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Taxonomic notes on Japanese *Ptilota* (Ceramiales, Rhodophyta)

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The correct names of two species of *Ptilota* growing in Japan are established. The alga known as *Ptilota pectinata* (GUNNERUS) KJELLMAN or *P. serrata* KÜTZING including *Ptilota californica* (=*Neoptilota californica*) sensu OKAMURA is identical with *P. filicina* J. AGARDH. The entity known as *P. pectinata* forma *litoralis* KJELLMAN is referred to *P. phacelocarpoides* A. ZINOVA. Diagnostic features of all the known species of the genus are discussed. It is concluded that the growth manner of first-order branches on the primary axis, the serration of leaflet-like determinate branchlets, the nature of thalli (erect or decumbent), and the shape of tetrasporangial clusters are of primary taxonomic significance at the species level. A full description of *P. phacelocarpoides*, which is poorly known in Japan, is given.

Key Index Words: *Ceramiales*—Ptilota—Ptilota filicina—Ptilota pectinata—Ptilota pectinata *f.* litoralis—Ptilota phacelocarpoides—Ptilota plumosa—Ptilota serrata—*taxonomy*—*Rhodophyta*.

The red algal genus *Ptilota* (Ceramiales) currently includes four species; these species and their type localities are as follows: *P. plumosa* (LINNAEUS). C. AGARDH (1817, unspecified in Atlantic Ocean), the type species, *P. serrata* KÜTZING (1847, Newfoundland, Canada) which includes (WHITTICK 1977) *P. pectinata* (GUNNERUS) KJELLMAN (1883), *P. filicina* J. AGARDH (1876, Vancouver Island, Canada) which includes (ABBOTT and HOLLENBERG 1976) *P. tenuis* KYLIN (1925), and *P. phacelocarpoides* A. ZINOVA (1972, Ussuri Bay in Peter the Great Bay, Primorskiy, USSR). *Ptilota plumosa* has been reported from various localities in Arctic Sea and North Atlantic Ocean (HARVEY 1853, KJELLMAN 1883, KYLIN 1923, ROSENVINGE 1923-24, TAYLOR 1957). The latter two species have been recorded from North Pacific Ocean (YENDO 1916, ABBOTT and HOLLENBERG 1976, PERESTENKO 1980, GABRIELSON *et al.* 1989). *Ptilota serrata* has been widely recorded from both regions (HARVEY 1853, KJELLMAN 1883, OKAMURA 1909, 1933, 1936 as *P. pectinata*, TAYLOR 1957, LEE and KANG 1986, GABRIELSON *et al.* 1989).

In Japan, the alga referred to as *Ptilota pectinata* or *P. serrata* is common in the intertidal and subtidal zones of Hokkaido and northern Honshu. Our recent studies show that this alga is different from the genuine *P. serrata*. Another entity which has been called *P. pectinata* f. *litoralis* KJELLMAN (OKAMURA 1909, 1936, SEGAWA 1956) is often found at the subtidal zone of Hokkaido coasts. In this report the correct names for these two Japanese algae are established.

Materials and Methods

Herbarium specimens deposited in the Herbarium, Department of Botany, Faculty of Science, Hokkaido University (SAP) were chiefly examined (Table 1). Several specimens identified by Japanese phycologists are voucher specimens mentioned in their publications: OKAMURA (1909, 1933, 1936), YAMADA (1934), KAWABATA (1936), NAGAI (1941), KAWASHIMA (1955), FUNAHASHI (1966) and TAZAWA (1975). In addition, our collections from Usu, Toyoura, Shizukari, Shiriuchi, Oshoro Bay, and Atsuta on the Hokkaido coast during 1985–1989 were used. These latter specimens are preserved in

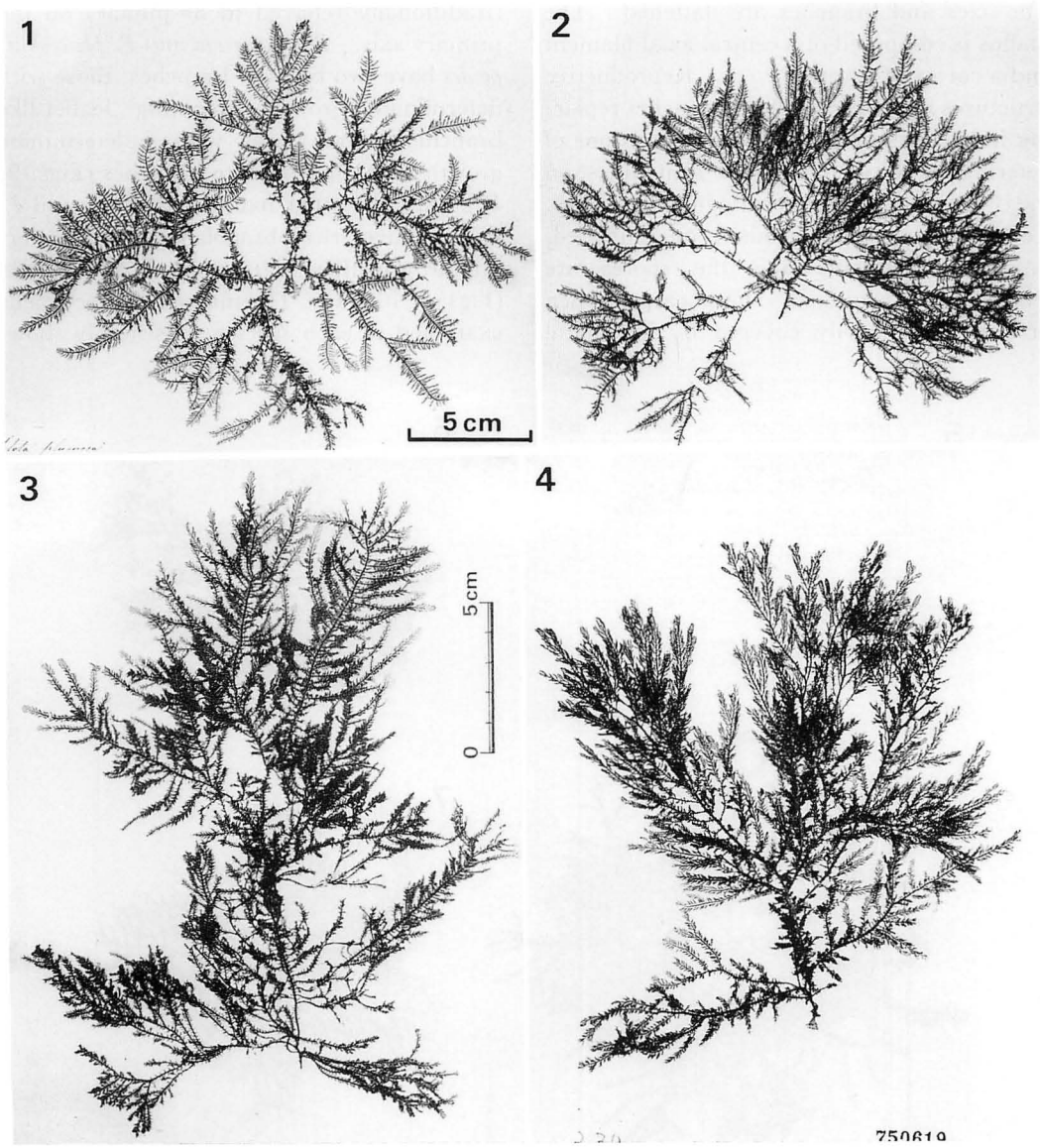
Table 1. *Ptilota* specimens examined in SAP.

Identified as	Locality	Date	Collected/identified by	Specimen number
Ptilota plumosa				
P. plumosa	Bohuslan, Sweden	undated	anonymous	040916
P. plumosa	Bohuslan, Sweden	22. vii. 1925	W.M. Rystrom	040929
P. plumosa	Bohuslan, Sweden	4. vii. 1946	T. Levring	040929A
P. plumosa	Mandals Skargard, Norway	18. vii. 1930	T. Arwidsson	040928
P. plumosa	Novaya Zemlya, USSR	24. vi. 1875	F.R. Kjellman	040918
Ptilota serrata				
P. serrata	Spitzbergen, Norway	viii. 1872	F.R. Kjellman	040936
P. serrata	Spitzbergen, Norway	vii. 1873	F.R. Kjellman	040926
P. serrata	Spitzbergen, Norway	12. v. 1873	F.R. Kjellman	040938
P. serrata	Novaya Zemlya, USSR	24. vi. 1875	F.R. Kjellman	040938A
P. serrata	Clam Bay, Nova Scotia, Canada	5. iii. 1969	E. Ogata/T. Edelstein	031046
Ptilota filicina				
P. filicina	Santa Cruz, California, USA	10. xi. 1965	L.E. Hair/I.A. Abbott	029115
P. filicina	Vancouver Island, Canada	vi. 1901	K. Yendo	048484
P. sp.	Shipley Bay, Alaska, USA	20. vi. 1913	T.C. Frye/W.A. Setchell	051412
P. pectinata	Atka Island, Aleutians, USA	v. 1931	Y. Kobayashi/K. Okamura	040939, Okamura Herb.
P. filicina	Shemya Island, Aleutians, USA	22. viii. 1975	N. Masuda/M. Masuda	053262, 053263
P. pectinata	Matsuwa Island, Kuriles, USSR	14. viii. 1935	M. Nagai	022038
P. pectinata	Urup Island, Kuriles, USSR	viii. 1933	Y. Yamada	015143, 026670
P. pectinata	Shikotan Island, Kuriles, USSR	vii. 1934	S. Kawabata	020978
P. californica	Robben Island, Sakhalin, USSR	9. ix. 1906	R. Kubo/K. Okamura	Okamura Herb.
P. pectinata	Peter the Great Bay, USSR	19. vii. 1928	A. Kuznetsov/S. Funahashi	032410
P. pectinata	Akkeshi, Hokkaido, Japan	1. vi. 1946	M. Kurogi	051160
P. pectinata	Hiroo, Hokkaido, Japan	30. iii. 1975	M. Ohta	047885
P. pectinata	Urakawa, Hokkaido, Japan	vi. 1902	N. Hattori/K. Okamura	Okamura Herb.
P. californica	Muroran, Hokkaido, Japan	15. viii. 1929	S. Yagi/K. Okamura	Okamura Herb.
P. pectinata	Muroran, Hokkaido, Japan	29. vi. 1935	T. Muraoka	019824
P. pectinata	Otaru, Hokkaido, Japan	2. v. 1954	N. Tazawa	028517, 028518
P. pectinata	Oshoro, Hokkaido, Japan	vi. 1932	K. Inagaki	022842
P. pectinata	Okushiri, Hokkaido, Japan	6. vii. 1944	Y. Hasegawa	025231, 025232
P. serrata	Shimofuro, Aomori, Japan	18. iv. 1987	T. Kitayama	052831
P. pectinata	Nakano, Iwate, Japan	1. vii. 1954	S. Kawashima	027881
Ptilota phacelocarpoides				
P. pectinata f. *litoralis*	Peter the Great Bay, USSR	31. viii. 1926	A. Kuznetsov/S. Funahashi	032408
P. pectinata f. *litoralis*	Nemuro, Hokkaido, Japan	27. vi. 1987	M. Matsumoto	052487
P. pectinata f. *litoralis*	Muroran, Hokkaido, Japan	vii. 1933	T. Kanda	023358
P. pectinata f. *litoralis*	Hakodate, Hokkaido, Japan	25. iv. 1943	T. Moritake/Y. Yamada	024271
P. pectinata f. *litoralis*	Usu, Hokkaido, Japan	16. vii. 1954	N. Tazawa	051155
P. pectinata f. *litoralis*	Rishiri, Hokkaido, Japan	28. viii. 1934	K. Inagaki	022835, 047733
P. pectinata f. *litoralis*	Yagishiri, Hokkaido, Japan	2. viii. 1981	M. Marui	044071
P. pectinata f. *litoralis*	Obira, Hokkaido, Japan	12. vi. 1981	M. Marui	044072
P. pectinata f. *litoralis*	Mashike, Hokkaido, Japan	26. vii. 1897	F. Nakajima/K. Okamura	Okamura Herb.
P. pectinata f. *litoralis*	Shioya, Hokkaido, Japan	vi. 1940	Y. Nakamura	023616
P. pectinata f. *litoralis*	Kesen-numa, Iwate, Japan	undated	K. Okamura	Okamura Herb.

SAP (053614-053650). The herbarium specimens were examined using a dissecting microscope with fiber-optical light (Nikon SMZ-10). Small portions of them were removed and prepared for microscope slides.

Results and Discussion

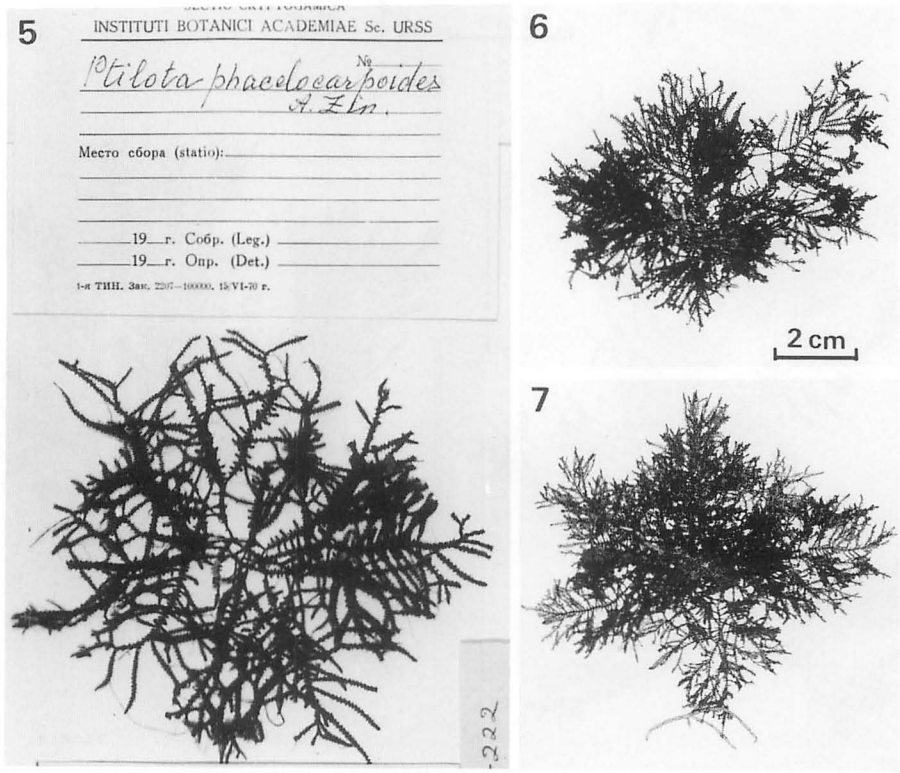
Specimens examined have the following features in common. Thalli are flattened, densely branched in an alternately pinnate manner in a single plane (Figs. 1-7). Primary axes of the thalli produce a pair of



Figs. 1–4. Herbarium specimens of three species of *Ptilota*. Fig. 1. *Ptilota plumosa* (Linnaeus) C. Agardh with cystocarps collected at Bohuslan, Sweden (SAP 040916). Fig. 2. *Ptilota serrata* Kützing with tetrasporangia collected at Spitzbergen, Norway on May 12, 1873 (SAP 040938). Fig. 3. *Ptilota filicina* J. Agardh with tetrasporangia collected at Vancouver Island, Canada in June 1901 (SAP 048484). Fig. 4. *Ptilota filicina* with procarps collected at Hiroo, Hokkaido, Japan on March 30, 1975 (SAP 047885). Scale in Fig. 1 applies also to Fig. 2; scale in Fig. 3 applies also to Fig. 4.

lateral opposite branches, one of which develops before the other. Some of the indeterminate branches grow well in a manner similar to that of the primary axis and so the primary axis becomes obscured. Determinate branches are leaflet-like and have reproductive activity. Adventitious branches are formed from the outermost cortical cells. The axes and branches are flattened. The thallus is composed of a central axial filament and a cortex of several layers. Reproductive structures are borne on short branches replacing indeterminate branches, on serrations of determinate branchlets, and sometimes on the apex of indeterminate branches. Tetrasporangia are terminal on clustered, uniseriate filaments and the spores are tetrahedrally arranged. Cystocarps, when present, are heavily covered by involucral bracts arising from the lower portion of their parent branches or branchlets. Spermatangia, when present, are in irregular clusters and are borne on specially developed branchlets.

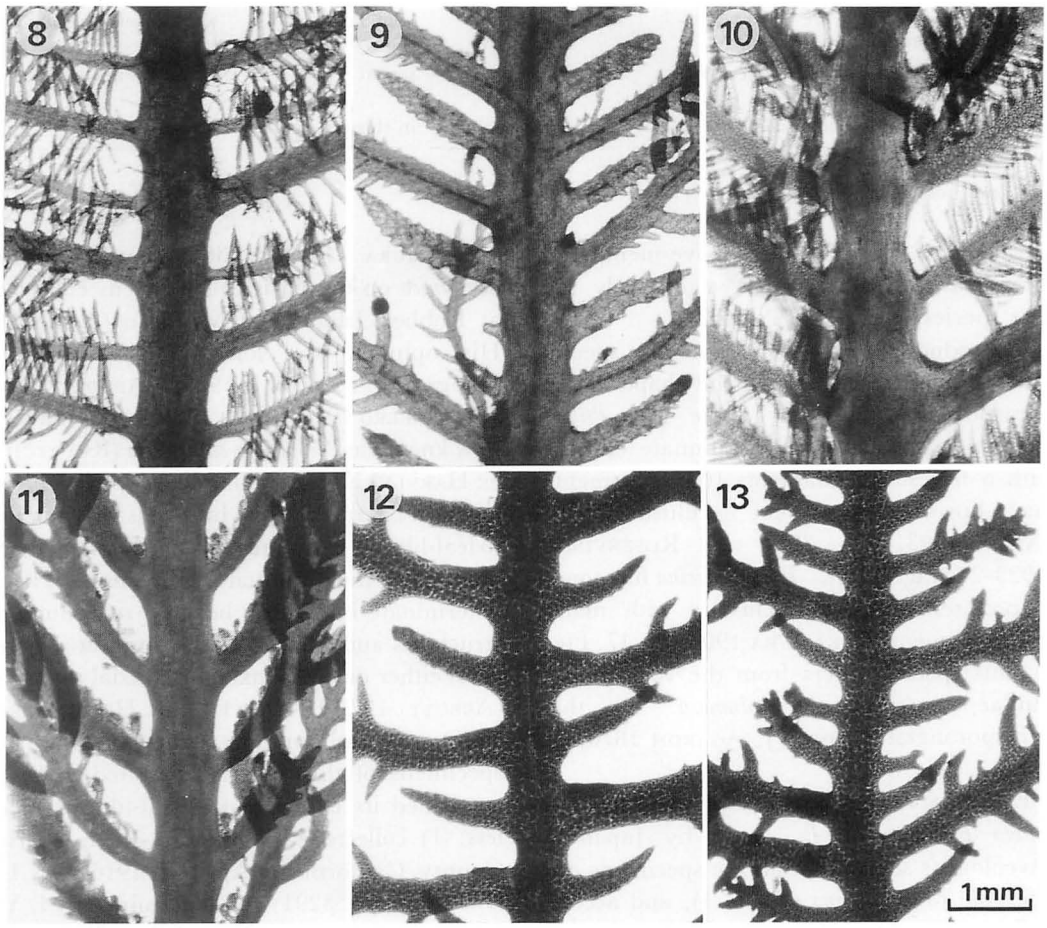
The most conspicuous diagnostic feature for the identification of individual specimens is the growth manner of first-order branches (traditionally referred to as pinnae) on the primary axis. *Ptilota serrata* and *P. phacelocarpoides* have two types of branches, those with determinate growth becoming leaflet-like branchlets and those with indeterminate growth becoming pinnate branches (Figs. 9, 12). On the other hand, *P. plumosa* and *P. filicina* have two branches with indeterminate growth which are dissimilar in size (Figs. 8, 10, 11). The majority of specimens examined of each species consistently shows



Figs. 5–7. Herbarium specimens of *Ptilota phacelocarpoides* A. ZINOVA. Fig. 5. Holotype specimen collected at Ussuri Bay in Peter the Great Bay, Primorskiy, USSR in August 1966 and deposited in LE (the photograph taken by I. YAMADA). Fig. 6. Vegetative specimen collected at Atsuta, Hokkaido on August 11, 1989 (SAP 053648). Fig. 7. Vegetative specimen collected at Oshoro Bay, Hokkaido on August 15, 1989 (SAP 053643). Scale in Fig. 6 applies also to Figs. 5 & 7.

this feature, but some specimens have irregular patterns. For example, in some plants of *P. phacelocarpoides* two of a pair of first-order branches develop indeterminately like the primary axis and even pinnate branches cease growth at early stages (Fig. 13). To judge from the original description (ZINOVA 1972) and from the holotype specimen (Fig. 5), some of the original material of *P. phacelocarpoides* may have a similar irregular pattern. In some specimens of *P. filicina* one of a pair of the first- or second-order branches cease vegetative growth at an early stage and often form reproductive structures.

Leaflet-like determinate branchlets of *Ptilota plumosa, P. serrata* and *P. filicina* are serrate both on the adaxial and abaxial margins. Those of *P. phacelocarpoides* are usually entire, but are sometimes serrate only on the abaxial margin. Furthermore, thalli of *P. phacelocarpoides* are decumbent, being attached to the substratum by adventitious rhizoids (Fig. 14), whereas those of the other



Figs. 8–13. Portion of main axes of four species of *Ptilota*, showing the growth manner of first-order branches. Fig. 8. *Ptilota plumosa* from Mandals Skargard, Norway (SAP 040928); note both of each opposite pair with indeterminate growth. Fig. 9. *Ptilota serrata* from Novaya Zemlya, USSR (SAP 040938A); note one of each opposite pair with determinate growth. Figs. 10, 11. *Ptilota filicina*: 10, from Vancouver Island (SAP 048484); 11, from Hiroo, Hokkaido (SAP 047885); note both of each pair with indeterminate growth. Figs. 12, 13. *Ptilota phacelocarpoides*: 12, from Atsuta, Hokkaido (SAP 053648); 13, collected at Oshoro Bay, Hokkaido on September 18, 1989 (SAP 053644); note a regular arrangement of opposite pairs, one with determinate growth, another with indeterminate growth in Fig. 12, and an irregular arrangement in Fig. 13. Scale in Fig. 13 applies also to Figs. 8–12.

Table 2. A comparison of four species of *Ptilota*.

Feature	*P. plumosa*	*P. serrata*	*P. filicina*	*P. phacelocarpoides*
Thallus erect or decumbent	erect	erect	erect	decumbent
Shape of opposite branch pairs on primary axis	similar	dissimilar	similar	dissimilar
Serration on determinate branches	abundant on both sides	abundant on both sides	abundant on both sides	sometimes on abaxial side
Position of reproductive structures	apex of short branches, serrations of determinate branches	apex of short branches, serrations of determinate branches, sometimes apex of indeterminate branches	apex of short branches, serrations of determinate branches, sometimes apex of indeterminate branches	apex of short branches, serrations of determinate branches, sometimes apex of indeterminate branches
Shape of tetrasporangial clusters	pinnate	cone-shaped	cone-shaped	cone-shaped
Sterile filaments on tetrasporangial pinnules	rare	abundant	abundant	abundant
Involucral bracts enveloping cystocarps	entire or serrate	entire or serrate[1)]	serrate	entire, sometimes serrate
Spermatangia	in clusters[2)]	?	in clusters	in clusters

[1)] Data from Harvey (1853)
[2)] Data from Rosenvinge (1923–24)

species are erect. The above-mentioned three features characterize vegetatively the four species examined (Table 2).

Reproductive features of the four species are very similar except for the shape of the tetrasporangial clusters (Table 2). *Ptilota plumosa* bears characteristic pinnate clusters with a few sterile filaments [these filaments may, however, be absent as illustrated by KYLIN (1923, Fig. 39C) and ROSENVINGE (1923-24, Fig. 291)]. *Ptilota filicina* has cone-shaped tetrasporangial clusters with many sterile filaments (OKAMURA 1909, Pl. 47, Fig. 8); this species differs from the vegetatively similar species, *P. plumosa* in this tetrasporangial feature (J. AGARDH 1876, p. 76).

Examination of specimens identified as *Ptilota pectinata* or *P. serrata* by Japanese phycologists shows that all the specimens are referable to *P. filicina* (Table 1), and accord well with J. AGARDH's original description. Thus, the voucher specimens of *Ptilota pectinata* of the following publications can be identified as *P. filicina*: OKAMURA (1909, 1933, 1936), YAMADA (1934), KAWABATA (1936), NAGAI (1941), KAWASHIMA (1955), FUNAHASHI (1966) and TAZAWA (1975).

OKAMURA (1909, 1936) recorded *Ptilota californica* on the basis of specimens collected at Robben Island and Muroran (Table 1). His opinion was followed by later investigators (TOKIDA 1954, ABBOTT and HOLLENBERG 1976, SAKAI 1986). This entity, now known as *Neoptilota californica* (RUPRECHT ex HARVEY) KYLIN, is characterized by one of a pair of lateral opposite branches growing into leaf-like determinate branchlets which alternate with indeterminate branches. These determinate branchlets bear no reproductive structures and sometimes have minute serrations either on the abaxial or adaxial margins (ABBOTT 1972, ABBOTT and HOLLENBERG 1976). An examination of the following two specimens of this species deposited in SAP confirmed its characteristic leaf-like branchlets: 1) collected at Duxbury Reef, Marin County, California on April 22, 1916 by N.L. GARDNER (No. 3291) and determined by E.Y. DAWSON (SAP 040914) and 2) collected at Tomales Bay, Marin County, California in August 1916 by N.L. GARDNER (No. 3443) and determined by P.C. SILVA (SAP 046617). OKAMURA's voucher specimens cited in Table 1 have no such leaf-like branchlets. OKAMURA (1909, 1936) emphasized

the occurrence of pinnate serrations on involucral bracts of his specimens. However, *P. filicina* often has pinnately serrated involucral bracts, as reported by PERESTENKO (1980). *Ptilota californica* sensu OKAMURA (1909, 1936) is identical with *P. filicina*.

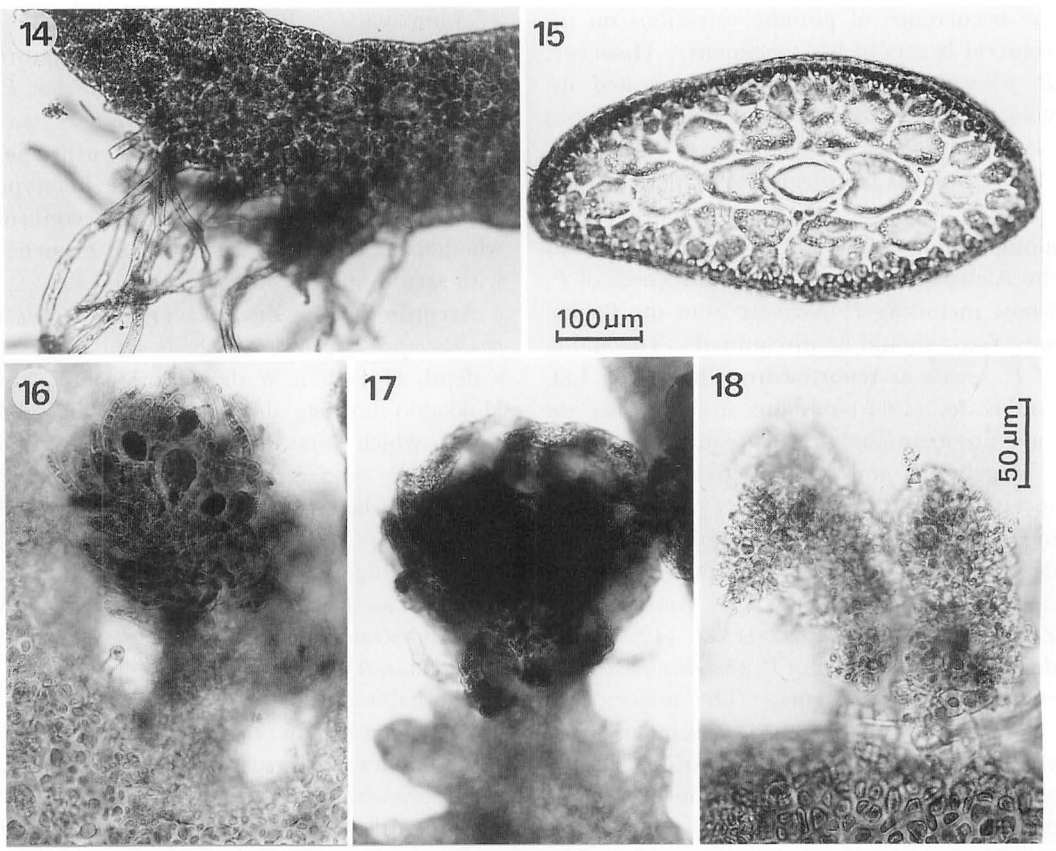
Ptilota filicina is thus widely distributed along both coasts of North Pacific Ocean and the Aleutian Islands. Previous records of *P. serrata* including *P. pectinata* from the Pacific west coast should be discounted. The status of *P. serrata* as reported from Korea by LEE and KANG (1986) remains uncertain as we have not examined any Korean specimens.

Vegetative and reproductive features of specimens identified as *Ptilota phacelocarpoides* in Table 1 agree with those of the original description (ZINOVA 1972) except for the serration of determinate branches. According to ZINOVA (1972) and PERESTENKO (1980), the determinate branches of *P. phacelocarpoides* are smooth at the margins. The majority of determinate branches in the specimens of *P. phacelocarpoides* collected at various localities in Hokkaido is smooth, but a few of them are serrate on the abaxial margin. A tetrasporangial specimen collected at Sobol Bay in Peter the Great Bay (SAP 032408) has no serration, but it is a small fragment 2 cm in length. PERESTENKO (1980) reported the presence of serrations on involucral bracts of her specimens from the type locality. This strongly suggests the possibility that *P. phacelocarpoides* has determinate branches with minute serrations on some margins. Fertile plants collected from Hokkaido bear adaxial serrations on which reproductive structures are produced. This feature has also been reported by ZINOVA (1972) and PERESTENKO (1980). Another discrepancy that requires consideration is the size of tetrasporangia. The size of tetrasporangia given by PERESTENKO (1980) on the basis of material from the Peter the Great Bay is 22–28 μm in diameter. The tetrasporangia of our Hokkaido plants are 42.5–67.5 μm long × 40.0–57.5 μm wide and those of a specimen collected at Sobol Bay (SAP 032408) are 50.0–62.5 μm long × 37.5–47.5 μm wide. PERESTENKO's dimensions may, however, be based on immature tetrasporangia. At present we think that *P. phacelocarpoides* and the alga known as *P. pectinata* f. *litoralis* in Japan are conspecific, although a re-examination of the holotype specimen is necessary in order to confirm whether or not a few determinate branches with serrate margins are present.

According to ZINOVA (1972), *Ptilota phacelocarpoides* grows on shells and rocks at a depth of 4–26 m at the type locality. In Hokkaido this alga also grows in the subtidal zone, which may be indicative of the ecological preference of this species. Although OKAMURA (1909, 1936) reported that this alga (as *P. pectinata* f. *litoralis*) grew near the high tidemark. His observation may be based on specimens entangled with some substrata after drifting or may depend on KJELLMAN (1883).

The habit illustration of *Ptilota pectinata* f. *litoralis* given by KJELLMAN (1883, Pl. 5, Fig. 2) resembles the gross morphology of *P. phacelocarpoides*. OKAMURA (1909) may have identified his specimens on the basis of this similarlity. This similarity is, however, superficial; KJELLMAN (1883) mentioned that his f. *litoralis* differed from the typical *P. pectinata* in the inner thallus structure: the axial cells of the former were not surrounded with a complete circle of large, paler-colored cells, whereas those of the latter were surrounded completely with such a circle. Our specimens have a inner structure similar to KJELLMAN's typical *P. pectinata* (=*P. serrata*) (Fig. 15). As the taxonomic significance of this difference is uncertain at present and no other critical features are available, it cannot be determined whether *P. pectinata* f. *litoralis* is a growth form (ecad) of *P. serrata* or an independent taxon.

The geographical distribution of *Ptilota phacelocarpoides* is limited to Hokkaido and northern Honshu in Japan and Primorskiy in the USSR. As an adequate description of this alga as found in Japan is unavailable, a description is given below based on specimens collected from Hokkaido.



Figs. 14–18. *Ptilota phacelocarpoides* collected at Oshoro Bay on September 18, 1989 (Figs. 14, 15) and on October 17, 1988 (Figs. 16–18). Fig. 14. Adventitious rhizoids from the surface cells. Fig. 15. Cross section of a main axis. Fig. 16. Tetrasporangial cluster on a short branch. Fig. 17. Cystocarp enveloped with well-developed involucral bracts. Fig. 18. Spermatangial clusters on the adaxial side of a determinate branchlet. Scale in Fig. 15 applies also to Figs. 14, 16 & 17.

Ptilota phacelocarpoides A. ZINOVA

Thalli decumbent, attached to substratum by basal rhizoids and adventitious rhizoids arising from surface cells of the thalli (Fig. 14), 3–10 cm long, dark red in color, pinnately branched in a single plane; primary axis forming a pair of lateral opposite branches, one with determinate growth, becoming cuneate, leaflet-like branchlets with or without abaxial serrations and the other with indeterminate growth, becoming pinnate branches (Fig. 12), some of which growing well in a manner similar to that of the primary axis and so the axis becoming obscured, sometimes both of an opposite pair growing indetermiantely and even pinnate branches ceasing growth at early stages, becoming determinate branchlets (Fig. 13); these axis and well-developed branches flattened, 600–1400 μm wide × 240–350 μm thick; tetrasporangial cluster cone-like in shape, on the apices of short branches (Fig. 16) and on the adaxial side of determinate branches, sometimes on the apices of indeterminate branches; tetrasporangia terminal on uniseriate filaments, provided with lots of sterile, uniseriate filaments, 42.5–67.5 μm long, 40.0–57.5 μm wide, spores tetrahedrally arranged; cystocarps on the apices of short branches replacing indeterminate branches and on minute branchlets borne on the adaxial side of determinate branches, globular, enveloped by involucral bracts (Fig. 17) sometimes with serrated margins; spermatangia in irregular clusters on

special branchlets borne on short branches and on the serrations of determinate branches (Fig. 18).

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増田道夫・佐々木真人：日本産紅藻クシベニヒバ属（イギス目）について

日本産のクシベニヒバとコバノクシベニヒバを，外国産の種と比較した結果，前者は *Ptilota filicina* J. AGARDH，後者は *P. phacelocarpoides* A. ZINOVA に該当することが明らかになった。また，カシワバベニヒバ *Ptilota californica* (＝*Neoptilota californica*) sensu OKAMURA は該種とは異なり，クシベニヒバと同一種であることが判明した。世界に産するこの属全4種の分類学的に重要な特徴について，1）主軸上の第一位枝の成長様式，2）小葉状の有限成長枝の鋸歯の有無，3）藻体が直立するか傾伏するか，及び4）四分胞子嚢群の形が種のレベルで意義のある形質であることを示した。コバノクシベニヒバについては北海道産の標本に基づいて記載を行なった。(060 札幌市北区北10条西8丁目　北海道大学理学部植物学教室)