Benthic Marine Algae on Japanese Tsunami Marine Debris

– a morphological documentation of the species

Part 1 – The Tsunami Event, the Project Overview, and the Red Algae

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- **Printing:** For better pdf printing, please reduce to letter (11" x 8.5") size, landscape orientation.
- **Citations to be used for this series:**
  - Hansen, G.I., Hanyuda, T. & Kawai, H. (2017). Benthic marine algae on Japanese tsunami marine debris – a morphological documentation of the species. Part 1. The tsunami event, the project overview, and the red algae. OSU Scholars Archive, Corvallis, pp. 1-50. http://dx.doi.org/10.5399/osu/1110
  - Hansen, G.I., Hanyuda, T. & Kawai, H. (2017). Benthic marine algae on Japanese tsunami marine debris – a morphological documentation of the species. Part 2. The brown algae. OSU Scholars Archive, Corvallis, pp. 1-61. http://dx.doi.org/10.5399/osu/1111
  - Hansen, G.I., Hanyuda, T. & Kawai, H. (2017). Benthic marine algae on Japanese tsunami marine debris – a morphological documentation of the species. Part 3. The green algae and cyanobacteria. OSU Scholars Archive, Corvallis, pp. 1-43. http://dx.doi.org/10.5399/osu/1112
- **Authors' roles in this series:**

  Our studies on the marine algae of tsunami debris have relied heavily on the molecular identifications of the species sequenced by T. Hanyuda and H. Kawai. However, this account is a morphological documentation of the species based on the published morphology, and the identifications may vary from those provided by my co-authors. These differences are mentioned in the text as morphological or sequence variants.

  A) Preparation of the "Morphological Documentation" series – Hansen
  B) Photographs and descriptions of the species on debris – Hansen unless otherwise noted
  C) Sequencing and molecular determinations – Hanyuda and Kawai as listed in Hanyuda *et al.* (2017)
- **Other publications supported:** The Scholars Archive presentations above provide photographic documentation for the species included in the following publications. The poster is a pictorial overview of some of the larger debris algae made for teaching.
  - Hansen, G.I., Hanyuda, T. & Kawai, H. (2017, In Review). The invasion threat of benthic marine algae arriving on Japanese tsunami marine debris in Oregon and Washington, USA.
  - Hanyuda, T., Hansen, G.I. & Kawai, H. (2017, In Press). Genetic identification of macroalgal species on Japanese tsunami marine debris and genetic comparisons with their wild populations. Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2017.06.053
  - Hansen, G.I. (2013). Some Marine Algae on Tsunami Debris. OSU Scholars Archive, Corvallis, a poster. http://ir.library.oregonstate.edu/concern/defaults/ns064b84v
- **Contents:** The Tsunami Event, The Path of the Floating Debris, Debris Items Carrying Japanese Benthic Marine Algae, Challenging Conditions Endured by the Debris Algae during the Trans-Pacific Trip; The Project Overview, Materials & Methods, Acknowledgements, Scientific Credits, Codes, Definitions & Abbreviations; The Red Algae – A Checklist of the Species on JTMD, The Species Descriptions, References for the Red Algae; and Appendix 1. The Japanese Debris Items.

Japan March 2011 Tōhoku Earthquake and Tsunami #15 & 48 by Douglas Sprott. https://www.flickr.com/photos/dugspr/albums

The Tsunami Event

The Great Tōhoku Earthquake and Tsunami:

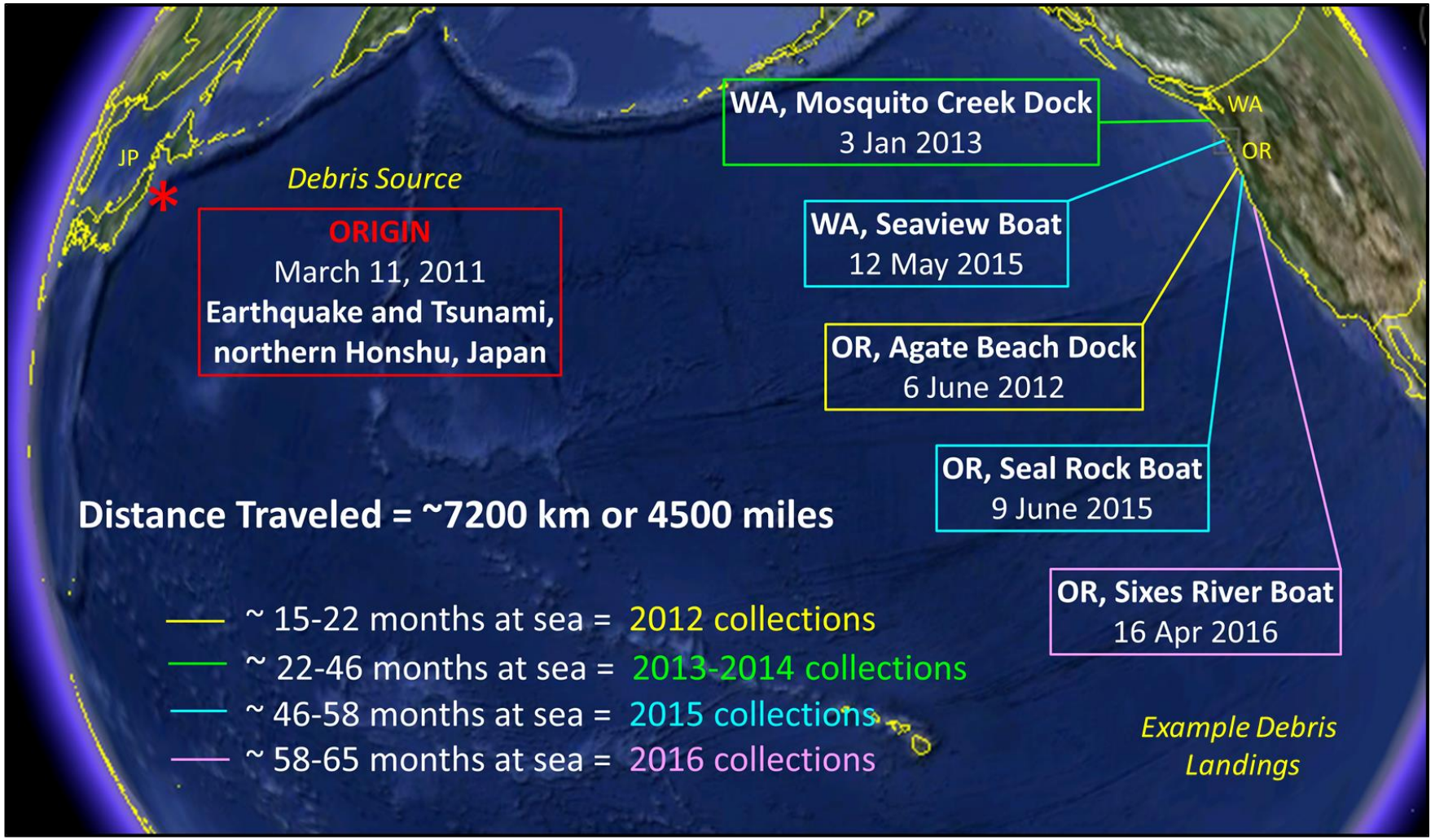
- **Date: 11 March 2011**
- **Earthquake:** a magnitude of ~9.0
- **Epicenter:** 129 kilometers (80 miles) off the east coast of the Oshika Peninsula, Tōhoku, Japan
- **Tsunami:** waves up to 133 vertical feet
  217 miles of coastline inundated
- **Killed or missing:** nearly 20,000 people

The Resulting Devastation:

- **Homes, businesses, cities and infra-structure destroyed!**
- **Resulting Debris** -- estimated at 20 million tons
  - 5 million tons washed into the sea
  - 70% sank -- **30% or about 1.5 million tons floated**
  - An **unknown amount** – was picked up and carried by currents crossing the North Pacific to North America

The Path of the Floating Debris

Many items made the long voyage across the North Pacific to Oregon and Washington



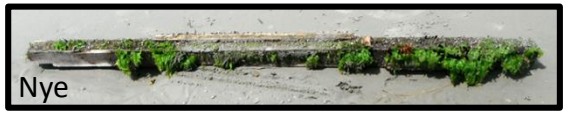
Base Map Source: "Pacific Ocean". Google Earth 2012. Accessed 10 Mar 2013

Debris items for this project were at sea for 15 to 65 months

Debris Items carrying Japanese Benthic Marine Algae

when they arrived on the shores of Oregon and Washington (see Appendix 1 for abbreviations)

Pictures courtesy WDFW, ODFW & HMSC debris scientists & volunteers



Marine algae were sampled from 42 debris items, verified as from the Japanese tsunami between June 2012 and July 2016.

Challenging Conditions Endured by the Debris Algae during the Trans-Pacific Trip

The Agate Beach Dock on June 5, 2012 – the first recognizable JTMD item to land on the OR-WA coast

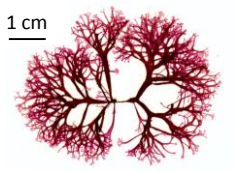
Lepas anatifera, the pelagic gooseneck barnacle – a major competitor for space with algae on debris

1. **Low nutrient conditions occurring at** sea (with nearshore nutrient pulses at the start & end of the trip).
2. **Varying temperature (SST) conditions** encountered during the N. Pacific transit:
   - NE Honshu temperature range = 7-23˚ C
   - North Pacific Current (43-47˚ N), June 2012 = 8-15 ˚ C
   - Oregon near-shore ocean temperatures = 9-12˚C
3. **Disturbance from storms and debris congestion**
4. **Herbivory and/or competition for space** with:
   - benthic animals on the debris – crabs, amphipods, etc.
   - pelagic animals – like *Lepas anatifera* and omnivorous fish
   - other algae
5. **Problems in life history recycling (**propagule release & settlement) due to
   - limited space and substrate type available for settlement
   - narrow current boundary layers allowing propagules to be carried away
6. **Erratic light & exposure changes –** particularly on the smaller tumbling debris.
7. **Sand or rock scour possibly occurring** when the debris landed on shore.

Even after enduring these difficult conditions at sea for 1-5⁺ years,
more than 84 Japanese marine algal species arrived alive on debris landing on Northeast Pacific shores.

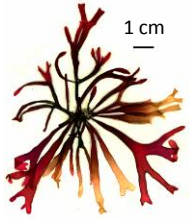
The Project Overview

- In order to determine the invasion threat to the NE Pacific of marine algae arriving on Japanese debris from the 2011 Great Tōhoku Earthquake and Tsunami, my colleagues and I took up the task of identifying the benthic marine algal species on 42 of the most heavily fouled debris items that landed on the shores of Oregon and Washington between June 2012 and July 2016. (see Appendix 1).



- Using both morphological and molecular methods, we identified 84+ Asian marine algal species and species complexes on Japanese Tsunami Marine Debris (JTMD), including 29 red, 30 brown, and 21 green algae and 4 cyanobacteria. 85% (71) of the species were sexually or asexually reproductive on arrival, and 61% (51) were reported to already occur In the NE Pacific before the March 2011 tsunami. The threat of invasion by these species was obvious, although it was not as severe as we originally thought (see **Hansen *et al*., in review**).

- The molecular studies: To confirm or correct the morphological identifications, 52 of the 84 JTMD species were sequenced by my coauthors, Hanyuda and Kawai. Many of their sequences matched precisely those of known species in GenBank and the DNA Data Bank of Japan, but, in a number of species (including some of our shared species), the sequences varied. These haplotype differences indicated either subspecific differences (such as races), close complexes with other species, or species that were new to science. These variants (noted in the text) and their biogeographic implications are discussed in **Hanyuda *et al*. (2017).**



- **The morphological studies**: This Scholars Archive account documents the morphological identifications of the JTMD algal species and their variants. It is divided into 3 parts: (1) The Tsunami Event, The Project Overview, and The Red Algae, (2) The Brown Algae, and (3) The Green Algae and Cyanobacteria. Each part provides pictures of the habit and anatomy of the actual debris species (unless otherwise noted), some data critical to their taxonomy, and also information on their frequency of occurrence on JTMD and published global biogeography.

Materials and Methods:

- The collections for this study were scraped from tsunami debris by hand or with a scraper by the author and numerous volunteers (see the acknowledgements). Sorting was carried out visually for larger species and with a dissecting and a compound microscope for the smaller species.
- After sorting, the algae were pressed (if large enough) and preserved in both 5% formalin/seawater (for photography) and in silica gel (for DNA sequencing in Japan). Morphological identifications were based on comparison with literature descriptions referenced in this account. Molecular identifications were provided by Hanyuda, Kawai, and others after sequencing and matching their results with the available molecular databases.
- Microscope pictures were taken with a Zeiss Axioskope microscope equipped with a Leica DFC-290 camera and edited with Photoshop CS5. Habits of the larger algae were captured using a Microtek Scanmaker 9800XL or a Panasonic Lumix camera.
- Filters and stains, primarily aniline blue/acid and iodine, were used to bring out the critical features in some samples.
- Distribution data was derived from on-line herbarium databases, personal collections for the NE Pacific, and www.algaebase.org (accessed July 2017) for global data. For more detailed global information, the reader is advised to check the current www.algaebase.org. This database by Mike and Wendy Guiry is exceedingly thorough and frequently updated.
- Longevity data is from the literature and personal observations of the species in the NEP. It refers to the life span of an individual thallus and not necessarily to seasonality. Our definitions are standard: perennial and pseudo-perennial = thalli lasting >1 year; annual = thalli lasting < 1 year, often day-length regulated; ephemeral = thalli shorter-lived than annuals that repeatedly reproduce, replacing their populations either seasonally or throughout the year when conditions are adequate for growth. If longevity is not known for a species, the most probable category is provided and preceded by a "~".
- Reproductive status is that of the debris specimens.
- Corrections, comments, identifications of unknowns, and observations on the species are invited by the author (hansengi@outlook.com).

Acknowledgements:

Financial support for this study was provided by Oregon Sea Grant, the Ministry of the Environment of Japan through the North Pacific Marine Science Organization (PICES), and personal savings. Collection assistance for the debris algae was generously provided by John Chapman, Russ Lewis, Jessica Miller, Thomas Murphy, Nancy Treneman, and the state and volunteer agencies in Washington and Oregon responsible for debris removal. Jim Carlton kept the BF (biofouling) item database. Algaebase.org greatly facilitated the distribution and reference searches. Judy Mullen (OSU libraries) provided critical and often obscure literature for the study. Cynthia Trowbridge provided valuable comments on the overall project. The US-EPA provided laboratory space for the Oregon part of the project.

Scientific Credits:

- Monographic experts generously assisted with the identification of a number of problematic species. Their names are listed in the text.
- Molecular sequencing of the debris species was primarily carried out by Hanyuda and Kawai (Kobe University), and questions concerning this part of the project should be directed to these scientists. (See Hanyuda *et al.*, 2017)
- The morphological photographs and descriptions of the debris algae in this account are by Hansen.
- The final species and species complex determinations were the made by Hansen using: the molecular interpretations of Hanyuda and Kawai, personal observations on the species morphology, and the available literature. Since they do not always reflect the molecular data, the purpose of this publication is partly to justify their use. Identifications indicated as approximate (see the abbreviations) may change as more information on the species becomes available.

Codes, Definitions & Abbreviations used in the Text:

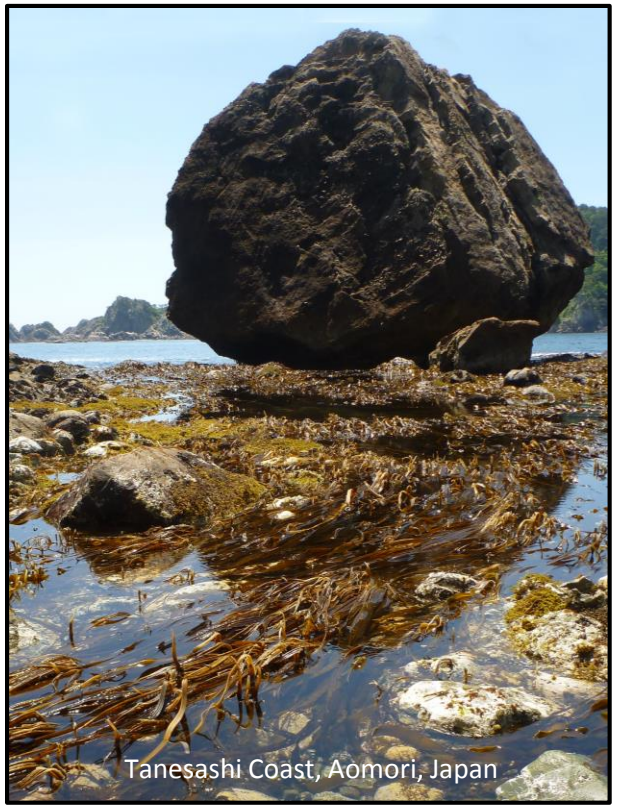
✶ = Species that have been sequenced. Sequencing procedures are provided in Hanyuda *et al*. (2017). The genes used are listed in Table S1 of this paper, and also on p. 10 of the current account.

= Identifications assisted by monographic experts. The expert names are listed on the species pages.

Reproductive types: ♂ = male, ♀ = female, ⊗ tetrasporic (all forms).

Approximate identifications: The JTMD species names shown in this account follow either the published morphology or the sequences. However, slight variations do occur in both the morphology and the sequences – and in their interpretation. For these, I use the following qualifying terms to indicate approximate identifications: ***sensu* X** = an identification according to scientist X; ***cf.*** = refer to (the most probable species identification); ***cpx.*** = a clade or group of closely related species that includes the unnamed isolate. The term ***cpx.*** includes both: (1) **morphological variants** = species with identical sequences that have different morphology, and (2) **sequence variants** = species that are morphologically correct with the literature whose sequences do not match exactly those for the same species deposited in GenBank. These variant types are noted in the text.

Distribution codes: G (Globally widespread) = species that appear to be naturally widespread globally, occurring on multiple continents and in different oceans; **A (Asian-only**) = species occurring only in Asia, from Russia to the Philippines; **A+ (Asian+)** = Asian species that have also been exported globally by human activities; **NP-P (North Pacific-P)** = species limited primarily to both the NE and NW Pacific but occasionally with occurrences in Alaska or the S. Pacific.


Tanesashi Coast, Aomori, Japan

Distribution abbreviations: Afr = Africa; AK = Alaska; A-Arc = Antarctic; Arc = Arctic; Aus = Australia; BC = British Columbia; Bra = Brazil; C = China; Car = Caribbean; ENA = Eastern North America; EUR = Europe including the British Isles; EUR-Arc = Europe and the European Arctic; HA = Hawaii; IO = Indian Ocean (including Indonesia); J = Japan; K = Korea; Med = Mediterranean; MX = Mexico; NEP = Northeast Pacific; NZ = New Zealand; OR = Oregon; Phil = Philippines; R = Eastern Russia; SA = South America (both coasts); Viet = Vietnam; WA = Washington. For brevity, we have excluded some island groups and Arctic areas. For more thorough distribution coverage, see www.algaebase.org.

Occurrence months: These are designated by the first 3 letters of the month.

Debris BF (Biofouling) numbers and collection abbreviations: These are provided in Appendix 1. Specimen numbers are listed with the species descriptions and in Hanyuda *et al*. (2017, Table S1).

The RED ALGAE

A Checklist of the Species on JTMD & their global and NEP distributions

KEY:

Pg = page number
JTMD = Japanese Tsunami Marine Debris
Global = general global occurrence
- A = Asian only
- A+ = Asian but also introduced by human activities globally
- NP-P = Northwest and Northeast Pacific, some with Alaska and S. Pacific occurrences
- G = globally widespread, including species with rare global occurrences

NEP = Northeast Pacific occurrence (Washington to Mexico)
- y = occurring in the NEP
- y-s = yes but only California and/or Mexico
- n = not known in the NEP

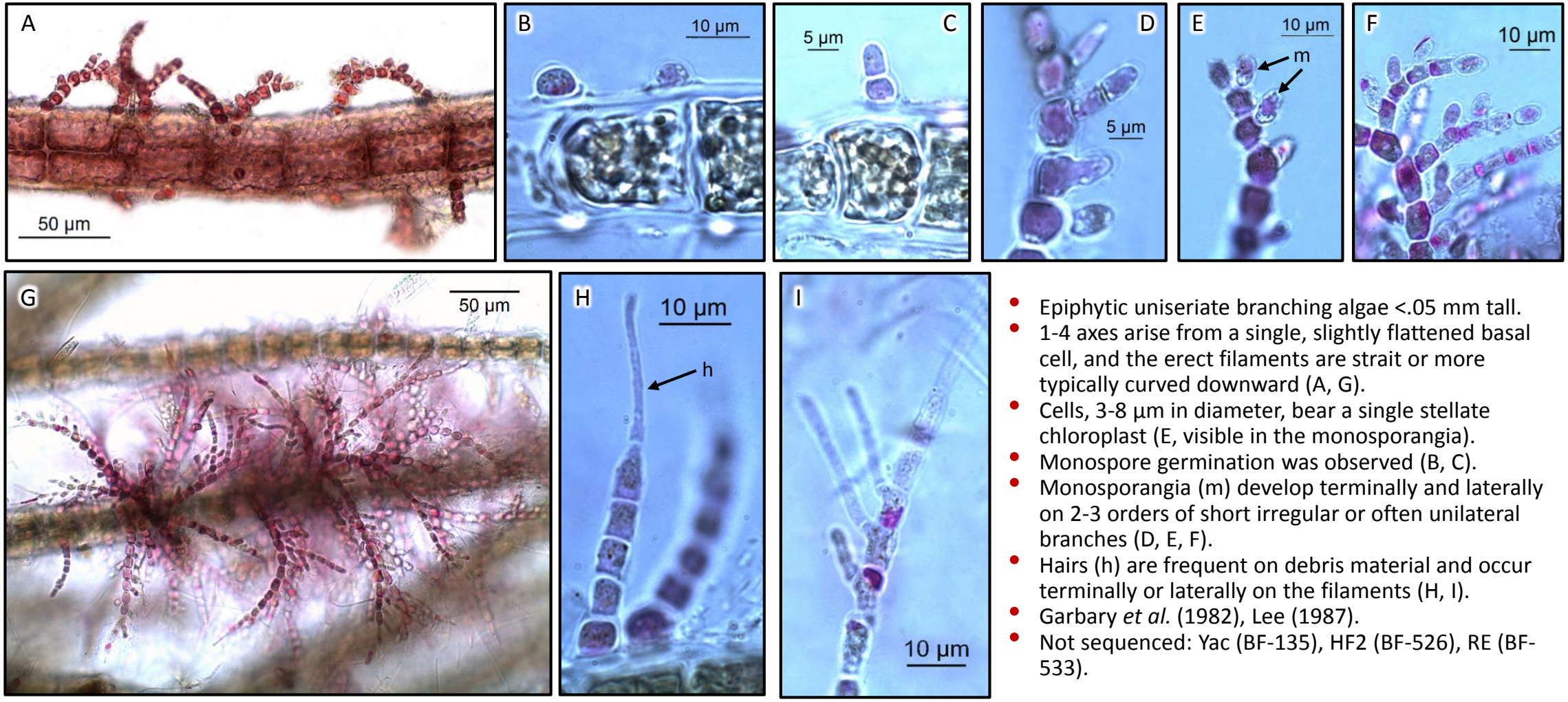
DNA = genes sequenced or expert assistance
- ✶ Gene codes: (1) *cox*1, (2) ITS rDNA, (3) *rbc*L, (4) 18S rDNA
- * = further study required
- # = Monographic expert assistance

The Species Descriptions

Please use the page number or ^F to call up the individual species.

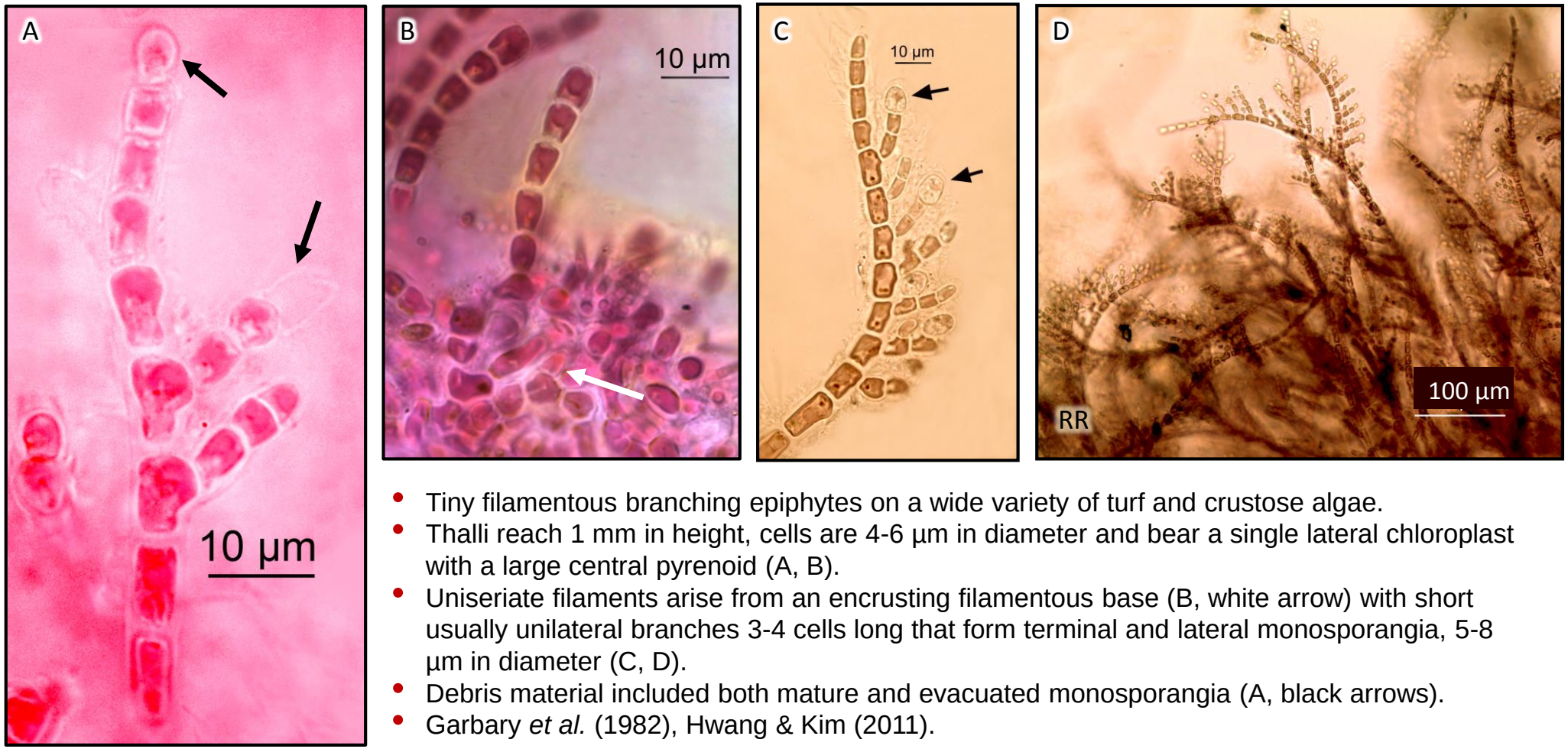
Pg	The Red Algal Species on JTMD	Global	NEP	DNA
11	*Acrochaetium microscopicum* (Nägeli *ex* Kützing) Nägeli *in* Nägeli *et* Cramer	G	y	
12	*Acrochaetium pacificum* Kylin	NP-P	y	
13	*Antithamnion nipponicum* Yamada *et* Inagaki	A+	y-s	#
14-15	*Bangia* cf. *fuscopurpurea* (Dillwyn) Lyngbye	G	y	(3)
16	*Ceramium sungminbooi* J. Hughey *et* G. Boo	A+	y	(1, 3)
17	*Chondrus giganteus* f. *flabellatus* Mikami	A+	n	(1, 3)
18	*Chondrus yendoi* Yamada *et* Mikami *in* Mikami	A	n	(1, 3)
19	*Colaconema daviesii* (Dillwyn) Stegenga cpx.	G	y	(3)*
20	*Colaconema savianum* (Meneghini) Nielsen cpx.	G	y	(3)*
21	*Erythrocladia irregularis* Rosenvinge	G	y	
22	*Erythrotrichia carnea* (Dillwyn) J. Agardh	G	y	
23	*Erythrotrichia incrassata* T. Tanaka	A	n	
24	*Grateloupia livida* (Harvey) Yamada	A	n	(3)
25	*Grateloupia turuturu* Yamada	A+	y-s	(3)
26	*Leptofauchea leptophylla* (Segawa) M. Suzuki *et al.*	A	n	#
27	*Meiodiscus spetsbergensis* (Kjellman) G.W. Saunders *et* J. McLachlan	G	y	
28	*Melanothamnus japonicus* (Harvey) Díaz-Tapia *et* Maggs	A+	n	#
29	*Melanothamnus yendoi* (T.Segi) Díaz-Tapia *et* Maggs	G	n	#
30	*Neodilsea yendoana* Tokida	A	n	(1, 2)
31	*Palmaria* cf. *mollis* (Setchell *et* N.L.Gardner) van der Meer *et* C.J. Bird	NP-P	y	(1, 3)*
32, 34	*Polysiphonia koreana* D. Bustamante, B.Y. Won *et* T.O. Cho	A	n	(3)* #
33-34	*Polysiphonia morrowii* Harvey	A+	n	(3)
35	*Polysiphonia villum* J. Agardh cpx.	G	y	(3)*
36	*Porphyrostromium japonicum* (Tokida) Kikuchi *in* Kikuchi *et* Shin	A	n	
37	*Ptilota serrata* Kützing	G	n	#
38	*Pyropia pseudolinearis* (Ueda) N. Kikuchi, M. Miyata, M.S. Hwang *et* H.G. Choi cpx.	A	n	(3)
39	*Pyropia yezoensis* (Ueda) M.S. Hwang *et* H.G. Choi *in* Sutherland *et al.*	A+	n	(3)
40	*Schizymenia dubyi* (Chauvin *ex* Duby) J. Agardh	G	y	(4)
41	*Tsunamia transpacifica* J. West, G. Hansen, T. Hanyuda *et* G. Zuccarello cpx.	NP-P	n	(4)
42	Unknown: *Erythrotrichia* sp. on a glass ball	–	–	–

***Acrochaetium microscopicum* – G (Globally widespread) –** Asia (R, J, C, K), AK-MX, Aus, SA, ENA, Car, EUR, Med, Afr & IO. On 3 debris items (Feb-Mar). Mainly epiphytic on *Polysiphonia.* Fertile (monosporangia). Ephemeral.



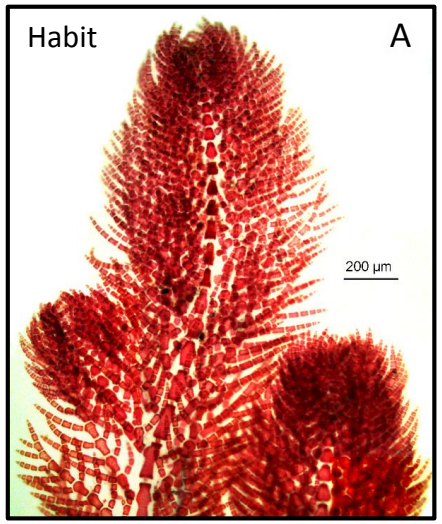
- Epiphytic uniseriate branching algae <.05 mm tall.
- 1-4 axes arise from a single, slightly flattened basal cell, and the erect filaments are strait or more typically curved downward (A, G).
- Cells, 3-8 µm in diameter, bear a single stellate chloroplast (E, visible in the monosporangia).
- Monospore germination was observed (B, C).
- Monosporangia (m) develop terminally and laterally on 2-3 orders of short irregular or often unilateral branches (D, E, F).
- Hairs (h) are frequent on debris material and occur terminally or laterally on the filaments (H, I).
- Garbary *et al.* (1982), Lee (1987).
- Not sequenced: Yac (BF-135), HF2 (BF-526), RE (BF-533).

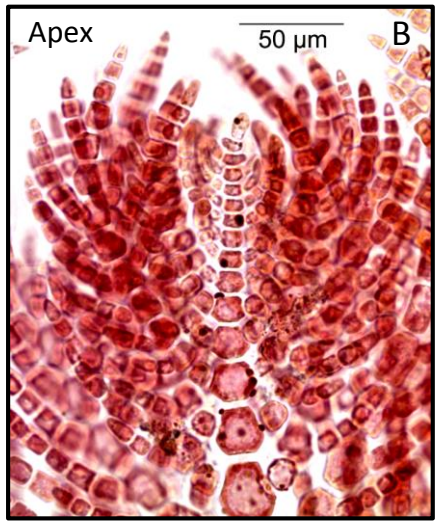
***Acrochaetium pacificum* – NP-P –** Asia (R, C, K), AK-MX, Aus, Peru. On 1 debris item (Feb), Yac (BF-135) but not sequenced. Reproductive (monosporangia). Epiphytic. Ephemeral.

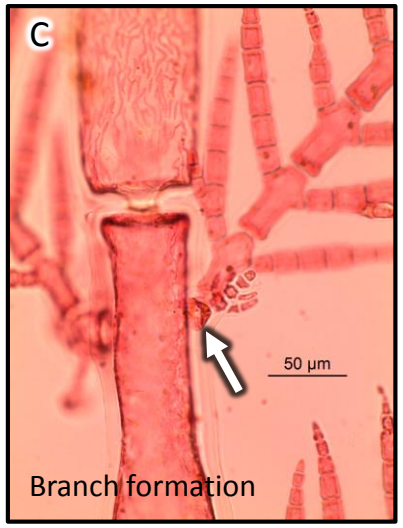


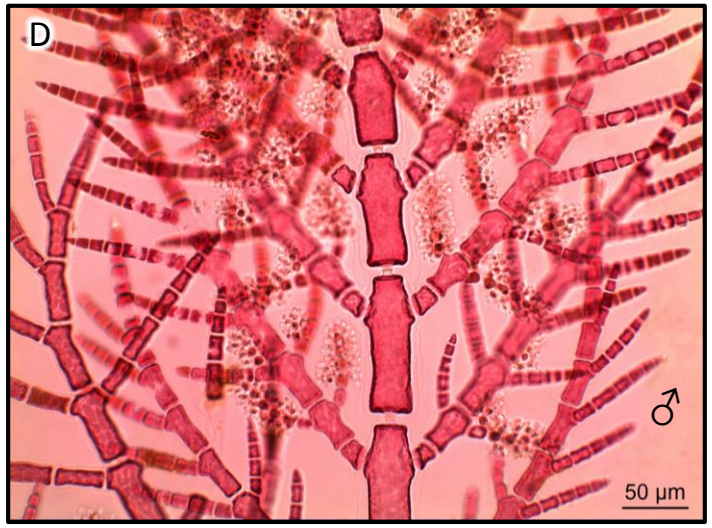
- Tiny filamentous branching epiphytes on a wide variety of turf and crustose algae.
- Thalli reach 1 mm in height, cells are 4-6 µm in diameter and bear a single lateral chloroplast with a large central pyrenoid (A, B).
- Uniseriate filaments arise from an encrusting filamentous base (B, white arrow) with short usually unilateral branches 3-4 cells long that form terminal and lateral monosporangia, 5-8 µm in diameter (C, D).
- Debris material included both mature and evacuated monosporangia (A, black arrows).
- Garbary *et al.* (1982), Hwang & Kim (2011).

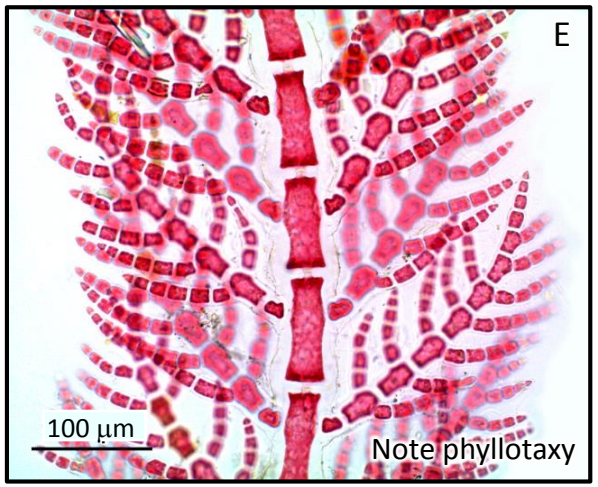
***Antithamnion nipponicum*[#] – A+ –** Asia (R, J, C, K), CA, EUR, ENA (NC). On 4 debris items (Jan-May). Exported from Asia with oysters for cultivation. Listed with the "**100 worst invaders in the Mediterranean**". Reproductive (♂). Ephemeral and isomorphic.

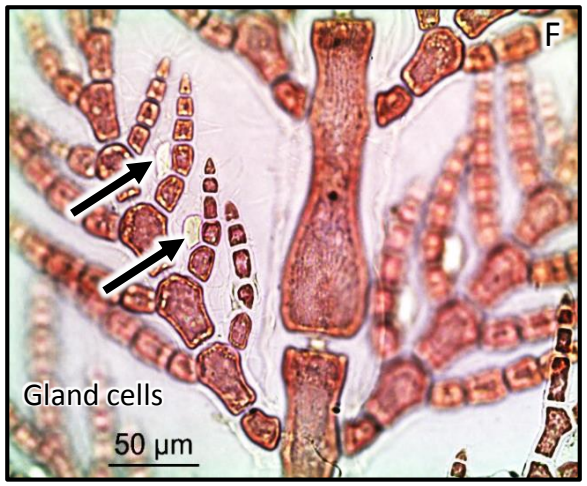








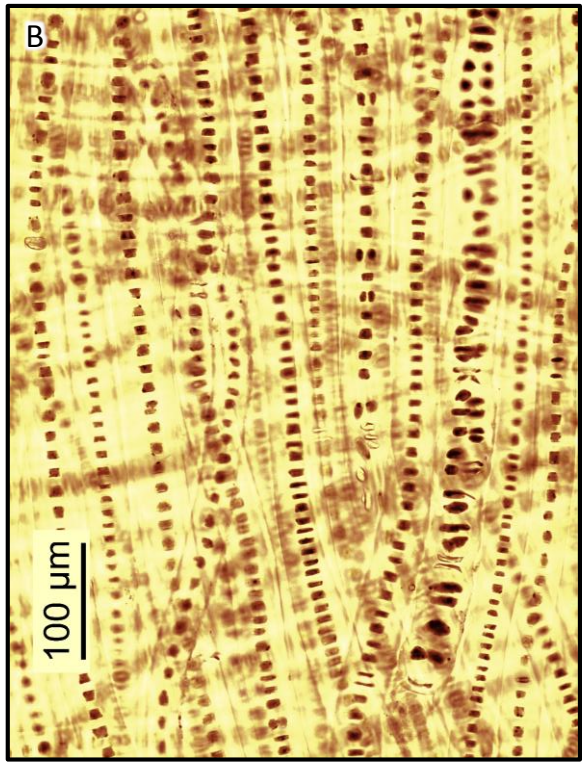


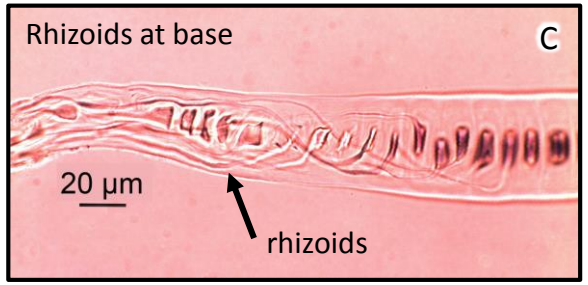


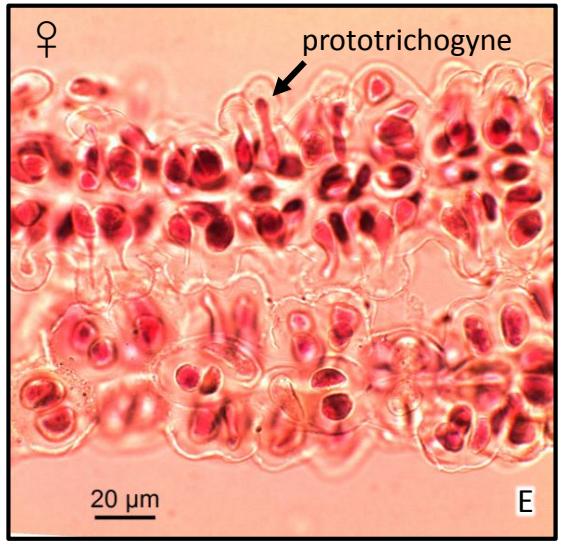
- Tiny epiphytic mat on corallines, kelps and *Codium*.
- Uniseriate, pinnately branched thalli, 1-2 cm tall, with axial filaments up to up to 70 µm broad (A).
- Apices are relatively straight (B).
- Determinant lateral branches have a small basal cells and a slightly sub-decussate phyllotaxy (E).
- Indeterminate branches and rhizoids develop from the basal cell of the determinant laterals (C, white arrow).
- Gland cells (F, black arrows) form on 1-2 cells of the secondary laterals.
- Reproduces sexually or by fragmentation: can quickly colonize a variety of substrates. Male thalli shown (D).
- Similar to and possibly synonymous with *A. hubbsii*.
- Not sequenced: MC (BF-8), Yac (BF-135), NC (BF-208), RE (BF-533).
- Cho *et al.* (2005), Athanasiadis (2009); # Confirmed by T. O. Cho.

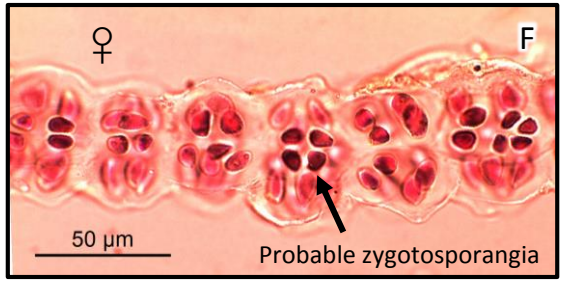
Bangia cf. _fuscopurpurea_✶ – G (Globally widespread) – On 3 debris items (May, Nov). ✶LBD-368 (BF-397).

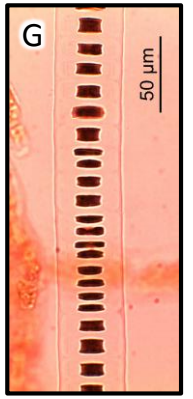
Not sequenced: SRT (BF-277), SVB (BF-402). A genetic variant of *B. fuscopurpurea.* Fertile & unisexual (green male and brown female filaments). Annual sexual and ephemeral (year around) asexual thalli are known. Heteromorphic: erect gametophytes alternate with a microscopic filamentous *Conchocelis*-like sporophyte.

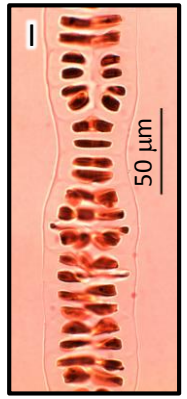


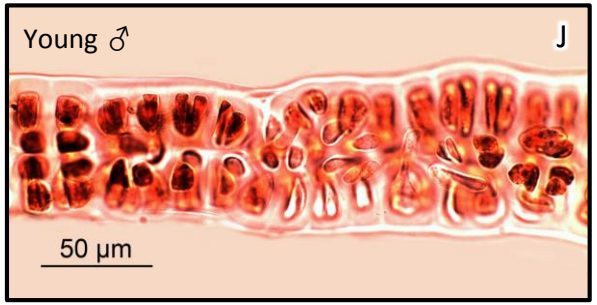


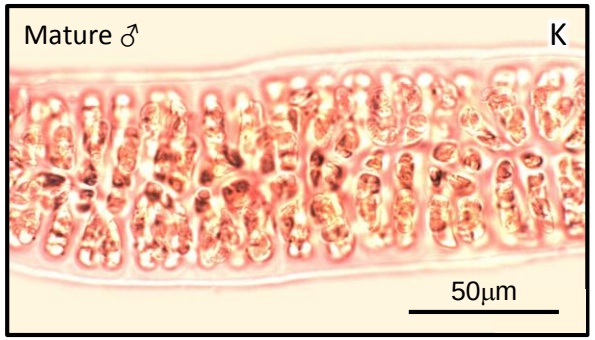




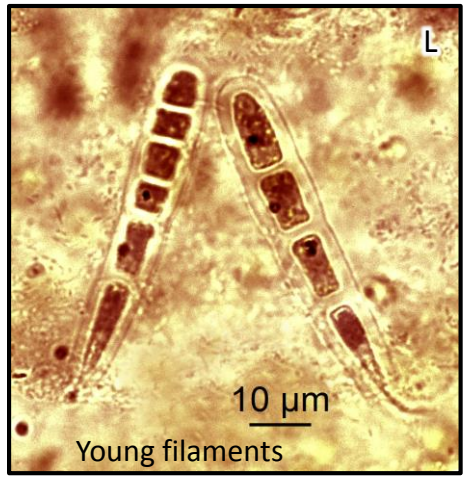


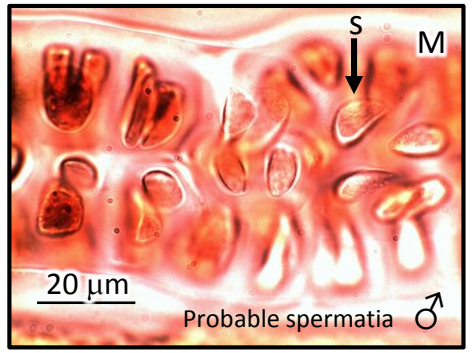


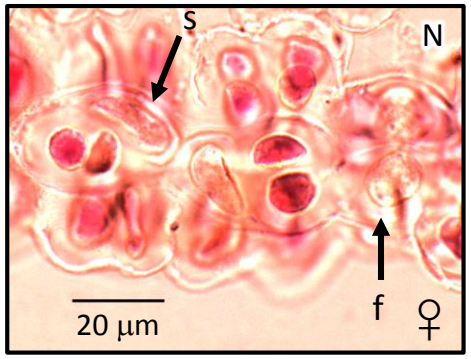


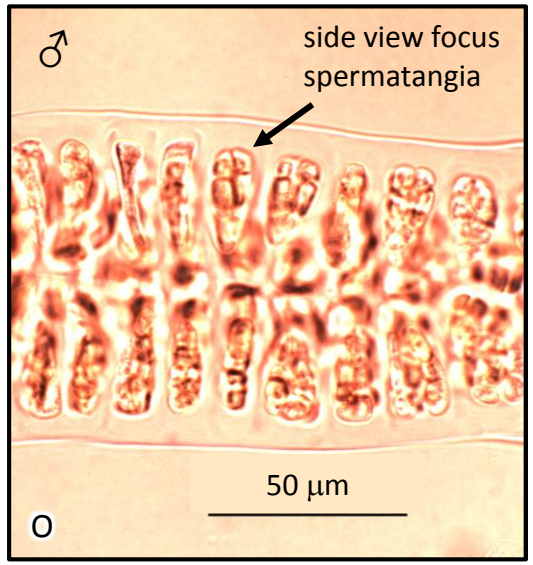


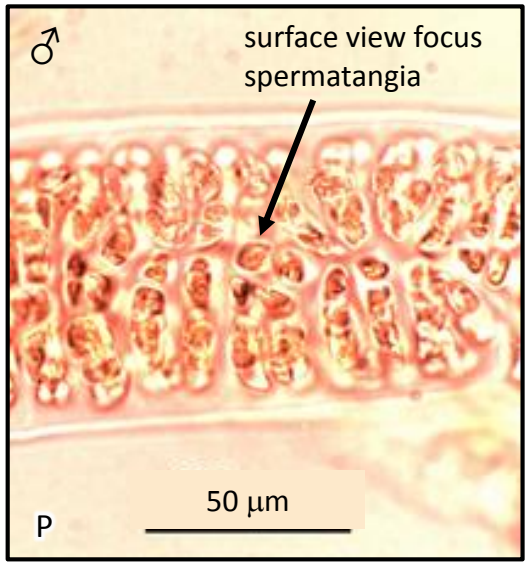
Bangia cf. *fuscopurpurea* #2 – more details on the debris species.

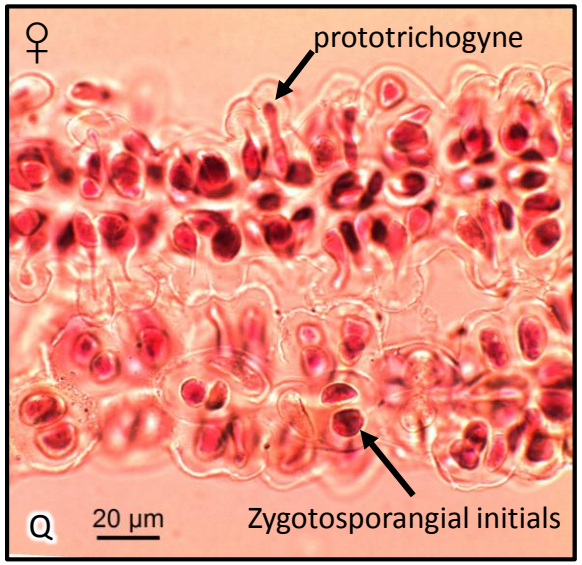






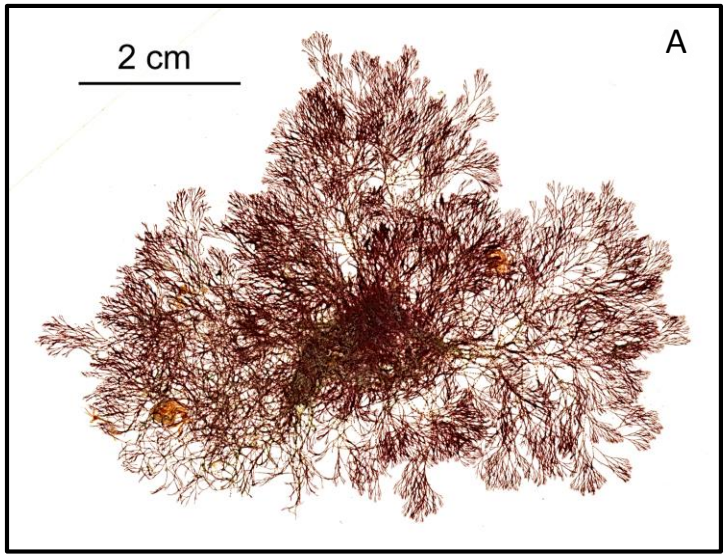


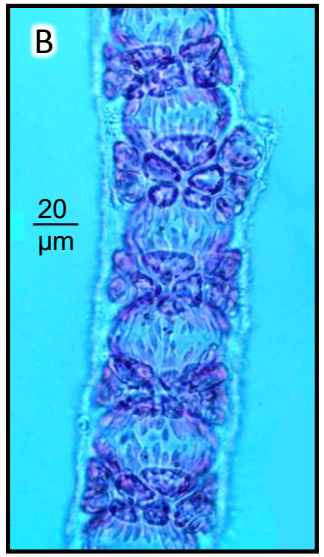


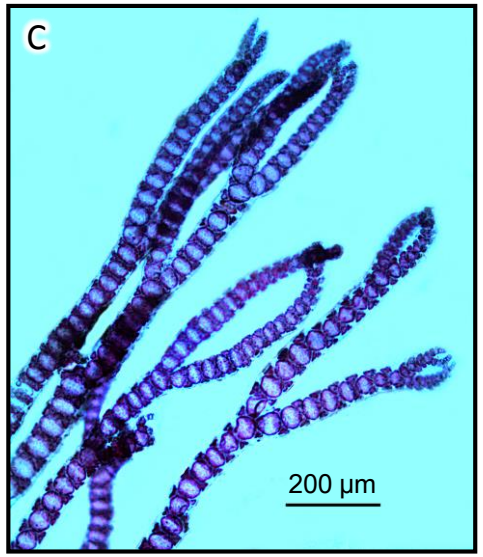


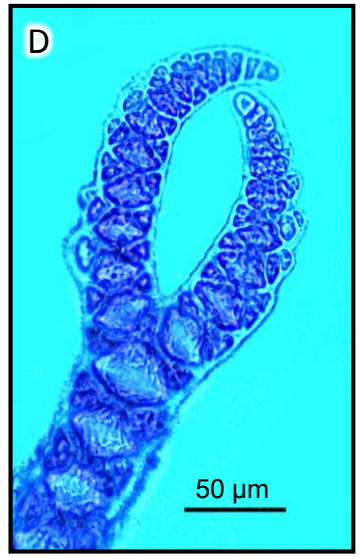
- Thalli on debris (and in Japan) were robust, draped in thick wefts on the LBD dock fragment with filaments up to 10-15 cm long (A, B). Spores germinate to form basal rhizoidal cells (C, L) and erect uniseriate filaments up to 50 µm in thickness (B). Each cell bears a single stellate chloroplast with a central pyrenoid.
- Developmental stages are shown (D-K): The filaments soon become biseriate, and each cell divides to eventually form male or female reproductive structures. Often the biseriate filaments appeared to split with each half becoming reproductive.
- Closer details of reproduction are shown in M-Q: M and N show probable spermatia (s) and fertilization (f). Mature reproductive filaments can be 100 µm in diameter.
- The native NE Pacific marine *Bangia* sp. differs from the debris form in that it typically produces uniseriate filaments that divide to form a hollow tube. Cells within the tube divide to produce zygotosporangia and spermatangia.
- Our sequencing revealed that (1) the *Bangia* species on debris is molecularly similar to *B. fuscopurpurea* (type locality, Wales), (2) the Oregon *Bangia* we processed was a different species, and (3) there are additional *Bangia* species on each coast.
- Molecular studies by Sutherland *et al.* (2011), Kucera and Saunders (2012), and others have revealed a number of new cryptic species and genera within the filamentous Bangiales. The taxonomy of this group is still under investigation.
- Tanaka (1950), Garbary *et al*. (1980, Fig. 9 h, k, n), Nelson *et al*. (1999, for terminology), Sutherland *et al*. (2011), Kucera & Saunders (2012).

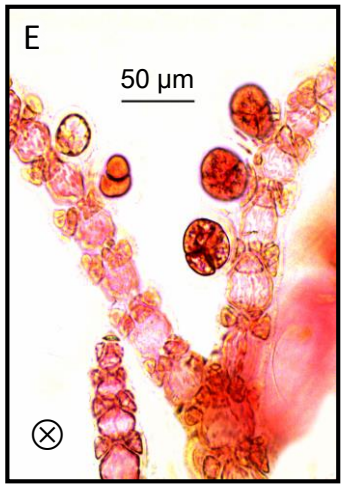
***Ceramium sungminbooi*✶ – A+ –** Asia (K), WA, OR, CA, EUR. Newly described.
On 5 debris items (Jan, Feb, Jun, Oct). Reproductive (tetrasporic and cystocarpic). Annual and isomorphic.

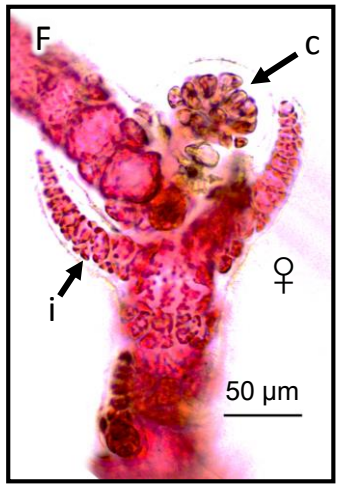








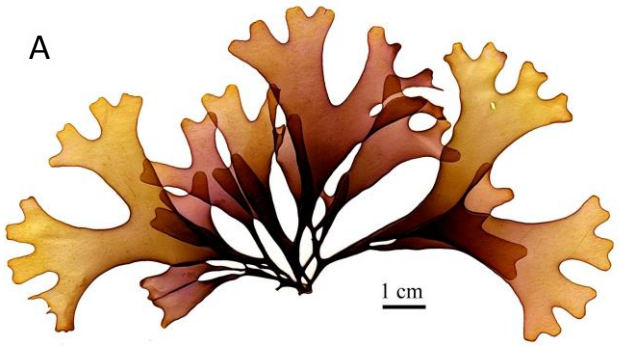


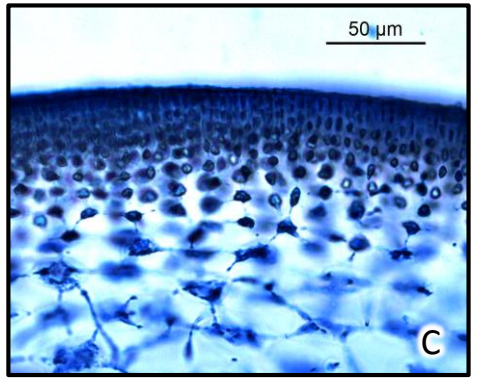


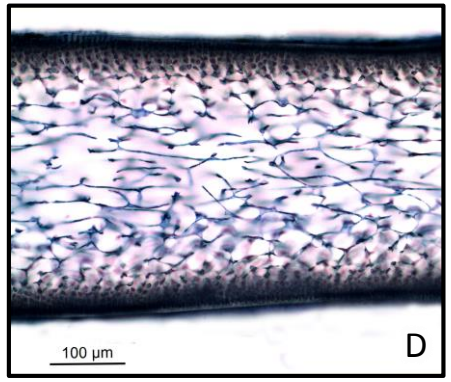
- Delicate rose-red uniseriate filamentous thalli that reach 3-5 (10) cm tall (A).
- Short corticating bands, only 3-6 cells tall, occur at each cell node (B).
- Branching is pseudo-dichotomous to irregular (C).
- The divided branch tips are typically straight and unequal in length (D).
- Tetrasporangia are emergent and tetrahedral and generally occur unilaterally only on the adaxial side of the branches (E).
- Near the branch apices, female thalli bear globose carposporophytes (F) with a single gonimolobe (c) and 2-4 involucral branches (i).
- Male thalli were not observed.
- Cho, Boo & Hansen (2002, as *C. cimbricum*), Hughey & Boo (2016).

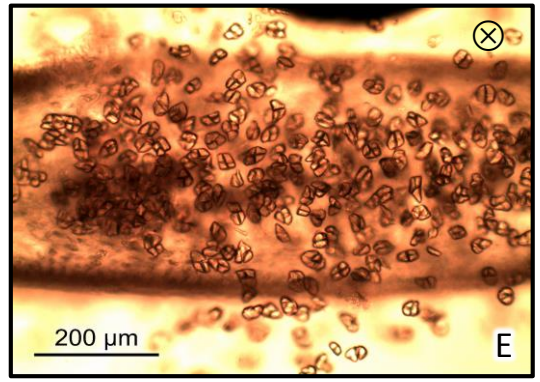
✶ MC-36 (BF-8); not sequenced: AB (BF-1) , CBD (BF-130), Yac (BF-135), Bev (BF-288).

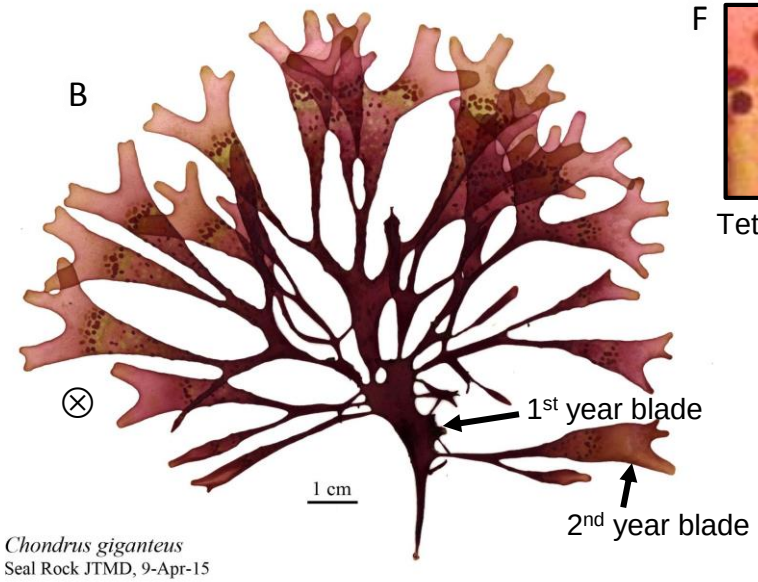
***Chondrus giganteus* f. *flabellatus** – A+ –** Asia (J, K), France (introduced on oysters for cultivation). On 2 debris items (Apr, Jun). Reproductive (tetrasporic). Isomorphic and pseudo-perennial.



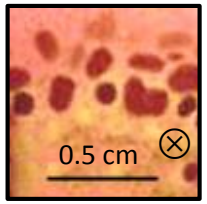








Chondrus giganteus
Seal Rock JTMD, 9-Apr-15

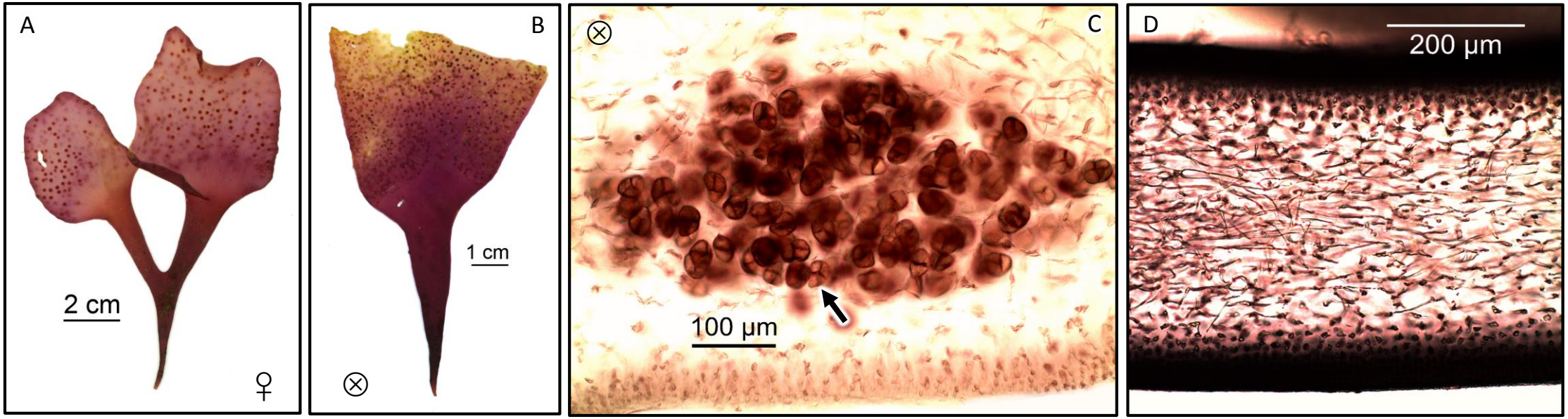


Tetrasporangial sori

- Thalli with flattened fan-shaped pseudo-dichotomously divided thalli with broadly rounded or bifurcate apices and a narrow cuneate base. Up to 6 ranks of branching have been observed. Proliferations are common along the lower margins and are known to occur on the blade surface.
- Thalli are 8-12 cm tall and 12-15 cm wide on debris (A, B).
- Thalli are 250-450 µm thick and contain a broad filamentous medulla with both rhizoidal filaments and stellate cells and a narrow cortex of about 6-8 small globose cells (C, D).
- The blades appear to survive for up to 2 years as evidenced by the production of new blades from the eroded first-year basal blades (B).
- Cruciate tetrasporangia (35-50 µm wide) develop in medullary sori that are thickly dispersed in the subapical portions of the upper branches and are frequently confluent (B, F). The medullary cells in the fertile areas form accessory filaments whose cells transform directly into tetrasporangia (E).
- Female thalli were not observed.
- Mikami (1965, Plate VII, #1), Verlaque *et al.* (2015).

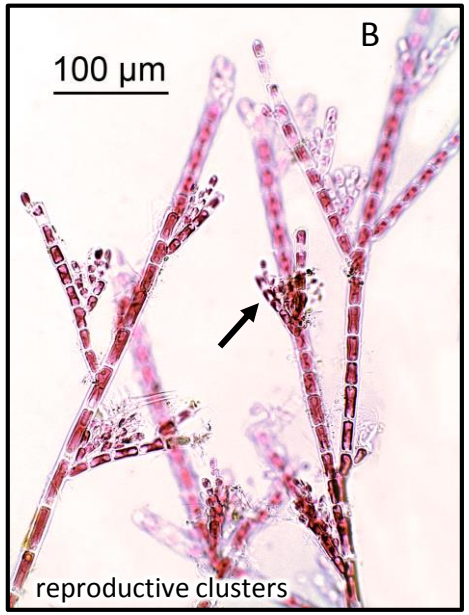
* BB-003a (BF-2), SR-203 and 237 (BF-356). Sequences could not distinguish the *forma*.

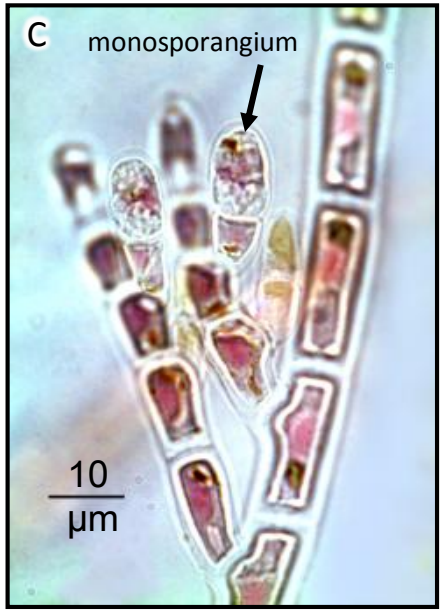
_Chondrus yendoi_* **– A –** **Asian only** (R, J, K). On only 1 debris item (Mar). * LB-003 (BF-285). Nicknamed the "Buddha's Ear". Sterile on debris, but reproductive specimens from Tōhoku are illustrated. Isomorphic and pseudo-perennial.

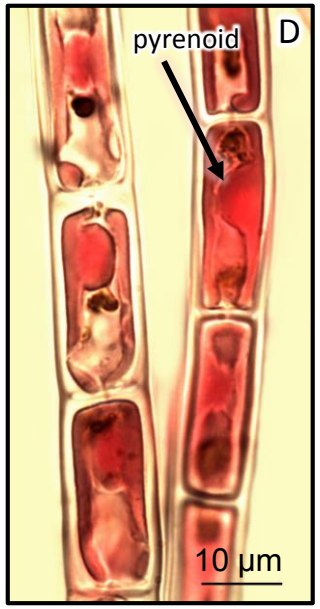


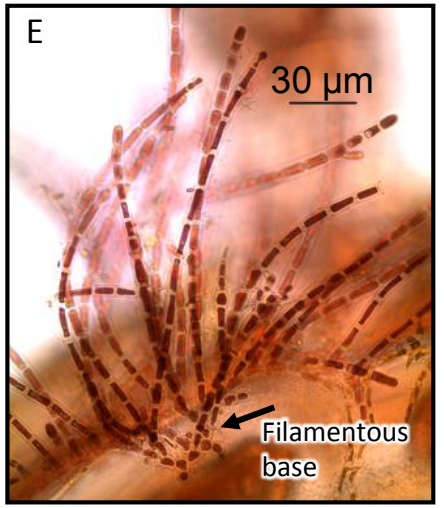
- Broadly lobed and often deeply divided rubbery blades that narrow to a long cuneate apophysis and small discoidal holdfast (A, B). Proliferations often occur along the apophysis and blade margin (not seen).
- Thalli reach 5-15 (30) cm in height and are caespitose in the field.
- Sterile blades reach >400 µm in thickness and consist of a densely filamentous medulla and narrow cortices, ~4-8 cells in length (D). Tetrasporic blades are ~650 µm thick.
- Cruciate tetrasporangia (up to 60 µm in height) develop in internal sori (C, arrow). The sori are thickly scattered across the upper blades of the sporophytes and are often confluent (B, F).
- Cystocarps, 1-3 mm in diameter, also develop in an irregular scattered array across the upper blades of female thalli (A, E). Male thalli were not observed.
- Mikami (1965, Plate IV, #2).

Colaconema daviesii cpx.* **– G (Globally widespread) –** Asia (R, J, K, C), AK-MX, SA, Aus, ENA, Car, EUR, Med, Afr. On 20 debris items (Jan-Jun, Oct). Epiphytic on *Lepas anatifera* and most debris macroalgae. Fertile (monospores). Ephemeral.

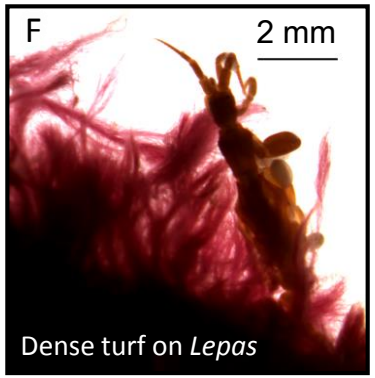


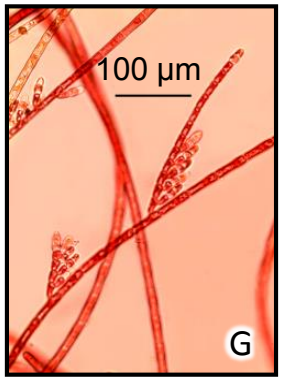






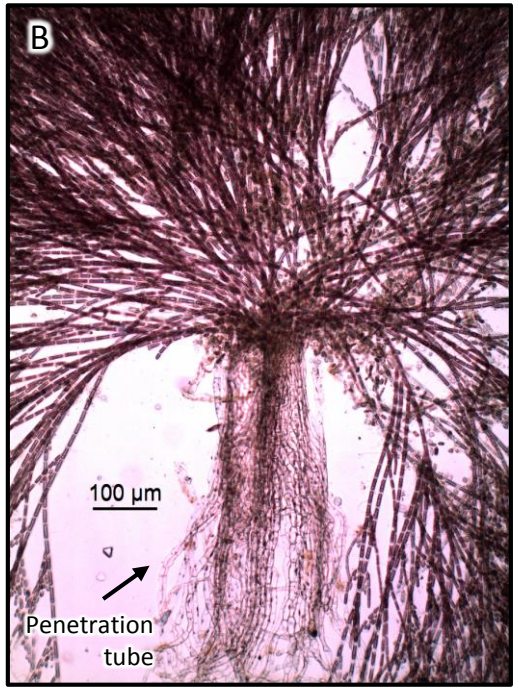
* HF2-736 (BF-526), SR-726 (BF-356); both are sequence variants.

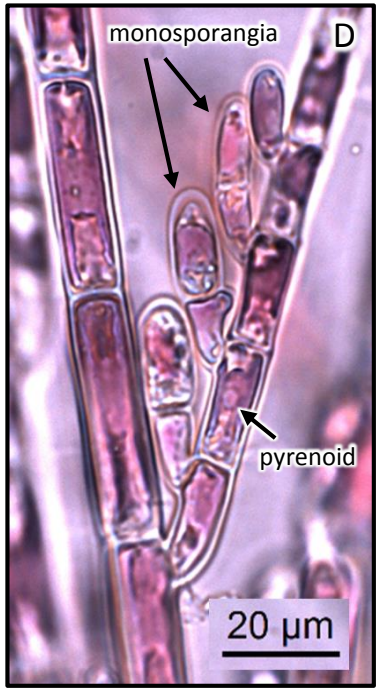


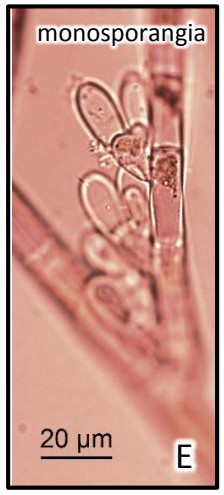


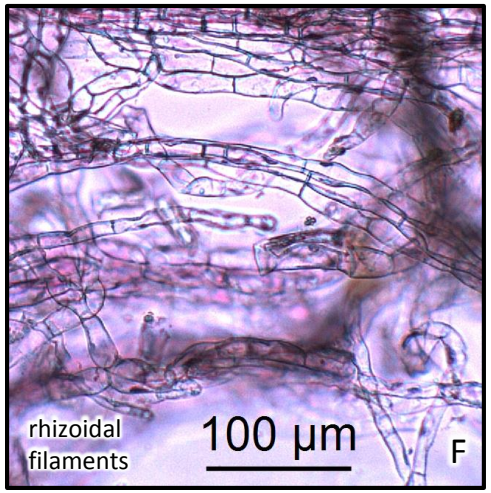
- Tiny branched uniseriate filaments, up to 6 mm tall, attached by a filamentous basal system and often forming a dense turf on their hosts (A, E, F).
- Branching is infrequent and alternate or irregular.
- Cells are 7-14 µm in diameter and 12-40 µm long, and each contains a parietal chloroplast with a large central pyrenoid (D).
- Monosporangia, 10-20 µm in length, appear clustered on spaced-out short lateral branches of the axes (B, arrow). These laterals, 4-15 cells in length, formed monosporangia on short, occasionally branched pedicels, most always on their adaxial side, toward the axis (C, G). Tetrasporangia not observed.
- Lee & Yoshida (1997), Lee (2008), Garbary *et al.* (1982). Stegenga (1985, fig. 20).

Colaconema savianum cpx.✶ – G (Globally widespread) – Asia (K, C, R), CA, SA, AUS, ENA, Car, EUR, Med, Afr. On 5 debris items (Jan-Mar, May, Jul). Epi-endophytic on *Codium* (with rhizoidal penetration tubes) and on rope. Reproductive (monosporangia). Ephemeral. ✶ RE-669 & 674 (BF-533); not sequenced: MC (BF-8), HF-1 (BF-28), svb (BF-402), Fal (BF-652). A sequence variant.



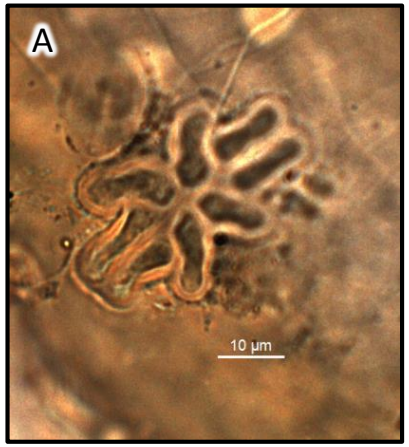


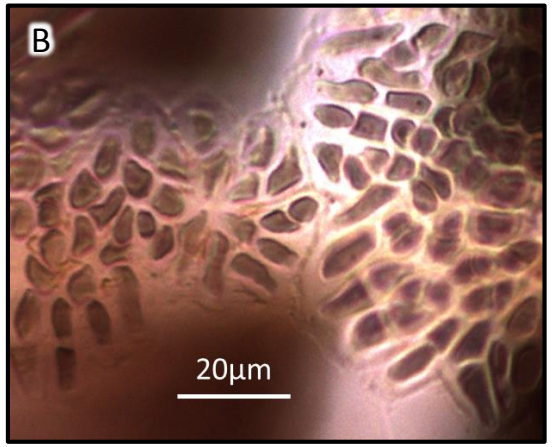


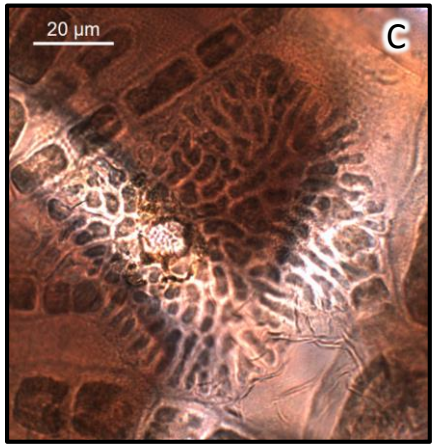


- Dense spherical clumps of filaments 3-10 mm in height on rope and anchored in *Codium fragile* subsp. *fragile* and also epiphytic on other algae.
- In *Codium,* the attachment is a filamentous penetration tube often 0.5 mm long composed of compressed branched rhizoidal filaments 9-15 µm in diameter (A, B, F). This differs from Womersley (fig. 7E) and Schneider & Searles (fig. 247) who illustrate the attachment as a pseudo-parenchymatous disc.
- Erect filaments are branched in a secund or occasionally irregular pattern and taper toward their tips.
- Cells 7-15 µm broad and 2-5x as long as broad – with a single parietal chloroplast and a central pyrenoid (D).
- Monosporangia, 7-20 µm long, often develop on a series of up to 6 cells, most often on the lower portion and adaxial side of normal branches (C). Sporangia are single or in pairs and on short 1-2-celled pedicels (D, E).
- Schneider & Searles (1991), Womersley (1994), Perestenko (1994/1996).

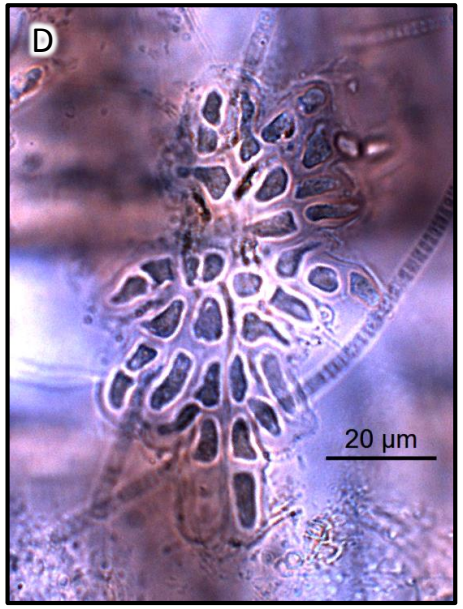
***Erythrocladia irregularis* – G (Globally widespread) –** including Asia (R, J, C, K), AK-MX & EUR.
Epiphytic on *Polysiphonia* and hydroids on the Oysterville boat (BF-331) (Mar). Reproductive (monospores). Ephemeral.

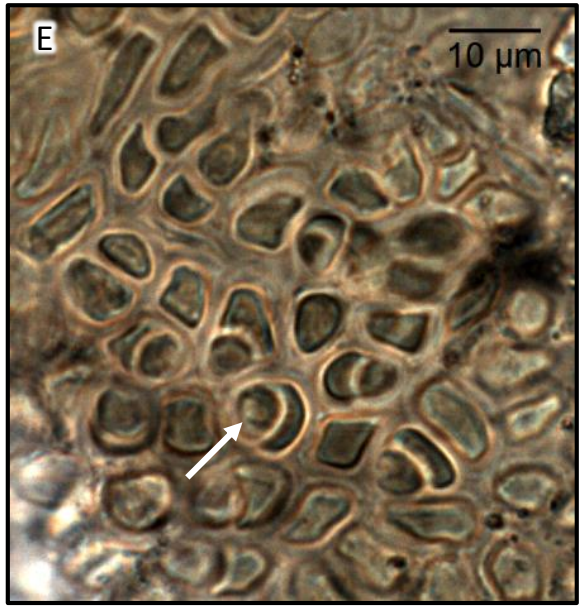


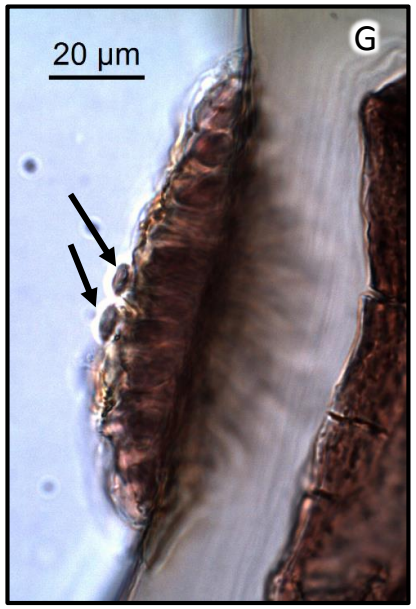


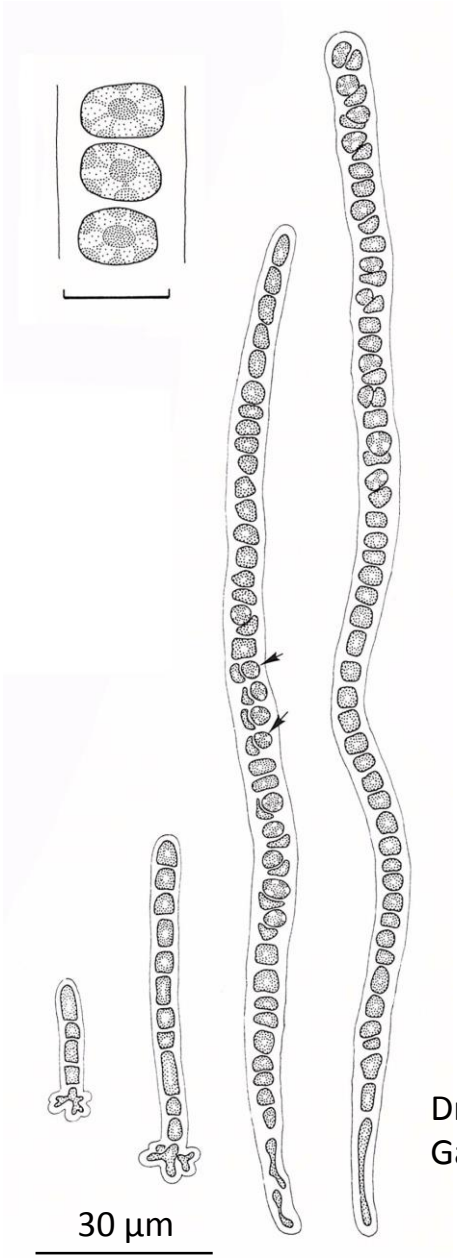


- Microscopic irregular filamentous discs with free marginal tips – without bifurcation. Developmental stages are shown (A, B, C, D).
- Monostromatic margins and polystromatic central reproductive areas.
- Filament apices are 5-7 µm in diameter.
- Cells have a single parietal chloroplast with a small central pyrenoid.
- Monosporangia, 4-6 µm in diameter (arrows), globose to slightly flat, cut off by a curved wall (E, F, G, white and black arrows).
- Only asexual reproduction is known.
- Garbary *et al.* (1980), Kim & Kim (2011), Tanaka (1944).









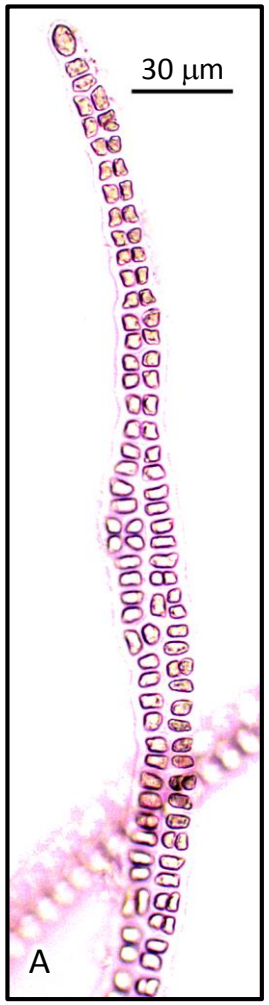
Drawings used in Fig. 4 of
Garbary, Hansen & Scagel (1980)

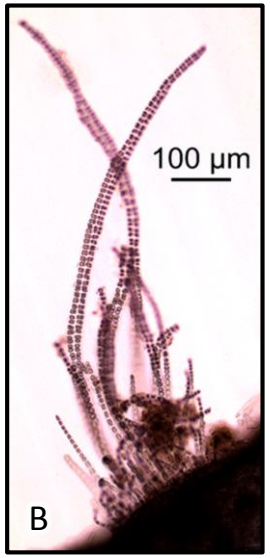
***Erythrotrichia carnea* – G (Globally widespread) –** Observed as an epiphyte on only the Agate Beach dock (BF-1) (Jun). Reproductive (monosporangia). Ephemeral.

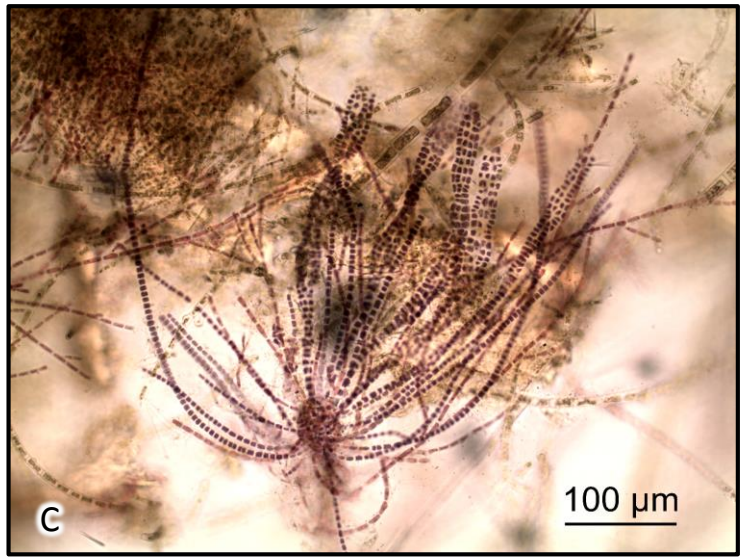
- Tiny unbranched uniseriate filaments, 9-12 µm in diameter and up to 5 mm in height.
- Each cell contains a single central stellate chloroplast with a central pyrenoid.
- Basal cells may have short branch-like extensions.
- Cells of the filaments are of irregular length
- Monosporangia (arrows), ~12 µm in diameter, are cut off from any cell in the filament via a curved wall
- Tanaka (1944), Garbary *et al*. (1980), Kim & Kim (2011).

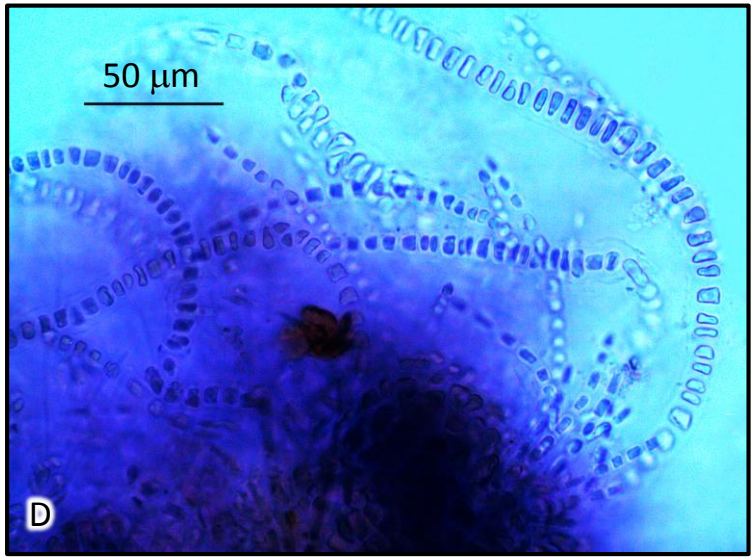
Debris specimen was not photographed. Illustrations at left are copies of my original drawings for my monograph of this group in British Columbia and Washington.

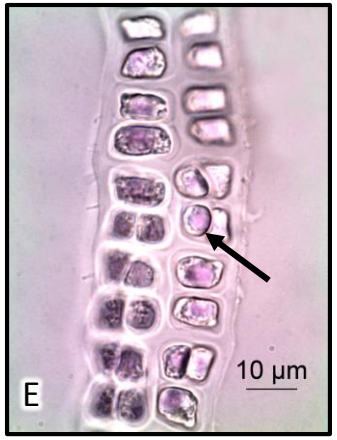
***Erythrotrichia incrassata* – A –** Asian only (J). Epiphytic on disintegrating algae.
On 6 debris items (Feb-May). Asexually reproductive on debris (monospores). Ephemeral.





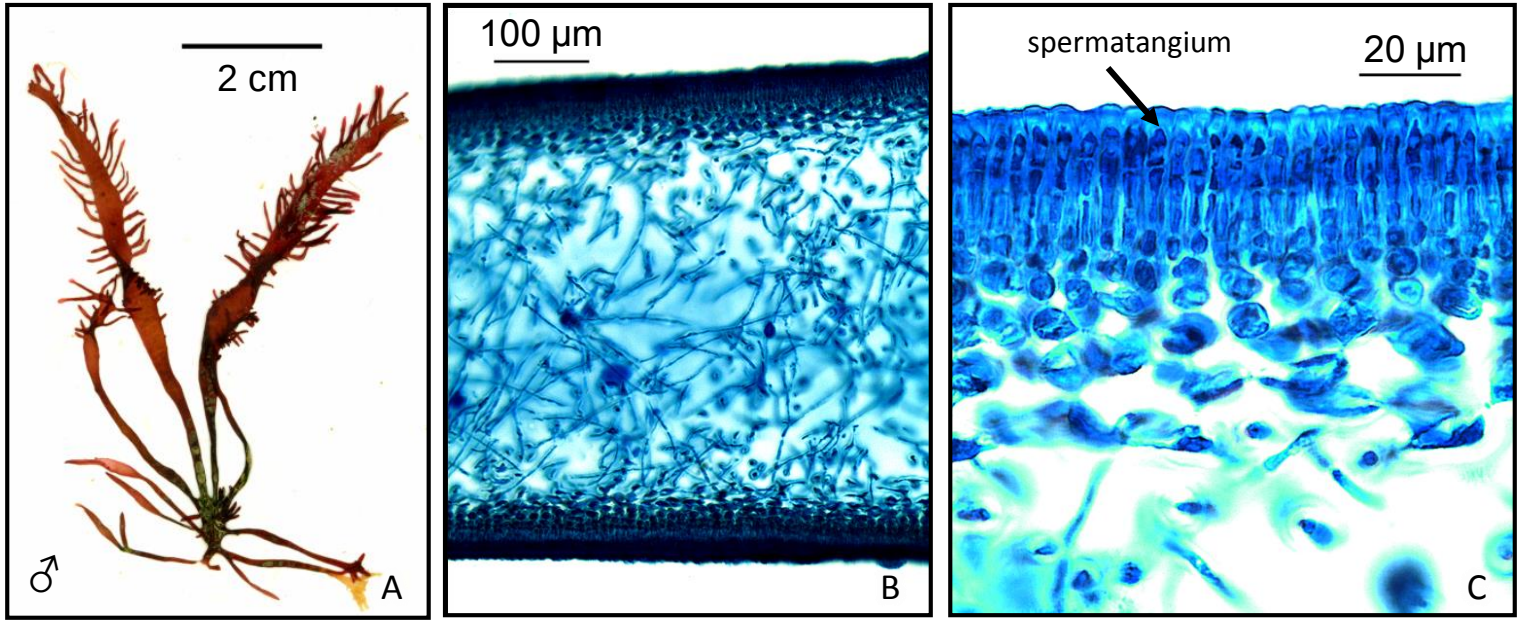






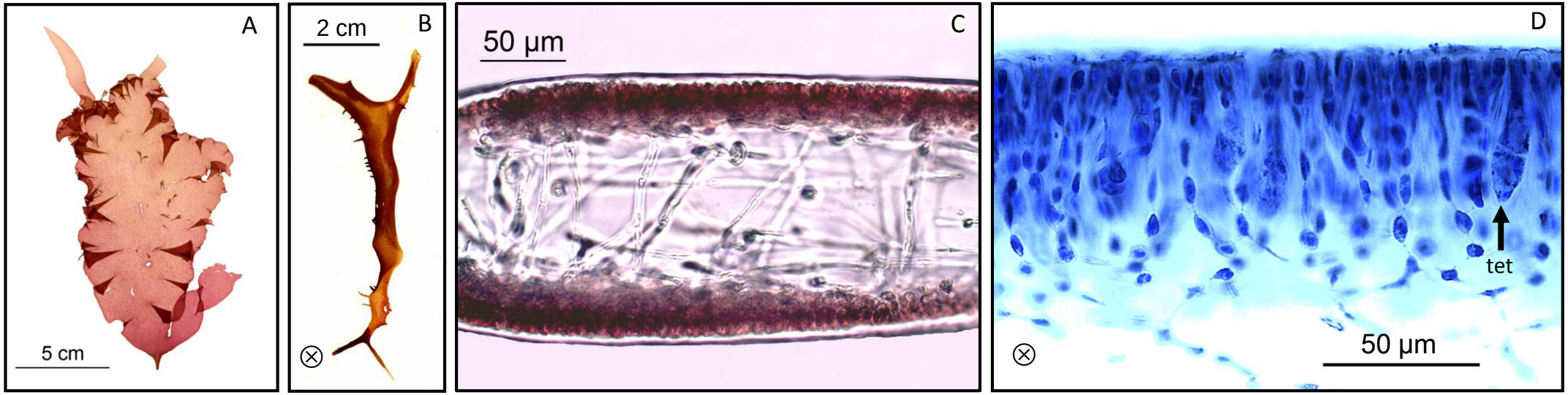
- Caespitose uniseriate to multiseriate flattened thalli that may be up to 5 mm tall.
- Attached to their substratum via a clustered filamentous base immersed in turf (B, C).
- Upright filaments are initially uniseriate but then divide both transversely and longitudinally becoming multiseriate and up to 6-8 cells in diameter (A, B, C, D).
- Cells contain a single stellate chloroplast with a central pyrenoid.
- Monosporangia (arrow) are cut off from the main cells by a curved wall (E).
- Difficult to separate from young *Porphyrostromium japonicum.*
- Tanaka (1944, figs. 11, 12). Not sequenced: GB (BF-23), fish (BF-40), CBB (BF-58), TBT (BF-160), LC (BF-173), Oys (BF-331).

Grateloupia livida ✶ **– A –** Asian only (J, C, K & IO). Only on the Benson Beach boat (Jun). ✶ BB-005 (BF-2). Reproductive (male only). Annual & isomorphic.



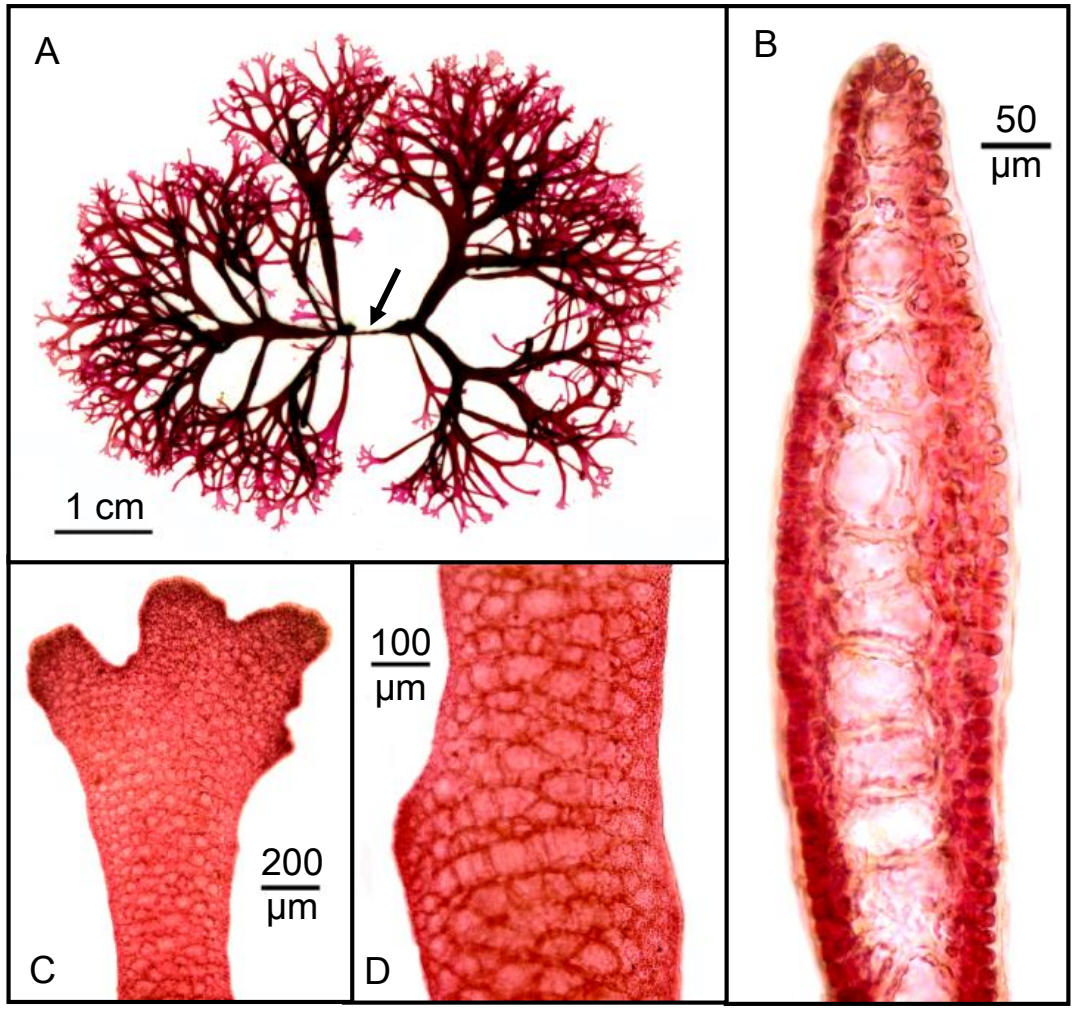
- Narrow flattened linear blades with acute apices that vary in overall habit sexually. Only male thalli were observed.
- Distinctly narrow male blades arose from a discoidal holdfast and bore closely spaced nearly terete marginal proliferations (A).
- The blades on debris were up to 7 cm tall, 0.4 cm broad, and 360-400 µm thick.
- Female and tetrasporangial blades (not seen) are more broadly lanceolate and irregularly branched or split. The tips are often forked, and blade-like proliferations can occur along the margins.
- Blades were slightly cartilaginous and had a filamentous medulla with rare stellate cells (B).
- Male sori occurred on the blade surface. Spermatangia (arrow) were cut off by horizontal walls (C).
- Yamada, Y. (1931).

***Grateloupia turuturu*✶ – A+ –** Asia (R, J, C, K), Aus, NZ, CA, ENA, Carib, SA, EUR, Medit, Afr. On 3 debris items (May, Apr, Jun). Introduced with oysters and fouling to Europe. Listed with "**100 worse invaders in the Mediterranean**". Reproductive (tetrasporic). Annual and isomorphic. ✶ BB-3b (BF-2), SixR-710 (BF-538), HF2 (B-526).



- Thin, gelatinous linear-lanceolate to ovate blades with a short stipe extending into a discoidal holdfast. The blades are undulate, somewhat lobed, and occasionally have short scattered proliferations along the margin (A, B).
- In Japan, thalli are 20-40 (70) cm in height, 5-10 cm wide, and 200-400 µm thick.
- The blades have a loose filamentous medulla with frequent anticlinal (cortex to cortex) and some periclinal filaments. The cortex and subcortex consists of around 6-8 cell layers (C).
- Cruciate tetrasporangia, 20-30 x 30-40 µm, occur scattered throughout the cortex (D). On debris, only small tetrasporic blades were present. Sexual thalli were not observed, but fertile female thalli would have clustered cystocarps, ~ 300 µm in diameter, scattered across the surface of the blade.
- A widespread and aggressive invader in many areas. Nicknamed the "red menace" in New England by Van Patton (2006).
- Except for an introduction into CA, the species is not yet known in the NE Pacific. However, due to its similarity in habit and anatomy to some native *Halymenia* species, it could easily be overlooked.
- Yamada (1941), Mineur *et al.* (2010), Streftaris & Zenotos (2006).

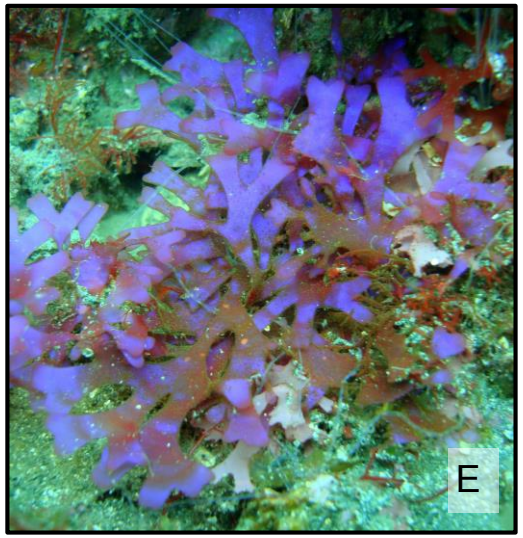
Leptofauchea leptophylla[#] – A – Asian only (J, K, Phil). Only on the 1st JTMD item in Oregon (Jun), the Agate Beach derelict dock (BF-1). Sterile on debris. Annual and isomorphic.



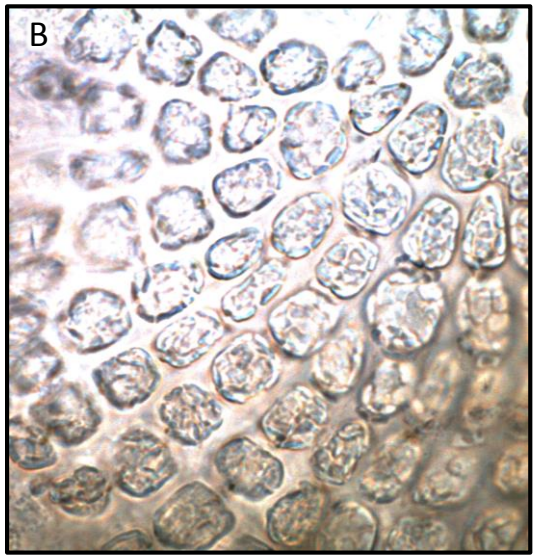
- Small highly-branched thalli, 4-6 cm tall, with a short stipe and iridescence under water.
- Branches are membranous and narrow, 3-5 mm in diameter, and 160 µm thick.
- Branching is repeatedly dichotomous to irregular and increases outwardly.
- Branch apices are rounded or knotched.
- Cystocarps are marginal (not seen).
- Tetrasporangia occur in banded nemathecia and are produced among paraphyses on the blade surface (not seen).
- Suzuki *et al.* (2012, figs. 1-15).).

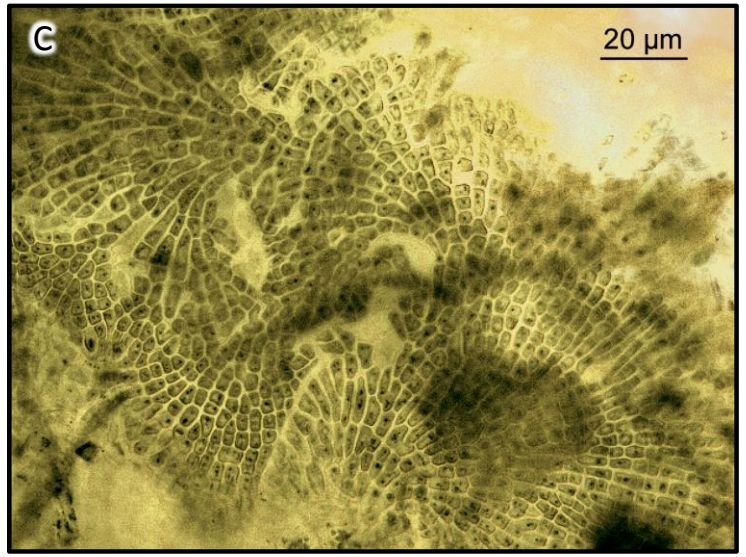
A. Habit of young tufted thallus with clear stipe (arrow).
B. Cross section with large medullary cells.
C. Knotched branch tips.
D. Optical surface view revealing large medullary cell rows.
E. Iridescent thallus in Japan.

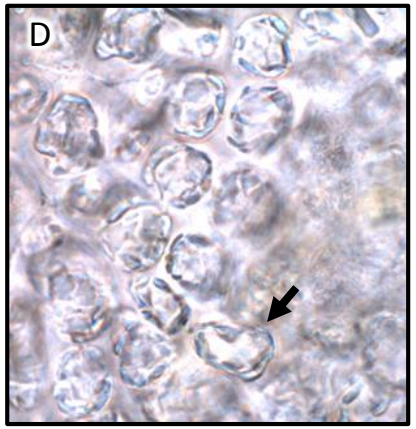
R. Tereda sent the field photo.
M. Suzuki identified the JTMD specimen.

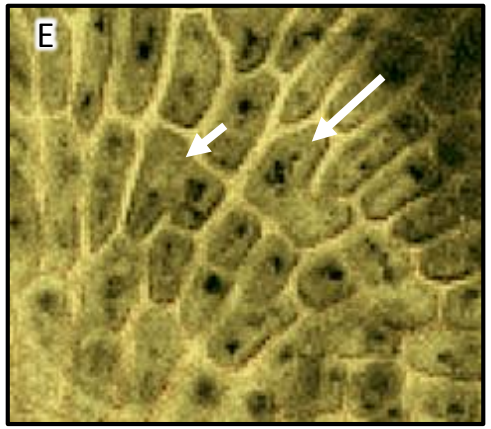


Meiodiscus spetsbergensis – G (Globally widespread) – Asia (R, J), AK-BC, EUR-Arc & Afr.
On barnacles on 1 debris item (Mar) – HF-2 (BF-526). Only the basal crust was observed. Sterile. Ephemeral.



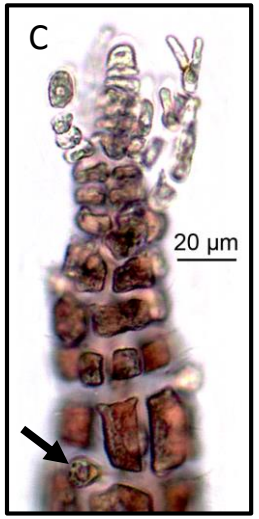


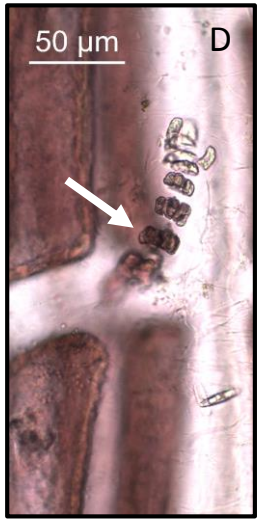


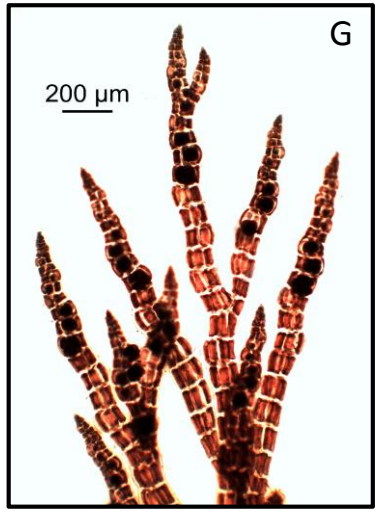


- A thin, crustose red alga with erect tetrasporangial filaments found growing on barnacles and hydroids.
- JTMD material was deteriorating; no erect reproductive structures were seen.
- The basal crust formed the classical fan shapes of this genus with cells in linear rows (A, B, C) and some cell fusions (D, E, black and white arrows).
- Discoidal chloroplasts were apparent in some material.
- Under short-day conditions, upright uniseriate filaments are known to develop, producing apomictic tetrasporangia terminally or on slightly branched laterals.
- Saunders & McLachlan (1991) demonstrated the asexual life history. Their culture studies revealed that spores germinate, reach maturity and release new tetraspores, all within 3 weeks, following the life cycle through 5 generations. This indicated to us that this species has ephemeral capabilities.
- Related species: *M. concrescens*. Life history demonstrated by West (1970).

Melanothamnus japonicus **– A+ –** Asia (R, J, C, K), NZ, ENA, Car. On 2 debris items (Feb, Apr).
Reproductive (only tetrasporic observed). Isomorphic, epiphytic & ephemeral*. Not sequenced: GB (BF-23), CBS (BF-50).





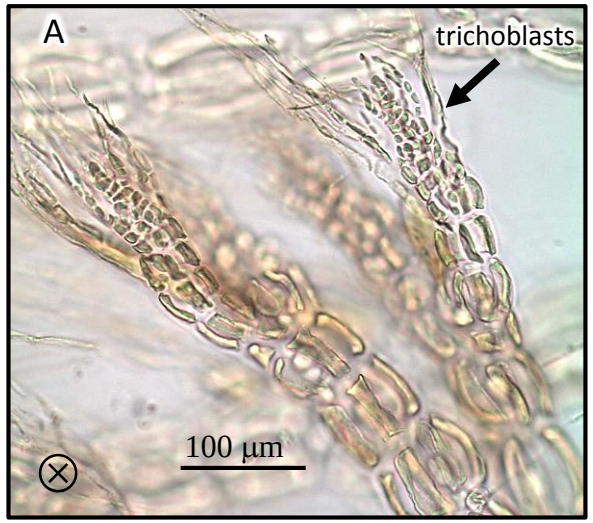


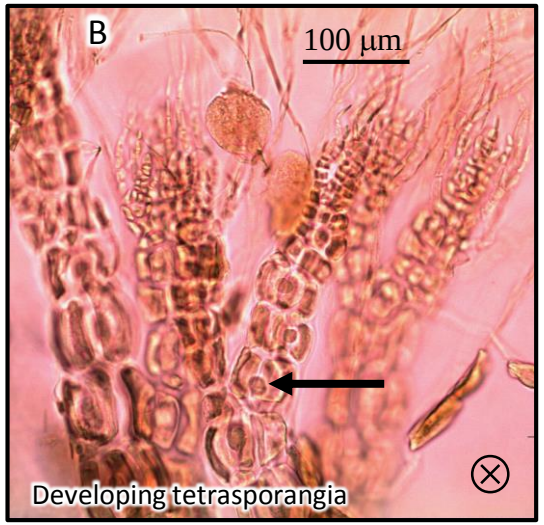
A. An epiphyte on *Codium* and other algae.
B. Terete sub-dicotomously branched polysiphonous thalli, 7-8 cm tall.
C. Narrowed tips have dome-shaped apical cells and often several trichoblasts that leave scar cells (black arrow) as they drop off.
D. Cicatrigenous branches (white arrow) frequent & form from scar cells.
E. Branches have 4 pericentral cells and cortication (white arrow) near the thallus base.
F. Tetrahedral tetrasporangia (reported as up to 100 µm in diameter).
G. Tetrasporangia developing in a spiral pattern near the branch apices.

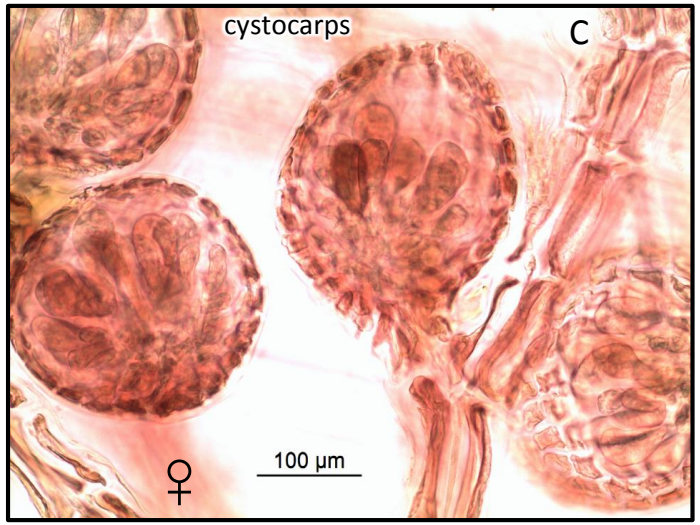
Kudo & Masuda (1986, figs. 2-5, Kim & Lee (1999), Kim & Yang (2006), Díaz-Tapia *et al.* (2017).

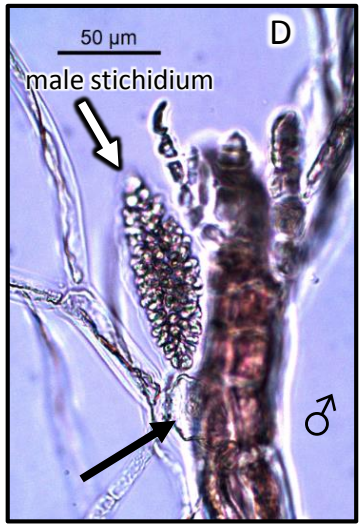
*Kudo & Masuda (1986) found thalli matured to spore release in 14-28 days and occurred from February to November in Japan. An ephemeral.

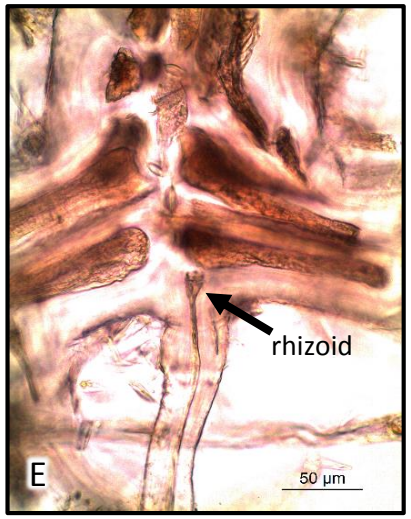
Melanothamnus yendoi✶ **– G – (Widespread – particularly in tropical areas) –** Asia (R, J, C, K), Polynesia, HA, ENA, Car, SA (Brazil), Bermuda, Med. On 2 debris items (Mar, Jul). Reproductive (⊗, ♀, ♂). ~Annual and isomorphic.









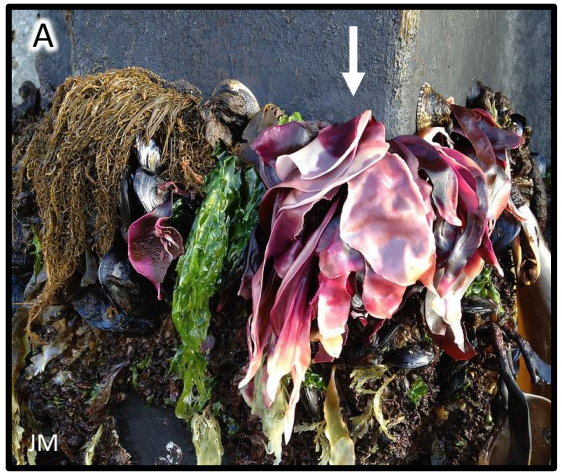


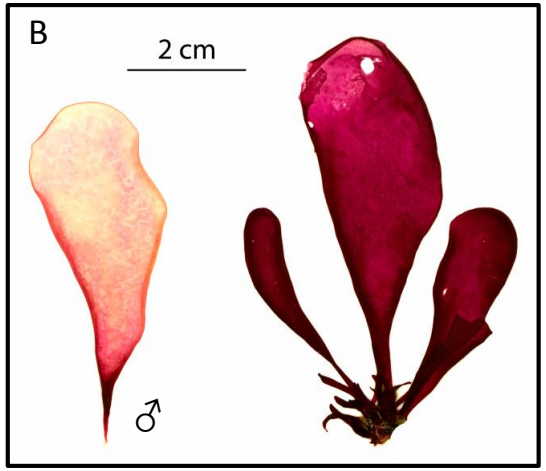
- Polysiphonous thalli, 2-3 cm tall – partially disintegrated on debris.
- 4 pericentral cells and numerous trichoblasts at the branch tips (A, B).
- Spiral or alternate endogenous branching.
- Occasional scar cells and cicatrigenous branches.
- Tetrahedral tetrasporangia reach 60 µm in diameter at maturity and form in a spiral series (B, black arrow).
- ♀ – cystocarps are globose to ovate (C).
- ♂ stichidia develop on the basal cells (D, black arrow) of a branched trichoblast and bear a single terminal sterile cell (D, white arrow).
- Rhizoids cut off by cross walls and initiated at the ends and center of pericentral cells (E, black arrow).
- Spring to early summer in Japan, suspected annual.
- Dias-Tapia et al. (2017) suggest that *Melanothamnus* species originated in the Pacific and give the example of *M. harveyi*, a well known Asian invader initially transported globally with oysters. We suspect that *M. yendoi* could be an undocumented A+ species.
- Segi (1951), Nam & Kang (2012)

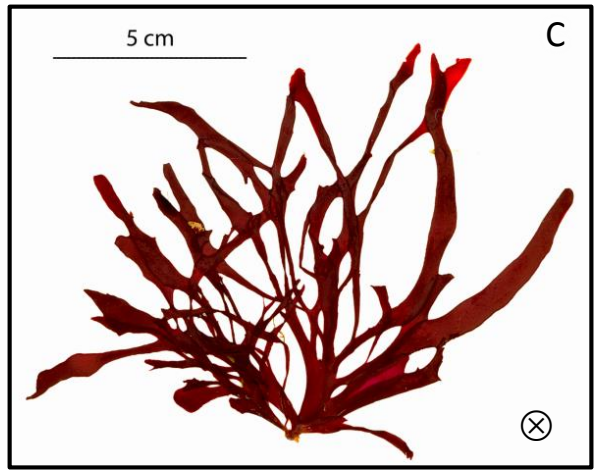
✶ Ump-706 (BF-705), Fal-754 (BF-652).

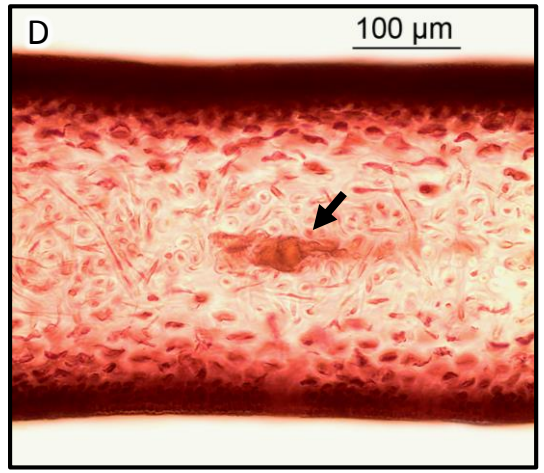
G

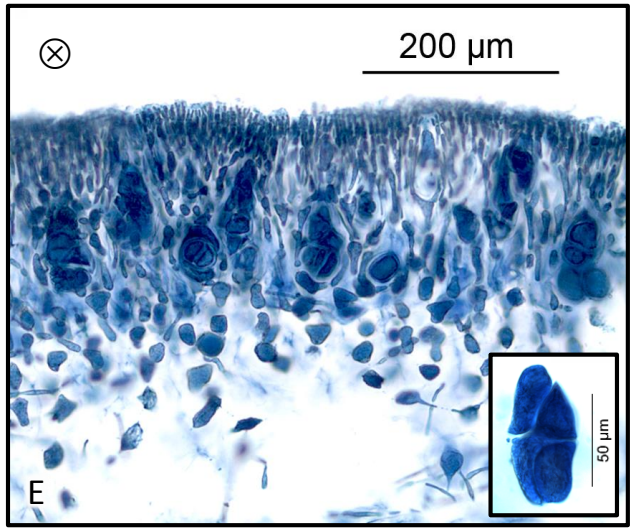
***Neodilsea yendoana*✶ – A –** Asian only (R, J). On the waterline of the Agate Beach Dock (Jun).
✶ AB-003 (BF-1). Reproductive (only tetrasporic and male observed). Spring-summer annual. Isomorphic.

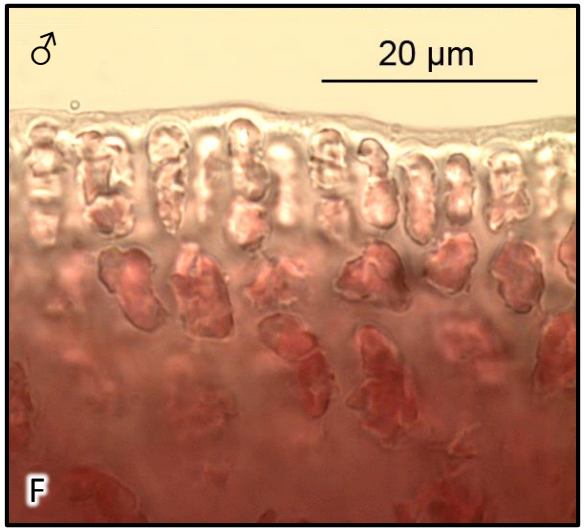






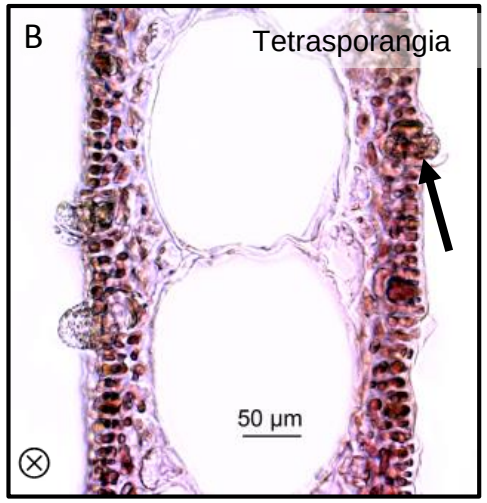


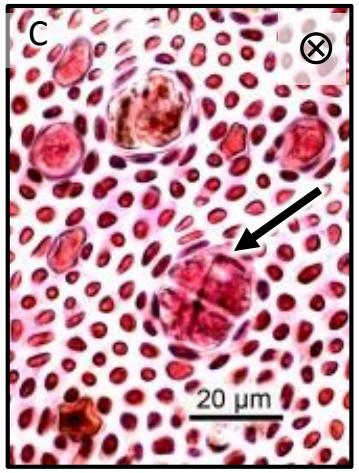


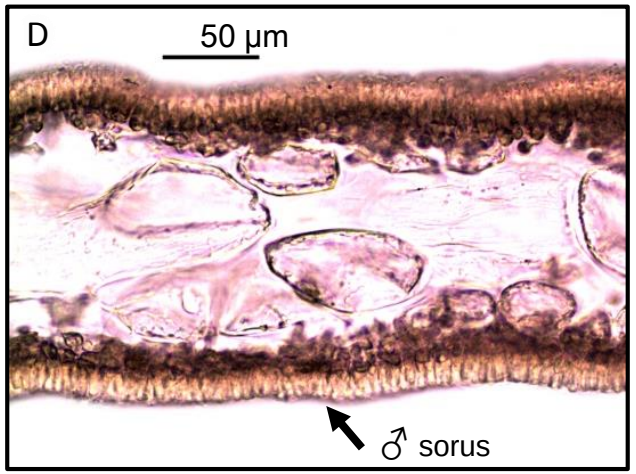


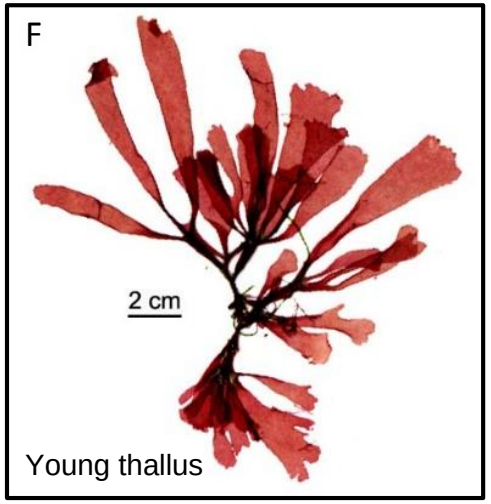
- Two forms were common: large, foliose deep red blades, obovate to broadly spatulate in shape (A, B) and also highly split tetrasporic thalli (C). Both had smooth margins and often surface rumpling.
- The blades were frequently clustered and all forms narrowed to a short stipe and discoidal holdfast.
- Thalli were 5-15 (30) cm tall and 180 µm thick when male and up to 700 µm thick in highly split tetrasporangial thalli.
- Medulla was filamentous with some refractive inclusions (D, arrow).
- Tetrasporagia were scattered in the cortex and irregularly cruciately divided (E). In JTMD material, the largest sporangia were 36x75 µm, larger than those reported in the literature.
- Thali were dioecious: male thalli were covered by a continuous lawn of spermatangia (F), making the blades light in color (B); fertile female thalli were not seen.
- Lindstrom (1984, 1994), Klochkova *et al.* (2009).

Palmaria cf. _mollis_✶ **– NP-P –** Asia (R, J, K, C, Phil), AK-CA. On 5 debris items (Jan, Mar, May-Jun).
Pacific Dulse – edible. Reproductive (⊗, ♂). Pseudo-perennial. Biphasic with a microscopic ♀ crust.



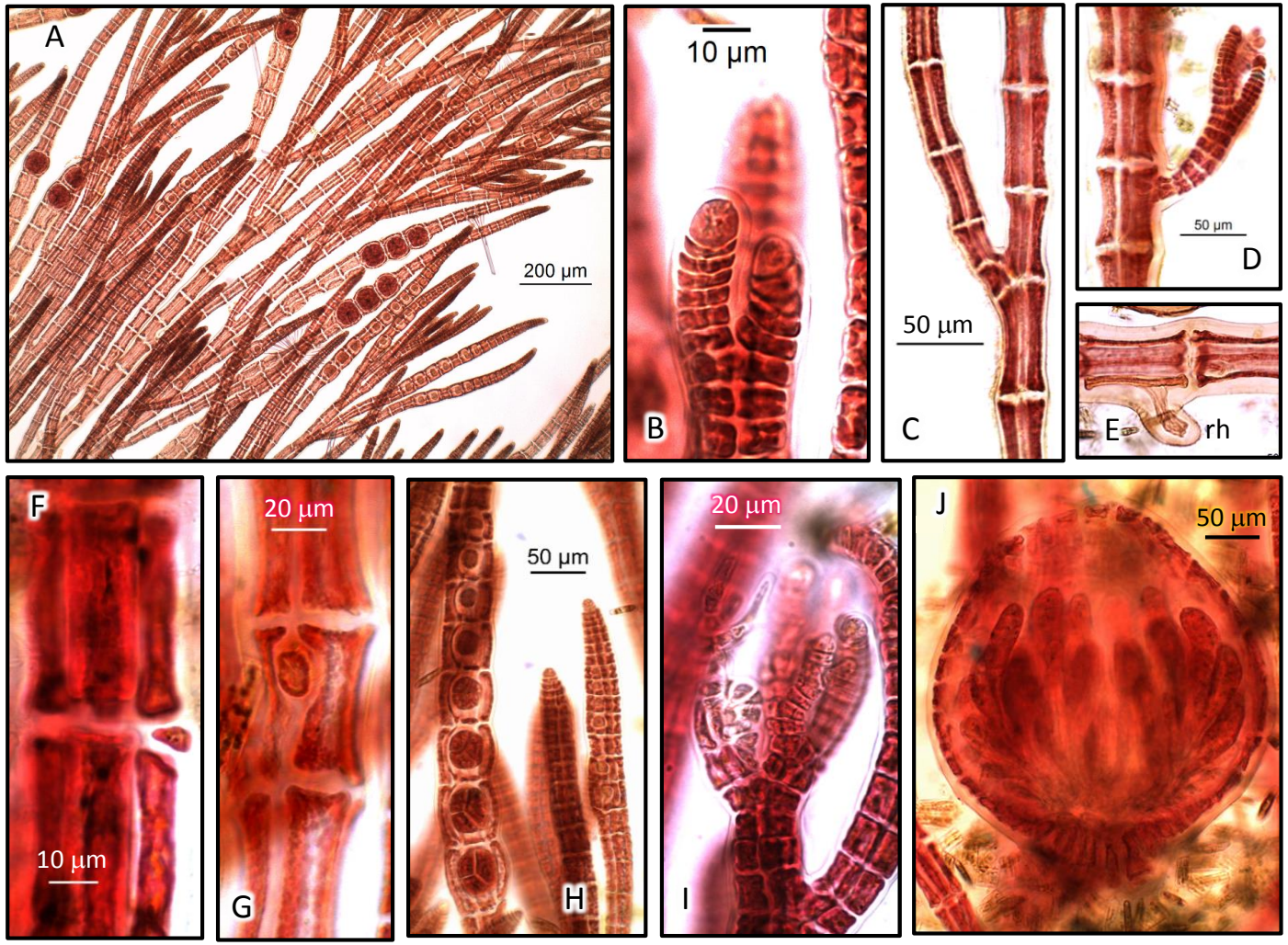






- Large foliose membranous blades arising from a discoidal holdfast. Blades are highly variable, ranging from strap-shaped to broad and irregularly lacerated or lobed. Proliferations are common along the lower margins (A, F).
- Thalli reach 20-50 cm in height and are (140) 300-500 µm thick.
- They consist of a medulla of 1-5 large isodiametric cells and a cortex of short (1-4) outwardly radiating rows of smaller globose cells (B).
- Tetrasporangia and spermatangia form in mottled sori on the blade surfaces.
- Cruciate tetrasporangia (B, C, long arrows), 60-75 µm long (but 40-62 µm in NE Pacific) are scattered among short 3-4 celled paraphyses and develop from a characteristic generative stalk cell (E, short arrow).
- Spermatangia, 5-10 µm long, develop from the cortical cells (arrow) and coat both surfaces of the blade (D). Female thalli (not observed) develop as microscopic discs.
- *P. mollis* in JPN and the NEP differ by 8 base pairs and may be a different species.
- Lee, I. K. (1978) as *Palmaria palmata* auct. Japan, Hawkes & Scagel (1986).
- ✶ SV-15-4 (BF-293), LBT-4 (BF-235), Nye-10 (BF-59). Not sequenced: Fish (BF-40), AB (BF-1).

Polysiphonia koreana[★] [#] **– A –** Asia (K), newly described. On 3 debris items (Mar, Jun). Reproductive (♀, and tet). Isomorphic, ~annual. Similar to *P. dokdoensis*. JTMD specimens are larger than those initially described for *P. koreana*. (see also p. 34)

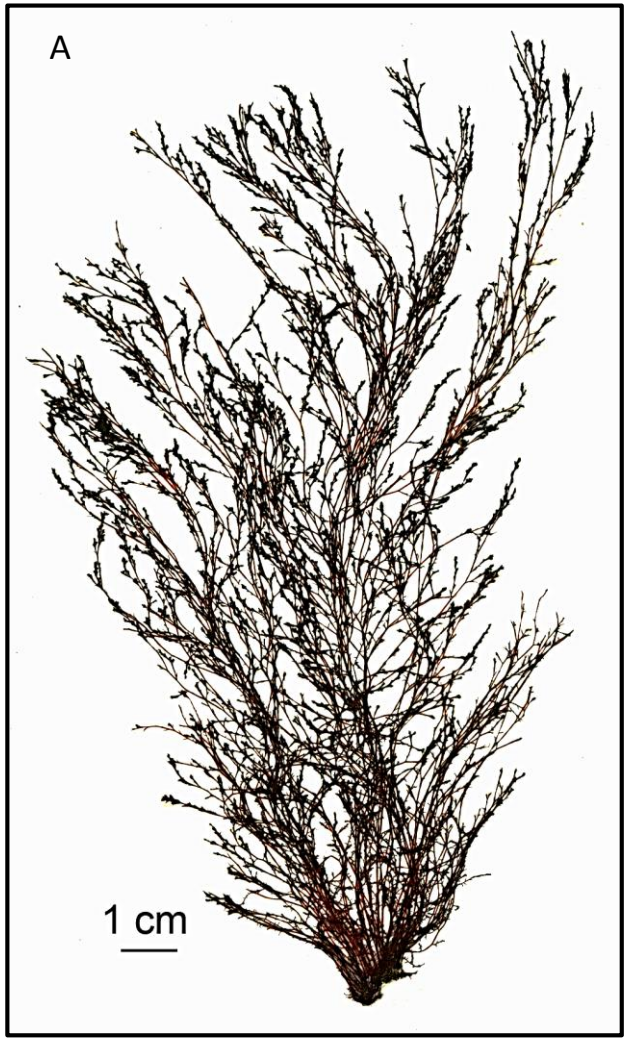


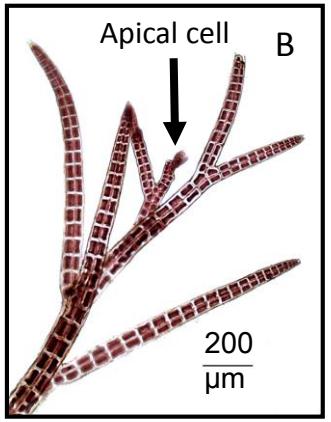
- Tufted straight *Polysiphonous* filaments: 1-2.5 cm tall and heavily branched, taller than Korean isolates which are only 0.8 – 1.8 cm tall.
- Filaments with 4 pericentral cells, endogenous ¼ spiral branches and some cicatrigenous branches (A, C, D).
- Rhizomatous base: 60–100 µm in diameter.
- Rhizoids (E) form in open connection with pericentral cells.
- Indeterminate apical cells are recessed and appear dome-shaped (B, but see N).
- Trichoblasts are rare and only seen on the female.
- 2 types of "scar cells" occur, and both are described for *P. koreana* and *P. dokdoensis*:
  1. Between 4 pericentral cells (normal for *Polysiphonia*) (F).
  2. Slightly inset between 2 pericental cells (this type initiates cicatrigenous branches) (G).
- Tetrahedral tetrasporangia occur in straight series, 50-60 µm in diameter (H).
- Female thalli have 4-celled carpogonial branches (I, K).
- Two types of cystocarps observed.
  1. Normal cystocarps are formed near the branch apices. These are ovoid-globose (diam. ~330 µm) – not slightly urceolate as described for the species (J, M, P).
  2. Adventitious cystocarps develop from type "1" scar cells and frequently occur behind the apices (O, on p. 34).
- Male thalli were not detected.
- Bustamante *et al.* (2014 & 2015).

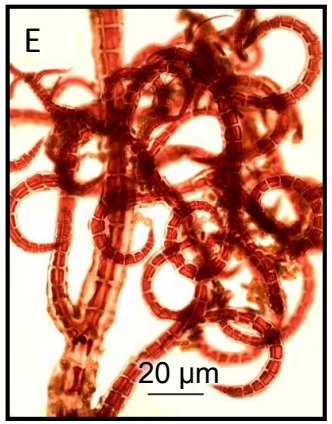
Bustamante & Cho helped with the identification.

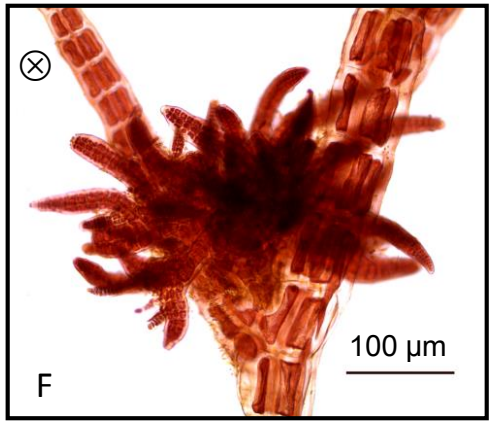
★ RE-676 & RE-687 (BF-533); not sequenced: AB (BF-1), LBT (BF-235).

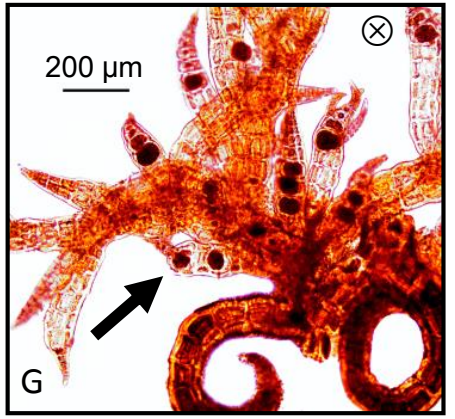
_Polysiphonia morrowii_* **– A+ –** Asia (R, J, C, K), NZ, SA, EUR, Med. On 9 debris items (Jan-Jun). Exported from Asia with oysters – on the **"100 worst invaders in the Mediterranean" list.** Reproductive (⊗, ♂). Pseudo-perennial. Isomorphic + fragmentation.

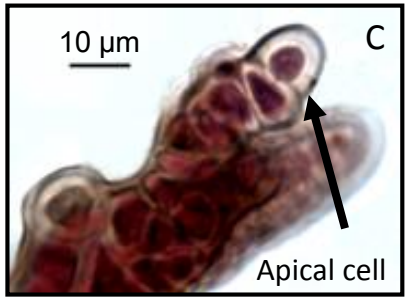


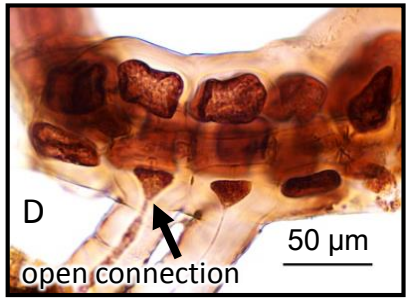


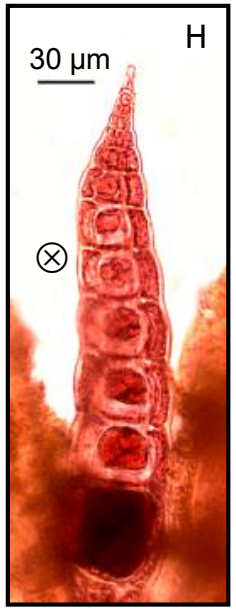


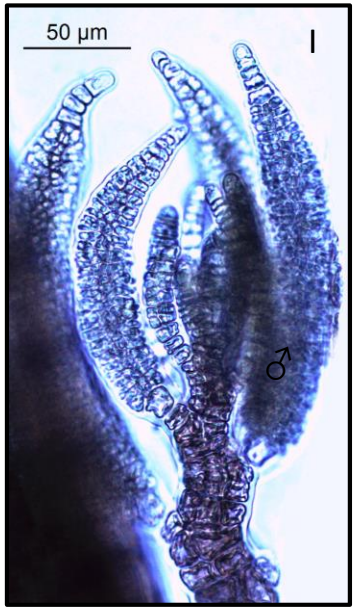










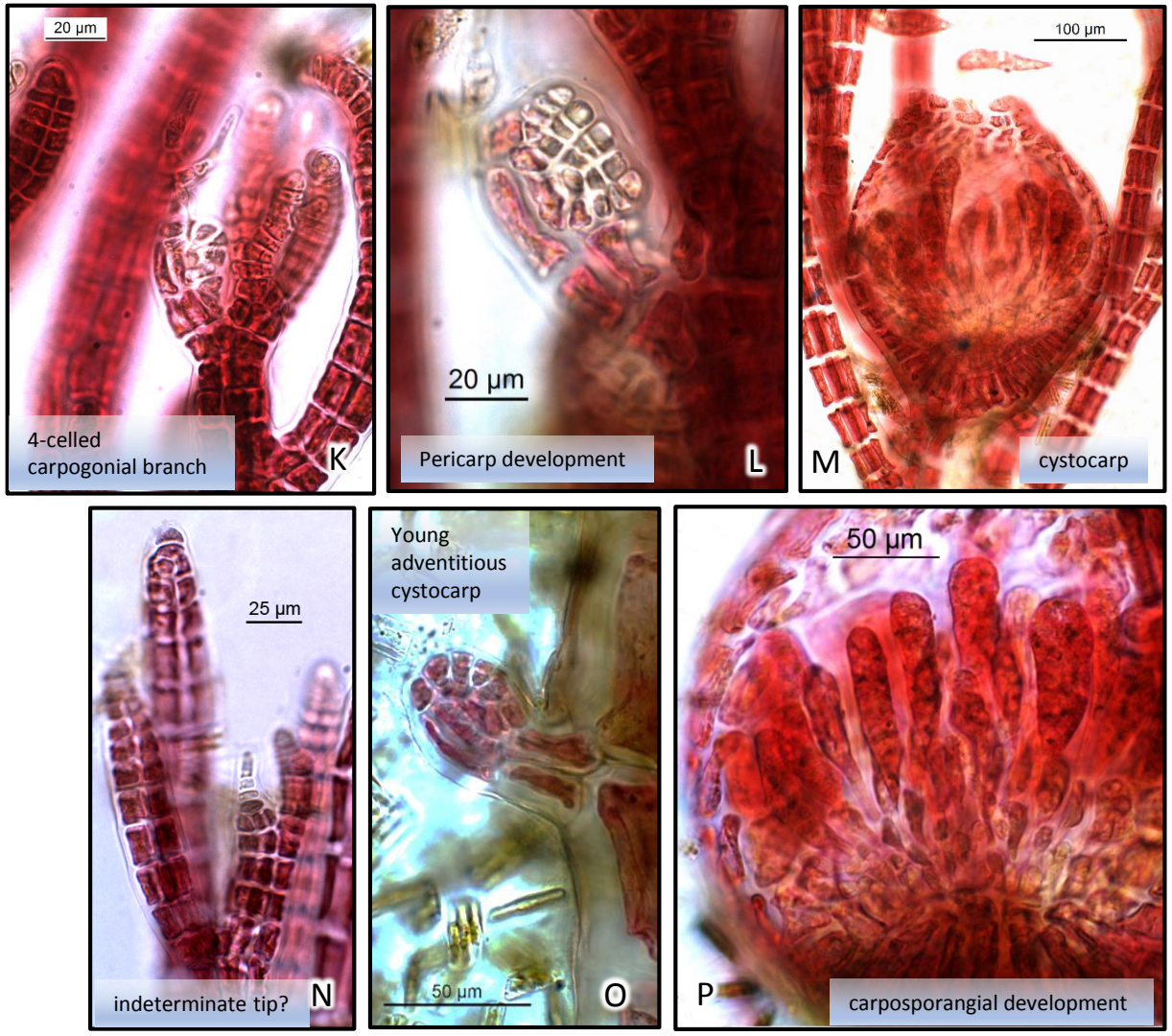


- Thalli caespitose, 5-20 cm tall with 4 pericentral cells and no cortication (A, B).
- Irregular to spiral endogenous branching.
- Indeterminate branch tips have recessed and dome-shaped apical cells (B & C, arrows).
- Determinant branch tips are sharply pointed.
- Laterals are often heavily recurved (E).
- Tetrahedral tetrasporangia (55 µm wide on debris) form in straight series on regular axes but also on reproductive stichidia in clusters of 6 or more at the branch divisions, appearing like burrs scattered across the thallus (F, G, H).
- Male stichidia topped by 4-5 sterile cells (I).
- Rhizoids open with pericentral cells (D).
- Segi (1951), Kudo & Masuda (1981, 1992*), Kim *et al.* (1994), Nam & Kang (2012), Croce & Parodi (2017).
- ✶ Man-129 (BF-461), RE-675 (BF-533) + more.

Similar to *Polysiphonia senticulosa (*AK-WA). Characteristics separating the two cross over & the holotypes need to be sequenced. (See p. 34, J and K).

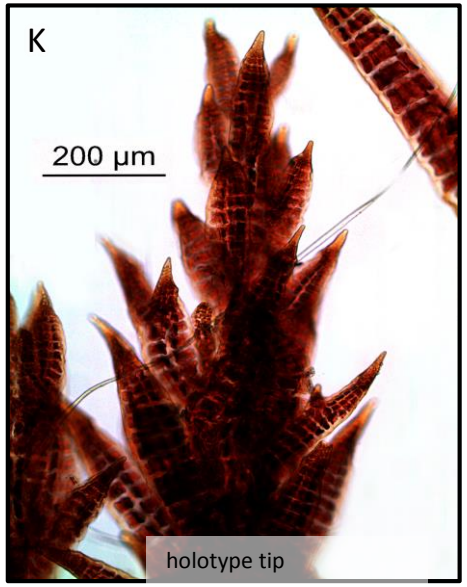
*Dec–Aug in Japan, germination to csp in 98 days.

#2 - *Polysiphonia koreana* – additional pictures



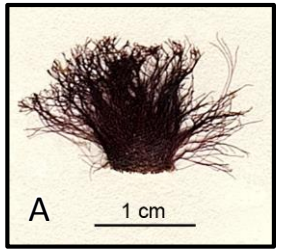
#2 – Additional data on *P. morrowii* and *P. senticulosa*

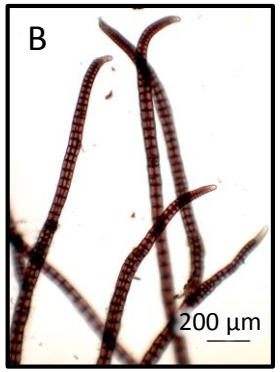
Fertile lateral tip of *P. morrowii* from JTMD material (BF-171).

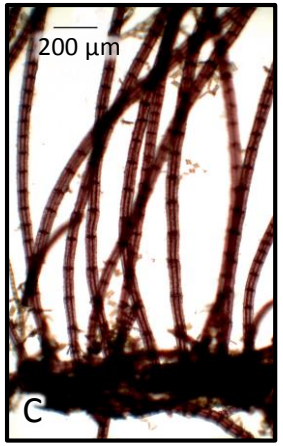


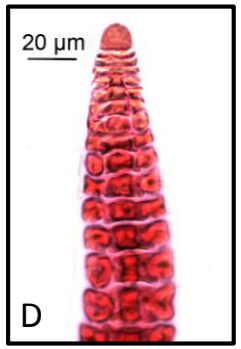
Lateral tip from holotype material of *P. senticulosa* (UC Berkeley). Note that lateral branchlets are closely spaced.

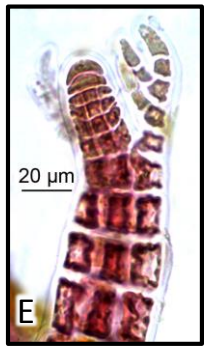
***Polysiphonia villum cpx.*✶ – G (Globally widespread) –** Asia (J, C, Viet, Phil), AK-MX, ENA, Car, SA, Afr, IO, AUS. On 3 debris items (Feb, Mar, Oct). ✶ HF2-628 (BF-526); not sequenced: CBD (BF-130), Yac (BF-135). Reproductive (tetrasporic, female). Isomorphic. Pseudo-perennial. Huisman *et al*. (2017) found that *P. villum* is a species separate from *P. scopulorum*. Our debris isolate is a slight sequence variant of *villum*.

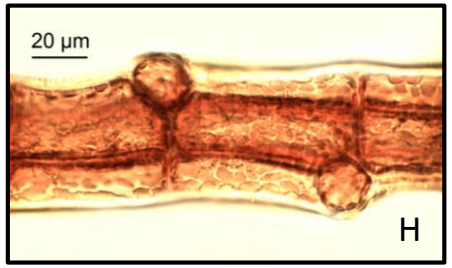


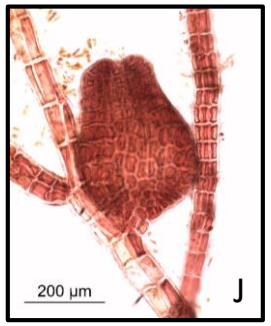


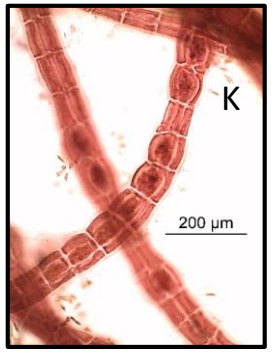


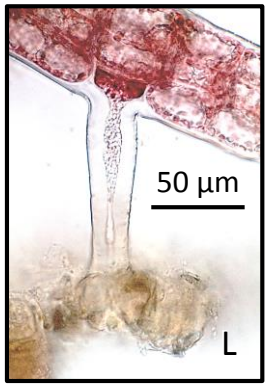


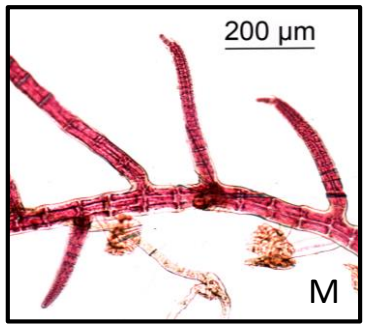


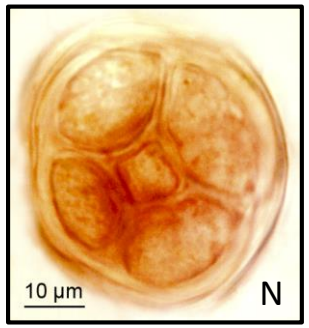










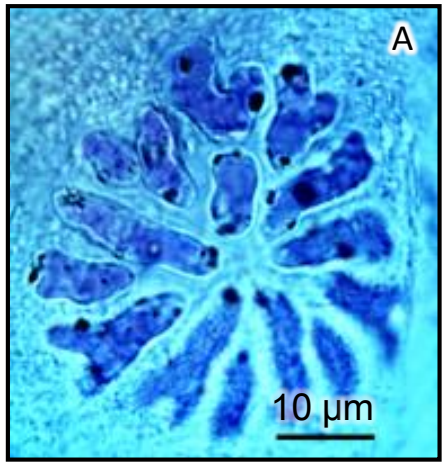


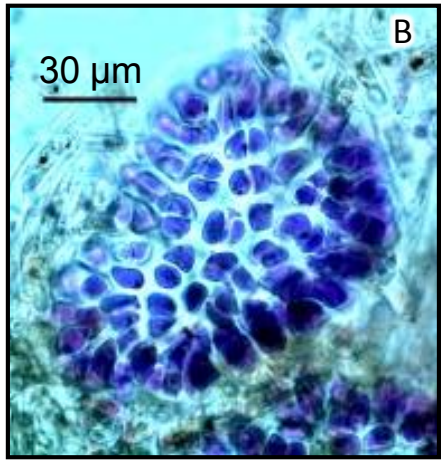
An rbcL sequence variant that is close to *P. villum* but not identical.

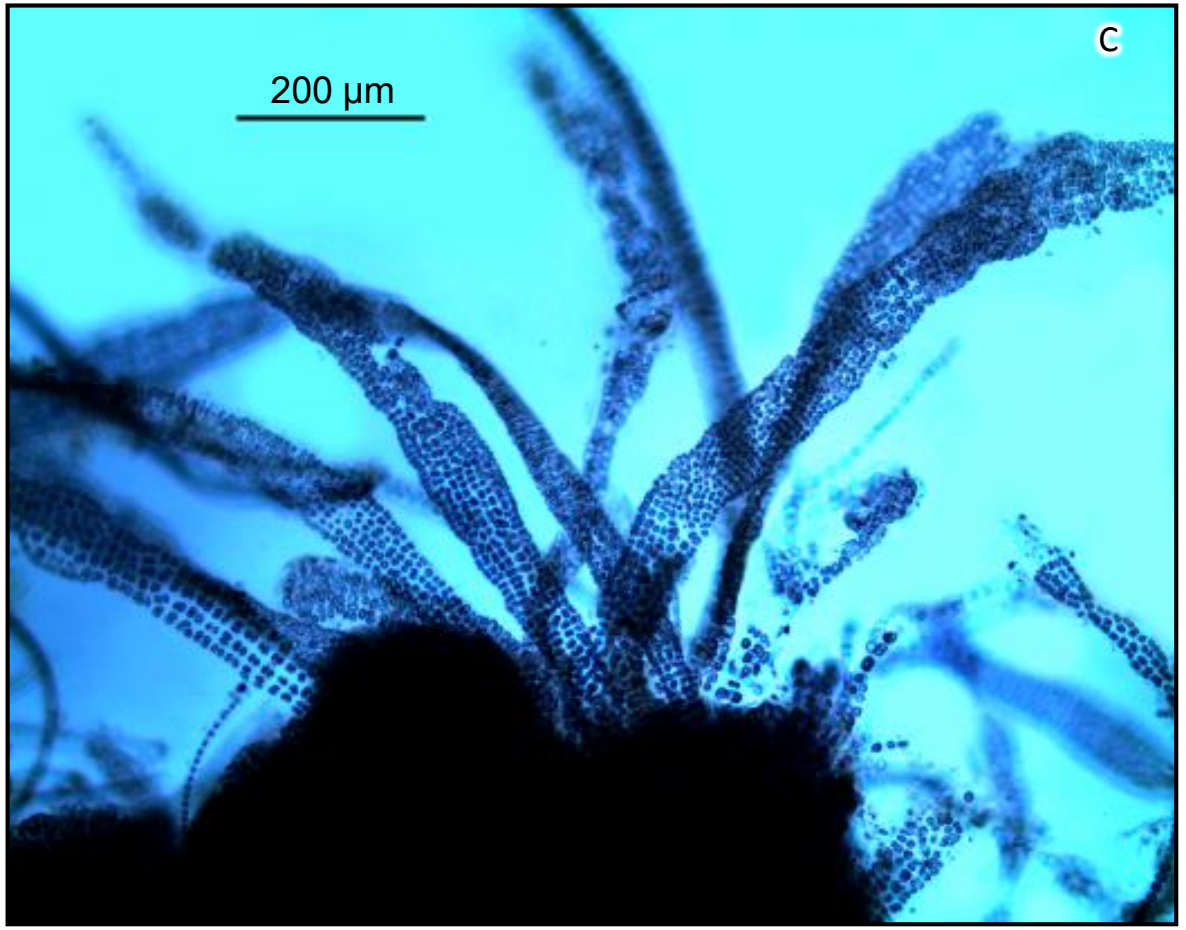
- Small Polysiphonous thalli, 5-10 mm tall (A), epilithic or epiphytic.
- Simple or occasionally branched axes 40-60 µm wide arising from a rhizomatous base (B, C, M).
- Branch apices narrow at their tips and contain a domed apical cell and rare trichoblasts (D, E).
- Axes have 4 pericentral cells (N) and sporadically a series of scar cells (not common in *P. villum*) (H, I).
- Branching is both endogenous (F) and exogenous (G).
- Cicatrigenous branches are often seen arising from scar cells (G).
- Tetrasporangia are tetrahedral, 50-60 µm in diameter, and form in linear or slightly askew rows on the axes (K).
- Cystocarps are slightly urceolate (J).
- Male thalli were not observed.
- Rhizoids (20-32 µm in diameter) form digitate tips and are in open connection with pericentral cells (L).
- Hollenberg (1968), Schneider & Searles (1991), Stuercke & Freshwater (2008), Abbott & Hollenberg (1976), Huisman *et al*. (2017).

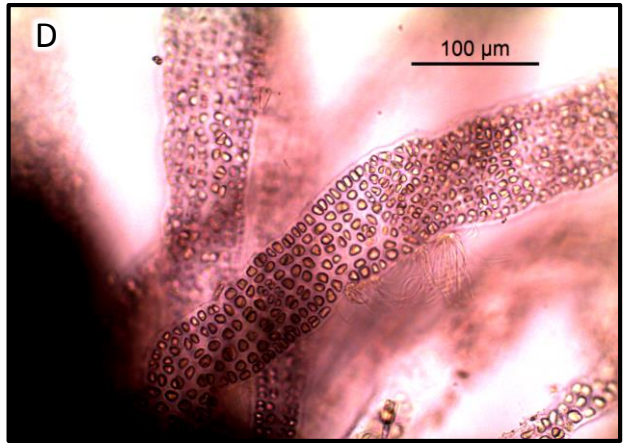
***Porphyrostromium japonicum* – A –** Asia only (J, C, K). A tiny epiphyte on *Lepas anatifera.* On 1 debris item (Jun), the Agate Beach dock (BF-1). Reproductive. Heteromorphic winter annual with an erect gametophyte (Nov-June in Japan) and a discoidal sporophyte. Mmonospore production occurs year around from both the erect and discoidal stage. Short-days are required for formation of the erect phase.

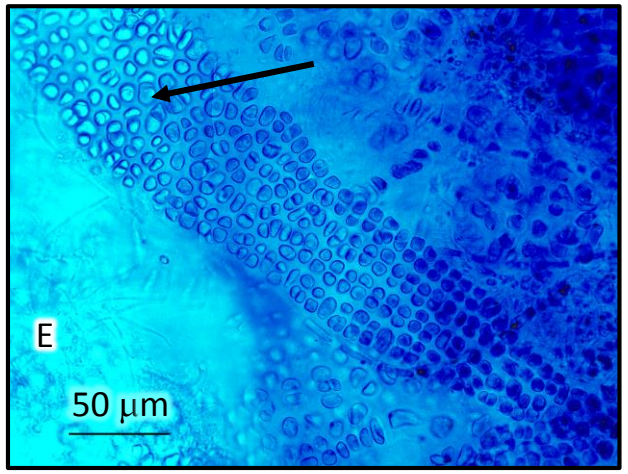
A. Young disk with bifurcate marginal cells. Parietal chloroplast with a central pyrenoid barely visible. B. Developing cushion. C. Mature stage with monostromatic blades up to 18 cells wide and reaching 3 mm in height. D & E. Additional blades showing extensive width and monosporangia (arrow) cut off by a curved wall. Kikuchi & Shin (2011), Zuccarello *et al.* (2011).



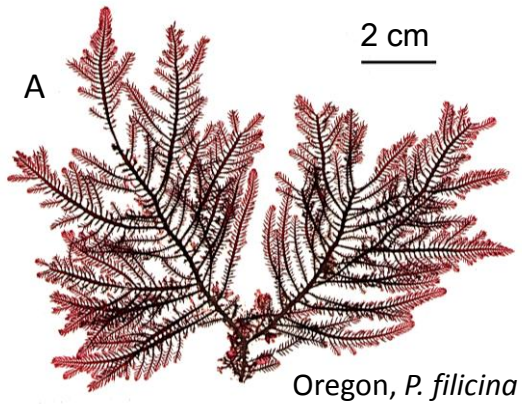








***Ptilota serrata*[#] – G (Globally widespread) –** Asia (R, J, K), AK, ENA, EUR-Arc. On 1 debris item (Jun) – the Agate Beach derelict dock (BF-1). Reproductive (female). Perennial and isomorphic.

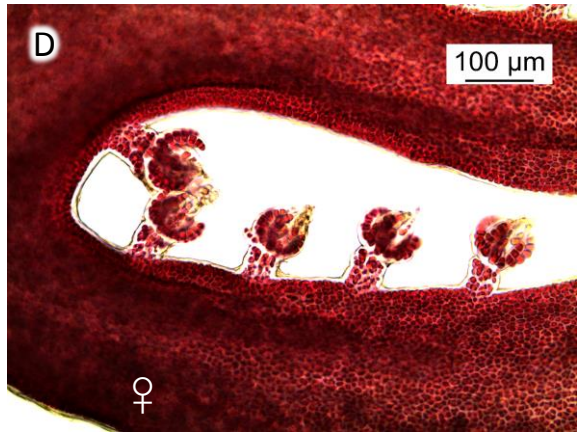


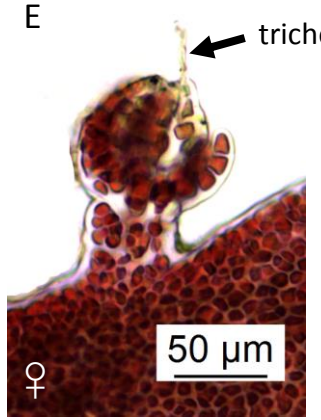
Oregon, *P. filicina* – a similar species

Agate Beach dock, 6-06-2012
= *P. serrata*

- Corticated bilaterally flattened feathery red thalli that were 10 cm tall on debris (B).
- Thalli have a distinct main axis ~1 mm in diameter and closely spaced opposite lateral branches. 3-4 orders of branching may occur and each bears opposite pinnate laterals with ultimate branches that are leaflike with serrations along both sides of the blade.
- The genus is characterized by having opposite indeterminate branches that mimic one another: in *P. serrata* (B), the opposite branches become nearly equal at maturity. In the closely related *P. filicina* (A), they are always unequal.
- Procarps in *P. serrata* form along the sides of third order branches as shown here (D, E). In *P. filicina*, they form along the sides of the main axes.
- Recent molecular studies indicate that *P. serrata* does not occur along the BC-OR coast and that the current records here are all *P. filicina.*
- Bruce & Saunders (2016), Hommersand *et al.* (2006).

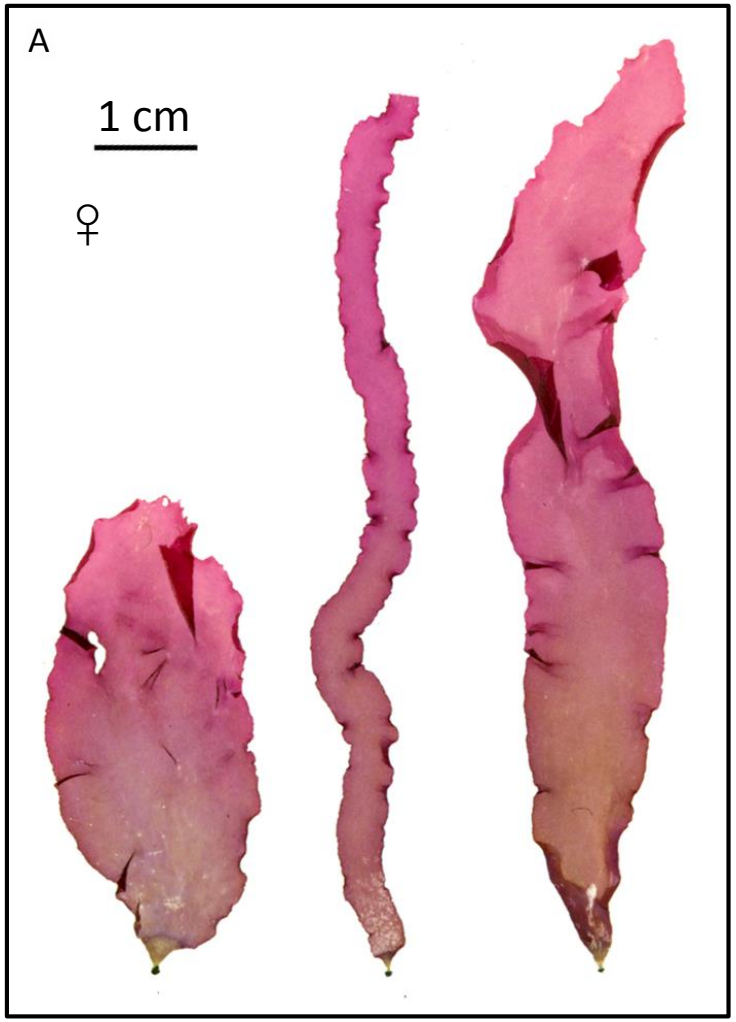
M. H. Hommersand assisted with the identification.

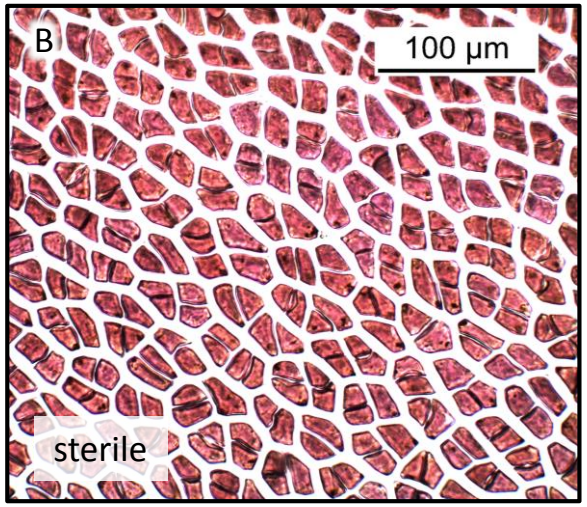


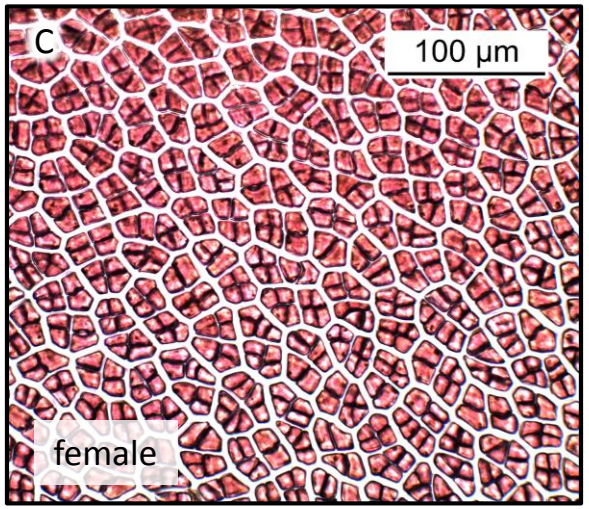


Margin of female thallus with procarps and their surrounding young bracts.

***Pyropia pseudolinearis* cpx.✶ – A –** Asia (R, J, K). Only on 1 debris item (Apr), the Seal Rock debris boat (BF-356). Reproductive (female). Heteromorphic annual.



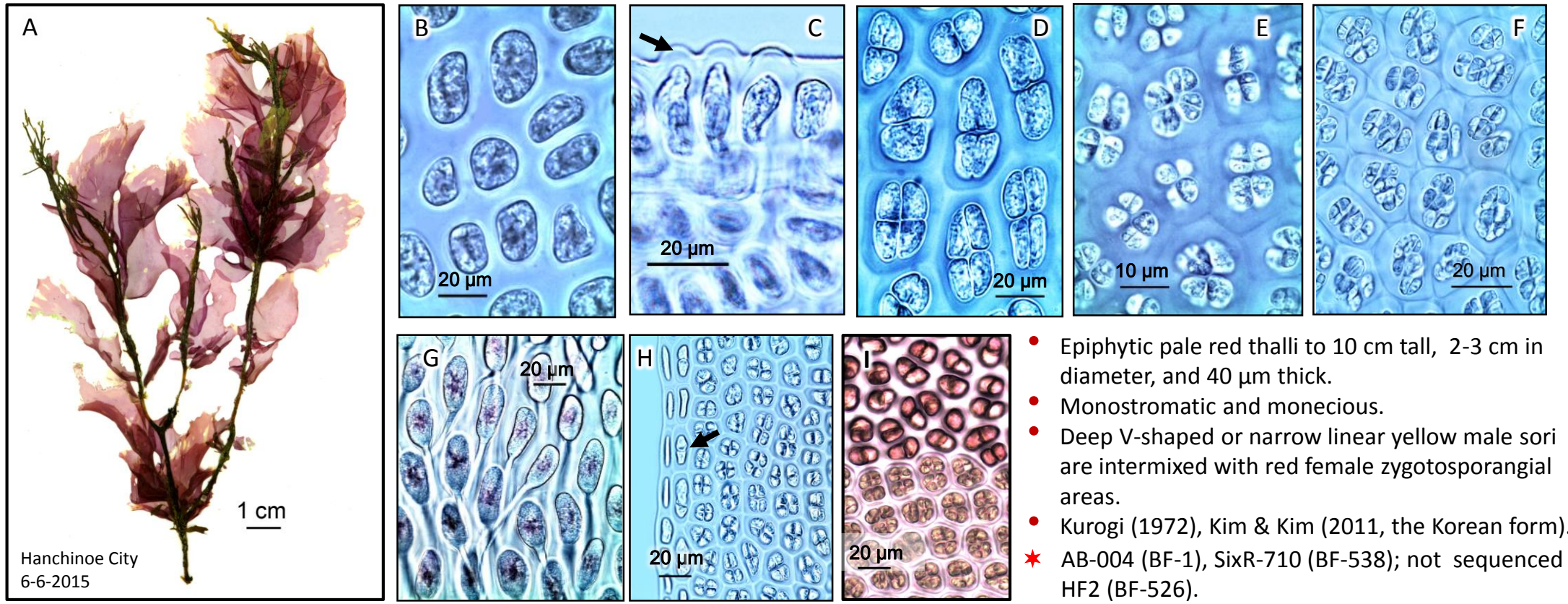




- Small linear to ovate blades with slightly undulate margins attached to the substratum by a very short stipe and discoidal holdfast (A).
- To 10 cm tall and of variable width on debris.
- Blades were monostromatic (40-70 µm thick) and dioecious.
- Only female thalli were observed.
- Zygotosporangia occurred in a uniform lawn or sorus over the mid and upper parts of the blades turning the thallus from brownish (B) to reddish pink (C).
- Sequences show this species is in the same clade with *P. pseudolinearis* but is not genetically identical. It is similar to *Pyropia* sp. (AB287965) in Lindstrom *et al.* (2015).
- Kim & Kim (2011), Klochkova *et al.* (2009), Lindstrom *et al.* (2015).

✶ SR-209 (BF-356).

Pyropia yezoensis ✶ **– A+ –** Asia (R, J, C, K), AK, ENA, Car, EUR, Med. Found on 3 debris items (Feb, Mar, Jun). The main nori cultivar in Japan. Introduced globally via oysters for cultivation or in fouling. Reproductive. Heteromorphic annual.



- Epiphytic pale red thalli to 10 cm tall, 2-3 cm in diameter, and 40 µm thick.
- Monostromatic and monecious.
- Deep V-shaped or narrow linear yellow male sori are intermixed with red female zygotosporangial areas.
- Kurogi (1972), Kim & Kim (2011, the Korean form).
- ✶ AB-004 (BF-1), SixR-710 (BF-538); not sequenced HF2 (BF-526).

A. Epiphytic habit. B. Surface view of vegetative cells, C. Optical section of young female areas showing prototrichogynes (arrow). D. Surface view of developing zygotosporangia, E & F. Surface view of developing spermatangia. G. Capitate rhizoids near blade base. H. Reproductive area with sterile margin (arrow). I. Margin between male (lighter colored) and female areas (redder) of thallus.

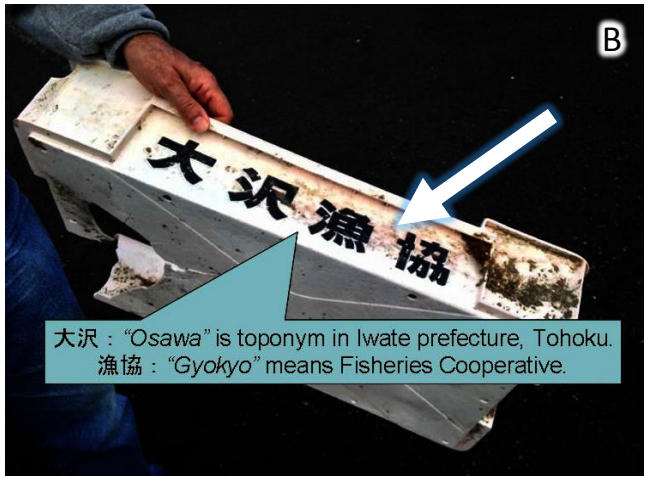
***Schizymenia dubyi*✶ – G (Globally widespread) –** Asia (J, C, K), CA, MX, Aus, SA, EUR, Med.
On 1 debris item (Mar). Sterile. Heteromorphic annual. Erect thalli are monoecious gametophytes.
The tetrasporophyte is the crustose *Haematocelis rubens* which bears gland cells and zonate tetrasporangia.

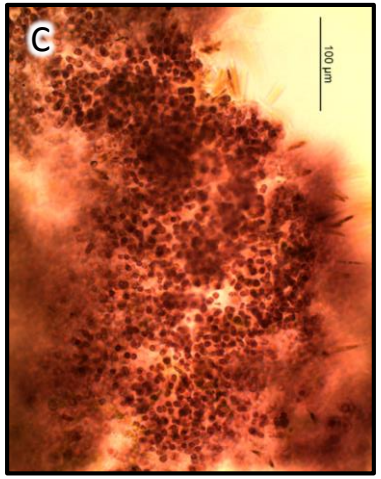
Schizymenia pacifica from Otter Crest, Oregon
Similar to *S. dubyi* in habit.

- A large smooth deep-red to brown entire, lobed or deeply cleft undulate blade reaching 15-40 cm in height and nearly as wide.
- Blades are thick, and mature specimens can be 400+ µm thick.
- Young thalli are membranous and thin and characterized by having a mucilaginous surface caused by the occurrence of numerous translucent ovoid gland cells (7-10 x 22-48 µm) that are scattered throughout the outer cortex. Older thalli are more leathery.
- Hughey & Miller (2009) discovered *S. dubyi* via sequencing in California and pointed out that the ostioles in *S. dubyi* were larger (45-60 µm) than in *S. pacifica* (18-42 µm).
- JTMD material was young (3 cm in height) and not fertile. Identification was made via sequencing.
- *Schizymenia dubyi* is nearly identical in morphology to a very common native NE Pacific species, *S. pacifica*. The native species is shown here for reference (A).
- Hughey & Miller (2009), Ramirez *et al*. (2012), Saunders *et al*. (2015)
- ✶ Man-125 (BF-461)

All JTMD material was sent to Japan for sequencing.
None was available for photography.

***Tsunamia transpacifica**# – NP-P – Recently described from debris in the NP.** On 4 JTMD items + numerous white hard plastic debris undocumented as from the tsunami. Ephemeral.



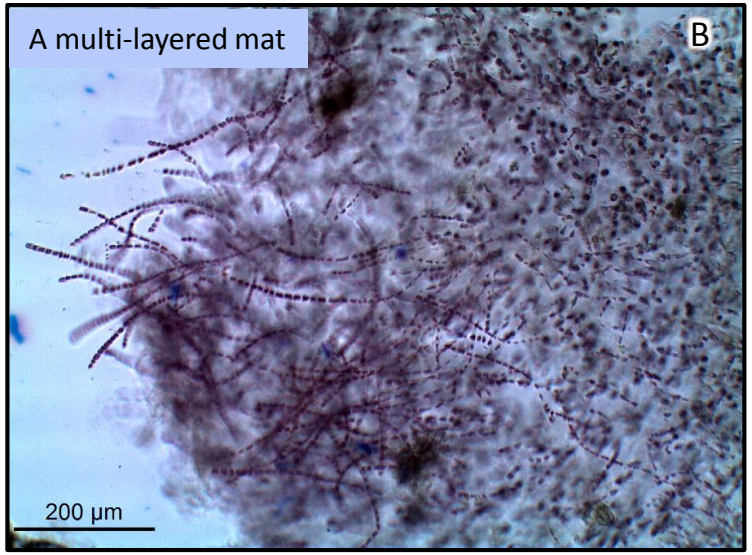


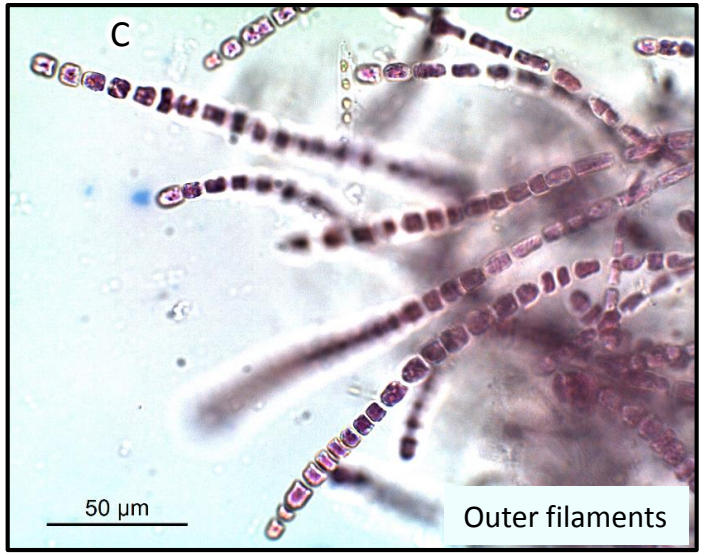
- A gelatinous pink crust often coating large areas of light-colored plastic debris items (A, B).
- On debris, individual cells, 9-12 µm in diameter, and occasional short filaments are embedded in a palmelloid gelatinous mass (C).
- The cells contain a single highly lobed chloroplast with no pyrenoid. The extreme lobing often gives the appears of multiple discoidal chloroplasts (D).
- In culture, the single cells are released as spores and germinate to form radiating branched thalli (E) that become pulvinate in shape and 1 mm in diameter. Mature colonies are confluent.
- Identity for the description was based on SSU, rbcL, and psbL sequences.
- West *et al.* (2016); LB-417 (Leadbetter Point, Long Beach Peninsula) = the holotype.

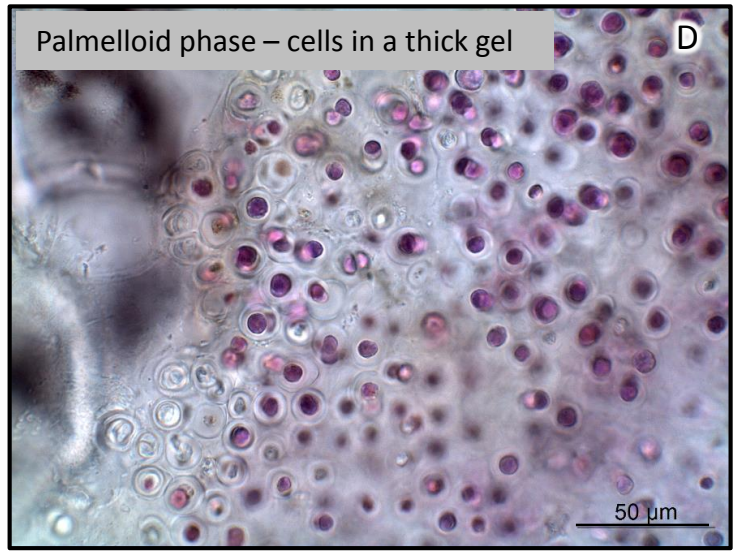
\# John West and Joe Zuccarello joined us in describing and naming this new species.

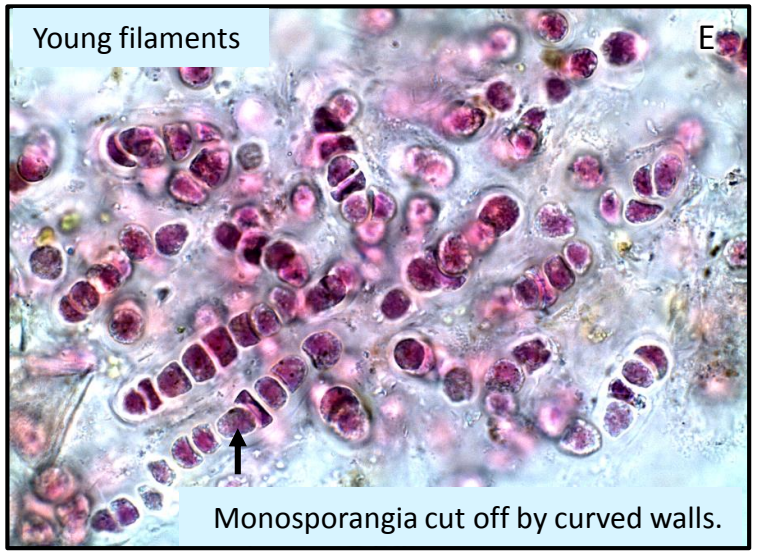
* LB-130 (BF-285), QS-622 (BF-656); not sequenced: SRT (BF-277), LBT (BF-500).

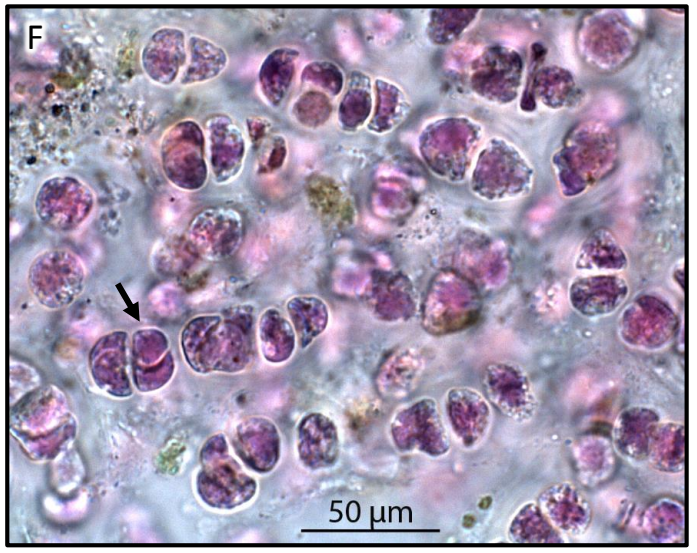
UNKNOWN: ***Erythrotrichia sp.,*** **A mat occurring on a glass debris ball** on the Long Beach Peninsula, WA, 2-Mar-2017











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Appendix 1 – The Japanese Debris Items

Japanese Tsunami Marine Debris (JTMD) items collected for the algal project, including their BF-numbers, state, site name, collection number abbreviations, collection date and year, and item type. All collections were made between Mosquito Creek, WA, and Sixes River, OR. Key: Abbrev.= collecting number abbreviation, BF # = biofouling number of Carlton *et al.* (2017, Table S1), OR = Oregon, WA = Washington.

BF #	State	Site Name	Abbrev.	Collection		Item
				Date	Year	
BF-1	OR	Agate Beach	AB	5-Jun	2012	dock
BF-2	WA	Ilwaco, Benson Beach	BB	15-Jun	2012	boat
BF-8	WA	Mosquito Creek	MC	5-Jan	2013	dock
BF-23	OR	Gleneden Beach, Salishan	GB	6-Feb	2013	boat
BF-28	OR	Horsfall Beach	HF1	21-Feb	2013	boat
BF-36	OR	Florence, Muriel Ponsler Park	MP	14-Mar	2013	boat
BF-39	OR	Cannon Beach, S Jockey Cap	SJC	22-Mar	2013	boat
BF-40	WA	Long Beach (fish boat)	Fish	22-Mar	2013	boat
BF-50	OR	Coos Bay North Spit	CBS	22-Apr	2013	boat
BF-58	OR	Clatsop Beach	CBB	30-May	2013	boat
BF-59/61	OR	Nye Beach	Nye	30-May	2013	post & beam
BF-108	OR	Cape Arago, Lighthouse Beach	CA	11-Jul	2013	post & beam
BF-130	OR	Clatsop Beach	CBD	9-Oct	2013	dock, pontoon
BF-134	WA	Twin Harbors State Park	TH	17-Jan	2014	boat
BF-135	OR	Yachats	Yac	18-Feb	2014	boat
BF-160	OR	Tillamook Bay spit	TBT	26-Apr	2014	tree
BF-171	OR	Tillamook Bay spit	TB	25-Apr	2014	post & beam
BF-173	OR	South Beach, Lost Creek	LC	27-Apr	2014	buoy
BF-188	OR	Cape Lookout Beach	CL	3-May	2014	boat

Appendix 1 (continued) – The Japanese Debris Items

BF #	State	Site Name	Abbrev.	Collection		Item
				Date	Year	
BF-196	OR	Waldport	Wal	12-May	2014	boat
BF-208	OR	Cape Arago, North Cove	NC	19-May	2014	boat
BF-223/224	WA	Long Beach, Ilwaco	Ilw2	29-May	2014	boats 2
BF-227/228	WA	Long Beach	LB2	5-Jun	2014	boats 2
BF-234	OR	South Beach	SBT	9-Feb	2013	tank
BF-235	WA	Long Beach	LBT	1-Mar	2013	tire
BF-277	OR	Seal Rock	SRT	30-Nov	2014	tote
BF-285	WA	Long Beach	LB	4-Jan	2015	boat fragment
BF-288	OR	Beverly Beach	Bev	20-Jan	2015	tote, pallet
BF-293	WA	Long Beach, Seaview	SV	28-Jan	2013	pipe
BF-331	WA	Oysterville	Oys	14-Mar	2014	boat
BF-356	OR	Seal Rock, in ocean	SR	10-Apr	2015	boat
BF-397	WA	Long Beach	LBD	1-May	2015	dock, pontoon
BF-402	WA	Long Beach, Seaview	SVB	12-May	2015	boat
BF-461	OR	Manzanita	Man	2-Mar	2015	tote, basket
BF-462	WA	Long Beach	LBF	4-Jan	2015	float
BF-500	WA	Long Beach	LBT	16-Feb	2016	tote
BF-526	OR	Horsfall Beach 2	HF2	22-Mar	2016	boat
BF-533	OR	Roads End	RE	28-Mar	2016	boat
BF-538	OR	Sixes River mouth	SixR	16-Apr	2016	boat
BF-545	OR	Umqua River mouth	Ump	26-Mar	2016	boat
BF-652	OR	Falcon Cove beach	Fal	26-Jul	2016	boat
BF-656	OR	Quail Street	QS	26-Mar	2016	carboy