996, 1998; Robba *et al.*, 2006; Kim *et al.*, 2007; Broom *et al.*, 2008; Martone *et al.*, 2012).

However, all of this work requires review following a study by Robba *et al.* (2006), based on analysis of the mitochondrial *cox1* gene region and focussing on red algae of Great Britain, which suggested that two genetically distinct species had been included in *C. officinalis*. These were subsequently distinguished as *C. officinalis* and *C. caespitosa* R.H. Walker, J. Brodie *et* L.M. Irvine. Hitherto, two species of the genus *Corallina*, *C. officinalis* L. (1758) and *C. elongata* Ellis & Solander (1786) were recorded for Great Britain and Ireland (Irvine & Johansen 1994), but a third *Corallina* species was thus recognised in the region by Walker *et al.* (2009). This result highlights the difficulty of distinguishing species using morphology alone and points to the importance of redefining *C. officinalis* and other species by combining morphological and molecular data from type specimens.

*Corallina officinalis* is the type species of the genus *Corallina*, and the lectotype specimen (see Jarvis *et al.*, 1993) is no. 1293.9 in Linnaeus's herbarium at the Linnean Society, London (LINN) (Walker *et al.*, 2009, fig. 5 a). The material consists of several separate pieces of fronds which may or may not belong to one specimen. In order to discover whether this material belongs to *C. officinalis* as currently understood in the type locality area 'Oceano Europaeo', permission was sought to submit a small portion to molecular investigation. Unfortunately it was not possible to obtain molecular sequence data thus leaving the molecular identity of this material unresolved. The lectotype of *C. elongata* (Irvine & Johansen, 1994) also presented a problem as it is a drawing made by Ellis (1755). Results from Walker *et al.* (2009) and our unpublished data indicate that there is more than one species going under the name *C. elongata*. To

overcome these problems and to enable revised definitions of *C. officinalis* and *C. elongata* to include both morphological and molecular data, an epitype specimen has been selected for each species. Similar details for the type specimen of *C. caespitosa*, included in the original description (Walker *et al.*, 2009), are repeated here for comparison.

## MATERIALS AND METHODS

The specimens of *Corallina officinalis*, from which molecular sequence data were generated by Walker *et al.* (2009), were reviewed and a suitable specimen was selected as an epitype. A specimen from South Devon confirmed from molecular data as *C. elongata* was chosen as an epitype of this species. Descriptions were prepared for each species based on type, epitype and other specimens for which molecular data existed (Walker *et al.*, 2009). Comparisons were made with the description of *C. caespitosa*. Terminology for species descriptions follows that of Irvine & Johansen (1994).

## RESULTS AND DISCUSSION

### Proposed epitype of *Corallina officinalis* Linnaeus

Linnaeus's (1758) description states '... in *O.* [Oceano] *Europaeo*'. It therefore is appropriate to choose epitype material from this region, and a specimen from Devon has been selected.

*Corallina officinalis* Linnaeus, *Systema naturae* ed. 12, Vol. 1., 1758, p. 805.

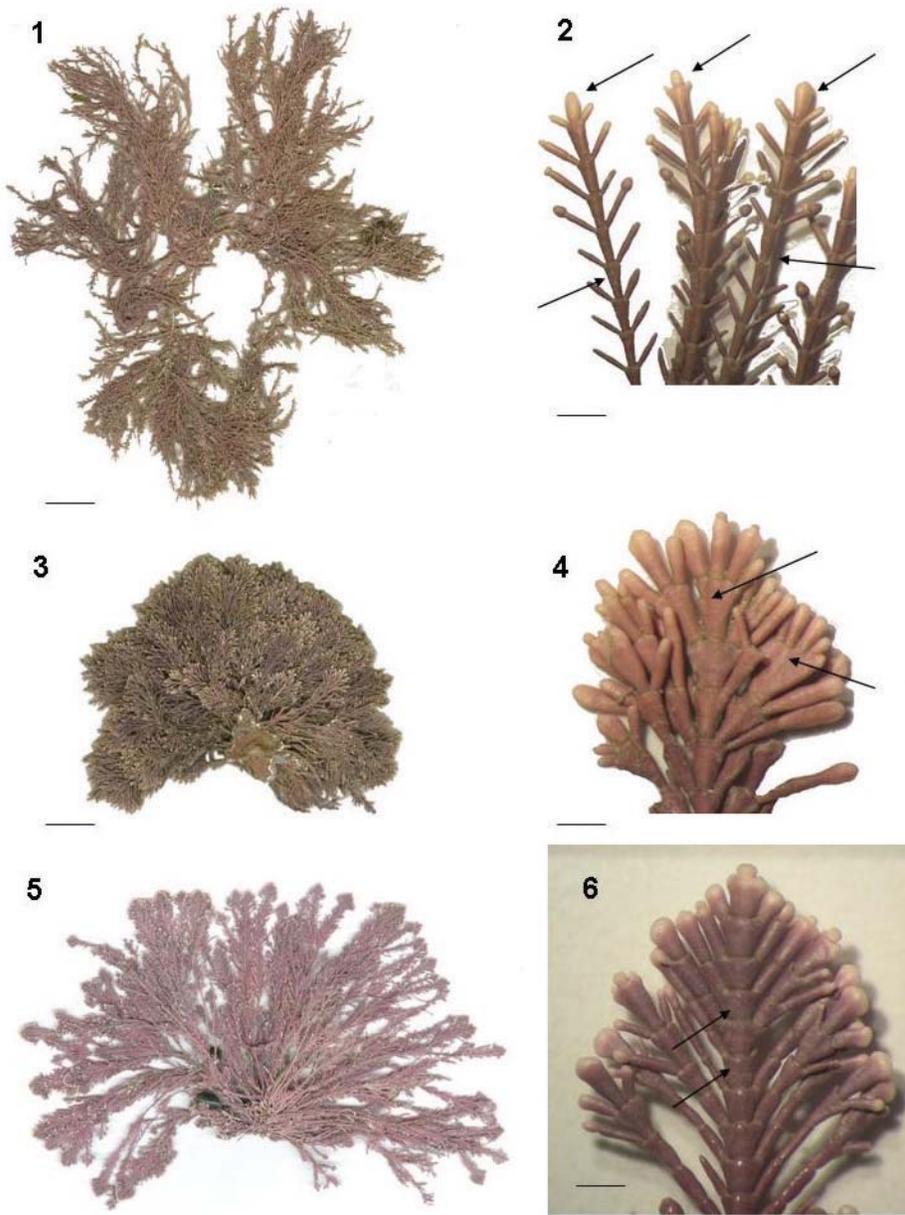
Lectotype (designated by L.M. Irvine in Jarvis *et al.*, 1993: 37): LINN no. 1293.9 (Walker *et al.*, 2009, fig. 5a).

Epitype (designated here BM001062598, Fig. 1): England: Devon, Sidmouth, 28 April 2007, leg. Juliet Brodie, JB39. In pool, lower shore, slightly silty, N50:40:30 W3:14:42. Genbank accession numbers: FM180073 [*cox1*], and JX315329 [*rbcl*] (Walker *et al.*, 2009).

*Revised description.* Thallus with a firmly attached crustose base, typically up to 70 mm in diameter, and individual uprights of branched, stiff, usually erect fronds up to 120 mm long; sparsely branched below, upper branching often in more than one plane, dense to sparse and straggly, simple to compound pinnate but often irregular, successive lateral branchlets typically separated by conspicuous gaps resulting from wide branch-angles combined with long intergenicula in the main axes; fronds consisting of genicula alternating with unlobed intergenicula, which in the main branches are 1-2 mm long and 0.3-1 mm broad, tending to be longer than broad and cylindrical to compressed, especially near genicula<sup>1</sup>. Genicula in main

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1. Note: there is much variation in the shape of intergenicula; for example, in all three species they are sometimes quite flat and extended into lateral wings. <sup>a</sup> Walker *et al.* (2009); <sup>b</sup> Walker *et al.* (unpublished); <sup>c</sup> from Genbank.



Figs 1-6. *Corallina officinalis*, *C. caespitosa* and *C. elongata*. **1.** *Corallina officinalis* Linnaeus: epitype. Scale bar = 7.5 mm. **2.** *Corallina officinalis* detail of apical intergenicula: upper arrows - trifurcate intergenicula; lower arrows - conspicuous gaps between lateral branchlets. Scale bar = 1 mm. **3.** *Corallina caespitosa* R.H. Walker, J. Brodie & L.M. Irvine: holotype. Scale bar = 7.5 mm. **4.** *Corallina caespitosa* detail of apical intergenicula: arrows - palm-like intergenicula with quadrifurcate apical intergenicula. Scale bar = 1.3 mm. **5.** *Corallina elongata* Ellis & Solander: epitype. Scale bar = 12 mm. **6.** *Corallina elongata* detail of apical intergenicula: arrows - tiny or non-existent gaps between lateral branchlets. Scale bar = 1.4 mm.

branches 180-350  $\mu\text{m}$  long and 180-350  $\mu\text{m}$  broad. Apical intergenicula mainly trifurcate (Fig. 2), occasionally branched four or more times, or rarely a single, undivided intergeniculum. Conceptacles axial and also often pseudolateral, spermatangial conceptacles beaked, carposporangial and tetrasporangial conceptacles rarely with surmounting branchlets.

*Habitat.* Marine, epilithic or occasionally on mollusc shells or non-geniculate corallines; sheltered or, less commonly, wave exposed shores, in damp sites throughout the littoral.

*Distribution.* The currently confirmed distribution, based on DNA sequence data, is the North Atlantic, including: England and Scotland (FM180075, FM180080, FM180070)<sup>a</sup>, Iceland (FM180078, FM180079)<sup>a</sup>, Faroes<sup>b</sup>, west coast of France (Le Croisic)<sup>b</sup>, west Greenland<sup>b</sup>, east coast of Canada (Nova Scotia, HQ919250)<sup>c</sup> and east coast of USA (Long Island Sound)<sup>b</sup>.

### ***Corallina caespitosa***

*Corallina caespitosa* R.H. Walker, J. Brodie *et* L.M. Irvine

Holotype (designated in Walker *et al.*, 2009: 290, BM000804549, Fig. 3): England: Devon, Sidmouth, Chit Rocks, 23 April 2005, *leg. Juliet Brodie and Lavinia Robba*, JBLR8; in a shallow rock pool on the exposed rocky shore, N50:40:29, W3:14:41. Molecular sequence information (Walker *et al.*, 2009): DQ191343 [cox1] and JX315330 [*rbcL*].

Isotype: BM000804550, [JBLR10] (Walker *et al.*, 2009, Fig. 3c).

*Description.* Thallus with a firmly attached crustose base, typically >10 mm in diameter, and individual uprights of branched, stiff, usually erect, diamond to fan-shaped, compact fronds up to 45 mm long; branching in one plane, dense, simple to compound pinnate to palmate, successive lateral branchlets typically separated by conspicuous gaps resulting from wide branch-angles combined with long intergenicula in the main axes, often with extra branchlets contributing to fan-shape; fronds of unlobed intergenicula, which in the main branches are 0.6-1.2 mm long and 0.3-0.7 mm broad, tending to be longer than broad and cylindrical to compressed, especially near genicula<sup>2</sup>. Genicula in main branches 160-220  $\mu\text{m}$  long and 200-340  $\mu\text{m}$  broad. Apical intergenicula mainly trifurcate or 4- (Fig. 4), sometimes up to 7 times branched, thus producing extra branchlets, or a single, undivided, asymmetric intergeniculum. Conceptacles axial, sometimes also pseudolateral, spermatangial conceptacles beaked, axial tetrasporangial conceptacles rarely bearing surmounting branchlets. Carposporangial conceptacles were not observed.

*Habitat.* Marine, epilithic on substrata in rock pools from upper limit of mid-littoral to lower limit of littoral zone.

*Distribution.* The currently confirmed distribution, based on DNA sequence data, is England (north to Yorkshire) (DQ191343, DQ191342, FM180072)<sup>a</sup>, Channel Isles (Jersey, DQ191344)<sup>d</sup>, France (Channel and Atlantic)<sup>b</sup>, Portugal<sup>b</sup>, Azores<sup>b</sup>, Canary Islands<sup>b</sup>, Italy<sup>b</sup>, Greece (FM180066, FM180067)<sup>a</sup>, east coast of Africa (Ghana)<sup>b</sup>, west coast of USA (California)<sup>b</sup>, Australia (NSW)<sup>b</sup>, Japan (HM918980)<sup>c</sup>.

2. See note under *C. officinalis*. <sup>a</sup>Walker *et al.* (2009); <sup>b</sup>Walker *et al.* (unpublished); <sup>c</sup>from Genbank; <sup>d</sup>Robba *et al.* (2006).

### Proposed epitype of *Corallina elongata* Ellis et Solander

The lectotype of this species is an illustration (Ellis, 1755) based on a specimen from Cornwall and described in Ellis & Solander (1786). The proposed epitype of *Corallina elongata* is a specimen from south-west Devon. This specimen was chosen because it was collected in 2012 close to the Cornwall border. It was in very good condition and a good example with which to illustrate the morphological concept of this species. Such material is difficult to come across.

*Corallina elongata* Ellis et Solander, *Nat. hist. Zooph.*, 1786, p. 119

Lectotype: (designated by Irvine & Johansen, 1994: 41): Ellis (1755) pl. 24, fig. 3 (drawn after decalcifying in vinegar).

Epitype (designated here BM001032350, Fig. 5): England: South Devon, Plymouth Sound, Renny Rocks, 8 March 2012, *leg. Christine A. Maggs* (J. Brodie specimen code: JBCorallina 2012-2), at lower littoral, N50:19:07, W4:07:18. Genbank accession numbers: JX315327 [*cox1*], and JX315328 [*rbcL*].

*Revised description.* Thallus with a firmly attached crustose base, typically up to 150 mm in diameter and individual uprights of branched, limp, feather-like fronds up to 200 mm long and often diamond-shaped towards the apex; branching in one plane, usually dense, simple to compound pinnate, occasionally irregular, successive lateral branchlets typically separated by inconspicuous (or absent) gaps resulting from narrow branch-angles combined with short intergenicula in the main axes; fronds consisting of genicula alternating with unlobed intergenicula, which in the main branches are 0.5-1 mm long and 0.4-0.8 mm broad, tending to be as long as broad, compressed, especially near genicula<sup>3</sup>. Genicula in main branches 140-190 µm long and 190-240 µm broad. Apical intergenicula mainly trifurcate (Fig. 6), occasionally 4 or more times branched. Conceptacles axial, never pseudolateral, spermatangial conceptacles beaked, carposporangial and tetrasporangial conceptacles often with surmounting branchlets.

*Habitat.* Marine, epilithic in pools and hanging from rock faces in both shady and well-illuminated damp sites; lower littoral to upper sublittoral.

*Distribution.* The currently confirmed distribution, based on DNA sequence data, is the south west coasts of England (FM180065, FM180069)<sup>a</sup> and Ireland (DQ191345)<sup>a</sup>.

### Relationship of *Corallina elongata* to *C. mediterranea*

*Corallina mediterranea* Areschoug in J. Agardh (1852, p. 568) was based on specimens from Egypt (Alexandria) sent to Areschoug by Johan Hedenborg between 1820 and 1830 (Marianne Hamnede, Swedish Museum of Natural History, pers. comm.). The name was still used throughout the Mediterranean (Hamel & Lemoine, 1952) and on the eastern coast of the Atlantic (Gayral, 1966; Ardré, 1970; Lawson & John, 1982) from France to Africa (Senegal) until Irvine & Chamberlain (1994) listed it as a synonym of *C. elongata*.

In Great Britain and Ireland the name has been considered a synonym of *C. elongata* since Batters (1902: '*C. elongata* Johnst. Br. Spong. et Corall. e spec. auth. in herb. Batt. = *C. mediterranea* Aresch.')

3. See note under *C. officinalis*. <sup>a</sup> Walker *et al.* (2009).

elsewhere. Its relationship to *C. elongata*, as here defined, awaits its typification and taxonomic verification. We have found herbarium specimens of *C. caespitosa* from Atlantic France to which the name *C. mediterranea* has been applied.

### CONCLUDING REMARKS

The results of this study highlight the taxonomic problems and misapplication of names within the genus *Corallina*, with profound implications for species delimitation and consequently the understanding of species distribution. For example, samples of *C. elongata* from Great Britain and Ireland, including the epitype, formed a clade, providing a revised concept of this species, whilst other specimens under that name from the Mediterranean grouped with *C. caespitosa* (see Walker *et al.*, 2009). Other authors (Babbini & Bressan, 1997; Boudouresque & Perret-Boudouresque, 1987) have also commented on the difficulty of distinguishing Mediterranean specimens of *C. officinalis* from *C. elongata* and questioned whether *C. officinalis* occurs in the Mediterranean. In the light of our study, further work is required to fully assess the range of morphological variation within and between species so that a complete review of all *Corallina* species concepts can be achieved (Walker *et al.*, unpubl.). Until that is undertaken the number of species and their distribution cannot be resolved.

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### REFERENCES

- AGARDH J.G., 1852 — *Species, genera et ordines algarum*. II. Lund.
- ANDRAKE W. & JOHANSEN H.W., 1980 — Alizarin red dye as a marker for measuring growth in *Corallina officinalis* L. (Corallinaceae, Rhodophyta). *Journal of phycology* 16: 620-622.
- ARDRE F., 1970 — Contribution à l'étude des algues marines du Portugal. 1. La Flore. *Portugaliae Acta Biologica (B)* 10:137-555.
- BABBINI L. & BRESSAN G., 1997 — Recensement de Corallinacées de la Mer Méditerranée et considerations phytogéographiques. *Biblioteca phycologica* 103.
- BAILEY J.C. & CHAPMAN R.L., 1996 — Evolutionary relationships among coralline red algae (Corallinaceae, Rhodophyta) inferred from 18S rRNA gene sequence analysis. In: Chaudhary B.R. and Agrawal S.B. (Eds), *Cytology, Genetics and Molecular Biology of Algae*, Amsterdam: SPB Academic Publishing, pp. 363-376.
- BAILEY J.C. & CHAPMAN R.L., 1998 — A phylogenetic study of the Corallinales (Rhodophyta) based on nuclear small-subunit rRNA gene sequences. *Journal of phycology* 34: 692-705.
- BATTERS E.A.L., 1902 — A catalogue of the British marine algae. *Journal of botany, British and foreign* 40 (Supplement): 1-107.
- BOROWITZKA M.A. & VESK M., 1978 — Ultrastructure of Corallinaceae. 1. Vegetative cells of *Corallina officinalis* and *Corallina cuvierii*. *Marine biology* 46: 295-304.
- BROOM J.E.S., HART D.R., FARR D.R., FARR T.J., NELSON W.A., NEILL K.F., HARVEY A.S. & WOELKERLING W.J., 2008 — Utility of *psbA* and *nSSU* for phylogenetic reconstruction in the Corallinales based on New Zealand taxa. *Molecular phylogenetics and evolution* 46: 958-973.

- BOUDOURESQUE C.F. & PERRET-BOUDOURESQUE M., 1987 — *A checklist of the benthic marine algae of Corsica*. GIS. Marseille, Posidonie publ., 121 p.
- COLTHART B.J. & JOHANSEN H.W., 1973 — Growth-rates of *Corallina officinalis* (Rhodophyta) at different temperatures. *Marine biology* 18: 46-49.
- DIGBY P.S.B., 1977a — Photosynthesis and respiration in the Coralline algae *Clathromorphum circumscriptum* and *Corallina officinalis* and the metabolic basis of calcification. *Journal of the marine biological association of the United Kingdom* 57: 1111-1124.
- DIGBY P.S.B., 1977b — Growth and calcification in the Coralline algae *Clathromorphum circumscriptum* and *Corallina officinalis*, and the significance of pH in relation to precipitation. *Journal of the marine biological association of the United Kingdom* 57: 1095-1109.
- ELLIS J., 1755 — *An essay towards a natural history of the corallines, and other marine productions of the like kind, commonly found on the coasts of Great Britain and Ireland*. London: Privately Published.
- ELLIS J. & SOLANDER D., 1786 — *The natural history of many curious and uncommon zoophytes, collected from various parts of the globe by the late John Ellis. Systematically arranged and described by the late Daniel Solander*. London: B. White & Son, xii + 208 p., 63 Plates.
- GAYRAL P., 1966 — *Les algues des côtes françaises (Manche et Atlantique)*. Paris, Editions Doin, Deren & Cie.
- GUIRY M.D. & GUIRY G.M., 2012 — AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>; searched on 27 February 2012.
- IRVINE L.M. & JOHANSEN H.W., 1994 — Corallinoideae. In Irvine L. M. & Chamberlain Y. M. (eds.) *Seaweeds of the British Isles Vol.1 Rhodophyta Pt. 2B. Corallinales, Hildenbrandiales*. London: HMSO, 276 p.
- HAMEL G. & LEMOINE P. (Mme), 1952 — Corallinacées de France et d'Afrique du Nord. *Archives du Museum national d'histoire naturelle*, series 7, 1: 17-136.
- JARVIS C.E., BARRIE F.R., ALLAN D.M. & REVEAL J.L., 1993 — A list of Linnaean generic names and their types. *Regnum Vegetabile* 127: 1-100.
- KIM J. H., GUIRY M. D., ÓAK J. H., CHOI D.-S., KANG S.-H., CHUNG H. & CHOI H.-G., 2007 — Phylogenetic relationships within the tribe Janieae (Corallinales, Rhodophyta) based on molecular and morphological data: a reappraisal of *Jania*. *Journal of phycology* 43: 1310-1319.
- LAWSON G.W. & JOHN D.M., 1982 — *The marine algae and coastal environment of Tropical West Africa*. J. Cramer, Vaduz.
- LINNAEUS C., 1758 — *Systema naturae* ed. 12, Vol. 1. Stockholm, Salvi.
- MARTONE P.T., LINDSTROM S.C., MILLER K.A. & GABRIELSON P.W. 2012 — *Chiharaea* and *Yamadaia* (Corallinales, Rhodophyta) represent reduced and recently derived articulated coralline morphologies. *Journal of phycology* 48: 859-868.
- MUNDA I., 1977 — Comparison of North European and South European associations of *Corallina officinalis* L. *Hydrobiologia* 52: 73-87.
- PEEL M.C., 1985 — Chloroplast structure in *Corallina officinalis*. *British phycological journal* 20: 190.
- PENTECOST A., 1978 — Calcification and photosynthesis in *Corallina officinalis* L. using (CO<sub>2</sub>)-C-<sup>14</sup> Method. *British phycological journal* 13: 383-390.
- ROBBA L., RUSSELL S.J., BARKER G.L. & BRODIE J., 2006 — Assessing the use of the mitochondrial *cox1* marker for use in DNA barcoding of red algae (Rhodophyta). *American journal of botany* 93: 1101-1108.
- WALKER R.H., BRODIE J., RUSSELL S. & IRVINE L.M., 2009 — The taxonomy and biodiversity of geniculate coralline algae in the northeastern Atlantic: *Corallina caespitosa* sp. nov. (Corallinoideae, Rhodophyta). *Journal of phycology* 45: 287-297.