

Morphology of *Zosterocarpus ogasawaraensis* sp. nov. (Phaeophyceae, Ochrophyta), a New Marine Deep-water Brown Alga from the Ogasawara Islands, Japan

Taiju Kitayama

Department of Botany, National Museum of Nature and Science,
Amakubo 4–1–1, Tsukuba, Ibaraki 305–0005, Japan
E-mail: kitayama@kahaku.go.jp

(Received 23 August 2013; accepted 2 October 2013)

Abstract A new brown alga, *Zosterocarpus ogasawaraensis* sp. nov. (Phaeophyceae, Ochrophyta) was collected from the deep water (73–82 m in depth) off Haha-jima Island, Ogasawara Islands, Japan. This is the first record of the deep-water brown algal genus *Zosterocarpus* from the North Pacific Ocean. This genus differs from all other phaeophycean members in having uniseriate filaments formed by intercalary meristems and plurilocular sporangia formed peripherally by longitudinal cell division on the surface of parental cells. This new species from Ogasawara Islands is distinguishable from the other species of the genus in having laterals with a rounded apex and a quite clear meristematic zone and in lacking swollen tannin-filled cells.

Key words : brown algae, Japan, Ogasawara Islands, Phaeophyceae, *Zosterocarpus ogasawaraensis*.

Introduction

There is only a few record of the marine deep-water brown algal genus *Zosterocarpus* (Phaeophyceae, Ochrophyta) from outside of the Mediterranean Sea. This genus was established by Bornet (1890) on the basis of *Z. oedogonium* (Meneghini ex Kützing) Bornet collected from the Adriatic Sea (inside the Mediterranean Sea) and was defined the features of the genus as branched uniseriate thalli formed by diffuse intercalary growth zones or meristems, outward plurilocular sporangia formed by peripheral divisions of cells of the laterals, and enlarged tannin-filled cells scattered and intercalary in laterals (Bornet, 1890; Fritsch, 1945; Hamel, 1931; Berecibar *et al.*, 2009; Guiry and Guiry, 2013). After fifty five years the second species for the genus, *Z. abyssicola* W.R.Taylor, was described from the Santa Maria Isl., the Galapagos Islands in the South Pacific Ocean (Taylor, 1945) and after forty two years further the third species, *Z. australicus* Womers-

ley was described from the Investigator Straits, off Adelaide, the southern Australia in the Indian Ocean (Womersley, 1987). Recently the type species, *Z. oedogonium*, was recorded from Berengas Archipelago in the Atlantic Ocean (Berecibar *et al.*, 2009), though there are no subsequent reports on the other two species. The genus has not previously been reported from the North Pacific Ocean. In consequence of the difficulty in collecting algal samples from a deep-water floor, the taxonomic position of the genus is still unclear.

Recently, as part of review of geographical change in the Japanese marine benthic algal flora, the author is investigating deep-water algal habitats around the Ogasawara Islands, where a notably rare brown alga, *Discosporangium mesarthrocarpum* (Meneghini) Hauck (Discosporangiales), is also distributed (Kitayama, 2012). In this study, to confirm identity of a species of *Zosterocarpus* collected from Hahajima Island, one of the Ogasawara Islands, the author

made anatomical observations on the alga using a microscope.

Material and Methods

The brown algal material referable to the genus *Zosterocarpus* was collected from the deep water (73–82 m in depth) off Hahajima Island in the Ogasawara archipelago (= Bonin Islands), Japan by dredge using the research vessel, the *Koyo* (87 tonnage), operated by the Ogasawara Fisheries Center, Tokyo Metropolitan. For preservation, the material was dried on sheets of paper or fixed in 10% Formalin-seawater. Anatomical observations were made on the material using a microscope. Voucher specimens were deposited in the algal herbarium of the National Museum of Nature and Science (TNS).

Results

Zosterocarpus ogasawaraensis Kitayama sp. nov. [Figs. 1–24]

Description: Thalli erect, up to 2.5 cm high, densely tufted, filamentous, brown in colour. Filaments uniseriate, 15–20 μm in diameter, branched alternately or laterally, lacking a swollen tannin-filled cell and a phaeophyceyan hair. Laterals

straight, arisen from a single cell of the parent axes, with an intercalary meristem at the base. Cells cylindrical, 14–78 μm long in the middle portion. Apical cells cylindrical or globose, 10–12 μm in diameter, obtuse or rounded at the apex. Haptera forked. Plastids numerous, discoid, without pyrenoids. Plurilocular sporangia peripheral, crustose on the vegetative filaments.

Holotype: TNS-AL 181520 (Fig. 1) deposited in TNS (National Museum of Nature and Science, Tsukuba, Japan), 5 July 2010, leg. T. Kitayama.

Type locality: Subtidal from 73 m to 82 m in depth, off Hahajima Island, Ogasawara Islands, Japan (26°44'08–15"N, 142°06'00–21"E).

Etymology: The species epithet 'ogasawaraensis' is from the Japanese name of the islands (= the Bonin Islands).

Japanese name: Rahotsu-midoro (nom. nov.).

Habitat: Growing on or entangled with dead coral or other benthic algae.

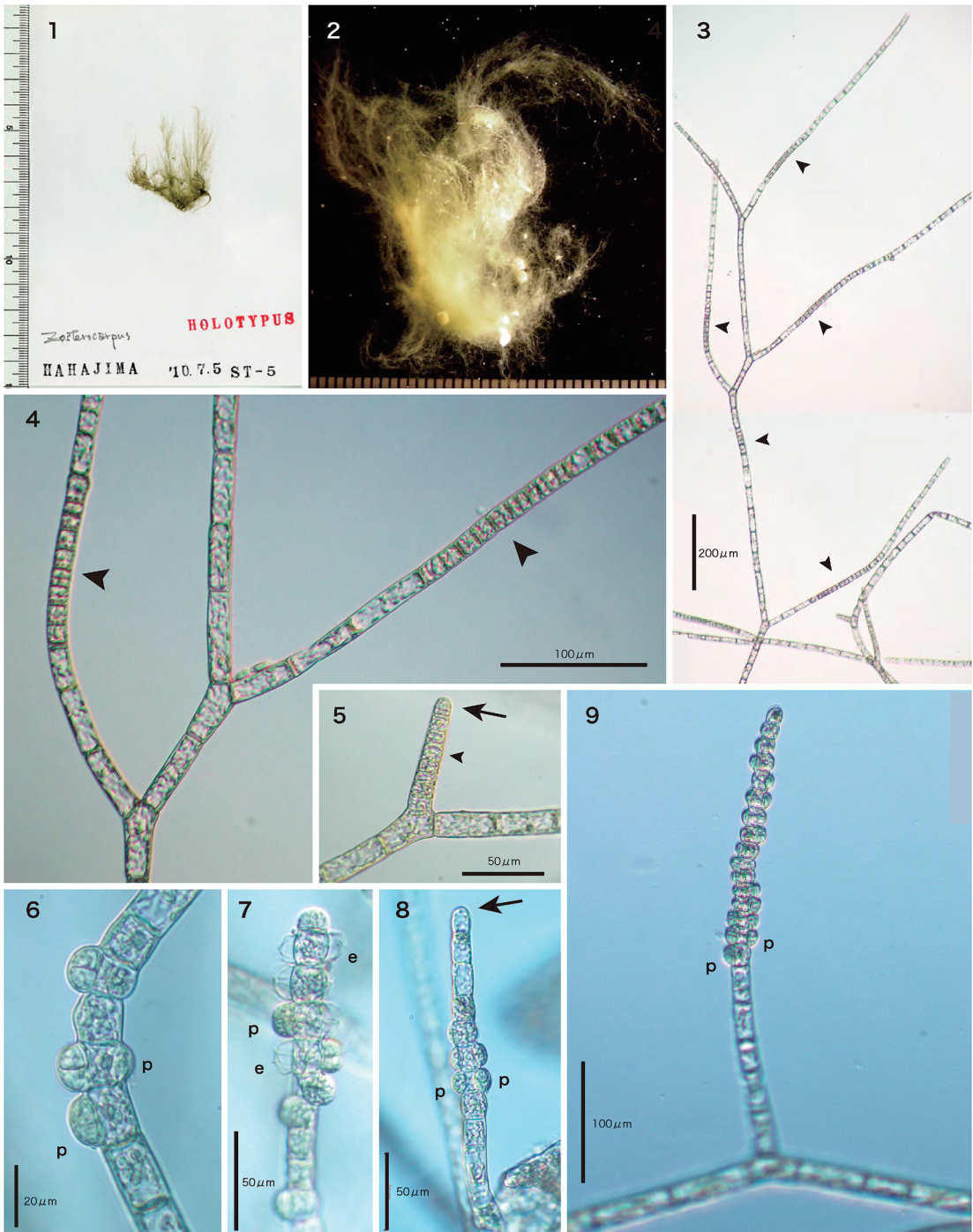
Vegetative morphology: Thalli are erect, up to 2.5 cm in height, densely tufted, composed of numerous filaments, medium brown in colour, epilithic, attached to rocks or entangled with grains of dead coral (Figs. 1, 2) by rhizoidal holdfasts. The filaments are uniseriate, 15–20 μm in diameter in the middle portion, branched alter-

Table 1. Comparisons of habit and morphology among *Zosterocarpus ogasawaraensis* and other species of the genus in the world

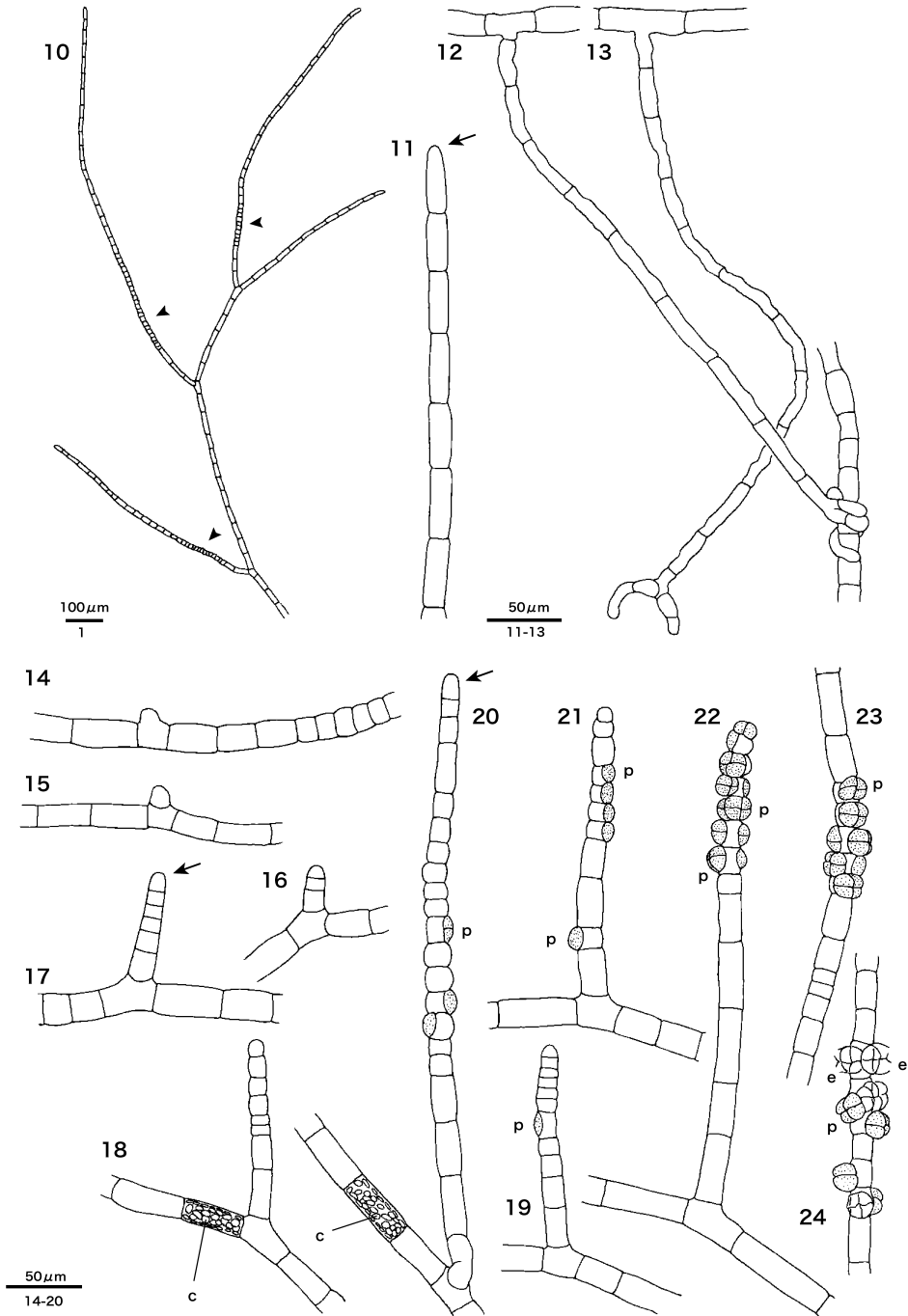
	<i>Z. ogasawaraensis</i> (The present study)	<i>Z. australicus</i> (Womersley, 1987)	<i>Z. abyssicola</i> (Taylor, 1945)	<i>Z. oedogonium</i> (Bornet, 1890, Hamel, 1931, Berecibar <i>et al.</i> , 2009)
Height of thalli	up to 2.5 cm	1–2 cm	1–2 cm	2–3 cm
Diameter of filaments				
Main portion	15–20 μm	20–25 μm	up to 32 μm	up to 45 μm
Terminal portion	10–12 μm	7–9 μm	11–16 μm	up to 17 μm
Length of vegetative cells	14–78 μm	20–75 μm *	58–65 μm	up to 65 μm
Basal cells of laterals	situated on the single cell of the parent axis	situated on the single cell of the parent axis	situated on the septum of 1–3 cells of the parent axis	situated on the septum of two cells of the parent axis
Apical cells	obtuse	acute	acute	acute
Intercalary meristematic zones	clear, situated near the base of the lateral	diffuse, occurred irregularly	diffuse, occurred irregularly	diffuse, occurred irregularly
Swollen tannin-filled cells	absent	absent	present**	present
Depth of habitat	73–82 m	31–41 m	55 m	20–70 m
Distribution	the North Pacific (Ogasawara Isls.)	the Indian Ocean (S. Australia)	the South Pacific (Galapagos Isls.)	the Mediterranean Sea (France, Italy, Spain, etc.), the North Atlantic (Berlengas Archipelago)

* Calculated using the "L/B" ratio showed in Womersley (1987, p. 36).

** Taylor (1945, p. 79) considered the swollen tannin-filled cells as "sporangia".



Figs. 1–9. *Zosterocarpus ogasawaraensis* sp. nov. from Ogasawara Islands, Japan. 1. Habit showing a thallus (Holotype: a dried specimen, TNS-AL 181520). 2. Habit showing tufts of erect filaments. 3. Erect filaments with several intercalary meristems (arrowheads). 4. Intercalary meristems (arrowheads). 5. Young lateral showing a intercalary meristem (arrowhead) and rounded apex of apical cell (arrow). 6–9. Plurilocular sporangia (p). 6. Young plurilocular sporangia. 7. Mature plurilocular sporangia and empty sporangia (e). 8. Young plurilocular sporangia on a lateral with an obtuse apical cell (arrow). 9. Lateral covered by many plurilocular sporangia showing a rounded apex.



Figs. 10–24. *Zosterocarpus ogasawaraensis* sp. nov. from Ogasawara Islands, Japan. 10. Erect filaments with several intercalary meristems (arrowheads). 11. Terminal portion of erect filament showing a rounded apical cell (arrow). 12, 13. Holdfasts with a forked hapteron. 14–18. Various stages of young laterals showing a rounded apical cell (arrow) (c: chloroplast). 19–22. Various stages of pulvilocular sporangia (p) on laterals showing discoïd chloroplasts (c). 19–21. Young plurilocular sporangia on laterals. 22. Lateral covered by many mature plurilocular sporangia. 23. Mature plurilocular sporangia in cluster on an erect filament. 24. Empty plurilocular sporangia (e) and mature plurilocular sporangia (p) in cluster on an erect filament.

nately or laterally, lacking a swollen tannin-filled cell (Fig. 3). Laterals are straight with a quite clear intercalary meristematic zone (growth zone) near the base (Figs. 3–5, 10, arrowheads). Each lateral is arisen from the single cell of the parent filaments at wide angle (Figs. 4, 5, 14–17), often appearing perpendicular to the cell (Figs. 9, 14–22). Cells of the erect filaments are cylindrical, 14–78 μm in length in the middle portion. Apical cells of the main erect filaments are cylindrical or globose, 10–12 μm in diameter, obtuse or rounded at the apex (Figs. 5, 8, 11, 17, 20, arrows). Holdfasts are elongate, cylindrical, rhizoidal, possessing a forked hapteron (Figs. 12–13). Plastids are numerous per cell, disc-shaped, round to ellipsoidal, 2–4 μm in diameter, without pyrenoids (Figs. 18, 20).

Reproductive morphology: Plurilocular sporangia are formed by longitudinal cell division peripherally on the surface of parent filaments (Fig. 6) and short laterals (Figs. 7–9, 19–22). Mature or empty sporangia usually composed of 4 locules (Figs. 7, 22–24). Locules are 6–9 μm in width (Figs. 7, 24). Formation of the plurilocular sporangia occurs in a cluster, resulting in crustose sori covering the filaments and laterals (Figs. 7–9, 22).

The specific characters that distinguished *Z. ogasawaraensis* from other members of the genus are shown in Table 1. *Z. ogasawaraensis* agrees well with *Z. australicus*, except for shape of apical cells on the terminal portion of vegetative filaments and form of intercalary meristematic zones. The apical cells are acute (angular) in the known species of the genus, while obtuse (rounded) only in *Z. ogasawaraensis*. The meristematic zones are quite clear and situated on the base of the laterals, while unclear and diffuse in other species.

Discussion

The new brown alga from the Ogasawara Islands, *Zosterocarpus ogasawaraensis*, possesses several characteristics of the genus *Zosterocarpus*: the branched uniseriate filamentous thalli, the

diffused intercalary meristematic zones in the vegetative erect filaments, external plurilocular sporangia formed peripherally on the filaments. However, *Z. ogasawaraensis* has no swollen tannin-filled cell, which is also a significant generic feature of *Zosterocarpus* derived from the type species, *Z. oedogonium*. According to Womersley (1987, p. 36), *Z. australicus*, which has been recorded only from the southern Australia since the original description, also does not have “the occasional swollen cells heavily packed with physodes”. He did not regard “tannin cells” or the swollen tannin-filled cells as indispensable to this genus because his species, *Z. australicus* has “numerous centrally aggregated physodes” in each cell of the erect filaments. In *Z. ogasawaraensis* the author could not observe such a structure in any cells. On the other hand, *Z. abyssicola* from Galapagos Isls. has the swollen tannin-filled cells as *Z. oedogonium* does, though Taylor (1945) considered these swollen cells as “sporangia”. In addition, in both *Z. ogasawaraensis* and *Z. australicus* laterals are always arising from the single cell of the filaments, while in *Z. oedogonium* and *Z. abyssicola* basal cells of the laterals are situated on the septum of the two or three cells of the parent filaments (Table 1). Fritsch (1945, p. 55) noted that “The genus is distinguished by the position of the laterals opposite the septa and the presence of enlarged fucosan-cells with greyish contents.”

These features suggest that *Z. oedogonium* and *Z. abyssicola* are closely related to each other and form the genus *Zosterocarpus* sensu stricto, while *Z. ogasawaraensis* and *Z. australicus* have a possibility of belonging to any other new taxon in generic rank outside *Zosterocarpus*. It may be possible, for instance, that *Z. ogasawaraensis* may relate to the deep-water algal genus *Discosporangium* (Discosporangiales), which has also uniseriate filaments with round apical cells, unique plurilocular sporangia and plastids without pyrenoids, though *Discosporangium* has no meristematic zone (Kitayama, 2012).

Bornet (1890), Funk (1955) and Pedersen (1984) placed this genus under the Tilopteridales because

of that weakly developed parenchyma and absence of phaeophycean hairs in *Z. oedogonium* and *Z. abyssicola*. However, Fritsch (1945, p. 55) placed *Z. oedogonium* under the Ectocarpales, not the Tilopteridales with some doubt and then most of the algologists followed the Fritsch's treatment (e.g., Papenfuss, 1951; Wynne, 1982; Womersley, 1987; Berecibar *et al.*, 2009). In the recent emendation of circumscription of the order Ectocarpales by Rousseau and de Reviers (1999), however, the order was redefined to include only taxa possessing an exserted, pedunculated pyrenoid. Thus it is difficult to place the genus *Zosterocarpus*, which has no pyrenoid, under the Ectocarpales.

Because of insufficiency of information on this deep-water algal genus, which is not easy to collect for the present, the taxonomic position of the genus *Zosterocarpus* is unsolved (Berecibar *et al.*, 2009) and the definition of the genus is unstable. Therefore the author places tentatively the new species from Ogasawara Islands under the genus *Zosterocarpus* with *Z. australicus*. To clarify the relationship among the *Z. ogasawaraensis* and other species of the genus *Zosterocarpus*, molecular analyses are required.

Acknowledgments

I am grateful to Mr. Yuji Aoki, director of the Ogasawara Fisheries Center, Tokyo Metropolitan, and the crew of the research vessel, *Koyo*, for providing me the facilities to processing the specimens. I thank Drs. Toshihiko Fujita, Kazunori Hasegawa, Hironori Komatsu, Department of Zoology, National Museum of Nature and Science for their kind help in the field study in the island. This study was undertaken as a part of the surveys of the flora of Izu and Ogasawara archipelagoes, Japan during 2006–2010, entitled "Study on Environmental Changes in the Sagami Sea and Adjacent Area with Time Serial Comparison of Fauna and Flora." A part of this study was supported by Grants-in-Aid for Scientific Research

(no. 25440225) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

- Berecibar, E., Wynne, M. J. and Santos, R. 2009. Report of the brown alga *Zosterocarpus oedogonium* (Ectocarpales) from Portugal, its first recorded occurrence outside of the Mediterranean Sea. *Nova Hedwigia* 89: 237–244.
- Bornet, É. 1890. Note sur deux algues de la Méditerranée: *Fauchea* et *Zosterocarpus*. *Bulletin de la Société Botanique de France* 37: 139–148, 5 figs, 1 plate.
- Fritsch, F. E. 1945. *The Structure and Reproduction of the Algae*, Vol. 2. Foreword, Phaeophyceae, Rhodophyceae, Myxophyceae. Cambridge University Press, Cambridge, 939 pp.
- Funk, G. 1955. Beiträge zur Kenntnis der Meeresalgen von Neapel. Zugleich Mikrophotographischer Atlas. *Pubblicazioni della Stazione Zoologica de Napoli* 25 (Suppl.): i–x, 1–178, 36 figs.
- Guiry, M. D. and Guiry, G. M. 2013. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>; searched on 8 August 2013.
- Hamel, G. 1931. *Phéophycées de France*. Fasc. I. Paris. pp. 1–80.
- Kitayama, T. 2012. First record of *Discosporangium mesarthrocarpum* (Meneghini) Hauck (Phaeophyceae, Ochrophyta) from the Ogasawara Islands, Japan. *Bulletin of the National Museum of Nature and Science, Series B*, 38: 147–152.
- Papenfuss, G. F. 1951. Phaeophyta. In: Smith, G. M. (ed.), *Manual of Phycology*. pp. 119–158. *Chronica Botanica*, Waltham, MA.
- Pedersen, P. M. 1984. Studies on primitive brown algae (Fucophyceae). *Opera Botanica* 74: 1–76, 40 figs.
- Rousseau, F. and de Reviers, B. 1999. Circumscription of the order Ectocarpales (Phaeophyceae): bibliographical synthesis and molecular evidence. *Cryptogamie, Algologie* 20: 5–18.
- Taylor, W. R. 1945. Pacific marine algae of the Allan Hancock Expeditions to the Galapagos Islands. *Allan Hancock Pacific Expeditions* 12: 1–316.
- Womersley, H. B. S. 1987. *The Marine Benthic Flora of Southern Australia*. Part II. South Australian Government Printing Division, Adelaide, 484 pp.
- Wynne, M. J. 1982. Phaeophyceae. In: Parker, S. P. (ed.), *Synopsis and classification of living organisms* 1: 115–125, pls. 15 & 16. McGraw-Hill Book Co., New York.