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Marine Plants of Pohnpei and Ant Atoll: Rhodophyta, with biogeographic comparisons to other Pacific atolls and island groups.

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Abstract—This is the second paper resulting from a study of marine benthic plants collected from Pohnpei Island and Ant Atoll in the Caroline Islands, Federated States of Micronesia, between 1994 and 1997. It documents the occurrence of 113 species of red algae (Division Rhodophyta), exclusive of crustose coralline algae. Of these, 56 are new records for Pohnpei, 76 are new records for Ant Atoll, and 53 are new records for Micronesia (here including the Caroline, Mariana, Marshall, Gilbert, and Ellice Islands). A previous paper reported 80 species of green and brown algae and seagrasses from Pohnpei and Ant, of which 8 were new records for Micronesia. Added to reports from the literature, the total known marine benthic flora of Ant and Pohnpei (exclusive of Cyanobacteria and crustose coralline algae) now stands at 244. The high volcanic nature of Pohnpei is very different from the low calcareous Ant Atoll, which led us to expect higher species numbers for Pohnpei relative to Ant, and greater differences in their algal floras than we found. Comparisons of the Ant-Pohnpei algal flora were also made, using the Jaccard and Sorensen's indices, to Ifaluk Atoll (Caroline Islands), Enewetak Atoll (Marshall Islands), the Northern Mariana Islands, and the distant south Pacific island groups of Fiji and French Polynesia. Biogeographic investigation of the marine plant flora revealed that Ant Atoll and Pohnpei have a large number of widespread and Indo-Pacific species, but very few probable regional endemics.

Introduction

This is the second paper resulting from marine benthic plant collections made by the first two authors between 1994 and 1997, at Ant Atoll (also known as Ahnt Atoll or as Pamuk-Imwinyiati) and Pohnpei Island (formerly Ponape), near the eastern end of the Caroline Islands in the Federated States of Micronesia (Fig. 1). Pohnpei and its two neighboring atolls, Ant and Pakin, were once collectively known as the Senyavin Islands (Douglas 1989). Ant Atoll is a low-lying coral atoll, 14 km across at its widest dimension. The south and east parts of the atoll have a string of four long, slender, vegetated islets. Another tiny islet marks the northwest end of the atoll. All signs of its ancient basaltic substrata have long disappeared. Ant has been inhabited by people in the past and is privately owned, but is not currently occupied. Pohnpei is a much younger, larger, volcanic island of basalt, on which the capital city, Kolonia, is located. The island itself is about 24 km across east to west, and 22 km across north to south. Its barrier reef, interrupted by small coral islets, is located up to 4 to 5 km offshore. Ant and Pohnpei are very different in age and geology; however, their reefs are less than 10 km apart. This is the only study we know of which compares the marine benthic flora of a high island and a nearby coral atoll.

The earliest reports of algal species from Pohnpei and Ant Atoll were those of Okamura (1916), Schmidt (1928), and Tokida (1939). The first phycologist to make detailed collections on Pohnpei and Ant Atoll was Yamada (1944a, 1944b), who described several new species from these islands. These included five mem-

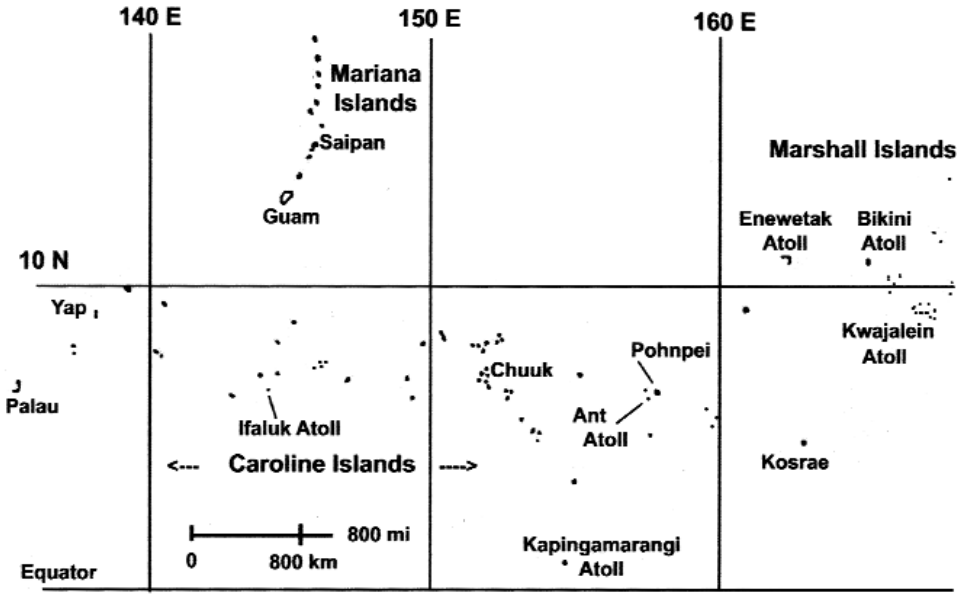

Figure 1.: Map of Micronesia, including parts of the Mariana Islands, Marshall Islands, and Caroline Islands.

bers of the Chlorophyta: *Caulerpa antoensis, Caulerpa matsueana, Halimeda micronesica, Dictyosphaeria mutica,* and *Rhipilia micronesica,* and five members of the Rhodophyta: *Crouania minutissima, Wrangelia anastomosans, Centroceras minutum, Centroceras apiculatum* (= *Corallophila apiculata*), and *Dasya adhaerens* (= *Dasya pilosa*). While most of the material from Yamada's short day-trip to Ant Atoll has been published, his larger collections from Pohnpei were never published.

Trono (1968, 1969) reviewed, described, and illustrated benthic marine algae of the Caroline Islands. Tsuda & Wray (1977) and Tsuda (1981a) compiled bibliographic references for 583 species from the Micronesian region: the Marshalls (Republic of the Marshall Islands), Carolines (Federated States of Micronesia and Republic of Palau), Marianas (Commonwealth of the Northern Mariana Islands and Guam), Gilberts (Republic of Kiribati), and Ellice Islands (Tuvalu).

Most reports since 1980 have been very limited in scope. Best & Pendleton (1980) conducted a biological survey in the northern Pohnpei lagoon, listing only 4 Cyanophyta, 14 Chlorophyta, 8 Phaeophyta, and 8 Rhodophyta identified to species. Enomoto et al. (1986) issued a report from the *Kagoshima-maru* expedition to the eastern Carolines, listing 36 species of Chlorophyta. Their collections of Phaeophyta and Rhodophyta, however, have not been published. These and other reports of marine benthic plants of the region are reviewed in Tsuda & Wray (1977), and Hodgson & McDermid (2000). McDermid & Edward (1999) reported on the seagrasses of Pohnpei. Thus within the last few decades, several publications have included marine plants of Pohnpei and Ant Atoll, but have not done justice to the Rhodophyta.

Island biogeography theory predicts that the species richness aspect of diversity should increase with island size, but decrease with distance from continental source areas (MacArthur & Wilson 1963, 1967, Roughgarden 1979, Lüning 1990, Silva 1992). Field and experimental work has shown that long-range seaweed dispersal surely occurs, but is probably relatively rare (Cambridge et al. 1987, van den Hoek 1987). Smaller islands are more likely than large ones to be missed by the dispersing propagules, resulting in lower species diversity. Doty (1954,1973) commented on the possible importance of differences other than size between high islands and low atolls, such as the greater run-off of nutrients on high islands, and the difference between basaltic and limestone substrata. Smith (1992) examined the effect of age-related substratum differences and settlement shadow effects on intertidal algal diversity on two high islands in Hawai‘i. She concluded that patterns of diversity are highly complex and that intermediate age islands such as O‘ahu seem to have the most algal diversity. She hypothesized that older islands, such as atolls consisting entirely of calcareous substrata, will have lower diversity, as will very young islands which offer only basaltic substrata. N'Yeurt & South (1997) discussed these aspects of diversity with reference to the small island of Rotuma as compared to the larger main islands of Fiji.

The first paper from this study (Hodgson & McDermid 2000) documented the occurrence and distribution of Magnoliophyta (seagrasses), Chlorophyta

(green algae), and Phaeophyta (brown algae) from Pohnpei and Ant Atoll. The current paper documents the occurrence and distribution of Rhodophyta (red algae), calculates indices of similarity comparing the entire known algal floras of Ant and Pohnpei to one another and to other south Pacific islands, then discusses biogeographic distributions.

Materials & Methods

Collections were made at 20 sites around Pohnpei and 11 sites at Ant Atoll (Table 1) between 1994 and 1997 at depths from less than 1 m to 27 m. Maps of

Table 1: Collection sites and dates on Pohnpei and Ant Atoll.

Site #	Location	Habitat	Depth	Collecting Dates	Municipality
	Pohnpei Island				
1	Nankepkep en Parem	intertidal reef flat	1 m	11/24/94	Nett
2	Mesenpal	nearshore	1-2 m	9/18/97	Uh
3	Dehbehk Island	nearshore	1-2 m	9/18/97	Uh
4	Takaieu	nearshore	1-2 m	9/18/97	Uh
5	Areu Passage	reef flat	unknown	4/89	Madolenihmw
6	Dau Rei Rei	lagoon patch reefs	1 m	11/21/94, 8/8/96	Madolenihmw
7	Nahpali Island	nearshore inner reef	1 m	8/10/96	Madolenihmw
8	Nahpali Island	outer barrier reef	20 m	8/11/96	Madolenihmw
9	Temwen Island	reef flat	1 m	10/87, 9/15/97	Madolenihmw
10	Lohd Pa	reef flat	1 m	9/17/97	Madolenihmw
11	Rohi	nearshore	1-2 m	9/17/97	Kiti
12	Paliapailong	nearshore	1 m	9/15/97	Kiti
13	Pehleng Pass	channel	2 m	2/23/95, 2/24/95	Kiti
14	Iohl	nearshore, silty	1 m	9/16/97	Sokehs
15	Oumoar	nearshore	1 m	2/15/95, 9/16/97	Sokehs
16	Sokehs Harbor	reef flat	1 m	3/14/89	Sokehs
17	Sokehs Passage	outer reef	4-15 m	11/24/94	Sokehs
18	Sokehs Passage	inner reef	0-3 m	11/24/94	Sokehs
19	Japanese Lighthouse reef	reef flat	1-5 m	3/1/89	Nett
20	Dekehtik	reef flat	1 m	4/89	Nett
	Ant Atoll				
A	Imwinyap	inner reef flat	0-3 m	11/25/94	
B	Imwinyap	sandy lagoon	0-1 m	11/25/94	
C	Nikalap Aru	sandy lagoon	0-2 m	11/25/94	
D	Nikalap Aru	sandy channel edge	0-2 m	11/25/94	
E	Imwinyap	outer nearshore reef	0-2 m	11/27/94	
F	Tauenai Passage	channel	3-22 m	11/27/94, 8/14/96	
G	Nikalap Aru	lagoon channel wall	3-22 m	11/27/94	
H	Pasa	inner sand flat	0-1 m	11/22/94, 8/14/96	
I	Nikalap Aru	outer reef	12-27 m	11/22/94	
J	Pamuk	outer reef	12-25 m	11/22/94	
X	precise location unknown			4/89	

Ant and Pohnpei showing these study sites are included in Hodgson & McDermid (2000). The sites on Ant, and the sites near Kolonia at the north end of Pohnpei were extensively and carefully collected, although usually only once. Other sites around Pohnpei were visited as part of a study of dredging sites, and include relatively few specimens. LMH spent four collecting days on Ant Atoll and two on Pohnpei in November, 1994; KM spent one collecting day on Ant Atoll and three on Pohnpei in August, 1996, and four days on Pohnpei in September 1997. Algae were preserved in 4% formalin-seawater for later study. Herbarium sheets and aniline blue-stained slides were made upon return to the University of Hawai‘i. Various references were used for identifying taxa of Rhodophyta, especially Yamada (1931, 1940, 1941, 1944a & b), Taylor (1950), Hollenberg (1968a, b, c), Abbott & Hollenberg (1976), Itono (1980), Meneses & Abbott (1987), Srimanobhas et al. (1990), and Abbott (1999). Several taxa could only be identified to genus, either because of the fragmentary nature of the specimen, or the lack of fertile structures. Crustose corallines and Cyanobacteria are not included in this report, and so are omitted in comparisons with other data from the literature as well.

Two indices of similarity were used to compare floras. The Jaccard Index was calculated using the formula: J.I. = c/ (a+b-c) x 100, where “c” is the number of species in common, “a” is the number of species found in only the first flora, and “b” is the number of species found only in the second flora. The Jaccard Index was chosen for ease of comparison with the work on Fiji by N’Yeurt & South (1996,1997). Sorensen’s Index of Similarity, also known as the coefficient of community, is considered particularly valuable for dealing with qualitative data (Pielou 1977). This index uses similar parameters to the Jaccard Index, and is calculated as S.I. = 2x/ (2x + y + z), where x is the number of species in common, y is the total known flora of the first island or group, and z is the total known flora of the second island or group. Seagrasses, crustose corallines and Cyanobacteria were omitted from these comparisons.

Distribution records and synonyms were assembled using Okamura (1916); Yamada (1926); Schmidt (1928); Tokida (1939); Kanda (1942, 1944); Taylor (1950); Glassman (1952); Dawson (1954, 1956, 1957); Chapman (1955, 1971); Gilmartin (1960); Abbott (1961, 1995, 1999); Hollenberg (1968a, b, c); Trono (1968, 1969, 1971); Tsuda & Trono (1968); Newhouse (1969); Womersley & Bailey (1969); Chapman & Dromgoole (1970); Den Hartog (1970); Womersley (1970); Tsuda (1972 a & b, 1981a & b, 1987); Tsuda & Belk (1972); Tsuda et al. (1974, 1977a, b); Abbott & Hollenberg (1976); Tsuda & Tobias (1977a, b); Tsuda and Wray (1977); Best & Pendleton (1980); Santelices & Abbott (1987); Silva et al. (1987); Wynne et al. (1989); Millar & Kraft (1993); N’Yeurt et al. (1996); Silva, Basson & Moe (1996); Payri & N’Yeurt (1997); Stegenga et al. (1997); Prud’homme van Reine (1998); Coppejans & Millar (2000); Kraft (2000); Littler & Littler (2000), and South & Skelton (2000).

Results

One hundred thirteen taxa of Rhodophyta were identified to species (Table 2), of which 76 are new records for Ant Atoll, 56 are new records for Pohnpei, and 53 are new records for Micronesia. Also identified were two species which should have been included in our first paper: *Uronema marina* (Chlorophyta) at Site A and *Chnoospora minima* (Phaeophyta) at Site 8. Both are new reports for Micronesia. Thus, the tally from our study as a whole stands at 113 reds, 60 greens, 17 browns, and 3 seagrasses, for a total of 193 species of which 63 are new records for Micronesia.

Several Rhodophyta species were common, found at two or more sites on both Ant Atoll and Pohnpei: *Actinotrichia fragilis, Anotrichium tenue, Centroceras minutum, Ceramium flaccidum, C. macilentum, Champia parvula, Corallophila apiculata, Erythrotrichia carnea, Griffithsia heteromorpha, Hypnea spinella, Peyssonnelia inamoena, Polysiphonia scopulorum,* and *Stylonema alsidii.* Other species, although found at several sites seemed restricted to one of the two islands. We collected *Ceramium clarionense, Ceramium codii, Corynocystis prostrata, Halichrysis coalescens, Herposiphonia delicatula, Herposiphonia obscura, Heterosiphonia crispella,* and *Hypoglossum simulans* at two or more sites, but only on Ant Atoll. *Gelidiopsis scoparia, G. variabilis, Hypnea valentiae, Laurencia succisa, Tricleocarpa fragilis,* and *Zellera tawallina* were found at three or more sites, but only on Pohnpei. Within the genus *Amphiroa, A. beauvoisii* and *A. misakiensis* were found only on Pohnpei, while *A. valonioides* occurred at three sites on Ant Atoll, but only one site on Pohnpei.

Species identified by previous workers for these islands, but not found in our study are listed in Table 3. Only 3 Rhodophyta previously known from Ant and 17 from Pohnpei were not again collected by us. Combining the results from our study plus reports from the literature (Table 4), 42 Rhodophyta, 33 Chlorophyta, 4 Phaeophyta, and no seagrasses were found restricted to Ant Atoll (77 total). Restricted to Pohnpei were 46 Rhodophyta, 21 Chlorophyta, 14 Phaeophyta, and 1 seagrass (82 total). Common to both Ant Atoll and Pohnpei were 45 Rhodophyta, 28 Chlorophyta, 8 Phaeophyta, and 2 seagrasses (83 total). The combined flora of the two islands consists of 133 Rhodophyta, 82 Chlorophyta, 26 Phaeophyta, and 3 Magnoliophyta, for a total of 244 species.

Jaccard's Index of Similarity (N'Yeurt & South 1997) and Sorensen's Coefficient of Community (Pielou 1977) were used to compare the known floras of Ant Atoll, Pohnpei, and other islands for which there is enough information (Table 5). The Jaccard Index comparing the flora of Ant Atoll to that of its high-island neighbor Pohnpei was 34 overall: 34 for Chlorophyta, 31 for Phaeophyta, and 34 for Rhodophyta. Sorensen's coefficient was 0.50 overall: 0.51 for Chlorophyta, 0.47 for Phaeophyta, and 0.51 for Rhodophyta. In all comparisons reported on Table 5, Sorensen's coefficient echoed the trends of the Jaccard Index, and so are not further discussed.

Table 2.: Species, sites, and references for collections from Ant Atoll and Pohnpei Island. The site numbers refer to sites in Table 1. New records for species are indicated in the first column: M=Micronesia, A=Ant, P=Pohnpei. The authors who previously reported the species from Ant, Pohnpei, or greater Micronesia (Caroline, Marshall, Mariana, Gilbert, or Ellice Islands) are listed in the last columns. Abbreviations for references: A61, A95, A99 = Abbott 1961, 1995, 1999; BP80 = Best & Pendleton 1980; D56, D57 = Dawson 1956, 1957; G52 = Glassman 1952; G60 = Gilmartin 1960; H68a, H68b, H68c = Hollenberg 1968a, 1968b, 1968c; It80 = Itono, 1980; K42, K44 = Kanda 1942, 1944; O16 = Okamura 1916; S28 = Schmidt, 1928; T39 = Tokida, 1939; T50 = Taylor 1950; T69 = Trono, 1969; TRC74 = Tsuda et al. 1974; Ts72, Ts81, Ts87 = Tsuda 1972, 1981a, 1987; TW77 = Tsuda & Wray 1977; Y44 = Yamada 1944b.

New Records	SPECIES	SITES	REFERENCES
	Acanthophora spicifera (Vahl) Børgesen	6	O16 S28 T39 K42 K44 Y44 G52 T69 Ts72 TW77 BP80
P	*Acrochaetium gracile* Børgesen	6	D57 TW77 Ts87
A,M	*Acrochaetium seriatum* Børgesen	A	
A	*Actinotrichia fragilis* (Forsskäl) Børgesen	F G I J 2 6 17 18 19	S28 T39 K44 D56 T69 Ts72 TRC74 TW77 BP80
A,M	*Aglaothamnion boergesenii* (Aponte & Ballentine) L'Hardy-Halos & Rueness	A	
P,M	*Amansia fimbrifolia* R.E. Norris	8 18	
P,M	*Amphiroa beauvoisii* Lamouroux	1 3 6 8 18	A95 (unpubl)
P,M	*Amphiroa misakiensis* Yendo	3 18	
A,P,M	*Amphiroa valonioides* Yendo	C D G 18	
	Amphiroa sp.	6	
A,P	*Anotrichium tenue* (C. Agardh) Nägeli	A B J 6 18	D56 D57 G60 A61 Ts87
P	*Antithamnion antillarum* Børgesen	8	T69 TW77
A,P	*Antithamnionella breviramosa* (Dawson) Wollaston	E 8	D57 TW77
A,P,M	*Antithamnionella graeffei* (Grunow) Athanasiadis	A 17	S28

A,P	*Asparagopsis taxiformis* (Delile) Collins & Harvey tetrasporophyte “Feldmannia hillebrandtii” phase only	F 6 8	S28 D56 D57 G60 T69 Ts87
	Callithamnion sp.	18	
A,M	*Caulacanthus ustulatus* (Turner ex Mertens) Kützing	B	
A	*Centroceras clavulatum* (C. Agardh) Montagne	A B 6	O16 T39 T50 C55 D56 D57 G60 A61 TW77
	Centroceras minutum Yamada	A B H 6 18	Y44 D56 A61 T69 TW77 Ts87
A,P,M	*Ceramium aduncum* Nakamura	J 17	
A,M	*Ceramium borneense* Weber-van Bosse	J	
A	*Ceramium clarionense* Setchell & Gardner	F J	D56 D57 TW77 D57
A,M	*Ceramium codii* (Richards) G. Mazoyer	A B F J	
P	*Ceramium fimbriatum* Setchell & Gardner	17	D56 T69 TW77
A	*Ceramium flaccidum* (Kützing) Ardissone	A F H J 6 8 17	S28 T39 T50 D56 D57 G60 T69 Ts81 Ts87 A95
A,P	*Ceramium macilentum* J. Agardh	A E G J 6 17	D56 D57 T69 G60 TW77 Ts81 Ts87
P,M	*Ceramium punctiforme* Setchell	18	S28
A,P	*Ceramium serpens* Setchell & Gardner	A 6	D56 D57 Ts87
A,P	*Ceramium vagans* Silva	A B F G J 17	D57 T69 Ts87
A,P	*Champia compressa* Harvey	E 17	O16 S28 T39 Ts72
A	*Champia parvula* (C. Agardh) Harvey	A B F H J X 6 17	O16 S28 G52 D56 D57 G60 T69 TW77 Ts87
P,M	*Cheilosporum spectabile* Harvey ex Grunow	17	S28
A,M	*Chondracanthus tenellus* (Harvey) Hommersand	F	

A,M	*Chondria dangeardii* Dawson	A	
A	*Chondria polyrhiza* Collins & Harvery	A	D57 TW77 Ts87
P	*Chondria simpliciuscula* Weber-van Bosse	B J 6	Y44 TW77
	Chondria sp.	B	
P	*Coelothrix irregularis* (Harvey) Børgesen	6	D57 T69 TW77 Ts87
P	*Corallophila apiculata* (Yamada) R.E. Norris	A B J 6 17	Y44 D56 D57 TW7 Ts87
P	*Corallophila huysmansii* (Weber-van Bosse) R.E. Norris	6	D56 T69 TW77
A,M	*Corallophila kleiwegii* Weber-van Bosse	A	
A,M	*Corynocystis prostrata* Kraft	B F G I	
P,M	*Cottoniella filamentosa* Børgesen	6	
A,M	*Crouania mageshimensis* Itono	F	
	Crouania minutissima Yamada	F	Y44 T69 D56 Ts72 TW77
A,M	*Cryptonemia umbraticola* Dawson	C	
A,M	*Dasya iridescens* (Schlech) Millar & Abbott	J	
P	*Dasya pilosa* (Weber-van Bosse) Millar	A J 17	Ts72 TW77
A,P,M	*Diplothamnion jolyi* van den Hoek	J 8 17	
A	*Erythrotrichia carnea* (Dillwyn) J. Agardh	A H 6 8	T50 G52 D56 D57 A61 T69 TW77
P	*Galaxaura rugosa* (Ellis & Solander) Lamouroux	18	It80
A	*Gelidiella adnata* Dawson	C	D56
P,M	*Gelidiella machrisiana* Dawson	6	

P,M	*Gelidiella myrioclada* (Børgesen) Feldmann & Hamel	F I 6	
	Gelidiella sp.	H 6 12	
P	*Gelidiopsis intricata* (C. Agardh) Vickers	B D G J 6	T39 K42 K44 Y44 D56 D57 G60 Ts72 TW77
A	*Gelidiopsis repens* (Kützing) Weber-van Bosse	B	O16 TS28 T39 D56 TW77
P,M	*Gelidiopsis scoparia* (Montagne & Millardet) DeToni	6 18	
P,M	*Gelidiopsis variabilis* (J. Agardh) Schmitz	6 8 18	
A,M	*Gloiocladia iyoense* (Okamura) R.E. Norris	F	
A	*Gracilaria salicornia* (C. Agardh) Dawson	C 6 9 15 20	S28 T60 TRC7 TW77 BP80 MA87
	Gracilaria sp.	20	
A,P,M	*Griffithsia heteromorpha* Kützing	B J 8 17	
A,P,M	*Griffithsia schouesboei* Montagne	J 17	
A,M,	*Gymnothamnion elegans* (Schousboe ex C. Agardh) J. Agardh	A	
A,M	*Halichrysis coalescens* (Farlow) R.E.Norris	A J	
A,P	*Halymenia dilatata* Zanardini	A 5	K42 K44 TW77
	Halymenia sp.	H	
P,M	*Herposiphonia crassa* Hollenberg	17	
A	*Herposiphonia delicatula* Hollenberg	A J	H68c T69 Ts72 TW77
P,M	*Herposiphonia dubia* Hollenberg	6	
A	*Herposiphonia obscura* Hollenberg	A J	H68c TW77
A	*Herposiphonia pacifica* Hollenberg	A 6	H68c T69 TW77

A	*Herposiphonia parca* Setchell	A 6	H68c T69 TW77 Ts87
A	*Herposiphonia secunda f. secunda* (C. Agardh) Ambronn	A	S28 T39 K42 K44 T50 D56 D57 TW77 Ts87
	Herposiphonia sp.	A	
A	*Heterosiphonia crispella* (C. Agardh) Wynne	A F J	Y44 T50 D56 D57 G60 A61 TW77Ts87
A	*Hypnea pannosa* J. Agardh	J 6 8 18	O16 S38 T39 K44 G52 D56 D57 T69 TW77
A,P	*Hypnea spinella* (C. Agardh) Kützing	A F G H J 4 6 8 15	T50 A61 TW77 Ts87
	Hypnea valentiae (Turner) Montagne	2 6 20	T69 TW77
	Hypnea sp.	F J	
A,M	*Hypoglossum caloglossoides* Wynne & Kraft	B F J	
P	*Hypoglossum minimum* Yamada	A J 17	Y44 D57 G60 A61 TW77 Ts87
A	*Hypoglossum simulans* Wynne, Price & Ballantine	A F J	T50 D57
	Hypoglossum sp.	F J	
A,P	*Jania adhaerens* Lamouroux	B G 4	TW77
A,P,M	*Jania pumila* Lamouroux	A 6	
	Laurencia cartilaginea Yamada	20	T69 TW77 T81
A,M	*Laurencia galtsoffii* Howe	A	
A	*Laurencia majuscula* (Harvey) Lucas	A 6	T69 TB72 Ts72 TW77 Ts81 A95
A	*Laurencia mariannensis* Yamada	A	T39 D56 D57 A61 T69 TW77Ts87
A,M	*Laurencia nidifica* J. Agardh	B	S28

P	*Laurencia succisa* Cribb	6 18 20	Ts81
A,M	*Laurencia undulata* Yamada	E	
	Laurencia sp.	6 17	
A,M	*Lejolisea pacifica* Itono	A	
	Lomentaria sp.	J	
P,M	*Lophocladia minima* Itono	6 17	
A,P,M	*Myriogramme bombayensis* Børgesen	F 8 17	
A	*Neosiphonia sparsa* (Setchell) Kim	A	H68a TW77
A,M	*Nitophyllum adhaerens* Wynne	J	
A,P,M	*Ossiella pacifica* Millar & Abbott	J 17	
A,P,M	*Peyssonnelia inamoena* Pilger	G J 8 17	
	Peyssonnelia sp.	E G J	
P	*Pleonosporium caribaeum* (Børgesen) R.E. Norris	17	G60
P	*Polysiphonia exilis* Harvey	6 17	H68b T69 TW77 Ts87
A,P	*Polysiphonia herpa* Hollenberg	A J 17	H68a T69 TW77
A,P	*Polysiphonia pentamera* Hollenberg	J 17	H68b T69 TW77 Ts87
A,M	*Polysiphonia pseudovillum* Hollenberg	A	H68a
A,M	*Polysiphonia saccorhiza* (Collins & Harvey) Hollenberg	A	H68a
A	*Polysiphonia savatieri* Hariot	A	H68a T69 TW77
A	*Polysiphonia scopulorum* Harvey	A D J 6 17	H68a T69 Ts72 TW77
A,P	*Polysiphonia sphaerocarpa* Børgesen	A B 6	H68a T69 TW77
P,M	*Polysiphonia tepida* Hollenberg	6	H68b

A,M	*Polysiphonia tsudana* Hollenberg	A	H68b
A,P	*Polysiphonia upolensis* (Grunow) Hollenberg	A 6	H68a T69 TW77
	Polysiphonia sp.	A C 6	
	Porolithon sp.	E	
P	*Portieria hornemannii* (Lyngbye) Silva	19	O16 S28 T39 T69 TW77
A,M	*Predaea weldii* Kraft & Abbott	F I	
	Pterocladiella sp.	B	
A,P,M	*Ptilothamnion cladophorae* (Yamada & Tanaka) Feldmann-Mazoyer	A B G H J 6	
	Rhodymenia sp. (?R. *prostrata* Tanaka)	17	
	Spirocladia sp.	17	
A	*Stylonema alsidii* (Zanardini) Drew	A H J 6 8 17	T50 G52 TW77 Ts87
A,M	*Stylonema cornu-cervi* Reinsch	J	
P,M	*Titanophora weberae* Børgesen	17 19	
	Tolypiocladia glomerulata (C. Agardh) Schmitz	17	O16 S28 T39 K44 T50 G52 T69 Ts72 TW77 BP80
	Tricleocarpa fragilis (L.) Huisman & Millar	6 8 18	T69 Ts72 TW77 It80
A,M	*Wrangelia dumontii* (Dawson) Abbott	J	
P,M	*Zellera tawallina* G. Martens	8 17 19	
	Addenda to Hodgson & McDermid 2000:		
A,M	*Uronema marinum* Womersley (Chlorophyta)	A	
P,M	*Chnoospora minima* (Hering) Papenfuss (Phaeophyta)	8	

Table 3: Rhodophyta (excluding crustose corallines) reported from the literature for Ant Atoll (A) or Pohnpei (P), but not found in this study. Abbreviations are as in Table 2.

	RHODOPHYTA	REFERENCE	POHNPEI OR ANT
1	*Acanthophora muscoides*	O16, T39, Y44b, G52	P,A
2	*Amansia glomerata*	BP80	P
3	*Amphiroa foliacea*	BP80	P
4	*Amphiroa fragilissima*	T69, BP80	P
5	*Ceratodictyon spongiosum*	T69	P
6	*Gelidiella acerosa*	T69	P
7	*Gelidium rigidum*	T39	P as *Gracilaria radicans*
8	*Halarachnion calcaerum*	S28, T39, G52	P
9	*Halymenia durvillei*	BP80	P
10	*Laurencia flexilis*	Y44b	A
11	*Laurencia implicata*	S28, T39, G52	P as *Laurencia intricata*
12	*Laurencia papillosa*	T69	P
13	*Laurencia perforata*	S28	P
14	*Laurencia yamadana*	T69	P
15	*Levillea jungermannioides*	T39, G52, TRC74	P
16	*Polysiphonia setacea*	H68a, T69	P
17	*Rhodymenia divaricata*	T69	P
18	*Spyridia filamentosa*	S28	P as *Spyridia biannulata*
19	*Wrangelia anastomosans*	Y44b	A

The flora of Ant Atoll is more similar to that of its neighboring high island Pohnpei than to floras of more distant atolls with comparable physical environments. The best-known atoll flora in the Pacific is that of Enewetak Atoll in the Marshall Islands (Fig. 1), about 630 km north-northeast of Pohnpei (Taylor 1950, Dawson 1957, Gilmartin 1960, Tsuda 1987). The Jaccard Index (Table 5) comparing Enewetak Atoll to Ant Atoll is 23 overall: 34 for Chlorophyta, 24 for Phaeophyta, and 15 for Rhodophyta, very similar to values obtained when comparing Enewetak to the combined Ant-Pohnpei flora (also 23 overall). Note that the Jaccard Index was higher for the Chlorophyta than for either Phaeophyta or Rhodophyta, for both sets of comparisons.

Table 4: Numbers of species restricted to Ant Atoll, restricted to Pohnpei, or found on both. In parentheses are the numbers of species from this study.

	restricted to Ant Atoll	restricted to Pohnpei	found on both Ant & Pohnpei	Totals
Rhodophyta	42 (39)	46 (29)	45 (45)	133 (113)
Chlorophyta	33 (27)	21 (11)	28 (22)	82 (60)
Phaeophyta	4 (2)	14 (9)	8 (6)	26 (17)
Magnoliophyta	0	1 (1)	2 (2)	3 (3)
Totals	79 (68)	82 (50)	83 (75)	244 (193)

Table 5: Numbers of species, Jaccard Index of Similarity, and Sorensen's Coefficient of Community for comparisons of the marine plant flora of Ant Atoll and the combined Ant-Pohnpei flora to Ifaluk Atoll, Enewetak Atoll, the Northern Mariana Islands, Fiji-Rotuma, and French Polynesia. (Seagrasses, Cyanobacteria and crustose coralline algae are excluded).

	Chlorophyta			**Phaeophyta**			**Rhodophyta**			**Overall**		
	# sp.	**J.I.**	**S.I.**	**# sp.**	**J.I.**	**S.I.**	**# sp.**	**J.I.**	**S.I.**	**# sp.**	**J.I.**	**S.I.**
Ant Atoll flora compared to	61			12			87			160		
Pohnpei	49	**34**	**0.51**	22	**31**	**0.47**	91	**34**	**0.51**	162	**34**	**0.50**
Enewetak Atoll (Marshall Islands) (Tsuda 1987)	91	**33**	**0.50**	24	**24**	**0.54**	99	**15**	**0.26**	215	**23**	**0.37**
Ant Atoll shallow flora compared to	61			12			67			140		
Ifaluk Atoll (Caroline Islands) (Abbott 1961)	38	**27**	**0.42**	2	**8**	**0.14**	23	**11**	**0.20**	63	**18**	**0.31**
Ant-Pohnpei flora compared to:	82			26			133			241		
Ifaluk Atoll	38	**25**	**0.40**	2	**4**	**0.07**	23	**8**	**0.14**	63	**13**	**0.24**
Enewetak Atoll	92	**34**	**0.51**	24	**28**	**0.44**	99	**15**	**0.26**	215	**23**	**0.37**
Northern Marianas (Tsuda & Tobias 1977a & b)	35	**22**	**0.36**	17	**34**	**0.51**	32	**12**	**0.22**	84	**18**	**0.31**
Fiji & Rotuma (N'Yeurt & South 1996)	107	**38**	**0.55**	42	**45**	**0.62**	188	**20**	**0.33**	337	**28**	**0.44**
French Polynesia (Payri & N'Yeurt 1997)	80	**32**	**0.48**	40	**32**	**0.48**	134	**27**	**0.42**	254	**29**	**0.45**

Table 6: Numbers of algal species, exclusive of crustose corallines, from selected islands of the Pacific, with locations, citations, and their approximate distances and directions from Pohnpei. The islands are listed from west to east.

ISLANDS	NUMBERS OF SPECIES				REFERENCES	LOCATION		DISTANCE
	C	P	R	Total		Latitude	Longitude	km from Pohnpei
Micronesian Region (5 island groups)	189	56	275	520	Tsuda & Wray 1977	20º to 10º S	130º to 177º W	
Caroline Islands (11 island groups from Palau to Pohnpei)	78	21	92	191	Trono 1968,1969,1971	7º to 11º N	134º to 165º E	
Kayangel Atoll (Palau) (Caroline Islands)	27	7	13	47	Tsuda 1981b	8º 03' N	134º 43' E	2574wnw
Yap (Caroline Islands)	41	15	5	61	Tsuda & Belk 1972	9º 24' to 9º 40' N	138º 01' to 138º 13' E	222 wnw
Ifaluk Atoll (Caroline Islands)	46	2	37	86	Abbott 1961	7º 15' N	144º 27' E	1495 w
Guam (Caroline Islands)	69	27	11	107	Tsuda 1972a, 1987	13º 13’ to 13º 39’ N	144º 36’ to 144º 57’ E	1607 nnw
Northern Mariana Islands	35	16	33	51	Tsuda & Tobias 1977	16º 22’ N to 20º 32’ N	144º 54’ E to 144º 51' E	1620nnw
Chuuk (Truk) (Caroline Islands)	42	12	25	79	Tsuda 1972b, Tsuda et al. 1977	7º 08' to 7º 40' N	151º 26’ to 152º E	690 w
Kapingamarangi Atoll (Caroline Islands)	45	8	nr	53	Newhouse 1969	1º 04' N	154º 48' E	730 sw

Ant Atoll (Caroline Islands)	60	12	86	158	**this study and** Yamada 1944a Enomoto et al. 1986	6º 43’ to 6º 50’ N	157º 54’ to 158º 02’ E	10 sw
Pohnpei (Caroline Islands)	51	22	93	166	**this study and** Okamura 1916 Tsuda et al. 1974	6º 45' to 7º 03' N	157º 54' to 158º 02' E	
(Ant-Pohnpei combined)	82	26	133	241	Tokida 1939 Schmidt 1928			
Enewetak Atoll (Marshall Islands)	89	24	106	222	Tsuda 1987	11º 20’ to 11º 40’ N	162º 00’ to 162º 25’ E	630 nne
Bikini Atoll (Marshall Islands)	82	12	54	148	Taylor 1950	11º 37' N	165º 33' E	931 ne
Gilbert Islands (Kiribati)	22	5	27	54	Tsuda 1964	2º N to 2º S	173 to 176º E	1664 ese
Howland & Baker Islands (n. of Phoenix Islands)	8	4	10	22	Tsuda & Trono 1968	0º 48’ N 0º 13' N	176º 38' W 176º 28' W	2860 ese
Fiji	113	42	228	383	N’Yeurt & South 1996	15º 42’ to 15º 21’ S	176º 44’ to 178º 10’ W	3380 se
Kanten (Canton Island) (Phoenix Islands)	21	9	22	52	Dawson 1959	2º 50' N	171º 43' W	3480 ese
Kirimati (Christmas Island) (Line Islands, Kiribati)	21	4	4	29	Gilbert 1983	1º 55’ N	157º 30’ W	4925 ese
French Polynesia	96	42	170	308	Payri & N’Yeurt 1997	7 to28º S	134 to155º W	6000 se

Table 7: Ant-Pohnpei species with nearly cosmopolitan distributions (10 sp., 4.1% of flora.)

Chlorophyta	**Rhodophyta**	
Cladophora vagabunda	*Centroceras clavulatum*	*Herposiphonia secunda*
Enteromorpha clathrata	*Ceramium flaccidum*	*Jania pumila*
Ulothrix flacca	*Champia parvula*	*Stylonema alsidii*
	Erythrotrichia carnea	

Ifaluk Atoll, in the Caroline Islands, lies about 1495 km almost due west of Pohnpei (Fig. 1). It is one of the few atolls for which we have information on all three major seaweed divisions (Abbott 1961). The collections from Ifaluk were made only from shallow waters, so we subtracted those species from the Ant flora which were collected only at depth (20 members of the Rhodophyta). The Jaccard similarity of the Ant Atoll shallow flora to that of Ifaluk Atoll was 18 overall: 27 for Chlorophyta, 8 for Phaeophyta, and 11 for Rhodophyta. The similarity values between the Ant Atoll shallow flora and Ifaluk Atoll were slightly higher than those between Ifaluk and the combined Ant-Pohnpei flora (13 overall). There were only 2 species of Phaeophyta and 23 of Rhodophyta identified on Ifaluk, so the low similarity values in those groups may be artifacts due to low sample sizes. The low number of species on Ifaluk (64) may also reflect its distance from any high island (compared to Ant's proximity to Pohnpei). Jaccard Indices for Ifaluk comparisons were lower than comparable values for the larger, better known flora of Enewetak.

Relatively complete species lists assembled for the Northern Mariana Islands (Fig. 1) (Tsuda & Tobias 1977a & b), for Fiji (N'Yeurt et al. 1996) and for French Polynesia (Payri & N'Yeurt 1997) make comparisons to those large island groups possible. The overall similarity between the flora of Ant and that of Pohnpei (34 overall) is greater, as expected, than the similarity between the combined Ant-Pohnpei flora and the floras of distant islands groups (18 to 28 overall). Interestingly, the overall Jaccard similarities of Ant-Pohnpei to the two more distant floras (Fiji and French Polynesia) are nearly the same (28 and

Table 8: Ant-Pohnpei species with pan-tropical and warm temperate distributions (34 sp., 13.9% of flora).

Chlorophyta	**Rhodophyta**	
Acetabularia parvula	*Acanthophora spicifera*	*Herposiphonia delicatula*
Bryopsis pennata	*Amphiroa beauvoisii*	*Heterosiphonia crispella*
Caulerpa racemosa	*Anotrichium tenue*	*Hypnea spinella*
Halimeda tuna	*Antithamnionella breviramosa*	*Hypnea valentiae*
Valonia aegagropila	*Antithamnionella graeffei*	*Jania adhaerens*
Phaeophyta	*Asparagopsis taxiformis*	*Laurencia majuscula*
Colpomenia sinuosa	*Caulacanthus ustulatus*	*Pleonosporium caribaeum*
Dictyota divaricata	*Ceramium codii*	*Polysiphonia scopulorum*
Hydroclathrus clathratus	*Chondria polyrhiza*	*Polysiphonia sphaerocarpa*
Lobophora variegata	*Coelothrix irregularis*	*Stylonema cornu-cervi*
Padina australis	*Cottoniella filamentosa*	*Tricleocarpa fragilis*
Sphacelaria novaehollandiae	*Gelidiopsis scoparia*	

Table 9: Ant-Pohnpei species with pan-tropical to subtropical distributions (51 sp., 20.9% of flora).

Chlorophyta		
Avrainvillea nigricans	*Neomeris annulata*	*Gelidiella acerosa*
Boodlea composita	*Phyllodictyon anastomosans**	*Gelidiopsis intricata*
Caulerpa brachypus	*Valonia utricularis*	*Gelidiopsis variabilis*
Caulerpa cupressoides	*Valoniopsis pachynema*	*Gymnothamnion elegans*
Caulerpa fastigiata	*Ventricaria ventricosa*	*Herposiphonia parca*
Caulerpa serrulata		*Hypoglossum simulans*
Caulerpa sertularioides	**Phaeophyta**	*Laurencia implicata*
Caulerpa taxifolia	*Chnoospora minima*	*Laurencia papillosa*
Caulerpa verticillata	*Dictyota crispata**	*Laurencia perforata*
Chaetomorpha crassa	*Padina boergesenii*	*Levillea jungermannioides*
Cladophoropsis membranacea	*Padina pavonia*	*Polysiphonia exilis*
Dictyosphaeria cavernosa	*Rosenvingea intricata*	*Polysiphonia setacea*
Enteromorpha flexuosa		*Polysiphonia tepida*
Halimeda discoidea	**Rhodophyta**	*Predaea weldii*
Halimeda gracilis	*Acanthophora muscoides*	*Spyridia filamentosa*
Halimeda incrassata	*Acrochaetium gracile*	*Titanophora weberae*
Halimeda opuntia	*Acrochaetium seriatum*	*Tolypiocladia glomerulata*
Halimeda simulans	*Amphiroa fragilissima*	
Halimeda taenicola	*Galaxaura rugosa*	

* = *Struvea anastomosans* and *Dictyota bartayresiana* in Hodgson & McDermid (2000)

29 respectively). As was the case for the atoll comparisons, the similarity index for Chlorophyta is slightly greater than for Phaeophyta and much greater than for Rhodophyta.

The species of marine plants known from Ant Atoll and Pohnpei, with allowance for limited collections of some species and some arguable assignments, fall approximately into seven biogeographic distribution categories (Tables 7 - 13). Some species are commonly found throughout a region; others may only be known from a few sites in the region, and we have made no effort to analyze those differences here.

Three groups consist of very widespread species and make up 38.9% of the flora. The first group contains about 4.1% of the Ant-Pohnpei flora, and consists of nearly cosmopolitan species found in all three major ocean basins (Pacific, Indian, Atlantic). These relatively small species, 3 Chlorophyta and 7 Rhodophyta, extend from the tropics into cool temperate, although usually not arctic, waters (Table 7). The second group consists of pan-tropical to warm tem-

Table 10: Ant-Pohnpei species with warm Atlantic and Pacific Ocean distributions (13 sp., 5.3% of flora).

Chlorophyta	**Rhodophyta**	
Caulerpa microphysa	*Aglaothamnion boergesenii*	*Nitophyllum adhaerens*
Derbesia fastigiata	*Antithamnion antillarum*	*Peyssonnelia inamoena*
Ulvella setchellii	*Diplothamnion jolyi*	*Polysiphonia pseudovillum*
	Griffithsia schouesboei	*Polysiphonia saccorhiza*
	Halarachnion calcaerum	*Rhodymenia divaricata*

perate species, again found in all three major ocean basins, and includes 5 Chlorophyta, 6 Phaeophyta, and 23 Rhodophyta, or 13.9% of the flora (Table 8). The third category of pan-tropical to subtropical species which do not appear to range into temperate waters, includes 24 species of Chlorophyta, 5 Phaeophyta, and 22 Rhodophyta, or 20.9% of the Ant-Pohnpei flora (Table 9).

Three species of Chlorophyta and 10 species of Rhodophyta, or 5.3% of the flora, have disjunct Atlantic and Pacific distributions, perhaps reflecting the geologically recent contact between those oceans at tropical Central America (Table 10).

The largest, single biogeographic group makes up 34.8% of the Ant–Pohnpei flora, and contains species which are found in at least one location in both the

Table11: Ant-Pohnpei species with Indian and Pacific Ocean distributions (85 sp., 34.8% of flora).

Chlorophyta
Anadyomene wrightii
Avrainvillea amadelpha
Avrainvillea erecta
Avrainvillea obscura
Boergesenia forbesii
Boodlea vanbosseae
Caulerpa filicoides e. andamanensis
Caulerpa lentillifera
Caulerpa okamurai
Caulerpella ambigua
Chlorodesmis fastigiata
Chlorodesmis hildebrandtii
Cladophora patentiramea
Cladophora socialis
Codium arabicum
Codium edule
Codium geppiorum
Codium repens
Halimeda bikinensis
Halimeda cuneata
Halimeda macroloba
Halimeda macrophysa
Halimeda micronesica
Halimeda renschii
Microdictyon okamurai
Neomeris bilimbata
Neomeris vanbosseae
Rhipidosiphon javensis
Rhipilia orientalis
Tydemania expeditionis
Udotea argentea
Valonia fastigiata

Magnoliophyta
Cymodocea rotundata
Enhalus acoroides
Thalassia hemprichii

Phaeophyta
Dictyopteris repens
Dictyota friabilis
Dictyota patens
Hincksia breviarticulata
*Padina boryana**
Padina minor
Sargassum cristaefolium
Sargassum ilicifolium
Sargassum polycystum
Sphacelaria tribuloides
Turbinaria decurrens

Rhodophyta
Actinotrichia fragilis
Amansia fimbrifolia
Amphiroa foliacea
Centroceras minutum
Ceramium fimbriatum
Ceramium macilentum
Ceramium serpens
Ceramium vagans
Ceratodictyon spongiosum
Champia compressa
Cheilosporium spectabile
Chondria dangeardii
Chondria simpliciuscula
Corallophila apiculata
Crouania minutissima
Dasya pilosa
Gelidiella myrioclada
Gelidiopsis repens
Gelidium rigidum
Gloiocladia iyoense
Gracilaria salicornia
Griffithsia heteromorpha
Halichrysis coalescens
Halymenia dilatata
Halymenia durvillei
Herposiphonia crassa
Herposiphonia obscura
Herposiphonia pacifica
Hypnea pannosa
Hypoglossum minimum
Laurencia flexilis
Laurencia mariannensis
Laurencia nidifica
Lophocladia minima
Myriogramme bombayensis
Polysiphonia pentamera
Polysiphonia tsudana
Portieria hornemannii
Ptilothamnion cladophorae

* = *P. tenuis* in Hodgson & McDermid (2000)

Table 12: Ant-Pohnpei species with tropical to subtropical Pacific Ocean distributions (43 sp., 17.6% of flora).

Chlorophyta	**Rhodophyta**	*Gelidiella machrisiana*
Halimeda cylindracea	*Amansia glomerata*	*Herposiphonia dubia*
Halimeda distorta	*Amphiroa misakiensis*	*Hypoglossum caloglossoides*
Halimeda fragilis	*Amphiroa valonioides*	*Laurencia cartilaginea*
Halimeda minima	*Ceramium aduncum*	*Laurencia galtsoffii*
Percursaria dawsonii	*Ceramium borneense*	*Laurencia succisa*
Rhipilia diaphana	*Ceramium clarionense*	*Laurencia undulata*
Spongocladia vaucheriaeformis	*Ceramium punctiforme*	*Laurencia yamadana*
Uronema marina	*Chondracanthus tenellus*	*Lejolisea pacifica*
	Corallophila huysmansii	*Neosiphonia sparsa*
Phaeophyta	*Corallophila kleiwegii*	*Ossiella pacifica*
Dictyota acutiloba	*Corynocystis prostrata*	*Polysiphonia herpa*
Dilophus radicans	*Crouania mageshimensis*	*Polysiphonia savatieri*
Hapalospongidion pangoense	*Cryptonemia umbraticola*	*Polysiphonia upolensis*
Turbinaria ornata	*Dasya iridescens*	*Wrangelia dumontii*
	Gelidiella adnata	*Zellera tawallina*

Pacific and Indian Oceans (Table 11). These 32 Chlorophyta, 3 Magnoliophyta (seagrasses), 11 Phaeophyta, and 39 Rhodophyta are within the Tropical Indo-West Pacific Region (van den Hoek 1984, Kay 1979), although their distributions within the region are incompletely known.

Other taxa have more restricted regional distributions. A group of 8 species of Chlorophyta, 4 Phaeophyta and 31 Rhodophyta, 17.6% of the flora, seems to be restricted to the tropical and subtropical Pacific (Table 12). A final group of 7 species of Chlorophyta and 1 species of Rhodophyta, 3.3% of the flora, has been found only in the Caroline Islands and the nearby Marshall and Mariana Islands, hence probably should be considered regional "endemics" (Table 13). Yamada (1944a) described 4 members of this group, *Caulerpa antoensis, C. matsuena*, *Rhipilia micronesica* and *Wrangelia anastomosans* from Ant Atoll. Taylor (1950) described *Rhipilia geppii* from Bikini and Enewetak Atolls in the Marshall Islands. *Rhipilia sinuosa* was described by Gilbert (1978), based on specimens from Guam, but also collected by him from other Micronesian and Mariana Islands. *Dictyosphaeria bokotensis* was reported by Dawson (1956) from Kwajalein in the Marshalls, by Newhouse (1969) for Kapingamarangi in the Carolines, and by Yamada (1944b) from Ant Atoll. *Dictyosphaeria mutica* has been reported only by Newhouse (1969) and Yamada (1944b).

Table 13: Ant-Pohnpei species restricted to the Micronesian region (8 sp., 3.3% of flora).

Chlorophyta		**Rhodophyta**
Caulerpa antoensis	*Rhipilia geppii*	*Wrangelia anastomosans*
Caulerpa matsuena	*Rhipilia micronesica*	
Dictyosphaeria bokotensis	*Rhipilia sinuosa*	
Dictyosphaeria mutica		

Discussion

Biogeographic theory would predict higher biodiversity on Pohnpei than on Ant. However, we found little overall difference in numbers of species. The total known marine flora of Pohnpei is 165 species and Ant is 160 species. We believe that Pohnpei has been under-collected, and we predict that more extensive collections from mangrove forests, the deeper reef slopes, and other as yet unexamined habitats, will increase the known flora of Pohnpei. On the other hand, few habitats remain unexamined on Ant Atoll.

In tropical Micronesia, there is a hot, wet, humid season and a cooler, drier trade-wind season. These two seasons are marked by changes in water temperature, rainfall, wave and wind strengths and directions, and other aspects of climate (Weins 1962, Lobban & Schefter 1997). Some species of algae exist as tiny filaments or crusts, which then grow into macroscopic stages only during certain seasons. Our collections were made only in August, September, and November. Genera that would be expected in a tropical flora, such as *Liagora*, are completely missing from our collections. We predict, therefore, that collections during other seasons will reveal additional species.

One way of describing biodiversity is to examine the degree of similarity between floras, as has been discussed by N'Yeurt & South (1997). Comparative data do not exist for other atoll-high island pairs. However, N'Yeurt et al. (1996) calculated a Jaccard Index for similarity between the main Fijian archipelago and the small isolated island of Rotuma, approximately 3.5º of latitude (480 km) closer to the equator than the closest main Fijian island. Their Jaccard similarity index was 18.3 overall: 27.5 for Chlorophyta, 4.4 for Phaeophyta, and 13.5 for Rhodophyta. If the Rotuma–Fiji indices are typical for a pair of islands so far apart, we would expect that the Ant–Pohnpei pair, in such close proximity, would be higher. This in fact was the case with a Jaccard index of 34 overall: 34 for Chlorophyta, 31 Phaeophyta, and 34 Rhodophyta.

With only a few exceptions, a pattern of higher similarity in the Chlorophyta than in the Phaeophyta or Rhodophyta was found by N'Yeurt & South (1997) in comparisons of Fiji and Rotuma to other Pacific Island groups. Since we also saw this pattern in comparisons with Ant and Pohnpei, it is probable that the higher degree of similarity of Chlorophyta in the tropical Pacific is real, and not an artifact of collection.

The number of species found on Ant Atoll and Pohnpei were compared to other islands, arranged generally from west to east in Table 6. The known flora of Ant and Pohnpei (244 species) now exceeds that previously reported for the remainder of the Caroline Islands (191 species) (Trono 1968, 1969, 1971). The difference is primarily due to our report of 113 species of Rhodophyta. Tsuda (1987) reported 107 species for Guam in a paper on Enewetak (however, the species list is not included, and so similarity indices could not be calculated.) Among the phycologically best-known Pacific islands are Enewetak (222 species) and Bikini Atoll (148 species) in the Marshall Islands. The Ant-Pohnpei flora is similar in richness, although our collections have yielded more Rhodophyta than

are known from Enewetak and Bikini. The paucity of Rhodophyta reported by authors of many Pacific studies seems to be due both to limited collecting effort and incomplete treatment of collections. Rhodophyta are often inconspicuous as members of turfs, are relatively difficult to identify, and often occur at SCUBA depths unavailable to many previous workers. On Ant Atoll, for instance, 20 species of Rhodophyta were found only while SCUBA diving.

The data from Tsuda & Wray (1977), Tsuda (1981a), Hodgson & McDermid (2000) and this paper indicate that the Micronesian region as a whole (including Ant and Pohnpei) is richer than French Polynesia (Payri & N'Yeurt 1997) or Fiji (N'Yeurt et al. 1996). This greater species richness in Micronesia may reflect a similar west-to-east decrease in diversity to that noted by zoogeographers (Kay 1979), and may be ascribable to the random nature of long distance dispersal (van den Hoek 1987). Alternatively, Micronesia's greater richness may be due to its larger geographical area or to differences in collecting effort. It will be interesting, as we fill in the gaps in our knowledge of the Micronesian marine flora, to examine these geographic trends within the Caroline Islands, which stretch over 30 degrees of longitude, but only about 4 degrees of latitude.

The marine flora of the Pacific is beginning to be known well enough for us to make biogeographic comparisons, although many mysteries remain. Santelices & Abbott (1987) found 101 species in the algal flora of the extremely isolated Easter Island in the eastern Pacific. That flora was made up of 35.6% species widely distributed in both temperate and tropical oceans; 23.8% widely distributed in warm waters, in all three oceans; and 20.7% with an Indo-Pacific distribution. Another 6% were known only from a few islands in the Pacific. Easter Island also had 13.9% endemic species, mostly Rhodophyta. Thus, this very isolated island has a flora dominated by widely distributed species, but also has a significant proportion of endemic species.

Although our biogeographic groupings do not directly correspond to those used by Santelices & Abbott (1987), they are similar enough to indicate that the Ant-Pohnpei flora is less dominated by widely distributed species, contains more Indo-Pacific and Pacific components, and has much lower endemism than Easter Island. These patterns are what would be expected based on the greater geographic isolation of Easter Island, on differences in water temperature and current patterns, and on the greater proximity of Ant and Pohnpei to hypothetical donor areas in the diverse Indo-West Pacific (van den Hoek 1984, N'Yeurt & South 1997).

In summary, our study of Ant Atoll and Pohnpei has filled a major gap in our knowledge of the distribution of marine plants in the western tropical Pacific Ocean, and has expanded the list of species known from Micronesia. This study also offers the first direct comparison of the floras of a high island and low atoll. We were delighted to visit Ant Atoll, the site of Yamada's important study in the 1940's and to increase our understanding of its distinctness from its nearest neighbor, Pohnpei. For the future, there is tiny Pakin Atoll 30 km northwest of Pohnpei, as well as a thousand other Pacific islands, which have not yet been visited by phycologists.

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References

Abbott, I. A. 1961. A checklist of marine algae from Ifaluk Atoll, Caroline Islands. Atoll Research Bulletin No.77: 1–5.

Abbott, I. A. 1995. Marine algae of Satawal, Caroline Islands. Unpublished species list.

Abbott, I. A. 1999. Marine Red Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, HI. 476 pp.

Abbott, I. A. & G. J. Hollenberg. 1976. Marine Algae of California. Stanford Univ. Press. 827 pp.

Best, B. & D. Pendleton. 1980. Marine plants of northern Ponape. *In*, C. Birkeland (ed.) Marine Biological Survey of Northern Ponape, Univ. of Guam Marine Laboratory Technical Report 62: 55–59.

Cambridge, M. L., A. M. Breeman, S. Kraak & C. van den Hoek. 1987. Temperature responses of tropical to warm temperate *Cladophora* species in relation to their distribution in the North Atlantic Ocean. Helgolander Meeresuntersuchungen 41: 329–354.

Chapman, V. J. 1955. Algal collections from Funafuti Atoll. Pacific Science 9: 354–356.

Chapman, V. J. 1971. The marine algae of Fiji. Extrait de la Revue Algologique No. 2: 164–171.

Chapman, V. J. & F. I. Dromgoole. 1970. The marine algae of New Zealand. Part III: Rhodophyceae, Issue 2: Florideophycidae: Rhodymeniales. Verlag von J. Cramer. p. 115–154 + 20 plates.

Coppejans, E. & A. J. K. Millar. 2000. Marine red algae from the north coast of Papua New Guinea. Botanica Marina 43: 315–346.

Dawson, E. Y. 1954. Marine plants in the vicinity of Nha Trang, Viet Nam. Pacific Science 8: 373–470.

Dawson, E. Y. 1956. Some marine algae of the southern Marshall Islands. Pacific Science 10(1): 25–66.

Dawson, E. Y. 1957. An annotated list of marine algae from Eniwetok Atoll, Marshall Islands. Pacific Science 11: 92–132.

Den Hartog, C. 1970. The seagrasses of the world. Verhandelingen der Koninklijke Nederlandse, Akademie van Wetenschappen, AFD. Natuurkunde 59: 1–275.

Doty, M. S. 1954. Distribution of the algal genera *Rhipilia* and *Sargassum* in the central Pacific. Pacific Science 8: 367–368.

Doty, M.S. 1973. Marine organisms – tropical algal ecology and conservation. *In*, A.B. Costin & R.H. Groves (eds.), Nature Conservation in the Pacific, pp 183–196. Australian National University Press, Canberra.

Douglas, N.N. (ed.) 1989. Pacific Islands Yearbook. 16th edition. Angus and Roberts Publishers, Australia. 717 pp.

Enomoto, S., S. James & T. Ajisaka. 1986. Marine algae from the atoll of Ant, Pohnpei: Chlorophyceae (preliminary report). *In*, The Prompt Report of the Fourth Scientific Survey of the South Pacific. Research Center for the South Pacific Kagoshima University & College of Micronesia. Report 5, Subject 2: 48–52.

Gilbert, W.J. 1978. *Rhipilia sinuosa* sp. nov. (Chlorophyta, Siphonales) from Micronesia. Phycologia 17: 311–313.

Gilmartin, M. 1960. The ecological distribution of the deepwater algae of Enewetak Atoll. Ecology 41: 210–221.

Glassman, S.F. 1952. List of non-vascular plants from Ponape, Caroline Islands. American Midland Naturalist 48:735–740.

Hodgson, L.M. & K. J. McDermid. 2000. Marine plants of Pohnpei and Ant Atoll: Chlorophyta, Phaeophyta and Magnoliophyta. Micronesica 32: 289–307.

Hollenberg, G.J. 1968a. An account of the species of *Polysiphonia* of the central and western tropical Pacific Ocean. I. Oligosiphonia. Pacific Science 22: 56–98.

Hollenberg, G.J. 1968b. An account of the species of the red alga *Polysiphonia* of the central and western tropical Pacific Ocean. II. *Polysiphonia*. Pacific Science 22: 198–207.

Hollenberg, G.J. 1968c. An account of the species of the red alga *Herposiphonia* occurring in the central and western tropical Pacific Ocean. Pacific Science 22: 536–559.

Itono, H. 1980. The genus *Galaxaura* (Rhodophyta) in Micronesia. Micronesica 16: 1–19.

Kanda, C. 1942. The seaweeds in Garu-berugairu watercourse in Palao. Kagaku Nanyo 5: 144–150.

Kanda, C. 1944. Ecological studies on the marine algae from Kororu and adjacent islands in the South Sea Islands. Palao Tropical Biological Station Studies. 2: 737–800.

Kay, E.A. 1980. Little Worlds of the Pacific: An Essay on Pacific Basin Biogeography. Lyon Arboretum, Honolulu, HI. 40 pp.

Kraft, G. T. 2000. Marine and estuarine benthic green algae (Chlorophyta) of Lord Howe Island, south-western Pacific. Australian Systematic Botany 13: 509–648.

Littler, D.S. & M. M. Littler. 2000. Caribbean Reef Plants. Offshore Graphics, Inc, Washington, D.C. 542 pp.

Lobban, C.S. & M. Schefter. 1997. Tropical Pacific Island Environments. University of Guam Press. 399 pp.

Lüning, K. 1990. Seaweeds: Their environment, biogeography, and ecophysiology. John Wiley & Sons, N.Y. 527 pp.

MacArthur, R. H. & E. O. Wilson. 1963. An equilibrium theory of insular zoogeography. Evolution 17: 373–387.

MacArthur, R.H. & E. O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ. 203 pp.

McDermid, K.J. & A. Edward. 1999. Seagrass community composition and biomass at Nahpali Island, Pohnpei. Micronesica 31: 255–262.

Meneses, I. & I.A. Abbott. 1987. *Gracilaria* and *Polycavernosa* (Rhodophyta) from Micronesia. Micronesica 20: 187–200.

Millar, A. J. K. & G. T. Kraft. 1993. Catalogue of marine and freshwater red algae (Rhodophyta) of New South Wales, including Lord Howe island, southwestern Pacific. Australian Systematic Botany 6: 1–90.

Newhouse, J. 1969. The algae of Kapingamarangi Atoll, Caroline Islands, Part I. Checklist of the Cyanophyta, Chlorophyta and Phaeophyta. Atoll Research Bulletin 121: 1–7.

N'Yeurt, A. D. R. & G. R. South. 1997. Biodiversity and biogeography of benthic marine algae in the southwest Pacific, with special reference to Rotuma and Fiji. Pacific Science 51: 18–28.

N'Yeurt, A. D. R., G. R. South & D. W. Keats. 1996. A revised checklist of the benthic marine algae of the Fiji Islands, South Pacific (Including the Island of Rotuma). Micronesica 29: 49–98.

Okamura, K. 1916. List of marine algae collected in Caroline and Mariana Islands, 1915. Botanical Magazine Tokyo 30: 1–14.

Payri, C. E. & A. D. R. N'Yeurt. 1997. A revised checklist of Polynesian benthic marine algae. Australian Systematic Botany 10: 867–910.

Pielou, E. C. 1984. The Interpretation of Ecological Data. John Wiley & Sons, New York. 263 pp.

Prud'homme van Reine, W. F. 1998. Seaweeds and biogeography in the Macaronesian region. Boletim do Museu Municipal do Funchai (Historia Natural) Supplement No. 5: 307–331.

Roughgarden, J. 1979. Theory of Population Genetics and Evolutionary Ecology: An Introduction. MacMillan Publ. Co., New York. 634 pp.

Santelices, B. & I. A. Abbott. 1987. Geographic and marine isolation: an assessment of the marine algae of Easter Island. Pacific Science 41: 1–20.

Schmidt, O.C. 1928. Verzeichnis der meeresalgen von Neu-Guinea und dem westlichen oceanien. Hedwigia 68: 19–86.

Silva, P. C. 1992. Geographic patterns of diversity in benthic marine algae. Pacific Science 46: 429.

Silva, P. C., P.W. Basson & R.L. Moe. 1996. Catalogue of the benthic marine algae of the Indian Ocean. University of California Publications in Botany 29: 1–1259.

Silva, P. C., E. L. Meñez & R. L. Moe. 1987. Catalog of the benthic marine algae of the Philippines. Smithsonian Contributions in Marine Science. 27: 1–179.

Smith, C. M. 1992. Diversity in intertidal habitats: an assessment of the marine algae of select high islands in the Hawaiian Archipelago. Pacific Science 46: 466–479.

South, G. R. & P. A. Skelton. 2000. A review of *Ceramium* (Rhodophyceae, Ceramiales) from Fiji and Samoa, South Pacific. Micronesica 33:45–98.

Srimanobhas, V., M. Baba, H. Akioka, T. Masaki, & H. W. Johansen. 1990. *Cheilosporum* (Corallinales, Rhodophyta) in Japan: a morphotaxonomic study. Phycologia 29: 103–113.

Stegenga, H., J. J. Bolton & R. J. Anderson. 1997. Seaweeds of the South African West Coast. Contributions Bolus Herbarium No.18. 655 pp.

Taylor, W. R. 1950. Plants of Bikini and Other Northern Marshall Islands. University of Michigan Press, Ann Arbor. xv + 227 pp.

Taylor, W. R. 1960. Marine Algae of the Eastern Tropical and Subtropical Coasts of the Americas. University of Michigan Press, Ann Arbor. 870 pp.

Tokida, S. 1939. A list of marine algae from Micronesia. Kagaku Nanyo 2: 16–26.

Trono, G. C. Jr. 1968. The marine benthic algae of the Caroline Islands, I. Introduction, Chlorophyta and Cyanophyta. Micronesica 4: 137–206.

Trono, G. C. Jr. 1969. The marine benthic algae of the Caroline Islands, II. Phaeophyta and Rhodophyta. Micronesica 5: 25–119.

Trono, G. C. Jr. 1971. Some new species of marine benthic algae from the Caroline Islands, western-central Pacific. Micronesica 7: 45–77.

Tsuda, R. T. 1972a. Marine benthic algae of Guam I. Phaeophyta. Micronesica 8: 87–115.

Tsuda, R. T. 1972b. Some marine benthic algae from Truk and Kuop, Caroline Islands. Atoll Research Bulletin No.155: 1–10.

Tsuda, R. T. 1981a. Bibliography of marine benthic algae of Micronesia: addendum. Micronesica 17: 213–218.

Tsuda, R. T. 1981b. Marine benthic algae of Kayangel Atoll, Palau. Atoll Research Bulletin No. 25: 43–48.

Tsuda, R. T. 1987. Marine benthic algae of Enewetak Atoll. *In,* D.M. Devaney, E. S. Reese, B.L. Burch & P. Helfrich (eds). The Natural History of Enewetak Atoll, Vol. 2 Biogeography and Systematics, pp. 1–9. U.S. Dept. of Energy.

Tsuda, R. T. & M. S. Belk. 1972. Additional records of marine benthic algae from Yap, Western Caroline Islands. Atoll Research Bulletin No.156: 1–5.

Tsuda, R. T. & W. J. Tobias. 1977a. Marine benthic algae from the Northern Mariana Islands, Chlorophyta and Phaeophyta. Bulletin of the Japanese Society of Phycology. 25: 19–24.

Tsuda, R.T. & W.J. Tobias. 1977b. Marine benthic algae from the Northern Mariana Islands, Cyanophyta and Rhodophyta. Bulletin of the Japanese Society of Phycology. 25: 155–158.

Tsuda, R. T. & G. C. Trono. 1968. Marine benthic algae from Howland Island and Baker Island, central Pacific. Pacific Science 22: 194–196.

Tsuda, R. T. & F. O. Wray. 1977. Bibliography of marine benthic algae in Micronesia. Micronesica 13: 85–120.

Tsuda, R. T., R. H. Randall, & J. A. Chase. 1974. Limited current and biological study in the Tuanmokot Channel, Ponape. University of Guam Marine Laboratory. Technical Report No. 15: 1–57.

Tsuda, R. T., S. S. Amesbury, & S. C. Moras. 1977a. Preliminary observations on the algae, corals, and fishes inhabiting the sunken ferry "Fujikawa Maru" in Truk Lagoon. Atoll Research Bulletin No. 212:1–6.

Tsuda, R.T., F.R. Fosberg & M.-H. Sachet. 1977b. Distribution of seagrasses in Micronesia. Micronesica 13: 191–198.

van den Hoek, C. 1984. World-wide latitudinal and longitudinal seaweed distribution patterns and their possible causes, as illustrated by the distribution of Rhodophytan genera. Helgolander Meeresuntersuchungen 38: 227–257.

van den Hoek, C. 1987. The possible significance of long-range dispersal for the biogeography of seaweeds. Helgolander Meeresuntersuchungen 41: 261–272.

Wiens, H. J. 1962. Atoll Environment and Ecology. Murray Printing Company, MA 532 pp.

Womersley, H. B. S. 1970. Marine algae of the Solomon Islands. Philosophical Transactions Royal Society, London, B, 259: 257–352.

Womersley, H. B. S. & A. Bailey. 1969. The marine algae of the Solomon Islands and their place in biotic reefs. Philosophical Transactions Royal Society, London, B, 255: 433–442.

Yamada, Y. 1926. The phyto-geographical relation between the Chlorophyceae of the Mariannas, Carolines and Marshall Islands and those of the Malay Archipelago, Australia and Japan. Proceedings Third Pan-Pacific Science Congress, Tokyo: 964–966.

Yamada, Y. 1931. Notes on *Laurencia*, with special reference to the Japanese species. University of California Publications in Botany.16: 185–310.

Yamada, Y. 1940. *Caulerpa* in Micronesia. Kagaku Nanyo 3: 11–23.

Yamada, Y. 1941. *Halimeda* in Micronesia. Kagaku Nanyo 4: 12–25.

Yamada, Y. 1944a. New *Caulerpas* and *Halimeda* from Micronesia. Scientific Papers of the Institute of Algological Research, Faculty of Science, Hokkaido University 3: 27–29.

Yamada, Y. 1944b. A list of the marine algae from the atoll of Ant. Scientific Papers of the Institute of Algological Research, Faculty of Science, Hokkaido University 3: 31–45.

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