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Geographic and Marine Isolation: An Assessment of the Marine Algae of Easter Island[1]

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ABSTRACT: The marine flora of Easter Island is one of the least known in the Pacific. Yet it appears as a most attractive flora because of its geographic isolation. This study reports the results of an expedition to the island, providing new records on the marine algal flora, giving the first description of the intertidal and shallow subtidal vegetation, and allowing for a first marine phytogeographic characterization of the island. There is a total of 166 taxa from this relatively small volcanic island to which 66 new records have been added. The marine algal flora of Easter Island appears rich and diverse as compared with that of other similar sized islands in the central Pacific and is monotonously similar in different habitats around the island. It is short and turfy in stature, composed mainly of species with wide geographic distribution in the tropics with a general affinity to the western Pacific. The previously reported 24% endemism of the marine flora is reduced to 14% by the current study, owing to the increased numbers of non-endemic taxa. In its Indo-Pacific relationship, the flora is similar in derivation to those invertebrates that have been studied.

EASTER ISLAND (27°07′ S; 109°22′ W), also known as Isla de Pascua, Tepito-Te Henua, or Rapa Nui, is one of the two Chilean geographic territories which does not fall within the influence of cold oceanic currents. Thus, the components of the marine algal flora can be expected to be quite different from those described for similar latitudes on the Pacific South American coasts (Howe 1914; Levring 1960; Dawson et al. 1964; Acleto 1973; Santelices and Abbott 1978; Santelices 1980).

In contrast to other islands in the central Pacific, Easter Island has a remarkably homogeneous topography and climate for most of its coastline. The island is small (106 km^2), triangular shaped, with a maximum length of 24 km and maximum width of about 12 km (Figure 1). Although it is hilly and relatively barren, maximum elevation is only 560 m above sea level. The coastline is characterized by cliffs with no beach and strand at their bases and an absence of sheltered bays. There are only three small sandy beaches characterized by coralline sand and surrounded by low cliffs (Anakena, La Perouse, and Ovahe; Figure 1). The winds are strong (normally 5–7 knots) and they change directions seasonally and daily. In January the predominant wind is E and SE, while in July it is NW, W, and SW. As a result, all parts of the island are exposed to storms and heavy swells at different times of the year. Data on other climatic elements (sunshine, relative humidity, cloudiness, precipitation, and temperature) show only small differences among the various points around the island. Therefore, the marine algal associations can be expected to be similar around most of the island, except in the few points where there are major topograhic changes.

Easter Island is one of the most isolated points in the Pacific Basin. It lies 4130 km west of the coast of Chile, almost equidistant from Antofagasta and Valparaíso. The nearest land to the east is Mas Afuera, an island in the Juan Fernández Archipelago about 3241 km away. The nearest land to the west is the uninhabited

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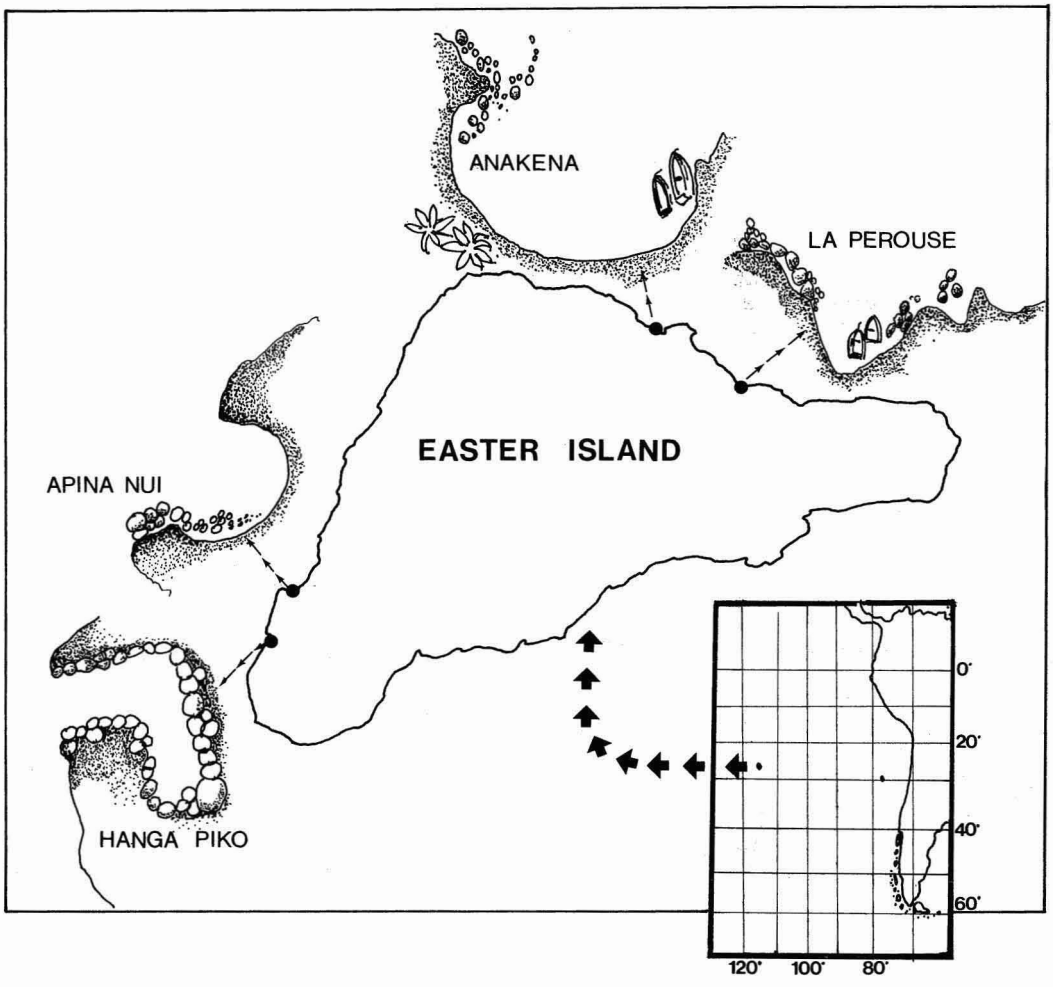

FIGURE 1. Map of Easter Island showing the study sites.

atoll Ducie Island 2315 km away, with Pitcairn Island 537 km further to the west. Algal collections at all of these sites would yield important insights into biogeographic relations, algal migration routes, and dispersion capacities.

So far, the knowledge of the marine algal flora of Easter Island is limited to two collections. The first was made by Skottsberg in intertidal habitats of a single locality (Hanga Piko) on the west side of the island. The sample included 20 "glasses" (volume not defined), a few herbarium specimens and a few stones with crustose coralline algae. The bulk of this collection was studied by Børgesen (1924) who identified 65 taxa, 24% of which were thought to be endemic. Later publications by Sjoestedt (1924), Petersen (1928), and Levring (1943) added one species of Phaeophyta, six species of Cyanophyta, and three species of calcareous Rhodophyta to the marine flora. In 1960, Etcheverry reported on 18 algal species collected by several people, adding four new records. Therefore, at present a total of 78 taxa of benthic algae is known for the island. This combined total includes seven species of Cyanophyta, nine Chlorophyta, 13 Phaeo-

phyta and 49 Rhodophyta. The subtidal flora of the island is incompletely known.

Due to the limited amount of material collected by Skottsberg, Børgesen did not attempt to make biogeographic or ecological characterizations of the island in 1924. He noticed, however, that as expected from its geographic situation, the flora was clearly subtropical in nature with a few tropical species. In addition, he remarked that most of the individuals in the several species found were small, with a creeping habit that produced strong haptera or rhizoids by which these individuals fastened to the substratum. Most of the species were low tufts, or cartilaginous. Børgesen interpreted these features as adjustments to the very strong surf that continually beats the shores of this extremely exposed island.

This study reports on three aspects of the marine flora of Easter Island. First, the results of a new taxonomic survey made in September 1981, are analyzed; second, ecological observations made during the floristic survey at various intertidal and subtidal habitats are provided with special emphasis on the type of algal associations found. Finally, the floristic affinities and the patterns of geographic distribution of this marine algal flora are discussed. A first report on the floristic similarities between Easter Island and other Pacific localities has been published elsewhere (Abbott and Santelices 1985).

STUDY SITES

The island was visited between 30 August and 10 September 1981. In the first three days, a rough survey of the island and a search for collecting places was conducted, in order to define habitats to be investigated.

Most of the coastline was volcanic rock with only a few sandy beaches. There were no natural ports and the few bays found were small and not sheltered. Wind direction and velocity changed frequently, and the few bays were rough when directly exposed to prevailing winds. The slope of the coast was steep, and intertidal and subtidal platforms, or exposed coral reefs, were infrequent.

Four localities were selected for further study. They represent the most different intertidal and shallow subtidal landscapes.

a) LA PEROUSE. This is a small bay on the northern side of the island used as a port by local people. Three types of habitats were explored here: volcanic rocky outcrops and platforms exposed to surf and wind; sheltered shallow lagoons with boulders 40–70 cm diam where sand is accumulated; and subtidal rocky outcrops normally surrounded by sand (down to 10 m depth).

b) ANAKENA BEACH. This is a sheltered, horse-shoe shaped bay northwest of La Perouse. Anakena is one of the few sandy beaches on the island and has volcanic rocky outcrops lining both sides of the bay. The outer east side of the rocky outcrops is exposed to waves. The rocky front gradually changes into flat, protected rocks as one moves southward onto the sandy beach. Closer to the beach the rocky platform is interrupted by extended sandy areas. In addition to these platforms, collections at Anakena included subtidal algae on rocks down to 8 m depth.

c) APINA NUI. This is a rocky area on the west side of the island, near Hanga Piko, the area in which Skottsberg collected in 1917. The area is representative of exposed and semi-exposed rocky intertidal with adjacent shallow subtidal habitats. The rocky exposed habitat in Apina Nui is similar to La Perouse. Pools and lagoons in Apina Nui, however, are more exposed to water movement than La Perouse and they do not accumulate sand. The only intertidal-shallow subtidal pool dominated by cerebriform corals found in the survey occurred at this locality. The subtidal of Apina Nui (down to 8 m) is volcanic rocks without sand accumulations.

d) HANGA PIKO. This represents the most sheltered intertidal situation on the island. It is a channel 200 m long and 20 m wide, built at right angles to the sea, used as a dock for small and medium-size boats. Boulders and stones are abundant in the bottom of the channel and they gradually merge into typically subtidal rocky plat-

forms similar to those described for Apina Nui.

MATERIALS AND METHODS

Each locality was studied during two consecutive low tides, normally within the same day. In the first tidal period, efforts were made to collect as completely as possible. In the second period, attention was drawn to a descriptive, qualitative survey of the various types of habitats and algal associations found in each locality. Also during the second visit taxa missed the first time were obtained. Collecting in the intertidal and subtidal was performed simultaneously by two persons. There were no facilities on the island for the use of SCUBA equipment, therefore diving was limited to depths of less than 10 m. Profiles relating to low water levels were constructed from diving and intertidal notes, including depths derived from wrist gauges or by direct measurements. Vegetation abundance and associations were derived from subjective estimates. Due to time and logistic limitations, quadrat reading was not possible.

All material was preserved in a solution of 5% formalin in seawater and transported to Santiago where large specimens were prepared as herbarium specimens and small ones kept in preservative for future study. The latter have subsequently been prepared as slide material. Both herbarium specimens and slide material are preserved in the Sala de Sistemática, Pontificia Universidad Católica de Chile in Santiago.

This study is restricted to the benthic Chlorophyta, Phaeophyta, and Rhodophyta. Since different systems of taxonomy are used for Cyanophyta, it seems best to omit them at this time. Some crustose Rhodophyta also have been excluded from this study because they were not specially collected during the survey.

Floristic comparisons between localities in the island have been based on numerical analyses. The degree of floristic similarity was calculated using Sorensen's (1948) coefficient of similarity. The resulting matrices were subjected to cluster analysis employing the weighted pair method (Sokal and Sneath 1963; Mueller-Dombois and Ellenberg 1974).

Close to 75% of the species reported from the island (in this or previous studies) was considered for the analysis of geographic affinities. All taxa with doubtful taxonomic position or validity were excluded. The geographic distribution of each species considered in the analysis was checked in a major floristic account for key geographic areas (e.g.: Setchell and Gardner 1920, 1925; Børgesen 1925–1930, 1941–1948; Hamel 1930, 1931, 1939; Taylor 1937, 1942, 1945, 1960; Okamura 1936; Feldmann 1937; Levring 1941, 1960; Dawson 1952–1958; Chapman 1956; Lindauer et al. 1961; Dawson et al. 1964; Pham-Hoang 1969; Acleto 1973; Santelices and Abbott 1978).

For geographic comparisons a number of selected Polynesian islands were used. Many of these islands are still poorly collected for marine algae and few modern examinations of species names have been conducted for the few places for which there is a known flora. Moreover, the nomenclature is for the most part out of date. Nevertheless, useful comparisons can be made with several island groups: with Samoa (Setchell 1924) and Tahiti (Setchell 1926) representing volcanic land masses somewhat similar in size to Easter Island; with atolls such as some of the Marshall Islands, including Eniwetak (Dawson 1956, 1957); with a continental tropical marine flora exhibited by Nha Trang, Vietnam (Dawson 1959); and finally with Juan Fernández Islands (Levring 1941) off the coast of Chile which, though tropical in location (ca 34°S), is bathed by cold, oceanic waters of the Perú Oceanic (Humboldt) Current. Comparisons included species distribution patterns and calculation of similarity values between the flora of Easter Island and each of these localities.

RESULTS

Taxonomy and Evaluation of Flora

A total of 107 species of benthic algae was identified from collections from Easter Island. All records of Chlorophyta, Phaeophyta, and

TABLE 1

RECORDS OF TAXA FROM EASTER ISLAND. Chlorophyta. Localities included in this study are La Perouse (LP), Anakena (AN), Apina Nui (AP), and Hanga Piko (HP). Footnotes refer to taxa under earlier names

SPECIES	BØRGESEN 1924	ETCHEVERRY 1960	THIS STUDY LP	AN	AP	HP
Ulva lactuca L.	+	+	+	+	+	+
Enteromorpha						
clathrata clathrata (Roth) Grev.	−	−	+	−	−	+
clathrata crinita (Roth) Hauck	−	−	+	−	−	+
compressa (L.) Grev.	−	−	+	−	−	+
flexuosa (Roth) J. Ag.	−	−	−	−	+	−
intestinalis (L.) Link	−	−	+	−	+	+
lingulata J. Ag.	−	−	+	−	+	−
salina Kuetz.	−	−	+	+	+	−
Chaetomorpha						
aerea (Dillw.) Kuetz.	−	−	−	+	+	+
linum (Muell.) Kuetz.	−	−	+	+	+	−
spiralis Okam.	−	−	+	+	−	−
Cladophora						
fascicularis (Mert.) Kuetz.	−	−	−	−	−	+
perpusilla Skottsb. & Levr.	−	−	+	+	−	−
socialis Kuetz.	+	+	+	−	+	−
Entoderma						
viride (Reinke) Lagerh.	+	−	+	+	−	−
Valonia						
ventricosa J. Ag.	+	−	+	+	+	−
Rhipidophyllon						
reticulatum (Asken.) Heydr.	+	−	+	+	−	−
Microdictyon						
japonicum Okam.[1]	+	−	+	−	+	−
Cladophoropsis						
herpestica (Mont.) Howe	−	−	+	−	+	−
sundanensis Reinb.	−	−	+	+	+	+
Rhizoclonium						
hookeri Kuetz.	−	−	−	−	−	+
Bryopsis						
hypnoides Lamour.	−	−	+	+	−	−
pennata Lamour.	−	−	+	+	+	+
Codium						
pocockiae Silva	−	+	−	−	−	−
spongiosum Kuetz.	−	−	−	+	+	+
Halimeda						
renschii Hauck[2]	+	+	+	−	+	−
tuna (Ell. & Sol.) Lamour.	−	−	+	+	−	−
Caulerpa webbiana Mont.	−	−	−	+	+	+
Acetabularia						
clavata Yamada	−	−	−	−	+	−
Ostreobium quekettii Born. & Flah.	+	−	−	−	−	−
Total (30 taxa)	8	4	21	15	17	12

[1] As *Microdictyon umbilicatum*.
[2] As *Halimeda opuntia* Lamour.

Rhodophyta so far reported from Easter Island are included in Tables 1, 2, and 3. Reports of Cyanophyta have been excluded from these tables as this group of organisms have not been considered in this study. Also excluded from these tables are the report of Levring (1943) of *Lithothamnion mesomorphum* Foslie, *Porolithon craspedium* Fos-

TABLE 2

RECORDS OF TAXA FROM EASTER ISLAND. Phaeophyta. Localities included in this study are La Perouse (LP), Anakena (AN), Apina Nui (AP), and Hanga Piko (HP)

SPECIES	BØRGESEN 1924	ETCHEVERRY 1960	THIS STUDY LP	AN	AP	HP
Ectocarpus						
breviarticulatus J. Ag.	+	+	−	−	−	−
chnoosporae Børg.	+	−	−	−	−	−
Giffordia						
duchassaingianus (Grun.) Tayl.	−	−	−	+	+	−
mitchelliae (Harv.) Ham.[1]	−	−	+	+	+	−
Feldmannia						
indica (Sond.) Wom. & Bail.	−	−	+	−	−	−
rhizoidea Hollen. & Abb.	−	−	−	+	+	−
Mesospora						
vanbosseae Boerg.	+	−	−	−	−	−
pangoensis (Setch.) Chihara	−	−	−	+	−	−
Ralfsia expansa J. Ag.	+	−	−	−	−	−
Elachista (?) sp.	+	−	−	−	−	−
Colpomenia						
sinuosa (Roth) Derb. & Sol.	+	+	+	+	+	+
Hydroclathrus						
clathratus (Bory) Howe[2]	+	+	+	+	+	+
Chnoospora						
fastigiata J. Ag.	+	−	+	−	−	−
Sphacelaria						
species	+	−	−	−	−	−
novae-hollandiae Sond.	−	−	+	+	+	+
taitensis Setch.	−	−	−	+	+	−
Dictyopteris						
australis (Sond.) Ask.	−	−	+	−	−	−
delicatula Lamour.	−	−	+	−	−	−
repens (Okam.) Boerg.	+	+	−	−	−	−
Dictyota						
acutiloba J. Ag.	−	−	−	Hanga	maikihu	−
cervicornis Kuetz.	−	+	−	−	−	−
crenulata J. Ag.	−	−	+	+	−	+
Lobophora						
variegata (Lamour.) Wom.[3]	+	+	+	+	+	+
Padina						
australis Hauck	−	−	−	+	−	+
Zonaria						
crenata J. Ag.	+	+	−	−	−	−
stipitata Tan. & Noz.	−	−	+	+	+	+
Stypopodium						
flabelliforme W. v. B.	−	−	+	+	+	+
Sargassum						
skottsbergii Sjoest.	+	+	+	+	+	−
Total (28 taxa)	13	8	13	14	11	8

[1] As *Ectocarpus mitchellae*.
[2] As *Hydroclathrus cancellatus*.
[3] As *Zonaria variegata*.

lie, and *Jania rubens* Lamour., collected by Skottsberg at Hanga Piko and a small collection made during our study at Tahai on the west side of the island, close to Apina Nui which contained eight species already included in Tables 1, 2, and 3 (*Ulva lactuca, Enteromorpha compressa, Cladophoropsis herpestica, Colpomenia sinuosa, Lobophora variegata, Zonaria stipitata, Sargassum skottsbergii* and *Gelidiella* sp.). The study of various taxa motivated taxonomic or biogeographic comments, which are included in Table 4.

Our collection includes 41 of the 65 taxa listed by Børgesen (1924). Most of the 24 species missing are either crustose calcareous algae not considered in this study or species likely to be overlooked in the field because of small size (e.g. *Ectocarpus* spp., *Elachista* sp., *Acrochaetium* spp.) or of crustose morphology (e.g.: *Ralfsia, Cruoriopsis*). All 17 species listed by Etcheverry (1960) have been collected again, with the exceptions of *Codium pocockiae* and *Dictyota cervicornis. Codium pocockiae* was identified by Silva (Etcheverry 1960) and collected at the low intertidal in Hanga Piko and Hanga Roa. Repeated visits to the same habitat failed to yield the species. The records of *Dictyota cervicornis* may never be verified. Although its taxonomic status is not well understood, we are reasonably certain that Etcheverry's identification is incorrect (see Table 4).

In addition to the 42 previous records, our collection contains 66 new records which includes 21 species of green algae, 15 brown algae and 30 species of red algae, giving a combined total from all reports of 144 species from Easter Island. Among these, 7 (4.9%) are Cyanophyta, 30 (20.8%) are Chlorophyta, 28 (19.4%) are Phaeophyta, and 79 (54.9%) are Rhodophyta.

Although a small number of specimens has yet to be identified to species level (Tables 1, 2, 3, and 4), we expect less than five taxa to be added as new records from these collections. The possibilities of increasing the number of endemic species to the island is therefore reduced. In light of these new findings the 24% of endemism proposed by Børgesen is likely to be reduced to less than 14% due to increase in number of non-endemic species found in the present study.

The R/P and R&C/P indices (Sorenson, 1948) calculated on the 144 species so far reported from Easter Island result in values of 2.8 and 3.9 respectively which are considered to be intermediate between cold-water or temperate floras and a tropical flora.

A floristic comparison between the four localities visited on the island indicates (Figure 2) that Anakena, La Perouse, and Apina Nui share close to 60% of the species found at each locality. Anakena and La Perouse have the closest floristic similarity especially when Chlorophyta and Rhodophyta are considered. Hanga Piko, an artificial dock, is the floristically most different locality. The difference, however, does not result from a unique flora for Hanga Piko but from a large reduction in the number of Rhodophyta and Chlorophyta as compared to the other sites. The floristic dissimilarity is slightly over 50%.

Ecological Observations

EULITTORAL VEGETATION: The eulittoral vegetation changes in relation to tidal height, exposure to wave impact, and presence of grazers. For descriptive purposes, ecological descriptions have been arranged in order of decreasing exposure to wave impact and an upper and a lower intertidal zone have been distinguished at each locality (Figure 3).

Exposed Localities: Both La Perouse and Apina Nui are exposed localities but most of the island coastline is equally exposed.

The upper intertidal shows a patchy vegetational cover which is abundant in some areas and absent in others. Patches are composed of short tufts of *Cladophora socialis, Giffordia duchassaingianus, Sphacelaria novae-hollandiae*, filamentous bluegreens, *Porphyra* sp., and short thalli of *Chnoospora fastigiata.* Upper intertidal pools are abundant especially at Apina Nui and they were monopolized by *Ulva lactuca, Cladophora perpusilla* and *Laurencia claviformis.* In the upper-most shallow tidal pools, *Lyngbya* sp. and diatoms are the dominant vegetation.

TABLE 3

RECORDS OF TAXA FROM EASTER ISLAND. Rhodophyta. Localities included in this study are La Perouse (LP), Anakena (AN), Apina Nui (AP), and Hanga Piko (HP)

SPECIES	BØRGESEN 1924	ETCHEVERRY 1960	THIS STUDY LP	AN	AP	HP
Goniotrichum						
alsidii (Zan.) Howe	–	–	–	–	+	–
elegans (Chauvin) LeJol.	+	–	+	+	+	–
Erythrotrichia						
carnea (Dillw.) J. Ag.	+	–	+	+	+	+
Erythrocladia						
laurenciae Børg.	+	–	–	–	+	–
subintegra Rosenv.	+	–	–	–	+	–
vagans Børg.	+	–	–	–	–	–
Porphyra sp.	–	–	+	–	–	–
Acrochaetium						
catenatulum Howe	–	–	+	+	+	–
discoideum Børg.	+	–	–	+	–	–
moniliforme Rosenv.	+	–	–	–	–	+
ralfsiae Børg.	+	–	–	–	–	–
Yamadaella sp.	–	–	+	+	–	–
Galaxaura						
collabens J. Ag.	+	+	+	–	+	+
(smooth form)	+	–	+	+	+	–
paschalis Børg.	+	–	+	+	+	–
Asparagopsis						
taxiformis (Del.) Coll. & Herv.	–	–	–	–	+	–
Falkenbergia						
rufolanosa (Harv.) Schmitz	+	–	+	+	+	–
Gelidium						
pusillum (Stachkh.) Le Jol.	+	+	–	–	+	–
Gelidiella sp.	–	–	–	–	+	–
Pterocladia						
capillacea (Gmel.) Born. & Thur.	–	–	–	+	+	–
Rhizophyllis						
pacifica Børg.	+	–	–	–	–	–
Peyssonellia sp.	–	–	+	–	–	–
rubra (Grev.) J. Ag.	–	–	–	–	–	+
Cruoriopsis						
dezawanii Web. v. Bosse	+	–	–	–	–	–
Ethelia						
pacifica Web. v. Bosse	+	–	–	–	–	–
Lithothamnion						
siamense Fosl.	+	–	–	–	–	–
Lithophyllum						
rasile Fosl.	+	–	–	–	–	–
samoensis Fosl.	+	–	–	–	–	–
Neogoniolithon						
myriocarpum (Fosl.) Adey[1]	+	–	–	–	–	–
Melobesia						
accola (Fosl.) Lem.	+	–	–	–	–	–
paschalis Lem.	+	–	+	–	–	–
Porolithon						
onkodes (Heydr.) Fosl.	+	+	–	–	+	–
gardineri (Fosl.) Fosl.	–	–	–	–	+	–
Amphiroa						
fragilissima (L.) Lamour.	+	–	+	+	+	+
yendoi Børg.	+	–	–	+	–	–
Jania tenella Kuetz.	+	–	+	–	+	–
Choreonema						
thuretii (Born.) Schmitz	–	–	+	–	–	–
Corallina sp.	–	–	+	–	+	–
Nemastoma sp.	–	–	–	–	–	+

TABLE 3 (continued)

SPECIES	BØRGESEN 1924	ETCHEVERRY 1960	THIS STUDY LP	AN	AP	HP
Predaea weldii Kraft & Abb.	−	−	+	−	−	−
Gelidiopsis						
acrocarpa (Harv.) Schm.	−	−	−	+	+	−
variabilis (Grev.) Schm.	−	−	+	+	+	−
Hypnea cenomyce J. Ag.[2]	−	−	+	+	+	+
esperi Bory	+	−	−	−	−	−
species[3]	+	−	−	−	−	−
Gracilaria sp.	−	−	−	−	+	−
Gymnogongrus aequicrassus Børg.	+	−	−	+	+	−
Botryocladia[4]						
skottsbergii (Børg.) Levr.	+	−	+	−	−	−
Champia						
parvula (C. Ag.) Harv.	−	−	+	+	+	−
species	+	−	−	−	−	−
Crouania attenuata J. Ag.	+	−	−	−	−	−
Ptilothamnion						
pluma (Dillw.) Thuret.	+	−	+	−	−	−
subsimplex Gordon	−	−	+	+	−	−
Callithamnion						
paschale Børg.	+	−	+	−	−	−
Pleonosporium sp.	−	−	−	−	+	−
Carpoblepharis						
schmitziana (Reinb.) Okam.	+	−	−	−	−	−
Ceramothamnion codii Rich.	+	−	−	−	−	−
Corallophila (?) sp.	−	−	−	−	+	−
Centroceras						
clavulatum (C. Ag.) Mont.	−	+	+	+	+	+
Ceramium						
cruciatum Coll. & Herv.	+	+	+	+	+	+
skottsbergii Peters.	+	+	+	+	−	−
Laurencia						
claviformis Børg.	+	−	+	+	+	+
Chondria						
dasyphylla (Good. & Wood.) C. Ag.	−	−	−	+	−	+
repens Børg.	+	−	−	+	+	+
Polysiphonia						
species	+	−	−	−	−	−
savatieri Har.	−	−	+	+	+	−
scopulorum var. villum (J. Ag.) Holl.	−	−	+	+	+	−
Lophosiphonia						
cristata Falk.	−	−	−	+	+	−
Herposiphonia						
pacifica Holl.	−	−	+	+	−	−
tenella (C. Ag.) Ambronn.	+	−	−	−	+	−
species	−	−	−	−	+	−
Dipterosiphonia						
dendritica (C. Ag.) Falk.	+	−	+	+	−	−
Dasya						
villosa Harv.	+	−	−	−	−	−
species	−	−	+	−	−	−
Taenioma perpusillum J. Ag.	−	−	+	+	−	−
Nitophyllum sp.	+	−	−	−	−	−
Heterosiphonia						
wurdemanni (Bail.) Falk.	−	−	−	−	+	−
Total (76 taxa)	45	6	33	29	37	12

[1] As *Lithophyllum myriocarpum*.
[2] As *Caulacanthus spinellus*, Etcheverry (1960).
[3] As *Caulacanthus spinellus*, Børgesen (1924).
[4] As *Chrysymenia skottsbergii*.

TABLE 4

TAXONOMIC AND GEOGRAPHIC COMMENTS ON SELECTED SPECIES

Cladophoropsis herpestica
The presence of this species in Easter Island confirms its pervasive distribution throughout the South Pacific from temperate to tropical waters.

Microdictyon japonicum
Setchell (1929) referred to *M. japonicum* the material identified by Børgesen (1924) as *M. umbilicatum*. In general, thalli of *M. japonicum* show more delicate blades and the color is a lighter green than in *M. umbilicatum* even while bearing in mind that species of *Microdictyum* show relatively wide variation in such features. The Easter Island material strongly resembles *M. japonicum* as recognized in Hawaii.

Acetabularia clavata
In the field this species can be found at the base of eroded corals together with crustose coralline algae, *Sphacelaria novae-hollandiae*, *Lobophora variegata*, and *Lophosiphonia cristata*, commonly between 1–1.5 m deep.

Dictyopteris repens
This taxon, and *D. delicatula* are relatively small in stature (as compared to *D. australis*, for example) and it may be that only one species is involved here.

Dictyota cervicornis
In the Caribbean, this is a well-marked species with one member of a dichotomy frequently short and spurlike and the margins occasionally with teeth. Neither of these features is shown in the illustrations of Etcheverry (1960), and none of the four specimens identified with *Dictyota* showed these features, either. This species is probably not in the Easter Island flora.

Padina australis
As interpreted by Allender and Kraft (1983) this species is closely related to *P. tenuis* Bory, differing in details of reproductive areas. Since our material was sterile, it is not possible to be certain as to specific attribution, but only to note that there is a 2-cell thick species in the flora.

Zonaria stipitata
Since first described by Tanaka and Nozawa (1962), this species has been collected, though not published upon, from widely different geographic areas in the Pacific. It has been reported recently by Chiang (1981) from Taiwan, and specimens (Herb. B. P. Bishop Museum) have been examined (Abbott, unpublished) from the Marquesas Islands (leg. J. Newhouse), Pitcairn Island, and New Caledonia (leg. P. McKown). The long, cylindrical stipes with hairy basal portions are distinctive. Depending upon the location of the sections through a blade, the sections may show a 3- or 4-layer medulla with a 1-layered cortex on each side. Womersley (1956) believed that Børgesen's recognition of *Z. crenata* from Easter Island was incorrect; we agree with this opinion. Etcheverry's (1960) identification of *Z. crenata*, as shown by his description and illustrations, is also in error. His plant is almost certainly *Stypopodium flabelliforme* which we found to be plentiful and at every station on the island. The 2-celled medulla that Etcheverry shows (Etcheverry 1960, pl. 4, fig. 2) is not that of *Zonaria* but characteristic of the upper portion of the blades of *Stypopodium* (Abbott 1977).

Yamadaella sp.
This taxon externally reminds one of a *Liagora* because of the pigmented hairs protruding through a calcium carbonate layer, or of a rigid *Galaxaura*. Internally, it is closer to *Galaxaura* because of its multiaxial medulla and large-celled cortex, which, however, is not differentiated between the outer (modified) "epidermal" layer and the colorless cortex of *Galaxaura*. Instead, the cortex is composed of pseudoparenchymatous filaments, and thus unlike either *Liagora* or *Galaxaura*. In terms of reproductive structures, it resembles *Liagora*.

Coralline algae
Lemoine in Børgesen (1924) reported upon more crustose coralline taxa than we found, which does not indicate a poor coralline flora but only that they were not collected. However, a special "parasitic" relationship with *Jania* is shown with abundant male, cystocarpic and tetrasporangial plants of *Choreonema thuretii*, known from the Atlantic coast of France, and Southern California south to Costa Rica (Abbott and Hollenberg 1976), and from the central Pacific (Taylor 1950).

Hypnea cenomyce
Species of *Hypnea* are hazardous to identify, even with large numbers of plants. Our collections, while common at all stations did not provide great variation. From the habit and branching pattern, and the encircling tetrasporangial sori, *Hypnea cenomyce* seems to be a better identification than some other species, including *H. esperi* of Børgesen (1924). We believe that *Caulacanthus spinellus* of Etcheverry (1960) is probably a species of *Hypnea*.

Gracilaria sp.
The small (3 cm tall), sterile plants found were too young to identify to species.

Botryocladia skottsbergii
This species is also known as *B. kuckuckii* (Weber van Bosse) Yamada and Tanaka (a synonym) from the central Pacific (Bikini Atoll), the western Pacific (Southern Japan into Indonesia), and Hawaii.

Pleonosporium sp.
Growing from the genicula of Corallina the plants were tetrasporangial.

Chondria repens
When first described, this was one of the endemic taxa, but it has since been reported from southern Japan, the Marshall Islands, and Hawaii and can be expected to be more widely distributed.

Taenioma perpusillum
Both tetrasporangial and spermatangial thalli were collected. As known elsewhere in the Pacific, it is a common component of turf.

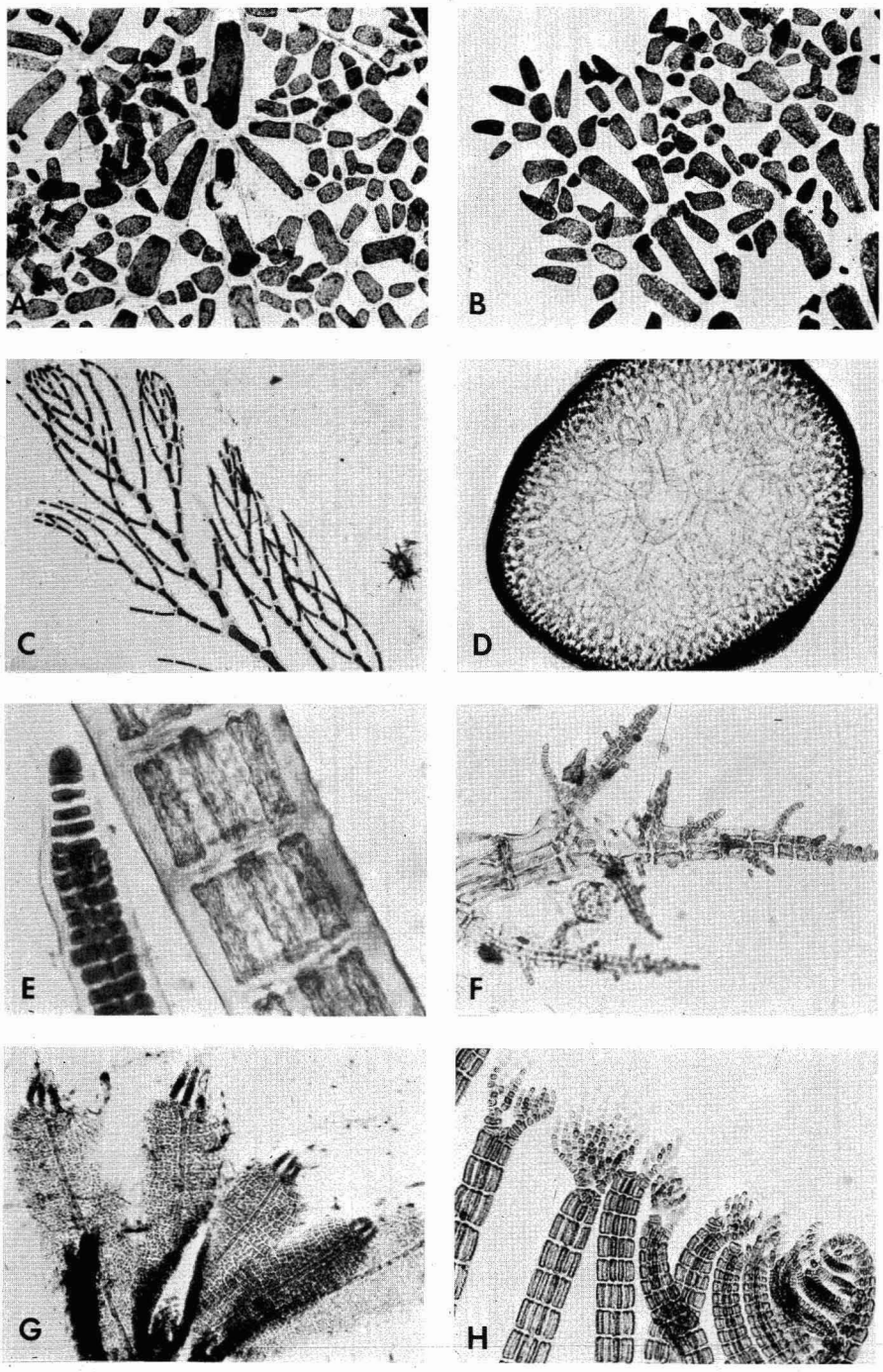

FIGURE 2. Selected species of benthic algae from Easter Island. *A*, *Microdictyon japonicum* from La Perouse (LP). *B*, *Rhipidophyllum reticulatum* from LP. *C*, *Callithamnion paschale* from LP. *D*, Transection of *Gracilaria* sp. from Apina Nui (AP). *E*, *Polysiphonia scopulorum* v. *villum* from AP. *F*, *Dipterosiphonia dendritica* from Anakena (AN). *G*, Spermatangia of *Taenioma* from AN. *H*, *Herposiphonia pacifica* from AN.

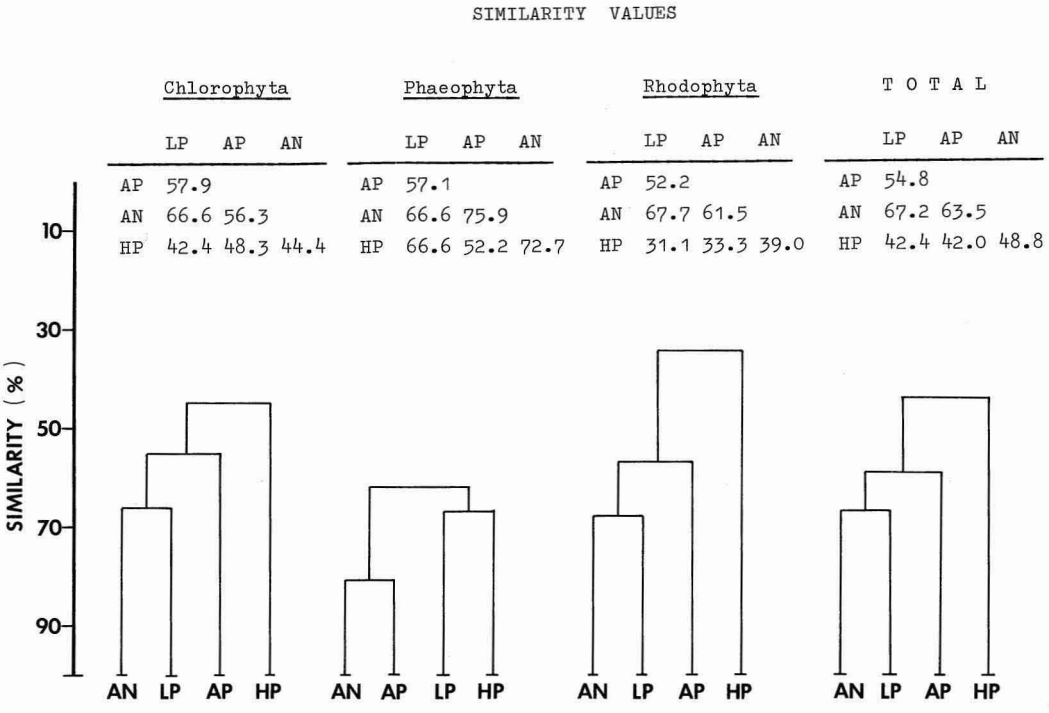

FIGURE 3. Floristic comparisons between four localities studied at Easter Island. LP: La Perouse; AP: Apina Nui; AN: Anakena; HP: Hanga Piko.

The low intertidal and shallow subtidal is devoid of erect frondose algae and covered by a pink crustose coralline algae. The rocks have variable densities of red sea urchins (1–10 individuals/m^2) in sizes ranging from 3 to 10 cm in test diameter and living in holes bored into the rocks. Erect, frondose algae are abundant in areas with reduced densities of sea urchins. There, *Sargassum skottsbergii* dominates between 0 and 2 m deep, sometimes completely covering the rock surface. Rounded cushions of *Hypnea esperi* and *Cladophora socialis* are common among the haptera of *Sargassum*. Short tufts of ectocarpoids and of *Sphacelaria novae-hollandiae* are frequent epiphytes either on *S. skottsbergii* or on *Cladophora*.

In the rocky platforms there are shallow subtidal (1–2 m deep) pools with boulders and large rocks. The algal associations found may also depend on the intensity of water movement. In pools with frequent water exchange there is no sand accumulation between boulders. In the upper intertidal levels of stones and boulders (about 0.5 m above low water levels), small rosettes of *Ulva lactuca* and cushions of *Hypnea spinella* are common. In deeper levels, the vegegation is turf-like, dominated by *Amphiroa fragilissima*, *Jania tenella*, *Laurencia claviformis*, and *Corallina* sp. In deeper positions of the pools, (2–3 m below low water) this surf community is replaced by an algal association dominated by *Pterocladia capillacea*, *Gelidiopsis scoparia*, *Valonia ventricosa*, and crusts of *Lobophora variegata*. *Sargassum skottsbergii* can be locally abundant at these depths and becomes larger and most abundant with increasing depth.

More sheltered shallow subtidal pools (e.g. at La Perouse) show sand accumulation among boulders. Here the lowest level of vegetation ($\pm$2 m below zero level) is formed by individuals of *Sargassum skottsbergii* and medium-sized individuals of *Zonaria stipitata* and *Stypopodium lobatum*. Between boulders with large amounts of sand, two different

types of associations can be found. One is turf-like, formed principally by *Amphiroa fragilissima*, *Jania tenella*, *Gelidium pusillum*, and *Ptilothamnion pluma*. The other is cushion-like formed by *Hypnea cenomyce*, *Colpomenia sinuosa*, and *Hydroclathrus clathratus*. The upper level of vegetation in the boulders (0.5 m above low water) contains bands of *Ulva lactuca* and *Enteromorpha clathrata*.

Sheltered Localities: The only sheltered intertidal habitats found on the island are the southward extension of the rocky outcrops lining Anakena Beach and the artificial dock built in Hanga Piko.

The low intertidal of the sheltered rocky outcrops of Anakena is dominated in cover and biomass by elongated and branched thalli of *Sargassum skottsbergii*. The level immediately above is dominated by *Ceramium skottsbergii*, *Ulva lactuca*, *Hydroclathrus clathratus*, *Centroceras clavulatum* and *Colpomenia sinuosa*. Sand accumulates on and around these rocky outcrops. Closer to the sandy beach, the continuity of the rocky platforms is interrupted by extended sandy areas. *Codium spongiosum*, *Gelidiopsis scoparia*, and large mats of *Ceramium skottsbergii* are the most conspicuous organisms on these rocks.

The sheltered dock of Hanga Piko contains boulders and stones with luxuriant growth of *Ulva lactuca*, *Chaetomorpha linum*, *Enteromorpha compressa*, *Enteromorpha intestinalis*, *Bryopsis pennata* (often represented by detached free-floating rounded cushions), large mats of *Caulerpa webbiana*, *Centroceras clavulatum*, and several species of *Polysiphonia*. In the shallow subtidal, long plants of *Sargassum skottsbergii* heavily loaded with epiphytes are common.

SUBTIDAL VEGETATION: Below 2–3 m deep the vegetation in all the localities visited is dominated by *Sargassum skottsbergii*, *Zonaria stipitata*, and *Lobophora variegata*. At La Perouse, the subtidal rocky platforms (4–8 m deep) have, in addition, good representation of *Microdyction japonicum* epiphytic on *Zonaria* and *Lobophora* and scattered individuals of *Galaxaura collabens*. In Tahai-Apina Nui, the subtidal has, in addition to the three brown algae, abundant *Asparagopsis taxiformis*. The subtidal vegetation at Anakena is fully dominated by *Lobophora variegata* and *Sargassum skottsbergii* while the deeper end of the dock in Hanga Piko (4–7 m deep), has abundant representation of *Dictyota crenulata*, *Padina australis*, and *Galaxaura collabens* in addition to *S. skottsbergii*, *L. variegata*, and *Z. stipitata*.

Geographic Relations

FLORISTIC AFFINITIES: The benthic algal flora of Easter Island comprises five groups of species with different patterns of geographic distribution (Table 5). About 35.6% of the flora (36 species) are species with wide distribution in both temperate and tropical waters. About 23.8% (24 species) are species of wide distribution in warm waters, many of which have been reported from localities in the Central Pacific, the Caribbean, and the Indian Ocean. Twenty-one species (20.7%) have a west Pacific (Indo-Pacific) pattern of distribution. Some of these species are restricted to a few islands in Polynesia; others are present also in Malaysia, northern Australia, Vietnam, Japan, and a few reach northern New Zealand.

A fourth group is represented by 14 endemic species (13.9%), most of them Rhodophyta. No endemic species of Chlorophyta have been reported for the island and only three Phaeophyta are recognized as endemic.

The fifth group is composed of six species found only in a few other localities in addition to Easter Island. One of these is biogeographically interesting because it corresponds to a species also found in Juan Fernández (*Cladophora perpusilla*). Four other species have been found in California (*Feldmannia rhizoidea*, *Fosliella paschalis*, and *Callithamnion paschale*) and California and Japan (*Chaetomorpha spiralis*) and could result from the same taxonomist (I. A. Abbott) working both floras. The sixth case in this group is rather puzzling and is represented by *Codium pocockiae*, reported previously only from South Africa.

COMPARISON OF MARINE FLORAS FROM SELECTED ISLANDS: Data in Table 6 indicate

TABLE 5

EXAMPLES OF PATTERNS OF GEOGRAPHIC DISTRIBUTION OF BENTHIC ALGAE REPORTED FROM EASTER ISLAND

GROUP 1	GROUP 2	GROUP 3
SUBCOSMOPOLITAN OR OF WIDE DISTRIBUTION IN TEMPERATE AND TROPICAL WATERS	WIDE DISTRIBUTION IN WARM WATERS	WEST PACIFIC PATTERN OF DISTRIBUTION
1. *Ulva lactuca*	1. *Valonia ventricosa*	1. *Cladophora socialis*
2. *Enteromorpha compressa*	2. *Caulerpa webbiana*	2. *Microdictyon japonicum*
3. *Chaetomorpha aerea*	3. *Codium spongiosum*	3. *Cladophoropsis herpestica*
4. *Bryopsis hypnoides*	4. *Hydroclathrus clathratus*	4. *Dictyopteris australis*
5. *Giffordia mitchelliae*	5. *Lobophora variegata*	5. *Padina australis*
6. *Ralfsia expansa*	6. *Sphacelaria novae-hollandiae*	6. *Zonaria stipitata*
7. *Colpomenia sinuosa*	7. *Asparagopsis taxiformis*	7. *Lithophyllum samoense*
8. *Gelidium pusillum*	8. *Porolithon onkodes*	8. *Predaea weldii*
9. *Pterocladia capillacea*	9. *Hypnea esperi*	9. *Botryocladia skottsbergii*
10. *Centroceras clavulatum*	10. *Gelidiopsis variabilis*	10. *Chondria repens*

GROUP 4	GROUP 5	
ENDEMIC TO EASTER ISLAND	SHORT RANGE DISTRIBUTION	DISTRIBUTION ELSEWHERE
1. *Ectocarpus chnoosporae*	1. *Cladophora perpusilla*	J. Fernández
2. *Sargassum skottsbergii*	2. *Chaetomorpha spiralis*	Japan, California
3. *Mesospora vanbosseae*	3. *Codium pocockiae*	South Africa
4. *Erythrocladia vagans*	4. *Feldmannia rhizoidea*	Central California
5. *Acrochaetium discoideum*	5. *Fosliella paschalis*	California, Revillagigedo
6. *Galaxaura paschalis*	6. *Callithamnion paschale*	California and Gulf of California
7. *Ethelia pacifica*		
8. *Amphiroa yendoi*		
9. *Ceramium skottsbergii*		
10. *Laurencia claviformis*		

TABLE 6

NUMBER OF SIMILAR TAXA FROM SELECTED PACIFIC ISLANDS

	TOTAL # GENERA	# OF COMMON GENERA	TOTAL # SPECIES	# OF COMMON SPECIES
Easter Island	85		135	
Samoa (Setchell, 1924)	43	31	67	13
Marshalls (Dawson, 1956)	75	42	141	30
Eniwetak (Dawson, 1957)	91	55	176	30
Nha Trang (Dawson, 1959)	98	53	132	18
Tahiti (Setchell, 1926)	68	46	123	33
Juan Fernández (Levring, 1941)	64	30	94	9

the total and shared number of genera and species between Easter Island and several other islands in the west Pacific. Numbers in Figure 4 refer to similarity values calculated from these numbers.

The number of genera shared among these localities is relatively high and is testimony to the commonality of genera in the tropics. On the other hand, the number of species shared is very much reduced. This is surprising since

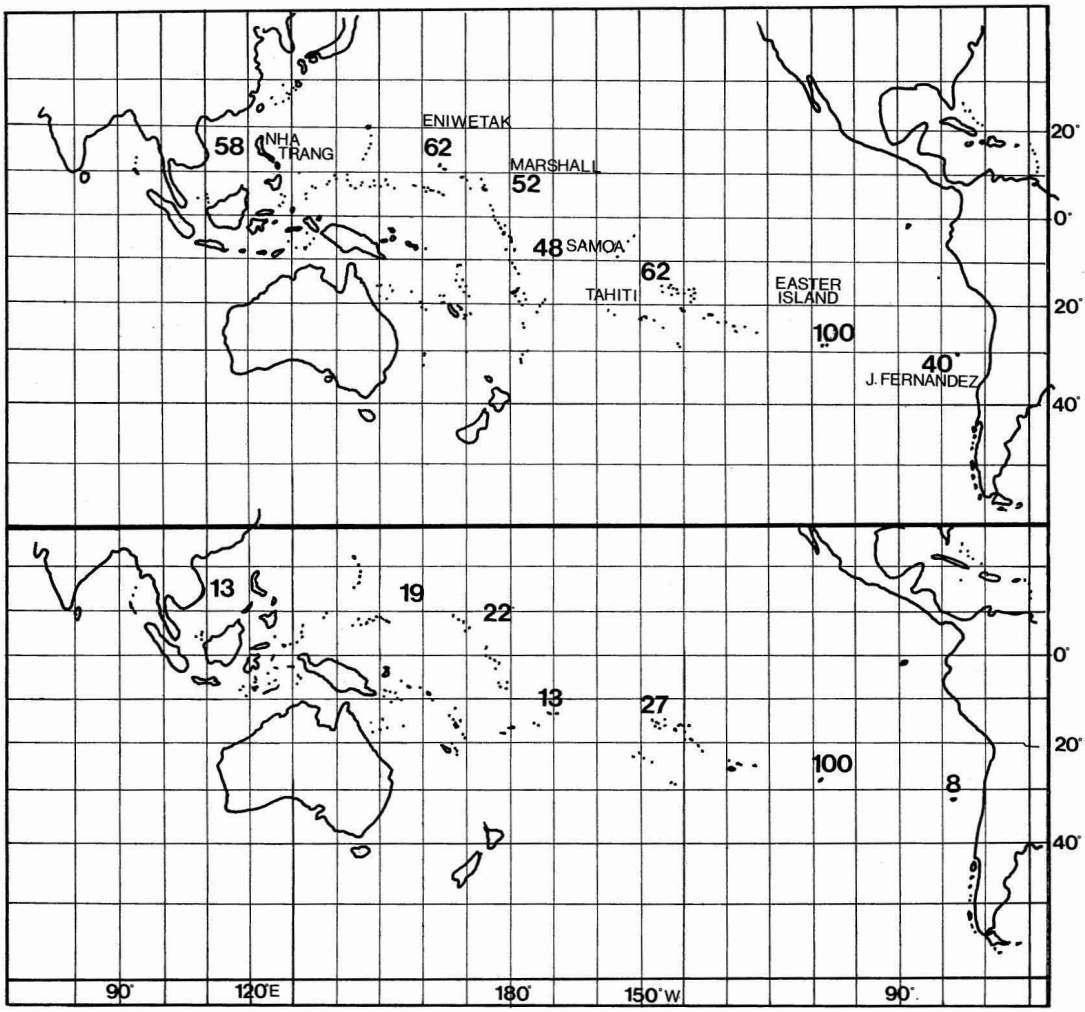

FIGURE 4. Similarity values between the marine algal flora of Easter Island and six other locations in the central Pacific. Values in upper map are based on genera; those in the lower map are based on species of algae.

79.2% of the flora of Easter Island is composed of species with wide distribution either in temperate and warm waters (group 1; Table 5), in warm waters (group 2; Table 5), or in the west Pacific (group 3; Table 5).

The similarity values between the flora of Easter Island and other localities in the west Pacific decreases as distance increases. However, even the most remote western locality considered (Nha Trang) maintains a higher similarity value than the nearby eastern Juan Fernández.

DISCUSSION

The results add 66 new records to the marine algal flora of Easter Island, giving a first description of the intertidal and shallow subtidal vegetation and allowing for a first phytogeographic characterization of the flora.

Although there are essentially only two major collections from Easter Island, that by Skottsberg (Børgesen 1924) and the one in this study, we believe that except for deep subtidal algae and coralline algae, the bulk of taxa is

now known for this remote volcanic island. The resulting list of 135 species of marine algae from Easter Island compares the flora favorably to the number from the more intensively collected Southern Marshall Islands (Dawson 1956) and Eniwetak in the Northern Marshall Islands (Dawson 1957) where 149 and 192 taxa respectively have been reported. Earlier collections from Bikini and the Northern Marshalls (Taylor 1950) yielded about 150 species. Intensity of collecting in the Marshall Islands makes those reports among the best known in the Pacific islands for useful comparison with collections from Easter Island and elsewhere. The larger high islands which should show a richer number of species have not been collected as thoroughly as the low Marshall Islands, and the conclusions on distribution patterns that apply to marine and terrestrial organisms and flowering plants (Kay 1980) cannot be applied to the marine algae at this time. From Pitcairn Island in the immediate west, only 21 species are reported by Tsuda (1976) and no other island or island group has been examined carefully for algal species, except Tahiti which is imperfectly known with 123 species reported (Setchell 1926). To the east of Easter Island, cold oceanic currents, whose major thrust is to the north, are likely to prohibit transfer of all but the hardiest of algal propagules. Therefore the diversity of the Juan Fernández marine flora cannot be compared because it is rather temperate in character with a high degree of endemism (32%).

From the ecological point of view, the vegetation of Easter Island appears as rather monotonous, having a similar construction in most localities visited. The high floristic similarity values found when comparing the flora of the subjectively estimated "most different" habitats in the island are good evidence of this. This observation explains why the small collection by Skottsberg at a single locality included such a large number of species that now represent over 50% of the total number of taxa known for the island.

Except for the beds of large *Sargassum skottsbergii* which are ubiquitous in the low intertidal and subtidal, the algae of Easter Island are in general short and turfy, more characteristic of coral atolls of the central Pacific than of volcanic islands. Børgesen (1924) also made this observation and interpreted the low stature, the presence of strong rhizoids and haptera in many of the species, or the crustose morphology of many others, as morphologies that allow adjustments to the very strong surf that continually beats the shores of the island. This is probably true, but herbivory should not be ruled out without further experimental evidence. Sea urchin densities are high at exposed localities, their abundance being correlated with absence or extreme patchiness of vegetation. In the most sheltered habitats visited, where sea urchin densities were low, frondose algae reached larger sizes, the vegetational cover was much less patchy, and algal cover could frequently reach 50–75%.

The pattern of geographic distribution shown by the marine algal flora of Easter Island indicates a high representation of species with wide geographic distribution and a surprisingly low representation of species with short-range distribution or endemic to the island. The high representation of species of wide distribution could be explained because of the geographic isolation of Easter Island. The island is so remote that it can be reached only by species with very good dispersion and colonization capacities which, because of these capacities, are common algae found everywhere. This is contrary to the common expectation that remote and isolated localities necessarily contain unique marine floras.

The low degree of endemism (14%) shown by the flora of Easter Island is equivalent to those found by Fell (1974) for echinoids and by Garth (1973) for brachyurans. These results, however, contrast with 27.3% of endemism found by Randall (1976) for fishes, 28% found by Holthuis (1972) for decapod macrurans, 33% reported by Wells (1972) for scleractinian corals, or the 24% described by Rehder (1980) for mollusks. These results tend to suggest different speciation velocities for different groups and this might be true also for the seaweeds, as clearly Phaeophyta and Rhodophyta have significantly higher representation of endemic species than the Chlorophyta at Easter Island. Still the values

of endemism shown by the two groups are relatively low (about 14%). No definite answer can be given at this time as little is known on speciation rates of benthic algae. However, perhaps the small size of the island habitat coupled with the absence of habitat heterogeneity has allowed for little diversification of the species. Perhaps reproduction of these species in Easter Island is mainly by asexual means and therefore speciation is slow. Or perhaps the repeated volcanic activity in the past has destroyed the oldest endemic vegetation.

It should be noted that the low degree of endemism (14%) shown by the marine algal flora is based on 144 taxa, whereas for most marine animal groups, the base number is less than seven in all groups known except for fishes, mollusks, and brachyurans. Thus, two species of six scleractinian corals reported by Wells (1972) are endemic (33%); of the four barnacles, two or 50% are endemic (Newman and Foster 1983). Altogether, the animal groups that have been studied from Easter Island show between 14–50% endemism, and Rehder (1980) offers these numbers as support for the distinct Rapanuian biogeographic district first recognized by Schilder (1965), and more recently by Newman and Foster (1983). From that viewpoint, the degree of endemism of the marine flora would also contribute to define a Rapanuian biogeographic district.

The numerical analyses of species further characterize the flora of Easter Island as having a general affinity with islands in the West Pacific and almost no relationship with islands in the East Pacific or continental Chile, regardless of distance. The affinities with the west are likely to be higher when the presently poorly known islands of the Society and Tuamotu archipelagoes are examined for algae. By contrast the flora of Easter Island has almost no relationship to the marine flora of Juan Fernández, probably due to the isolating effect of the low temperature of the Perú Current. Thus, it is suggested that islands in the west have been the species source for Easter Island with only limited floristic exchange with the east. These results do not support the inclusion by Udvardy (1975) of Juan Fernández in the Southeastern Polynesian Province of Gressitt (1961) and Usinger (1963). This biogeographical province, as defined by Gressit includes Easter Island southwest to Rapa (approximately 3500 km distant, near 145°W). Both Gressitt and Usinger placed Juan Fernández in the Neotropical Province, which from the algal view point seems to be correct.

In conclusion, the marine algal flora of Easter Island can now be characterized as rich and diverse as compared with that of other islands of similar size in the central Pacific, monotonously similar in different habitats around the island, short and turfy in stature, composed mainly of species with wide geographic distribution, reduced endemism, and with a general geographic affinity with the west Pacific.

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