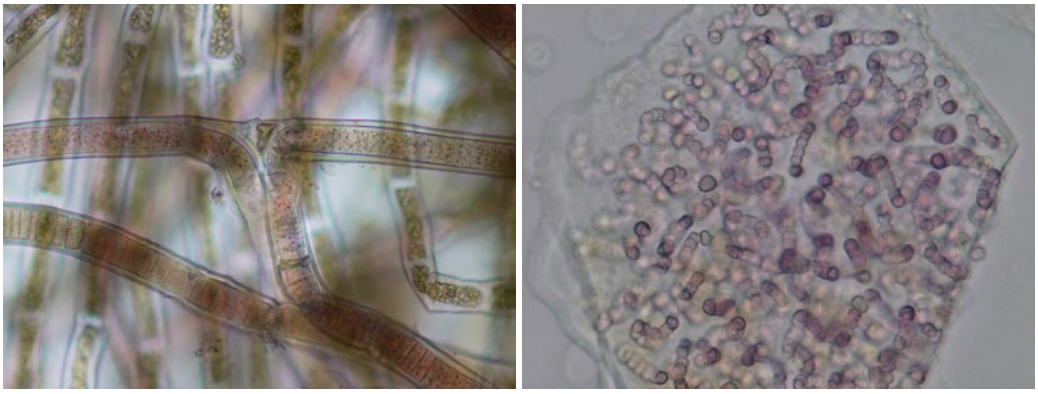

Freshwater Algae Collected During the 2002 Pacific Biological Survey, Bishop Museum Austral Islands Expedition to Raivavae and Rapa, French Polynesia

Prepared for:

Délégation à la Recherche

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RÉSUMÉ

Nous avons effectué des prospections biologiques aux îles Australes en Polynésie française, dans les îles de Raivavae et Rapa, dans le cadre du programme sur l'Etude Biologique du Pacifique (Pacific Biological Survey) du Bishop Museum et du programme de recherche "Inventaire et Valorisation de la Biodiversité" mené par la Polynésie française avec le soutien et le concours de la Délégation à la Recherche (Ministère de la Culture, de l'Enseignement Supérieur et de la Recherche, Gouvernement de Polynésie française). Dans ce rapport, nous avons fourni de nouvelles données sur les espèces d'algues d'eau douce dans les îles de Raivavae et Rapa. L'objectif de cette partie sur l'évaluation de la biodiversité d'eau douce dans les îles Australes a été de recenser les macro-algues d'eau douce trouvées dans ces îles éloignées.

Un total de 12 espèces de macro-algues appartenant à trois divisions a été collecté dans les habitats aquatiques durant ces prospections, 7 étant trouvées à Raivavae et 9 sur l'île de Rapa. Il est difficile de déterminer si ces espèces sont indigènes ou introduites en raison du manque de données historiques des macro-algues de rivière, comme c'est également le cas pour les îles Hawaii. Cependant, nous supposons l'absence complète d'espèces aquatiques introduites en raison du fort isolement de ces îles ; et que sur Raivavae, le nombre disponible en habitat d'eau douce étant limité, ces espèces de macro-algues sont probablement indigènes aux deux îles. Plusieurs spécimens n'ont pu être identifié qu'au niveau taxonomique du genre (e.g. Oedogonium sp. 1, Spirogyra sp. 1 et sp. 2) car les caractères se rattachant à la reproduction sexuelle nécessaires pour l'identification de l'espèce n'étaient pas présents au moment de la récolte. Malgré des efforts de collecte bien plus longs et plus grands, seules deux espèces supplémentaires de macro-algues ont été collectées par rapport à Rapa. Bien que seulement 12 taxa distincts ont été identifiés dans les habitats d'eau douce aux îles Australes lors de cette étude (5 Cyanophytes, 5 Chlorophytes et deux Tribophytes), il est probable qu'une biodiversité d'eau douce plus importante sera révélée si les efforts de prospections sont poursuivis dans le futur.

ABSTRACT

The Pacific Biological Survey (PBS) of the Bishop Museum conducted biological surveys in the Austral Islands, French Polynesia, of Raivavae and Rapa Islands as part of an “Inventaire et Valorisation de la Biodiversité” or inventory and evaluation of biodiversity, a research program conducted in French Polynesia with the assistance and support of the Délégation à la Recherche (Ministère de la Culture, de l’Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française). In this report we provide new records of freshwater stream algae species from the islands of Raivavae and Rapa. The objective of this portion of the Austral Islands biodiversity assessment was to survey the freshwater macroalgae found in these remote islands.

A total 12 species of macroalgae from three divisions were collected in aquatic habitats during these surveys, with 7 species being found on Raivavae and 9 on the island of Rapa. Whether these species are native or introduced is difficult to ascertain because of the lack of historical stream macroalgae records, as is the case for the Hawaiian Islands. However, it is speculated that because of the very remote nature of these islands, the complete lack of other introduced aquatic species;

and on Raivavae the limited amount of available freshwater habitats, these macroalgae species are probably native or indigenous to the two islands. Several collections could only be identified to the taxonomic level of genus (e.g. *Oedogonium* sp. #1, *Spirogyra* sp. #1 and #2) since characters pertaining to sexual reproduction are required for specific identification, and these were not present at the time of collection. Despite much longer and greater sample efforts on Raivavae, two fewer macroalgae species were collected than on Rapa. Although only 12 distinct taxa were identified from stream habitats in French Polynesia for this survey (five Cyanophyta, five Chlorophyta and two Tribophyceae), it is likely that as survey efforts continue in the future a larger diversity will be revealed.

Raivavae Taro Fields

INTRODUCTION

From 18 November to 18 December 2002 the Pacific Biological Survey (PBS) of the Bishop Museum conducted biological surveys in the Austral Islands of Raivavae and Rapa as part of an "Inventaire et Valorisation de la Biodiversité" or inventory and evaluation of biodiversity, a research program conducted in French Polynesia with the assistance and support of the Délégation à la Recherche (Ministère de la Culture, de l'Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française). These floral and faunal surveys were conducted in cooperation with the Bishop Museum, and French and American scientists from the parc naturel régional de Corse, Paris Muséum National D'Histoire Naturelle, Délégation à la Recherche de la Polynésie française, and the University of California at Berkeley.

Funding for these biodiversity surveys originated from the Délégation à la Recherche (Ministère de la Culture, de l'Enseignement Supérieur et de la Recherche, Gouvernement de la Polynésie française), with matching funding coming from the Pacific Biological Survey of the Bishop Museum. In this report we provide new records of freshwater algae species from the islands of Raivavae and Rapa. The objective of this portion of the Austral Islands biodiversity assessment was to survey the freshwater macroalgae found in these remote islands. This report is an addition to the Pacific Biological Survey, Bishop Museum companion report on the freshwater fauna found by Englund (2003) during these surveys. Surveys on Raivavae occurred from 18 November – 7 December 2002, while Rapa was assessed from 7 – 18 December, 2002.

STUDY AREA

Biodiversity surveys took place in Raivavae and Rapa Islands which are located in the southernmost part of the Austral Islands. Lying at 23°S, Raivavae is still tropical in climate and has the same latitude as the island of Kauai has to the north in the Hawaiian archipelago, while Rapa is located at 27° N and is more temperate in climate. Raivavae is surrounded by a large barrier reef with an extensive set of low-lying offshore motus (islets) while Rapa entirely lacks a fringing reef system. The Austral Islands span 1500 km in a northwesterly direction starting from the submerged Macdonald Seamount to the Marotiri Rocks lying 90 km from Rapa, to the northernmost coral atoll of Maria. The average geological age of Raivavae is 6.5 Myr and the highest altitude is 438.5 m on Mt. Hiro; Rapa averages 5 Myr (Craig et al. 2002) with Mt. Perau the highest point at 650 m. Rapa is significantly larger than its nearest high-island neighbor Raivavae, and is 40 km^2 in size, while Raivavae is 16.7 km^2. Rapa should not be considered geologically separate from the other Austral Islands as its estimated age is consistent with the formation of a hotspot at the Mcdonald Seamount, while an additional two hotspots have been postulated for Rarotonga and Rurutu (Turner and Jarrard 1982).

Both Rapa and Raivavae have been inhabited and extensively disturbed for long time periods, with only remnant native vegetation remaining. On Raivavae native vegetation is found only in upper elevation gulches and a few surrounding areas below the ridgetops, and the summit ridges here are periodically burned to allow islanders easy access to this grassy goat pastureland. Some remnant montane summit forest still occurs on Rapa, but similar to Raivavae most of the ridge tops have

been overgrazed, and a disturbed, overgrazed grassland is found in all but the highest summit areas and a few interior gulches.

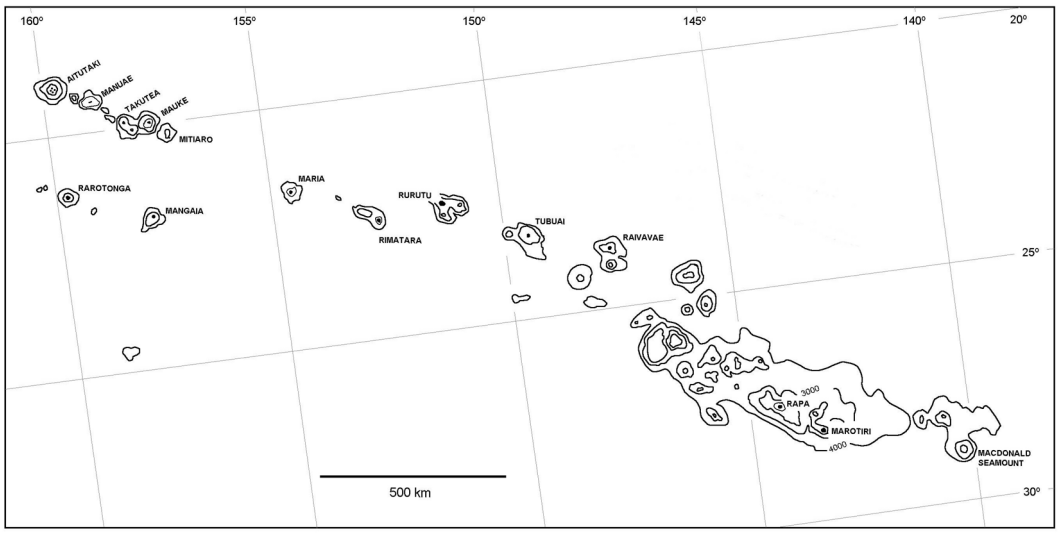


Figure 1. Southern French Polynesia showing the Macdonald Seamount hotspot, and the Austral and Cook Islands chain. Adapted from Craig et al. (2001) with permission of the author.

When possible attempts were made to use local names for geographic locations, however, sometimes conflicting names were given, or the name of the stream, waterfall or other landmark was unknown. A complete description of aquatic habitats sampled during this project can be found in Englund (2003).

Table 1. Sample localities and GPS coordinates for algae sampling surveys on Raivavae, Austral Islands conducted in November-December 2002.

Locality	Date[1]	Lat Long Coords	Host Plant/Habitat	Elev (m)
Vaipa Stream	25-Nov-02	S23.86222 W147.64679	Above capitage & upstream of dense Hibiscus	220
Taro fields btw. Mahanatoa and Rairua	26-Nov-02	S23.86918 W147.67701	Taro wetlands	2-3
Vaipa Stream, mid-elevation	29-Nov-02	S23.86333 W147.64676	Stream- stairstep cascades	213

[1]Dates taken from Garmin GPS reflect Greenwich Mean Time (GMT) dates.

Table 2. Sample localities and GPS coordinates for algae sampling surveys on Rapa, Austral Islands conducted in December 2002. [1]Dates taken from Garmin GPS reflect Greenwich Mean Time (GMT) dates.

Locality	Date[1]	Lat Long Coords	Habitat	Elev (m)
Tumu Cascade- at base of cascade	13-Dec-02	S27.60702 W144.35401	Largest cascade visible from road circling Haure'i bay	12
Tumu Cascade - stream above large cascade	13-Dec-02	S27.60786 W144.35819	Stream	159
Above large cascade/stream entering ocean on west side of Agairao Valley	14-Dec-02	S27.58481 W144.32932	Stream/Metrosideros/Fagraea	85

METHODS

Macroalgae sampling protocol

At each sampling location, a stream segment approximately 20 m in length was established and thoroughly searched for as many species of macroalgae present during benthic (bottom) sampling for aquatic invertebrates. All available habitats were examined, including rocks, sticks and fallen trees, sediment, macrophyte vegetation, and dams and diversions. Additionally, algae samples were collected from still-water habitats such the abundant taro fields and wetland habitats found on Raivavae and Rapa. Representative samples of each macroalgal taxon were collected using long-handled forceps and razor blades and were fixed in a 20 mL scintillation vial with 2.5% $CaCO_3$-buffered glutaraldehyde (diluted from 25% glutaraldehyde; Fisher Scientific). Global Positioning Satellite (GPS) readings, were made at each sampling station using a Garmin hand-held GPS receiver and waypoints were recorded in WGS84.

Laboratory analysis

Preserved collections were kept as cool as possible during ship and airline transport as refrigeration was not always available, but were refrigerated upon returning to Hawaii, because samples kept at room temperature in glutaraldehyde will eventually lose their color, making identification more difficult. Samples were identified using a combination of compound and dissecting microscopes, with the 100X objective lens used for the most detailed levels of examination. Literature references used to aid identification included both general references and specific papers on individual taxonomic groups. General references included Smith (1950), Prescott (1951), Bold and Wynne (1985), Van den Hoek et al. (1995), Entwisle et al. (1997), Dillard (1999) and Graham and Wilcox (2000). Additional references for specific taxonomic groups were used as follows: blue-green algae (Desikachary, 1959; Anagnostidis and Komárek, 1988, 1990; Komárek and Anagnostidis, 1989), green algae (Collins, 1908-1918; Kadlubowska, 1984; Mrozinska, 1985; Sarma, 1986; Kargupta and Sarma, 1992), and tribophyte algae (Ettl, 1978; Nichols et al., 1992). Taxa were photographed using an Olympus BX-41 compound microscope equipped with an Olympus DP12 digital camera.

Data analysis

Identifications for each aquatic habitat were compiled, and the total number of taxa for each stream determined. In addition, the number of taxa in each broad taxonomic category (e.g. Cyanophyta, Chlorophyta, etc.) was determined and compared across sites. Identified specimens will be accessioned to the Bishop Museum in Honolulu, Hawaii and the Museum National d'Histoire Naturelle in Paris, as identification, amount of specimens collected, and time permits.

RESULTS

A total 12 species of macroalgae from three divisions were collected in aquatic habitats during these surveys, with 7 species being found on Raivavae and 9 on the island of Rapa (Table 3). Several collections could only be identified to the taxonomic level of genus (e.g. *Oedogonium* sp. #1, *Spirogyra* sp. #1 and #2) since characters pertaining to sexual reproduction are required for specific identification, and these were not present at the time of collection. Despite much longer and greater sample efforts on Raivavae, two fewer macroalgae species were collected than on Rapa.

Table 3. Macroalgae species collected in November and December 2002 on Rapa and Raivavae, Austral Islands.

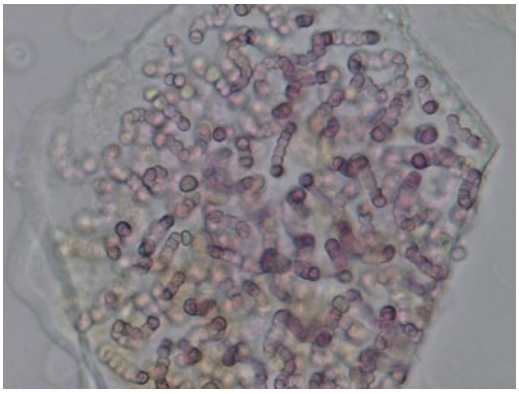
	Raivavae – Vaipa Stream 213 m	Raivavae – Vaipa Stream 220 m	Raivavae – Taro wetlands 2m	Rapa – Tumu Cascade base	Rapa – Above Tumu Cascade 159 m	Rapa– Agairao Stream cascade 85 m
Taxon						
Cyanophyta (Blue-Green Algae)						
Nostoc paludosum Kützing	X			X		
Michochaete uberrima N.Carter	X					
Phormidium corium (C.Agardh) Gomont				X		
Microcoleus vaginatus (Vaucher) Gomont						X
Scytonema crispum (C.Agardh) Bornet	X	X				
Chlorophyta (Green Algae)						
Desmidium sp. #1						X
Oedogonium sp. #1 (need reproductive structures for further ID)	X			X		X
Rhizoclonium hieroglyphicum (C.Agardh) Kützing	X	X		X		
Spirogyra sp. #1 (need reproductive structures for further ID)	X	X				
Spirogyra sp. #2 (need reproductive structures for further ID)			X	X	X	X
Chromophyta, Tribophyceae (Yellow-Green Algae)						
Tribonema vulgare Pascher					X	
Vaucheria sp. #1 (need reproductive structures for further ID)				X		
Total Macroalgae Species	6	3	1	6	2	4

This could also be due to a wider variety and much greater amount of permanent aquatic habitats, as the larger Rapa Island is also wetter, especially in the upper summit areas. Of interest was one species of green algae, *Spirogyra* sp. #2, found in the extensive Raivavae taro fields, and also found in still pools of the Tumu Cascade, Rapa.

Whether these species are native or introduced is difficult to ascertain because of the lack of historical stream macroalgae records, as is the case for the Hawaiian Islands (Sherwood 2002). However, it is speculated that because of the very remote nature of these islands, the complete lack of other introduced aquatic species; and on Raivavae the limited amount of available freshwater habitats, these macroalgae species are probably native or indigenous to the two islands.

The following photographs were taken from the algae specimens collected on Rapa and Raivavae, and are provided below as a preliminary guide to freshwater macroalgae found in these two islands.

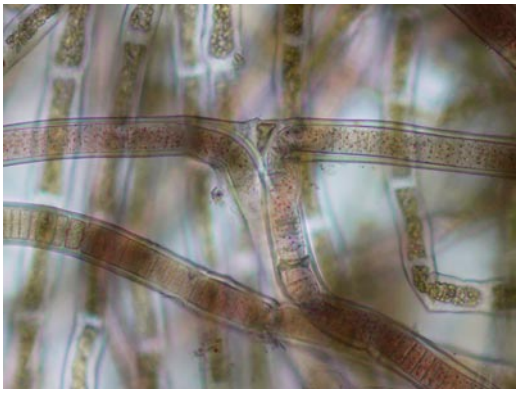
Cyanophyta (Blue-Green Alga)



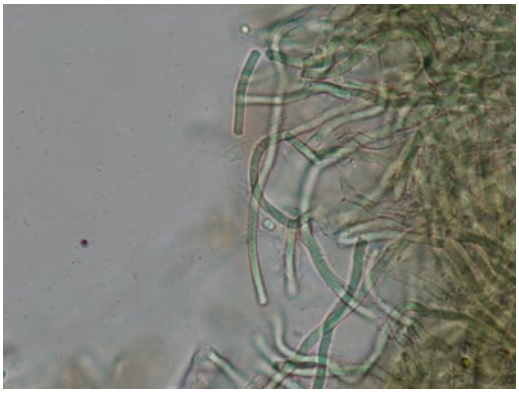
Nostoc paludosum : Raivavae/Rapa

Microcoleus vaginatus: Rapa

Michochaete uberrima: Raivavae

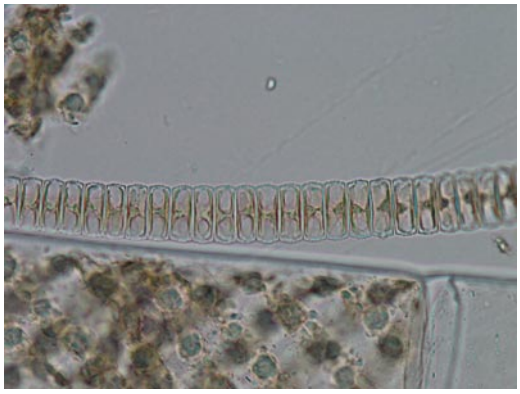


Scytonema crispum: Raivavae

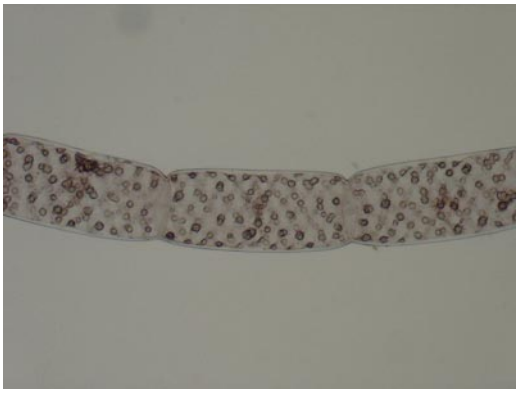


Phormidium corium: Rapa

Chlorophyta (Green Algae)



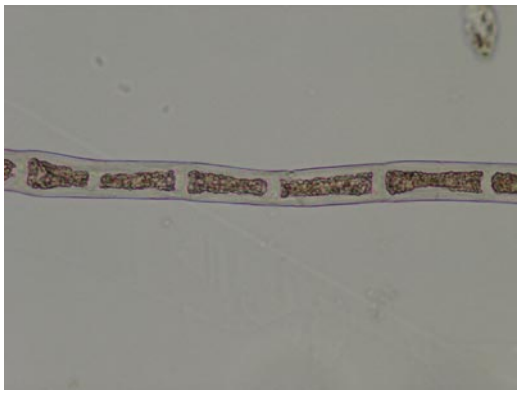
Desmidium sp. #1: Rapa



Spirogyra sp. #1: Raivavae

Oedogonium sp. #1: Raivavae and Rapa

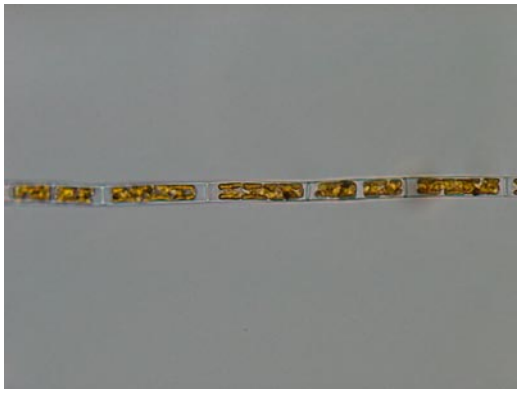
Spirogyra sp. #2: Raivavae and Rapa



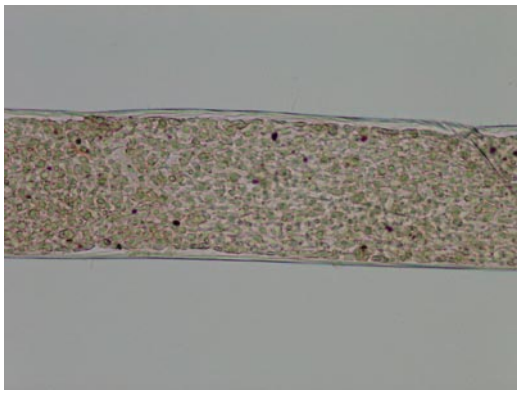
Rhizoclonium hieroglyphicum: Raivavae and Rapa

Raivavae: 29 Nov 2002, Vaipa Stream 213 m

Tribophyta (Yellow-Green Algae)



Tribonema vulgare: Rapa



Vaucheria sp. #1: Rapa

Rapa: 13 Dec 2002, Tumu Cascade,
12 m elevation

Rapa: 14 Dec 2002, Agairao Stream cascade,
85 m elevation

DISCUSSION

Relatively few oceanic islands have been surveyed for their freshwater algal flora in recent years, and many never have been in the past, although individual algal groups have been examined in some cases. For example, stream algae have been examined by Starmach (1975) from the Seychelles, by Johansson (1976) for the Azores, and by Lobban et al. (1990) for Yap. Relatively more research has been completed for the Hawaiian Islands, with surveys completed historically by Nordstedt (1876), Tilden (1902), Lemmerman (1905), MacCaughey (1917, 1918a,b), and more recently by Fungladda et al. (1983), Vis et al. (1994), Sherwood (2002) and Filkin et al. (2003).

All of the macroalgal species identified during the survey are known from other regions of the world, with the possible exception of the collections that could not be identified to species. As such, relatively little ecological information can be drawn from these collections with regard to the conditions of the streams in which they were found. Among the blue-green algae, *Nostoc paludosum* is also known from India, the United States, South Africa, Hawaii and Europe; *Microchaete uberrima* is known from, among other places, Hawaii and India, *Phormidium corium* is known from widespread localities including from Europe, the Arabian Gulf, India, Hong Kong and Bermuda; *Microcoleus vaginatus* is practically ubiquitous in desert soils from around the world with occasional reports from flowing waters, and *Scytonema crispum* is known from Fiji, Hawaii, Europe, India and North America. The tribophyte alga *Tribonema vulgare* is also widespread, having been reported from Europe, China, Russia and Japan. The green alga *Rhizoclonium hieroglyphicum* is known from diverse locations such as North America, Hawaii and Europe. The green algal genera *Spirogyra*, *Desmidium* and *Oedogonium* are common worldwide.

It is interesting to note that no red freshwater red algae were collected during the survey. Red algae species such as *Audouinella pygmaea* (Kütz.) Weber-Van Bosse and *Compsopogonopsis leptoclados* (Mont.) Krishnamurthy are widespread throughout stream systems in the Hawaiian Islands (Vis et al. 1994, Sherwood 2002). Results from studies on other islands are mixed. Kumano and Bowden-Kerby (1986) described six new species of the red algal genus *Batrachospermum* from Micronesia, while a preliminary survey of the Fiji Islands did not report any freshwater red algae from these islands (Sheath and Cole, 1996). Although recent freshwater algal surveys have not been undertaken on most other Pacific islands, from these few studies the distribution of algal groups does not appear to be homogenous throughout the Pacific. Although most of the green algal taxa included in this report could not be identified to the taxonomic species level because of the absence of necessary reproductive characteristics, the genera themselves (*Desmidium, Spirogyra, Oedogonium*) are extremely widespread in distribution and their presence in French Polynesian streams is not surprising. Likewise, the tribophyte genus *Vaucheria* is common in areas around the world.

Although only 12 distinct taxa were identified from stream habitats in French Polynesia for this survey (five Cyanophyta, five Chlorophyta and two Tribophyceae), it is likely that as survey efforts continue in the future a larger diversity will be revealed.

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