

New records of three marine red algae from Japan

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SUMMARY

Three species in the red algal order Ceramiales, *Dasya longifila* Masuda et Uwai (Dasyaceae), *Endosiphonia horrida* (C. Agardh) P. Silva (Rhodomelaceae) and *Laurencia flexilis* Setchell (Rhodomelaceae), are reported from Japan for the first time, and their morphological features are described along with taxonomic comments. Our findings point to the northernmost limit of geographic distribution of these species in the north-western Pacific. *Dasya longifila* is characterized by small, sparsely corticated axes, long pseudolaterals in which intercalary cell divisions take place, and a small number of tetrasporangial stichidia and spermatangial branches per fertile pseudolateral. *Endosiphonia horrida* is characterized by frequently anastomosing branches that form a bush-like tuft without a percurrent axis, inner cortical cells becoming the same length as the axial and periaxial cells, and luxuriously developed, unbranched trichoblasts. *Laurencia flexilis* is characterized by numerous cartilaginous rigid axes developing from a basal disc without creeping branches, the production of 4 periaxial cells per vegetative segment and the absence of longitudinally oriented secondary pit-connections between contiguous superficial cortical cells.

Key words: *Dasya longifila*, *Endosiphonia horrida*, Japan, *Laurencia flexilis*, Rhodophyta, taxonomy.

INTRODUCTION

The marine benthic algal flora in Japanese waters are well studied, with 1489 species (953 of Rhodophyceae, 230 of Chlorophyceae and 306 of Phaeophyceae) enumerated from this region (Yoshida *et al.* 2000). However, further investigations are necessary to confirm the taxonomic status of some taxa (Yoshida 1998). Additional species, including newly described ones, continue to be reported from the region, especially members of poorly studied genera in Japan, such as *Peyssonnelia* (Kato & Masuda 2002, 2003) in the Peyssonneliaceae, *Chondria* (Tani & Masuda 2003) and *Herposiphonia* (Masuda & Shimada 2003) in the Rhodomelaceae. In addition, molecular phylogenetic studies have revealed the presence of 'cryptic' species

or synonyms in taxonomically difficult groups, which are a result, in part, of the high degree of morphological variation within individual species, such as *Polyopes* (Kawaguchi *et al.* 2003) in the Halymeniaceae, *Ulva* (Hiraoka *et al.* 2004) in the Ulvaceae and *Elachista* (Uwai *et al.* 2000) in the Elachistaceae.

Our recent field surveys along the coasts of the Ryukyu Islands and the Bonin Islands, which are included in the tropical region in the North Pacific, as defined by Michanek (1979), revealed the presence of three species in the Ceramiales (Rhodophyta): *Dasya longifila* Masuda et Uwai (Dasyaceae), *Endosiphonia horrida* (C. Agardh) P. Silva (Rhodomelaceae), and *Laurencia flexilis* Setchell (Rhodomelaceae), which were hitherto unknown in Japanese waters.

MATERIALS AND METHODS

Specimens collected were initially fixed in 10% formalin in seawater, and some were dried later as voucher herbarium specimens or mounted in 30% Karo corn syrup on microscope slides, which are deposited in the Herbarium of the Graduate School of Science, Hokkaido University, Sapporo (SAP). Sections were made by hand using a razor blade and pith stick. These were then stained with 0.5% (w/v) cotton blue in a lactic acid/phenol/glycerol/water (1:1:1:1 (v/v)) solution and mounted in 30% Karo corn syrup on microscope slides.

RESULTS AND DISCUSSION

Dasya longifila Masuda et Uwai (in Masuda *et al.* 2003: 247, figs 17–24)

Japanese name: Nagage-dajia (new name).

Type locality: Pantai Layang Layangan, Pulau Labuan, Sabah, Malaysia.

Geographical distribution: Tropical regions in the North Pacific Ocean (Masuda *et al.* 2003).

Specimens examined: Toyohara (24°16'05"N, 123°50'40"E), Iriomote Island, Okinawa Prefecture,

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9.v.2001, *leg.* M. Masuda, spermatangial (SAP 097825); 27.iii. 2005, *leg.* M. Masuda, vegetative (SAP 097826), tetrasporangial (SAP 097827, 097828), spermatangial (SAP 097829, 097830), cystocarpic (SAP 097831). Kondo-hama (24°19'32"N, 124°04'32"E), Taketomi Island, Okinawa Prefecture, 23.iii.2004, *leg.* M. Masuda, vegetative (SAP 097834).

Morphology

Thalli grow solitarily on stipes or leaves of the brown alga *Hormophysa cuneiformis* (J. Gmelin) P. Silva and stalks of the green alga *Acetabularia ryukyuensis* Okamura et Yamada, both of which inhabit the upper subtidal zone in reef flats.

The thalli are pink in color and soft and fleshy in texture. Individual thalli consist of 4–8, terete, erect (sometimes decumbent) axes that arise from a discoid holdfast 0.5–1.5 mm in diameter and bear numerous pseudolaterals (Fig. 1). Erect axes possess 5 periaxial cells per segment (Figs 2,3). Reproductive axes are 2–17 mm high and 200–400 µm in diameter just above the holdfast, becoming gradually narrower upwards (sometimes that diameter is retained to the middle portion) to 150–300 µm in diameter (their segments being 0.7–1.1 diameters long) at the middle portion and decreasing to 40–50 µm below the apices. These axes are discontinuously corticated by descending rhizoidal filaments in the middle to lower portions of the axis; the lower regions of older axes are entirely corticated by a single layer or sometimes two layers of cells (Fig. 3).

Well-developed axes usually form 2–4, polysiphonous branches 1–6 mm long, which replace pseudolaterals. These axes sometimes form adventitious polysiphonous branches in the lower portion. One or 2 lower branches sometimes become prostrate branches that are attached to the substratum by rhizoidal attachments (modified from pseudolaterals) and issue secondary erect axes.

Pseudolaterals develop singly (occasionally two) from each segment of the axis and branches and reach up to 6 mm long. They are monosiphonous and are subdichotomously branched three to six times, and their branching intervals become conspicuously longer from the proximal portion towards the mid-portion (from 1 to 3 segments to 4–18 or more segments). Ultimate-order ramuli of these pseudolaterals are 0.4–5.8 mm long and consist of 14–185 cells. These cells are 15–100 µm long (length : diameter ratio of 0.8–7.8). This wide range of variation is a result of the presence or absence of intercalary cell divisions in pseudolaterals (Fig. 4): just after intercalary divisions the cells are much shorter than cells in which such divisions do not take place. Intercalary divisions are found in well-grown pseudolaterals (except old ones that are devoid of distal

portions) rather than young pseudolaterals. The cells after intercalary divisions might become elongate. The pseudolaterals are straight and gradually taper from 45–60 µm proximally to 7–12 µm terminally. Adventitious monosiphonous filaments are sometimes formed from cortical cells of the lower axis and are narrower than pseudolaterals.

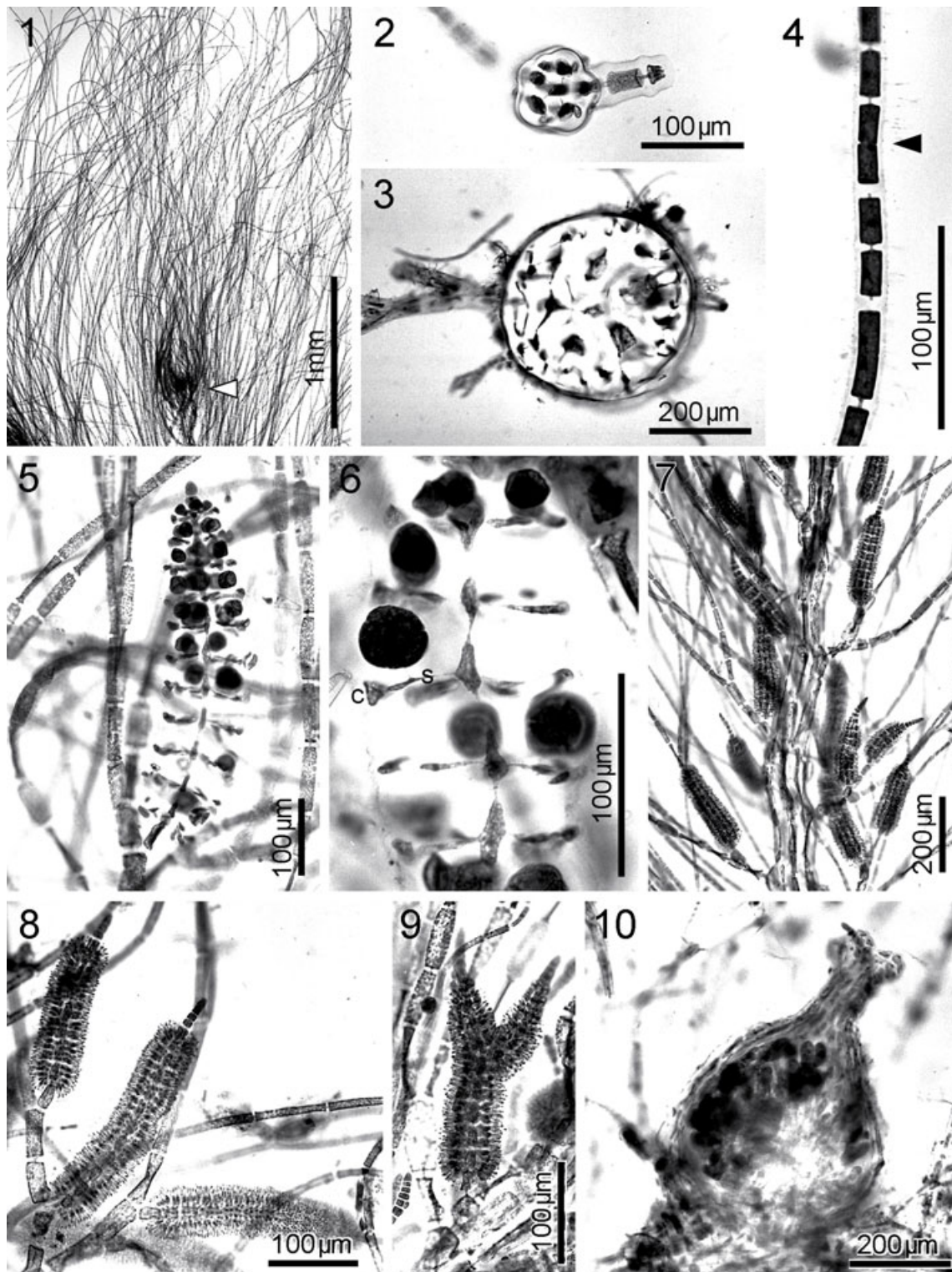
Tetrasporangial stichidia develop on the second or third (rarely fourth) subdichotomy of fertile pseudolaterals. The stichidia are usually formed, with 1 (occasionally 2) per pseudolateral. They are conical, with a 1-celled (sometimes 2-celled) monosiphonous pedicel (Fig. 5) (rarely sessile), with a 2–6-celled uniseriate sterile tip 20–70 µm long. The fertile portions are 250–700 µm long by 120–140 µm wide and consist of 7–20 segments. Each fertile segment bears 5 sporangia, each of which is provided with 2 undivided cover cells that are not palisade-like and expose most of the sporangium (Figs 5,6). Tetrasporangia reach 40–50 µm in diameter at maturity. The fertile pseudolaterals are subdichotomously forked three to five times, and their branching intervals become conspicuously longer towards the mid-portion (from 1 to 3 segments to 6–12 segments).

Spermatangial branches develop singly on the second or third (occasionally first or fourth) subdichotomy of pseudolaterals (Fig. 7). The spermatangial branches are formed, usually singly, with sometimes 2 or 3 per pseudolateral (Figs 7,8). These spermatangial branches possess 1-celled (rarely two-celled) pedicels; sometimes they are sessile. The fertile portions are terete, 160–400 µm long by 65–80 µm wide and consist of 8–15 segments with a 3- to 22-celled uniseriate sterile tip (up to 750 µm long). In rare cases, spermatangial branches are once divided at the proximal or distal portion (Fig. 9). The fertile pseudolaterals are subdichotomously branched three to five times, and their branching intervals become slightly longer towards the mid-portion (from 1 or 2 segments to 3–5 segments).

Cystocarps are lateral and sessile on the bearing axis and branches. They are urceolate, 600–750 µm high (including necks that are 200–350 µm high and 140–300 µm wide) by 500–650 µm wide when mature (Fig. 10).

Taxonomic remarks

There is a wide range in overall sizes of thalli of *Dasya* species from minute species with erect axes of approximately 2 cm (such as *Dasya kristeniae* Abbott (1999)) to large species with maximum lengths reaching 2 m (such as *Dasya hapalathrix* Harvey (Parsons & Womersley 1998)). The axis dimension is generally a critical taxonomic feature, although it must be used with caution depending on species. Some species have been reported to possess very variable lengths of fertile axes (e.g. *Dasya clavigera* (Womersley) Parsons with axes



Figs 1–10. *Dasya longifila*. 1. Uppermost portion of an axis: arrowhead indicates the apical region. 2. Transverse section (TS) of the middle portion of an axis. 3. TS of the lower portion of an axis. 4. Intercalary division (arrowhead) of a cell of a pseudolateral. 5. Tetrasporangial stichidium. 6. Close-up of a tetrasporangial stichidium. c, cover cell (one of 2 cover cells being out of focus); s, stalk cell connecting with a tetrasporangium. 7. Middle portion of an axis with fertile pseudolaterals bearing spermatangial branches. 8. Three spermatangial branches on a single pseudolateral. 9. Distally divided spermatangial branch. 10. Mature cystocarp.

Table 1. A morphological comparison of Malaysian and Japanese *Dasya longifila*

	Malaysia	Japan
Dimension of axes (height by diameter)	1.5–6.0 mm by 100–350 µm	2–17 mm by 150–400 µm
Length : diameter ratio of segments of axes	0.4–1.0	0.7–1.1
Pseudolaterals (length by diameter)	Up to 10 mm by 40–65 µm proximally to 10–15 µm terminally	Up to 6 mm by 45–60 µm proximally to 7–12 µm terminally
Intercalary cells divisions in pseudolaterals	Present	Present
Cell length of pseudolaterals (length : diameter ratio)	15–100 µm (1–4)	15–100 µm (0.8–7.8)
Number of tetrasporangial stichidia per pseudolateral	1 (occasionally 2)	1 (occasionally 2)
Fertile portions of tetrasporangial stichidia (length by diameter)	350–680 µm by 110–130 µm	250–700 µm by 120–140 µm
Number of tetrasporangia per fertile segment	5	5
Number of tetrasporangial cover cells	2	2
Palisade-like tetrasporangial cover cells	Absent	Absent
Number of spermatangial branches per pseudolateral	1	1 (sometimes 2 or 3)
Fertile portions of spermatangial branches (length by diameter)	150–450 µm by 60–80 µm	160–400 µm by 65–80 µm
Shape of cystocarps	Urceolate	Urceolate
Dimension of cystocarps (height by diameter)	700–750 µm by 380–450 µm	600–750 µm by 500–650 µm
Reference	Masuda <i>et al.</i> (2003)	Present paper

from 1 to 60 cm high (Parsons & Womersley 1998). Small-statured species of *Dasya* with sparsely corticated axes are compared by Masuda *et al.* (2003). Our alga under study are most similar to *D. longifila* described from Sabah, Malaysia and characterized by the long pseudolaterals (often longer than the axis) in which intercalary cell divisions take place and a small number of tetrasporangial stichidia and spermatangial branches per fertile pseudolateral (Masuda *et al.* 2003). Our material agrees with the Malaysian collection, including type material deposited in SAP except for a few differences (Table 1). Our specimens have slightly larger and thicker axes than the type collection, but their ranges overlap with each other. Pseudolaterals of our specimens are slightly shorter than those of Malaysian material. Furthermore, the length : diameter ratio of cells in our specimens is larger than that of Malaysian material. This might be a result of more frequent intercalary cell divisions in Malaysian material. Mature cystocarps of our material are slightly wider than those of Malaysian specimens, which do not reach maturity. These minor differences are insufficient to recognize two distinct infraspecific taxa.

In Japan the following 5 species and 1 variety of *Dasya* are known: *Dasya collabens* Hooker et Harvey, *Dasya minor* Noda, *Dasya rigidula* (Kützinger) Ardissonne var. *okiensis* Kajimura, *Dasya scoparia* Harvey ex J. Agardh, *Dasya sessilis* Yamada and *Dasya villosa* Harvey (Kajimura 1998; Yoshida *et al.* 2000). Among these taxa *Dasya minor* is most similar to *D. longifila*, but is distinguished by the great number (at least 10) of spermatangial branches per pseudolateral and narrower (up to 36 µm) spermatangial branches (Noda & Kitami

1971). The number of spermatangial branches per pseudolateral is a significant taxonomic feature, as pointed out in a previous paper (Masuda *et al.* 2003). Although the length of spermatangial branches shows a wide range of variation in each species of *Dasya*, the width does not show such variation and is taxonomically more significant (Masuda *et al.* 2003). Similarly, the number of tetrasporangial stichidia per pseudolateral and their length are significant taxonomic features (Masuda *et al.* 2003). An illustration of *D. minor* (Noda & Kitami 1971; fig. 13.2) indicates the production of a single tetrasporangial stichidium on each pseudolateral as in the case of *D. longifila*. However, their width is narrower (107–114 µm) than that of *D. longifila*.

Endosiphonia horrida (C. Agardh) P. Silva (in Silva *et al.* 1996: 494)

Japanese name: Kakurekudanori (new name).

Basionym: *Sphaerococcus horridus* C. Agardh (1822: 322)

Type locality: Mauritius. *Homotypic synonyms*: *Gigartina horrida* (C. Agardh) Greville (1830: lix); *Hypnea horrida* (C. Agardh) J. Agardh (1847: 14)

Heterotypic synonym: *Endosiphonia clavigera* Falkenberg (1901: 568–571) (type locality: Madagascar).

Geographical distribution: Tropical regions in the North Pacific Ocean (Tseng *et al.* 1983, as *E. clavigera*) and in the Indian Ocean (Silva *et al.* 1996).

Specimens examined: Kabira (24°28'26"N, 124°07'20"E), Ishigaki Island, Okinawa Prefecture, 24.iii.2005, leg. M. Masuda and M. Tani, tetrasporangial (SAP 097835).

Morphology

Plants grow on dead coral in the lower intertidal zone of reef flats. They are attached to the substratum by a primary discoid holdfast and prostrate branches that bear secondary holdfasts. A single thallus consists of several terete axes, which are 1.4–1.8 mm in diameter in the lower portion and gradually become slender upwards, reaching 700–900 μm in the upper portion; however, these axes are not percurrent (Fig. 11) and it is virtually impossible to distinguish the axes without injuring the thallus. Axes are much branched in an irregularly radial manner and bear progressively shorter and narrower branches up to seven orders. However, short spine-like determinate branchlets 300–500 μm long and 250–350 μm wide are sporadically present on the axis and branches of any order (Fig. 12). Indeterminate branches anastomose frequently and form a purplish-brown, cartilaginous, bush-like tuft 10–18 cm in diameter and 3–5 cm in height.

Internally, the axis and branches are composed of an axial cell and 4 periaxial cells per segment (Fig. 13) and a variously developed cortex depending on the thallus position: 6–8 layers in the lower axis and 2 or 3 layers in the upper axis and branches. Cells of the inner layers of the cortex (2 or 3 in the lower axis (Figs 14) and 1 in the upper axis and branches (Fig. 15)) are longer than those of the outer layers, becoming as long as the axial and periaxial cells.

Deciduous vegetative trichoblasts are formed on the distal portion of young branches (Fig. 16), usually in a spiral manner. They are also formed adventitiously in a small group or solitarily from the surface cells (the outermost cortical cells) of branches of any order (Figs 17–20). All ordinary and adventitious trichoblasts are unbranched and consist of 6–9 segments. Development of trichoblasts can be summarized as follows. After formation of 6–9 segments composed of short, barrel-shaped, lightly colored cells (Fig. 17), the elongation begins from the distal cells of the trichoblasts (Fig. 18) and successively descends to the proximal cells (Figs 19 and 20). Full-grown trichoblasts (Fig. 21) become paler in color and are 2–3 mm in length and 15–35 μm in diameter, with a distinct narrow proximal segment 5–10 μm in diameter (Fig. 22). The segments are much elongated and 400–600 μm long (length : diameter ratio of 15–28), except for the 30–50 μm long proximal segment (length : diameter ratio of 3–10).

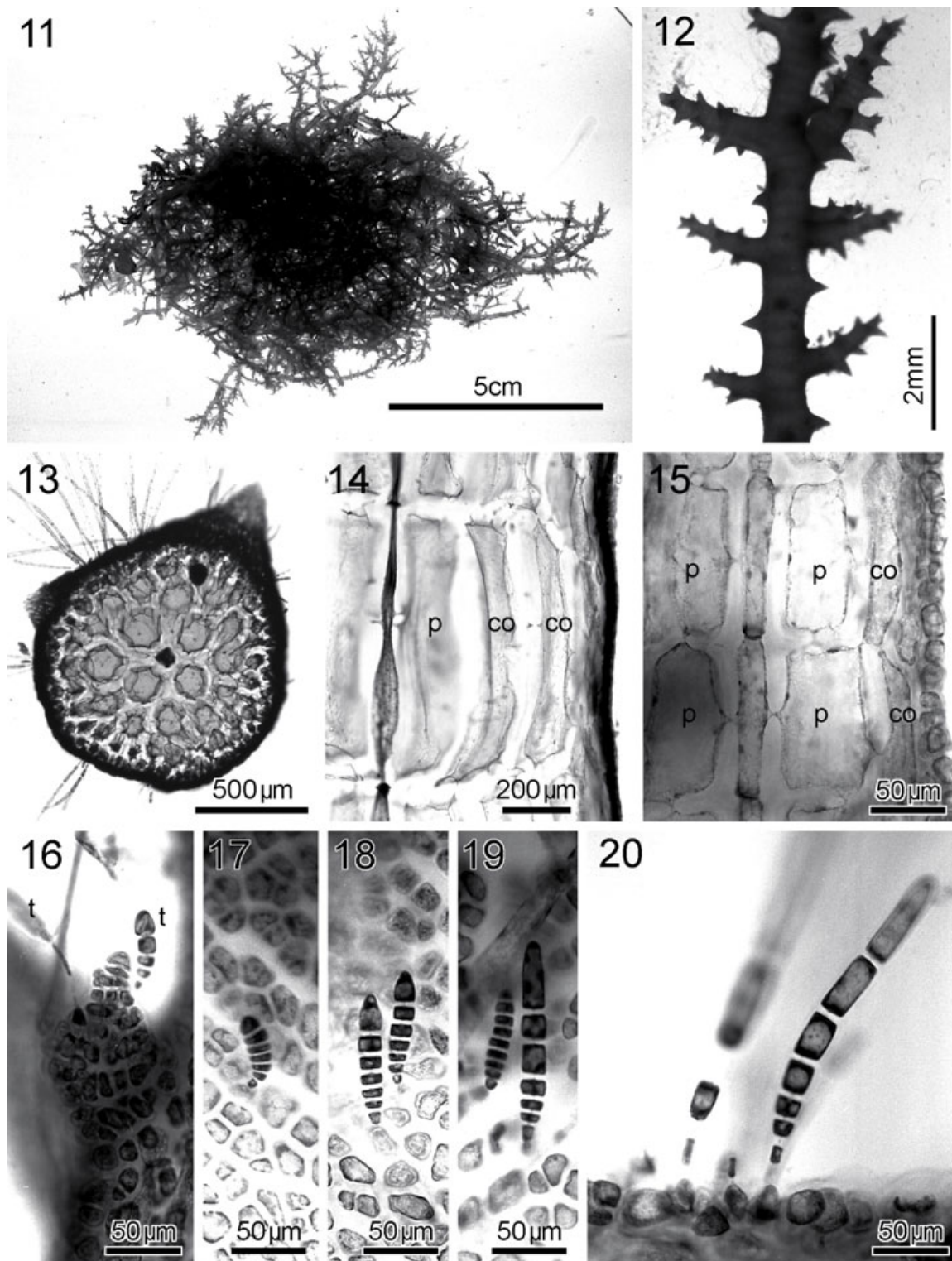
Tetrasporangial stichidia develop on the distal portion of young branches (Fig. 23) in a spiral manner, replacing vegetative trichoblasts. They are also formed adventitiously from the surface cells of distal branches (Fig. 24). The stichidia are provided with a 2 celled (rarely 3 celled) monosiphonous pedicel. Cells of the pedicels are 30–100 μm in length by 25–35 μm in diameter. Polysiphonous portions of the stichidia are

500–950 μm in length by 130–160 μm in diameter and fertile except for several distal segments. Each of the successive 12–28 fertile segments bears a single tetrasporangium provided with 2 cover cells (Fig. 25). These tetrasporangia are spirally arranged so that the fertile portion of each stichidium is conspicuously helical (Fig. 23). Mature tetrahedrally divided tetrasporangia cause the segment to swell and are 70–75 μm in diameter. No lateral branchlets are present on the stichidia.

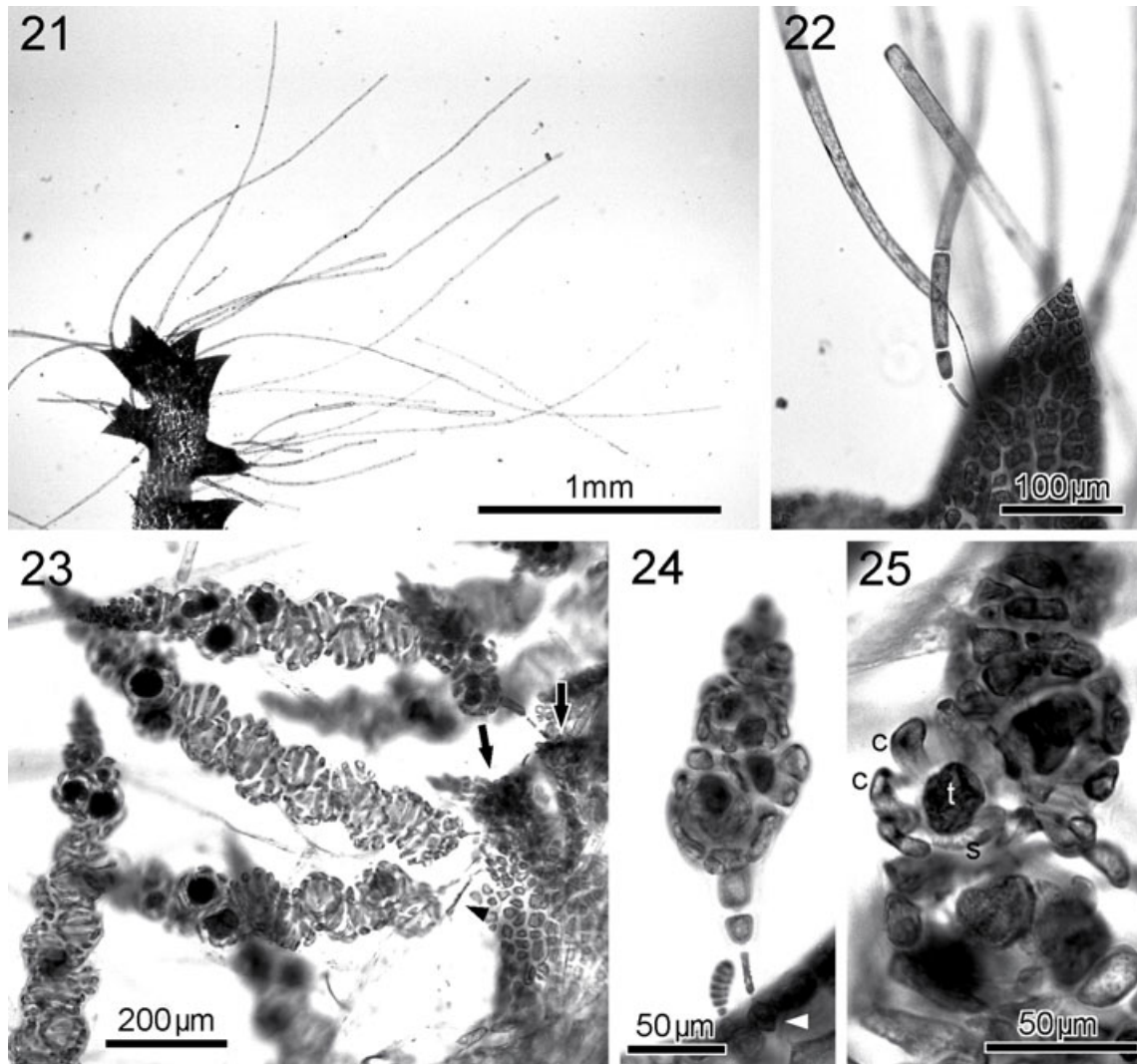
Taxonomic remarks

As there is no historical review of the genus *Endosiphonia*, such information is given below. Zanardini (1878) established *Endosiphonia* with a single species *Endosiphonia spinuligera* Zanardini from Wokam, Aru Islands, Indonesia. Five additional species were ascribed to the genus. *Endosiphonia thuretii* (Bornet) Ardissonne (1883) was based on a later homonym, *Endosiphonia* Ardissonne (1883), which was replaced by *Choreonema* (Schmitz 1889: 455), so that the species is now known as *Choreonema thuretii* (Bornet) Schmitz in the Corallinales (Silva *et al.* 1996). Two species were placed in the synonymy of other *Endosiphonia* species: *E. spinuligera* is a synonym of *Endosiphonia spinulosa* (Harvey) Womersley *et* Parsons (2003); and *Endosiphonia clavigera* Falkenberg (1901) under *E. horrida* (Silva *et al.* 1996). *Endosiphonia* currently includes 4 species, *E. horrida*, *Endosiphonia curvata* Weber-van Bosse (1923), *Endosiphonia gardineri* (Weber-van Bosse) Weber-van Bosse (1923) and *E. spinulosa*, all of which are known in the Indo-Pacific region.

Endosiphonia horrida was first described as *Sphaerococcus horridus* C. Agardh (1822) on the basis of material from Mauritius in the Indian Ocean. It was transferred to *Gigartina* as *Gigartina horrida* (C. Agardh) Greville (1830). Later, it was transferred to *Hypnea* by J. Agardh (1847) and had been known as *Hypnea horrida* (C. Agardh) J. Agardh for over 100 years. The conspecificity of this alga and *E. clavigera* was pointed out by Børgesen (1953); however, he adopted the younger name, *E. clavigera*. Silva transferred *S. horridus* to *Endosiphonia* (in Silva *et al.* 1996). *Endosiphonia curvata* was described from Indonesian material (Ile Gisser) by Weber-van Bosse (1923). *Pseudoendosiphonia gardineri* Weber-van Bosse (1913) is the generic type of the new monotypic genus *Pseudoendosiphonia* Weber-van Bosse. This species was described from material collected at Amirante Islands in the Indian Ocean. It was subsequently transferred into *Endosiphonia*, as *E. gardineri* (Weber-van Bosse) Weber-van Bosse (1923). This act also effectively subsumed the genus *Pseudoendosiphonia* Weber-van Bosse under *Endosiphonia* Zanardini. *Endosiphonia spinulosa* was first described as *Alsidium spinulosum* Harvey (1855) on the basis of material from Garden Island, Rottneest



Figs 11–20. *Endosiphonia horrida*. 11. Wet habit of a portion (about one-quarter) of one clump. 12. Portion of a branch, which sporadically bears spinous branchlets. 13. Transverse section of the lower portion of a branch. 14. Longitudinal section (LS) of the lower portion of an axis. p, periaxial cell; co, cortical cell. 15. LS of the middle portion of a penultimate branch. p, periaxial cell; co, cortical cell. 16. Apex of a young branchlet bearing two trichoblasts (t) (other trichoblasts are out of focus, so that the spiral arrangement is not clear). 17–19. Surface view of a penultimate-order branch, showing developing vegetative trichoblasts, which are produced from the surface cell. 20. LS of a penultimate-order branch, showing trichoblasts, each of which develops from the surface cell.



Figs 21–25. *Endosiphonia horrida*. 21. Apex of a penultimate branch bearing mature undivided trichoblasts. 22. Apex of an ultimate branch, showing very narrow proximal portions of trichoblasts. 23. Tetrasporangial stichidia borne on short ultimate branchlets (arrows); arrowhead indicating a monosiphonous pedicel. 24. Longitudinal section of a penultimate-order branch, showing a tetrasporangial stichidium developing from a surface cell (arrowhead). 25. Younger portion of a tetrasporangial stichidium. c, cover cell; s, stalk cell; t, tetrasporangium.

Island and Cape Riche, Western Australia. It was recently transferred to *Endosiphonia* by Womersley and Parsons (2003).

Our observations of *E. horrida* are in agreement with those of Falkenberg (1901, as *E. clavigera*) and Børgeesen (1943, as *Hypnea horrida*). This species is characterized by: (i) frequently anastomosing branches that form a bush-like tuft without percurrent axes; (ii) inner cortical cells that become the same length as the axial and periaxial cells; and (iii) luxuriously developed, unbranched trichoblasts. In contrast, *E. gardineri* (Weber-van Bosse 1923, as *Pseudoendosiphonia gardineri*) and *E. spinulosa* (Womersley & Parsons 2003) have erect thalli with percurrent axes and ramified

trichoblasts. Furthermore, *E. gardineri* has inner cortical cells, which are always much shorter than the axial and periaxial cells. The little known Indonesian species, *E. curvata* is distinguished from *E. horrida* by the presence of a percurrent axis with curved branches, only a single (innermost) layer of cortical cells as long as the axial and periaxial cells, and the absence of anastomosing branches (Weber-van Bosse 1923).

The presence of spine-like branchlets in *Endosiphonia* indicates its superficial resemblance to *Acanthophora*. However, *Acanthophora* produces 5 periaxial cells per segment and multiple tetrasporangia per segment of lateral branches bearing spine-like branchlets (Abbott 1999).

Laurencia flexilis Setchell
(1926: 101, pl. 19)

Japanese name: Harigane-sozo (Yamada 1944).

Type locality: Reef at Tahara Mountain, Tahiti.

Geographical distribution: Tropical regions in the Pacific (Setchell 1926; Cribb 1983; Masuda *et al.* 1999) and Indian Ocean (Silva *et al.* 1996).

Specimens examined: Nihon-iwa (27°07'02"N, 142°13'54"E), Ani-jima, the Bonin Islands, 22.vi.2005, *leg.* A. Kurihara, vegetative (SAP 099511-099513).

Morphology

Plants grow gregariously on bedrock in shallow tide pools in the lower intertidal zone on exposed, high-energy coasts. Several basal discs of different individuals might become confluent and constitute a large basal system from which numerous erect axes are formed (Fig. 26). Erect axes are up to 7 cm long, dark brown or brownish-red in color, solidly cartilaginous and rigid in texture, adhering weakly to paper when dried. The axes are terete, percurrent and are 0.6–1.0 mm in diameter just above the basal disc, 0.9–1.1 mm in the lower to middle portions and 0.5–0.6 mm at the apex. They bear first-order branches in an irregularly spiral manner at intervals of 0.1–2.5 mm and at angles of 25–90° (Fig. 27), although are often naked in the lower third to half portion. These first-order branches are up to 4 cm long and bear one or two further orders of branches. All branches are basally constricted (Fig. 27). Proliferations frequently develop from injured (perhaps grazed) ends of main axes and lateral branches. Prostrate or stolon-like branches are absent.

Each axial cell produces 4 periaxial cells (Fig. 28). Superficial cortical cells in transverse sections are slightly elongated radially and are 15–30 µm thick throughout the first-order branches. Longitudinally oriented secondary pit-connections are absent between contiguous superficial cortical cells (Fig. 29). Superficial cortical cells do not project even at the branch apices. The presence or absence of *corps en cerise* was not confirmed because living material was not available for examination. Lenticular thickenings are absent in the walls of medullary cells. Intercellular spaces are absent in both cortical and medullary layers.

Colorless vegetative trichoblasts are formed in the apical pit of the axis (Fig. 30) and branches. They are subdichotomously divided six to eight times. Full-grown trichoblasts are 1.2–1.5 mm in length and 35–40 µm in diameter proximally, gradually tapering upwards, the segments are 80–350 µm long (length : diameter ratio of 2–11) in the lower to middle portions. They are deciduous and eventually fall off near the periphery of the pit. Reproductive structures were not found in our material.

Taxonomic remarks

Laurencia flexilis was originally described on the basis of material from Tahiti by Setchell (1926). It has been reported from scattered localities in the tropical region of the Pacific and the Indian Ocean, including the Great Barrier Reef (Cribb 1983), Mauritius (Børgesen 1945) and Sarawak in Malaysia (Masuda *et al.* 1999). This alga has been characterized by the absence of longitudinally oriented secondary pit-connections between contiguous superficial cortical cells (Cribb 1983; Masuda *et al.* 1999) and the production of four periaxial cells per vegetative segment (Masuda *et al.* 1999). The presence of *L. flexilis* in the Canary Islands and Salvage Islands in the North Atlantic (John *et al.* 2004) needs confirmation, because such critical features have not been reported. Our examination of one of Setchell's (1926) original specimens of *L. flexilis* collected from reefs between Papenu and Huan, Tahiti (no. 5115, 5.vi.1922) and deposited in SAP (039881) confirmed the absence of longitudinally oriented secondary pit-connections (Fig. 31); however, the number of periaxial cells connected with an axial cell was uncertain because of insufficient rehydration of its internal structure.

Laurencia flexilis seems to be similar in habit to *Laurencia tropica* Yamada (1931), which was first described from material collected at Saipan Island, Mariana Islands. Although Yamada (1931) considered that *L. tropica* closely resembled *L. flexilis* in texture and internal structure, he provisionally recognized *L. tropica* as distinct from *L. flexilis* on the basis of the branching manner (branches being loosely disposed in *L. flexilis* vs densely disposed in *L. tropica* and the absence of intermediate forms). *L. tropica* has been widely reported from tropical regions in the

Figs 26–32. *Laurencia flexilis*. 26–30. Material from Ani-jima, the Bonin Islands (22.vi.2005); 31, one of Setchell's (1926) original specimens from Tahiti (5.vi.1922). 26. Herbarium specimen (Herbarium of the Graduate School of Science, Hokkaido University, Sapporo (SAP 099511)). 27. Apex of a main axis. 28. Transverse section of the upper portion of an axis. a, axial cell; p, periaxial cell. 29. Longitudinal section (LS) of the middle portion of an axis, showing the absence of longitudinally oriented secondary pit-connections between adjacent superficial cortical cells. 30. Apex an axis bearing trichoblasts in the apical pit. 31. LS of the middle portion of an axis, showing the absence of longitudinally oriented secondary pit-connections between adjacent superficial cortical cells. 32. Holotype specimen of *L. tropica* from Saipan Island (Herbarium of the Graduate School of Science, Hokkaido University, Sapporo (SAP 13870)). LS of the middle portion of a second-order branch: arrowheads indicating longitudinally oriented secondary pit-connections.

north-western Pacific defined by Michanek (1979): the Ryukyu Islands, southern Japan (Ohba & Aruga 1982), Hainan Island, southern China (Xia & Zhang 1982), Vietnam (Pham 1969) and the Philippines (Silva *et al.* 1987). Xia and Zhang (1982) proposed to reduce *L. tropica* as a variety of *L. flexilis* based on the discovery of less ramified plants similar to Setchell's (1926, pl. 19, figs 1–5) illustrations of *L. flexilis*, together with very closely ramified plants identical to the type illustration of *L. tropica* (Yamada 1931, pl. 20) in their collection from Hainan Island, southern China.

We examined the holotype specimen of *L. tropica* collected at Charanka, Saipan Island (date unknown) and deposited in SAP (13870). The specimen has longitudinally oriented secondary pit-connections between contiguous superficial cortical cells (Fig. 32), although the number of periaxial cells per vegetative segment is uncertain. This difference is in marked contrast to *L. flexilis*, which has no such connections and strongly indicates that these two entities are separate species.

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REFERENCES

- Abbott, I. A. 1999. *Marine Red Algae of the Hawaiian Islands*. Bishop Museum Press, Honolulu, 477 pp.
- Agardh, C. A. 1822. *Species Algarum Rite Cognitae, Cum Synonymis, Differentiis Specificis et Descriptionibus Succintis. Voluminis Primi Pars Posterior*. Berling, Lund, pp. 169–398.
- Agardh, J. G. 1847. Nya alger från Mexico. *Öfvers. Kongl. Vet.-Akad. Förhandl.* **4**: 5–17.
- Ardissonne, F. 1883. Phycologia mediterranea. Parte prima. Floridee. *Mem. Soc. Crittogamologica Ital.* **1**: 1–516.
- Børgeesen, F. 1943. Some marine algae from Mauritius. III. Rhodophyceae. Part 2. Gelidiales, Cryptonemiales. *K. Danske Vidensk. Selsk. Biol. Meddel.* **19**(1): 1–85.
- Børgeesen, F. 1945. Some marine algae from Mauritius. III. Rhodophyceae. Part 4. Ceramiales. *K. Danske Vidensk. Selsk. Biol. Meddel.* **19**(10): 1–68.
- Børgeesen, F. 1953. Some marine algae from Mauritius. Additions to the parts previously published, V. *K. Danske Vidensk. Selsk. Biol. Meddel.* **21**(9): 1–62.
- Cribb, A. B. 1983. *Marine Algae of the Southern Great Barrier Reef. Part I. Rhodophyta*. Handbook no. 2. Australian Coral Reef Society, Brisbane, 173 pp.
- Falkenberg, P. 1901. Die Rhodomelaceen des Golfes von Neapel und der angrenzenden Meeres-abschnitte. *Fauna Flora Golfes Neapel* **26**: 1–754.
- Greville, R. K. 1830. *Algae Britannicae*. MacLachlan & Stewart, Edinburgh, lxxxviii + 218 pp.
- Harvey, W. H. 1855. Some account of the marine botany of the colony of Western Australia. *Trans. Royal Irish Acad.* **22**: 525–66.
- Hiraoka, M., Shimada, S., Uenosono, M. and Masuda, M. 2004. A new green-tide-forming alga, *Ulva ohnoi* Hiraoka et Shimada (Ulvales, Ulvophyceae) from Japan. *Phycol. Res.* **52**: 17–29.
- John, D. M., Prud'homme van Reine, W. F., Lawson, G. W., Kostermans, T. B. and Price, J. H. 2004. A taxonomic and geographical catalogue of the seaweeds of the western coast of Africa and adjacent islands. *Beih. Nova Hedwigia* **127**: 1–339.
- Kajimura, M. 1998. A new variety of *Dasya rigidula* (Dasyaceae, Rhodophyta) from the Sea of Japan. *Bull. Fac. Life Env. Sci. Shimane Univ.* **3**: 53–63.
- Kato, A. and Masuda, M. 2002. A morphological study of *Peyssonnelia meridionalis* (Gigartinales, Rhododophyta), with discussion of spermatangial types within the genus. *Phycologia* **41**: 191–8.
- Kato, A. and Masuda, M. 2003. A new crustose red alga *Peyssonnelia rumoiana* (Rhodophyta, Gigartinales) from Japan. *Phycol. Res.* **51**: 21–8.
- Kawaguchi, S., Shimada, S., Wang, H. W., Faye, E. J. and Masuda, M. 2003. *Polyopes tosaensis* Kawaguchi & Masuda, sp. nov. (Halymeniaceae, Rhodophyta) from Japan. *Eur. J. Phycol.* **38**: 315–24.
- Masuda, M. and Shimada, S. 2003. A new red alga, *Herposiphonia japonica* (Ceramiales, Rhodomelaceae) from the north-western Pacific. *Cryptogamie, Algol.* **24**: 195–208.
- Masuda, M., Abe, T., Kawaguchi, S. and Phang, S. M. 1999. Taxonomic notes on marine algae from Malaysia. I. Six species of Rhodophyceae. *Bot. Mar.* **42**: 449–58.
- Masuda, M., Uwai, S., Kogame, K., Kawaguchi, S. and Phang, S. M. 2003. Taxonomic notes on marine algae from Malaysia. X. Four species of *Dasya* (Rhodophyceae), with the descriptions of *Dasya longifila* sp. nov. & *D. malaccensis* sp. nov. *Bot. Mar.* **46**: 243–55.
- Michanek, G. 1979. Phytogeographic provinces and seaweed distribution. *Bot. Mar.* **22**: 375–91.
- Noda, M. and Kitami, T. 1971. Some species of marine algae from Echigo Province facing the Japan Sea. *Sci. Rep. Niigata Univ.-Ser. D. (Biol.)* **8**: 35–52.
- Ohba, H. and Aruga, Y. 1982. Seaweeds from Ishigaki Island and adjacent islets in Yaeyama Islands, southern Japan. *Jpn. J. Phycol.* **30**: 325–31 (in Japanese).
- Parsons, M. J. and Womersley, H. B. S. 1998. Family Dasyaceae Kützting 1843: 413, 414. In Womersley, H. B. S. (Ed.) *The Marine Benthic Flora of Southern Australia*.

- Rhodophyta – Part IIIC. Ceramiales – Ceramiaceae, Dasyaceae*. State Herbarium of South Australia, Adelaide, pp. 422–510.
- Pham, H. H. 1969. *Marine Algae of South Vietnam*. Trung-Tam Hoc-Lieu Xuat-Btan, Saigon, 558 pp. (in Vietnamese).
- Schmitz, F. 1889. Systematische Übersicht der bisher bekannten Gattungen der Florideen. *Flora* **72**: 435–56.
- Setchell, W. A. 1926. Tahitian algae collected by W. A. Setchell, C. B. Setchell, and H. E. Parks. *Univ. Calif. Publ. Bot.* **12**: 61–142.
- Silva, P. C., Meñez, E. G. and Moe, R. L. 1987. Catalog of the benthic marine algae of the Philippines. *Smithsonian Contr. Mar. Sci.* **27**: 1–179.
- Silva, P. C., Basson, P. and Moe, R. L. 1996. Catalogue of the benthic marine algae of the Indian Ocean. *Univ. Calif. Publ. Bot.* **79**: 1–1259.
- Tani, M. and Masuda, M. 2003. A taxonomic study of two minute species of *Chondria* (Ceramiales, Rhodophyta) from the north-western Pacific, with the description of *Chondria econstricta* sp. nov. *Phycologia* **42**: 220–31.
- Tseng, C. K., Xia, B. M., Xia, E. Z. *et al.* 1983. Rhodophyta. In Tseng, C. K. (Ed.) *Common Seaweeds of China*. Science Press, Beijing, pp. 43–161.
- Uwai, S., Kogame, K. and Masuda, M. 2000. Morphology and life history of four Japanese species of *Elachista* (Elachistaceae, Phaeophyceae), including a new record of *E. fucicola*. *Phycol. Res.* **48**: 267–79.
- Weber-van Bosse, A. 1913. Marine algae, Rhodophyceae, of the 'Sealark' Expedition, collected by Mr. J. Stanley Gardiner, M.A. *Trans. Linn. Soc. London, 2nd Ser. Bot.* **8**: 105–42.
- Weber-van Bosse, A. 1923. Liste des algues du Siboga. III. Rhodophyceae. Seconde partie. Ceramiales. *Siboga-Expeditie Monographie* **59c**: 311–92.
- Womersley, H. B. S. and Parsons, M. J. 2003. Tribe Lophothalieae Schmitz. & Falkenberg 1897: 445. In Womersley, H. B. S. (Ed.) *The Marine Benthic Flora of Southern Australia. Rhodophyta. Part IIID. Ceramiales – Delesseriaceae, Sarcomeniaceae, Rhodomelaceae*. Australian Biological Resources Study, Canberra and the State Herbarium of South Australia, Adelaide, pp. 235–82.
- Xia, B. M. and Zhang, J. F. 1982. A new raw material for the manufacture of agar-agar from Hainan Island, China. *Oceanol. Limnol. Sinica* **13**: 538–43 (in Chinese).
- Yamada, Y. 1931. Notes on *Laurencia*, with special reference to the Japanese species. *Univ. Calif. Publ. Bot.* **16**: 185–310.
- Yamada, Y. 1944. A list of the marine algae from the atoll of Ant. *Sci. Pap. Inst. Algol. Res., Fac. Sci., Hokkaido Imp. Univ.* **3**: 31–45.
- Yoshida, T. 1998. *Marine Algae of Japan*. Uchida-Rokakuho, Tokyo, 1222 pp. (in Japanese).
- Yoshida, T., Yoshinaga, K. and Nakajima, Y. 2000. Check list of marine algae of Japan (revised in 2000). *Jpn. J. Phycol. (Sôri)* **48**: 113–66.
- Zanardini, G. 1878. Phyceae papuanae novae vel minus cognitae a cl. O. Beccari in itinere ad Novam Guineam annis 1872–75 collectae. *Nuov. Gior. Bot. Ital.* **10**: 34–40.