

The marine algal flora of Hsiao-Liuchiu island

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Abstract. The composition, distribution and seasonal variation of marine algae in the Hsiao-Liuchiu were studied. A total of 148 species of seaweeds were identified, including 3 species of Cyanophyta, 45 species of Chlorophyta, 23 species of Phaeophyta and 77 species of Rhodophyta. Among them, 92 species were reported for the first time from Hsiao-Liuchiu and 11 species were new to Taiwan. Most of algae in Hsiao-Liuchiu were of tropical or subtropical elements. The marine algal flora in this area is similar to that of southern Taiwan and shows strong affinity with those of the Philippines and Indo-West Pacific areas.

Key words: Algae population; Chlorophyta; Cyanophyta; Ecology of seaweeds; Hsiao-Liuchiu; Marine algal flora; Phaeophyta; Rhodophyta; Taiwan.

Introduction

Hsiao-Liuchiu is a small island located about 14.9 Km (8 N miles) southwest of Taiwan, with a coastline of approximately 11.89 Km and an area of about 6.8 sq. Km. (Fig. 1). It is an uplifted coral reef covered with recent soil, forming a plateau not higher than 70 meters (Yang *et al.*, 1975). Being immersed the year round in the clear, warm water from the branching Kuroshio Current, the annual average water temperature is above 26°C and the coral reef is of tropical composition (Chu, 1961; Nitani, 1971; Yang *et al.*, 1975).

There are many previous publications dealing with the benthic marine algae of Taiwan and its adjacent islands (Yamada, 1925a,b, 1936, 1950; Shen and Fan, 1950; Chiang, 1960, 1962a,b, 1972, 1973a,b; Taniguti, 1976; Chou and Chiang, 1981; Chen and Chiang, 1981a,b; Yang and Chiang, 1982; Chiang and Chen, 1982, 1983; Chiang and Wang, 1987; Lewis and Norris, 1987). However, only a few works have been concerned with the algae in Hsiao-Liuchiu. The first investigation of seaweeds in this island was made by Yamada (1950). He listed 49 species of marine algae (24 green and 25 brown

algae). Since then no general study of the marine algae from this district has been made, except some fragmentary notes that can be found in scattered literatures (Chou and Chiang, 1981; Yang, 1981; Yang and Chiang, 1982; Chiang and Chen, 1982). In this paper, we attempt to clarify the composition, distribution and seasonal variation of seaweeds in Hsiao-Liuchiu. We also briefly compare the marine algal flora of Hsiao-Liuchiu with those of the neighbouring regions.

Materials and Methods

The materials were collected every two months during September 1987 to July 1989. Six sampling stations were established according to their locations and topographical components (Fig. 1). The collections were extended from the littoral zone to a depth of about 15 meters. Skin and SCUBA diving equipment were used for underwater observation and collection. Specimens were either dried and mounted, or preserved in 10% formalin seawater. The identification of materials was made by comparison with the specimens in the Phycological Herbarium of the Institute of Oceanography, National Taiwan University; or with refer-

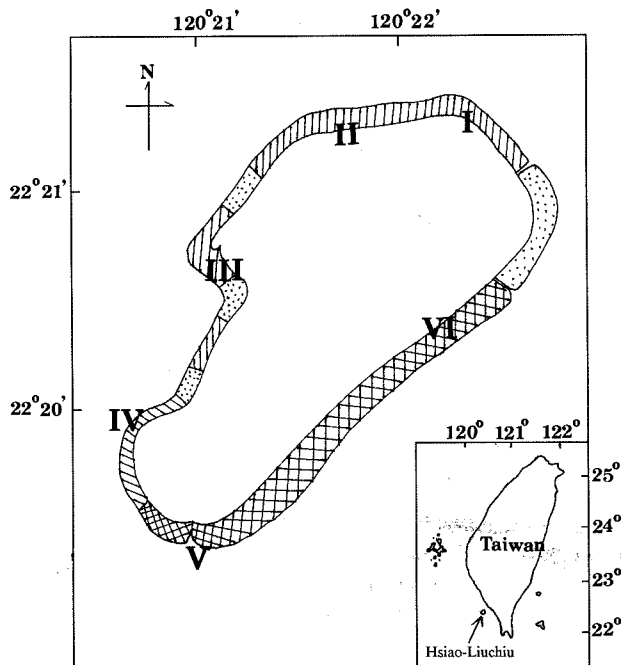


Fig. 1. Map of Hsiao-Liuchiu, showing the six sampling sites and the shoreline features. (Modified from Yang, *et al.*, 1975). I. Hwa-pin-yen (花瓶岩); II. Lu-ing-chue (露營區); III. San-Zu-gou (山豬溝); IV. Wu-kwei-dong (烏鬼洞); V. Hai-tzu-kou (海仔口); VI. Long-shia-dong (龍蝦洞).

▨ : Emerged limestone shoreline.
 ▧ : Rocky and terrace-developed shoreline.
 ▩ : Sandy shoreline.

ences, such as: Abbott (1984), Balakrishnan (1961), Boergesen (1914-1920; 1940-1957), Chiang (1972), Cordeiro (1977a,b), Humm and Wicks (1980), Itono (1977), Littler *et al.* (1989), Okamura (1907-1935; 1936), Papenfuss *et al.* (1982), Taylor (1960), Thoi (1969), Tseng (1984), Yamada (1930-1944), Yendo (1909-1918), Yoshida *et al.* (1985a,b). All the collections are deposited in the Herbarium of Taiwan Museum.

Results

General Description of Physical Environment

The shoreline features of Hsiao-Liuchiu have three major types of structural components. They are recently emerged limestone, rocky shoreline, and sandy shoreline. Rocky terrace shoreline is located along the north and northwestern coast (such as stations I and II). Small sandy beaches are scattered on the western and north-eastern coast (such as station III). On the

south-western part of the island, there is an area of collapsed bedrock; the littoral zone is short and slopes steeply into sea (station IV). On the southern and south-eastern parts of the island (stations V and VI), a broad emergent limestone-platform about 30-80 meters from shore extends roughly parallel to the beach. A fringing coral reef is also well developed there. Numerous linear indentations run perpendicular to the shoreline and various sizes of tidal pools exist in the littoral zone, whereas coral reef is more common in the sublittoral zone.

This area is mild in winter (14°C-25°C) and hot in summer (27°C-33°C). The temperature of sea water fluctuated in a smaller range than that of the air, varying only from 23°C to 29°C, with yearly fluctuation within 6°C. The seasonal change in salinity ranged from 32.0‰ to 35.5‰. In the summer rainy season, the salinity of surface water may drop to 28-30‰. The pH value varied from 8.0 to 8.5. There was very low industrial pollution in Hsiao-Liuchiu.

The Composition, Distribution and Seasonal Variation

There are a total of 148 species of seaweeds identified in this study. They belong to 93 genera and 40 families, and include 3 species of Cyanophyta, 45 species of Chlorophyta, 23 species of Phaeophyta and 77 species of Rhodophyta (Tables 1-2). 92 species of them are new to Hsiao-Liuchiu. Eleven species are new to Taiwan. They are *Ventricaria ventricosa* (J. Ag.) Olsen & West, *Hydroclathrus tenuis* Tseng et Lu, *Kallymenia perforata* J. Ag., *Sebdenia agardhii* (De Toni) Codomier, *Botryocladia skottsbergii* (Boerg.) Levring, *Cryptarachne okamurai* (Yamada et Segawa) Zhang et Xia, *Crouania minutissima* Yamada, *Griffithsia subcylindrica* Okam., *Wrangelia argus* (Mont.) Montagne, *Wrangelia tayloriana* Tseng and *Tolyptocladia glomerulata* (C. Ag.) Schmitz & Haptfleisch. Among them, *Kallymenia*, *Sebdenia*, *Botryocladia*, *Crouania*, *Wrangelia* and *Tolyptocladia* are genera new to Taiwan.

As shown in Table 1, the occurrence of 148 macroalgal species were checked bimonthly in six studied sites. It was found that the species composition and abundance of algae on platform shoreline with many tidal pools and grooves were greater than on sloping rocky shoreline. The Hai-tzu-kou, which was composed of a broad emergent limestone platform with variously sized tidal pools and deep furrows, contained abundant algal species (127 species). Next to this were

Table 1. Continued

Scientific name	Sampling sites						Vertical distribution							Month											
	I	II	III	IV	V	VI	SZ	UL	ML	LL	IZ	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.		
Champicaceae																									
* <i>Champia bifida</i> Okamura	+	+	+	+	+	+																			
* <i>C. parvula</i> (C. Ag.) Harvey	+	+	+	+	+	+																			
Rhodymeniaceae																									
** <i>Botryocladia skottsbergii</i> (Boerg.) Levring	+																								
** <i>Cryptarachne okamurai</i> (Yamada et Segawa) Zhang et Xia	+																								
Ceramiales																									
* <i>Centroceras clavulatum</i> (Agardh) Montagne	+	+	+	+	+	+																			
* <i>Ceramium</i> sp.	+	+	+	+	+	+																			
** <i>Crouania minutissima</i> Yamada	+	+	+	+	+	+																			
* <i>Dasyphila plumarioides</i> Yendo																									
* <i>Griffithsia coacta</i> Okamura	+																								
** <i>G. subcylindrica</i> Okamura	+																								
* <i>Spyridia filamentosa</i> (Wulfen) Harvey	+	+	+	+	+	+																			
** <i>Wrangelia argus</i> Mont.	+	+	+	+	+	+																			
** <i>W. tayloriana</i> Tseng	+	+	+	+	+	+																			
Delesseriaceae																									
* <i>Claudea batanensis</i> Tanaka	+	+	+	+	+	+																			
* <i>Martensia denticulata</i> Harvey																									
* <i>Vanvoorstia coccinea</i> J. Agardh	+	+	+	+	+	+																			
Rhodomelaceae																									
* <i>Acanthophora spicifera</i> (Vahl) Boergesen	+	+	+	+	+	+																			
* <i>Acrocystis nana</i> Zanardini	+	+	+	+	+	+																			
* <i>Amanasia glomerata</i> C. Agardh	+	+	+	+	+	+																			
* <i>Bostrychia tenella</i> (Vahl) J. Agardh	+	+	+	+	+	+																			
* <i>Chondria armata</i> (Kützting) Okamura	+	+	+	+	+	+																			
* <i>Herposiphonia subdisticha</i> Okamura	+	+	+	+	+	+																			
* <i>Laurencia intermedia</i> Yamada	+	+	+	+	+	+																			
* <i>L. obusa</i> Lamouroux var. <i>densa</i> Yamada	+	+	+	+	+	+																			
* <i>L. papillosa</i> (C. Agardh) Greville	+	+	+	+	+	+																			
* <i>L. undulata</i> Yamada	+	+	+	+	+	+																			
<i>Levilella jungermannioides</i> (Her. & Mart) Harvey	+	+	+	+	+	+																			
* <i>Neurymenia fraxinifolia</i> (Mert. ex Turm.) J. Ag.	+	+	+	+	+	+																			
* <i>Polysiphonia</i> sp.	+	+	+	+	+	+																			
** <i>Tolytiocladia glomerulata</i> (C. Agardh) Schmitz	+	+	+	+	+	+																			
* <i>Vidua obtusiloba</i> (Mert. ex C. Ag.) J. Agardh	+	+	+	+	+	+																			

*New records for Hsiao-Liuchiu; **New records for Taiwan.

SZ: Supralittoral zone; UL: Upper littoral zone; ML: Middle littoral zone; LL: Lower littoral zone; IZ: Infralittoral zone.

Table 2. Numbers of algal taxa during studying period in Hsiao-Liuchiu

Phylum	No. of families	No. of genera	No. of species	No. of new records for Hsiao-Liuchiu	No. of new records for Taiwan
Cyanophyta	2	2	3	3	0
Chlorophyta	10	23	45	22	1
Phaeophyta	6	14	23	8	1
Rhodophyta	22	54	77	59	9
Total	40	93	148	92	11

Long-shia-dong (117 species), Hwa-pin-yen (99 species), Lu-ing-chue (95 species), San-zu-gou (70 species) and Wu-kwei-dong (56 species).

In general, the structure of algal communities in six studied sites are quite similar to each other. From table 1 the vertical distribution was analysed, and it was found that the seaweeds commonly inhabited an area from the tidal zone to a depth of 10 meters. The supralittoral zone was generally poorly vegetated. Only *Bostrychia tenella* was abundant there. The flora of the upper wave-washed regions (upper littoral regions) was dominated by green algae, such as *Enteromorpha* spp. and *Ulva* spp.

In the middle littoral region, the algal community was a mixture of *Ulva*, *Enteromorpha*, *Chaetomorpha* spp., *Boodleia* sp., *Cladophoropsis*, *Valoniopsis*, *Dictyosphaeria*, *Hydroclathrus clathratus*, *Colpomenia sinuosa*, *Acanthophora spicifera*, *Gelidiella acerosa*, *Acrocystis nana*, *Gracilaria* spp., *Liagora* spp., *Laurencia* spp., *Hypnea* spp., *Rivularia* and *Symploca* spp.

On the exposed rocks of the lower littoral region or subtidal fringe, the scattered patches of *Spyridia filamentosa*, *Hypnea charoides*, *Leveillea jungermannioides*, *Padina* spp., *Tolyptocladia glomerulata*, *Sarcodia*, *Asparagopsis taxiformis*, *Caulerpa* spp., *Gracilaria* spp., *Wrangelia* spp. and *Sargassum* spp. were usually found with a minor number of *Codium* spp., *Hydroclathrus*, and *Champia*.

The algal communities in the tidal pools and indentations were quite complicated, with the following species being common elements: *Boergesenia forbesii*, *Bornetella nitida*, *Neomeris* spp., *Caulerpa* spp., *Codium* sp., *Halimeda* spp., *Lobophora*, *Padina* spp., *Hormophysa triquetra*, *Turbinaria* spp., *Centroceras clavulatum*, *Griffithsia* spp., *Amphiroa* spp., *Jania*, *Carpopeltis*, *Galaxaura* spp., *Ceratodictyon spongiosum*, *Gracilaria eucheumoides*, *Amansia glomerata*, *Laurencia* spp. and

Cheilosporum spp.

The algal community of the sublittoral region was more or less similar to that in the tidal pools and indentations. But there were some seaweeds which existed only in the sublittoral zone about 2-15 meters deep; they are *Ventricaria ventricosa*, *Codium tenue*, *Zonaria stipitata*, *Liagora farinosa*, *Galaxaura obtusata*, *Scinaia moniliformis*, *Dudresnaya japonica*, *Halymenia durvillaei* var. *celyanica*, *Kallymenia perforata*, *Sebdenia agarthii*, *Eucheuma serra*, *Botryocladia skottsbergii*, *Cryptarachne okamurai*, *Dasyphila plumarioides*, *Claudea batanensis*, *Vanvoorstia coccinea*, *Chondria armata*, *Neurymenia fraxinifolia* and *Vidalia obtusiloba*.

On the western side of the island, the shallow platforms in the littoral and sublittoral (about 0.5-2 meters deep) regions were also covered with a luxuriant growth of marine angiosperm, *Thalassia hemprichii* and *Halodule uninervis*.

According to the data obtained, the marine algae grew actively from January to May (Table 3). During summer and early autumn (from July to November), the vegetation of the littoral region was inconspicuous, but, an abundance of other algae inhabited the tidal pools and the sublittoral region. The 37 species which occurred commonly throughout the year, such as *Enteromorpha compressa*, *Anadyomene wrightii*, *Boodleia*

Table 3. The variation of occurrence of species in different months

	Jan.	Mar.	May	July	Sep.	Nov.
Cyanophyta	1	3	3	2	0	0
Chlorophyta	27	38	32	32	23	23
Phaeophyta	9	21	23	15	4	2
Rhodophyta	50	75	66	48	33	39
Total	87	137	124	97	60	64

composita, *Dictyosheria cavernosa*, *Chaetomorpha crassa*, *Caulerpa* spp., *Padina minor*, *Hypnea* spp., *Amansia glomerata*, *Centroceras clavulatum*, *Gracilaria* spp. *Mastophora rosea*, *Spyridia filamentosa*, *Laurencia* spp., and so on, are characteristically well-developed in the littoral zone. Among them, the *Enteromorpha compressa* and *Gracilaria coronopifolia* were used for food by native people.

Discussion

In the records of seaweeds of Taiwan from numerous publications (Yamada, 1925a,b, 1936, 1950; Shen and Fan, 1950; Chiang, 1960, 1962a,b, 1972, 1973a,b; Taniquiti, 1976; Chou and Chiang, 1981; Chen and Chiang, 1981a,b; Yang and Chiang, 1982; Chiang and Chen, 1982, 1983; Chiang and Wang, 1987; Lewis and Norris, 1987), there are about 490 species of marine algae listed. There were 148 species of marine algae registered in this study. Among them, eleven species are new to Taiwan. Though Hsiao-Liuchiu is a small island, an area of only 6.8 sq. Km., its marine algal flora is rather complicated.

Based on the present study, it was found that most of the algae are of tropical or subtropical elements. Those such as *Boergesenia forbesii*, *Acetabularia* sp., *Codium* spp., *Neomeris* spp., *Bornetella* spp. *Halimeda* spp., *Valonia* spp., *Caulerpa* spp., *Turbinaria* spp., *Sargassum* spp., *Galaxaura* spp., *Gracilaria* spp., *Liagora* spp., *Asparagopsis taxiformis*, *Ceratodictyon spongiosum*, *Claudea batanensis* and so on, are all widely distributed in tropical seas. It can be concluded that the marine algal flora of Hsiao-Liuchiu is of tropical composition. According to the physical factors—the island is an uplifted coral reef and the annual average water temperature is above 26°C—it is obvious that Hsiao-Liuchiu is in fact situated in a very good environment for the growth of tropical species.

In comparison with the neighboring areas, it has been found that the topography, the temperature fluctuation of sea-water, and the marine algal flora of Hsiao-Liuchiu are more or less similar to that of southern Taiwan (Chiang, 1973a; Chiang and Wang, 1987). 126 species (85%) of seaweeds occurred in both areas. Since the western coast of Taiwan is mostly alluvial plain, it was hard to find traces of seaweeds. Even on the shores of Penghu islands, located 40 kilometers west of Taiwan, the biota are also quite different from

those in Hsiao-Liuchiu (Chiang, 1962b). As on the Hengchun Peninsula, the marine flora of Hsiao-Liuchiu differs from those of northern and north-eastern Taiwan (Chiang, 1960, 1962a, 1973a; Wang and Chen, 1980). The differences in the composition of the marine flora of these areas may be caused by the differences in their topography and water temperature.

According to the occurrence record of seaweeds in the world, the marine algal flora of Hsiao-Liuchiu shows strong affinity with those of the Philippines and the Indo-West Pacific system (Boergesen, 1914-1920, 1940-1957; Cordero, 1977a,b; Dawson, 1956; Itono, 1973; Kamura, 1963; Liao and Satto, 1980; Okamura, 1936; Papenfuss *et al.*, 1982; Segawa and Kamura, 1960; Silva *et al.*, 1987; Tanaka and Itono, 1972; Taylor, 1960, 1966; Thoi, 1969; Tseng, 1984; Vannajan and Trono, 1977, 1978; Womersley and Bailey, 1970).

It is well known that the distribution of algae is greatly influenced by the current (Chiang, 1973a). The Kuroshio Current brings warm water up from the Philippines and the equatorial region toward southern Taiwan, where it branches, sending one small branch to the Taiwan strait and through the Hsiao-Liuchiu (Chu, 1961; Fan, 1982). It could be suggested that the West-Pacific group generally extends their distribution range from the tropical Pacific to east Asia along the Kuroshio Current. In other words, the composition and distribution of seaweeds of Hsiao-Liuchiu may be influenced by the Kuroshio Current.

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小琉球嶼的海藻相

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本研究旨在調查小琉球嶼海藻種類的組成、分佈及季節性變化。從一九八七年九月至一九八九年七月，計鑑定出 148 種，包括藍綠藻 3 種，綠藻 45 種，褐藻 23 種及紅藻 77 種。其中有 92 種是本地區之首次記錄，有 11 種是臺灣的新記錄種。小琉球的海藻相與臺灣南部之恆春半島極為相似，大多屬於熱帶、亞熱帶性種類。由這些海藻之地理分佈，顯示小琉球海藻之組成與菲律賓、印度西太平洋海藻區系有密切之關係。