Jap. J. Phycol. (Sôrui) 29: 7-13. March 10, 1981

Aspects of the morphology, ultrastructure and distribution of the two species of *Yamadaea* SEGAWA (Rhodophyta, Corallinaceae)

D. J. GARBARY*, H. W. JOHANSEN** and R. F. SCAGEL*

*Department of Botany, University of British Columbia, Vancouver, British Columbia, V6T 2B1, Canada.
**Department of Biology, Clark University, Worcester, Mass. 01610, U.S.A.

GARBARY, D. J., JOHANSEN, H. W. and SCAGEL, R. F. 1981. Aspects of the morphology, ultrastructure and distribution of the two species of *Yamadaea* SEGAWA (Rhodophyta, Corallinaceae). Jap. J. Phycol. 29: 7-13.

Examination of the morphology and ultrastructure (with the scanning electron microscope) of *Yamadaea melobesioides* Segawa and *Y. americana* DAWSON et STEELE provides additional criteria for distinguishing them. Differences include colour, frond size, shape and density, number of intergenicula per frond, and the size and position of conceptacle ostioles. In *Y. americana* epithallial cells are larger and have less pronounced cell walls. Trichocytes are reported for the first time in *Yamadaea*, although they were found only in *Y. melobesioides*. The distributions of the two species are revised, with *Y. melobesioides* known only from Japan and *Y. americana* known only in North America from the Queen Charlotte Islands, British Columbia to Monterey, California.

Key Index Words: *Algal distribution*; *Corallinaceae*; *scanning electron microscopy*; Yamadaea.

In the Corallinaceae (Rhodophyta), *Yamadaea* is unusual in appearance. A thallus is comprised of an extensive epilithic crustose base from which arise erect, articulated fronds (Segawa, 1955). However, unlike other articulated coralline algae, the fronds are limited to one or sometimes two intergenicula and attain a maximum height of about 2 mm (SEGAWA, 1955; DAWSON and STEELE, 1964). Anatomically and reproductively, the fronds of *Yamadaea* are similar to those of *Corallina* (SEGAWA, 1955; JOHANSEN, 1969).

Yamadaea is presently known only from the north Pacific. Originally described from Japan, the type species, *Y. melobesioides* SEGAWA (1955), was later reported from California (HOLLENBERG and ABBOTT, 1966). A second species, *Y. americana* DAWSON et STEELE (1964), was first described from the San Juan Islands, Washington, but now this species is known as far north as the Queen Charlotte Islands (HAWKES *et al.*, 1978). Other than papers in which the two species are described, references in the literature are limited to range extensions. The present study was initiated to consider in detail the morphology of these species and to re-examine the application of the name *Y. melobesioides* to coralline algae in the eastern Pacific. This work is part of a larger study in which surface structures (as seen with the scanning electron microscope-SEM) provide additional characteristics for specific and generic delimitation in the Corallinaceae (see GARBARY, 1978; GARBARY and SCAGEL, 1979; GARBARY and VELTKAMP, 1980; and GARBARY and JOHANSEN, 1980 and in prep. for other contributions).

Materials and Methods

Specimens of *Yamadaea americana* examined were from the following herbaria:

University of British Columbia (UBC); Univeristy of California, Berkeley (UC); Allan Hancock Foundation Herbarium, Los Angeles (AHFA); and the G. M. Smith Herbarium, Monterey, California (GMS). Material of *Y. melobesioides* was collected by H.W.J. and Dr. T. MASAKI, and fragments of these plants are deposited in UBC. Few specimens of *Yamadaea* have been collected, hence this report is based on three collections of *Y. melobesioides* and 10 of *Y. americana*.

Scanning electron microscopy was carried out as follows: fragments of herbarium specimens were rinsed in tap water, air dried, mounted on stubs with a silver conducting paint and coated with gold. Specimens were examined in a Cambridge Stereoscan Mark 2A at 20 kv. During specimen preparation the cell protoplasts disintegrate, leaving only the calcite cell walls and cellular debris (see also GARBARY, 1978, and GARBARY and VELTKAMP, 1980).

Results and Discussion

Our observations support the proposal of DAWSON and STEELE (1964) that *Yamadaea americana* is distinct from *Y. melobesioides* and provide additional characteristics that strengthen this distinction (see Table 1). DAWSON and STEELE (1964) noted that the erect fronds of *Y. americana* were 2-3 times as tall as in *Y. melobesioides*. HOLLENBERG and ABBOTT (1966) and ABBOTT and HOLLENBERG (1976) inferred that size could not distinguish these taxa because supposed material of *Y. melobesioides* was similar in size to *Y. americana*. We have examined several collections of *Yamadaea* from the Queen Charlotte Islands to Monterey, California. Based on the criteria proposed by DAWSON and STEELE (1964), all North American plants can be accommodated in *Y. americana*. Our observations, however, extend the range of several morphological characteristics. Thus, in the type description of *Y. americana*, intergenicular diameter was given as up to 610-650 μm. Our studies show greater variation, with measurements of 590-1020 μm in mature plants. This contrasts with the range of 290-600 μm for *Y. melobesioides*. Despite the overlap in

Table 1. A comparison of some morphological features of *Yamadaea melobesioides* and *Y. americana*.

Characteristics	Species	
	Y. melobesioides	*Y. americana*
Number and arrangement of fronds	abundant and tightly clustered	few and usually scattered
Thallus colour	dull purple-pink	rose-pink
Number of intergenicula/frond	1	1-2
Frond height	450-650 μm	1000-2000 μm
Frond diameter	350-550 μm	700-1000 μm
Frond shape	obovate	clavate
Ostiole position	strictly apical	apical to eccentric
Diameter of ostioles	30-40 μm	60-80 μm
Trichocytes	common to absent	absent
Surface structure	walls and concavities well developed	walls and concavities poorly developed
Size of concavities (±s.d.)	6.0±0.9 μm	12.1±1.3 μm
Cell wall thickness (±s.d.)	1.8±0.7 μm	1.4±0.4 μm
% of thallus in concavities	40-55%	69-75%

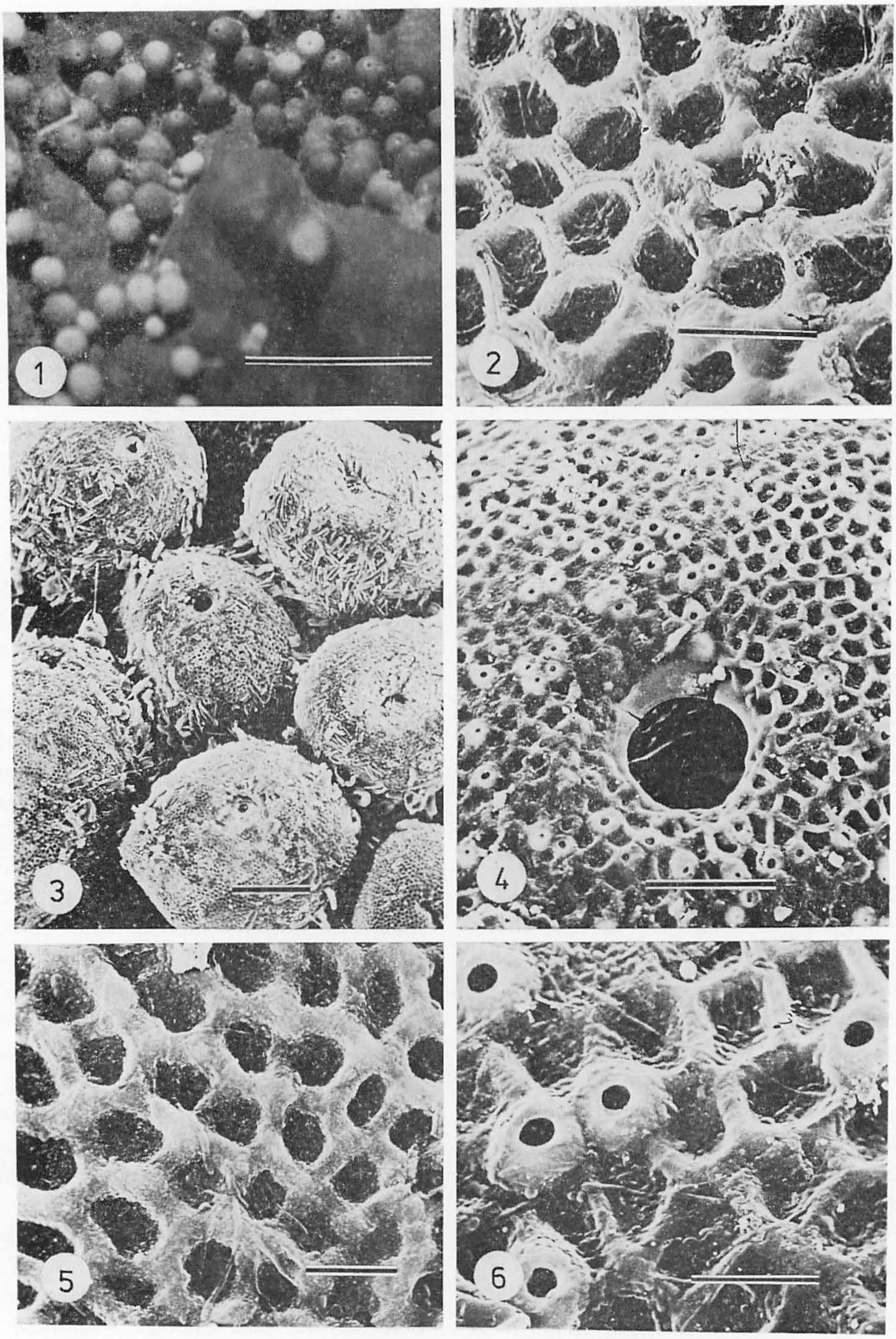
measurements, all populations easily fit into one size category or the other.

Several aspects of gross morphology either not commented upon or not emphasized in earlier studies readily distinguish the two species. (1) *Yamadaea melobesioides* is dull purple-pink or vinaceous to almost grey, whereas *Y. americana* is generally rose-pink in colour. (2) The fronds of *Y. melobesioides* are more densely aggregated than in *Y. americana*, where usually no more than 2-3 are found in close proximity (compare Figs. 1, 3 with Fig. 7). (3) The height: diameter ratio of mature fronds of *Y. melobesioides* is approximately 1.25, whereas in *Y. americana* it is 1.5-1.9, resulting in frond outlines that are obovate for *Y. melobesioides* and more clavate for *Y. americana.* (4) In *Y. melobesioides* the conceptacle ostioles are smaller; 30-40 μm in diameter versus 55-80 μm in *Y. americana.* DAWSON and STEELE (1964) refer to even larger ostioles 125-130 μm in diameter for *Y. americana*, but we have not found any this size. An additional ostiole character distinguishing the two species is the usually slightly eccentric ostiole of *Y. americana* (they are strictly apical in *Y. melobesioides*) (Figs. 9-10). DAWSON and STEELE (1964) did not notice this although they commented that the conceptacles in all reproductive types are often rostrate or beaked.

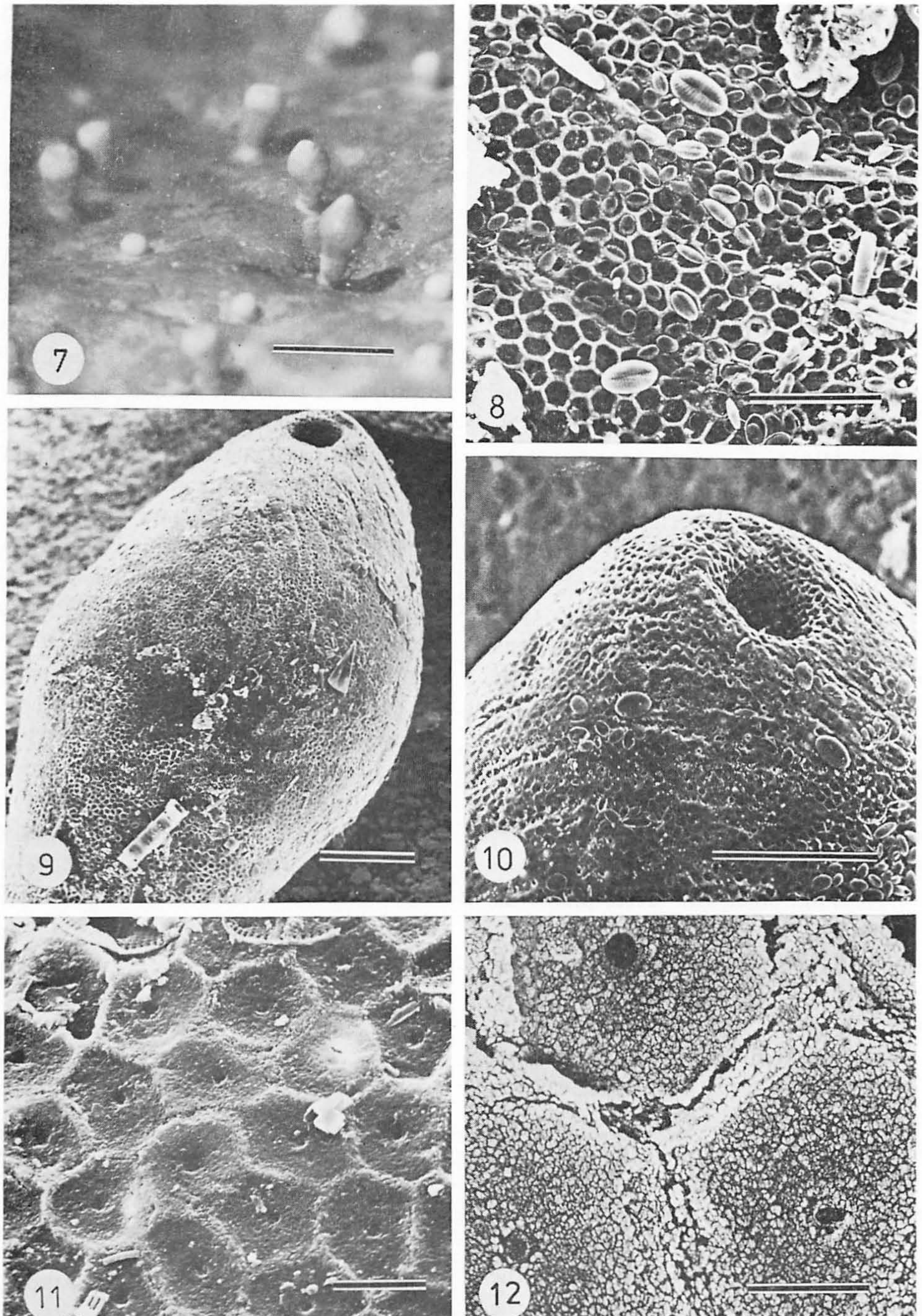
The surfaces of intergenicula and basal crusts as observed with the SEM provide features that clearly distinguish the two species of *Yamadaea.* The surfaces of *Y. melobesioides* are similar to those in many other members of the Corallinoideae. Thus there are well-developed concavities in the sites previously occupied by epithallial cells (these disintegrate during specimen preparation) and relatively prominent cell walls (Figs. 2, 4-6) separating the epithallial concavities. On the other hand, lateral walls of epithallial cells in *Y. americana* are little developed, and the basal pit-connections (their remains, the plugs being destroyed during tissue preparation) are more prominent when viewed by SEM (Figs. 11-12). The concavities and walls of *Y. melobesioides* are round to slightly irregular whereas those of *Y. americana* are more angular and polygonal (compare Figs. 2, 5-6 with Figs. 8, 11). In the type description of *Y. americana*, DAWSON and STEELE (1964) referred to a "faintly tessellate" surface, and this is reflected in the ultrastructural views. The surfaces of *Y. americana* are very different from other members of the Corallinaceae examined to date, and, with the SEM, it should be possible to identify crusts of *Y. americana* which are devoid of erect or fertile branches. Within each species there are no differences in surface morphology between the prostrate and erect parts of the thallus.

In addition to the general appearance of the plant surfaces, several aspects of surface morphology can be expressed in numerical terms. GARBARY (1978) measured three features and showed that they were useful in characterizing species: diameter of epithallial concavities, thickness of cell walls, and the proportion of thallus surface taken up with concavities. These characteristics also provide criteria for distinguishing *Yamadaea americana* and *Y. melobesioides.* Thus *Y. americana* has greater concavity diameters, slightly thinner cell walls, and a higher proportion of the surface is comprised of concavities (see Table 1 for results of measurements). The differences between these taxa are very pronounced with the values for *Y. americana* for concavity diameter and the proportion of the surface taken up with concavities at or near the extremes of recorded values in the Corallinaceae (GARBARY, 1978).

In this study, trichocytes are reported from *Yamadaea* for the first time. Trichocytes are present in one of the two collections of *Y. melobesioides* examined with the SEM, where they appeared as small concavities raised above the thallus surface (Figs. 4, 6). In this collection the trichocytes are common in both the erect and basal parts. Despite the sporadic occurrence of the trichocytes, this feature might pro-



Figs. 1-6. *Yamadaea melobesioides*. Figs. 2-6 are from the SEM. 1. Light micrograph of plants with clustered fronds (scale: 2 mm). 2. General view of crust surface (scale: 10 μm). 3. Apex of intergenicula with central ostioles (scale: 200 μm). 4. General view of surface on erect branch with scattered trichocytes (scale: 35 μm). 5. Detail of surface on non-fertile frond (scale: 10 μm). 6. Detail of trichocytes and surrounding cells (scale: 10 μm).



Figs. 7-12. *Yamadaea americana*. Figs. 8-12 are from the SEM. 7. Light micrograph of plants with scattered fronds (scale: 2 mm). 8. General view of crust surface with accumulated debris (scale: 60 μm). 9. Whole intergeniculum with eccentric ostiole (scale: 150 μm). 10. Apex of fertile intergeniculum with detail of cells around ostiole (scale: 150 μm). 11. General view of cells on surface of frond (scale: 10 μm). 12. Detail of frond surface with outlines of pit connections (scale: 5 μm).

vide an additional characteristic distinguishing the two species of *Yamadaea*, since trichocytes were not found in any of the six collections of *Y. americana* examined with the SEM. What is important is the potential ability of the species to produce trichocytes rather than their presence or absence in a particular plant. The trichocytes of *Y. melobesioides* are similar to those of *Corallina officinalis* L. both in morphology and occurrence, and in the latter species trichocytes are present or absent in plants from different collections from the same site (GARBARY and JOHANSEN, unpublished data).

The reported distributions of the species of *Yamadaea* are as follows: *Y. americana* was known from Washington to northern British Columbia, whereas *Y. melobesioides* was recorded from Japan (the type locality) and California. Our examinations of collections supposed *Y. melobesioides* from California reveal that they are similar to *Y. americana*, both in terms of gross morphology and the ultrastructure of plant surfaces. That the material from California originally determined as *Y. melobesioides* should, in fact, be *Y. americana* is not surprising, since the descriptions of these plants (HOLLENBERG and ABBOTT, 1966; ABBOTT and HOLLENBERG, 1976) are much closer to *Y. americana* than to the Japanese species, in terms of frond size and frond distribution on the crust. Thus all material of *Yamadaea* from the eastern Pacific can be ascribed to *Y. americana* for which the known distribution is extended from northern Washington to the Monterey Peninsula. This solves the previous biogeographic problem of explaining why *Y. melobesioides* should be present at the extremes of the distribution range with the second species having an intermediate range. Further floristic studies of the intervening regions (Alaska, the Aleutian and Kurile Islands) would be of interest in determining the geographic limits of the two taxa, and whether or not they are completely allopatric. At present, the occurrence of *Y. melobesioides* in North America can be discounted, but since both species are relatively rare and inconspicuous, the possibility that *Y. melobesioides* occurs in North America cannot be discarded.

Of the 12 genera currently placed in the subfamily Corallinoideae (JOHANSEN, 1976), nine have been examined with the SEM (all genera except *Alatocladia*, *Marginosporum* and *Serraticardia*) (GARBARY, unpublished data). Two main types of surface structure differentiate JANIA and *Haliptilon* from the remaining genera. The two surface morphologies were designated the *Corallina*-type and the *Jania*-type, and the taxonomic implications are dealt with separately (GARBARY and JOHANSEN, 1980, and in prep.). Within plants showing the *Corallina*-type surface, there is little morphological diversification that can be used to characterize particular genera. It is therefore of interest that the two species of *Yamadaea* portray more variation than exists among six other genera of the subfamily Corallinoideae with a *Corallina*-type surface. This morphological divergence within *Yamadaea* and the apparent uniformity within much of the Corallinoideae supports the contention of JOHANSEN (1969) that *Yamadaea* is primitive in the subfamily.

Acknowledgement

We thank Mr. L. VETO for providing technical assistance with the electron microscopy; Dr. Y.M. CHIANG for translating SEGAWA'S (1955) paper; Dr. T. MASAKI for providing collections of *Yamadaea melobesioides*, and the Curators of UC, AHFH and GMS for providing type and other materials of *Y. americana* for study.

References

ABBOTT, I.A. and HOLLENBERG, G.J. 1976. Marine algae of California. Stanford University Press, California.

DAWSON, E.Y. and STEELE, R.L. 1964. An eastern Pacific member of *Yamadaia* (Corallinaceae) from the San Juan Islands, Washington. Nova Hedwigia **8**: 1-4.

GARBARY, D. 1978. An introduction to the scanning electron microscopy of red algae. In D.E.G. IRVINE and J.H. PRICE (eds) Modern approaches to the taxonomy of red and brown algae. Academic Press, London.

GARBARY, D. and JOHANSEN, H.W. 1980. Scanning electron microscopy of *Corallina*, *Jania* and *Haliptilon* (Corallinaceae, Rhcdophyta). J. Phycol. **16**, (Suppl.) : 12.

GARBARY, D. and SCAGEL, R.F. 1979. Scanning electron microscopy of *Clathromorphum* spp. (Corallinaceae, Rhodophyta). Proc. Micros. Soc. Can. **6**: 14-15.

GARBARY, D. and VELTKAMP, C.J. 1980. Observations on *Mesophyllum lichenoides* (Corallinaceae, Rhodophyta) with the scanning electron microscope. Phycologia **19**: 49-53.

HAWKES, M.J., TANNER, C.E. and LEBEDNIK, P.A. 1978. The benthic marine algae of northern British Columbia. Syesis **11**: 81-115.

HOLLENBERG, G.H. and ABBOTT, I.A. 1966. Supplement to Smith's Marine algae of the Monterey Peninsula, California. Stanford University Press, California.

JOHANSEN, H.W. 1969. Morphology and systematics of coralline algae with special reference to *Calliarthron*. Univ. Calif. Publ. Bot. **49**: 1-98.

JOHANSEN, H.W. 1976. Current status of generic concepts in coralline algae (Rhodophyta). Phycologia **15**: 221-244.

SEGAWA, S. 1955. Systematic anatomy of the articulated corallines (supplementary report), the structure and reproduction of *Yamadaea melobesioides* Segawa. Bot. Mag., Tokyo **68**: 241-247. [in Japanese].

D.J. ガーバリー・H.W. ヨハンゼン・R.F. スケージェル：サビモドキ属 *Yamadaea* の2種の形態と分布

サンゴモ科，サビモドキ属の2種 *Yamadaea melobesioides* SEGAWA（サビモドキ）と *Y. americana* DAWSON et STEELE の走査型電子顕微鏡による，形態及び超微構造の観察の結果，これら2種を区別する際の付加的な分類形質をいくつか得ることができた。藻体の色・大きさ，藻体当りの節間部 intergeniculum の数・形・密集度，生殖巣孔の大きさ・位置において2種間に差異がみられる。これら2種を比較すると，*Y. americana* では，表皮細胞は大きく，細胞壁はあまり厚くならない。サビモドキ属では初めて，毛細胞 trichocyte の存在が明らかになった。ただしこの細胞は *Y. melobesioides* だけに見られた。これら2種の分布域を次のように改めた。*Y. melobesioides* は日本にだけ分布する種である。*Y. americana* は北米にだけ知られており，クィーン・シャーロット諸島（ブリテッシュ・コロンビア州）からモントレー（カリフォルニア州）にかけて分布している。

井上 勲：微細藻類ノート (2). 培養の海産微細藻類フロラ研究への応用 Isao INOUYE: Notes on microalgae in Japan (2). Employment of labolatory culture to floristic studies of marine microalge

先に述べた方法（本誌，井上，1980）は 1) 予備培養で10%以上に増殖した藻のみを分離する，2) 10%以下の優先度の藻については，大まかな稀釈をくりかえすことで優先順位をあげる。3) 小容量の容器を用いることで培養期間を短縮し，分離の効率をあげるという点に特徴があった。この方法は技術的に容易で，場所をとらず，しかも試料水によって，増殖してくる種は，採集場所や時期により異るので，この予備培養と稀釈法を組みあわせた方法で以下にあげるようにかなりの数の藻を分離することができる。分離される微細藻類の大部分は，天然の試料では個体数が少なく確認が困難なものであり，また固定すると変形あるいは破裂などの変化をおこし同定が不可能になるものが多い。わが国で従来行われてきた海産微細藻類の研究が，比較的個体数が多く，しかも固定試料を用い得る珪藻類や有殻の渦鞭毛藻を主な対象としてきたことは明らかであり，その他の微細藻類が取り扱われることが少なかったのは上記のような理由によるものと思われる。従って，補助的な手段として培養技術を導入することによって，従来の微細藻類フロラの研究では見過されがちだった藻群をとり扱うことが可能になると思われる。

先に報告した方法を用いて筆者が確認した微細藻類のリストを以下にあげる。単藻培養にまで至らなかったが，出現を確認できたものも含めた。また種名の決定ができていないものは除いた。

Cryptophyceae クリプト藻綱