

Brown Algae from Chaojing, Keelung City, Taiwan

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Abstract. Sixteen species of brown algae (Phaeophyceae) were reported from the shore of Chaojing, Keelung, Taiwan. Among them eight species belong to the Dictyotales and two to the Fucales. Consequently, the seaweed community of Chaojing is considered as typical of subtropical one, while it has also several temperate species together. *Spatoglossum asperum*, *Ralfsia verrucosa*, *Feldmannia irregularis* and *Scytosiphon gracilis* are new records for Taiwan.

Key words: brown algae, *Feldmannia irregularis*, flora, Keelung, Phaeophyceae, *Spatoglossum asperum*, Taiwan.

Introduction

Brown algae (Phaeophyceae, Ochrophyta, kingdom Chromista) are most important botanical components of coastal marine communities, in terms of productivity and biomass. In Taiwan the marine macro-algal flora has been well investigated and published numerous reports by many algologists since Martens (1868) and there had been recorded over 500 species of marine algae from the coasts and small islands of Taiwan (Lin *et al.*, 2005). However, compared to red (Rhodophyta) and green seaweeds (Chlorophyta, both belonging to the kingdom Plantae), the species richness and distribution of the brown algae have been understudied in Taiwan. Chaojing, Keelung City, is located in the northern area of Taiwan, so close to both China and Japan. Hence, this area is under the influence of both the warm Kuroshio Current in summer and the cold China Coastal Current in winter. In 2010 we collected several specimens of brown algae from the coast of Chaojing in order to make clear its brown algal flora, which expected to be related to the algal flora of Japan. In this paper we are going to report several species for adding to the inventory of Taiwanese marine

brown algae.

Materials and Methods

The collections of brown algae were carried out at the coast of Chaojing, Keelung City, Taiwan (33°07′49″N, 139°48′24″E) on March 2, March 3, May 25, May 27 in 2010. The samples were collected from both intertidal zone and subtidal zone by walking and snorkeling. Collected specimens were fixed in 10% Formalin-seawater within 2 hours in the laboratory of the Institute of Marine Biology, National Taiwan Ocean University. Identification at the species level of both dried specimens and liquid-preserved specimens were made. Voucher specimens were deposited in the algal herbarium of the National Museum of Nature and Science (TNS). Only the specimen of *Scytosiphon* was deposited to the algal herbarium, Hokkaido University (SAP). In the present paper, orders and families were classified, according to Norris (2010) and nomenclatural treatment of species names referred mainly to Silva *et al.* (1996), Guiry & Guiry (2011), and Yoshida & Yoshinaga (2010).

Results

A list of brown algae collected from Chaojing

Class Phaeophyceae, Kjellman in
Engler et Prantl, 1891
Order Dictyotales Kjellman in Engler
et Prantl, 1896
Family Dictyotaceae J.V. Lamouroux
ex Dumortier, 1822

1. *Dictyota ceylanica* Kützting (Figs. 1, 13)

Dictyota ceylanica Kützting, Tab. Phycol. 9: 11, pl. 25, f. 1 (1859) [type locality: Sri Lanka].

Synonym: *Dictyota ceylanica* Kützting var. *anastomosans* Yamada, Sci. Pap. Inst. Algol. Res. Hokkaido Univ. 3: 186, f. 4 (1950).

Specimens examined: Chaojing, 25 May 2010 (TNS-AL 174151), 27 May 2010 (TNS-AL 174152).

Thalli are epiphytic, aggregating in dense and creeping on the branches of *Corallina*. Axes are regularly dichotomous, tapering with an apex or two apices. Blades are narrow, 240–1200 μm in width. Blade margins have adventitious laterals and often numerous rhizoids (Fig. 1, arrowheads).

Distribution: Taiwan; Pacific Ocean, Indian Ocean.

Remarks: Yamada (1950) described the new variety of the species, *Dictyota ceylanica* var. *anastomosans*, based on the plants from “Ryukyusho”, Taiwan. He regarded the “fascicles of rhizoids” for fixing themselves to each other as the important character to separate his plant as a new variety. According to De Clerck (2003), who made a monograph of *Dictyota* in the Indian Ocean, and Kraft (2009), however, *Dictyota ceylanica* has usually patches of rhizoids for attachment. Thus we could not recognize this variety, *D. ceylanica* var. *anastomosans*, as a substantial taxon under the species.

2. *Dictyota coriacea* (Holmes) I.-K. Hwang, H.-S. Kim et W.J. Lee (Fig. 14)

Glossophora coriacea Holmes, J. Linn. Soc. Bot., 31: 251 (1896) [type locality: Enoura (Odawara, Kanagawa?), Japan].

Dictyota coriacea (Holmes) I.-K. Hwang, H.-S. Kim et W.J. Lee, Algae, 19: 189 (2004).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174153), 3 Mar. 2010 (TNS-AL 174154), 25 May 2010 (TNS-AL 174155), 27 May 2010 (TNS-AL 174156).

Distribution: China, Japan, Korea, Taiwan; California, México.

3. *Padina arborescens* Holmes (Fig. 15)

Padina arborescens Holmes, Linn. J. Bot., 31: 251, pl. 12, f. 1 (1896) [type locality: Enoshima, Kanagawa, Japan].

Specimens examined: Chaojing, 3 Mar. 2010 (TNS-AL 174157), 25 May 2010 (TNS-AL 174158).

Distribution: China, Japan, Korea, Taiwan.

4. *Padina crassa* Yamada (Fig. 16)

Padina crassa Yamada, J. Fac. Sci. Hokkaido Univ. ser. V. 1: 67, pl. 17, f. 2 (1931) [type locality: Shibagaki, Noto, Ishikawa, Japan].

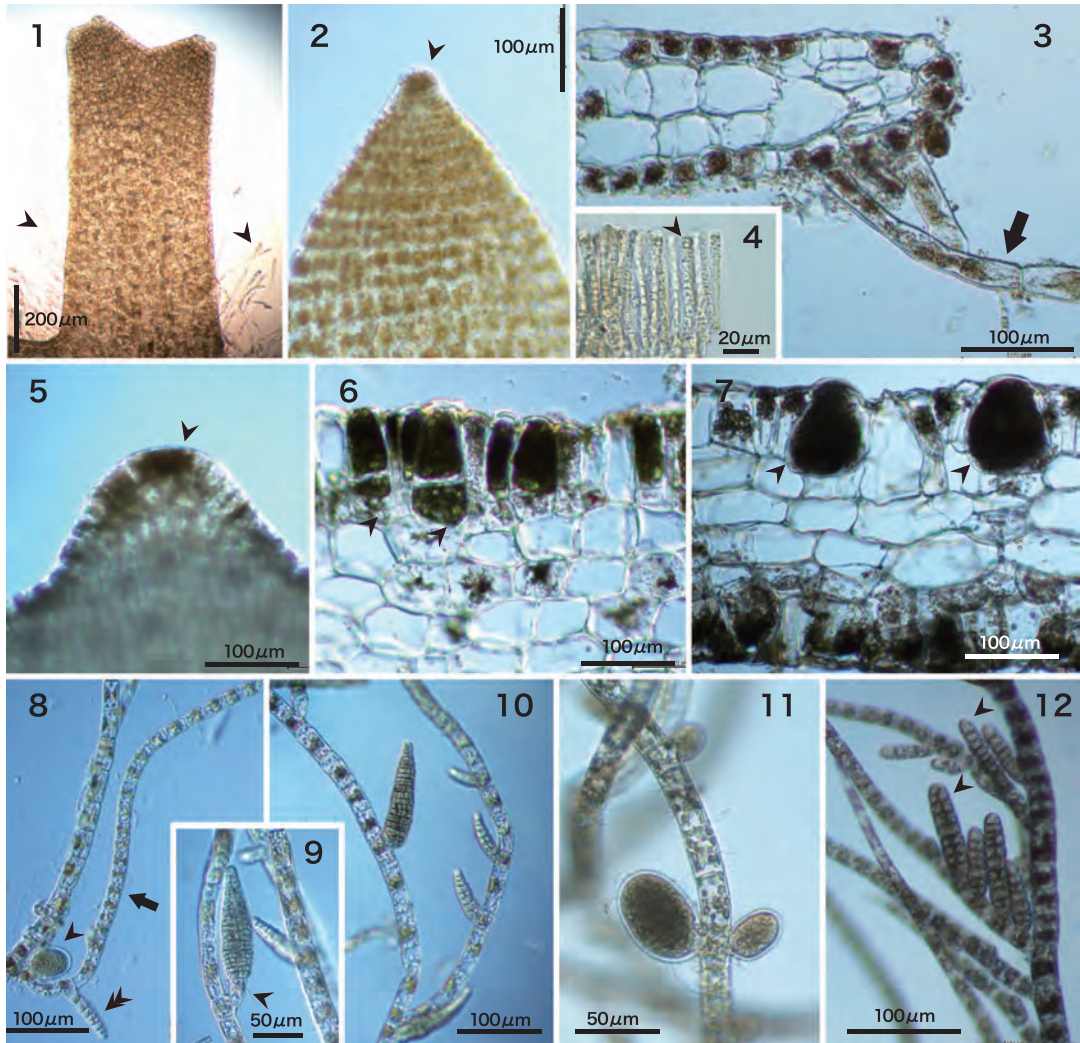
Specimens examined: Chaojing, 27 May 2010 (TNS-AL 174159, 174160).

Distribution: China, Japan, Korea, Taiwan.

The “*Vaughaniella*” stage of *Padina* species (Figs. 2, 3, 17)

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174161, 174162).

Thalli are prostrated, irregularly ramified. Blades are flat, constricted at the base, tapering to apex. Apices have an apical cell (Fig. 2, arrowhead). Cross sections show a single layer of pigmented cortical cells and a several



Figs. 1–12. Brown algae from Chaojing, Keelung (microscopic morphology). 1. *Dictyota ceylanica* (TNS-AL 174152). Lateral with numerous rhizoids (arrowheads). 2–3. *Vaughaniella* stage of *Padina* species (TNS-AL 174162). 2. Apex of blade showing an apical cell (arrowhead). 3. Transverse section of the blade with rhizoidal filaments (arrow) produced from the margin. 4. *Ralfsia verrucosa* (TNS-AL 174177). Plurilocular sporangia with single sterile cells (arrowhead). 5–7. *Spatoglossum asperum*. 5. Dentate margin of blade showing a marginal growth zone with apical cells (arrowhead) (TNS-AL 174167). 6. Transverse section of the blade of female plant showing a group of oogonia with stalk cells (arrowheads). 7. Transverse section of the blade of sporangial plant showing two mature sporangia (arrowheads). 8–11. *Feldmannia irregularis*. 8. Erect filaments with growth zone (arrow) and unilocular sporangium (arrowhead) and young plurilocular sporangium (double arrowhead) (TNS-AL 174179). 9. Plurilocular sporangium with a stalk cell (arrowhead) (TNS-AL 174179). 10. Plurilocular sporangia without a stalk cell (TNS-AL 174179). 11. Unilocular sporangia (TNS-AL 174179). 12. *Hincksia mitchellae* (TNS-AL 174182). Erect filaments with elongate-cylindrical plurilocular sporangia (arrowheads).

layered medulla of non-pigmented cells. Blade margins produce rhizoidal filaments underneath. (Fig. 3, arrow).

Remarks: Presumably the present plants are *Vaughaniella* stage of *Padina crassa* Yamada, but we need more observation on the life history of the alga.

5. *Rugulopteryx okamurae* (E.Y. Dawson)

I.-K. Hwang, W.J. Lee et H.-S. Kim

(Fig. 18)

Dilophus okamurae E.Y. Dawson, Bull. Torrey Bot. Club, 77: 86 (1950) [type locality: Nomo, Nagasaki, Japan].

Rugulopteryx okamurae (E.Y. Dawson) I.-K. Hwang, W.J. Lee et H.-S. Kim in Hwang, Lee, Kim et De Clerck, Phycologia, 48: 5, f. 1–49 (2009).

Specimens examined: Chaojing, 27 May 2010 (TNS-AL 174163, 174164).

Distribution: China, Japan, Korea, Taiwan.

6. *Spatoglossum asperum* J. Agardh

(Figs. 5–7, 19, 20)

Spatoglossum asperum J. Agardh, Acta Univ. Lund. 29: 36 (1894) [type locality: Sri Lanka (Silva *et al.* 1996)].

Synonym: *Spatoglossum pacifica* auct. formosan.

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174165, 174166), 3 Mar. 2010 (TNS-AL 174167), 25 May 2010 (TNS-AL 174168, 174169).

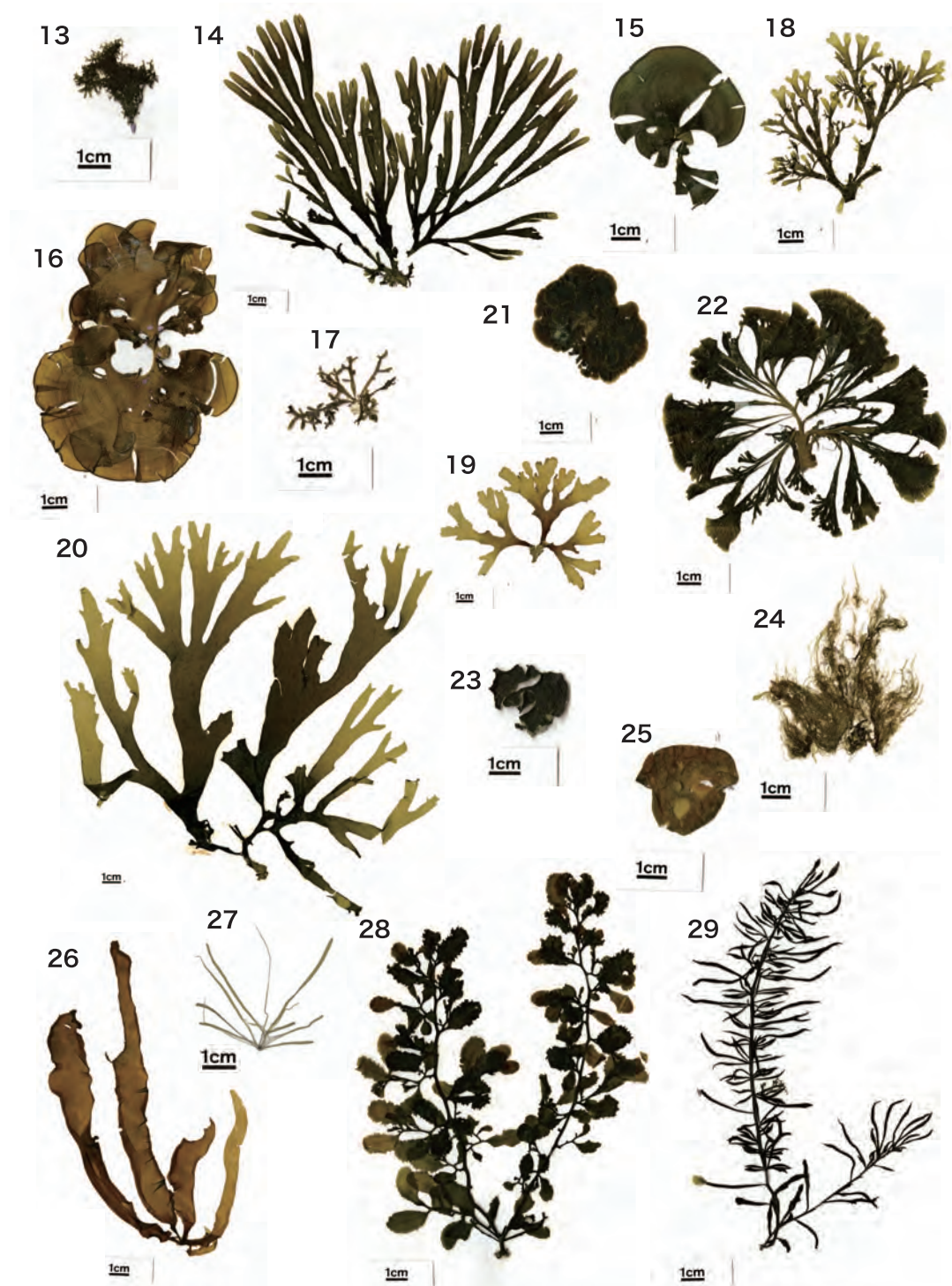
Thalli are erect, up to 22 cm in height, epilithic, growing on the subtidal rocks. Fronds are flattened, having a stipe with a holdfast matted with rhizoids, branched subdichotomously or irregularly. Color of the

fronds is brown, but changes into dark green or black after death. Blades are broadening from their base upwards, irregular in shape when young (Fig. 19), linear or strap-like when mature (Fig. 20), 0.4–2.8 cm in width, having a group of apical cells at each apex, lacking entirely midribs. Margins of the blades are entire or dentate with several apical cells (Fig. 5, arrowhead). In transverse view, the blades are 120–360 μm in thickness, composed of cortex of single cell layer and medulla of 2–5 cell layer. Cortical cells are roundly quadrangular, 15–40 μm in width. Phaeophycean hair tufts are scattered on surface of the thalli. Oogonia are cylindrical, 34–60 μm in width, with a stalk cell, clustered, embedded in the cortical layers (Fig. 6). Sporangia are conical to globular, 62–96 μm in width, embedded in the cortical layers, without stalk cells (Fig. 7).

Distribution: Japan, Philippines, Taiwan; Australia, French Polynesia, New Caledonia, India, Pakistan, Sri Lanka, Yemen, Oman, Kenya, Madagascar, Mauritius, Tanzania (see Kitayama 2011).

Remarks: In Taiwan, the *Spatoglossum*-like plants have been regarded as “*Spatoglossum pacificum* Yendo”, which was originally described by Yendo (1920) in Japan. However, this species was transferred recently to the genus *Dictyopteris* as *D. pacifica* (Yendo) I.-K. Hwang, H.-S. Kim et W. J. Lee based on the materials from Korea (Hwang *et al.* 2004). The genus *Spatoglossum* is distinguished from the genus *Dictyopteris* in having embedded gametangia and sporangia in cortical layers, lacking midrib (even the lowermost portion of

Figs. 13–29. Brown algae from Chaojing, Keelung (dried specimens). 13. *Dictyota ceylanica* (TNS-AL 174152). 14. *Dictyota coriacea* (TNS-AL 174155). 15. *Padina arborescens* (TNS-AL 174157). 16. *Padina crassa* (TNS-AL 174159). 17. “*Vaughaniella*” stage of *Padina* species (TNS-AL 174161). 18. *Rugulopteryx okamurae* (TNS-AL 174163). 19–20. *Spatoglossum asperum*. 19. Young plant (TNS-AL 174165). 20. Old plant (TNS-AL 174168). 21. *Zonaria diesingiana* (TNS-AL 174173). 22. *Zonaria* sp. (TNS-AL 174174). 23. *Ralfsia verrucosa* (TNS-AL 174184). 24. *Hinckesia mitchellae* (TNS-AL 174181). 25. *Colpomenia sinuosa* (TNS-AL 174184). 26. *Petalonia binghamiae* (TNS-AL 174187). 27. *Scytosiphon gracilis* (SAP). 28. *Sargassum cristaefolium* (TNS-AL 174192). 29. *Sargassum fusiforme* (TNS-AL 174196).



thalli), changing color of the thalli after death. The plants from Chaojing have no these characters for *Dictyopteris* and are similar to the *Spatoglossum asperum* in both the vegetative and reproductive morphology. The algae identified as “*S. pacifica*” so far are considered to be as *S. asperum*, not *Dictyopteris pacifica*. *S. asperum* is different from other Asian species of *Spatoglossum* in having dentate margin, tufts of phaeophycean hairs, spherical sporangia without stalk cells (Kitayama 2011). Thus we use this name for the plants tentatively, though the taxonomy of species under the genus is still unsolved and it is required more researches on the relationship with the other closely related species of the *Spatoglossum*: *S. macrodontum* J. Agardh (1882), *S. vietnamense* Pham-Hoàng Hô (1969), *S. dichotomum* C. K. Tseng et Lu in C. K. Tseng (1983), *S. latum* J. Tanaka (1992), etc.

7. *Zonaria diesingiana* J. Agardh
(Fig. 21)

Zonaria diesingiana J. Agardh, *Linnaea*, **15**: 443 (1841)
[type locality: Australia].

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174170, 174171), 3 Mar. 2010 (TNS-AL 174172), 25 May 2010 (TNS-AL 174173), 27 May 2010 (TNS-AL 174175).

Distribution: China, Japan, Korea, Philippines, Taiwan; Australia.

8. *Zonaria* sp.
(Fig. 22)

Specimens examined: Chaojing, 25 May 2010 (TNS-AL 174174, 174176).

Distribution: Taiwan.

Remarks: This species is now under investigation.

Order Ralfsiales Nakamura ex Lim et Kawai in
Lim *et al.*, 2007
Family Ralfsiaceae Farlow, 1881

9. *Ralfsia verrucosa* (Areschoug) Areschoug
(Figs. 4, 23)

Cruoria verrucosa Areschoug, *Linnaea*, **17**: 264. pl. 9. f. 5, 6 (1845) [type locality: Bahusia, Norway].

Ralfsia verrucosa (Areschoug) Areschoug, *Nova Acta Reg. Soc. Sci. Upsal.* ser. 2, **13**: 362 (1847).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174177), 25 May 2010 (TNS-AL 174178).

Thalli are crustose, forming numerous uniseriate plurilocular sporangia with a single terminal sterile cell (Fig. 4, arrowhead).

Distribution: China, Japan, Korea, Taiwan; Atlantic Ocean.

Remarks: This species is a new record in Taiwan.

Order Ectocarpales Setchell et N. L. Gardner,
1922

Family Acinetosporaceae Hamel
ex J. Feldmann, 1937

10. *Feldmannia irregularis* (Kützinger)
G. Hamel
(Figs. 8–11)

Ectocarpus irregularis Kützinger, *Phycologia Germanica*: 234 (1845) [type locality: Adriatic Sea].

Feldmannia irregularis (Kützinger) G. Hamel, *Pheophycees de France*. Fasc. V: xvii, f. 61 (1939).

Specimens examined: Chaojing, 25 May 2010 (TNS-AL 174179, 174180).

Thalli are minute, epiphytic, tufted erectly or prostrate on the surface of blade of *Spatoglossum asperum* or *Sargassum fusiforme*. They are filamentous, branched irregularly and have intercalary meristematic zones each at the base of the ultimate branches. Filaments are straight or curved, uniseriate, 10–22 μm in diameter. The cells contain many discoid chloroplasts. Plants have both plurilocular sporangia and unilocular sporangia (Fig. 8). Plurilocular sporangia are pedicellate (Fig. 9) or sessile (Fig. 10), usually conical, with an acute apex, 20–34 μm in width. Unilocular sporangia are sessile or pedicellate, usually ovoid, 25–52 μm in width (Fig. 11).

Distribution: Japan, Korea, Taiwan; Cosmo-

politan.

Remarks: This species is a new record in Taiwan.

11. *Hincksia mitchellae* (Harvey) P. C. Silva
(Figs. 12, 24)

Ectocarpus mitchellae Harvey, Smithon. Contr. Knowl., 3: 143. pl. 12G. (1852) [type locality: Nantucket, Massachusetts, U.S.A.].

Hincksia mitchellae (Harvey) P. C. Silva in P. C. Silva, Meñez et Moe, Smithon. Contr. Marine Science, 27: 73 (1987).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174181, 174182).

Distribution: China, Japan, Korea, Taiwan; Cosmopolitan.

Order Scytosiphonales J. Feldmann, 1949
Family Scytosiphonaceae Farlow, 1881

12. *Colpomenia sinuosa* (Mertens ex Roth)
Derbès et Solier
(Fig. 25)

Ulva sinuosa Mertens ex Roth, Catalecta botanica, 3: 327, pl. 12, f. a (1806) [type locality: near Cádiz, Spain].

Colpomenia sinuosa (Mertens ex Roth) Derbès et Solier in Castagne, Supplément au catalogue des plantes qui croissant naturellement ...: 95 (1851).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174183), 25 May 2010 (TNS-AL 174184, 174185), 27 May 2010 (TNS-AL 174186).

Distribution: Cosmopolitan.

13. *Petalonia binghamiae* (J. Agardh)
K. L. Vinogradova
(Fig. 26)

Endarachne binghamiae J. Agardh, Acta Reg. Soc. Physiogr. Lund, 7: 27 (1896) [type locality: California, U.S.A.].

Petalonia binghamiae (J. Agardh) K. L. Vinogradova, Nov. Syst. Plant. Non Vasc., 10: 31 (1973).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174187, 174188)

Distribution: China, Japan, Korea, Taiwan;

California, México, Australia.

14. *Scytosiphon gracilis* Kogame
(Fig. 27)

Scytosiphon gracilis Kogame, Phycological Research, 46: 40, f. 2–28 (1998) [type locality: Ohma, Aomori, Japan].

Specimens examined: Chaojing, 3 Mar. 2010 (SAP).

Thalli are erect, slender, without constriction.

Distribution: Japan, Taiwan; México, Chile.

Remarks: This species is a new record in Taiwan.

Order Fucales Kylin, 1917
Family Sargassaceae Kützinger, 1843

15. *Sargassum cristaefolium* C. Agardh
(Fig. 28)

Sargassum cristaefolium C. Agardh, Species algarum ..., 1: 13 (1820) [type locality: "Ceylon", Sri Lanka].

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174189, 174190), 3 Mar. 2010 (TNS-AL 174191), 25 May 2010 (TNS-AL 174192, 174193), 27 May 2010 (TNS-AL 174194, 174195).

Distribution: China, Japan, Taiwan; Indian Ocean, South Pacific.

16. *Sargassum fusiforme*
(Harvey) Setchell
(Fig. 29)

Cystophyllum fusiforme Harvey, Proc. Amer. Acad. Arts & Sci., 4: 328 (1860) [type locality: Shimoda, Shizuoka, Japan].

Sargassum fusiforme (Harvey) Setchell, Hong Kong Naturalist, 2: 248 (1931).

Specimens examined: Chaojing, 2 Mar. 2010 (TNS-AL 174196, 174197), 27 May 2010 (TNS-AL 174198).

Distribution: China, Japan, Korea, Taiwan.

Remarks: This species was recorded recently by Huang (2003). There is a possibility of that

the plants of the species was introduced from Japan by ship.

Discussion

Sixteen species of brown algae were reported from the coast of Chaojing, Keelung. Eight species belong to the Dictyotales and two to the Fucales, while no kelp species (Laminariales) was observed. Consequently, the seaweed community of Chaojing is considered as subtropical one. On the other hand, brown algal flora of this area contains the temperate elements: *Padina arborescens*, *Petalonia binghamiae*, *Scytosiphon gracilis*, *Sargassum fusiforme*, etc. This result supports Huang (1999)'s hypothesis, that the cold China Coastal Current caused unusual distribution of several temperate algae in the northern Taiwan, while there is also a possibility of accidentally introduction of these temperate brown algal species from China or Japan by ship. The present materials were collected only March and May on the same year, thus more research is required in order to characterize the present brown algal flora of northern Taiwan. After the enough investigation in this area, we will make an inventory of the brown algae in Chaojing, Keelung, adding the previous records by many researchers in Taiwan.

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Region" of the National Museum of Nature and Science.

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台湾基隆市潮境の褐藻類

北山太樹・林 綉美

2010年3月と5月に台湾基隆市潮境の海岸の褐藻相を調査した結果、5科16種が確認された。そのうちアミジグサ目が8種、ヒバマタ目が2種で、基本的に亜熱帯の海藻相の特徴を示したが、*Sargassum fusiforme* (Harvey) Setchell ヒジキ (ホンダワラ科) など若干の温帯性種もみられた。*Spatoglossum asperum* J. Agardh モンナシグサ (アミジグサ科), *Feldomania irregularis* (Kützting) G. Hamel ミルシオミドロ (アキネトスポラ科), *Ralfsia verrucosa* (Areschoug) Areschoug イソイワタケ (イソガワラ科), *Scytosiphon gracilis* Kogame ウスカヤモ (カヤモノリ科) は台湾新記録となる。