Preliminary Studies of Philippine *Eucheuma* Species (Rhodophyta) Part 1, Taxonomy and Ecology of *Eucheuma arnoldii* Weber-van Bosse[1]

G. T. KRAFT[2]

ABSTRACT: The fleshy, noncalcified, red alga *Eucheuma arnoldii* Weber-van Bosse is unique in its often close resemblance to the habits of certain types of branched coelenterate corals. The present study of the alga in three Philippine areas attempts to clarify its taxonomic relationships and presents ecological data dealing with its depth distributions, substrata preferences, standing crops, and community associations. A new variety, *E. arnoldii* var. *alcyonida*, is described, and the previously described taxa *E. cupressoideum* Weber-van Bosse and *E. cupressoideum* var. *verticillata* Yamada are placed in synonomy with *E. arnoldii* var. *arnoldii*. Possible lines of more detailed, future research on this species are suggested.

RED ALGAE of the genus *Eucheuma* are a conspicuous element of the marine flora on many reefs in the Philippines, Malaysia, and Indonesia. They appear to belong to at least six distinct species and perhaps 10 or more forms. Many of the forms have been described as independent species by taxonomists (e.g., Weber-van Bosse, 1928) who were unacquainted with large collections of living material.

Three *Eucheuma* species are intensively harvested, primarily in the Philippines, where sun-dried thalli are sold to American and European carrageenin processors. These taxa, currently known in the trade as *Eucheuma cottonii, E. spinosum,* and *E. striatum,* are subjects of continuing systematic revision, ecological study, and cultivation attempts by researchers from the University of Hawaii and the Philippine Fisheries Commission (Doty, 1969). A recently described fourth species (Kraft, 1969) is of restricted occurrence and of no present commercial value. The remaining two, while little exploited, have been objects of preliminary studies by me in the course of research on the ecology of Philippine *Eucheuma.* Both taxa, *E. gelatinae* (Esper) J. Ag. and *E. arnoldii* W.-v.B., show some unique morphological and ecological features. Emphasis is placed on the latter species in this paper.

PURPOSE OF THE STUDY

The purpose of the overall study has been to examine selected Philippine *Eucheuma* populations under natural conditions to further both a taxonomic and an ecological understanding of the several species. An attempt has been made to determine the range of habit variation among populations and to arrive at a natural grouping of entities into taxa. The study further attempts to relate various features of the habitat, such as substrata types, depth ranges, and community associations, with the distribution of the species. Though the resulting ecological data are most useful when used to compare the several *Eucheuma* species, this initial report will concentrate on the information gathered and conclusions reached in regard to *E. arnoldii.*

PROCEDURES AND METHODS

The research was conducted from March to August 1968. Three habitat types were recognized and compared in the course of the study:

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[2] Present address: The University of Adelaide, Botany Department, Adelaide, Australia 5001.

(*a*) a living-coral reef area fringing a large limestone land mass, (*b*) a noncoral reef area fringing a large basaltic land mass, and (*c*) several living-coral reef areas surrounding small, riverless, limestone islands and cays (Fig. 1, regions *A*, *B*, and *C*, respectively).

In each of the study areas, preliminary surveys were conducted to determine the location and extent of the *Eucheuma* communities. Sites of most vigorous growth were then selected for detailed study. The time available was a major factor in determining the extent of preliminary survey and number of samples made in each locality. At Hundred Islands (Fig. 1*A*) and Bulusan (Fig. 1*B*), the preliminary surveys were from 4 to 5 days, allowing confident choice of the most productive *Eucheuma* areas over rather large expanses of reef. In the northern Sulu Sea islands (Fig. 1*C*), all areas were reconnoitered at best only an hour or two. Here time limitations were partly overcome by relying on guidance from local seaweed harvesters. Bulusan and the Sulu Sea islands were primarily studied for *Eucheuma* species other than *E. arnoldii*. Ecological observations on *E. arnoldii* in these areas thus tend to be outside the ring-throw sampling context (see below).

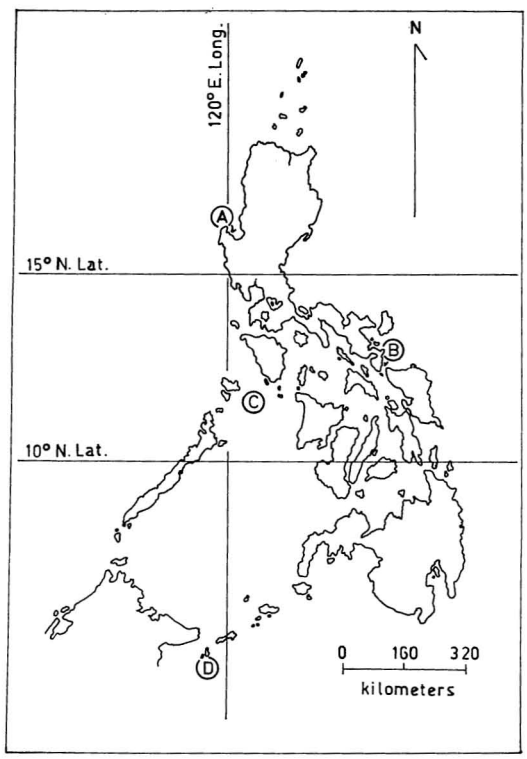


FIG. 1. The Philippine Islands, showing the algal sample locations cited in the text. *A*, The Hundred Islands; *B*, Bulusan; *C*, the islands of the northern Sulu Sea; *D*, Sitangkai, site of an additional collection of *Eucheuma arnoldii* made by Mr. Parker Laite of Marine Colloids Corporation in December 1967.

In each of the areas studied, populations within and adjacent to chosen areas in which *Eucheuma* occurred were sampled by throwing 45-cm-diameter rings onto the reef at various haphazardly spaced distances along lines laid out across the community. Because of low seaweed densities in the Hundred Islands, two rings were placed side-by-side at each toss in order to double the size of the area covered. Data taken with each ring throw included sample locality for mapping, depths with time measurements for later relation to the tidal datum planes (U.S. Department of Commerce, 1968), and descriptions of substrata. Also noted were current patterns and water turbulence at the time of sampling. After the ecological notes were recorded, the contents of each ring were harvested. The harvests from each sample were sorted into recognizable species later in the day and wet-weighed on a triple-beam balance accurate to 0.1 g. Species names, at times tentative, were assigned to the components. Voucher herbarium sheets and liquid-preserved specimens were prepared of each species in the field for later taxonomic verification and study.

The only reef found during the study with *Eucheuma arnoldii* as the dominant *Eucheuma* species was at the Hundred Islands site in west-central Luzon (lat 16°11′ N, long 120°-03.5′ E). Consequently, this reef was sampled for *E. arnoldii* much more heavily than were other areas visited. Thirty-eight samples, each covering 0.320 m^2, were taken along two grid lines (Fig. 2) laid out across an isolated living-coral reef patch. The reef, some 100 m long and up to 25 m wide, lay about 1 km offshore from Telbang Barrio. Thus, a total of 12 m^2 was actually harvested and measured out of an area approaching 2,000 m^2 in extent.

Bulusan, on the southeast coast of Luzon (lat 12°43′ N, long 124°08.3′ E) is a basaltic region with broad, intertidal reef platforms

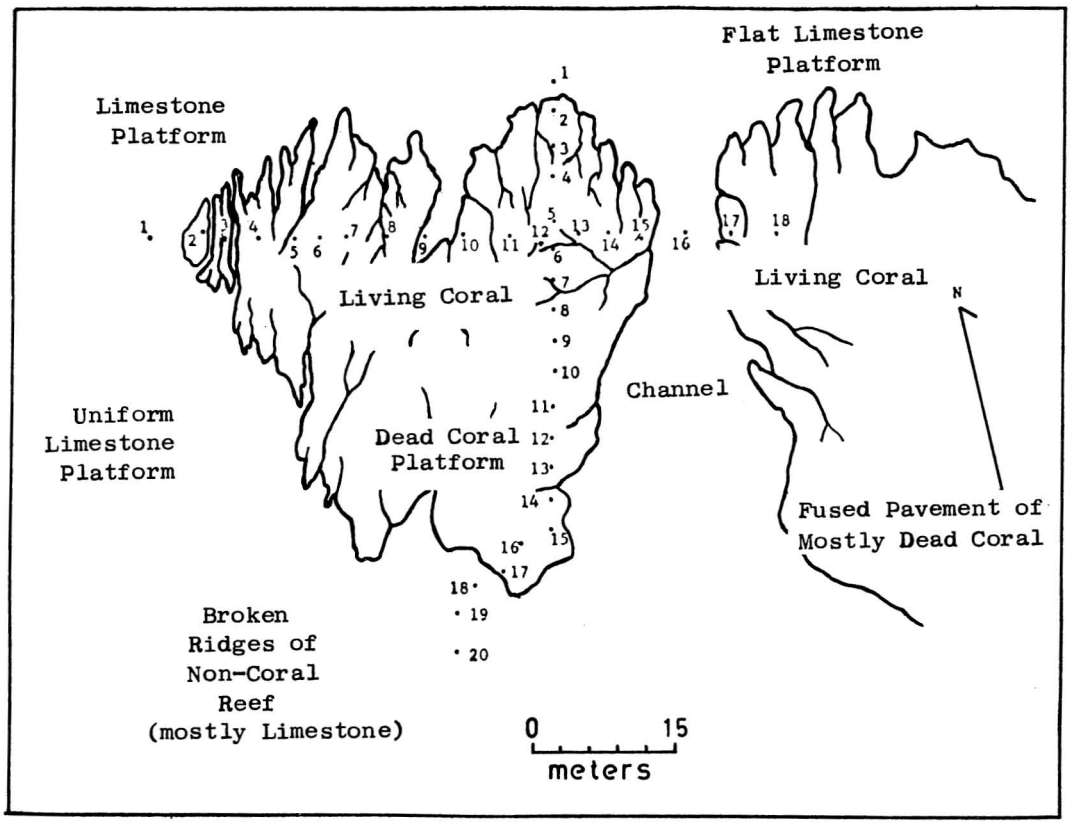


FIG. 2. The coral reef patch at Hundred Islands showing the locations of the sample numbers along the two transects. Reef boundaries are very approximate.

fronting the shores. *Eucheuma arnoldii* was not a common element of the flora here, and ring sample studies in this area were confined to other species of *Eucheuma*. Data recorded concerning *E. arnoldii* included depths, substrata, and communities around the 12 individual thalli that were found.

Several remote islands in the northern Sulu Sea, south of the island of Mindoro, were visited aboard a commercial *Eucheuma*-collecting vessel. Among those where *E. arnoldii* was found were Nangalao Island (lat 11°25′ N, long 120°10′ E), Barangonan Island (lat 11°20.75′ N, long 119°41.6′ E), the Quiniluban Group, including Cambug Rock (lat 11°27.5′ N, long 120°47′ E), and Panagatan Cays (lat 11°51′ N, long 121°18′ E). The reefs around these small islands consist of extremely diverse aggregations of living coral species at the margins and subtidally, and often of fused low-littoral pavements of dead coral shards fronting the shores. At the limestone Panagatan Cays, a broad shallow lagoon was surrounded by reefs and low islands nowhere higher than 15 m.

Eight rings were thrown into a *Eucheuma arnoldii* community of 6 × 10 m extent on the southeast reef at Panagatan Cays. The site occupied a shallow depression in the consolidated coral-fragment reef some 10 m inward from its elevated seaward margin. The area covered by each ring was 0.160 m^2, so that a total of 1.25 m^2 was harvested from the approximately 60 m^2 area.

TAXONOMY

Up to now, *Eucheuma arnoldii* has been known only from the type specimen, a dried cystocarpic thallus described and well illus-

trated by Weber-van Bosse (1928:421, Pl. 13, Fig. 1). The collection was taken from minus 18 m on a "coral and lithothamnion bottom" off Ceram (lat 03°50′ S, long 130°50′ E), just west of New Guinea. Most of the species' diagnosis is based on presumed trends towards dichotomous, unilateral, and opposite branching, features that, because the specimen is pressed, are given undue prominence.

In the same publication, Weber-van Bosse (1928:421–422, Pl. 14, Fig. 3) described a second species, *Eucheuma cupressoideum*, based upon both a dried and a preserved specimen from Torres Strait. It differed from *E. arnoldii* in its smaller size, thinner and anastomosing branches, and its tufted habit. Collars of spines were said to be present in some branches, lacking in others.

Our abundant Philippine collections contain several specimens conforming to Weber-van Bosse's description of *Eucheuma cupressoideum*. Such thalli (Fig. 3) grew intermixed with stouter individuals that, when pressed, closely match the original illustration of *E. arnoldii*. Anastomosing branches occur in both, as does the tufted habit and occasionally a whorled appearance. The thalli of *cupressoideum*-type plants are generally thinner and more wiry than the thalli of *arnoldii*-type plants, but in all other morphological respects they are similar, intergrades being common.

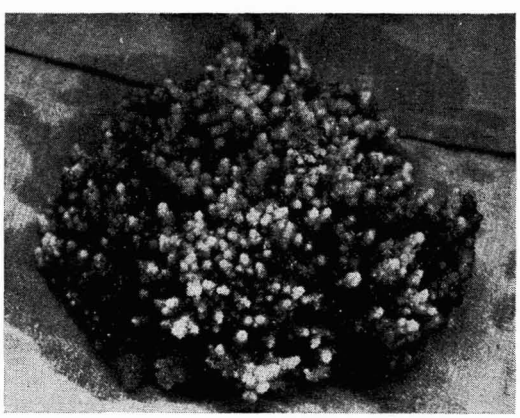


FIG. 3. A growth form corresponding to the *Eucheuma cupressoideum* of Weber-van Bosse. Though the branches are thinner, their spines and arrangement are similar to typical *Eucheuma arnoldii*. From 0.5 m below lowest tides at Hundred Islands (no. K1035).

From her account, it is clear that Weber-van Bosse intended *Eucheuma arnoldii* to be the species with priority in any possible future merger with *E. cupressoideum*, for she says of the latter: "Des recherches ultérieures démonteront si cette algue est une espèce autonome ou une variété de l'*E. arnoldii*."

In his paper on Formosan and Ryukyuan *Eucheuma* species, Yamada (1936:131–134, Fig. 11–13, Pl. 28–29) recorded and illustrated *E. cupressoideum* from 6 to 12 ft depths on a coral reef. The locality is Miyako Jima (lat 24°28.2′ N, long 125°12′ E), located near the northermost latitude of reef-building corals. Yamada's plants formed large intertwined mats, a feature common to much *E. arnoldii* found in the Philippines. Fronds in Yamada's collection with thicker-than-usual branches and pronounced collars of spines are given separate status as var. *verticillata*. Yamada's excellent drawings show an intermediate form between *E. arnoldii* and *E. cupressoideum* as Weber-van Bosse seemed to picture them.

Eucheuma cupressoideum var. *verticillata* Yamada is listed without collection data in a report by Isaac (1968:4) on marine algae from Kenya. This report constitutes the only non-Asian record of the species.

GENERAL DESCRIPTION OF PHILIPPINE MATERIAL

Eucheuma arnoldii is characterized by a wide range of coloration and shapes. Common to the specimens identified with the species in this report are:

1. Branch cross sections (Fig. 4) composed of a medulla of intermixed, large and small, fairly isodiametric cells, and a thin cortex of progressively smaller cells. Although the inner medullary cells can become elongated along the line of the main axis, there is no central cable of rhizoids or densely aggregated filaments present.
2. Bushy, cartilaginous, and fleshy thalli that are branched in all planes. The branches are, for the most part, vertically aligned (Fig. 5 and 6). When seen in nature among and on the madreporarian and alcyonid corals with which they grow, the plants can be almost indistinguishable from several of

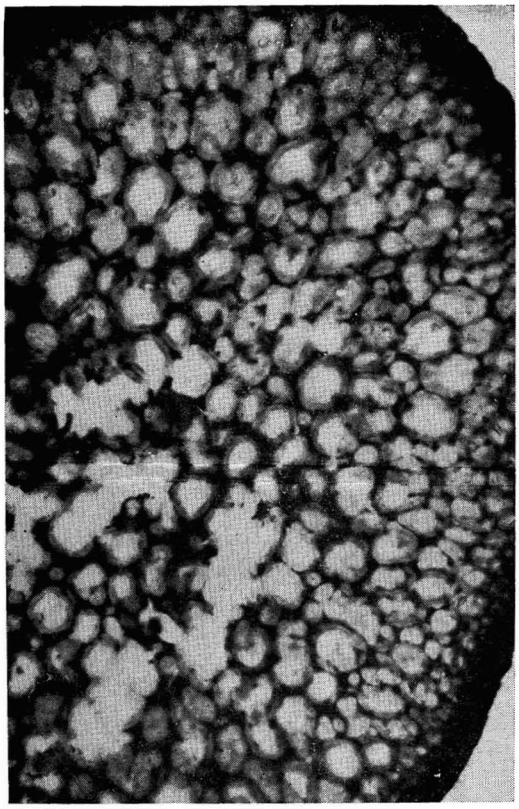


FIG. 4. Branch cross section from 2 mm behind an apex from the plant illustrated in Fig. 6. Stained in Toluidine Blue.

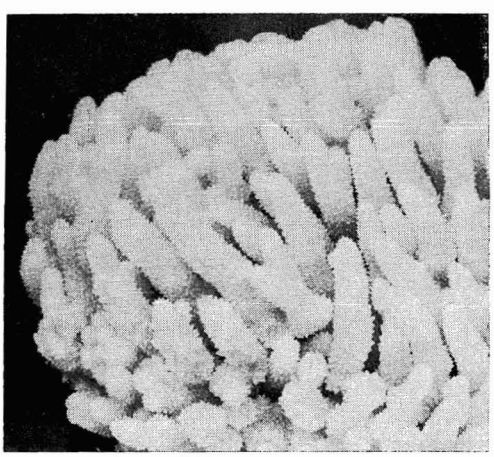


FIG. 5. Habit of a "soft-coral" (*Eucheuma arnoldii* var. *alcyonida*) form from 60 cm below lowest predicted tides at Bulusan. Note the domed apices and spines of mostly uniform length characteristic of the variety. Color salmon-pink when fresh (no. K003).

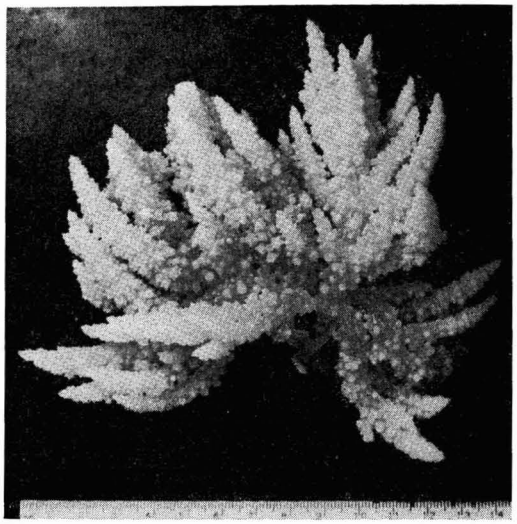


FIG. 6. Habit of a cystocarpic, "hard-coral" form of *Eucheuma arnoldii* (var. *arnoldii*) collected by local harvesters at Nangalao Island. Color when fresh was ivory white, with blue flecks on the spines (no. K541).

the *Acropora, Pocillipora* (cf. Fig. 7), *Porites,* and some soft coral types.

3. Surfaces of the thalli mostly covered with short spines, which are of two main types (see below).
4. Thickened areas bearing spines, often alternating with thinner, spineless bands or "nodes," particularly along young branches (Fig. 8–9). When present, these give a distinctive "collared" or whorled appearance to the thalli which is accentuated in drying.

HABIT RANGE IN THE PHILIPPINE COLLECTIONS

The apparent coral mimicry of *Eucheuma arnoldii* is certainly the alga's most immediately striking feature. This is recognized by seaweed harvesters in the Philippines, who sometimes call the plant *Eucheuma "corallum."*

The habit range of the Philippine collections falls broadly within the following two categories:

1. *Eucheuma arnoldii* var. *arnoldii*: Thalli with or without annular collars; branch apices acute, subacute, or blunt; spines 1 mm or longer, broad based, overlapping, acute.

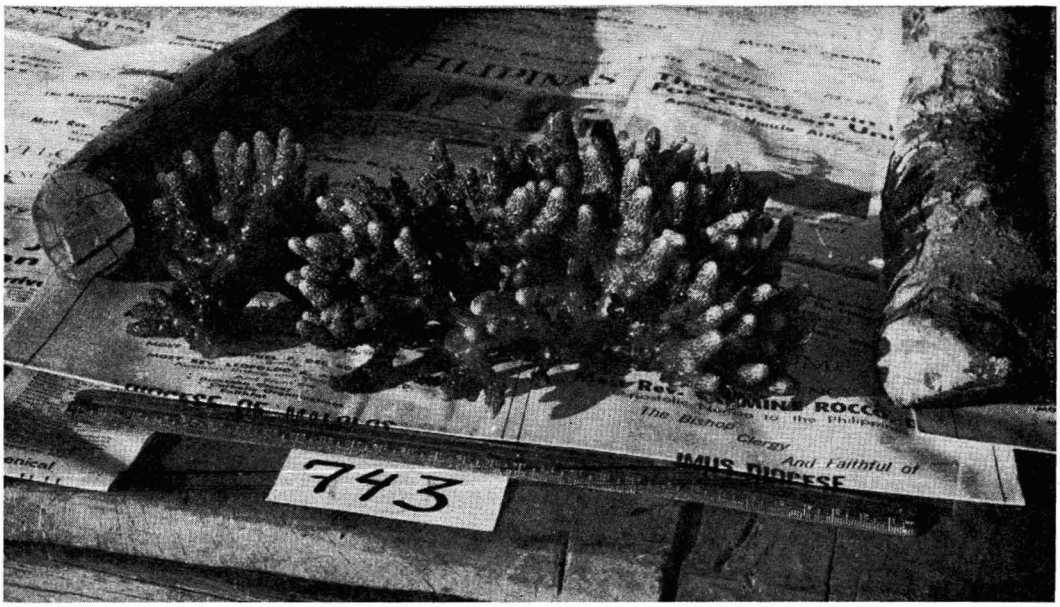


FIG. 7. *Eucheuma arnoldii* thalli that closely resemble the appearances of some *Pocillopora* and *Porites* coral species. From the shallow sublittoral reef at Cambug Rock, Quiniluban Island (no. K743).

simple or multifid (Fig. 10); spines not of uniform length along branches.

2. ***Eucheuma arnoldii*** var. ***alcyonida*** var. nov.: Thalli sine vel cum collis leviter annulatis; apices late rotundati, tholiformes; spinae minutae, minae quam 1 mm, bases vix lati quam apices, aeque disposites; omnes spinae plus minusve eiusdem longitudinis.

   Thalli with or without faint annular collars; apices broadly rounded, dome-shaped; spines minute, less than 1 mm, bases not much wider than tips, evenly spaced; all spines more or less the same length. Holotype, number K910 (Fig. 11), is deposited in the algal herbarium of the University of Hawaii (UH).

Eucheuma arnoldii var. *alcyonida* is named for its resemblance to certain soft corals of the family Alcyoniidae with which I have found it to be consistently associated (Fig. 11).

The visual impression usually given by the two varieties in the field is that they are quite distinct from one another. Both varieties were commonly found growing together in the same areas, however, and their general habits and anatomies are similar. One specimen was collected (Fig. 12) which possessed separate branches displaying features of both varieties.

Forms fall within *Eucheuma arnoldii* var. *arnoldii* corresponding to Weber-van Bosse's *E. cupressoideum* and Yamada's *E. cupressoideum* var. *verticillata.* It does not seem warranted to maintain these forms as distinct taxa.

Tetrasporangial thalli are unreported for both *Eucheuma arnoldii* and *E. cupressoideum*, but were found in about equal numbers with cystocarpic plants during the Philippine study (Fig. 13–14). No correlation between growth form and reproductive state was noticeable.

ECOLOGY

Eucheuma arnoldii has not figured in any of the very few ecological studies that have involved tropical marine algae.

When I finally realized that not all of the seeming corals I was seeing were animals, I found *Eucheuma arnoldii* at almost every Philippine site visited where branched corals occurred. Conversely, I never discovered *E. arnoldii* on reefs lacking branched corals.

Recent studies of shallow coral reef floras in the Solomon Islands by Womersley and Bailey

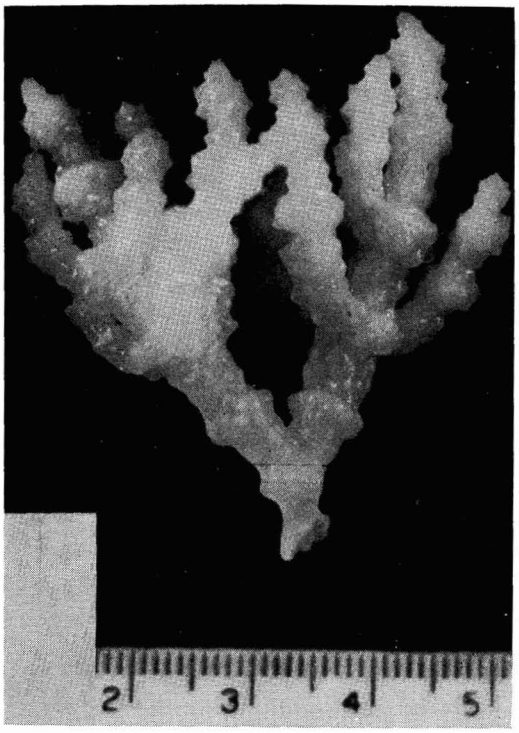


FIG. 8. A young thallus of *Eucheuma arnoldii*, showing regular development of annular collars and whorled branching. Collected from a shallow, subtidal, coral reef flat at Barangonan Island. Plants salmon colored when living (no. K599).

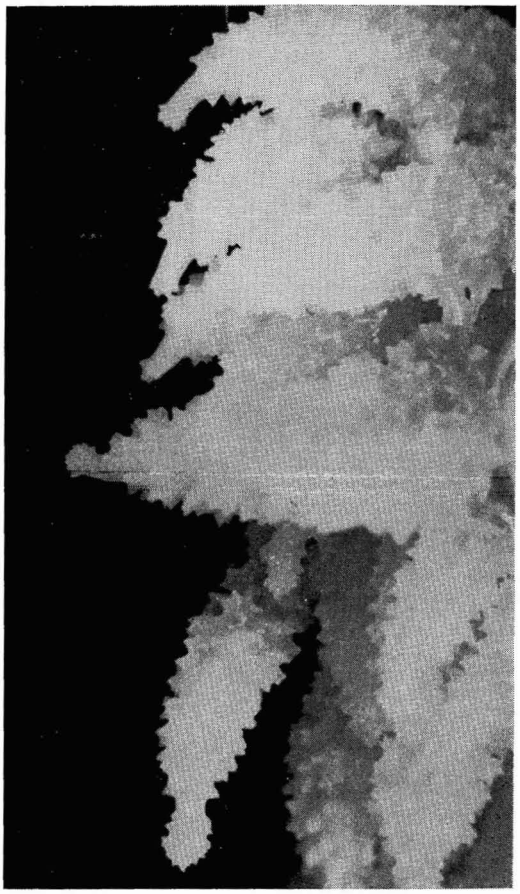


FIG. 9. Branches of a noncollared "hard-coral" thallus, all showing a recent spurt of growth that may indicate one way in which the collaring effect is brought about. Specimen taken from Nangalao Island (no. K542).

(1970), in Melanesia and French Polynesia by Denizot (1968), and in the Tuamotus by Chevalier et al. (1970) have not recorded *E. arnoldii*, and thus suggest that the distribution of this species in the tropics may be spotty or perhaps confined to the western and southwestern rim of the Pacific. Though the resemblance of the plants to corals is striking, it is not so great as to cause them to be overlooked in such surveys.

Tide Levels and Substrata

Although the distributions of some of the *Eucheuma* species were found to reach no higher than the lowest yearly tide levels (LLLW), *E. arnoldii* was found to be rather uniformly distributed within about a 1.25-m vertical range that extended above this mark (Fig. 15).

Eucheuma arnoldii was found in only one area at Bulusan, just seaward of an intertidal reef flat, where the thalli grew on the tops of narrow pinnacles that rose almost vertically from a 12-m depth to a point about 1.2 m below zero (mean lower low) tide level. Over the rounded crests were widely scattered stalked coelenterates and "sea-whip" corals, with the *E. arnoldii* thalli in close association, at times anchored to the distal tines of the stony corals (Fig. 16). The area was subject to incoming wave surge, but was 75 cm below the level of the lowest predicted yearly tides.

The species, as well as several types of reef-building corals, was found at shallower depths at several northern Sulu Sea islands. At Cambug Rock in the Quinilubans, it was found on

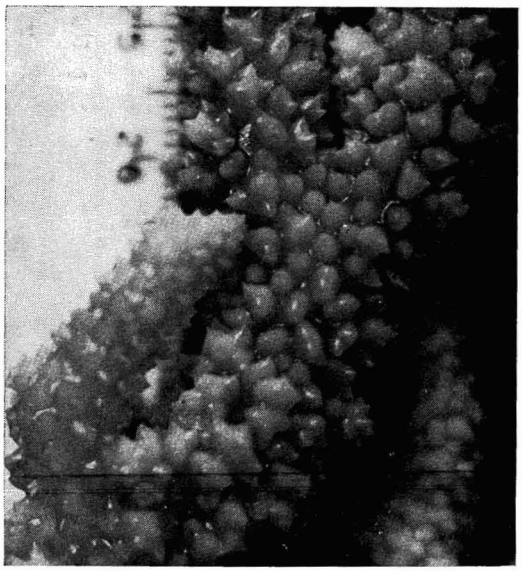


FIG. 10. Close-up of the spines on the thallus of Fig. 13, showing overlapping bases, uneven lengths, and frequently multifid tips common to the "hard-coral" forms.

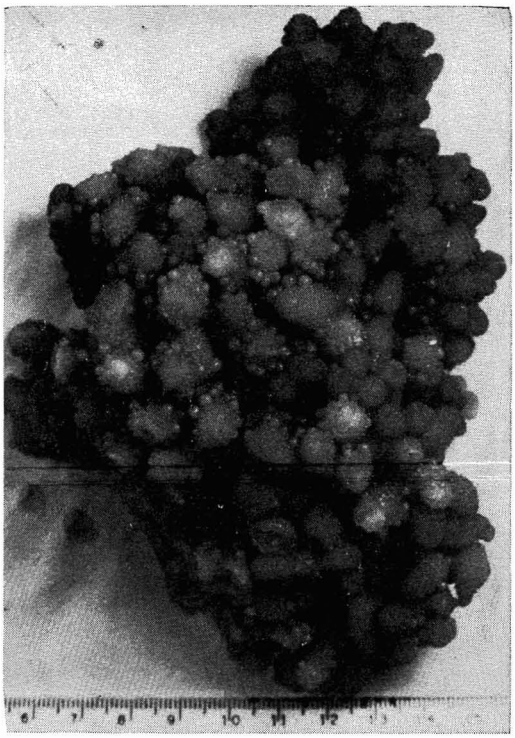


FIG. 11. Habit of the holotype specimen of *Eucheuma arnoldii* var. *alcyonida* showing domed apices, minute spines, and several unhealed or only partly healed branch tips previously lost to grazing animals. The thallus is cystocarpic. Color orange-pink when living. Specimen taken from approximately 1 meter below lowest tides at Bulusan (no. K910).

a coral-fragment platform dissected by sand channels, several meters inward from the raised outer reef margin. Isolated living coral colonies also grew in this area where it was 60 cm below lowest tides. A patch of *E. arnoldii* located on a solid coral pavement at Panagatan ranged between 50 to almost 60 cm below LLLW. A single thallus was found at the 42-cm level, the lowest yearly tidal mark. At Barangonan Island, several wide-spreading, matlike thalli, each well over a kilogram in weight and over 15 cm tall, were anchored to cemented coral shards 12 cm below LLLW. Though the bases of such thalli are doubtless always submerged, the upper branches are probably exposed for short daylight periods several times a year.

Thalli of *Eucheuma arnoldii* occurred intertidally to nearly the mean low (0) tide mark in the Hundred Islands, an elevation corresponding to the highest reaches of the living corals on the reef. There was a slight tendency for the numbers of plants to be greatest at around the 45-cm level, close to the depth of the lowest yearly tides; but the species also occurred abundantly among the tines of the uppermost corals comprising the reef, an area where several daytime exposures of nearly 1 hour occurred during this study, which was conducted during the hot, dry season in July. The species was also a frequent associate of the deepest-growing living corals in this particular area.

Thirty-eight depth measurements made on isolated individuals or on groups of thalli in the three study regions showed no one narrow band within the brief vertical range of the species where plants grew with much greater frequency than elsewhere. In all three areas, "suitable" appearing substrata for *E. arnoldii* were seen well below the actual range of the species in these regions. Investigations were carried out down to 6–9 m in limited spots, but *E. arnoldii* was not found at these depths. Weber-van Bosse's and Yamada's collection records, however, suggest that undetected,

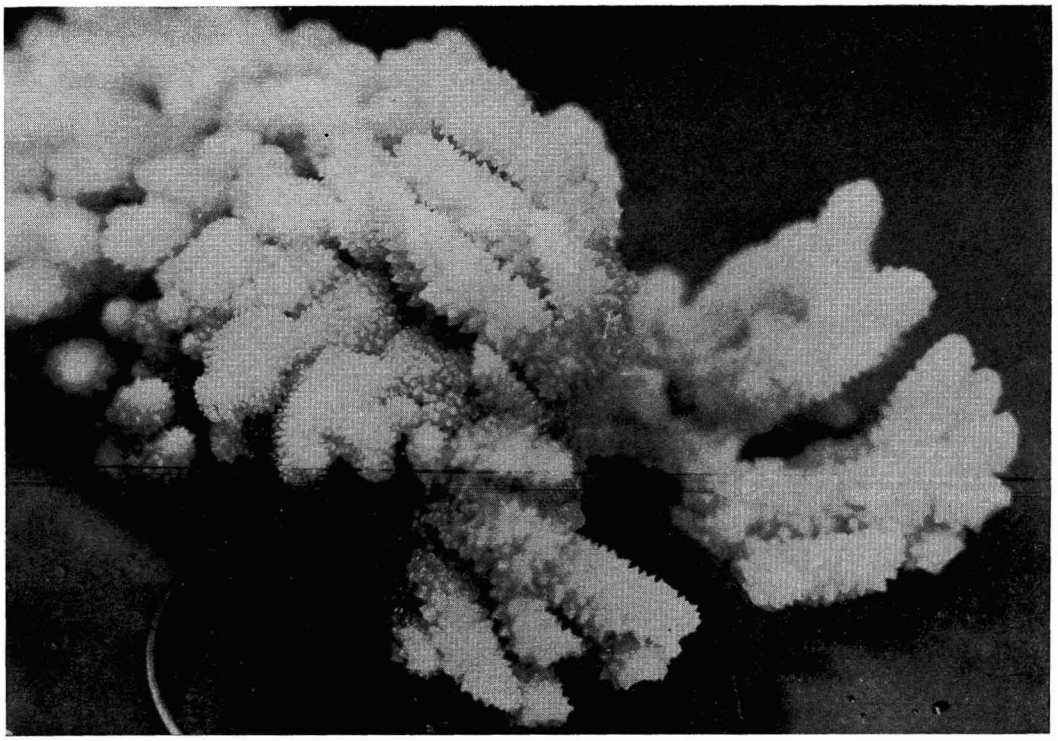


FIG. 12. Thallus of *Eucheuma arnoldii* bearing separate branches which possess either hard- or soft-coral type spine features. Specimen was found growing on living coral in the shallow subtidal at Bulusan (no. K912).

deeper populations may have been present in the study areas.

Thalli grew equally robustly on a variety of substrata, including rock, algal limestone, consolidated dead coral, and living coral. Although the basal portions of branched hard corals provide attachment surface for many species of algae, the polyp-bearing outer tines are almost always free of algal epiphytes. *Eucheuma arnoldii* was one of only two algal species found anchored to the living portions of stony corals, the other being *Gelidiopsis intricata* (Ag.) Vickers, which formed a fine red fuzz 3 to 6 cm in length on certain species of *Acropora* in precisely the fashion illustrated by Kanda (1944:758, Fig. 19). Where corals hosted *E. arnoldii*, the branch form and coloration of both were often hard to tell apart.

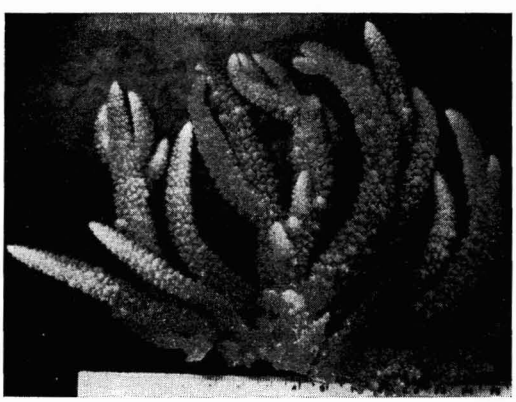


FIG. 13. Half of a robust tetrasporophyte from the Nangalao Island collections. Color of the thallus was dark green with yellow spines when fresh (no. K539).

Landward from the raised coral-debris pavements on many reefs, the solid substrata commonly gave way to areas where humps and mounds of coral, a few meters or less in extent, were surrounded by sand-floored channels. Still farther from the reef margins, bottoms often became mostly sand overlying scattered chunks of just-buried coral rubble. A variety of large algae was found anchored to the shards on the sand flats (e.g., *Turbinaria ornata, Eucheuma cottonii, E. striatum, Laurencia*

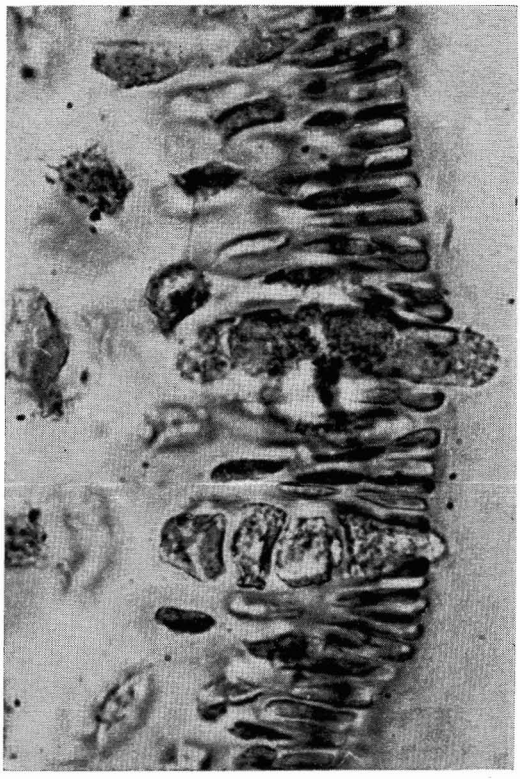


FIG. 14. Section through the outer cortex of the tetrasporophyte shown in Fig. 13. Stained in Chlorazol Black E.

papillosa), but *E. arnoldii* was not encountered in such habitats. As a general rule, *E. arnoldii* was absent from all areas studied where conditions permitted sand deposition on the reef to any great extent. An exception was met only at Cambug Rock, where several *E. arnoldii* thalli were collected from coral chunks on the sand next to mounds that were fringed with numbers of head-type and branched corals.

Standing Crops

The results of the seaweed-harvesting study suggest that in areas of living coral predominance generally, standing crops of algae are relatively low and are composed of fewer species when compared with those of other reef types. This is a trend that other investigators have already pointed out (e.g., Koster, 1967: 272).

At Bulusan, for example, the standing crops were calculated for two low-littoral, intertidal reef flats populated by *Eucheuma cottonii* and *E. gelatinae*, but not by *E. arnoldii* or branched corals. The first area, nearly 350 m^2, was ring-sampled 20 times. Its standing crop averaged 4.6 kg/m^2 wet weight, the total being composed of 45 algal species. The second area, about 200 m^2, was sampled the same way 14 times. The standing crop averaged 4.5 kg/m^2 and was composed of 62 species. By contrast, standing crops within the *Eucheuma arnoldii*-living coral communities sampled at Panagatan and the Hundred Islands averaged 2.0 and 0.65 kg/m^2, respectively. Fifteen algal species comprised the Panagatan samples, whereas 35 made up the Hundred Islands total.

The average amount of *Eucheuma arnoldii* as measured by the eight Panagatan samples was 350 g/m^2. Within the 29 samples from the Hundred Islands counted as inside the *E. arnoldii* community, *E. arnoldii* averaged 300 g/m^2, or nearly one-half the entire algal standing crop. The closeness of the two figures may be coincidence, but both sample areas were representative of *E. arnoldii* habitats which had been undisturbed by commercial harvesters. The figures may thus represent something of a typical magnitude for the higher ranges of *E. arnoldii* standing crops.

The characteristically wide-scattered distribution of *E. arnoldii* requires that a rather large number of samples be taken in an area to ensure that the species is adequately represented in a ring-throw type of survey. It can be seen (Fig. 17) that samples along the transects at the Hundred Islands varied greatly in the amounts of algae contained, with the few heaviest numbers often being mostly composed of *Eucheuma arnoldii* or *E. cottonii*. Out of 29 ring samples thrown within the *E. arnoldii* community, only seven actually contained that species. This suggests that greater reliability of frequency data could have been achieved had considerably more, and possibly smaller, samples been made.

The nine samples marked (Fig. 17), which were considered to be outside the *Eucheuma arnoldii* community at Hundred Islands, yielded a standing crop average of 1.6 kg/m^2, and reflected the greater seaweed densities in the areas surrounding the living-coral reef.

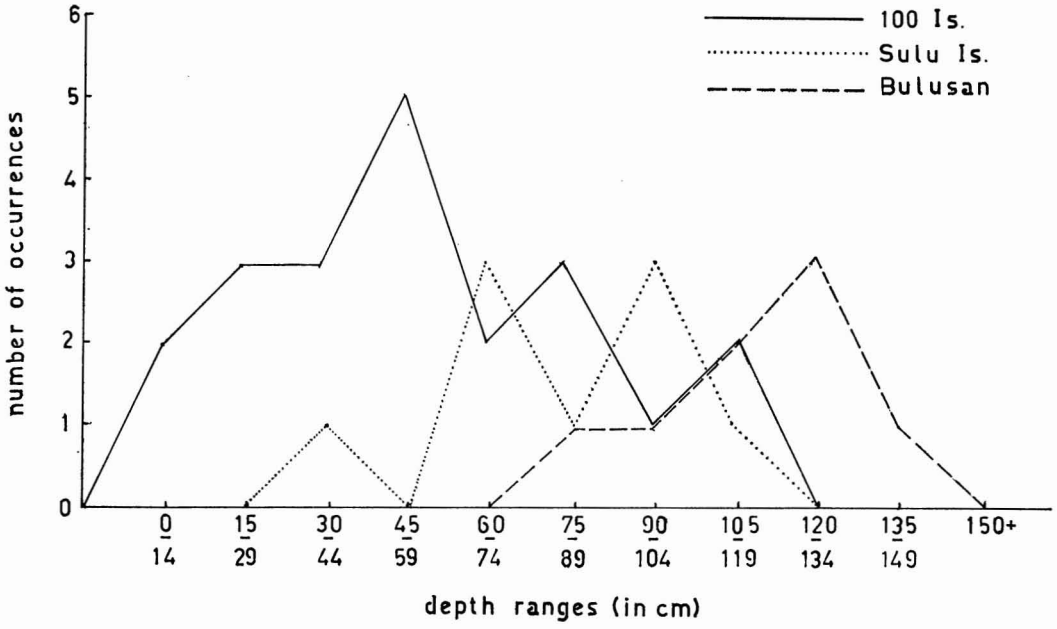


FIG. 15. The number of times that individuals or clumps of *Eucheuma arnoldii* appeared within various depth ranges at the study sites. The level of the lowest predicted yearly tides falls within the 30 to 44 cm class in all areas. Zero (0) depth represents the yearly mean of the daily lower low tides.

Species Associations

The seeming restriction of *Eucheuma arnoldii* to areas of living branched corals was not matched by any of the dominant algal species associated with it.

The only alga growing with *E. arnoldii* in all three study areas was *Turbinaria ornata.* At both Bulusan and Panagatan, *Caulerpa racemosa* was present, as was *Eucheuma cottonii* at both Panagatan and the Hundred Islands. These associated species have wide Philippine distributions on both coral and noncoral reefs, however, and all three can be found on sand flats where coral rubble is strewn.

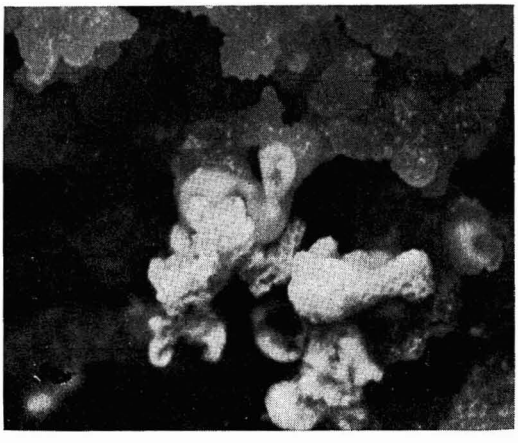


FIG. 16. The underside of the thallus pictured in Fig. 5, with detail of the holdfast attachment to a polyp-bearing arm of the host coral. One major and several secondary holdfasts have formed.

At Panagatan (Fig. 18*a*), *Eucheuma arnoldii*, *Caulerpa brachypus*, and *Laurencia papillosa* formed the bulk of the eight samples. The *Eucheuma arnoldii* thalli were present as isolated clumps from 0.5 to 2 m apart, whereas the *Caulerpa brachypus* was draped over the broken tines of staghorn coral like a thick grass, all but obscuring the *Laurencia* that grew beneath. Around the rim of the depression that contained the *Caulerpa brachypus* and living coral was a fused coral platform on which *C. racemosa* and *C. racemosa* var. *laetevirens* were dominant. The *Eucheuma arnoldii* was confined to the depression and immediate rim area. *Eucheuma cottonii* and *Turbinaria ornata* were present as widely scattered, large, individual thalli.

The flora associated with *Eucheuma arnoldii*

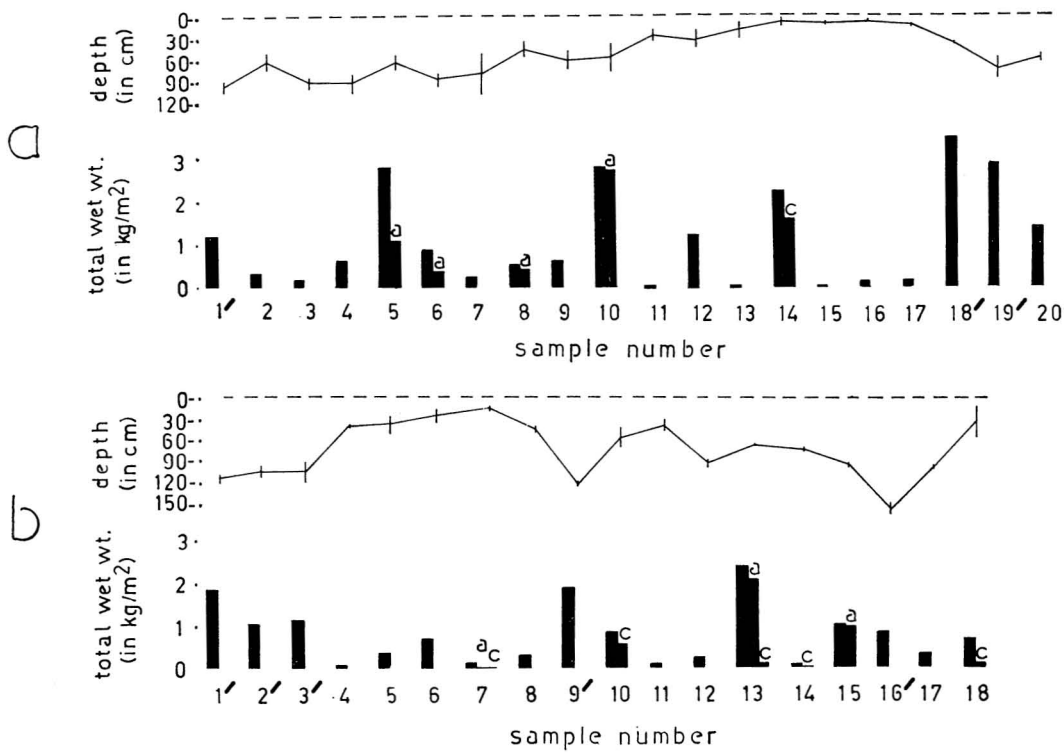


FIG. 17 The standing crop totals and depths of the Hundred Islands ring samples mapped in Fig. 2. Sample numbers marked with an "′" have been treated as being outside the *Eucheuma arnoldii* community.

Lower scales: the total wet weights of each sample, translated into kg/m². The right-hand columns of pairs, when present, represent the amount of the sample total made up by *Eucheuma* spp.: *a, E. arnoldii; c, E. cottonii.*

Upper scales: Reef depth profiles along the two transects. Vertical strokes show extremes of relief at each sample site. Lines connecting the samples show the general reef profile relative to zero tidal level, but are not horizontally to scale. *a*, The transverse transect; *b*, the longitudinal transect.

on the pinnacles at Bulusan mostly consisted of *Turbinaria decurrens*, with scattered *T. ornata* and *Liagora* sp., and with *Caulerpa racemosa* trailing over the rocky substratum.

Of the 38 samples taken at the Hundred Islands, nine were judged to be adjacent to the *Eucheuma arnoldii* community and 29 within it (Fig. 17; 18*b, c*). Inside its community, *E. arnoldii* dominated the sampling by weight. When *E. arnoldii* was absent, sample weights tended to be low, partly owing to the absence of any *Caulerpa* species from the area at this time. *Turbinaria ornata*, to 45 cm long, was anchored to dead limestone between the corals and contributed heavily to a few samples. *Eucheuma cottonii* was less frequently found than was *E. arnoldii*, but was present as prostrate clumps over dead substrata. Comprising about 1 percent each of the standing crop were *Ceratodictyon spongiosum, Hormophysa triquetra, Gracilaria gigas*, and *Gelidiopsis intricata.*

A rudimentary community analysis (Table 1), based on the frequency of occurrence of the 10 most common species of the combined 38 ring samples, shows that between the *Eucheuma arnoldii*-coral community and the surrounding reef flat, two distinctive algal associations were present.

The four species of Group 1 are the most frequently associated algae of the *Eucheuma arnoldii* community. The *Hypnea* and *Laurencia* species commonly formed low turfs around the bases of several coral types.

In the surrounding limestone flats and the channels dissecting the coral reef, *Sargassum* sp. and *Gracilaria gigas* were the dominant algae. Group 2 is rather heterogeneous, since

the area surrounding the coral reef was not uniformly populated in all directions, nor was it so heavily sampled.

Linking the two groups by its nearly even distribution through both was *Turbinaria ornata.*

Wounding

The reaction of each of the *Eucheuma* species to wounding caused by grazing animals was different and characteristic. *Eucheuma arnoldii* was the most heavily preyed-upon of all the species studied, often being ground down to the level of the coral fingers through which its lower stems and branches protruded. Parrot-beaked fish of the type that normally feed on the stony corals (cf. Denizot, 1963:5) were probably responsible.

When a branch was eaten away, healing over by the pigmented cortex occurred slowly and without deformation of the branch (Fig. 11). In this way also, *E. arnoldii* further mimicked the appearance of corals, with their white scars left from broken tines.

What advantage such mimicry might offer the species is hard to see, particularly in light of the heavy grazing that does take place on it. The cystocarps tend to be borne in greatest abundance in the lower, more protected regions of even undamaged plants (Fig. 6, 11), a feature of obvious utility to a species so heavily grazed.

Water Movement

Eucheuma arnoldii was never found in surf zones, but seemed to prefer habitats where currents were relatively swift and the water free from silt. Unlike some other species of *Eucheuma*, it was never found in turbid, slack-water habitats. Its general absence from areas of sand deposition is also perhaps an indication of water-movement requirements.

Thallus forms which were decumbent and much secondarily attached were found most commonly at low-littoral depths. Corals seem to behave analogously, with low stubby pavements usually forming intertidally and at shallow subtidal depths, and with the more elaborate stalked forms typically occurring in deeper water. Deeper-growing thalli of *E. arnoldii,* such as were found at Nangalao, produced densely tufted heads of stout branches at the end of a single main stalk (Fig. 6), a growth habit that would certainly be vulnerable to the tearing action of waves or heavy swells in higher reaches.

Epiphytes

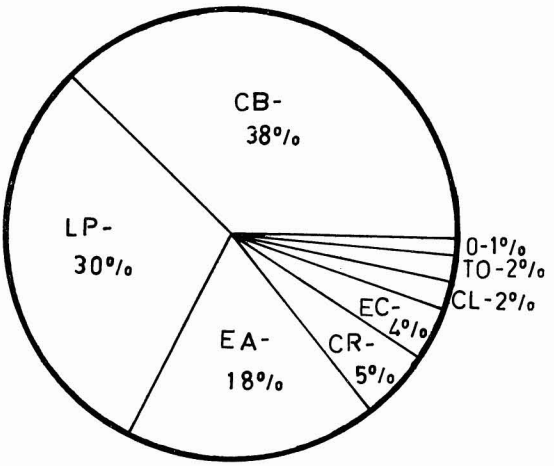
Although the thalli of *Eucheuma arnoldii* present extensive surfaces on which the growth of attached algae and animals might be expected to take place, there were no instances seen during the study of thalli hosting macroscopic epiphytes. In several instances *Laurencia cartilaginea* formed secondary attachments to *Eucheuma arnoldii*, but the basal holdfasts of the *Laurencia* were to the nonliving substratum.

DISCUSSION AND CONCLUSIONS

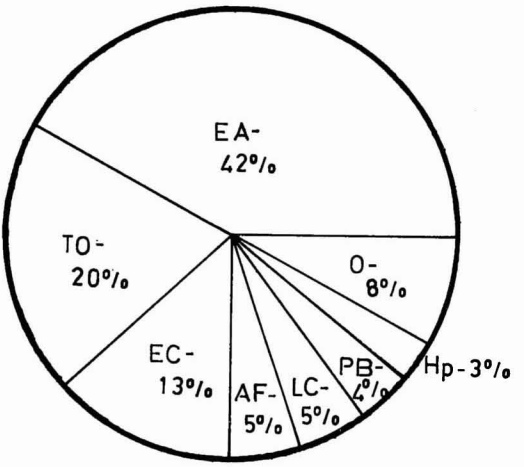
Because the length of the present study did not permit a determination of seasonal growth patterns and rates for *Eucheuma arnoldii*, future work may be needed to confirm reports of local harvesters in all three study areas that the species is present throughout the year. A more detailed study of the species in its natural habitats could also show how long the individual plants persist. Such information is needed if natural stocks of the alga are not to be depleted by too-frequent harvesting.

Closer observation of thallus development may show whether the alternating sequences of spinous annular collars and smooth "nodes" that characterize many *Eucheuma arnoldii* thalli (cf. Fig. 9) reflect succeeding periods of slow and rapid branch growth. Experiments with transplanted thalli might show this phenomenon

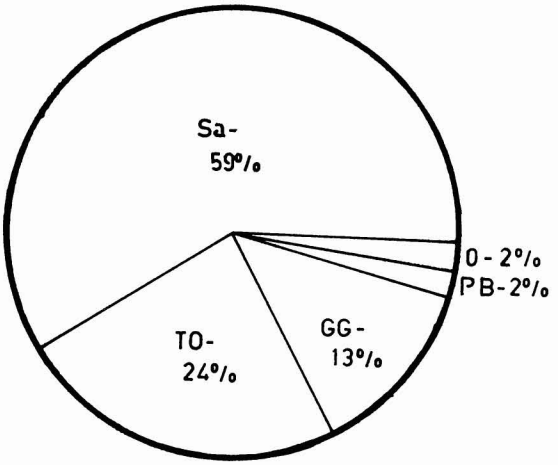
FIG. 18. The algal species composition, by wet weight, at two study sites as measured by the ring-throw sampling method. *a,* The *Eucheuma arnoldii* community at Panagatan; *b,* the *E. arnoldii* community at Hundred Islands; *c,* the non-*E. arnoldii* samples from the flats surrounding the community represented in "*b*" above. *AF, Amphiroa fragilissima; CB, Caulerpa brachypus; CL, Caulerpa racemosa* var. *laetevirens; CR, Caulerpa racemosa; EA, Eucheuma arnoldii; EC, Eucheuma cottonii; GG, Gracilaria gigas; Hp, Hypnea* sp.; *LC, Laurencia cartilagines* A; *LP, Laurencia papillosa; PB, Padina boryana; Sa, Sargassum* sp.; *TO, Turbinaria ornata; O,* other species.


CB-
38%
LP-
30%
EA-
18%
CR-
5%
EC-
4%
CL-2%
TO-2%
0-1%

a


EA-
42%
TO-
20%
EC-
13%
AF-
5%
LC-
5%
PB-
4%
Hp-3%
0-
8%

b


Sa-
59%
TO-
24%
GG-
13%
PB-2%
0-2%

c

TABLE 1

INDICES OF THE FREQUENCY WITH WHICH THE DOMINANT SPECIES (BY WET WEIGHT) OCCUR TOGETHER WITHIN THE 38 RING SAMPLES FROM THE HUNDRED ISLANDS SITE

SPECIES	*Eucheuma arnoldii*	*Laurencia cartilaginea*	*Hypnea* SPECIES	*Eucheuma cottonii*	*Turbinaria ornata*	*Amphiroa fragilissima*	*Padina boryana*	*Padina japonica*	*Gracilaria gigas*	*Sargassum* SPECIES
Group Number 1										
Eucheuma arnoldii	—									
Laurencia cartilaginea	57	—								
Hypnea species	57	67	—							
Eucheuma cottonii	25	36	57	—						
Turbinaria ornata	24	50	45	31	—					
Group Number 2										
Amphiroa fragilissima	20	38	24	30	47	—				
Padina boryana	13	27	18	38	44	57	—			
Padina japonica	12	18	19	00	31	40	00	—		
Gracilaria gigas	11	16	17	11	55	26	20	32	—	
Sargassum species	00	14	15	10	56	32	52	18	64	—

NOTE: Numbers are the result of applying the formula $C = 2Sj/Sa + Sb$, where Sj represents the number of joint occurrences of species "a" with species "b," and Sa and Sb are the total number of occurrences in the sampling of each of the two species, respectively. Numbers are arranged, as much as possible, so as to increase toward the right and decrease toward the bases of the columns. Group 1 includes species characteristic of the living coral reef. Group 2 includes species of the surrounding flats and traversing channels. Common to both groups in about equal frequency is *Turbinaria ornata*.

to be phenotypical, perhaps related to particular recurring patterns of tides.

Eucheuma arnoldii has not been used thus far in cultivation and physiological experiments. It would be useful to learn if growth can be maintained in cultures or on farms not immediately adjacent to stalked coelenterate corals, and whether the alga's spores can "set" in the absence of these animals. It will also be interesting to see if the type of coral present (whether hard or soft) exercises any control or influence over the ultimate mature habits of cultivated thalli.

I stated above that the range of coloration found among populations of *Eucheuma arnoldii* is very great. The narrow range of depths at which the thalli were found during the study seems to rule out differing light intensities as a simple cause of this phenomenon. At least one other *Eucheuma* species, *E. striatum*, behaves the same way in the Philippines, and further studies may show whether the variety of coloration simply reflects the different ages of the thalli or the influences of a greater complex of factors.

Although two varieties of *Eucheuma arnoldii* are recognized in this paper, the species as a whole is a distinctive and well delimited one within the genus *Eucheuma*. Its lack of medullary rhizoids and the vertical alignment of its branches should ensure that the species will not be confused with any other species of *Eucheuma* and, indeed, any other alga.

While some *Eucheuma arnoldii* was present in each of the three regions visited, only at the Hundred Islands was there a reef patch where it was the dominant *Eucheuma* species found. Even in this region, however, *E. arnoldii* was not widespread, and prior floristic studies of the Hundred Islands area by Menez (1961) and Domentay (1961) do not record it.

As seen so far in the Philippines, *Eucheuma arnoldii* is an alga of low-littoral to shallow sublittoral depths, restricted to habitats of silt-free, rapidly moving water, and to close association with the branched corals growing at or near the seaward margins of reefs.

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