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Notes on the Marine Algae of the Bermudas. 10. *Woelkerlingia sterreri* sp. nov. (Rhodophyta, Wrangeliaceae), a First Record of the Genus in the Western Atlantic

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ABSTRACT.—A new species of the red algal genus *Woelkerlingia*, *W. sterreri* C. W. Schneid. & M. J. Wynne, is described from a single collection made in Bermuda. The collection contained male and female (dioecious) individuals as well as tetrasporangia and polysporangia on sporophytes. The Bermudian species is compared with and distinguished from *W. minuta* of the Mediterreanean Sea, up to now the only other species recognized in the genus, as well as other members of the Spermothamnieae. *Tiffaniella gorgonea* is excluded from the flora of Bermuda after looking at Collins and Hervey material on which the historic record was solely based.

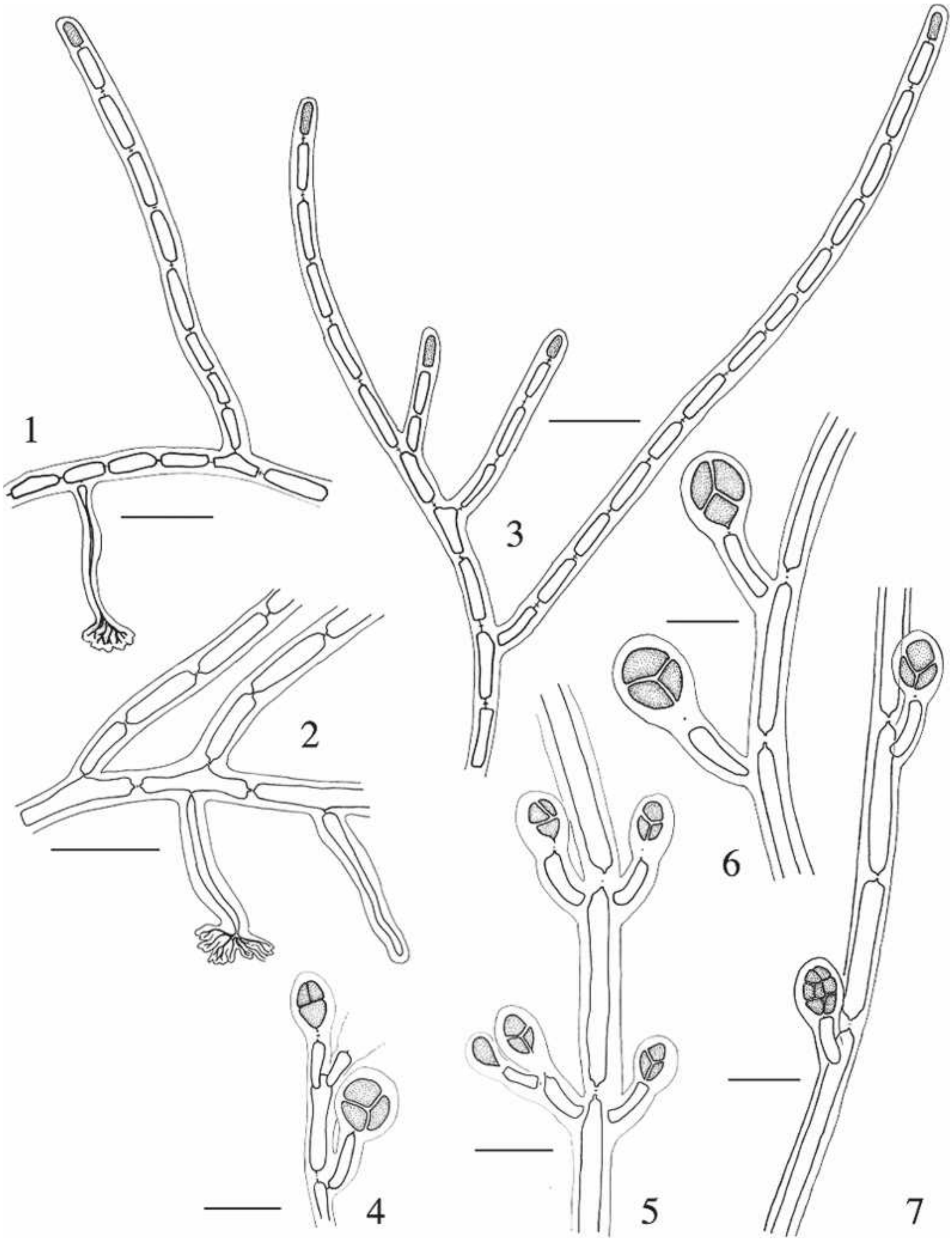
INTRODUCTION

A total of 12 species assigned to the tribe Spermothamnieae (family Wrangeliaceae [Choi et al., 2008]) are currently recognized as occurring in the tropical-subtropical western Atlantic Ocean (Wynne, 2005): six species of *Spermothamnion*, three of *Tiffaniella*, two of *Ptilothamnion*, and a single species of *Lejolisia*, namely, *L. exposita* C.W. Schneid. & Searles (in Searles and Schneider, 1989). Díaz-Pulido and Bula-Meyer (1997) reported *L. mediterranea* Bornet from the Caribbean with "*cf.*" due to their tentative assignment. The two western Atlantic species of *Ptilothamnion* include *P. occidentale* Searles in Searles & Schneider (1989), with a type locality of Gray's Reef, Georgia, and *P. speluncarum* (Collins & Herv.) D. L. Ballant. & M. J. Wynne (1998), based on *Rhodochorton speluncarum* Collins & Herv., with a type locality from Bermuda (Collins and Hervey, 1917). Of that dozen species of Spermothamnieae, four species are known to be present in the Bermudas (Schneider, 2003). These include the above-mentioned *Ptilothamnion speluncarum*, *Spermothamnion investiens* (P. Crouan & H. Crouan) Vickers, *S. macromeres* Collins & Herv., and *Tiffaniella gorgonea* (Mont.) Doty & Meñez.

Annual collections in Bermuda continue to turn up additions to the published list of species of red, green, and brown benthic algae for these western Atlantic islands (Schneider, 2003, 2004; Schneider and Lane, 2005, 2007; Saunders et al., 2006; Schneider et al., 2006). In this paper, a new species in the red algal family Wrangeliaceae, tribus Spermothamnieae, is described. Male and female gametophytes allowed for the placement of the new endemic species in the presently monotypic genus *Woelkerlingia* Alongi, Cormaci & G. Furnari, previously known only from the type species, *W. minuta* Alongi, Cormaci & G. Furnari, in the Mediterranean Sea (Alongi et al., 2007).

MATERIALS AND METHODS

The site location was taken using a Garmin™ GPS III Plus (Olathe, Kansas, USA). Specimens were liquid-preserved in 4-5% Formalin-sea water and then mounted in 20% Karo™ corn syrup, 1% aniline blue and 1N HCl in a ratio of 97:1:2 on glass microscope slides. A small amount of material was removed from historic dried herbarium specimens, and soaked in 10% HCl for one hour before teasing apart and



FIGS. 1-7. *Woelkerlingia sterreri* sp. nov. [*CWS/CEL* 03-52-4]. 1. Habit of erect filament with unilateral branchlets. Scale bar = 100 μm. 2. Prostrate axis with rhizoid and erect filament. Scale = 100 μm. 3. Prostrate axis with rhizoids and erect filaments. Scale bar = 50 μm. 4-7. Erect filaments bearing tetrasporangia and polysporangia. Scale bars = 25 μm.

mounting as above. Drawings were made using a Zeiss camera lucida and from photomicrographs taken using a Carl Zeiss Axioskop 40 microscope (Oberkochen, Germany) equipped with a model 11.2 Spot InSight 2 digital camera (Diagnostic Instruments, Sterling Heights, Michigan, USA). Scanned digital images were composed in Photoshop™ 7.0 (Adobe Systems, San Jose, California, USA). The holotype of the new species was deposited in MICH. Herbarium abbreviations follow Holmgren et al. (1990) and standard author initials are from Brummitt and Powell (1992).

RESULTS

Woelkerlingia sterreri C. W. Schneid. et M. J. Wynne, sp. nov. (Figs 1-12)

Plantae decumbentes et erectae, axes prostrati ramos erectos prodientes ad 2-3 mm alto in medianis positionibus in superficiebus cellularum axialium, et a rhizoideis unicellularibus cum hapteris digitatis affixae a paginis ventralibus eadem cellularum in medio prodientibus; cellulae prostratae axiales 24-34 µm diametro et 30-106 µm longitudine; axes erecti simplices vel parce, unilaterales et irregulariter ramosi, rami a extremis distalibus cellulae ferentium prodientes; axes erecti cellulae 17-24 µm diametro et 65-100 (-120) µm longitudine compositi, idem diametri a base ad apici; cellulae apicales saepe densae impletae; sporangia terminalia in opposititer ad irregulariter producientibus unicellularis (ad bicellularis) ramis lateralibus in extremis distalibus cellulae erectae axialis; rami sporangiferi in positionibus medianis axium erectum; sporangia tetrahedrice divisa vel ulteriora divisa in 8-16 sporas; sporangia obovoidea globosis, 24-43 µm diametro; gametophytae dioeciae, spermatangia in capitulis compactis in ramis erectis terminaliter portata; filum fertile femineum in ramo erecto terminale, ramo subtento postea superatum; filamenta fertila feminea duarum vel trium cellularum composita, cellula basalis ramum carpogonialem et cellulas consociatas ferens; carposporophyta ignota.

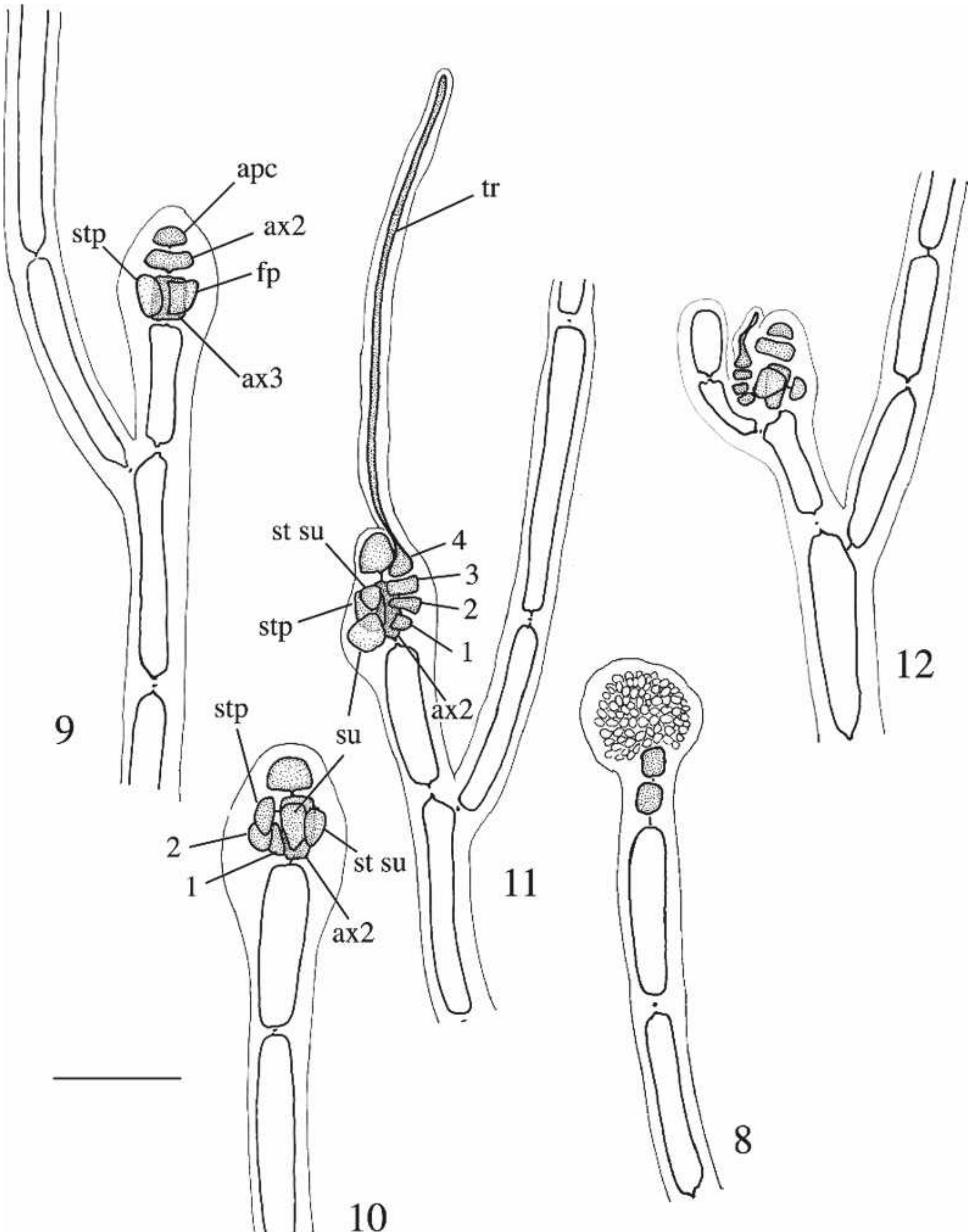
Description.—Plants decumbent and erect, prostrate axes producing erect branches to 2-3 mm tall from median positions on dorsal surfaces of axial cells, and attaching by unicellular rhizoids with digitate haptera issuing centrally from the ventral surfaces of the same cells (Figs 1, 2); prostrate axial cells 24-34 µm diam. and 30-106 µm long; erect axes simple to sparingly, unilaterally and irregularly branched, branches arising from the distal ends of bearing cells (Figs 1, 3); erect axes composed of cells 17-24 µm diam. and 65-100 (-120) µm long, of same diameter from base to apex; apical cells often cytoplasmically dense; sporangia terminal on 1(-2)-celled, oppositely to irregularly produced lateral branches on distal ends of erect axial cells; sporangial branches in median portions of erect axes; sporangia tetrahedrally divided (Figs 4-7) or further dividing into 8-16 spores (Fig. 7); sporangia obovoid to globose, 24-43 µm in diameter; gametophytes dioecious, spermatangia borne terminally in compact heads on erect branches (Fig. 8); female fertile filament terminal on an erect branch, later overtopped by a subtending branch (Figs 9, 11); female fertile filaments comprised of 2 or 3 cells, the basal cell bearing the carpogonial branch and affiliated cells (Figs 9-12); carposporophytes unknown.

Holotype.—*C.W. Schneider/C.E. Lane* 03-52-4, male, female, ⊕, 8.x.2003, Tobacco Bay, St George's Island, Bermuda, western Atlantic, 32° 23.333'N, 64° 40.733'W, on a discarded piece of nylon rope from 3 m [deposited in MICH; Isotypes CAT, MSM, NY, US, Herb. CWS].

Etymology.—Named for Dr. Wolfgang Sterrer, former director of the Bermuda Natural History Museum, an exceptional marine zoologist who initiated and continues to manage the Bermuda Biodiversity Project. He has greatly enabled our marine activities in Bermuda and we honor him here.

DISCUSSION

In a recent paper by Alongi et al. (2007), generic limits within the tribe Spermothamnieae were examined and refined, with the result that two species that had been assigned to *Lomathamnion* Gordon (1972) were assigned to newly designated genera. *Lomathamnion capense* Stegenga (1984) from southern Africa became the ba-



FIGS. 8-12. *Woelkerlingia sterreri* sp. nov. [*CWS/CEL* 03-52-4, holotype]. Scale bar (all figs) = 25 μm. 8. Terminal spermatangial sorus. 9. Early development of three-celled fertile female filament, subtending branch. 10. Early development of two-celled fertile female filament, subtending branch. 11. Mature female gametophyte and associated cells on two-celled fertile female filament. 12. Female gametophyte and associated cells on three-celled fertile female filament, with formation of subtending branch. Legend: apc = apical cell of fertile female filament; ax2, ax3 = subapical axial cells; fp = fertile periaxial cell (becomes supporting cell); stp = sterile periaxial cell; st su = sterile cell on supporting cell; su = supporting cell; tr = trichogyne; 1, 2, 3, 4 = cells of the carpogonial branch.

sis of the monotypic segregate genus *Stegengaea* Alongi, Cormaci & G. Furnari, and *L. humile* (Kütz.) Stegenga (1989), also from southern Africa, became the basis of a second monotypic segregate genus, *Hommersandiella* Alongi, Cormaci & G. Furnari. In addition, Alongi et al. (2007) recognized a new genus and species within this tribe, namely, *Woelkerlingia minuta,* from a site off Sicily in the Mediterranean Sea. The most critical criteria for generic separation include the number of cells in the fertile female filament. In *Woelkerlingia* and *Hommersandiella,* the fertile female filament consists of only two cells (apical and subapical), and in *Lomathamnion* and *Stegengaea* it consists of three cells (apical, subapical, and hypogynous). Other useful characteristics are the number of periaxial cells borne on the fertile female subapical cell, the presence or absence of a sterile cell on the supporting cell, one or two auxiliary cells per procarp, the manner of spermatangial production (in a distinct head, in an umbellate cluster, or in loose tufts), and the nature of sporangia (tetrasporangia or polysporangia) and their position. Vegetative traits include the shape of the attachment structures and the number of erect filaments produced from each cell of the prostrate system. In all genera of Spermothamnieae, the subapical cell of the fertile female filament cuts off the fertile periaxial cell that serves as the supporting cell of the carpogonial branch. Feldmann-Mazoyer's (1941) proposed recognition of the tribe Lejoliseae (to accommodate the genera *Lejolisia* and *Ptilothamnion*) on the basis of a 2-celled fertile female filament has not been accepted (Hommersand, 1963; Gordon, 1972; Itono, 1977; Athanasiadis, 1996; Womersley, 1998). With the removal of propagule-producing genera into the tribe Monosporeae (Huisman and Gordon-Mills, 1994), the subsequent descriptions of *Ptilothamnionopsis* (Dixon, 1971) and *Gordoniella* (Itono, 1977) and the three recent new genera by Alongi et al. (2007), the Spermothamnieae now includes a total of 13 genera.

Our new ceramiaceous plants from Bermuda conform in most respects to those given in the recent protolog for the genus *Woelkerlingia*, nicely summarized in a table with the related genera *Lomathamnion, Stegengaea* and *Hommersandiella* (Alongi et al. 2007). *Woelkerlingia* is described as distinct from the other three outlined by virtue of having two cells in the fertile female filament and the production of two periaxial cells on the fertile female cell in this axis (Alongi et al. 2007). Our plants, however, have either two or three cells in the fertile female filament (Figs 9-12), the 3-celled axes having affinities to those in *Stegengaea* and *Hommersandiella.* In the latter two genera, the female ontogenetic cell is always subapical, while in the Bermuda plants they are only subapical when 2-celled fertile female filaments are formed (Figs 10, 11). In the 3-celled fertile female filaments, the basalmost cell bears the development of the female apparatus, thus no obvious hypobasal cell exists in the fertile filament a feature dissimilar to *Lomathamnion* and *Stegengaea*. The cell hypobasal to the ontogenetic cell of the fertile female axis is not cytoplasmically dense, appearing as an elongate cell similar to all others in vegetative portions of the axis. The Bermuda plants have fertile female filaments that develop similar to those of *Lomathamnion epicodii* Gordon (1972), but the latter species always produces three cells in the fertile filament and they are borne on short lateral branches subterminally, while ours have 2 or 3 cells in the fertile filament and are terminal, later subtended by a lateral branch. For all of these these reasons, and finding no other significant character on which to base a new genus, we chose to place our new species in *Woelkerlingia*.

Aside from the partial disparity in number of cells in the fertile female filament, the Bermuda plants are similar in some respects to the more diminutive and only other member of the genus, *Woelkerlingia minuta* (Table 1). Still, they differ in a number of features. The shorter erect upright branches of *W. minuta* taper from base to apex, whereas those in the new species are longer and uniform in diameter throughout their lengths (Figs 1, 3). The two species display different branching patterns in upright branches (Table 1). Sporangia of *W. minuta* are formed on (1-)2-4-

TABLE 1. Morphological and geographical comparison of *Woelkerlingia sterreri* sp. nov. and *W. minuta* (data from present study and Alongi et al., 2007).

Characteristics	*Woelkeringia sterreri*	*Woelkerlingia minuta*
Habit	Attached to nylon rope	Epiphytic
Height of erect filaments	2-3 mm	1 mm
Shape of erect filaments	Same diameter base to apex	Tapered distally
Branching or erect filaments	Simple, sparingly unilateral	Simple to sparingly pseudodichotomous
Diameter of median erect filament cells	17-24 μm	12-22 μm
Prostrate axes diameter	24-34 μm	15-25 μm
Attachment structures	Unicellular, digitate haptera	Digitate haptera
No. of cells of fertile female axis	2-3	2
Sterile cell from supporting cells	1	1
No. periaxial cells on fertile female cell	2	2
Position of fertile female cell	Lowermost	Lowermost
Carposporophyte	Not yet seen	From one auxiliary cell
Spermatangia	In spermatangial heads	In spermatangial heads
Position of tetrasporangial branches	Median on erect axes	From both erect/prostrate axes
Tetrasporangia	Tetrahedrally divided	Tetrahedrally divided
Polysporangia	Present	Absent
Diameter of sporangia (μm)	24-43	45-55
Apical cell of erect filaments	Relatively densely staining	Not distinctively denser
Geographical distribution	Western Atl.: Bermuda	Mediterranean Sea: Italy

celled branches in basal positions near the prostrate axes, whereas those of *W. sterreri* are formed on 1-(2-)celled branches in median positions on upright branches (Figs 4-7). *Woelkerlingia sterreri* produces these tetrasporangial branches singly in short secund series (fig. 6) or alternate on contiguous cells of the uprights (Fig. 7), and often is seen with two opposite branches borne from the same axial cell (Figs 4, 5). When the sporangium on a sporangial branch approaches maturity, a subtending branch may form on the same branch, subsequently producing a second sporangium giving the appearance of a pair (Fig. 5). Rarely, three tetrasporangial branches are issued from same cell. The new species continues division in occasional tetrasporangia to form polysporangia (Fig. 7), a feature known for many species in the Spermothamnieae (Bornet, 1892; Doty and Meñez, 1960; Itono, 1977; Stegenga, 1984; Bárbara et al. 1992, 2001), but until now not in *Woelkerlingia*.

Woelkerlingia sterreri is most easily differentiated from the four other species in the Spermothamnieae that are known from Bermuda by features of its gametangia and sporangia, and is especially distinct from *Ptilothamnion speluncarum* with its loose involucre around cystocarps and sessile tetrasporangia (Ballantine and Wynne, 1998). A recent fertile female collection of *P. speluncarum* confirms its continued presence in Bermuda, the type locality. But gametangia, especially the fertile female filaments, are rarely found on any of the species of this tribe in Bermuda. Although we have not as yet found gametophytes of either, both *Spermothamnion investiens* and *S. macromeres* issue rhizoids from proximal positions on the ventral side of prostrate axial cells, and the latter issues upright branches off the prostrate axes from the distal ends of the same cells, clearly providing a vegetative marker different than in *W. sterreri*.

Tiffaniella gorgonea likewise has proximal rhizoids and distal erect axes issued from prostrate axial cells, but produces clusters of polysporangia at the bases of erect axes, nicely illustrated from the Caribbean by Taylor (1942, pl. 4). This species, with a type locality in the Canary Islands, produces multicellular rhizoids on its host, *Codium* (Kützing, 1862, Tab. 2, figs c, d [authentic Montagne material]; Børgesen, 1930; Taylor, 1942), a character also at odds with *Woelkerlingia sterreri*. Collins and

Hervey (1917, p. 132) noted "tetraspores with tripartite division . . . borne on an upcurved pedicel", and Howe (1918, p. 526) tentatively agreed with their assessment as *Spermothamnion gorgoneum* (Mont.) Vickers even though the plants were "sterile [and] manifestly different from the cystocarpic and polysporic codiicolous plants from Jamaica . . . and Barbados. . . ." Because of the doubts remaining as to the identity of these collections, we needed to see if they might represent an early collection of *W. sterreri*. As such, we borrowed the NY Collins and Hervey Bermuda specimens used in their account of *S. gorgoneum* (1917), and subsequently observed by Howe (1918) (*A. B. Hervey*, undated, Bermuda; *F. S. Collins* 8488, 8 Dec. 1915, Bethel's Island). The mica mounts of these plants are epiphytic on *Codium* and have unicellular rhizoids issued from the proximal ends of prostrate axial cells, similar to those found in *Spermothamnion investiens* and *S. macromeres*. However, a fresh mount from dried material (*FSC* 8488) revealed several prostrate axes with both unicellular and multicellular rhizoids. Two of the three collections contained tetrasporangia, one (*A. B. Hervey,* 5 Mar. 1921, Buildings Bay [NY]) having been gathered after both Collins and Hervey (1917) and Howe (1918) discussed *T. gorgonea* (as *S. gorgoneum*) in Bermuda. Unlike *T. gorgonea*, all of the sporangia observed in the Collins and Hervey material were tetrahedrally divided and borne on upcurved one-celled pedicels in median positions on upright branches, the sporangial branch then issuing one or more subtending branches and additional tetrasporangia. There were no basal polysporangia, leading us to conclude the early 20th century specimens assigned to *S. gorgoneum* cannot be that species. Although the position and division of the tetrasporangia are similar in arrangement, the origin of branches and rhizoids seem to rule these collections out as *W. sterreri*. The specimens also match *S. macromeres* in tetrasporangial characteristics, but this species has not been reported as having produced multicellular rhizoids. Could these be a consequence of attaching to the host *Codium*? In that there have been no additional reports of *T. gorgonea* since the Collins and Hervey (1917) and Howe (1918) accounts (Schneider 2003), this effectively removes this species from the flora of Bermuda. When Doty and Meñez (1960) transferred *S. gorgoneum* to *Tiffaniella*, they did not report on any Bermuda specimens.

We discovered the type collection of *Woelkerlingia sterreri* in a somewhat protected habitat of a tangled mass of rope, allowing for more luxuriant growth than might normally be found with natural grazing pressure, thus making its presence obvious. If, as we suspect, this species also grows on other plants or rock, perhaps they would be obscure, being more readily removed by herbivorous fish and invertebrates, thus making the collection of fertile plants even more difficult.

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