

## DISTRIBUTION OF THE ALGAE BELONGING TO THE GENUS *CAULERPA* IN FRENCH POLYNESIA (ATOLL OF TAKAPOTO AND ISLAND OF MOOREA)

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### ABSTRACT

Eleven species of algae belonging to the genus *Caulerpa* were found during several field trips in the atoll of Takapoto and in the island of Moorea: *C. bikinensis*, *C. serrulata* var. *pectinata*, *C. serrulata* var. *serrulata*, *C. pickeringii*, *C. racemosa* var. *clavifera*, *C. racemosa* var. *peltata*, *C. sertularioides* f. *brevipes*, *C. seuratii*, *C. urvilliana*, *C. verticillata*, *C. webbiana*. Only two species live in both sites: *C. pickeringii* and *C. racemosa* var. *peltata*.

In the atoll of Takapoto *C. bikinensis* forms very dense populations covering all the substratum from 40 m to more than 70 m on the outer slope. The biomass reaches 5 kg/m<sup>2</sup> (wet weight). Several scuba dives allowed us to check the presence of this *Caulerpa* all around the atoll.

### INTRODUCTION

The genus *Caulerpa* (Caulerpales, Chlorophyta) includes more than 100 species which are widely distributed in all warm seas. A number of investigations dealing with their distribution show the particular biogeographical interest of the above genus. In French Polynesia, Montagne (1845), Weber van Bosse (1910) and Setchell (1926) mentioned the presence of the following taxa: *C. cupressoides* (West) J. Ag.; *C. freycinetii* var. *typica* Weber van Bosse; *C. freycinetii* var. *de boryana* (J. Ag.) Weber van Bosse; *C. mamillosa* Montagne; *C. peltata* Lamouroux; *C. pickeringii* Harvey and Bailey; *C. racemosa* var. *chemnitzia* (Esper) Lamouroux; *C. racemosa* var. *clavifera* (Turner) Weber van Bosse; *C. racemosa* var. *laetevirens* (Montagne) Weber van Bosse; *C. sedoides* (R. Brn) C. Ag.; *C. sertularioides* (Gmelin) Howe; *C. seuratii* Weber van Bosse; *C. taxifolia* (Vahl) C. Ag.; *C. urvilliana* Montagne and *C. webbiana* Montagne. Since that time, two taxonomic reviews updating Boergesen (1932), Eubank (1946) led to some modifications in the above list: *C. peltata* = *C. racemosa* var. *peltata* (Lamouroux) Eubank and *C. freycinetii* = *C. serrulata* (Forsskal) J. Ag. emend. Boergesen.

The field trip that we made in French Polynesia (summer, 1978) allowed us to complement the inventory of *Caulerpa* in this part of the South Pacific Ocean and to better define the biotopes of the species found.

### METHODS

The different species listed herein have been sampled in the atoll of Takapoto and in the island of Moorea. The atoll of Takapoto (Figs. 3-4) belongs to the King George islands and is located in the north-eastern part of the Tuamotu archipelago. It is characterized by an almost closed lagoon that communicates with the open sea by a few spillways (hoas) which flow intermittently in both directions. The island of Moorea faces Tahiti. It is a volcanic island circled by coral reefs (Figs. 1-2). Places we investigated were limited to the northwestern part of the island. Our survey was made by scuba diving. Logistic support was supplied by the "Antenne du Muséum National d'Histoire Naturelle et des Hautes Etudes" in Moorea, and by the "Service de la Pêche" in Takapoto.

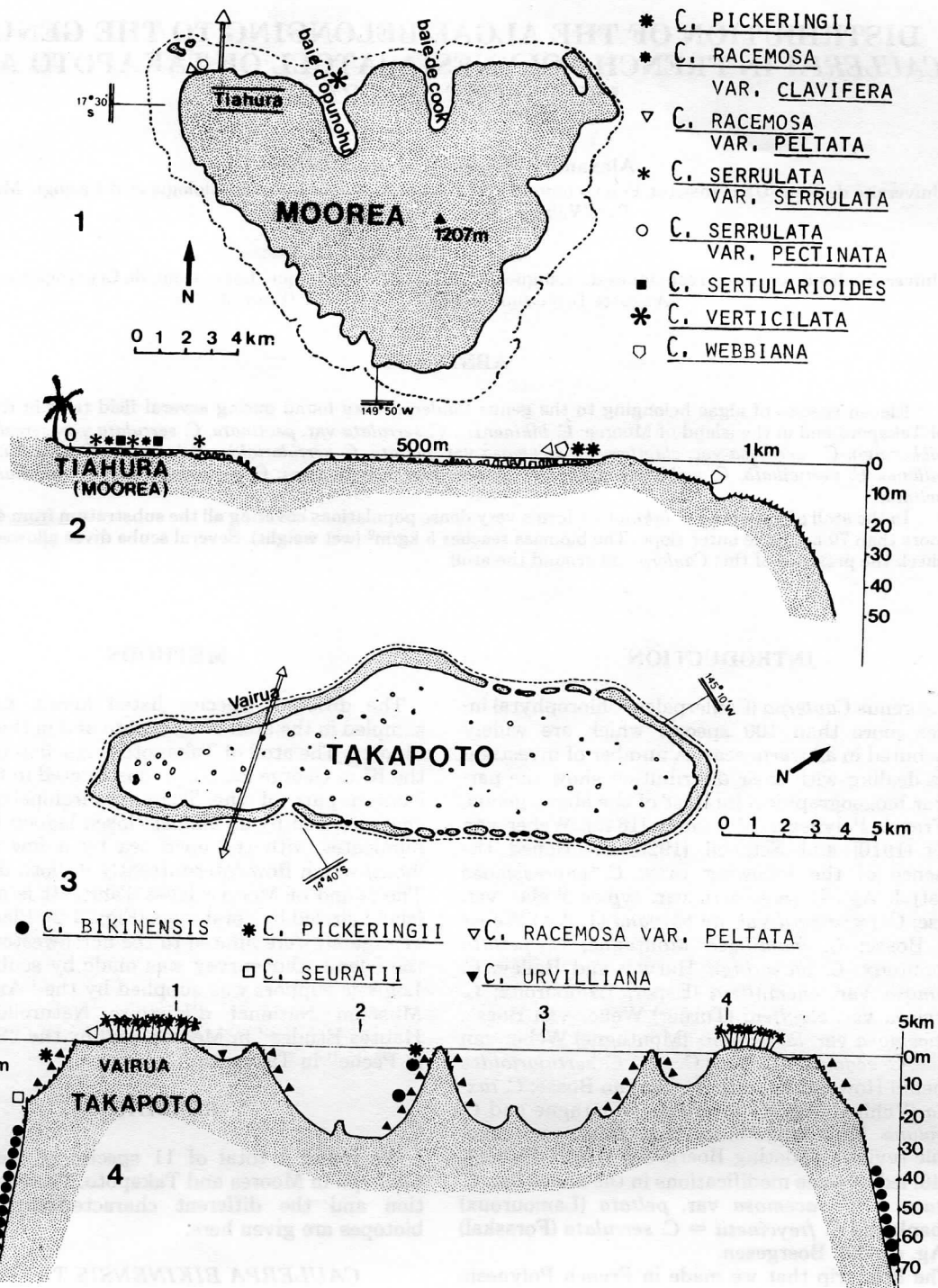
### RESULTS

We found a total of 11 species or varieties of *Caulerpa* in Moorea and Takapoto. Their exact location and the different characteristics of their biotopes are given here.

#### *CAULERPA BIKINENSIS* TAYLOR

Ref.: Taylor (1950. Pp. 66-67, pl. 33)

This species belongs to the section Sedoideae J. Agardh and to the group Claviferae which in-



Figures 1-4. 1. Map of the island of Moorea. 2. Cross-section of the coral reef of Tiahura in Moorea. 3. Map of the atoll of Takapoto. 4. Cross-section of the atoll of Takapoto.

cludes *C. racemosa* and its various forms and varieties, amongst them specimens looking like *C. bikinensis*.

We found it in Takapoto on the outer slope as well as in the lagoon. On the outer slope, it forms a very dense vegetation (rate of coverage exceeding 75%) from a depth of 35 m. At a depth of 70 m, the vegetation is still very dense and extends downwards as far as is possible to see. *C. bikinensis* appears to form around the atoll an almost continuous belt. We checked its presence in several places distributed along the east coast (exposed to the prevailing wind and the resulting surf) and along the west coast (sheltered). Jaubert and Vasseur (pers. comm.) found it in July, 1974 and August, 1975. The biomass, measured from samples of 1 m<sup>2</sup>, taken at depths of 40 to 45 m, reaches 5 kg/m<sup>2</sup> (wet weight).

In the lagoon, we found the above species in the dark microcavities of some pinnacles, within the 1 to 7 m depth range.

The presence of *C. bikinensis* is noted by Taylor (1950) in the Rongelap and Bikini atolls (North Pacific); by Dawson (1956) in the atoll of Eniwetok and Abbott (1961) in the atoll of Ifaluk (North Pacific).

The morphology of the thalli we sampled on the outer slope (Fig. 5) corresponds exactly to the characteristics given by Taylor. The size of the different parts of the thalli are slightly bigger than for the specimens from Bikini and Rongelap. Stolons: 50 cm to 1 m in length and 1 cm in diameter. Rhizoids: 15 cm in length and 5 mm in diameter at their insertion point on the stolon. The maximum length of fronds is 15 cm and their diameter varies from 2 to 3 mm. Most of the ramuli are alternate and distichous. Their size can reach 1.2 cm in length and 1 cm in width. Most of them end by a flat or slightly convex disc which suggests similarities with *C. racemosa* var. *chemnitzia*. Thalli sampled in the lagoon (Fig. 6) are significantly slender (diameter of stolons: 2 to 4 mm, length of fronds smaller than 10 cm).

Specimens of *C. bikinensis* which live on the outer slope of the atoll of Takapoto have more amyloplasts than chloroplasts.

#### *CAULERPA PICKERINGII* HARVEY AND BAILEY

Ref.: Harvey and Bailey (1851, p. 373); Weber van Bosse (1898, Pp. 272-273, pl. 21, Figs. 7 and 8)

We sampled this species in Moorea and Takapoto. In the lagoon of Takapoto, *C. pickeringii* is frequent in the 0.3 to 5 m depth range. On the outer slope, it grows deeper (7 to 20 m) and seems fairly infrequent. In Moorea, *C. pickeringii* proliferates on the algal ridge between 0.1 to 0.5 m, namely in front of

Tiahura. Its geographical distribution seems to be limited to Polynesia (Denizot 1967) where it has been found by Harvey and Bailey (1851) and Weber van Bosse (1898), whereas it is not mentioned by Setchell (1926) in his list of the algae of Tahiti.

This species has been mistaken or identified as another species by several authors, either as *C. elongata* of Tanzania (Jaasund 1976-1977) or *C. webbiana* of Hawaii (*C. webbiana* var. *pickeringii* Eubank 1946). We consider that both species are different from *C. pickeringii* and have a much wider geographical distribution: Indian Ocean and Pacific Ocean for the former, Atlantic Ocean, Indian Ocean and Pacific Ocean for the latter. Due to these uncertainties the presence of *C. pickeringii* in the Caroline Islands, noted by Trono (1968) must be verified (only one thallus sampled).

In Takapoto, *C. pickeringii* (Figs. 11-12) is identical to the specimens sampled by Harvey and Bailey in Wilson Island and drawn by Weber van Bosse (1898, pl. 21, Fig. 7).

In Moorea, the stolons of *C. pickeringii* (Figs. 13-14) are most often masked by ramuli which form a very dense cover (2 to 5 cm in length; 3 to 4 mm in diameter). This form is identical to the ones described by Weber van Bosse (1898, pl. 2, Fig. 8) from a specimen sampled in Tahiti by Vernier.

Microscopic observations show that *C. pickeringii* of Takapoto differ from specimens of Moorea by the size and the shape of the ramuli. Ramuli of specimens from Takapoto fit the previous descriptions of Weber van Bosse (1898, pl. 21, Fig. 7): 0.5 to 0.6  $\mu$ m in length, 130  $\mu$ m in diameter at the lower part and 65  $\mu$ m at the extremity, 3 dichotomies and angular extremities ended by a mucron. Ramuli of specimens from Moorea are slightly longer (0.65 to 0.7 mm) and slender (100  $\mu$ m at lower part and 50  $\mu$ m at the extremity). They exhibit 4 to 5 dichotomies and it is interesting to point out that their extremities are rounded (with a mucron).

The ramuli of both types of *C. pickeringii* form a uniform covering on fronds and stolons. Thus they look like *Codium*. It is not the case of *C. elongata* and *C. webbiana* whose stolons are partly stripped or carry only a few ramuli. This is to our opinion a very basic character which makes the difference between the above two species.

#### *CAULERPA RACEMOSA* VAR. *CLAVIFERA* (TURNER) WEBER VAN BOSSE

Ref.: Weber van Bosse (1898, p. 361, pl. 33, Fig. 5)

We found the above *Caulerpa* in Moorea. It is frequent on the backreef flats in very shallow waters where it is always exposed to full sunlight. *C. sertularioides* and *C. serrulata* var. *serrulata* grow in the same biotope.

*C. racemosa* var. *clavifera* is widely distributed in the warm seas (Atlantic, Indian and Pacific Oceans). It was sampled in Tahiti by Setchell (1926, p. 85). In Moorea we sampled a number of specimens (Fig. 15). All of them are characterized by the small size of the different parts of the thallus (a diameter of 1 mm for rhizomes; fronds are 2 cm high; between 1 and 3 mm in diameter for ramuli).

*CAULERPA RACEMOSA* VAR. *PELTATA*  
(LAMOUREUX) EUBANK

Ref.: Eubank (1946, p. 421)

In Takapoto the above *Caulerpa* grows in the outer reef flat and on the outer slope (3 m) in the most sheltered side of the atoll. In Moorea we found it on the fringing reef and on the reef front (1 m). It always grows in the shadow of microcavities. Setchell found it in Tahiti and called it *C. peltata* (1926, p. 86).

Characteristics of the specimens (Fig. 16) we sampled are: stolons measuring 1 to 1.5 mm in diameter; disc-like ramuli measuring 2 to 5 mm in diameter. Several specimens sampled in Moorea exhibit, on the same stolon, fronds typical of the var. *peltata* and others typical of the var. *clavifera*. This confirms the observations of Peterson (1972) concerning the growth forms resulting from light variations (var. *peltata* when irradiance is weak; var. *clavifera* when irradiance is strong).

*CAULERPA SERRULATA* VAR. *SERRULATA*  
(WEBER VAN BOSSE) TSENG (= VAR. *TYPICA*)

Ref.: Weber van Bosse (1898, Pp. 312-313, pl. 25, Figs. 4-5 = *C. freycinetii* var. *typica*)

The above species is frequent on the fringing reef of Moorea in sheltered and very shallow waters. It is always exposed to full sunlight. Setchell (1926, p. 85) found it in Tahiti and described it under the name of *C. freycinetii* var. *typica* (Weber van Bosse). *C. serrulata* var. *serrulata* has a very wide geographic distribution (Atlantic, Indian and Pacific Oceans). This alga exhibits different growth forms (Figs. 7-8) according to light variations. In fully illuminated biotopes, fronds less than 1.5 cm in length are smaller than in shaded biotopes (6 cm for the less lighted ones).

Several times, we found it in a reproductive stage (August 4, 5, 6, 13, 19 and 21, 1978). Reproductive

papillae measure 1.5 to 2.5 mm in length and 180 to 200  $\mu$ m in diameter. Thalli are monoecious, the male gametes (without stigma) are 8  $\mu$ m in length while the female gametes are 10  $\mu$ m in length. We observed several fusions which produced zygotes. This confirms the observations of Goldstein and Morrall (1970) and Price (1972) who described the complete life history of this alga.

*CAULERPA SERRULATA* VAR. *PECTINATA*  
(WEBER VAN BOSSE) NOV. COMB. = *C.*  
*FREYCINETII* VAR. *PECTINATA* WEBER  
VAN BOSSE

Reef.: Weber van Bosse (1898, Pp. 516 and 517, pl. 26, Figs. 4, 5, 6)

We found only one group of specimens under a pile wharf (depth 0.5 to 1m). This variety has been described by Weber van Bosse (1898) from specimens sampled by Mazé and Schramm in the West Indies (Guadeloupe). Mazé and Schramm noted it (1870, p. 78) under the name of *C. pectinata* Kützing. Meanwhile, Weber van Bosse (1898) pointed out that *C. serrulata* var. *pectinata* was completely different from *C. pectinata* described by Kützing (1849, p. 495 and 1857: Tab. 5, Fig. 4) which is nearer *C. crassifolia* (C. Ag.) J. Ag.

The characteristics of the thalli (Figs. 9-10) are: stolons 1.5 to 2 mm in diameter; fronds 1.5 to 5 cm in length. Fronds are very typical, they are laterally and regularly dentate and most of the time are divided. Their extremities are sometimes twisted, a character which allows us to link this variety to the *serrulata* species.

*CAULERPA SERTULARIOIDES* (GMELIN)  
HOWE F. *BREVIPEDES* (J. AGARDH)  
SVEDELIUS

Ref.: Weber Van Bosse (1898, p. 294-295). (= *C. plumaris* f. *brevipes*)-Svedelius (1906, Pp. 114-115, Figs. 7, 8 p. 114)—Howe (1905, p. 576)

This species is frequent in Moorea on the back fringing reef in the 0-1.5 m depth range. Stolons tend to cover dense vegetations of *Halimeda incrasata* which was observed in Polynesia by Grunow (1868, p. 34 = *C. plumaris*) and by Setchell (1926, p. 84). It is widely distributed in the Indian and Pacific Oceans.

Stolons of the specimens we sampled are sometimes divided and can reach a length of 40 cm

Figures 5-27. 5. *Caulerpa bikinensis* (outer slope of Takapoto, 40 m). 6. *Caulerpa bikinensis* (lagoon of Takapoto, 7 m and 1 m). 7. Different forms of fronds of *Caulerpa serrulata* var. *serrulata* from Moorea. 8. Marginal serrations of fronds of *Caulerpa serrulata* var. *serrulata*. 9. Fronds of *Caulerpa serrulata* var. *pectinata* from Moorea. 10. Marginal serrations of fronds of *Caulerpa serrulata* var. *pectinata*. 11-12. *Caulerpa pickeringii* from Takapoto. Habit of the

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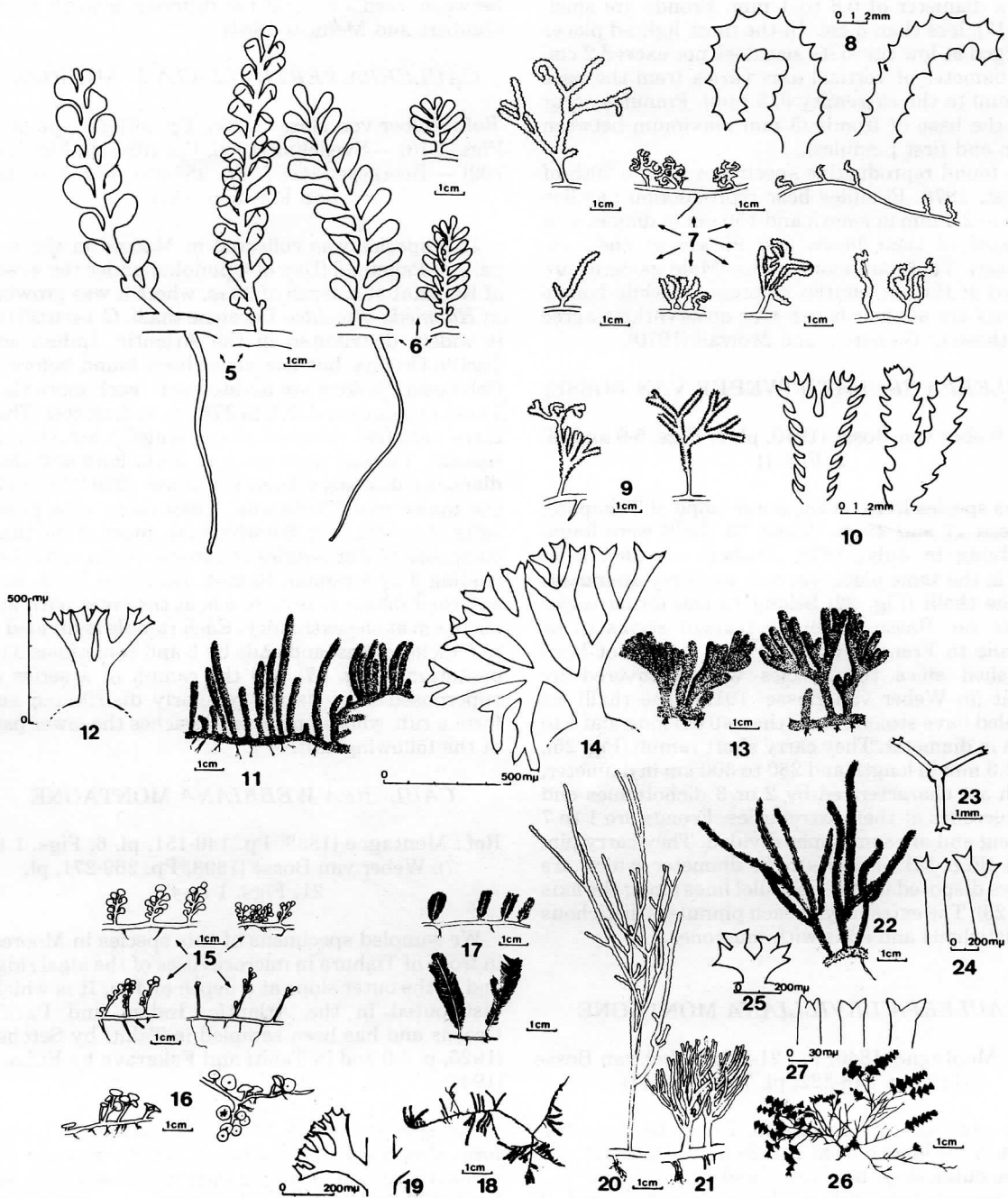
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thallus and detail of a ramulus. 13-14. *Caulerpa pickeringii* from Moorea. Habit of the thallus and detail of a ramulus. 15. *Caulerpa racemosa* var. *clavifera* from Moorea. 16. *Caulerpa racemosa* var. *peltata* from Moorea. 17. *Caulerpa sertularioides* from Moorea. 18-19. *Caulerpa webbiana* from Moorea. Habit of the thallus and detail of a frond ramulus. 20-21. *Caulerpa urvilliana* from the lagoon of Takapoto. Habit of fronds: deep water (25 m), and shallow water (3 m) (the smaller one). 22-25. *Caulerpa seuratii* from the outer slope of Takapoto. Habit of the thallus (Fig. 22); transverse section of a frond showing the triseriate insertion of pinnules (Fig. 23); dichotomous or trichotomous extremities of pinnules (Fig. 24); stolon ramulus (Fig. 25). 26-27. *Caulerpa verticillata*. Habit of a thallus and detail of the extremities of pinnules.

with a diameter of 0.8 to 1 mm. Fronds are small (Fig. 17), less than 5 cm. In the most lighted places (emerged at low tides) its size does not exceed 2 cm. The diameter of vertical axis varies from the base (0.8 mm) to the extremity (0.5 mm). Pinnules occur from the base of fronds (3 mm maximum between stolon and first pinnules).

We found reproductive specimens on the 20th of August, 1978. Pinnules bear reproduction papillae of 1.8 to 2.4 mm in length and 150  $\mu$ m in diameter at the level of their bases and 90  $\mu$ m at their extremities. Thalli are monoecious. Male gametes are located at the extremities of pinnules while female gametes are at their bases. Our observations agree with those of Goldstein and Morrall (1970).

#### *CAULERPA SEURATII* (WEBER VAN BOSSE)

Ref.: Weber van Bosse (1910, pl. 1, Figs. 5-9 and pl. 2, Fig. 1)

This species lives on the outer slope of Takapoto, between 17 and 25 m. About 20 thalli were found by diving in July, 1978. Jaubert sampled it in 1975 in the same place where it was very abundant. All the thalli (Fig. 22) belong to the forma *major* Weber van Bosse (1910). *C. seuratii* seems to be endemic to French Polynesia and it has not been published since the species was discovered by Seurat (in Weber van Bosse 1910). The thalli we sampled have stolons more than 40 cm long and 1 to 4 mm in diameter. They carry short ramuli (Fig. 25), 1 to 1.3 mm in length and 250 to 300  $\mu$ m in diameter, which are characterized by 2 or 3 dichotomies and by mucrones at their extremities. Fronds are 1 to 7 cm long and are sometimes divided. They carry pinnules (Fig. 24) of 300  $\mu$ m in diameter which are always disposed in three parallel lines along the axis (Fig. 23). The extremity of each pinnule is distichous or tristichous and ends with mucrones.

#### *CAULERPA URVILLIANA* MONTAGNE

Ref.: Montagne (1845, Pp. 21-22); Weber van Bosse (1898, p. 318-322; pl. 7: Figs. 7-11).

We sampled this species in Takapoto. It is frequent in the lagoon from 1 to 28 m. We found it also on the outer slope between 3 and 25 m.

Its geographical distribution is limited to tropical and pan-tropical areas of the Pacific Ocean. It was noted in Polynesia by Weber van Bosse (1910) and Denizot (1967 and 1972).

A number of sampled specimens exhibit several very different light-dependent growth forms (Figs. 20-21). Biometric investigations and light measurement allowed us to specify the relationship existing

between irradiance and the different growth forms (Jaubert and Meinesz 1981).

#### *CAULERPA VERTICILLATA* J. AGARDH.

Ref.: Weber van Bosse (1898, Pp. 267-268, pl. 20, Figs. 7-10) — Svedelius (1906, Pp. 108-109, Fig. 1, p. 109) — Boergesen (1907, Pp. 355-357, Fig. 1, p. 356 and Fig. 2, p. 357)

This species was collected in Moorea in the reef pass of Papetoai (Bay of Opunohu) under the wreck of Kersaint at a depth of 30 m, where it was growing on *Halimeda discoidea* Decaisne thalli. *C. verticillata* is widely distributed in the Atlantic, Indian and Pacific Oceans, but has never been found before in Polynesia. Stolons are divided and reach more than 15 cm in length and 225 to 375  $\mu$ m in diameter. They carry ramified rhizoids whose lengths are very irregular. Vertical axes are 1 to 3 cm long and their diameter decreases from the lower (220-225  $\mu$ m) to the upper part (70-85  $\mu$ m). They carry superposed tufts of ramuli (Fig. 26) which are, most of the time, composed of 2 or 3 series of verticils; each verticil including 3 or 4 ramuli. Ramuli are 2.5 to 3 mm long and their diameter is 55-65  $\mu$ m at the lower part, and 25-30  $\mu$ m at the extremity. Each ramule is divided (3 to 5 dichotomies) and ends by 2 and sometimes 3 indentations (Fig. 27). All the ramuli of a series of superposed verticils are regularly distributed and form a tuft whose upper part reaches the lower part of the following tuft.

#### *CAULERPA WEBBIANA* MONTAGNE

Ref.: Montagne (1838, Pp. 146-151, pl. 6, Figs. 1 to 7). Weber van Bosse (1898, Pp. 269-271, pl. 21, Figs. 1 to 4)

We sampled specimens of this species in Moorea, in front of Tiahura in microcavities of the algal ridge and of the outer slope at a depth of 4 m. It is widely distributed in the Atlantic, Indian and Pacific Oceans and has been sampled in Tahiti by Setchell (1926, p. 84) and in Tahiti and Fakarava by Eubank (1946).

Our specimens (Fig. 18) correspond to the typical form described by Montagne (1838). Stolons can reach a length of 7 cm and their diameter varies between 400 and 500  $\mu$ m. They carry a number of irregular rhizoids measuring 9  $\mu$ m at their extremities. Vertical axes are 0.5 to 1 cm long and 200-300  $\mu$ m in diameter. They carry short dichotomously branched ramuli (Fig. 19) and can reach a length of 300  $\mu$ m for a diameter of 80  $\mu$ m at the lower part and 30  $\mu$ m at the upper part. Ramuli end by one or several mucrones exhibiting various shapes.

## CONCLUSION

Among the 11 species or varieties of *Caulerpa* we found in Moorea or Takapoto, 3 are new for Polynesia: *C. bikinensis*, *C. verticillata* and *C. serulata* var. *pectinata* nov. comb.

We found two species endemic in Polynesia: *C. seuratii* and *C. pickeringii*, but we underline that the last one has been confused or considered as being similar to *C. elongata* or *C. webbiana* which are widely distributed in tropical waters.

The distribution of the genus *Caulerpa* in French Polynesia shows that there are big differences in vegetation from one island to another. Thus among the 11 specimens sampled in Moorea and Takapoto, only two species were found in both places: *C. pickeringii* and *C. racemosa* var. *peltata*.

Two species are quantitatively important in the reef ecosystem: *C. bikinensis* and *C. urvilliana*. *C. bikinensis* forms a very dense belt from the depth of 35 m down to more than 70 m on the outer slope of the atoll of Takapoto. *C. urvilliana* is the most abundant macrobenthic alga of the lagoon of Takapoto.

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