Jap. J. Phycol. (Sôrui) 30: 265-271. December 15, 1982

Halosaccion americanum sp. nov. (Rhodophyta, Palmariaceae) in Pacific North America

In Kyu LEE

Department of Botany, Seoul National University, Seoul 151, Korea

LEE, I. K. 1982. *Halosaccion americanum* sp. nov. (Rhodophyta, Palmariaceae) in Pacific North America. Jap. J. Phycol. 30: 265-271.

Halosaccion americanum sp. nov. (Rhodophyta, Palmariaceae) is described from the Pacific North America. It was referred to *H. glandiforme* (S. G. GMELIN) RUPRECHT since SETCHELL and GARDNER (1903). The species is characterized and different from *H. glandiforme* by a larger and more cylindrical thallus, branched cortical cell rows in vegetative thallus, branched sterile filaments in tetrasporangial sorus, and three to four spermatangia developing on one mother cell. Female plants are unknown. *H. americanum* extends from the Aleutian Islands, Alaska to southern California.

Key Index Words: Halosaccion; *Palmariaceae*; *Rhodophyta*; *taxonomy*.

Halosaccion glandiforme (S. G. GMELIN) RUPRECHT was originally described by S. G. GMELIN (1768) from Kamchatka as *Ulva glandiforme*, and investigated more extensively by RUPRECHT (1850). Since SETCHELL and GARDNER (1903), a simple and saccate *Halosaccion* occurring along the Pacific North America was referred to as *H. glandiforme*, whereas the plants occurring in Japan were referred to as *H. saccatum* after YENDO (1909), which was an incorrect name for the same species (LEE, 1978).

LEE (1977, 1978) described *H. minjaii* I. K. LEE and *H. yendoi* I. K. LEE from the algae known as *H. saccatum* and *H. glandiforme* in the Aleutian Islands, Alaska (USA), Kurile and Saghalien Islands (USSR), and Hokkaido (Japan). LEE *et al.* (1979) also clarified the taxonomic characteristics of *H. glandiforme* from Kamchatka.

According to the present investigation, *H. glandiforme* in the Pacific North America was different from *H. glandiforme* in Kamchatka, not only in vegetative structure but in tetrasporangium and spermatangium formation, as well. A new species of *Halosaccion* is therefore proposed from the Pacific North America.

Materials examined

The materials were collected from Duxbury Reef, California, the type locality, during August, 1978 and April, 1979. Formalin preserved materials from Davenport, Santa Cruz, California, collected in February 23, 1976 and kindly sent by Dr. NEUSHUL, University of California, Santa Barbara, were also examined. Herbarium specimens examined were summarized as below.

In the Herbarium, Department of Botany, University of California, Berkeley (UC)

California: Santa Cruz M022161 (⊗), 94188; Moss Beach MO* in UC 1019535-6 (⊗), 975584, 402251-2; Monterey 74693, 94194 (⊗), 975579; Humboldt County 975583; Fanshell Beach 975577; Duxbury Reef 94189, 975580-1; San Luis Obispo 392778, 975578. *Oregon*: Coos County DS** in UC 501540; South Bay DS in UC 501575 (⊗), M142745 (⊗), M107959; Cape Blanco 496537. *Washington*: Lopez Isl. MO in UC 796585 (max. 14 cm). *Alaska*: Prince Wm. Sound M155363; Yakutat Bay 94201 (max. 7 cm);

Kodiak Isl. 503814. (*MO: Missouri Botanical Garden Herbarium. **DS: Dudley Herbarium of Stanford University)

In the Herbarium, Faculty of Agriculture, Hokkaido University (SAPA)

California: Moss Beach, Oct. 1916 (by N. L. GARDNER, No. 6355) 2 specimens (⊗, ♂, max. 28 cm), Sep. 1927(by N.L. GARDNER, No. 6368) 3 specimens (⊗, sterile, max. 14 cm). *Aleutian Islands*: Unalaska, June-Aug., 1899 (by W. A. SETCHELL and A. A. LAWSON, No. 4051) 10 specimens (sterile, max. 1.5 cm).

Halosaccion americanum sp. nov. I. K. LEE

Thallus gregarius, flavibrunneus aut purpureus, saccatus, simplex, coriaceus, cylindricus, late rotundus ad apicem, breviter stipitatus per discum affixus, 10-20-(30) cm altus, 2-3 cm latus; frons in sectione ex stratis corticalibus et medullosis composita, 300-500 μm crassa, strato corticali ex 2-3 seriebus oblongarum cellularum ramosarum et perpendiculariter paginae dispositorum composito, cellulis superficialibus spathulatis aut oblongis, 5.0-7.5 μm latis, 12-20 μm longis, strato medulloso ex 6-8 seriebus cellularum composito, cellulis medullosis rotundis aut ellipticis, cum connectivo stellari protoplasmico mutue, cellulis intimis 80-100 μm latis; in thallo vetere cellulae medullosae intimae saepe stratum cellulam corticalem versus cavitatem centralem parientes; tetrasporangia e superficiali corticali cellula terminale praesentia, cellula stipitata, elliptica, cruciate divisa, 23-30 μm lata, 45-55 μm longa, cellulis sterilibus inter tetrasporangia filamentis ramosis cum 3-4 cellulis elongatis transmutatis; spermatangia 3-4 super cellula matris evoluta, elliptica, 6-7 μm lata, 15-17 μm longa; cystocarpia ignota.

Thallus gregarious, yellow-brown to purple, saccate, simple, coriaceous, cylindrical, broadly round at apex, shortly stipitate, attached by a disc, 10-20-(30) cm high, 2-3 cm broad; frond in section composed of cortical and medullary layers, 300-500 μm thick, cortical layer composed of 2-3 rows of oblong cells branched and arranged perpendicularly to surface, superficial cells spatulate to oblong, 5.0-7.5 μm broad, 12-20 μm long, medullary layer composed of 6-8 rows of cells, medullary cells round to elliptical, with stellate protoplasmic connections between one another, innermost cells 80-100 μm broad; in old thallus innermost medullary cells frequently regenerating cortical cell layer toward central cavity; tetrasporangia occurring terminally from superficial cortical cells, with a stalk cell, elliptical, cruciately divided, 23-30 μm broad, 45-55 μm long, sterile cells among tetrasporangia converted into branched filaments with 3-4 elongate cells; spermatangia developing 3-4 on a mother cell, elliptical, 6-7 μm broad, 15-17 μm long; cystocarps unknown.

Type Locality: Duxbury Reef, California, U. S. A.

Holotype: UC 1446017 (LIK #36399, tetrasporophyte), collected on 17 October 1978, preserved in the Herbarium, Department of Botany, University of California, Berkeley (UC).

Isotype: LIK #36398 (male plant), collected on 17 October, 1978, preserved in the Herbarium, Department of Botany, Seoul National University (SNU).

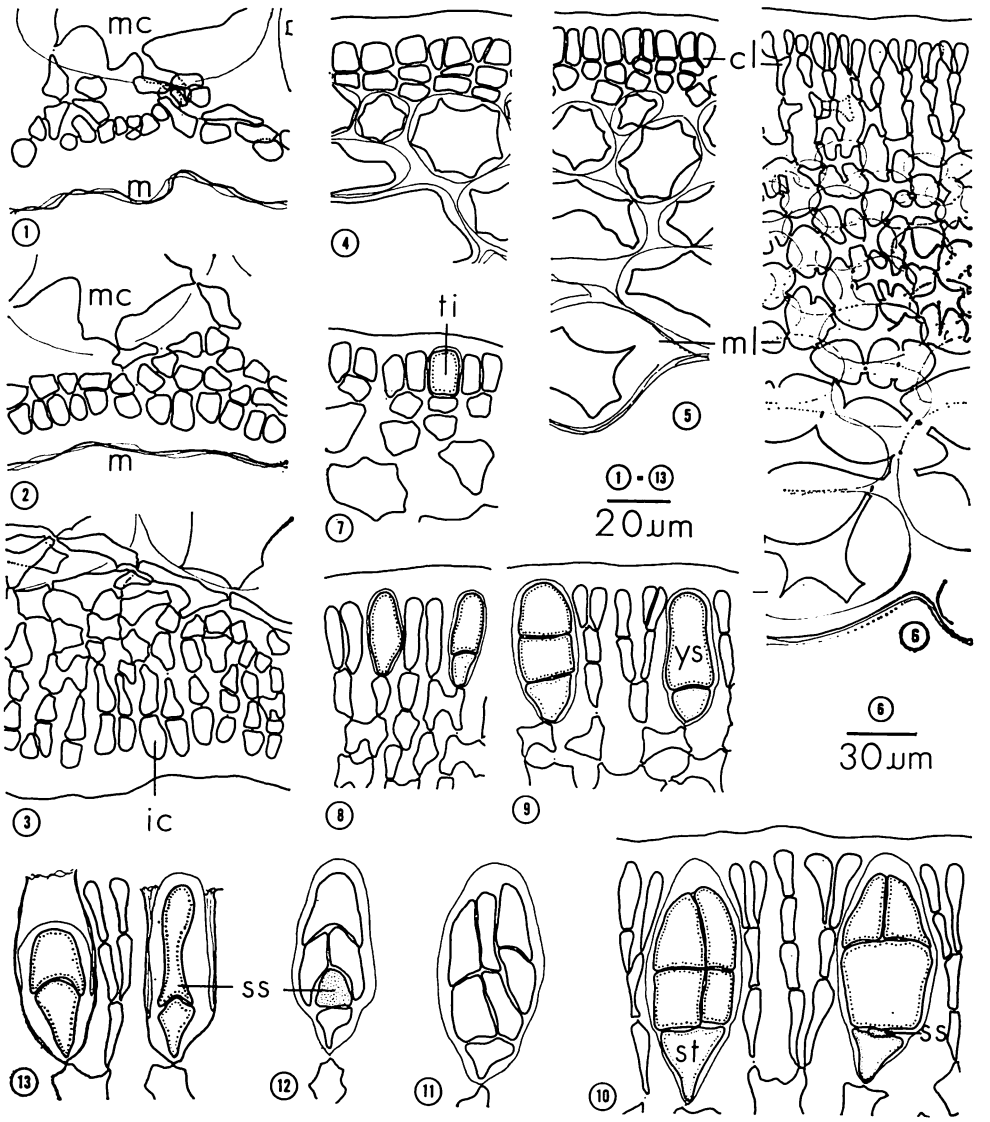
Distribution: Aleutian Islands, Alaska to Pt. Conception, California of Pacific North America.

Amplification of diagnosis

Vegetative Thallus: The plants in the type locality grew to a maximum height in September—October (Figs. 23, 24). They were comparatively large among the species of *Halosaccion*. The regeneration of new saccate fronds from the ruptured margin of old thalli was not rarely seen. Anatomically, the cortical cells are densely pigmented outwards, and have numerous secondary pit-connections with adjacent cells, while the medullary cells are modified characteristically into stellate forms connected radially with adjacent cells (Fig. 6). Hair cells were not observed in mature thallus.

In young plants the central portion of the thallus was filled with large hyaline medul-

lary cells, and the medullary margin observed in *H. minjaii* (LEE 1977) and *H. glandiforme* (LEE *et al.* 1979) was not seen. The cortical cells are short and rectangular (Fig. 4; 10-15 μm broad, 7-10 μm long in 1.2 cm high fronds), and become longer during the growth (Fig. 5). On the other hand, in old thalli innermost medullary cells regenerate forming irregularly shaped small cells inwards, which develop into a new cortical cell layer towards the central cavity (Figs. 1-3). Thus, the thalli usually become thick.

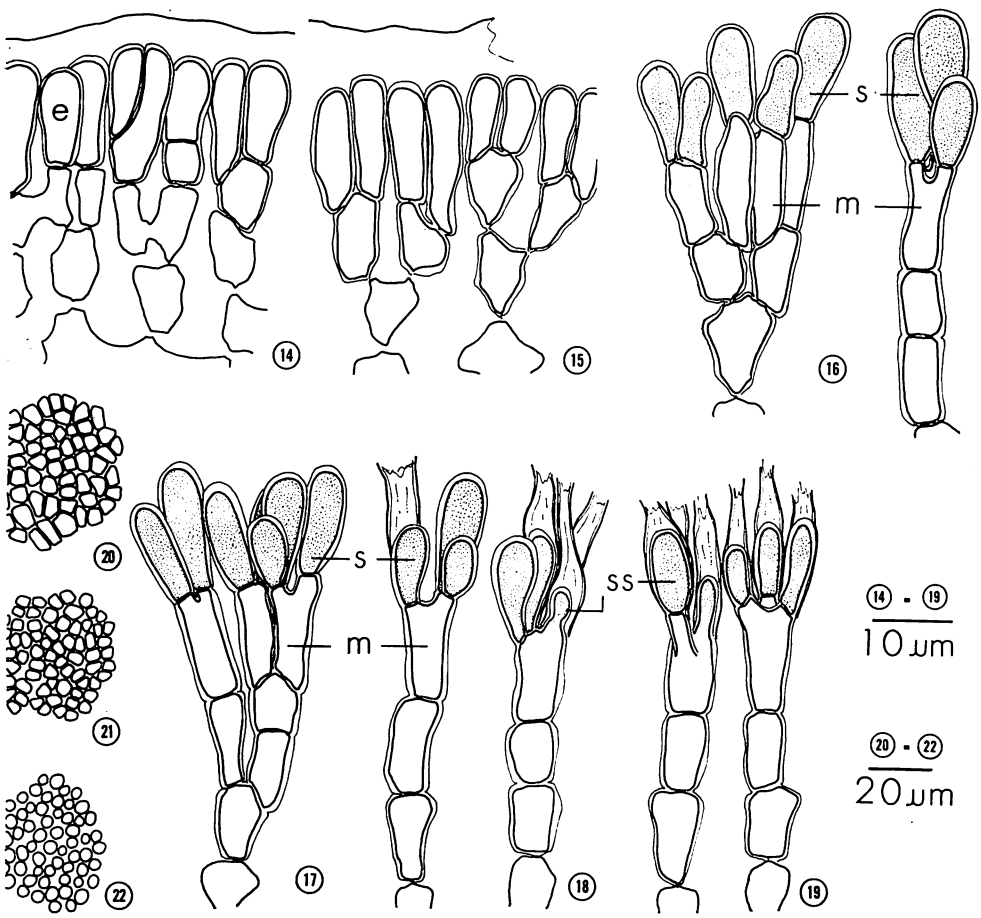


Figs. 1-13. Vegetative structure and tetrasporangium formation of *Halosaccion americanum* I. K. LEE. 1-3. Regeneration of cortical layer from innermost medullary cells; 4. Transverse section of 1.2 cm high vegetative thallus in middle portion; 5. The same of 3.5 cm high thallus; 6. The same of fully grown thallus; 7-10. Development of tetrasporangia; 11. Abnormally divided tetrasporangium; 12-13. Development of secondary tetrasporangia (cl: cortical layer, ic: inner cortical cell, m: margin, mc: medullary cell, ml: medullary layer, ss: secondary sporangium, st: stalk cell, ti: tetrasporangium initial, ys: young sporangium).

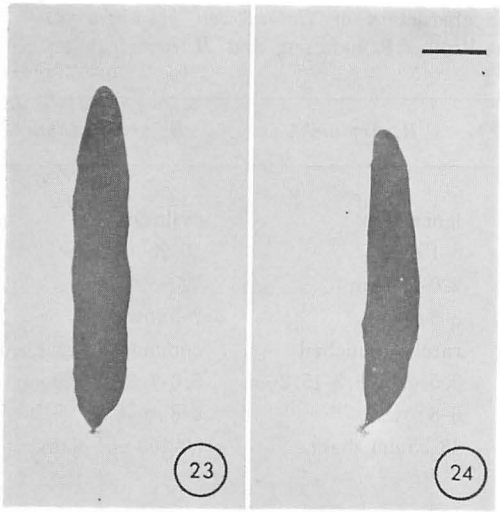
Tetrasporangium Formation: Tetrasporangial sori cover almost all the frond except for the uppermost and lowermost portions of the thallus. They develop from the superficial cortical cells as well as from the regenerated inner cortical cells facing the central cavity. Tetrasporangial initials become wider than adjacent sterile cells but are nearly equal in height (SPARLING 1961). They divided into the sporangium and the stalk cell by an unequal periclinal plane when they become about 30 μm long (Figs. 7, 8). The sporangium when about 40 μm long is divided periclinally (Fig. 9 left), and then anticlinally to form tetraspores (Fig. 10).

Sterile cortical cells in tetrasporangial sori elongate at the same time as the tetrasporangial initials, and become generally branched filaments showing almost the same height as stalked mature tetrasporangia (Figs. 8-10). Secondary tetrasporangia commonly develop from a stalk cell after the primary tetrasporangium discharges tetraspores (Fig. 13). They frequently develop when the primary sporangium is still growing (Fig. 10 right), or not released yet (Fig. 12). Occasionally, abnormally divided sporangia were seen (Fig. 11).

Spermatangium Formation: Spermatangial sori develop in a manner similar to the



Figs. 14-22. Spermatangium formation of *Halosaccion americanum* I.K. LEE. 14-15. Elongation and oblique divisions of superficial cortical cells; 16-18 left. Development of primary spermatangia from mother cells; 18 right-19. Formation of secondary spermatangia; 20-22. Development of spermatangia from surface view (e: superficial cortical cell, m: spermatangial mother cell, s: spermatangium, ss: secondary spermatangium).



Figs. 23-24. *Halosaccion americanum* I. K. LEE. 23. Holotype specimen (tetrasporophyte), collected at Duxbury Reef, California on 17 October 1978; 24. Isotype specimen (male plant). *Scale*: 5 cm.

tetrasporangial sori. The spermatangia originate from superficial cortical cells (Figs. 20-22). The cortical cell elongates to about 15 μm and divides obliquely into two to three outer cells and one lower cell (Fig. 14). The outer cells divide outwardly again into two spermatangial mother cells and one lower cell (Fig. 15). Sometimes, a superficial cell divides again into two spermatangial mother cells and one lower cell (Fig. 17 right). Thus, about six to ten mother cells are formed from a single cortical cell.

The spermatangial mother cell protrudes three to four primary spermatangia subterminally; three almost simultaneously or the third slightly later (Figs. 16, 17 right), or two earlier and the two later (Fig. 18). Four primary spermatangia were observed rarely. Secondary spermatangia are common within the empty cavity (Fig. 19). The mother cell is 6-8 μm broad and 10-17 μm long. The superficial cuticle over the sorus is shed when the spermatangial mother cells are formed.

Discussion

Halosaccion americanum is a very distinct species among the members of *Halosaccion*. The genus includes about sixteen species at present. As RUPRECHT (1850) and J. AGARDH (1852) discerned, they can be divided into two by the shape of thallus, simple and branched ones. In the former *H. firmum* (POST. et RUPR.) KÜTZING, *H. fucicola* (POST. et RUPR.) KÜTZING, *H. glandiforme* (S. G. GMELIN) RUPRECHT, *H. levringii* CHAPMAN et DROMGOOLE, *H. minjaii* I. K. LEE, and *H. yendoi* I. K. LEE show a saccate form and more approximate *H. americanum* in outer appearance. However, *H. levringii*, *H. yendoi* are different in vegetative structure (CHAPMAN and DROMGOOLE 1970, LEE 1978), and *H. minjaii* in the shape of tetrasporangial sori (LEE 1977) from the present species. *H. fucicola* is characteristic in obovate-oblong shape and membranaceous thallus (POSTELS and RUPRECHT 1840, Fig. 25A). As a result, *H. americanum* is related more to *H. glandiforme* and *H. firmum* in thallus shape.

SETCHELL and GARDNER (1903) mentioned that North Pacific species of saccate *Halosaccion* were described under twelve different specific names, and referred them to as *H. glandiforme*. On the other hand, YENDO (1909) discussed many species and forms described by POSTELS and RUPRECHT (1840) and RUPRECHT (1850) under *Halosaccion* or *Dumontia* seemed in large part induced from the polymorphism. He concluded *H. saccatum* (syn. of *H. glandiforme*) and *H. firmum* were the independent species in the North Pacific.

As summarized in Table 1, *H. americanum* is characterized by a large thick frond, branched cortical cell rows in vegetative thallus as well as in sterile filaments of tetrasporangial sori, lack of hair cells in mature thallus, and three to four primary spermatangia on a spermatangial mother cell. The frequent regeneration of inner cortical layer from innermost medulla toward the central cavity may be also one of the characters of this species, since no such a character was mentioned in other species of the genus.

In comparing *H. americanum* with *H. glandiforme* and *H. firmum*, it rather closely approximates *H. firmum* in vegetative struc-

Table 1. A comparison of some taxonomic characters of *Halosaccion glandiforme* (S.G. GMELIN) RUPRECHT, *H. firmum* (POST. et RUPR.) RUPRECHT, and *H. americanum* I.K. LEE

Characters \ Species	*H. glandiforme**	*H. firmum***	*H. americanum*
Thallus			
Shape	elliptical	lanceolate	cylindrical
Height	5-10 cm	8-15 cm	10-20-(30) cm
Thickness	170-200 μm	220-350 μm	300-500 μm
Cortical layer	3-4 rows	3-5 rows	2-3 rows
Cortical filament	unbranched	rarely branched	commonly branched
Superficial cell	4.5-5.5×5-10 μm	3.5-4.0×8.3-15.2 μm	5.0-7.5×12-20 μm
Medullary layer	5-8 rows	6-8 rows	6-8 rows
Innermost cell	50-80 μm diam.	48-55 μm diam.	80-100 μm diam.
Regeneration of cortex from innermost medulla	−	−	+
Hair cell	+	−	−
Tetrasporangia			
Size	18-22×35-43 μm	20-28×40-48 μm	23-30×45-55 μm
Sterile cell row	unbranched	rarely branched	commonly branched
Spermatangia			
No. of mother cells from a cortical cell	6-10	2	6-10
No. of primary spermatangia	2	2	3-4
Size	3.5-4.5×12-14 μm	3.7×15.8 μm	6-7×15-17 μm

* Acccrding to LEE *et al.* (1979), and ** LEE (1978).

ture by the arrangement of cortical cells and in tetrasporangium formation by the modification of sterile filaments in the sorus (LEE 1978). However, both species are distinguished by the shape and size of the thallus, the thickness of vegetative structures, rows of the cortical filaments, and particularly by the spermatangium formation. *H. firmum* produces two spermatangial mother cells directly from a superficial cortical cell, and two primary spermatangia from a mother cell, whereas *H. americanum* produces six to ten spermatangial mother cells which are cut off from the cells derived from a superficial cortical cell, and three to four primary spermatangia from a mother cell.

Althought the development of spermatangial mother cells is similar in both *H. americanum* and *H. glandiforme*, the number of primary spermatangia from a mother cell is different by formation of two spermatangia in the latter. Moreover, *H. americanum* is easily distinguished from *H. glandiforme* by the shape of thallus and arrangement of cortical cells (LEE *et al.* 1979).

So far the present investigation is concerned, *H. americanum* occurs from Unalaska, Alaska to Pt. Conception, California.

Acknowledgements

I wish to express my sincere thanks to Dr. John A. WEST for his critical reading of the manuscript, and also to Prof. Munenao KUROGI and Dr. Paul C. SILVA for their helpful advice in this study. I am grateful to Dr. Michael NEUSHUL for sending the material.

References

AGARDH, J.G. 1852. Species Genera et Ordines Algarum. 2: 337-720. Lund.

CHAPMAN, V.J. and DROMGOOLE, F.I. 1970. Marine algae of New Zealand. Part III, Rhodo-

phyceae, Issue 2, Rhodymeniales. 50 pp. 12 pls.
GMELIN, S. G. 1768. Historia Fucorum. 239 pp, 33 pls. Petropoli ex Typographia Academiae Scientarum.
LEE, I. K. 1977. *Halosaccion minjaii* spec. nov. (Rhodophyta, Rhodymeniales) from the Aleutian Islands. Phycologia **16**: 245-252.
LEE, I. K. 1978. Studies on Rhodymeniales from Hokkaido. Journ. Fac. Sci., Hokkaido Univ., Ser. V (Botany) **11**: 1-194, pl. 1-5.
LEE, I. K., MAKIENKO, V. F., and KUROGI, M. 1979. On the structure and reproductive organs of *Halosaccion glandiforme* (GMELIN) RUPRECHT, Rhodophyta. Jap. J. Phycol. **27**: 25-30.
POSTELS, A. and RUPRECHT, F. J. 1840. Illustrationes algarum in itinere circa orbem jussu Imper. NICOLAI I. 22 pp. 40 pls. St. Petrsbourg.
RUPRECHT, F. J. 1850. Algae Ochtenses, *referred to* Tange des Ochotskischen Meeres. *In* VON MIDDENDORFF, A. T. (ed.), Reise in den Aüssersten Norden und Osten Sibiriens Wärend der Jahre 1843 und 1844. 1. Botanik, 191-435, 9-18 pls, (1851).
SETCHELL, W. A. and GARDNER, N. L. 1903. Algae of northwestern America. Univ. Calif. Publ. Bot. **1**: 165-418, 17-27 pls.
SPARLING, S. R. 1961. A report on the culture of some species of *Halosaccion*, *Rhodymenia* and *Fauchea*. Amer. J. Bot. **48**: 493-499.
YENDO, K. 1909. Notes on algae new to Japan. Bot. Mag. Tokyo **23**: 117-133.

Addendum

After this manuscript was completed I saw the paper by GUIRY (J. mar. biol. Ass. U. K. (1982), **62**: 1-13) in which he described *Devaleraea*, a new genus based on *Halosaccion ramentaceum* and also included *H. yendoi* and *H. arcticum* on the basis of vegetative characters. In this present treatment I do not want to discuss the use of vegetative characters only to define this new genus. In other species of *Halosaccion* and *Palmaria* the details of tetrasporangium and spermatangium development as well as vegetative structure indicate a more complicated phylogenetic relationship. These will be discussed in a future paper.

李 仁圭：北米太平洋沿岸産の紅藻新種 *Halosaccion americanum* に就いて

北米太平洋沿岸から採集した紅藻の1新種 *Halosaccion americanum* は SETCHELL と GARDNER (1903) により *H. glandiforme* と同定されたものである。しかし，この種は体の外形が円筒状になり，皮層細胞が表皮に対し分枝した列になり，四分胞子嚢は分枝した sterile cell 列の中に形成され，精子器母細胞は3－4個の第1精子器を形成する点により *H. grandiforme*，または他の種らと区別される。*H. americanum* は Aleutian 列島，Alaska から北米 California 沿岸まで生育している。