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A KEY TO THE OSCILLATORIACEAE IN NORTHWEST EUROPEAN SALTMARSHES

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SUMMARY

A key and short description are given of eleven species of *Oscillatoriaceae* distinguished during an investigation of saltmarsh algal communities in Northwest Europe. The deviations from and agreements with the two main classification systems for *Oscillatoriaceae*, one by Geitler (1932), the other by Drouet (1968), are indicated.

INTRODUCTION

In 1968, Dr. F. Drouet completed a revision of the *Oscillatoriaceae*. In this paper he reduced the number of then acknowledged species from over a thousand (see Geitler 1932) to twenty-three. It had a milder reception than an earlier revision of the coccoid *Cyanophyceae* (Drouet & Daily 1956) that harvested an avalanche of derogatory comments in papers (Desikachary 1968). Drouet's adversaries expressed gratitude only for awakening algologists' interest in the potentials of the blue-green algae (Desikachary 1970), but did not consider his work seriously. The new classification system for the *Oscillatoriaceae* had also more positive responses (Humm 1969). In recent years most investigators have chosen between the 'Geitlerian' or classical system (Christensen & Thomsen 1974) and Drouet's system (Parke & Dixon 1976), or proposed an alternative (Bourrelly 1970).

In 1970, the present author started an investigation of saltmarsh algal vegetation in Northwest Europe. The first results indicated that the *Oscillatoriaceae*, with *Vaucheria* spp. and some filamentous green algae, determined the dynamics of the vegetation system in the saltmarshes of the Western Wadden area (and, as appeared later, in most Northwest European saltmarshes). One of the objectives of this study was to distinguish and name the algal communities of this system. In vegetation science it is customary to name a community after a dominant or a characteristic species in it. Consequently, a clear definition of species, certainly of dominant and characteristic ones such as the *Oscillatoriaceae*, was required to make any system developed more widely applicable. Therefore, the classification of the *Oscillatoriaceae* received continuous critical attention.

At the start of the investigation, the identification key of Lindstedt (1943) was used with the work of Geitler (1932) as a reference manual. In a later stage identifications were also made with the aid of the key by Frémy (1934). As a means of cross- reference, the *Oscillatoriaceae* were always identified with Drouet (1968) too, and in cases of doubt compared with the herbarium material available at the Leiden Rijksherbarium.

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An unsatisfactory element in using the 'classical' works (Geitler 1932, Frémy 1934, Lindstedt 1943) was that the identification result often did not match in the ecological sense, i.e. the name found referred to a species not at all expected in saltmarshes. Furthermore, the differences observed between various field populations were gradual and over a wide range. This supported the view of Drouet (1962, 1963, 1964, 1968) that many taxa given the rank of species by e.g. Geitler (1932) are in fact only ecological variants of one species.

The concepts of Drouet (1968) were nearly always found to be broader than could be concluded from the variation noticed in my saltmarsh material. Some characters given in his key, e.g. the granulation of the cross-walls, were not always usable. Another difficulty in using Drouet (1968) was met in applying his lists of synonyms as an identification or a cross-reference tool. Various reasons to disagree with his synonymy concepts will be mentioned in notes to the diagnoses in the present paper.

In 1972, the findings on the classification of *Oscillatoriaceae* were presented to algology staff and students of the Rijksherbarium and a preliminary key (Polderman 1972) was given to them for testing during their own field investigations (Marchand 1976, Vink 1978, Lavaleye 1978). Later versions were also used by algology students of the Laboratory of Aquatic Ecology at Nijmegen Catholic University (e.g. Op den Buijs 1977). Maas (1977) studied there the variability of the most frequent and abundant saltmarsh *Oscillatoriacea, Microcoleus lyngbyaceus*, both by field measurements and culture experiments in the laboratory.

With a description of the algal vegetation in a saline seepage area near Vlissingen (The Netherlands) my concepts for the identification of *Oscillatoriaceae* were described as partly following Drouet's system, but with several restrictions (Polderman 1974). As a result of this and several later investigations eleven species of *Oscillatoriaceae* were distinguished in saltmarshes along the North Sea, the British Channel, the Irish Sea, and the Atlantic Ocean between Roscoff and Trondheim. The purpose of the following key, with short diagnoses and some critical remarks, is to explain the author's concepts of the classification of *Oscillatoriaceae*, consistently used for several major papers on saltmarsh algae (Polderman 1979a, b).

KEY TO THE SPECIES

Before using this key, it is useful to realise that the species are very variable. Single specimens often lack sufficient characters for an accurate identification, especially loose filaments of *Microcoleus* or *Schizothrix*. It is advisable to base the identification on several specimens and to check the identification with the description.

1a. Trichomes spirally wound. Cross-walls not visible. . . **9. Spirulina subsalsa**
1b. Trichomes generally straight. Cross-walls obvious. 2
2a. Diameter trichomes 1 – 3.5 μm, average in population 1.5 – 3 μm.. . 3
2b. Diameter trichomes minimally 3 μm, average in population over 3.5 μm. 4
3a. Apical cell obtuse to rounded . . . . . **8. Schizothrix calcicola**
3b. Apical cell sharply acute. . . . . **4. Microcoleus tenerrimus**
4a. Diameter trichomes 3 – 7 μm, average in population 4 – 6 μm. . . . 5
4b. Diameter trichomes (5 –)7 – 36 μm or more, average in population over 6 μm. 8

5a. Length-width ratio cells 0.3 – 2.0. Granulation at the cross-walls usually present or apical cell asymmetrically acute. 6
5b. Length-width ratio cells 1 – 4. No concentration of granula at the cross-walls. Apical cells symmetrical. 7
6a. Apical cell asymmetrically acute, if rounded not thickened. Length-width ratio cells 0.3 – 1. . . . . **6. Oscillatoria brevis**
6b. Apical cell widened, obtuse to rounded. Trichomes often aggregated in one sheath. Length-width ratio cells 0.5 – 2.0 . . . **5. Microcoleus vaginatus**
7a. Apical cell symmetrically acute, if rounded not thickened; trichomes aggregated in one sheath. Length-width ratio cells 1 – 4. **2. Microcoleus chthonoplastes**
7b. Apical cell rounded, often with a disciform hyaline structure; trichomes in separate sheaths, or without sheaths. Length-width ratio cells 1 – 2. **10. Symploca atlantica**
8a. Apical cell acute. Length-width ratio cells 0.3 – 1. Trichomes aggregated into one sheath. Diameter trichomes 7 – 11 μm. . . **1. Microcoleus acutirostris**
8b. Apical cell rounded. 9
9a. Length-width ratio cells 0.1 – 1. 10
9b. Length-width ratio cells 1 – 1.5. Sheath usually present around each trichome. Diameter trichomes (6 –)8 – 14 μm. . . . . **11. Symploca fasciculata**
10a. Length-width ratio cells 0.2 – 0.3. Apical cell often deviating from other cells. Diameter trichomes 6 – 36 μm or more. Trichomes sometimes tapering towards the apical cell; without sheaths, with separate sheaths or aggregated into one sheath. . . . . **3. Microcoleus lyngbyaceus**
10b. Length-width ratio cells 0.3 – 1.0. Apical cell rounded usually not deviating from other cells. Diameter trichomes 6 – 12 μm, generally without a sheath. **7. Oscillatoria nigroviridis**

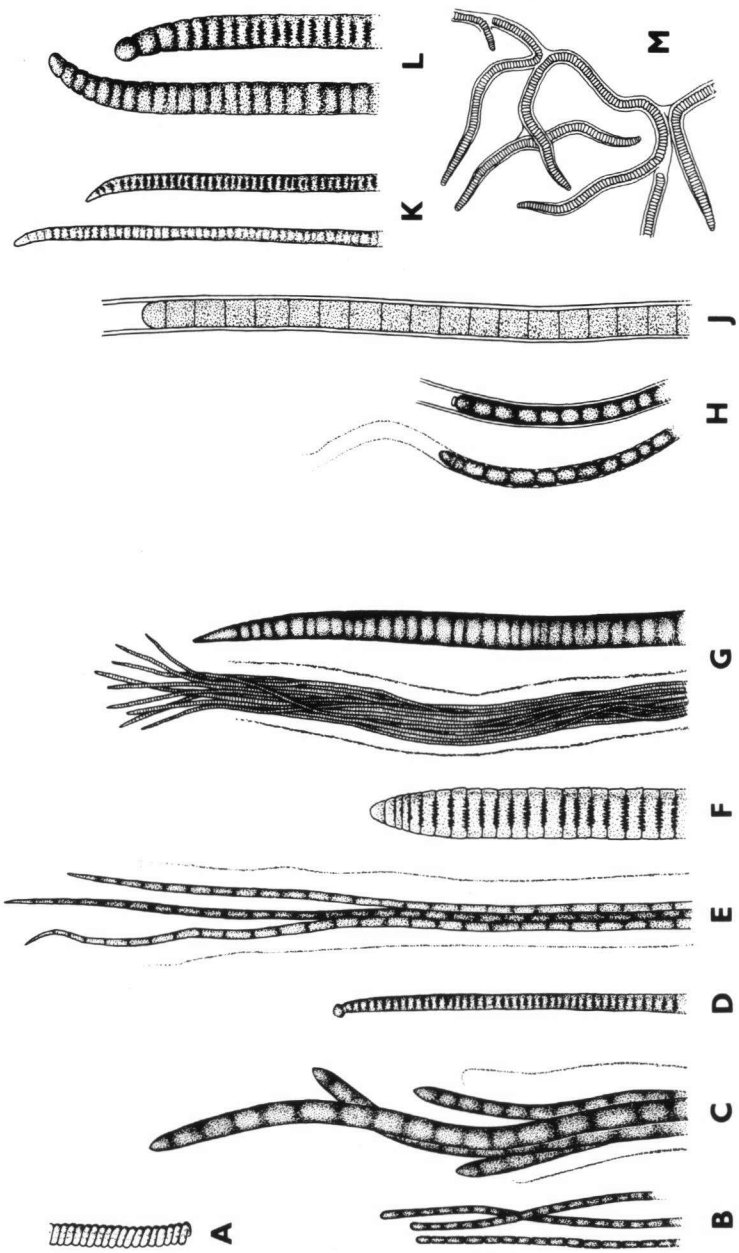
DIAGNOSES

The taxa in the lists of synonyms have been named in accordance with the nomenclature used by Christensen & Thomsen (1974). The latter include author's names of *Oscillatoriaceae* species from before the starting point of algal nomenclature (Gomont 1892 – 1893). In previous papers (Polderman 1974, 1975) the procedure of non-citing the pre-starting point authors was followed. This mode of citation is allowed by the International Code of Botanical Nomenclature (1972) and it is applied in the present paper. Taxa mentioned in the text that are to be interpreted either in the sense of Drouet or Geitler are indicated as such. For the nomenclature of the phanerogamic communities mentioned, refer to Westhoff & Den Held (1969).

1. Microcoleus acutirostris Gomont. – Fig. 1G

Synonym: *Sirocoleum kürzii* (Zell.) Gom. *ex* Gom.

Trichomes 7 – 11 μm wide, greyish to brownish green, tapering towards the tip; in a common sheath from which trichomes are occasionally released. Length-width



Figs. 1 & 2. *Oscillatoriaceae* and one *Scytonematacea* (2M) of Northwest European saltmarshes. – 1A. *Spirulina subsalsa*. – 1B. *Schizothrix calcicola*. – 1C. *Microcoleus chthonoplastes*. – 1D. *Microcoleus vaginatus*. – 1E. *Microcoleus tenerrimus*. – 1F. *Microcoleus lyngbyaceus*. – 1G. *Microcoleus acutirostris*. – 2H. *Symploca atlantica*. – 2J. *Symploca fasciculata*. – 2K. *Oscillatoria brevis*. – 2L. *Oscillatoria nigroviridis*. – 2M. *Plectonema battersii*.

ratio 0.3 – 1 (Carter 1933). Cells homogeneously granulated, but occasionally with granula concentrated at the cross-walls (Frémy 1934). Cross-walls infrequently constricted. Apical cell acute, longer than wide.

N o t e s : Drouet (1968) placed this species in *Porphyrosiphon kürzii* (Zeller) Drouet. Frémy's (1934) descriptions of both *Microcoleus acutirostris* and *Sirocoleum kürzii* conflict with the description of *Porphyrosiphon kürzii* (Zeller) Drouet. According to Drouet (1968), the length-width ratio of *P. kurzii* cells is up to 1/3, whereas measurements found by Carter (1933: fig. 13, 14) and measurements made by the author are up to 1. Frémy (1934) mentioned granulation of the cross-walls for *Sirocoleum kürzii*. The absence of granula at the cross-walls is a generic character of *Porphyrosiphon sensu* Drouet. Sometimes I found a mixture of granulated and non-granulated material.

E c o l o g y: *Microcoleus acutirostris* was collected in South England, Scotland, Norfolk, the Southwest Netherlands, and the Wadden area, mostly in the lower saltmarsh zones in the undergrowth of *Salicornia* and *Spartina*. Most records were made in autumn.

2. Microcoleus chthonoplastes Gomont. – **Fig. 1C**

Trichomes 3 – 6 μm wide, dark green, united in a common sheath; single trichomes observed in preparations, frequently constricted at the cross-walls. Length-width ratio 1 – 4. Granula homogeneously distributed over the cells. Apical cell generally acute.

N o t e s : Drouet (1968) placed *M. chthonoplastes* in *Schizothrix arenaria* (Berk.) Gom., for which species measurements of 1 – 6 μm are given. Though the present author has an insufficient knowledge of the material which led Drouet to include *M. chthonoplastes* in *Schizothrix arenaria*, he prefers the well-known name *Microcoleus chthonoplastes* for reasons of continuity.

E c o l o g y: In Northwest Europe, *M. chthonoplastes* and *M. lyngbyaceus* play an important role in the algal vegetation, particularly in summer. Extensive sheets of *M. chthonoplastes* and *M. lyngbyaceus* replace green algae and *Vaucheria* mats in the *Salicornietum*, *Puccinellion maritimae* and *Armerion maritimae*.

3. Microcoleus lyngbyaceus Gomont. – **Fig. 1F, 3**

Synonyms: *Hydrocoleum lyngbyaceum* Kütz. *ex* Gom.; *Hydrocoleum glutinosum* (C.Ag.) Gom. *ex* Gom.; *Lyngbya confervoides* (C.Ag. *ex* Gom.) Gom.; *Lyngbya majuscula* (Dillw.) Harv. *ex* Gom.; *Lyngbya aestuarii* (Mert. *in* Jürg.) Liebm. *ex* Gom.; *Lyngbya semiplena* (C.Ag.) J.Ag. *ex* Gom.; *Oscillatoria limosa* C.Ag. *ex* Gom.; *Oscillatoria bonnemaisonii* Crouan fr. *ex* Gom.

Trichomes 6 – 36 μm wide, yellow-green, dark green, blue-green to violet, or greyish green; with (*Lyngbya* type) or without a sheath (*Oscillatoria* type), occasionally several united in one sheath (*Microcoleus* type); trichomes sometimes slightly constricted at the cross-walls or tapering towards the tip (Fig. 1F). Cells granulated especially at the cross-walls. Length-width ratio (0.1 –)0.2 – 0.3. Apical cells generally rounded or flat (Fig. 3), hyaline or slightly granulated, but many other forms exist (Maas 1977); length-width ratio 0.2 – 1. Sheath, if present, very distinct, generally 1 – 2 μm thick; but under special circumstances values of 130 μm have been measured (Maas 1977).

Fig. 3. *Microcoleus lyngbyaceus* (× 500), 'Lyngbya'type, in a sample from a *Vaucheria* mat.

N o t e s: Bourrelly (1970) remarked that so far no cultural evidence existed for the origin of a '*Microcoleus*-type' specimen from a '*Lyngbya*-type' specimen. Maas (1977) succeeded in achieving this. His measurements of material show a narrower range of the diameter than the 3.5–80 μm indicated by Drouet (1968) for *Microcoleus lyngbyaceus* (Kütz.) Crouan. For the remainder he could agree with Drouet (1968) in adopting the name *Microcoleus lyngbyaceus*.

E c o l o g y: *Microcoleus lyngbyaceus* has largely the same ecology and distribution as *Microcoleus chthonoplastes*. Some detail differences are mentioned by Polderman (1975).

4. Microcoleus tenerrimus Gomont. – **Fig. 1E**

Trichomes 1.5–3.5 μm wide, greyish green (olive-green according to Frémy (1934)); in a common sheath, but in preparations free trichomes have been observed. Length-width ratio 2–4. Apical cell acuminate, narrowed over the whole length, sometimes with a minute knob at the tip. Not granulated or constricted at the cross-walls.

N o t e s: Drouet (1968) places this species in *Schizothrix tenerrima* (Gom.) Drouet, for which measurements of 1 – 6 μm and frequent constriction at the cross-walls are reported. Because of these differences and for reasons of continuity the name *Microcoleus tenerrimus* is preferred.

E c o l o g y: *M. tenerrimus* is frequent but not commonly abundant in upper saltmarsh habitats at and above the level of the *Armerion maritimae.*

5. Microcoleus vaginatus Gomont. – **Fig. 1D**

Synonyms: *Phormidium autumnale* (C.Ag.) Gom. *ex* Gom.; *Phormidium uncinatum* (C.Ag.) Gom. *ex* Gom.

Trichomes 4 – 7 μm wide, greyish green to blue-green, slightly tapering towards the tip. Apical cell generally widened, obtuse to rounded, and sometimes with minute mucous 'hairs'. Occasionally cells empty and flattened. Length-width ratio cells 0.5 – 2. Cross-walls generally granulated. Sheaths up to 0.5 μm thick. Filaments sometimes entangled into compact threads with sheaths either separate or merged.

N o t e : Kann & Komarek (1970) give more synonyms of *Phormidium autumnale* from freshwater habitats.

E c o l o g y: *M. vaginatus* is a freshwater and terrestrial species, which may extend into saltmarshes to the level of the *Puccinellion maritimae.* A *Microcoleus vaginatus* community was found in most Northwest European saltmarshes in moist *Armerion maritimae* habitats.

6. Oscillatoria brevis Gomont. – **Fig. 2K**

Trichomes 3 – 7 μm wide, grey-green or blue-green, generally constricted at the cross-walls. In the trichomes biconcave empty cells may be present, slightly wider than other cells. Granulation of the cells varies from concentrated at the cross-walls to completely absent. Length-width ratio 0.3 – 1. Well-developed apical cells asymmetrically acute, length-width ratio 1 – 3. In some populations transitions from rounded to sharply acute apical cells are present.

N o t e s: Drouet (1968) considered *Oscillatoria brevis* as the basionym of *Athrospira brevis* (Kütz.) Drouet. Because of differences between his and the above description (e.g. granulation) the name *O. brevis* was preferred.

E c o l o g y: *O. brevis* is widely distributed at all levels in Northwest European saltmarshes, mostly in the role of a companion species.

7. Oscillatoria nigroviridis Gomont. – **Fig. 2L**

Trichomes 6 – 12 μm wide, grey-green or blue-green, sometimes tapering towards the tip, constricted at the cross-walls, which are frequently granulated. Length-width ratio 0.3 – 1. Apical cell rounded. Sheath generally absent, if present very thin.

N o t e s: The material of *Oscillatoria nigroviridis* occurring in Northwest European saltmarshes is quite different from the type material of *Porphyrosiphon*

notarisii (Menegh.) Kütz. *ex* Gom., the taxon Drouet placed it in. This material possesses a typical firm reddish sheath and is not granulated at the cross-walls. *Oscillatoria nigroviridis* has seldom been observed with a sheath (if so then the sheath is very thin). Forms with and without granula at the cross walls have been observed (Lindstedt 1943, Polderman 1974). According to the key by Drouet (1968) granulated forms of *Oscillatoria nigroviridis* (e.g. *O. nigroviridis* Thw. in Harv. *ex* Gom.) should be considered to be forms of his *Microcoleus lyngbyaceus* (Kütz.) Crouan, but the differences between *Oscillatoria nigroviridis* Gomont and *Microcoleus lyngbyaceus* Gomont are numerous (Polderman 1974). Cultivation of *M. lyngbyaceus* by Maas (1977) never indicated any similarity between this species and *O. nigroviridis*.

Ecology: *O. nigroviridis* is abundant in Northwest European saltmarshes, although less than *M. chthonoplastes* and *M. lyngbyaceus*. Polderman (1979 a, b) reckoned *O. nigroviridis* with these two species to be the dominants of one algal community.

8. Schizothrix calcicola Gomont. – **Fig. 1B**

Synonyms: *Phormidium fragile* Gom.; *Phormidium gracile* Gom.; *Phormidium minutum* Lindst.; *Plectonema nostocorum* Born. *ex* Gom.; *Plectonema norvegicum* Gom. *ex* Gom.; *Lyngbya infixa* Frémy; *Schizothrix vaginata* (Näg. *ex* Gom.) Gom.

Trichomes 1 – 3.5 μm wide, generally greyish green but other colours observed in culture. Length-width ratio 0.25 – 4. Cross-walls not granulated. Apical cell obtuse to rounded. Trichomes with or without separate sheath, or occurring in a common sheath.

Notes: The measurements found approximate those given by Drouet (0.2 – 3.5 μm), who also mentioned other characters (e.g. spiralization) that were not observed. The culture experiments by Stam & Holleman (1975), with strains identified by Dr. F. Drouet personally, indicated the possibility that certain strains from freshwater habitats should be considered separate species from strains originating from marine habitats, which appeared to be genuine *Schizothrix calcicola sensu* Drouet.

In my studies, one species was explicitly excluded from the synonymy with *Schizothrix calcicola*, viz. *Plectonema battersii* Gomont (Fig. 2M). In saltmarshes, *P. battersii* occurs frequently as an epiphyte on decaying phanerogams and on larger algae especially. Parke & Dixon (1976) classified *P. battersii* into the *Scytonemataceae*, but in 1976 they withdrew this opinion in favour of Drouet's system. An important difference between *P. battersii* and the taxa classified into *Schizothrix calcicola* as in the present paper is in the tapering of the trichome towards the apex in *P. battersii*. Stam & Holleman (pers. comm.) never observed tapering trichomes in their cultures of strains of several *Phormidium*, *Plectonema*, and *Lyngbya* taxa. The mode of growth of *Plectonema battersii*, being partly prostrate partly erect, is rather alien to that of other *Oscillatoriaceae* and resembles more the *Scytonemataceae*. For this reason, the opinion expressed in an earlier paper (Polderman 1975), that *P. battersii* is a separate species in the *Scytonemataceae*, is maintained, contrary to the concept of Drouet.

Ecology: Small quantities of *S. calcicola* were found in each habitat in the Northwest European saltmarshes visited. Large quantities of *S. calcicola* were

reported by Nienhuis (1970) and Polderman (1975) at various levels in the saltmarsh. Algal mats with *S. calcicola* as a single dominant as found with, for example *M. lyngbyaceus* or *S. atlantica*, were not observed.

9. Spirulina subsalsa Gomont. – **Fig. 1A**

Synonyms: *Spirulina subtilissima* Kütz. *ex* Gom., *Spirulina major* (Kütz. *ex* Gom.) Gom.

Trichomes spirally wound, 1 – 2 μm wide, blue-green or greyish green. Cross-walls not visible. Spiral 1.5 – 5 μm wide. Despiralization (Drouet 1968), or other colours (Lindstedt 1943) were not observed.

N o t e s : *Spirulina subsalsa* according to this description fits within *Spirulina subsalsa sensu* Drouet 1968. The latter concept is broader, e.g. the trichome measurements by Drouet range from 0.4 – 4 μm.

E c o l o g y: *S. subsalsa* is widely distributed in Northwest European saltmarshes as a companion species in mats of *Vaucheria*, filamentous green algae, or other *Oscillatoriaceae*. Masses of *Spirulina subsalsa* were observed among *Ruppia* in the brackish waters of 'De Bol', Texel (The Netherlands).

10. Symploca atlantica Gomont. – **Fig. 2H**

Synonyms: *Symploca funicularis* Setch. & Gardn.; *Phormidium corium* (C.Ag.) Gom. *ex* Gom.; *Phormidium molle* Kütz. *ex* Gom.; *Lyngbya lutea* (C.Ag.) Gom. *ex* Gom.

Trichomes 3 – 6 μm wide, greyish green to dark green, generally each in one sheath; sometimes constricted at the cross-walls. Cells homogeneously granulated or not granulated. Length-width ratio 1 – 2. Apical cell rounded to slightly obtuse, often with a disciform hyaline structure at the tip. Filaments sometimes tangled into thick erect threads in which each trichome keeps its own sheath.

N o t e s : Drouet (1968) placed *Symploca atlantica* in *Oscillatoria submembranacea* Ardiss *et* Straff. *ex* Gom. The last-mentioned taxon does not include all species considered as synonyms of *Symploca atlantica* by the present author. Drouet classified *Phormidium corium* into *Schizothrix rubella* Gom., *Phormidium molle* in *Schizothrix friesii* (C.Ag.) Gom.; and *Lyngbya lutea* was the basionym of his *Oscillatoria lutea* C.Ag. In studying material from Northwest European saltmarshes so many transitional stages between specimens that would have been classified into these taxa and *Symploca atlantica* have been found that synonymy is likely. Culture experiments will have to confirm or reject this hypothesis.

E c o l o g y: *Symploca atlantica* occurs in all Northwest European saltmarshes. A *S. atlantica* community plays an important role in the undergrowth of *Armerion* and *Halimione portulacoides* vegetation and on vertical creek-walls.

11. Symploca fasciculata Gomont. – **Fig. 2J**

Synonyms: *Symploca hydnoides* Kütz. *ex* Gom. *sensu auctores typo excludendo.*

Trichomes (6 –)8 – 14 μm wide, greyish green to blue-green, not constricted at the cross-walls; in a distinct sheath approximately 2 μm thick. Cells homogeneously granulated; length-width ratio 1 – 1.5. Apical cell rounded.

N o t e s : According to Drouet (1968), who classified this species into *Schizothrix mexicana* Gom., *Symploca hydnoides* is a *nomen excludendum* (= *Calothrix crustacea* Born. *et* Flah.).* For this reason, the name *S. fasciculata* was chosen instead of the more commonly used name *S. hydnoides*.

E c o l o g y: Records of *S. fasciculata* were confined to the southern part of the area investigated (France, Norfolk, and Hampshire in England). It occurs mainly in the *Halimionetum portulacoidis* and on creek-walls.

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* Frémy (1934) distinguished a *S. hydnoides* f. *fasciculata* with a description similar to the above one.

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