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FLORA OF RONGELAP AND AILINGINAE ATOLLS, REPUBLIC OF THE MARSHALL ISLANDS

BY

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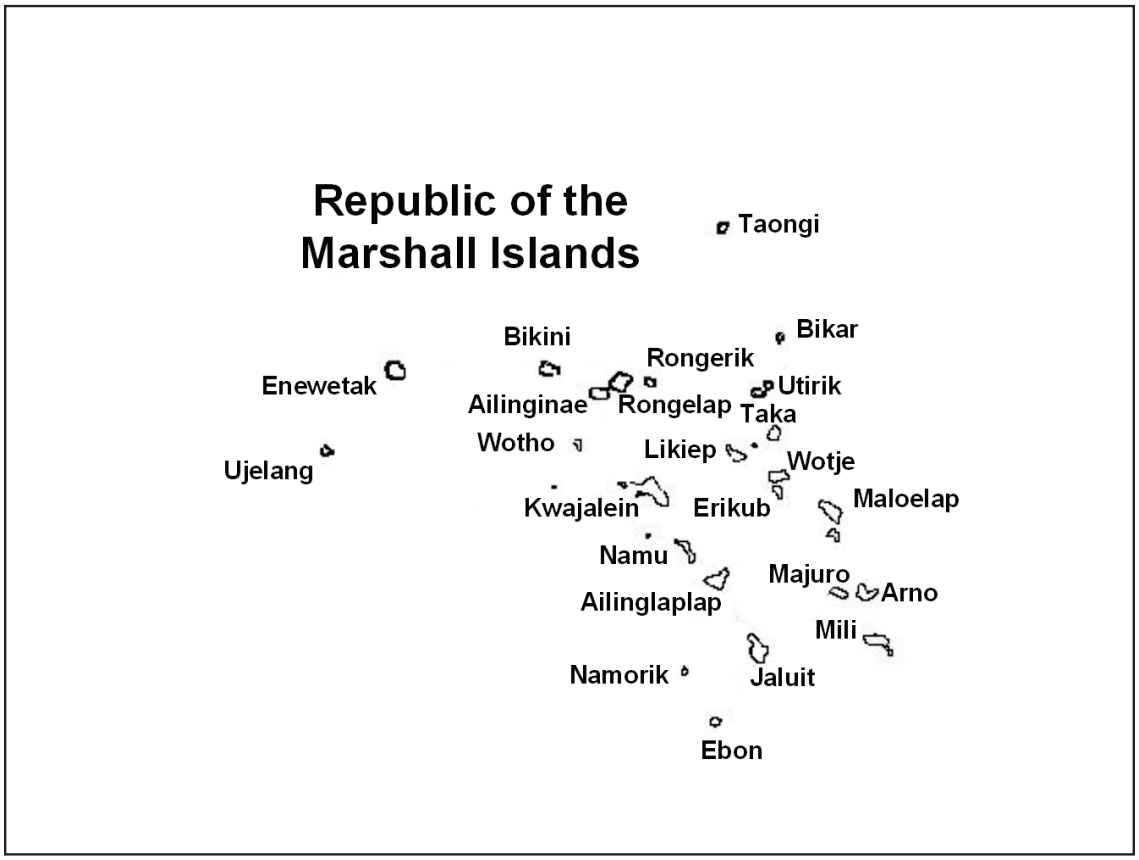

Figure 1. Map of the Republic of the Marshall Islands including the study sites of Rongelap and Ailinginae atolls.

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ABSTRACT

Rongelap and Ailinginae atolls are best known as the home of Rongelap islanders who were displaced following exposure to nuclear radiation in 1954. As a result, the atolls have experienced various levels of habitation in the last fifty years. Consequently, a thorough survey of the flora of the atolls has not been undertaken since William Randolph Taylor visited the area in 1946 prior to the nuclear tests in the area. Our chief research objectives were to document the terrestrial vascular plant species richness of both Rongelap and Ailinginae atolls and to provide baseline data on distribution between islets within the atolls. The flora of the atolls was investigated using transect methodologies and plant checklist surveys. Sixty-three vascular plant species were found on Rongelap atoll and 29 species were identified on Ailinginae atoll. The repatriation of the Rongelap community provides a wonderful opportunity for future research examining changes in species diversity and abundance throughout and following construction within the atoll. Taylor's work provided a snapshot of the flora of Rongelap prior to the changes invoked by nuclear testing and the evacuation of the community. This work provides a baseline of data (prior to the construction of most of the community) that we hope others will build upon by examining both terrestrial and marine species.

INTRODUCTION

Atoll environments are extreme and support very few terrestrial plant species. Atoll species face several challenges to survival such as high salinity levels, drought, disturbance, and poor soils (Manner et al., 1999). There are few species that can survive in these conditions therefore, most atoll species are indigenous and common, very few are endemic (Mueller-Dombois and Fosberg, 1998). Species diversity on atolls is largely determined by rainfall levels. For example, Canton Island in the Phoenix group receives 500 mm of rainfall a year and is inhabited by only 14 vascular plant species while Arno Atoll in the Marshall Islands supports nearly ten times as many species with 4,000 mm of rainfall (Wiens, 1962; Hatheway, 1955).

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Unfortunately, we have no record of the original vegetation of the Marshall Islands (Mueller-Dombois and Fosberg, 1998), but it is thought to have been composed of a small number of species common throughout the Pacific (Muller and Vander Velde, 1999). Indigenous species diversity in the Marshall Island archipelago (Fig. 1) is a continuum with 9 indigenous species found on Taongi (Pokak) in the north (Mueller-Dombois and Fosberg, 1998) at one end of the continuum and 44 and 56 indigenous species on Arno and Majuro atolls (Hatheway, 1953; Vander Velde, 2003) at the other end. Within the Marshall Islands, the indigenous vegetation is relatively similar from atoll to atoll, but with recent introductions of ornamental, weedy, and food species from all over the world, Vander Velde (2003) recorded 563 species on Majuro Atoll, home to the capitol of the Marshall Islands.

Because of the poor species richness of the vegetation, the first inhabitants of the Archipelago had to depend on the few indigenous species available and a few they brought with them. As a result, they found numerous uses for the species they had available and manipulated the environment to suit their needs (Muller and Vander Velde, 1999). This manipulation was so pervasive that in speaking of a survey performed on Bikini Atoll (a neighbor of Rongelap Atoll) Fosberg (1985) asserted that he was unable to find any unaltered natural vegetation. Thaman (2006) further suggests that the terrestrial ecosystems of the Marshall Islands are poor, degraded, disturbed, and highly modified. This is due to several factors including, limited land area, rapid urbanization and damage during World War II, plant introductions, and low native habitat diversity.

Study Sites

Rongelap Atoll lies at the drier northern end of the Ralik chain in the Marshall Island archipelago. The atoll consists of 61 islets with a combined area of 3.07 square miles while the lagoon has an area of 387.77 square miles. The vegetation is simple and typical of the floras of other atolls in the Northern Marshall Islands (Taylor, 1950; Thomas et al., 1989).

In 1946 William Randolph Taylor visited Rongelap Atoll as part of an effort by the United States government to document the plant and animal life of the area. The data gathered was to provide a baseline for future comparison of Bikini and the nearby atolls prior to and following nuclear testing. During his visit to the atoll, Taylor (1950) collected 38 vascular plant species and hinted at relative abundance for a few species. Taylor's collection provided a starting point for this research on Rongelap as well as an opportunity to make comparisons of the flora before and after atomic tests took place.

As a result of exposure to nuclear fallout indigenous Rongelap Islanders have a complex evacuation history and have not inhabited the atoll since 1985 (Greenpeace, 2005) when they evacuated because of health and safety concerns. They are still dealing with health concerns and living in exile but hope to return to live permanently on Rongelap again soon.

The uninhabited atoll of Ailinginae is made up of 25 islets ranging from one to three meters in elevation. The atoll is located approximately 13 km west-southwest of Rongelap Atoll. Traditionally, Ailinginae was occupied for brief periods by

Rongelap Islanders gathering resources such as crabs, fish, and turtle eggs. While the vegetation is predominately indigenous, there are aboriginal (*Morinda citrifolia* and *Tacca leontapetaloides*) and colonial (*Cocos nucifera*) introductions present. Since the Rongelap Islanders evacuated Rongelap Atoll, Ailinginae has not been utilized as a resource. In fact, few if any visitors have been there in the last 50 years as the U.S military actively restricted access to the area (Matayoshi, 2001).

Objectives

Our chief research objectives were to document the terrestrial vascular plant species richness of both Rongelap and Ailinginae atolls and to provide baseline data on distribution between islets within the atolls. We expected to find the same plant species collected by Taylor (1950) on Rongelap. We further predicted that plant species would be distributed within the atolls based on theories of island biogeography (Niering, 1963; MacArthur and Wilson, 1967). That the number of species would increase with increase in islet area. Or in other words, that the larger islets would support more species than the smaller islets within the atolls.

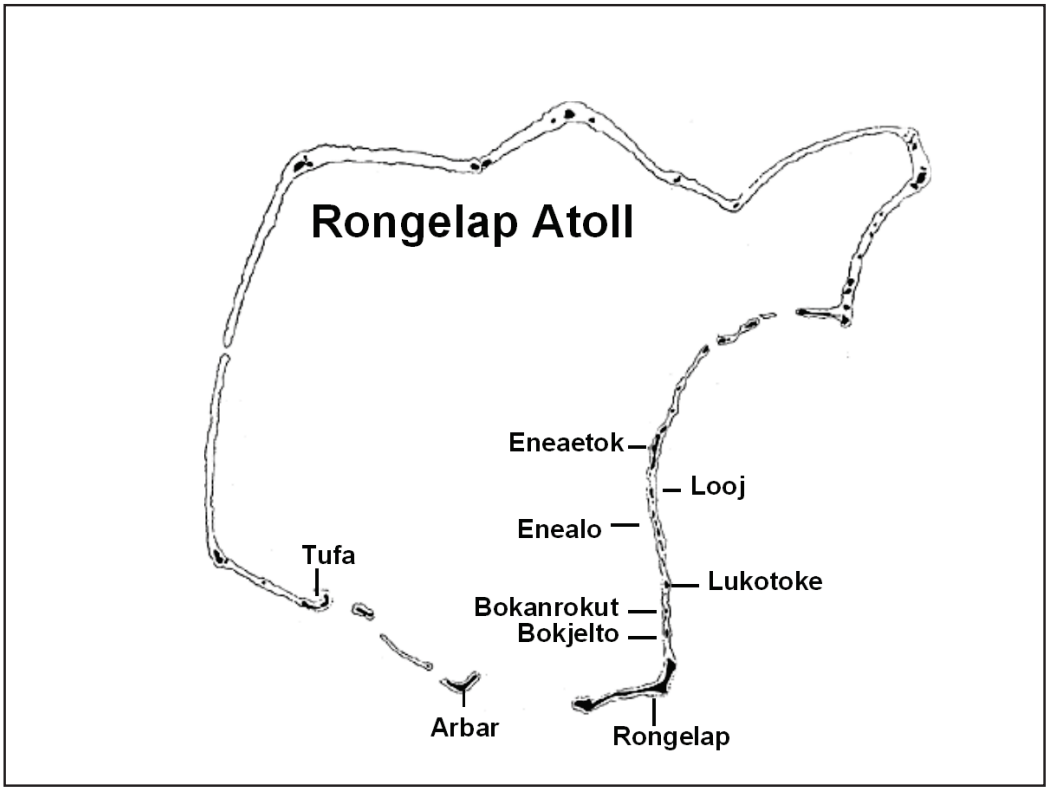

Figure 2. Map of Rongelap Atoll, with surveyed islets labeled.

METHODS

Rongelap Atoll

The current availability and distribution of vascular plant species on Rongelap Atoll were investigated using a combination of belt transects (Hill et al., 2005) and a checklist inventory (McClatchey and Bridges, 2007). Transect courses were chosen by dividing each surveyed islet into sections and completing three random (determined using a random number table) parallel transects two meters wide and 25 meters apart within each section (Fig. 2). Each transect was run perpendicular to the island from the edge of the lagoon through the vegetation to the ocean side beach using GPS. In determining which sections of the islets would be included, an attempt was made to survey all resource areas including the ocean side beach, strandwall, rubble land complex, broad-leaf scrub and coastal forest, breadfruit and coconut agroforestry, taro patches, habitation zones, and the lagoon beach (Merlin et al., 1994; Mueller-Dombois and Fosberg, 1998).

A checklist inventory (Bridges and McClatchey 2005) was kept throughout the vegetation survey in order to record data regarding species not encountered within the transects. The checklist included all species encountered throughout all environments visited within the atoll. All plant species encountered were photographed, collected (Alexiades, 1996), and documented through herbarium vouchers (Merill, 1981) that were collected with the permission of the Rongelap government and indigenous landowners and deposited in the herbaria of the University of Hawaii at Manoa (HAW).

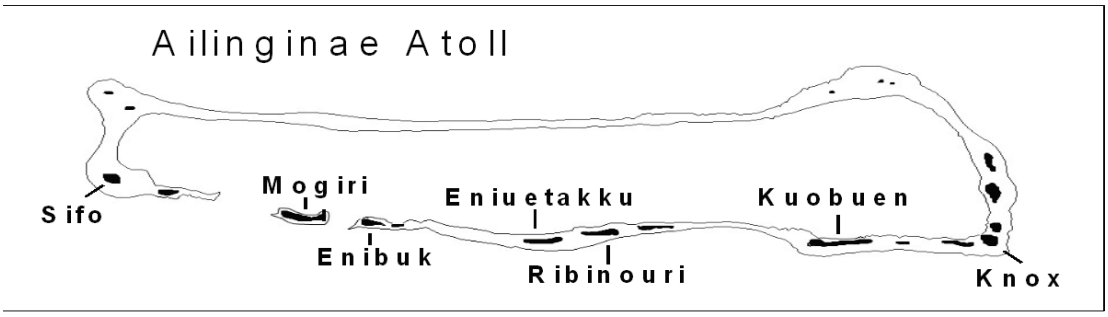

Figure 3. Map of Ailinginae Atoll, with surveyed islets labeled. (After Bridges and McClatchey 2005)

Ailinginae Atoll

The flora of Ailinginae was investigated using two methods, a quantitative plant survey using transects and a general plant checklist survey. A detailed description of these methodologies is given by Bridges and McClatchey (2005). The survey of Ailinginae resulted in 22 transects with an average length of 234 m. The total length of all transects was 5,047 m covering 2.4% of the total area of the surveyed islets (Fig. 3).

RESULTS

Rongelap Atoll

Nine islets including, Arbar, Bokanrokut, Bokjelto, Enealo, Eneaetok, Looj, Lukotoke, Rongelap, and Tufa were surveyed in Rongelap Atoll. A total of 60 individual transects were completed on the surveyed islets. Half of the transects were conducted on Rongelap, the largest islet within the atoll. Transect length varied with the longest at 740 m and the shortest at 32 m depending on the size of the islet being surveyed. Average transect length was 206 m, while the total length of all transects was 12,354 m. Sixty-three vascular plant species were found throughout the atoll. Table 1 summarizes the species currently found on Rongelap and Ailinginae atolls and compares these to the collections of Taylor (1950).

Table 1. Vascular Plant species currently found on Rongelap and Ailinginae atolls. Species collected by Taylor (1950) are included for comparison. The status or origin of each species and local names are included when known. I = Indigenous, A = Aboriginal introduction, and R = Recent introduction.

Latin Binomial	Rongelap Name	Status	Collected by Taylor	Present on Rongelap	Present on Ailinginae
Acanthaceae					
Pseuderanthemum reticulatum (Hort) Kanehira		R	X		
Pseuderanthemum atropurpureum (Bulliard) L.H. Bailey		R	X	X	
Amaryllidaceae					
Crinum asiaticum L.	Kiôp	R	X	X	
Apocynaceae					
Plumeria rubra L.	Meria	R		X	
Ochrosia parviflora (G.Forst.) Hensl.	Kôjbar	I	X	X	X
Catharanthus roseus (L.) G.Don		R		X	
Arecaeae					
Cocos nucifera L.	Ni	I/A	X	X	X
Asteraceae					
Melanthera biflora (L.) Wild	Kibwebwe	I	X	X	X
Heliotropium curassavicum L.		R		X	
Tridax procumbens L.		R		X	
Bignoniaceae					
Tecoma stans (L.) Kunth		R		X	
Boraginaceae					
Cordia subcordata Lam.	Kôňo	I	X	X	X
Heliotropium foertherianum Diane & Hilger	Kiden	I	X	X	X

Table 1 (Con't)

Latin Binomial	Rongelap Name	Status	Collected by Taylor	Present on Rongelap	Present on Ailinginae
Caricaceae					
Carica papaya L.	Keinabbu	R	X	X	
Casuarinaceae					
Casuarina equisetifolia L.		R		X	
Clusiaceae					
Calophyllum iphyllum L.	Lukwej	A	X	X	X
Combretaceae					
Terminalia samoensis Rechinger	Ekkôñ	I	X	X	X
Convolvulaceae					
Ipomoea pes-caprae (L.) R.Br.	Topo	A		X	
Ipomoea alba L.	Marpeď e	I	X	X	X
Cyperaceae					
Fimbristylis cymosa R.Br.	Beredijiman	I	X	X	X
Cyperus ferax Rich.	Bukor	R		X	
Dioscoreaceae					
Tacca leontopetaloides (L.) Merr.	Makmôk	A	X	X	X
Euphorbiaceae					
Phyllanthus amarus Schum. & Thonning	Jiljino-awa	R		X	
Euphorbia hirta L.		R		X	
Euphorbia atoto G. Forst.	Pedol	I		X	
Codiaeum variegatum (L.) Blume		R		X	
Fabaceae					
Canavalia microcarpa (DC) Piper	Marlap	I	X	X	
Caesalpinia sp.		R	X		
Goodeniaceae					
Scaevola taccada (Gaertner) Roxb.	Kôňňat	I	X	X	X
Lauraceae					
Cassytha filiformis L.	Kaônôn	I	X	X	X
Lythraceae					
Pemphis acidula Forster	Kôñe	I	X	X	X
Malvaceae					
Hibiscus rosa-sinensis L.	Lo-buroro	R		X	
Sida fallax Walpers	Wűt kio	I	X	X	
Moraceae					
Artocarpus altilis (Park.) Fosberg	Mâ	A	X	X	

Table 1 (Con'td)

Latin Binomial	Rongelap Name	Status	Collected by Taylor	Present on Rongelap	Present on Ailinginae
Musaceae					
Musa acuminate X balbisiana Colla	Keebrañ	A		X	
Nyctaginaceae					
Bougainvilla glabra Choisy		R		X	
Pisonia grandis R.Br.	Kañal	I	X	X	X
Boerhavia tetrandra G. Forst.	Bwilbwil kaj	I	X	X	X
Boerhavia diffusa L.	Bwilbwil kaj	I		X	X
Pandanaceae					
Pandanus tectorius Sol. ex Park.	Bôb	I/A	X	X	X
Poaceae					
Digitaria pruriens (Trinius) Buese		R	X	X	X
Eragrostis amabilis (L.) Wight & Arn.		R	X	X	
Eleusine indica (L.) Gaertner	Katejukjuk	R	X	X	
Paspalum setaceum Michx.	Wujooj Kateju##	R		X	
Cenchrus echinatus L.	Karmwijmwij	R	X	X	
Eustachys petraea (Sw.) Desv.		R		X	
Stetaphrum micranthum (Desv.) C.E.		R		X	
Thuarea involuta (Forster f.) R. Br.	Wujooj Kukon##	R	X	X	X
Lepturus repens (Forster f.) R. Br.	Wujooj	I	X	X	X
Polypodiaceae					
Microsorum scolopendria (Burm. f.) Copel.	Kino	I		X	X
Portulacaceae					
Portulaca oleracea L.		R		X	
Portulaca quadrifida L.		R		X	
Portulaca lutea Sol.		R	X	X	X
Rhizophoraceae					
Bruguiera gymnorhiza (L.) Savigny	Joñ	I	X	X	
Rubiaceae					
Guettardia speciosa L.	Wűtilomar	I	X	X	X
Morinda citrifolia L.	Nen	A	X	X	X
Sapindaceae					
Allophylus timorensis (DC) Bl.	Kűtaak	I	X	X	
Simaroubaceae					
Soulamea amara Lam.	Keinwa	I		X	X
Solanaceae					
Physalis angulata L.	Kaôrôr	R		X	

Table 1 (Con'td)

Latin Binomial	Rongelap Name	Status	Collected by Taylor	Present on Rongelap	Present on Ailinginae
Surianaceae					
Suriana maritima L.	Kalañe	I	X	X	X
Tilliaceae					
Triumfetta procumbens G. Forst.	Atat	I	X	X	X
Urticaceae					
Laportea ruderalis (G. Forst.) Chew		I		X	X
Verbenaceae					
Clerodendron inerme (L.) Gaertner	Wűlej	I	X	X	X
Premna serratifolia L.	Kaar	I		X	

Species were not uniformly distributed throughout the atoll (Table 2). The largest islet of Rongelap was home to all but two species *(Bruguiera gymnorhiza (L.) Savigny* and *Pemphis acidula* Forster) while Bokanrokut, the smallest of the surveyed islets, supports only three. *Guettardia speciosa*, *Scaevola taccada*, and *Terminalia samoensis* were found on all nine islets surveyed while *Cassytha filiformis* and *Heliotropium foertherianum* were found on all but one islet. Twenty-seven species, most of which are ornamental, food, and weedy species are found only on Rongelap islet.

Ailinginae Atoll

Eight of the largest islets in the atoll including Sifo, Mogiri, Enibuk, Eniuetakku, Ribinouri, Kuobuen and Knox were surveyed. A total of 29 species were identified throughout Ailinginae Atoll (Table 1). Eleven of these species were found on each of the surveyed islets including: *Boerhaavia tetandra*, *Cordia subcordata*, *Fleurya ruderalis*, *Guettardia speciosa*, *Lepturus repens*, *Microsorium scolopendria*, *Pemphis acidula*, *Pisonia grandis*, *Scaevola frutescens*, *Suriana maritima*, and *Heliotropium foertherianum*. Three species, *Cassytha filiformis*, *Ipomoea alba*, and *Morinda citrifolia* were each only lacking from one islet (Bridges and McClatchey, 2005).

Table 2. Distribution of terrestrial vascular plant species within Rongelap Atoll by islet. While running transects, grass and sedge species were lumped together because of difficulty and time needed for identification of these species therefore specific distribution data for these species is not available.

Taxa	Arbar	Bokanrokut	Enealo	Looj	Rongelap	Tufa	Eneaetok	Lukotoke	Bokjelto
Allophylus timorensis (DC) Bl.					X				
Artocarpus altilis (Park.) Fosberg					X				
Boerhavia diffusa L.			X	X					
Boerhavia tetrandra G. Forst.	X	X	X	X	X	X		X	
Bougainvilla glabra Choisy					X				
Bruguiera gymnorhiza (L.) Savigny	X								
Calophyllum inophyllum L.					X				
Canavalia microcarpa (DC) Piper					X		X		
Carica papaya L.					X				
Cassytha filiformis L.	X		X	X	X	X	X	X	X
Casuarina equisetifolia L.					X				
Catharanthus roseus (L.) G.Don					X				
Cenchrus echinatus L.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clerodendron inerme (L.) Gaertner					X		X		
Cocos nucifera L.					X	X	X	X	X
Codiaeum variegatum (L.) Blume					X				
Cordia subcordata Lam.			X		X				
Crinum asiaticum L.					X				
Cyperus ferax Rich.					X				
Digitaria pruriens (Trinius) Buese	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eleusine indica (L.) Gaertner	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eragrostis amabilis (L.) Wight & Arn.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Euphorbia atoto G. Forst.					X				
Euphorbia hirta L.					X				
Eustachys petraea (Sw.) Desv.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fimbristylis cymosa R.Br.					X				
Guettardia speciosa L.	X	X	X	X	X	X	X	X	X
Heliotropium curassavicum L.					X				
Heliotropium foertherianum Diane & Hilger	X	X		X	X	X	X	X	X
Hibiscus rosa-sinensis L.					X				
Ipomoea alba L.	X				X	X	X	X	
Ipomoea pes-caprae (L.) R.Br.					X				
Laportea ruderalis (G. Forst.) Chew	X								
Lepturus repens (Forster f.) R. Br.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Microsorum scolopendria (Burm. f.) Copel.	X				X		X		
Morinda citrifolia L.				X	X		X	X	
Musa acuminate X balbisiana Colla					X				

Table 2 (Con'td)

Taxa	Arbar	Bokanrokut	Enealo	Looj	Rongelap	Tufa	Eneaetok	Lukotoke	Bokjelto
Ochrosia parviflora (G.Forst.) Hensl.					X				
Pandanus tectorius Sol. ex Park.		X			X	X	X	X	
Paspalum setaceum Michx.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pemphis acidula Forster	X								
Phyllanthus amarus Schum. & Thonning					X				
Physalis angulata L.					X				
Pisonia grandis R.Br.	X			X	X	X	X	X	
Plumeria rubra L.					X				
Portulaca lutea Sol.					X				
Portulaca oleracea L.				X	X	X			
Portulaca quadrifida L.					X		X		
Premna serratifolia L.					X				
Pseuderanthemum atropurpureum (Bulliard) L.H. Bailey					X				
Scaevola taccada (Gaertner) Roxb.	X	X	X	X	X	X	X	X	X
Sida fallax Walpers					X		X		
Soulamea amara Lam.					X				
Stenotaphrum micranthum (Desv.) C.E.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Suriana maritima L.			X		X	X			
Tacca leontopetaloides (L.) Merr.					X				
Tecoma stans (L.) Kunth					X				
Terminalia samoensis Rechinger	X	X	X	X	X	X	X	X	X
Thuarea involuta (Forster f.) R. Br.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tridax procumbens L.					X				
Triumfetta procumbens G. Forst.					X	X	X	X	X
Melanthera biflora (L.) Wild					X				

DISCUSSION

Within Rongelap atoll, we were able to locate all but two of the species (*Pseuderanthemum reticulatum* (Hort) Kanehira and *Caesalpinia* sp.) collected by Taylor. Both of these are recently introduced ornamental species and likely did not survive without human maintenance. Clearly several species have been introduced to Rongelap Atoll since Taylor's survey in 1950. We collected 24 more species than Taylor found in 1946. With the exception of the five indigenous species (*Boerhavia diffusa* L., *Laportea ruderalis* (G. Forst.) Chew, *Microsorum scolopendria* (Burm. F.) Copeland, *Premna serratifolia* L., and *Soulamea amara* Lam.) Taylor did not encounter, the additional species are ornamental, weedy, or fruit species. Unfortunately we can only compare the species present in 1946 and 2002 since Taylor did not record abundance and distribution data with the exception of a few general observations.

Species diversity varied considerably within the atolls between the large and small islets. In fact, one transect through the widest part of Rongelap islet (724 m.) contained 20 species while a transect across the tiny islet of Roggutsu (48m.) contained only two. These transects were the extremes and the remaining transects fell within a continuum between the two. As a general rule, the longer the transect, the more species diversity was found. With that being said, there were islets within each of the atolls that did not fit the predicted pattern of increased species numbers with increasing area. Reasons for this could be that we may not have encountered all species within all islets, or it may be that within a small island ecosystem such as an atoll, the benefits of increased area are less important than other stochastic factors such as rainfall, habitat, storms, and a freshwater lens (Wester et al., 1992, Lomolino, 2000). McClatchey and Bridges (2007) further suggest that within an atoll, the shape of islets may also be a factor that affects species richness with vegetation of round islets being more diverse than more narrow islets. Our data certainly seems to support this hypothesis since the longer transects ran through the widest or most round sections of the islets although more analysis will have to be done before drawing any further conclusions.

CONCLUSIONS

The species diversity of Rongelap will change as it is once again manipulated by Rongelap Islanders. As the Rongelap community prepares to inhabit the atoll on a permanent basis, they will likely be introducing new species from Majuro and Kwajalein atolls where they are living now. Both atolls have large populations and are major thoroughfares for the country. Residents of Majuro in particular enjoy receiving and sharing new species (Vander Velde, 2003). In fact, Rongelap Islanders have already begun trading cuttings of *Sida fallax* Walps., which is found naturally on Rongelap, but not on Majuro. Also, as members of the Rongelap community return they will bring with them ornamentals and food species for their gardens and will inadvertently introduce new weed species in the process. These introduced species will likely spread from Rongelap islet to other islets in the atoll. It is then feasible that those species could be introduced to Ailinginae either through planned or accidental introductions.

Ailinginae is currently being considered for World Heritage Site status, which would certainly stem the tide of plant introductions by limiting visitors and activities within the atoll. Distance from Rongelap and the difficulty of the journey will likely further deter visitors. While the resources on Ailinginae are similar to those on Rongelap there are many more Coconut Crabs (*Birgus latro)* on Ailinginae that may be affected by the repatriation of the Rongelap Community. Coconut crab is a culturally important species that the community has not had access to since their evacuation. As a result, it is a prized delicacy that may entice community members to visit the atoll and harvest other resources as well as crabs.

The repatriation of the Rongelap community provides a wonderful opportunity for future research examining changes in species diversity and abundance throughout and following construction within the atoll. Which species will be introduced? How will

human maintenance and manipulation change the landscape? Taylor's work provided a snapshot of the flora of Rongelap prior to the changes invoked by nuclear testing and the evacuation of the community. This work provides a baseline of data prior to construction of most of the community that we hope others will build upon by examining both terrestrial and marine species.

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