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The Red Algal Genus *Scinaia* (Galaxauraceae, Nemaliales) on Jeju Island, Korea

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We report six species of the genus *Scinaia* (Galaxauraceae, Nemaliales) from Jeju Island, Korea. Five of the species, *S. cottonii* Setchell, *S. tokidae* Kajimura, *S. okiensis* Kajimura, *S. flabellata* Kajimura, and *S. confusa* (Setchell) Huisman, are newly recorded in the Korean flora. *Scinaia okamurae* (Setchell) Huisman was previously recorded. *Scinaia japonica* Setchell, which is known from Korean waters, was not found. We examined thallus habits, vegetative morphology, and reproductive structures in all six species. We also appraise several morphological characters for their value in separating *Scinaia* species.

Key Words: Galaxauraceae, *Scinaia*, *S. cottonii*, *S. tokidae*, *S. okiensis*, *S. flabellata*, *S. confusa*, *S. okamurae*, *S. japonica*

INTRODUCTION

Bivona-Bernardi (1822) established the genus *Scinaia* on the basis of the monotypic species *S. forcellata*. For many years, this species was cited as *S. furcellata* (Turner) Bivona-Bernardi. However, recently, the specific epithet, *S. forcellata* Bivona-Bernardi, was restored (Dixon and Irvine 1970; Huisman 1985). The genera *Scinaia* Bivona-Bernardi (1822), *Gloiophloea* J. Agardh(1872), *Pseudoscinaia* Setchell (1914), and *Pseudogloiophloea* Levering(1955) at one time comprised the *Scinaia* assemblage, but *Pseudoscinaia* and *Pseudogloiophloea*, have now been merged into *Scinaia* (Huisman 1985).

In Korea, three *Scinaia* species have been recorded (Lee and Kang 2002): *S. japonica* Setchell (1914), *S. latifrons* Howe (1911), and *S. okamurae* (Setchell) Huisman (1985). Apart from the record of its occurrence, no information, such as locality or morphology, has been published for *Scinaia latifrons* (Lee and Kang 1986). *Scinaia japonica* is well-known from Korean waters (Okamura 1936; Yamamoto and Kawamoto 1942; Rho 1954, 1958; Chyung and Park 1955; Kang 1956, 1960, 1966, 1968; Lee 1976; Lee and Kang 1986; Koh 1990; Lee and Koh 1991; Park *et al*. 1994; Lee and Kim 1999; Lee *et al*. 2000). *Scinaia okamurae* was previously referred to as *Gloiophloea okamurae* Setchell or *Pseudogloiophloea okamurae* (Setchell) Chihara (Kang 1968; Lee and Kang 1986; Lee and Koh 1991).

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MATERIALS AND METHODS

We collected plants from the subtidal regions of Jeju Island, Korea, by scuba diving. The samples were kept in seawater during transport to the laboratory to reduce thermal impact. In the laboratory the collected samples were immediately fixed in 5% formalin/seawater for 3 to 5 days. Most of the fixed samples were prepared as dried herbarium specimens. Thalli were sectioned using a benchtop freezing microtome (MFS no. 222; Nippon Optical Works, Tokyo, Japan). Sections and parts of specimens were mounted on glass slides in 50% corn syrup solution. Olympus research microscopes (BX50F3, SZH-ILLB; Olympus Optical Co., Tokyo, Japan) with camera systems (C35DX, PM-P20, PM20; Olympus Optical Co.) were used to observe the thalli. Wet-preserved or pressed specimens were photographed with a Nikon F2 camera (Nikon, Tokyo, Japan) mounted on a photostand (Dongwon, Seoul, Korea). All collections examined were deposited at the Herbarium of the Department of Life Science, Cheju National University, Korea.

RESULTS

***Scinaia* Bivona-Bernardi 1822: 232.**

J. Agardh 1851: 420; Huisman 1985: 403-418.

Synonyms: *Pseudoscinaia* Setchell 1914:119 (Huisman

1985).

Pseudogloiophloea Levring 1953: 420 (Huisman 1985).

Type species: *S. forcellata* Bivona-Bernardi 1822: 232 (Dixon and Irvine 1977: 145).

Scinaia has a life history with heteromorphic alternation of generations. The tetrasporophyte is an *Acrochaetium*-like thallus (Ramus 1969; Yoshizaki 1993), that has not been found in the field (Dixon and Irvine 1977). *Scinaia* species are either monoecious or dioecious. Monosporangia are produced by both generations for asexual reproduction (Ramus 1969; Yoshizaki 1993).

The gametangial thalli are erect, cylindrical, multiaxial, flaccid or cartilaginous, dark red, have a small discoid holdfast, and furcate dichotomously in two or three dimensions. The segments are either constricted or unconstricted. The thalli consist of axial strands, radial filaments (medullary filaments), hypodermal filaments, rhizoidal filaments, and utricles. The axial strands, which are aggregations of somewhat thicker tubules, are pierced by numerous radial filaments. The radial filaments are fine, tubular, ca. 2.5 μm in diameter, and connect between the axial strands and the hypodermal filaments. The hypodermal filaments are anticlinal, comprise several cells, branch dichotomously in two or three dimensions, and abut on the utricles. The hypodermal cells are obovoid to clavate, slightly curved or contorted, and contain either small, packed granules (deeply pigmented) or a parietal laminate chloroplast. The rhizoidal filaments, which are also tubular and morphologically similar to the radial filaments, are disposed periclinally near the hypodermal cells. The utricles are colorless, with rather thick walls, and as densely compact as the palisades of cortex. The utricles are of two types: inflated and slender. The inflated utricles are globose to ellipsoid and apparently colorless. The outer surfaces of the end walls of the inflated utricles have faint, irregular patterns (chromatophores, sensu Kajimura 1988, 1991, 1995). The slender utricles are linear to cylindrical and have been described as colored cells (cortical cells; Setchell 1914; Huisman 1985, 1986). However, these utricles contain no colored substances, although they seem to be colored under the microscope. Chloroplasts occur in the hypodermal cells and are ribbon-shaped and parietal.

Spermatangia of *Scinaia* are always produced in sori. The spermatangial mother cells intervene between or emerge over the utricles. One to three spermatangia are borne on the tips of the spermatangial mother cells. The cystocarps are immersed in the medullae and are globose, with a rather long neck and ostiole. The carposporangia are formed in short chains on the gonimoblast filaments. Monosporangia are borne between the utricles and obconical (Ramus 1969; Dixon and Irvine 1977; Huisman 1985, 1986; Kajimura 1988, 1991, 1995; Yoshizaki 1993).

There is no consensus on the morphological characters that discriminate *Scinaia* species. Setchell (1914) distinguished *Scinaia* species on the basis of thallus habit, utricle shape, and monoecism/dioecism. Huisman (1986) used a combination of habit and morphological characters, but did not regard the monoecism/dioecism or geographical locality as specific characters. He also suggested that the sterile branches on the hypogenous cell are important in species separation. Kajimura (1991) distinguished the Japanese *Scinaia* species on the basis of thallus habit, mode of furcation, monoecious/dioecious, and spermatangial sorus type. We used a combination of characters to identify *Scinaia* species: thallus habit, mode of furcation, branch tip shape, utricle shape and arrangement, spermatangial sorus shape, and monoecism/dioecism.

Key to the species of *Scinaia* from Jeju Island

1. Thallus flaccid, inflated utricles only .....(2)
1. Thallus cartilaginous, inflated utricles interspersed with slender utricles .....(5)
   2. Furcate in two dimensions.....(3)
   2. Furcate in three dimensions .....(4)
3. Segments flat or compressed .....*S. cottonii*
3. Segments cylindrical.....*S. flabellata*
   4. Branch apices pointed, belt-shaped spermatangial sori.....*S. okiensis*
   4. Branch apices obtuse, cap-shaped spermatangia sori .....*S. tokidae*
5. Branch apices papillate, monoecious .....*S. okamurae*
5. Branch apices pointed, dioecious.....*S. confusa*

Scinaia cottonii **Setchell 1914: 103.**

Fig. 1

Scinaia cottonii Setchell 1914: 103; Okamura 1921: 94; Tseng 1983: 64, pl. 35, fig. 1; Lee and Kang 1986: 319; Kajimura 1995: 535-541, figs. 1-18; Yoshida 1998: 505.

Scinaia latifrons sensu Lee and Kang 1986: 319; Lee and Kang 2002: 487.

Korean name: Nabjagheuneulpul (납작흐늘풀).

Type: BIRM (E.M. Holmes no. 9). (Herb. School of Biological Science, University of Birmingham, England).

Type locality: Enoura, Japan.

Distribution: Western coasts of North Pacific.

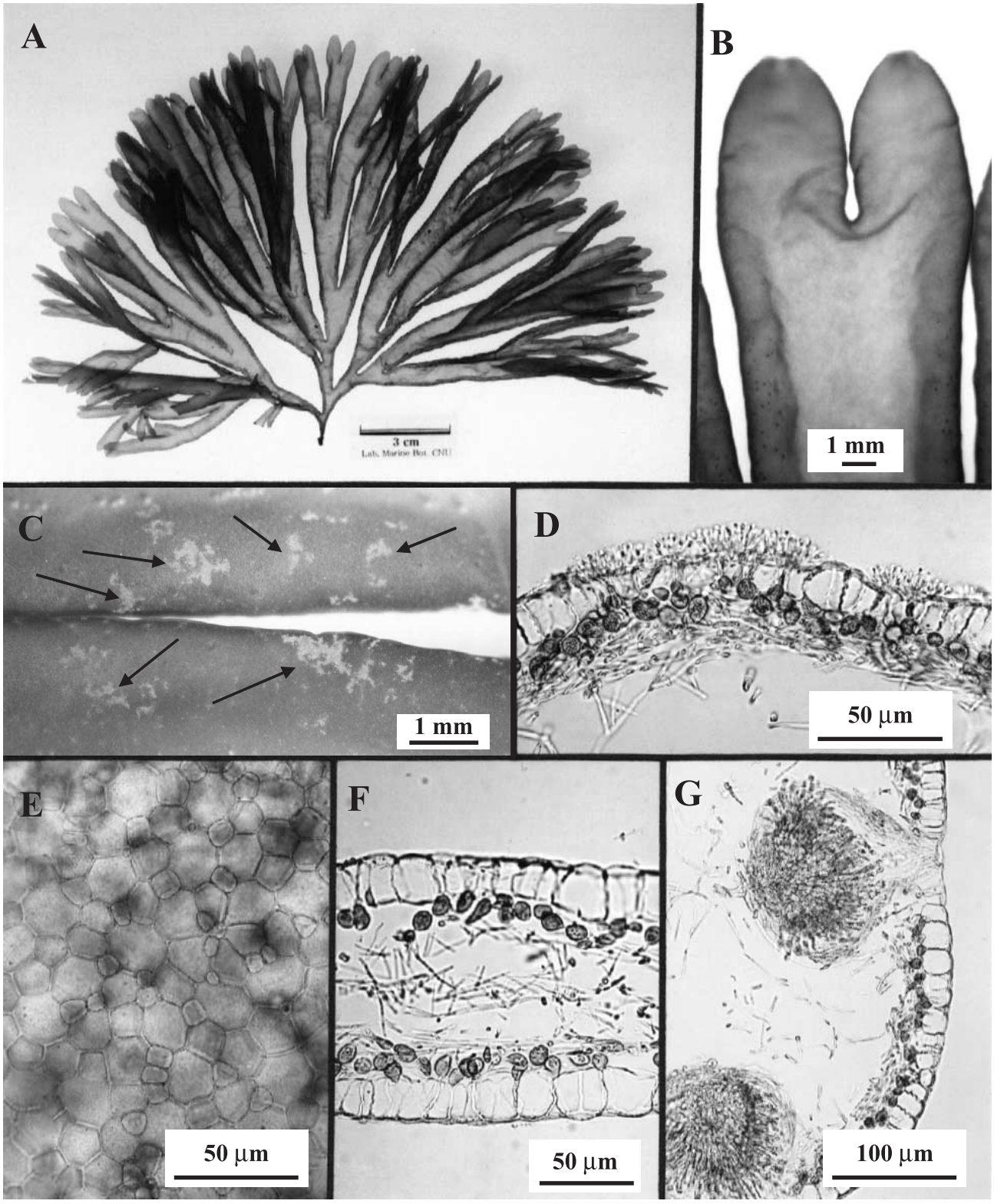

Fig. 1. *Scinaia cottonii* Setchell. A. Thallus. B. Branch apices. Note the inflated margins bearing cystocarps (small dots). C. The margins bearing spermatangial sori (arrows). D. Transverse section of the marginal portion of the segment bearing spermatangial sori. E. Surface view of segment. F. Transverse section of segment. G. Transverse section of the marginal portion of the segment bearing cystocarps.

Vegetative morphology: The thalli (14-18 cm tall) are flaccid, with short and terete stipes, deep pink, furcate dichotomously five to eight times in two dimensions, and have narrow axils (Fig. 1A). The branches are of equal height, unconstricted, and have round apices (Fig. 1B). The segments (8-10 mm wide) are flat, with inflated margins, broaden slightly upward, and have no axial strands. The epidermis consists of inflated utricles, hypodermal filaments, and rhizoidal filaments. The inflated utricles (13-25 μm diameter; 27-33 μm radially) are colorless, polygonal in surface view, globose to ellipsoid in transverse section, with outer ends convex (Fig. 1E, F). The hypodermal filaments comprise several cells forming short moniliform chains that furcate in three dimensions. The hypodermal cells (18-20 μm long, 8-13 μm diameter) dispose in somewhat loose groups near the inner side of the utricle palisade. The hypodermal filament basal cells are linear, slightly contorted, and connect to the radial filaments. Rhizoidal filaments develop from the hypodermal filament basal cells and generally orient periclinally near the hypodermal cells. Medullae comprise the axial lamellae and radial filaments. The axial lamellae are loose aggregations of relatively thick tubules (5-15 μm diameter). The axial laminae (12-25 μm thick) are disposed periclinally, parallel to the longitudinal axis of the segments, and can not be seen through the cortex in surface view. The radial filaments (ca. 2.5 μm diameter) are straight, thin-walled, and connect between the hypodermal filaments and axial lamellae, passing through the axial lamellae.

Reproductive morphology: The plants are monoecious. Spermatangial sori and cystocarps aggregate in the marginal inflated regions. The cystocarps (200-230 μm diameter), are immersed below the cortical layers, globose, and have pericarps of filamentous cells (Fig. 1G). The carposporangia (8-13 μm long, 5-8 μm diameter) are ellipsoid and borne in short chains of three or four sporangia at the ends of the gonimoblast filaments. Spermatangial sori form irregular shapes in the inflated margins (Fig. 1C). Spermatangial mother cells (8-10 μm long, ca. 2 μm diameter) are borne on the terminal cells of the hypodermal filaments, protrude out over the segment surfaces, and are linear to obclavate (Fig. 1D). The spermatangia (ca. 2 x 3 μm) are borne in threes on the end of the spermatangial mother cells and are ellipsoid to ovoid.

Habitat: *Scinaia cottonii* grows on small pebbles or shells submerged in sand substrates at depths of 15 to 18 m off Seobseom. It does not form populations although two to four plants may occur on a common holdfast.

Specimens examined: LYP-2004-207 (Seobseom, Jeju Island 2004-04-10); LYP-2004-243 (Seobseom, Jeju Island 2004-04-10); LYP-354 (Seobseom, Jeju Island 2004-05-14); LYP-2006-32 (Seobseom, Jeju Island 2000-06-15); LYP-2006-46 (Seobseom, Jeju Island 2006-05-13).

Remarks: The plants examined agree with the figure and the description by Setchell (1914: 103) and Kajimura (1995: 535-541, figs. 1-18). The flattened or complanate unconstricted section of the genus *Scinaia* comprises three species: *S. complanata* (Collins) Cotton (1907), *S. latifrons* Howe (1911), and *S. cottonii* Setchell (Setchell 1914). Setchell (1914) described *S. cottonii* on the basis of two specimens collected by Saido at Enoura, Japan and deposited in Herbarium E.M. Holmes (no. 9). Setchell (1914) distinguished *S. cottonii* from the closely related *S. latifrons* on the basis of its smaller size, utricle dimensions, and less marked intermarginal aggregation of cystocarps. Okamura (1921) described specimens as *S. cottonii*, but maintained that *S. cottonii* was conspecific with *S. latifrons*. The name *S. cottonii* was accepted for the Japanese plants in subsequent works (Okamura 1936). Kajimura (1995) distinguished between *S. latifrons* and *S. cottonii*, based on characters including spermatangial sori formation, monoecism vs. dioecism, hypodermal cell size, presence or absence of utricles in the parts bearing spermatangial sori, and mature cystocarp size. Okamura (1921) declared the transverse wrinkles on *S. cottonii* segments to be a distinct characteristic; however, these transverse wrinkles seem to occur more often on older plants. Yoshida (1998) and Lee and Kang (1986) regarded *S. cottonii* as conspecific with *S. latifrons*. In Korea, the only record of *S. latifrons* is in the list of Lee and Kang (1986).

***Scinaia tokidae* Kajimura 1988: 176.**

Fig. 2

Scinaia tokidae Kajimura 1988: 176, figs. 1-17, 52-54; Yoshida 1998: 507.

Korean name: Tangeonheuneulpul (탕건흐늘풀)

Type: SAP 051782 (OS 99116) (Herb. Botany Department, Hokkaido University)

Type locality: Tsudo, Oki Island, Japan.

Distribution: The western coasts of North Pacific.

Vegetative morphology: The plants (5-12 cm tall) are flaccid, deep pink, form bunches, have a short and terete stipe, furcate dichotomously five to seven times in three dimensions, and have narrow axils (Fig. 2A). The branches are of equal height and have blunt and swollen apices.

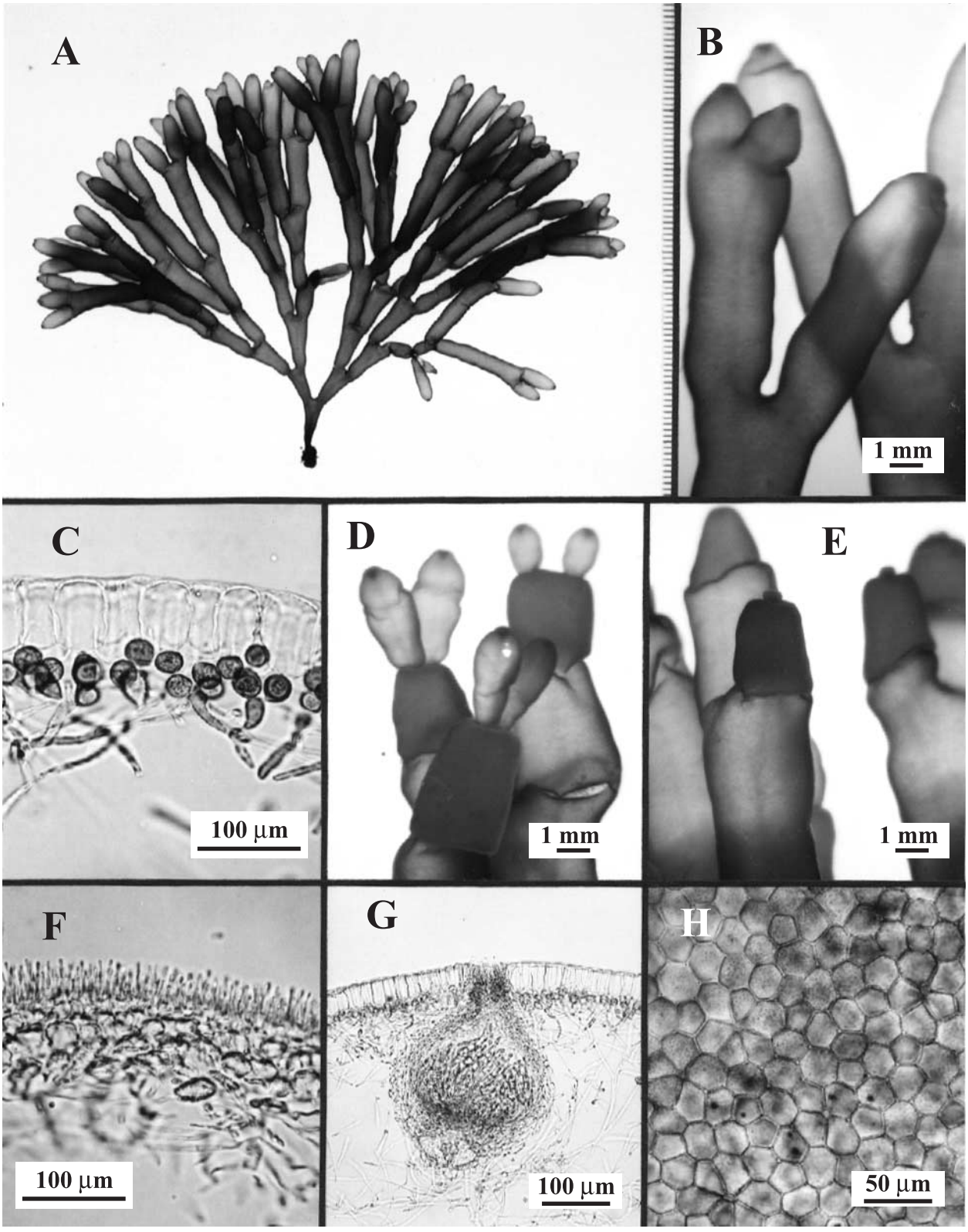

Fig. 2. *Scinaia tokidae* Kajimura. A. Thallus (scale unit = mm). B. Branch apices. C. Transverse section of segment. D. Additional segments arising on the tip of the segment bearing cap-shaped spermatangial sori. E. Cap-shaped spermatangial sori. F. Transverse section of the segment bearing spermatangial sori. G. Transverse section of the segment bearing cystocarps. H. Surface view of segment.

The segments (2-4 mm diameter) are cylindrical, slightly inflated at the upper portios. The apex of the terminal segments is conical to hemispherical (Fig. 2B). Constrictions are often present between the base of new segments and the tip of the segments bearing cap-shaped spermatangial sori (Fig. 2D). The epidermis consists of inflated utricles, hypodermal filaments, and rhizoidal filaments (Fig. 2C). The utricles (40-55 μm diameter; 70-80 μm radially) are colorless, polygonal in surface view, ellipsoid in transverse sections, and have slightly convex outer ends (Fig. 2H). The hypodermal cells (8-13 μm diameter) are deep red, obovoid, have thick walls, and disperse more or less evenly near the inner sides of the utricle palisade. The hypodermal filament basal cells (2-5 μm diameter) are linear to clavate, somewhat contorted and in various lengths, contain parietal ribbon-shaped chloroplasts, and connect to the radial filaments. The medullae comprise axial strands and radial filaments. The axial strands (220-300 μm diameter) are compact aggregations of somewhat thick tubules (5-15 μm diameter), and can be seen through the cortex in surface view. The radial filaments (ca. 2.5 μm diameter) are straight, thin-walled, pass through the axial strands, and connect to the hypodermal filament basal cells.

Reproductive morphology: The plants are dioecious, with male and female plants similar in morphology. The spermatangial sori always form on the apex of the terminal segments and appear cap-shaped (Fig. 2E). Occasionally, new segments arise on the terminal segment tips with spermatangial sori; these also produce cap-shaped spermatangial sori in the terminal region (Fig. 2D). In the region of spermatangial sori, the epidermis, which lacks colorless utricles, is composed of three to five layers of hypodermal cells. The spermatangial mother cells (ca. 10 μm long, ca. 2 μm diameter) develop on the outermost hypodermal cells, form two or three spermatangia on each tip, and are linear, with a slightly inflated base (Fig. 2F). The spermatangia (3-4 μm long, ca. 2 μm diameter) are ovoid to ellipsoid. Cystocarps (200-230 μm diameter) are distributed on the second to fourth segments from the branch ends and are immersed below the cortical layers, globose, with pericarps of fusiform cells (Fig. 2G). Carposporangia (9-12 μm long, 4-6 μm diameter) are borne in short chains of three or four sporangia at the ends of the gonimoblast filaments.

Habitat: *Scinaia tokidae* grows on small pebbles or shells submerged in sand substrates at depths of 15 to 18 m off Seobseom and other localities. It is associated with *S. cottonii* and occasionally grows in groups of two to four on a common holdfast.

Specimens examined: LYP-2004-431 (Seongsan, Jeju Island 2000-07-31); LYP-2004-432 (Seongsan, Jeju Island 2000-07-31); LYP-2004-253 (Seobseom, Jeju Island 2004-04-10); LYP-2004-254 (Seobseom, Jeju Island 2004-04-10); LYP-2004-351 (Seobseom, Jeju Island 2004-05-14); LYP-2005-180 (Udo Islet, Jeju Island 2005-07-13); LYP-2005-227 (Seobseom, Jeju Island 2005-06-12); LYP-2006-42 (Sindo, Jeju Island 2006-05-11, coll. Y. Ko); LYP-2006-47 (Seobseom, Jeju Island 2006-05-13, coll. Y. Ko); LYP-2006-50 (Seobseom, Jeju Island 2006-05-13); LYP-2006-97 (Seobseom, Jeju Island 2006-05-30); LYP-2006-141 (Mureung, Jeju Island 2006-05-23).

Remarks: This species is characterized by thick, soft segments; branches of equal height, with rare constrictions, and utricles that appear virtually equal in size in surface view. Cap-shaped spermatangial sori are formed at terminal segment apices; The spermatangial sori form in immature cortical regions, where utricles do not form. Conseguently, segment growth appears to be restrained by the formation of the spermatangial sori. In some plants up to third order new segments may arise on the end of the terminal segments, with the spematangial sori remaining below the upper node. However, the shape of these differs from the belt-shaped spermatangial sori of *S. okiensis*, which are formed in mid-segment regions. Segments of the plants from Seongsan and Udo Islet have several constrictions and are 1.5-3 mm in diameter.

***Scinaia okamurae* (Setchell) Huisman 1985: 417.**

Fig. 3

Scinaia okamurae (Setchell) Huisman 1985: 417; Yoshida 1989: 506; Lee and Oh 1986: 230; Lee and Lee 1988: 177.

Basionym: *Gloiophloea okamurae* Setchell 1914: 115, pl. 15, figs. 50-56; pl. 16, fig. 57 (as *okamurai*); Okamura 1936: 435, fig. 202 (as *okamurai*); Rho 1954: 33; Chyung and Park 1955: 23; Rho 1958: 113; Kang 1960: 20; Kang 1966: 61; Kang 1968: 197; Lee 1976: 33.

Synonyms: *Pseudogloiophloea okamurae* (Setchell) Chihara 1969: 3, fig. 1 (as *okamurai*); Lee and Kang 1986: 319; Lee and Koh 1991.

Korean name: Maekkeunkkeobjil (매끈껍질)

Type: UC (Alg. Japon. Exsicc. No. 2) University of California, Berkeley.

Type locality: Enoshima, Kanagawa, Japan (Yoshida 1998).

Distribution: The western coasts of North Pacific.

Vegetative morphology: Plants (5-7 cm tall) are dark brown or red-gray, somewhat cartilaginous, and furcate

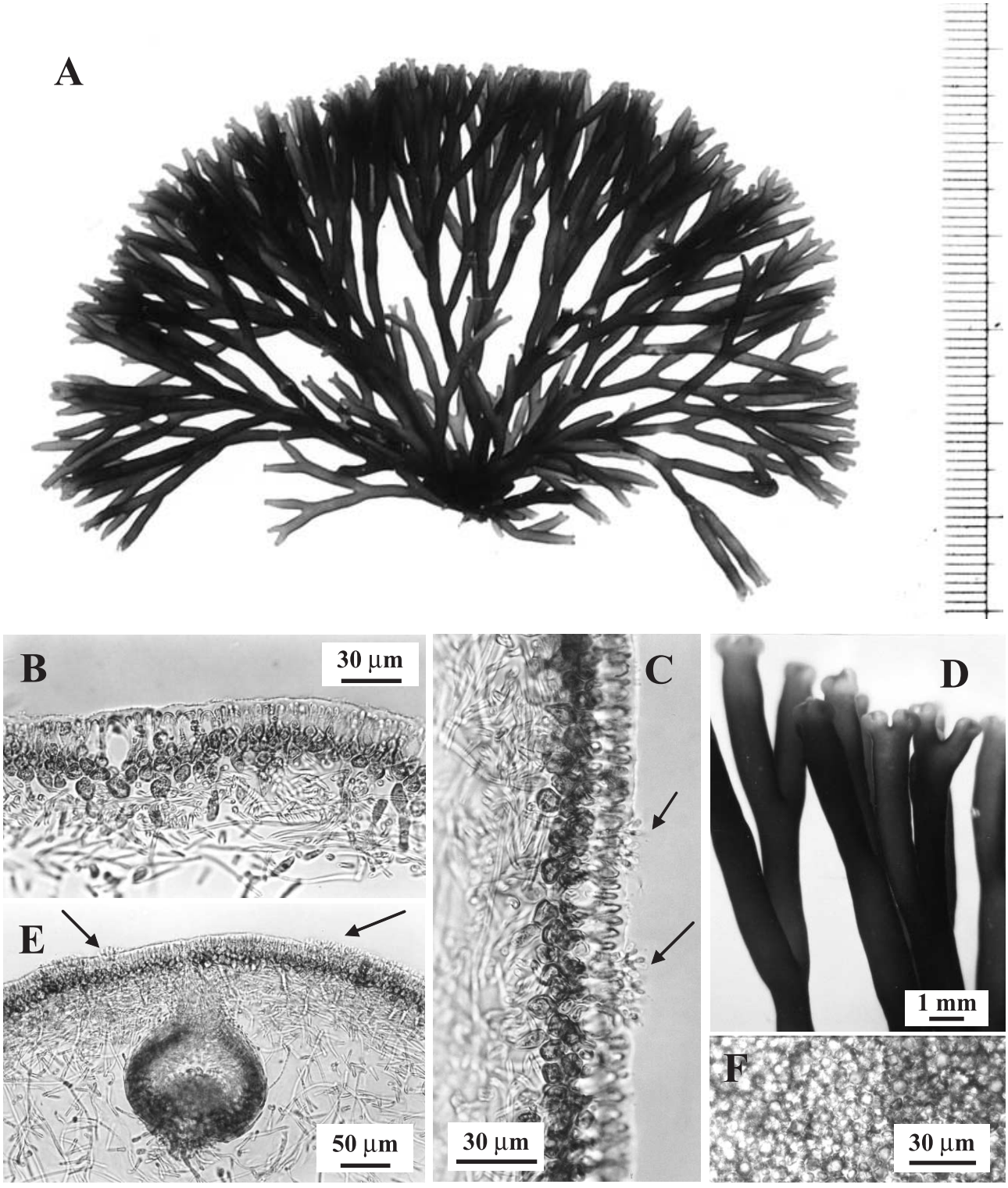

Fig. 3. *Scinaia okamurae* (Setchell) Huisman. A. Thallus (scale unit = mm). B. Transverse section of blanch. C. Spermatangial sori (arrows). D. Branch apices. E. Cystocarp and spermatangial sori (arrows). F. Surface view of segment.

dichotomously and profusely, at more or less acute angles, in three dimensions (Fig. 3A). The branches are of equal height, with a papillate apex (Fig. 3D). The segments (1-1.5 mm diameter) are cylindrical and continuous, comparatively rigid, and have axial strands not visible in surface view. The epidermis is composed of cortical cells, utricles, hypodermal filaments, and rhizoidal filaments. The cortical cells are linear, pigmented, and varying from slim-waisted to clavate. The inflated utricles (7-15 μm diameter; 13-20 μm radially), which are dis-

persed among the slender utricles, are thick walled, globose to fusiform, and pigmented by a cap-like stain inside the end walls in transverse section; and in surface view, they are round and slightly immersed in the cortical layers (Fig. 3B, C, F). The slender utricles (3-5 μm diameter; 7-11 μm radially) are pigmented inside the end walls, thick-walled, round to ellipsoid in surface view, and linear in transverse section. The hypodermal cells (5-9 μm diameter) aggregate closely under the utricles, form a 20-40-μm-thick layer, and contain granules. The hypodermal filament basal cells (13-20 μm long, 4-8 μm diameter) are light red, fusiform to clavate, contain chloroplasts, and connect to the radial filaments. The rhizoidal filaments (ca. 3 μm diameter) are slightly undulate, accumulate rather densely among the hypodermal filaments, and form an up to 60 μm thick layer. The medullae consist of axial strands and radial filaments. The axial strands (200-280 μm diameter) can not be seen through the cortex in surface view. The radial filaments (ca. 3 μm diameter) are straight or slightly undulate, with thin walls, and somewhat densely entangled.

Reproductive morphology: The plants are monoecious. Spermatangial sori are interspersed among cystocarps in the segments. The spermatangial sori occur in speckles on the segment surfaces (Fig. 3E). The spermatangial mother cells (8-10 μm long, ca. 2 μm diameter) are borne on the terminal cells of the hypodermal filaments, are linear to obclavate, and intervene between the utricles. The spermatangia (ca. 5 μm long and 3 μm diameter) are borne in threes on the end of the spermatangial mother cells. They are ellipsoid to ovoid, and emerge over the segment surfaces (Fig. 3C). The cystocarps are 120-170 μm in diameter (Fig. 3E). The pericarps are composed of fusiform cells in the middle to basal parts and filamentous cells from the upper parts to the ostioles. The carposporangia are ellipsoid to cylindrical, 15-18 μm long and 7-8 μm in diameter.

Habitat: *Scinaia okamurae* grows as single thalli on rocks in the lower intertidal zone and is associated with species of *Gelidium* and *Pterocladiella*.

Specimens examined: LYP-2004-366 (Mogjiseom, Jeju Island 2003-03-20); LYP-2005-54 (Seorim, Jeju Island 2005-05-19); LYP-2005-57 (Mureung, Jeju Island 2005-05-20); LYP-2005-79 (Seorim, Jeju Island 2005-06-05); LYP-2006-143 (Mureung, Jeju Island 2006-05-23).

Remarks: The plants examined agree quite well with the descriptions and figures by Setchell (1914: 116, pl. 15, figs. 50-56; pl. 16, fig. 57) and Okamura (1936: 435, fig. 202). *Scinaia okamurae* is easily distinguished from other Jeju Island *Scinaia* species by its somewhat cartilaginous property and the papilate apex of the terminal segments. The cartilaginous texture is due to the thick layer of hypodermal cells, the tight attachment of the utricles and hypodermal filaments, and the dense entanglement of the radial filaments in the medullary lumen between the axial strands and hypodermal filaments. However, the pericarps of the Jeju Island plants are composed of fusiform cells in the middle to basal parts and fine filaments from the upper parts to the ostioles, whereas the pericarps of the Japanese plants are composed only of fine filaments from base to ostiole (Okamura 1936). The cortex of *S. okamurae* comprises utricles of various sizes. The cortical cells are linear, of equal height, and varying from slim-waisted to clavate. The cortical cells are presumably transformed into slender utricles in the mature cortex, as cortical cells are rare in the mature cortex. The slender utricles have the same form as cortical cells, but have thick walls and are colored only inside the outer end walls (cap-like pigmentation). This structure is similar to the cortex of *S. berggrenii* (Levring) Huisman (Huisman 1985: 413, figs. 40, 41, 45).

***Scinaia flabellata* Kajimura 1988: 183.**

Fig. 4

Scinaia flabellata Kajimura 1988: 183, figs. 38-51, 59; Yoshida 1998: 504.

Korean name: Buchaeheuneulpul (부채흐늘풀)

Type: SAP 051085 (OS 99120) (Herb. Botany Department, Hokkaido University).

Type locality: Tsudo, Oki Island, Japan.

Distribution: The western coasts of North Pacific.

Vegetative morphology: The plants (5-9 cm tall) are deep pink, flabellate, flaccid, with narrow axils, and they furcate dichotomously five to seven times in two dimensions (Fig. 4A). The segments (2-2.5 mm diameter) are cylindrical and straight. The terminal segments are of equal height and have a conical apex (Fig. 4B). The segments are mostly unconstricted. The epidermis is composed of inflated utricles, hypodermal filaments, and rhizoidal filaments. The inflated utricles (18-25 μm diameter; 27-35 μm radially) are colorless, polygonal in surface view, subglobose to ellipsoid in transverse section, and the outer ends are slightly convex (Fig. 4C, D). No obviously smaller utricles are visible in surface view. The hypodermal cells (13-15 μm long, 8-10 μm diameter) disperse in one or two layers near the inner side of the utricle palisades (Fig. 4G). The hypodermal filament basal cells, which connect to the radial filaments, are linear to

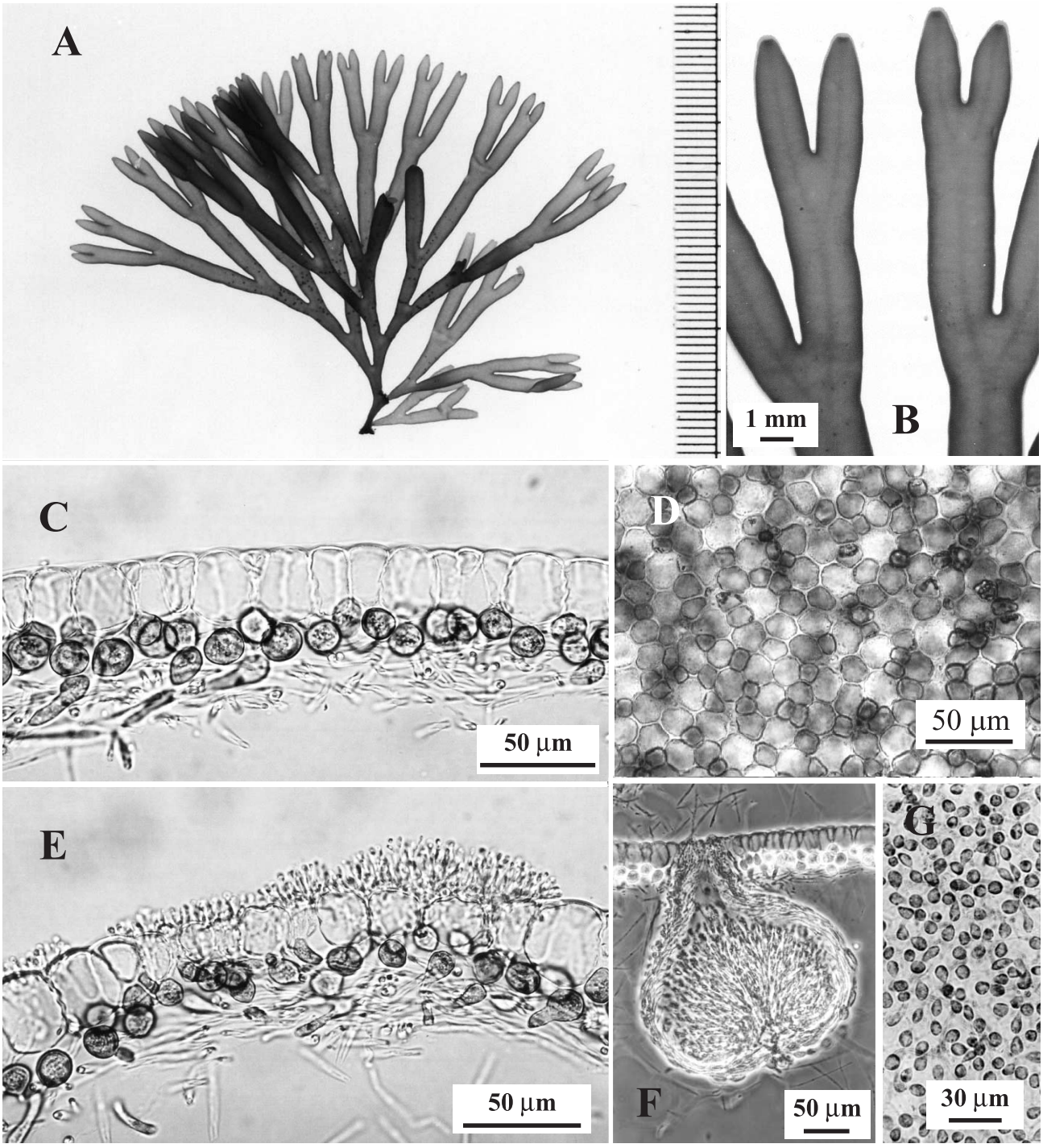

Fig. 4. *Scinaia flabellata* Kajimura. A. Thallus (scale unit = mm). B. Branch apices. C. Transverse section of segment. D. Surface view of segment. E. Transverse section of the segment bearing spermatangial sori. F. Transverse section of the segment bearing cystocarps. G. Surface view of hypodermal cells.

clavate, somewhat curved, contain parietal ribbon-shaped chloroplasts, and are up to 40 μm long and 5-8 μm in diameter where inflated. The medullae consist of axial strands and radial filaments. The axial strands (150-180 μm diameter), which are visible in surface view, are compact aggregations of rather thick tubules. The radial filaments (ca. 2.5 μm diameter), which are straight and thin walled, connect to the hypodermal filament basal cells and pass through the axial strands.

Reproductive morphology: The plants are monoecious. The spermatangial sori, which appear in somewhat whitish stains on middle segment surfaces, are

interspersed among cystocarps and barely discernable under a stereomicroscope. Spermatangial mother cells develop on the outermost hypodermal cells and intervene between utricles or protrude out over the segment surfaces. The spermatangial mother cells (10-12 μm long, ca. 2 μm diameter) are linear to obclavate and form two or three spermatangia on each tip (Fig. 4E). The spermatangia (3-4 μm long, ca. 2 μm diameter) are ovoid to ellipsoid. The cystocarps (230-270 μm diameter) are globose, distributed on the second to fourth segments from the branch ends, and have pericarps of fusiform cells (Fig. 4F). Carposporangia (17-20 μm long, 6.5-7 μm diameter) are ellipsoid to cylindrical.

Habitat: *Scinaia flabellata* grows on small pebbles or shells submerged in sand substrates at depths of 15 to 18 m off Seobseom, Jeju Island. It grows as a single thalli, but is associated with *S. cottonii*, *S. tokidae*, and *S. okiensis*. *Scinaia flabellata* was extremely rare, and only a few individuals were collected at this locality.

Specimens examined: LYP-2004-254 (Seobseom, Jeju Island 2004-04-10); LYP-2006-52 (Seobseom, Jeju Island 2006-05-13).

Remarks: *Scinaia flabellata* is characterized by soft, flaccid segments, the branch apices of equal height, dichotomous braching in two-dimensions, lack of constrictions, subglobose utricles, and monoecism. Consequently, the thallus habit of *S. flabellata* is not tufted, but is spread flabellately on a plane. Kajimura (1988) discriminated *S. flabellata* from allied species with generally unconstricted terete segments on the basis of utricle and overall thallus size and the two dimensional diverging mode. *Scinaia flabellata* plants from Jeju Island had no constricted segments and are more robust than the Japanese plants.

***Scinaia okiensis* Kajimura 1988: 180.**

Fig. 5

Scinaia okensis Kajimura 1988: 180, figs. 32-37, 56-58; Yoshida 1998: 506.

Korean name: Wanjangheuneulpul (완장흐늘풀).

Type: SAP 051783 (OS 99118) (Herb. Botany Department, Hokkaido University).

Type locality: Tsudo, Oki Island, Japan.

Distribution: The western coasts of North Pacific.

Vegetative morphology: The plants (9-12 cm tall) are flaccid, deep pink, and form bunches (Fig. 5A). The branches, which furcate dichotomously seven to ten times in three-dimensions, have narrow axils and rather pointed apices, are unequal in height, and are constricted in various portions (Fig. 5E). The segments (1.5-3 mm diameter) are cylindrical, equal in diameter, and show less obvious axial strands in surface view. The terminal segments are gradually attenuated toward the apex, and the basal segments are slightly inflated upward. The epidermal layers consist of inflated utricles, hypodermal filaments, and rhizoidal filaments. The utricles (12-30 μm in diameter; 27-30 μm radially) are colorless, polygonal in surface view, ellipsoid to ovoid, with somewhat wrinkled radial walls in transverse section, and have slightly rounded or flat outer ends (Fig. 5C, F). The hypodermal cells (8-10 μm diameter) are deep red and disperse more or less evenly under the utricle palisades (Fig. 5D). The hypodermal filament basal cells (4-5 μm diameter) are linear to clavate, slightly curved, and contain parietal ribbon-shaped chloroplasts. The medullae comprise axial strands and radial filaments. The axial strands (150-180 μm diameter) are compact aggregations of rather thick tubules and can be seen through the cortex in surface view. The radial filaments (ca. 2.5 μm diameter) are thin walled, connect to the hypodermal filament basal cells and pass through the axial strands.

Reproductive morphology: The plants are dioecious. The male and female plants are similar in morphology. The belt-shaped (intercalary belt-type, sensu Kajimura) spermatangial sori form on the middle portion of all but the terminal and lower segments. The utricles in the fertile and sterile regions are identical in morphology (Fig. 5G). The spermatangial mother cells, which intervene between the utricles or protrude out over the segment surfaces, are also linear to obclavate and produce two to three spermatangia on the tips. These spermatangia (3-4 μm long, ca. 2 μm diameter) are ovoid to ellipsoid. Cystocarps intersperse in the second to fourth segments from the end of the branches. The cystocarps (200-230 μm diameter) are globose, immersed below the cortical layers and have pericarps composed of fusiform and linear cells (Fig. 5H). Carposporangia (10-15 μm long, 5-8 μm diameter) are borne in short chains of three or four sporangia at the ends of the gonimoblast filaments and are ellipsoid to cylindrical.

Habitat: *Scinaia okiensis* grows on rocks in the subtidal regions of Jeju Island. It is widespread in Jeju Island waters and is occasionally associated with *S. cottonii* and *S. tokidae*.

Specimens examined: LYP-2004-208 (Seobseom, Jeju Island 2004-04-10); LYP-2004-251 (Seobseom, Jeju Island 2004-04-10); LYP-2004-352 (Seobseom, Jeju Island 2004-05-14); LYP-2004-353 (Seobseom, Jeju Island 2004-05-14); LYP-2005-181 (Udo, Jeju Island 2005-07-13); LYP-2005-

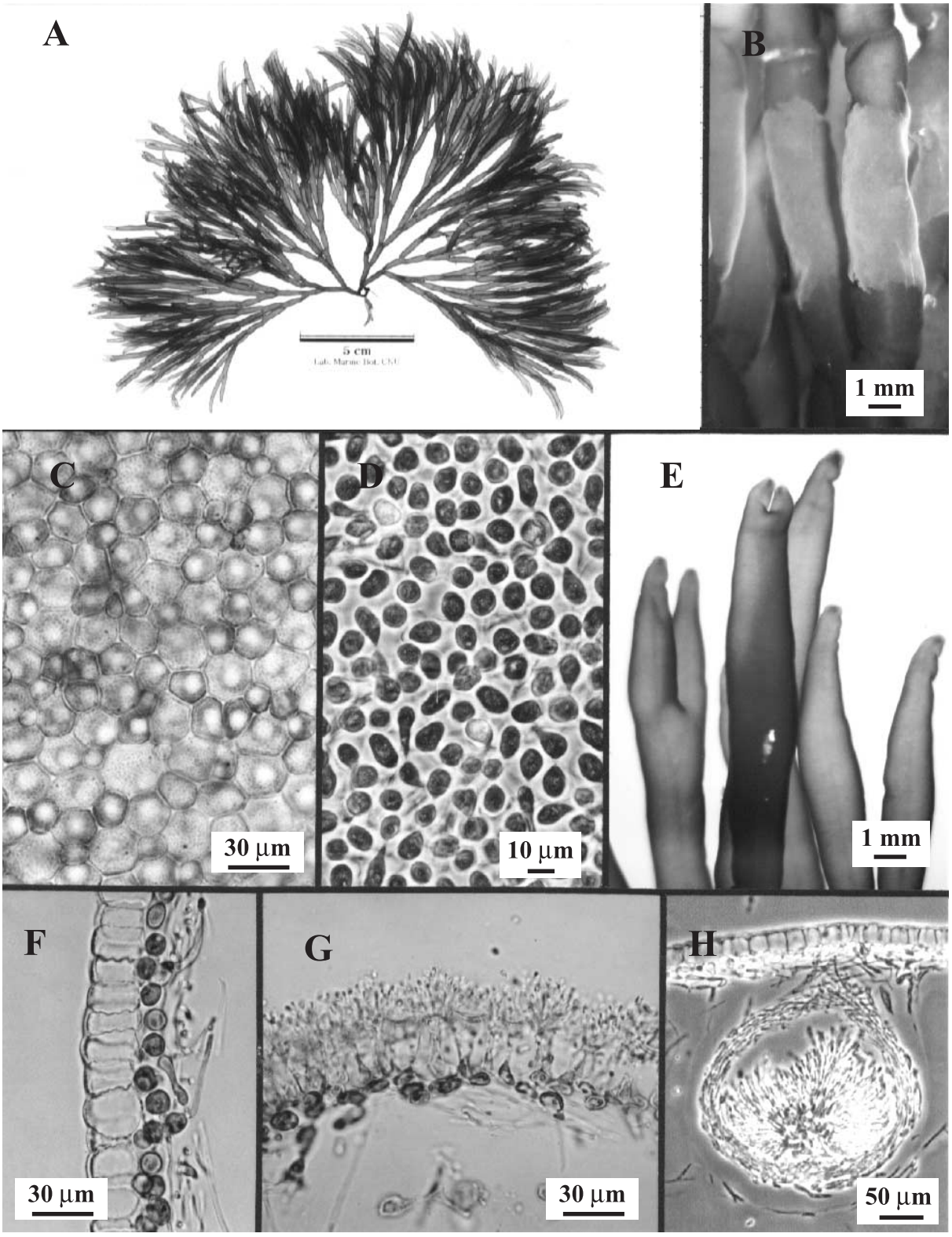

Fig. 5. *Scinaia okiensis* Kajimura. A. Thallus. B. Belt-shaped spermatangial sori on the segment of male thallus. C. Surface view of segment. D. Hypodermal cells in surface view. E. Branch apices. F. Transverse section of segment. G. Transverse section of the segment bearing spermatangial sori. H. Transverse section of segment bearing cystocarps.

182 (Udo, Jeju Island 2005-07-13); LYP-2005-228 (Seobseom, Jeju Island 2005-06-12); LYP-2006-51 (Seobseom, Jeju Island 2006-05-13); LYP-2006-48 (Seobseom, Jeju Island 2006-05-13); LYP-2006-85 (Seobseom, Jeju Island 2006-05-13).

Remarks: Kajimura (1988) distinguished *S. okiensis* from allied species on the basis of the utricle and overall thallus size. Kajimura (1988) also declared that the intercalary belt-type of spermatangial sori is critical for characterizing *S. okiensis*. The Jeju Island plants accord well with the description and figures of Kajimura (1988). However, they are larger (10-16 cm tall) than the Japanese plants (2-6 cm tall) and generally have ample branches. Consequently, the overall thallus size is ineffective for distinguishing *S. okiensis*. *Scinaia okiensis* is characterized by the flaccid texture, furcated in three dimensions, ample branches in unequal height, pointed branch apices, and belt-shaped spermatangial sori. Occasionally, the branch apices of some Jeju Island plants are hooked.

***Scinaia confusa* (Setchell) Huisman 1985: 417.**

Fig. 6

Scinaia confusa (Setchell) Huisman 1985: 417.

Basionym: *Gloiophloea confusa* Setchell 1914: 118, pl. 14, figs. 44-47; Smith 1944: 190, pl. 42, fig. 1.

Synonyms: *Pseudogloiophloea confusa* (Setchell) Levring in Svedelius 1995: 13; Ramus 1969: 1-28; Abbott and Hollenberg 1976: 335, fig. 277.

Korean name: Alsongheuneulpul (알송흐늘풀).

Type: UC ? (Herb. University of California, USA).

Type locality: Monterey, California, USA.

Distribution: The eastern coasts of North Pacific.

Vegetative morphology: The plants (6-16 cm tall) are more or less cartilaginous, form bunches, and are red to deep red (Fig. 6A). The branches furcate dichotomously seven to ten times in three dimensions, have narrow axils, are equal in height, lack constrictions, and have rather pointed apices. The segments (1.5-2.5 mm diameter) are cylindrical and equal in diameter. The terminal segments are gradually attenuated toward the apex, and the basal segments are slightly inflated upward (Fig. 6B). The epidermal layers comprise inflated and slender utricles, hypodermal filaments, and rhizoidal filaments. The inflated utricles (25-30 μm long, 15-23 μm diameter) are globose to ellipsoid (Fig. 6D). The slender utricles (25-30 μm long, 5-10 μm diameter) are linear and have slightly swollen tips (Fig. 6D). In surface view, slender utricles surround inflated ones (Fig. 6F). The utricle outer end walls are rather thick and appear as colored caps. The hypodermal cells (15-23 μm long, 12-15 μm diameter), which are not apparent in surface view, aggregate rather densely near the inner side of the utricle palisades. Rhizoidal filaments (ca. 2.5 μm diameter) also aggregate rather densely and form the inner cortical layers. In surface view, the axial strands (250 μm diameter) can not be seen through the cortex. The radial filaments (ca. 2.5 μm diameter) are straight, rather ample, and thin walled.

Reproductive morphology: The plants are dioecious. Male plants are somewhat smaller than female plants, but are similar in morphology (Fig. 6C). The branch apices of male thalli are usually slightly bent. The spermatangial sori form on all but the lowermost segments of the thallus. The thalli bearing spermatangial sori are bright pink and distinguished from the usually deep red female thalli (Fig. 6C). The spermatangial mother cells are also linear, rise above the segment surfaces, and produce two to three spermatangia on the tips (Fig. 6E). These spermatangia (3-4 μm long, ca. 2 μm diameter) are ovoid to ellipsoid. The cystocarps (190-230 μm diameter) are globose, immersed in the medullae and have pericarps of filamentous cells (Fig. 6G). The carposporangia (13-15 μm long, 4-6 μm diameter) are cylindrical to ellipsoid.

Habitat: *Scinaia confusa* grows on the lower intertidal and subtidal rocks on the northwestern coasts of Jeju Island. This species is more abundant than the other described species on Jeju Island.

Specimens examined: LYP-2005-58 (Mureung, Jeju Island 2005-05-20); LYP-2006-43 (Sindo, Jeju Island 2006-05-1); LYP-2006-80 (Suwolbong, Jeju Island 2006-05-26); LYP-2006-142 (Mureung, Jeju Island 2006-05-23).

Remarks: The plants examined agree in all respects with the descriptions and figures of Setchell (1914). The distinguishing characteristics of this species include the cartilaginous thallus, branches of equal diameter, inflated utricles interspersed among slender utricles, and dioecism. *Scinaia confusa* plants from Jeju Island are similar to the *S. snyderae* type specimen in the overall thallus shape and surface-view arrangement of utricles (Huisman 1985: figs. 28, 33). The latter species may be conspecific with *S. confusa* (Abbott and Hollenberg 1976; Huisman 1985). *Scinaia confusa* was thought to be endemic to the North American west coast. Consequently, this is a first record of *S. confusa* on the west coast of the North Pacific.

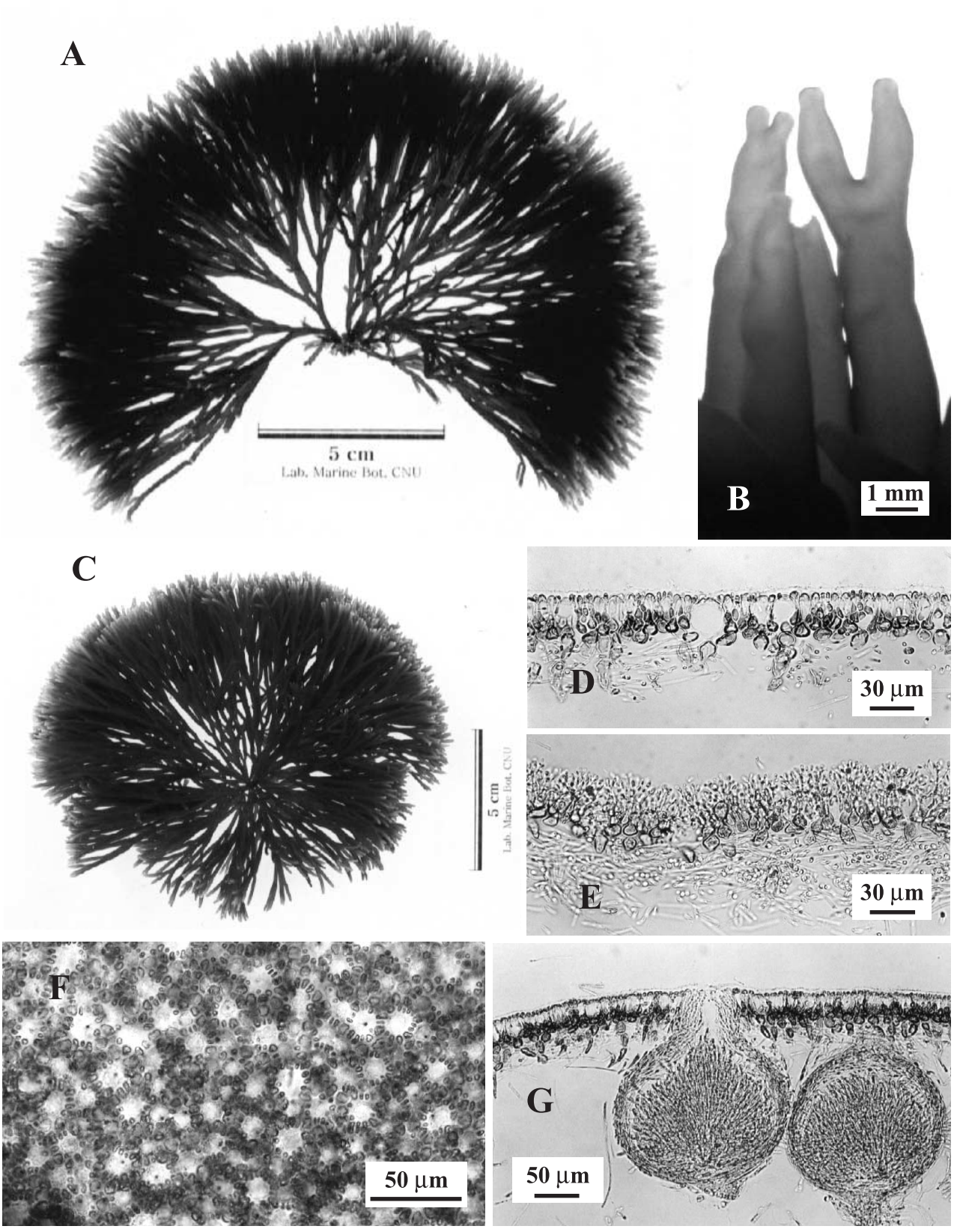

Fig. 6. *Scinaia confusa* Setchell. A. Female plant. B. Branch apices. C. Male plant. D. Transverse section of segment. E. Transverse section of the segment bearing spermatangial sori. F. Surface view of segment. G. Transverse section of the segment bearing cystocarps.

DISCUSSSION

Diverse species of *Scinaia* are abundant on Jeju Island. We collected *Scinaia cottonii* and *S. flabellata* from subtidal regions of Seobseom at depths of 15 to 18 m. *Scinaia tokidae* and *S. okiensis* occur in the subtidal regions of coastal Jeju Island. *Scinaia okamurae* and *S. confusa* are found in the lower intertidal and subtidal regions, at depths of 5 to 10 m, off the northern coasts of the island. However, we did not find the member of *S. moniliformis*-group on Jeju Island.

Setchell (1914) described *Scinaia japonica* on the basis of the specimen (Herb. Univ. Calif., No. 90835) that was collected by K. Yendo at Misaki, Bay of Tokyo, Japan, and referred to as *S. furcellata*. Setchell (1914, p. 98) wrote, "It seems also to be the same plant as the one figured by K. Okamura in his *Icones of Japanese Algae* (1907, pl. III) under *Scinaia furcellata*." Of *Gloiophloea okamurae* (as *okamurai*), Setchell (1914, p. 116) wrote, "This is not the same, however, as the *Scinaia furcellata* of his Icones of Japanese Algae (vol. 1, no. 1, p. 10, pl. 2, fig. 19, and pl. 2, figs. 16-20, 1907), which is true *Scinaia* and is referred above to *Scinaia japonica*." Accordingly, most figures of *S. furcellata* in the *Icones of Japanese Algae* (1907, pl. II, fig. 19; pl. III, figs. 16-19) represent *S. japonica* (Okamura 1936; Yoshida 1998). However, the description of *S. furcellata* by Okamura (1907, p. 12) may not refer to the type specimen of *S. japonica* (UC No. 90835). Therefore, studies of the type specimen are critical for characterizing *S. japonica*. Yoshizaki (1993) stated that *S. japonica* is dioecious, whereas Kajimura (1991) maintained, after examining the holotype (UC No. 90835), that the species is monoecious, with spermatangial sori as speckles. In the taxonomic key to the Japanese species of *Scinaia*, Yoshida (1998) classified *S. japonica* as monoecious, but stated that it was dioecious in the species description. Yoshida (1998) also described the thallus of *S. japonica* as softly membranous with viscous material (flaccid), whereas Setchell (1914) described it as cartilaginous. The *S. moniliformis*-type cortex (sensu Huisman 1986) is composed of inflated utricles, thin layers of hypodermal cells, and somewhat scanty rhizoidal filaments. The *S. forcellata*-type cortex (sensu Huisman 1986) is composed of both inflated and slender utricles, rather dense layers of hypodermal cells, and ample rhizoidal filaments. Consequently, a thallus with the *S. moniliformis*-type cortex is soft and flaccid, whereas that with a *S. forcellata*-type cortex is cartilaginous. The status of *S. japonica* needs additional study. This species was not found on Jeju Island during the course of this study. Consequently, records of *S. japonica* in Korean waters should be reappraised.

The occurrence of *S. confusa* in Korean waters supports the suggestion of Huisman (1986) that the geographical location of *Scinaia* species is ineffectual in distinguishing species. The utricles of *S. tokidae* and *S. okiensis* are scarcely distinguishable. The cortex morphology of *S. okamurae* and *S. confusa* is of no value as a determining character. Consequently, the shape and size of utricles cannot delineate *Scinaia* species. However, monoecious or dioecious character may be species-specific. Using this characteristic, *Scinaia cottonii* and *S. confusa* are easily distinguished from *S. latifrons* and *S. okamurae*, respectively. The two- or three-dimensional diverging pattern is also a useful distinguishing character (Kajimura 1991) as is the shape of the branch apex.

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