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The flora, fauna and water chemistry of Tagimaucia crater, a tropical highland lake and swamp in Fiji

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SUMMARY. 1. Tagimaucia crater lake and swamp are located at an altitude of 820 m in Taveuni, Fiji (lat. 16°S; long. 179°56′ W). Rainfall exceeds evaporation in all seasons and residence time for water in the shallow lake (2.5–5.5 m deep) is only 4 days.

2. Dissolved ion concentrations are low (conductivity 14–18 $\mu S\,cm^{-1}$ at 25°C), and the water is slightly acidic (pH 5.0–6.5 at 25°C). Median total phosphorus (0.5 $g\,m^{-3}$) and total nitrogen (3.3 $g\,m^{-3}$) are moderately high and probably represent dissolved and suspended organic matter. Median chlorophyll *a* concentrations (2.5 mg^{-3}) were low and indicate low phytoplankton productivity.

3. The swamp vegetation is dominated by *Lepironia articulata* (Retz.) Domin and algae which form floating sedge peat islands, and *Pandanus taveuniensis* St John and other small trees where alluvium and colluvium are infilling the margins of the crater. The surrounding slopes are forested.

4. The fauna of the lake and swamp are low in both diversity and abundance. The only aquatic vertebrates observed were *Anguilla* eels and cane toads, *Bufo marinus* L., and the only bird was the swamp harrier, *Circus approximans approximans* Peale. A variety of aquatic insects were observed but crustaceans and other invertebrate taxa were scarcely recorded.

5. Although the swamp and lake are otherwise undisturbed, several recently introduced plants and animals have been recorded.

Introduction

Although there is high rainfall over most of the Fiji islands, stream and river drainage is generally well developed so there are few natural lakes or ponds, and freshwater swamps only occupy small areas. In the lowland valleys of the larger rivers, cut-off river meanders and channels form lakes which fill up after high rainfall or flooding. Further upstream the rivers may be temporarily dammed by landslides, and there are legends and geological evidence which indicate the sites of several former lakes (Rodda, 1976, 1984): none of these lakes exist at present, though there are some small ponds created by the damming of streams.

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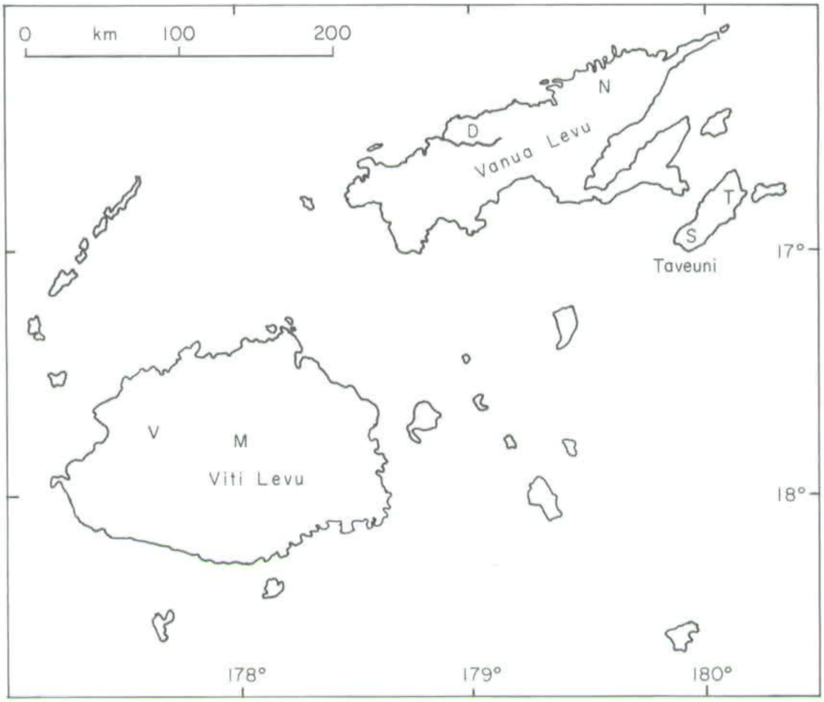

FIG. 1. Map of part of the Fiji archipelago showing the location of places mentioned in the text. D, Dreketi. valley; M, Monasavu dam; N, Nakelikoso; S, Salialevu; T, Tagimaucia crater; V, Vaturu dam.

Volcanic craters may form lake basins, and several lakes occur in recent craters on the island of Taveuni (Fig. 1). The largest of these, an explosion crater, contains Lake Tagimaucia. Several of the other volcanoes in southern Taveuni have small craters, formed by the eruption of lava, scoria and ash, and some of these contain lakes of 0.1–1 ha. Lava may block existing drainage patterns and there are a number of shallow ponds and swamps in north-eastern Vanua Levu, especially in the Dreketi valley (Fig. 1), which seem to be the product of Pleistocene lava flows and, perhaps, tectonic tilting.

Two major dams were completed in Viti Levu during 1983, the Monasavu and Vaturu dams (Fig. 1), and this has raised interest in the natural freshwater lakes of Fiji.

Freshwater peat swamps are associated with most of the lakes and other areas of impeded drainage. The freshwater swamps of the largest island, Viti Levu, have been described by Ash & Ash (1984) who suggested that three different mechanisms are responsible for the creation of peat swamps in Fiji. On areas of impeded drainage, perhaps occasionally submerged, there would naturally be forest vegetation but, as a result of forest clearance, gardening and burning during the past 3500 years, conditions were created which favoured open-habitat species of sedges which form peat and thereby favour other peat swamp species: this type of peat swamp is both created and maintained by man. In shallow or seasonal lakes some sedges may establish on the lake bed and gradually accumulate a layer of peat; eventually infilling the lake. In deep lakes, some sedges may grow around the shore and form a floating peat mat which is both thickened and extended across the lake surface as the sedges grow. Parts of the floating peat mat may break loose, probably as a result of fluctuating water levels, and form a floating island: a characteristic feature of swamps of this type. There are two lakes with floating islands in Fiji, a small (1 ha) lowland basin near Nakelikoso in Vanua Levu (Fig. 1) and the Tagimaucia crater. The peat swamp and lake are closely inter-related and Tagimaucia lake and swamp are treated together in this paper.

Tagimaucia crater is visited infrequently, and the 5 or 8 h walk (from the west or east coasts, respectively) is on steep and narrow forest tracks. The lake and swamp have been little affected by human disturbance, though sedges may have been harvested in the past and the footprints of more recent visitors are forming a track across the swamp. The crater has been visited by various scientists, mostly botanists, but little has been published except Seemann's (1862) description: '. . . a large extinct crater filled with water, and on the north-eastern part covered with a vegetable mass, so much resembling in colour and appearance the green fat of the turtle, as to have given rise to the popular belief that the fat of all the turtles eaten in Fiji is transported hither by supernatural agency, which is the reason why on the morning after a turtle-feast the natives always feel very hungry. This jelly-like mass is several feet thick, and entirely composed of some microscopic cryptogams, which, from specimens I submitted to the Rev. M. J. Berkeley, a weighty authority in these matters, proved to be *Hoomospora transversalis* of Brebisson, and the representative of quite a new genus, named *Hoomonema fluitans* Berkl. A tall species of sedge was growing among them, and gave some degree of consistency to the singular body'. And Commander Goodenough's (1876) account of a visit to the crater during which he determined the depth of the lake as 13–16 ft (4–5 m). More recently, Koyama (in Smith, 1979, pp. 231–232) considered the swamp to be 'a fascinating and perhaps unique area in Fiji'.

Methods

Tagimaucia crater was visited periodically (September and December 1982, February, July and December 1983, and November 1984) and observations were made on the vegetation, structure of the peat swamp, lake bathymetry, water chemistry and fauna. A palynological study of the crater is being made by the first author, and cores were taken in several parts of the crater. Lake bathymetry was determined by taking soundings with a weighted line on transects across the lake. Water transparency was measured with a Secchi disc. Water samples for chemical analysis were taken at about 9 a.m. from just below the lake surface and at a depth of about 2 m near the lake edge, on each occasion that the crater was visited. Water samples were frozen a few hours after collection and analysed at the Institute of Natural Resources, University of the South Pacific (USP). In general, methods for chemical analysis of the water samples were those described in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, 1981).

Alkalinity was measured by titration with 1×10^{-3} mol dm^{-3} sulphuric acid using a mixture of bromocresol green and methyl red indicator. Calcium, magnesium, sodium and potassium were measured by flame atomic absorption spectrophotometry. Ammonia was measured using the phenate spectrophotometric method. Nitrate was measured using the cadmium reduction column method. Nitrogen was analysed by Kjeldhal digestion followed by distillation of the ammonia and determination of the ammonia using the phenate method. Phosphate was measured using the molybdate/tartrate/ascorbic acid method. Phosphorus was measured by oxidation with perchloric acid followed by the phosphate determination (as above). Chlorophyll *a* was measured by the spectrophotometric method after extraction with 90% acetone; no correction was made for phaeophytin *a*. Turbidity was measured using the nephelometric method. pH and conductivity were measured in the laboratory using meters, at 25°C.

Plankton were sampled by towing plankton nets of 20 (60 μm) mesh at a depth of about 1 m in December 1982, and by examining the planktonic algae which settled from water samples collected at the same time as those for chemical analysis. Algae were identified from Prescott (1979) and Fritsch (1971). Vascular plant specimens were identified and lodged at the SUVA herbarium, USP. Nomenclature follows Smith (1979, 1981), Brownlie (1977) and Parham (1972). Sedge biomass was estimated by oven-drying representative samples.

The vertebrate fauna was recorded by observation, including diving in the lake. One litre of Quinaldene was released in a small

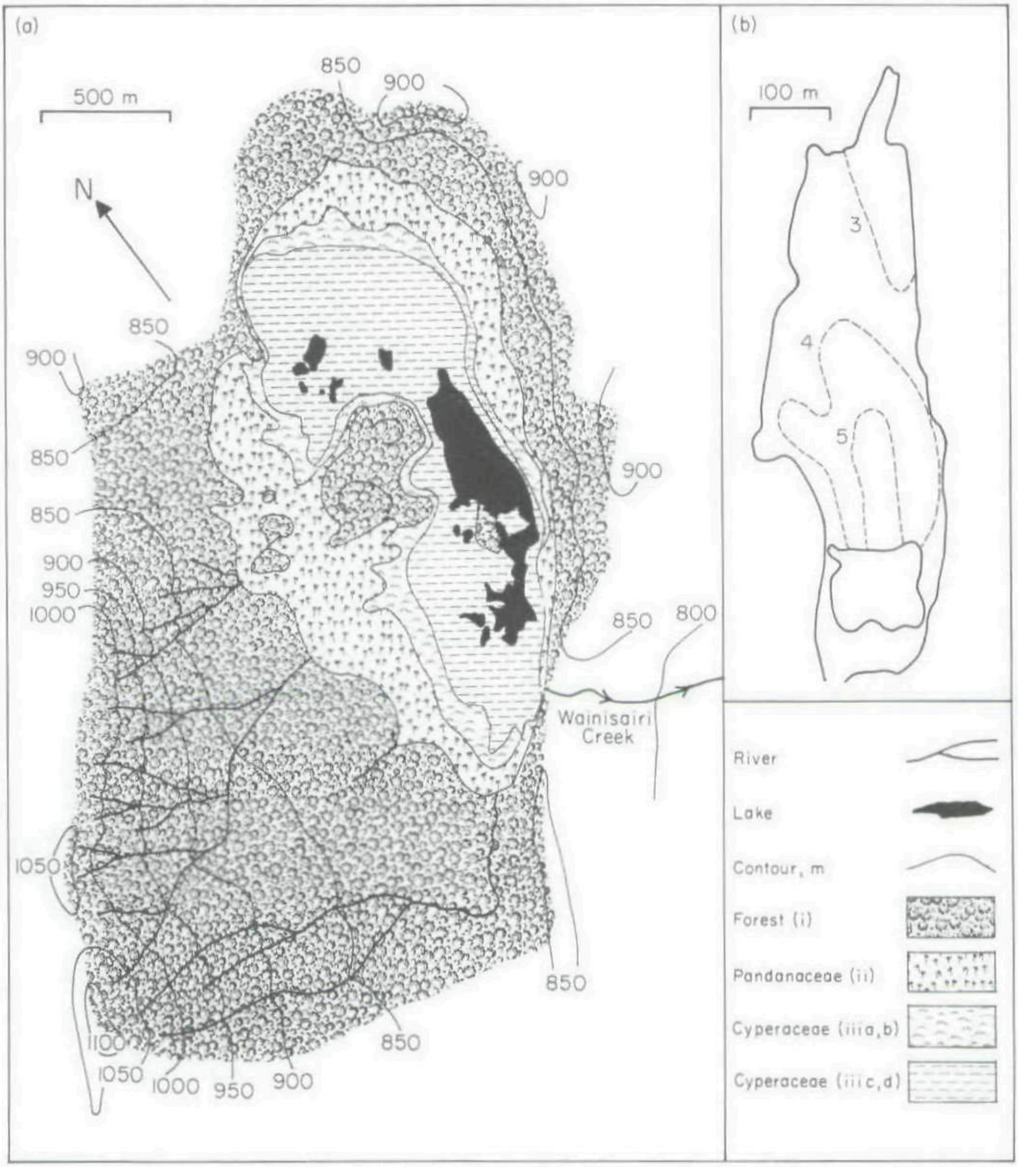

FIG. 2. (a) Map of Tagimaucia crater catchment and lake based upon aerial photography of 22 June 1967; showing vegetation types (see text for details). (b) Depth contours of the main lake below the outflow level.

embayment of the lake but did not result in the appearance of any aquatic vertebrates at the surface. Baited hooks were set to catch eels and fish but without success; terrestrial invertebrates were captured with sweep nets and by examination of the swamp vegetation. A fluorescent U.V. lamp, over an alcohol filled collecting tray, was set up near the lake for two nights each in December 1982, February 1983 and July 1983. Where necessary, animal specimens were sent for identification to the University of Canterbury, New Zealand.

Results

Tagimaucia crater and catchment

Tagimaucia crater is situated on the eastern side of the central mountain ridge of Taveuni at an altitude of 820 m (Figs. 1 and 2). The mountains are formed of Pliocene–Quaternary basic volcanics, and the crater is a late Quaternary maar. The crater contains several small volcanic cones, and is bounded on its eastern margin by a fault scarp 60–80 m high. The scarp continues to the south-west for a further 2 km and has diverted several eastern-flowing rivers such that some now flow into the crater.

The catchment of the crater consists largely of the eastern flanks of the central range, which reach an altitude of 1100 m, while the northern and eastern margins are formed by the short steep slopes of the maar and the scarp. The catchment has a total area of 619 ha of which 213 ha (34.6%) is swamp and open water and the remainder is forested. The crater is drained by the eastern-flowing Wainisairi Creek which has cut a steep-sided rocky valley through the scarp; the outflow being about 8 m wide.

The sedge peat swamp is contained within, and is infilling, the lake basin. Alluvium and colluvium are accumulating at the margins of the swamp, and are most extensive on the western and northern sides of the crater where there are larger catchments. These inorganic deposits grade into sedge peat further from the edge. In some places the transition to peat is gradual but around much of the edge there are narrow water-filled fissures 2–3 m deep and the central part of the peat swamp comprises a floating peat mat 2–3 m thick (Figs 3 and 4). The floating peat is dissected by fissures to form a number of interlocking islands, and these enclose several open water bodies. The water bodies have a total area of 16 ha and the largest, known as Lake Tagimaucia, has a depth of 2.5–5.5 m below the outflow level (Figs 2 and 3).

Much of the floating peat has a jelly-like surface 10–25 cm thick, composed of cyanophyta and algae, which has a low permeability and it has been observed that rainwater runs off the floating islands into the fissures and lake. Water entering the swamp and lake passes to the outflow by flowing beneath the peat islands and along fissures. Since the outflow is relatively narrow, the lake level may rise by 1 m or more after heavy rainfall.

The climate of the catchment is strongly influenced by the prevailing humid south-easterly winds which rise over the central range producing clouds and rain. These conditions prevail on most days throughout the year, and Des Voeux Peak on the central range has an average annual rainfall of 9800 mm (Public Works Department records, 1976–83). Average rainfall in the catchment is likely to be intermediate between that of Des Voeux Peak and sites on the east coast such as Salialevu which has an average annual rainfall of 5800 mm (Fiji Meteorological Service records, 1913–74).

The cloudy climate greatly reduces both incoming solar radiation and outgoing radiation such that air temperatures show little diurnal variation. On the basis of short-term observations and extrapolation from other stations, the mean daily air temperature range at the crater is likely to be between 15 and 21°C in July and 18 and 24°C in January, and relative humidity is likely to be 94–98% for most of the year.

It is unlikely that the catchment experiences many weeks in which evaporation exceeds rainfall, and annual evapotranspiration is unlikely to exceed 900 mm. Annual rainfall in the catchment probably totals about $5\times10^7\,m^3$, evapotranspiration may be estimated as $5\times10^6\,m^3$, while the lake has a water volume (excluding peat) of about $5\times10^5\,m^3$. By assuming that all rainwater not lost by evaporation passes through the lake, the average residence time for water in the lake (the time to fill the lake) is estimated as only 4 days. The water reaching the lake may follow several routes, and the proportions may be approximated on the basis of habitat area in the catchment: direct rainfall (2.8%), run-off from the floating sedge peat islands (14.5%), run-off from the surrounding swamp (17.5%) and run-off from forested slopes (65.4%). Rainfall is likely to be higher on the upper slopes of the catchment but this is offset by evapotranspiration, and the proportion of water entering from the slopes is likely to be rather lower than the percentage indicated above.

Water chemistry

Results of chemical analyses are summarized in Table 1. They are presented in terms of the median observed value (or the average of the two values closest to the median) and the overall range of values. No significant differ-

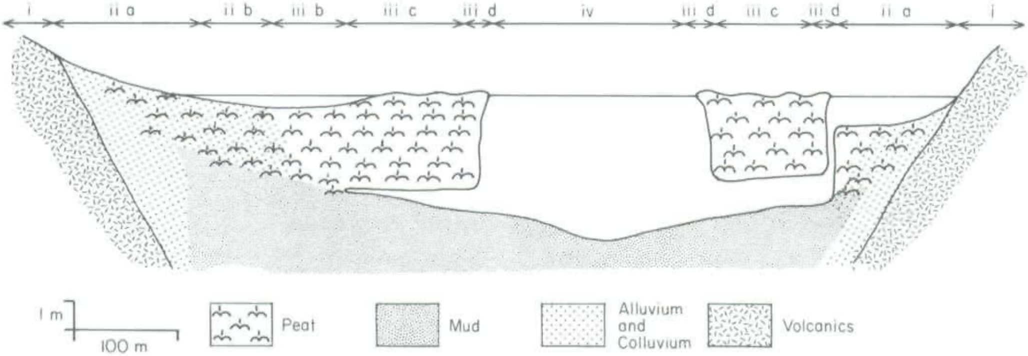

FIG. 3. Diagrammatic cross-section of Lake Tagimaucia under flood conditions, with a water level about 1 m above the outflow level. Vegetation types are indicated by number as in text and Fig. 2.

ences were apparent between lake surface samples and deeper water samples, and though there was some variation between different sampling dates this did not reveal any consistent patterns.

The pH (5–6.5) and alkalinity (2.6 g m^{-3} $CaCO_3$) indicate slightly acidic conditions, probably determined by CO_2 and HCO_3 ions. Conductivity values (14–18 $\mu S\,cm^{-1}$) indicate a low concentration of dissolved salts, and this was apparent for individual cations, nitrate and ammonium ions. Total phosphorus and nitrogen concentrations were moderately high, however, and probably represented organic forms of these nutrients, perhaps in peat or humic materials. A Secchi disc was visible to a depth of 2–3 m, virtually the bottom of the lake, indicating a moderate amount of dissolved or suspended matter. The water colour was brown, indicating organic matter. Chlorophyll *a* concentrations were low and indicate low phytoplankton biomass.

Comparative chemical values for world mean rainwater (Garrels & Mackenzie, 1971)

FIG. 4. View looking south across a small lake in the northern part of Tagimaucia crater, showing floating sedge peat with abundant *Lepironia articulata, Freycinetia pritchardii* along the lake margin, and forested cloud covered hills along the eastern side of the crater with *Pandanus taveuniensis* at their base.

TABLE 1. Chemical analyses of water from Lake Tagimaucia, World mean rainwater (Garrels & Mackenzie, 1971) and basaltic groundwater in Taveuni (pers. comm., Mineral Resource Department, Fiji). All values are $g\,m^{-3}$ unless stated otherwise.

	Median value	Range	No. of observations	Rainwater	Groundwater
pH (pH units)	5.9	5.0–6.5	13	5.7	7.1
Bicarbonate alkalinity as $CaCO_3$	2.6	2.1–6.0	13		
Conductivity ($\mu S\,cm^{-1}$ at 25°C)	16	14–18	9		
Ca^{++}	2.6	0.5–4.1	9	0.08	17
Mg^{++}	0.5	0.3–0.9	9	0.28	10
Na^{+}	5.9	1.7–17.0	9	1.9	9.5
K^{+}	1.2	0.2–4.9	9	0.3	1.7
NH_3	<0.01	<0.01–0.02	9	<0.1	
NO_3	0.02	<0.01–0.1	13	<0.1	
N	3.3	0.3–19.0	6		
PO_4	0.09	<0.03–0.4	13		
P	0.5	0.1–0.8	4		
Chl *a* ($mg\,m^{-3}$)	2.5	1.4–3.6	2		
Turbidity (N.T.U.)	4	2.0–4.0	4		

and for basaltic groundwater from Taveuni (pers. comm., Mineral Resources Division, Fiji) are given in Table 1. It is apparent that the lake chemistry is intermediate between that of rainwater and groundwater, reflecting the relatively short period of contact the water has had with the substrate.

Vegetation

The vegetation of the crater comprises four distinct communities, which nevertheless show some overlap in species distributions. On the well-drained slopes which surround the swamp there is forest vegetation, disturbed by occasional land slides in some of the steeper slopes. There are two major swamp communities, a Pandanaceae-rich type on alluvium and colluvium around the swamp margins, and a Cyperaceae dominated type on peat. The open water in the lake and ponds supports a sparse algal community. The distribution of these communities is shown in Fig. 2 and their composition is described below:

(i) *Forest vegetation.* The forest is stunted, with canopy trees 8–18 m high, including emergent tree ferns (*Cyathea medullaris* (Forster) Swartz) and palms (*Clinostigma exorrhizum* (H. Wendl.) Becc., *Veitchia simulans* H. E. Moore). Common trees in the forest are *Calophyllum vitiense* Turril., *Ficus storckii* Seem. and *Syzygium* sp. Epiphytes are abundant, including the 'Tagimaucia Flower' (*Medinilla waterhousei* Seem.) and *Freycinetia storckii* Seem. Bryophytes cover most trunks, fallen logs and the forest floor.

(ii) *Pandanaceae community* (cf. Table 2). Vegetation characterized by Pandanaceae occurs on frequently waterlogged inorganic sediments: (a) Near streams, where there is abundant alluvium, the vegetation comprises scattered, stunted trees 3–5 m high, overgrown with a dense tangle of *Freycinetia storckii.* (b) Where the substrate is peaty, with a little alluvium, the vegetation is characterized by *Pandanus taveuniensis,* scattered small trees 3–5 m high, and sedges up to 3 m high with a biomass of 3–6 $kg\,m^{-2}$. Old stumps of *Pandanus* are found occasionally nearer to the peat swamp and indicate some recent changes in the environment, perhaps more frequent flooding as a result of blocking of the outflow by the expanding sedge peat islands.

(iii) *Cyperaceae community* (cf. Table 2). The sedge-dominated community may be divided into four zones along a transect from the inorganic sediments at the margin to the peats at the centre of the swamp: (a) At the margin of the swamp, adjacent to steep forested slopes, is a zone which evidently receives run-off from the slopes. This zone may be flooded to a depth of 0.2–1 m after heavy rain. The zone is rarely more than 5–10 m wide, and has a distinct vegetation of sedges, *Eleocharis dulcis* and *E. ochrostachys,* and a few herbaceous dicotyledons such as *Polygonum dichotomum.* (b) Merging with the zone described above, but lacking the dicotyledonous

TABLE 2. Tagimaucia swamp vegetation (excluding epiphytes and algae). Introduced species are indicated by an asterisk (for further information see Ash & Ash, 1984).

	Pandanaceae community		Cyperaceae community			
Species	a	b	a	b	c	d
Trees and shrubs						
**Clidemia hirta* (Linn.) D. Don			+			
Garcinia myrtifolia A. C. Smith	+	+				
Geniostoma vitiense Gilg. & Benedict		+				
Melastoma denticulatum Labill.		+				
Metrosideros collina (Forst.) A. Gray	+	+				+
Pittosporum pickeringii A. Gray		+				
Rapanea myricifolia (A. Gray) Mez.	+	+				
Scaevola floribunda A. Gray						+
Spiraeanthemum vitiense A. Gray	+	+				
Syzygium gracilipes (A. Gray) Merrill & Perry	+	+				
Weinmannia affinis A. Gray	+	+				+
Pandanaceae and Arecaceae						
Freycinetia pritchardii Seem.						+
Freycinetia storckii Seem.	+++	+				
Pandanus taveuniensis St. John		++				
Physokentia rosea H. E. Moore						+
Cyperaceae						
Eleocharis dulcis (Burm. f.) Trin. ex Henschel		+++	+++			
Eleocharis ochrostachys Steudel			++	+++		
Hypolytrum nemorum (C. B. Clarke) Koyama	+					
Lepidosperma sp.					+	
Lepironia articulata (Retz.) Domin		+++	++	++	+++	+
Machaerina falcata (Nees) Koyama		+	+			
**Rhynchospora corymbosa* (L.) Britton		++	++			
Herbs						
**Centella asiatica* Urban		+	+			
**Mikania micrantha* H.B. & K.		+	++			
**Paspalum distichum* Linn.		+	+			
**Paspalum orbiculare* Forst.		+	+			
**Polygonum dichotomum* Bl.			++			
Spathoglottis pacifica Reichb. f.					+	+
Ferns and fern allies						
Culcita straminea (Labill.) Maxon						+
Dicranopteris caudata (Copel) S. John		++			+	+
Lycopodium cernuum Linn.					+	+
Nephrolepis hirsutula (Forst.) Presl.		+				
Bryophytes						
Leucobryum sanctum (Brid.) Hampe					++	
Sphagnum cuspidatum Ehrh. ex Hoffm.					+	++

species, is a zone dominated by *Eleocharis ochrostachys*. The substrate is more peaty and may be flooded to depths of 0.5–1 m. This zone varies in width, from no more than a few metres wide adjacent to steep slopes to 100 m wide adjacent to *Pandanus* communities. There is often a water-filled fissure, 20–50 cm wide and 2–3 m deep, separating this community from the next. (c) The floating peat is characterized by the sedge *Lepironia articulata* which grows to a height of 120–200 cm along fissures, and has a biomass of 2–4 kg m^{-2}, but both the height and density decline towards the centre of the islands where the biomass was only 0.05–1 kg m^{-2}. The moss *Leucobryum sanctum* forms extensive patches and a few herbs occur sporadically on the islands. The jelly-like surface of the islands is made up of live and dead plant material and supports a diverse algal community including abundant filamentous forms. Prominent amongst the algae are Cyanophyta, including *Anabaena*, *Oscillatoria, Spirulina* and various Chroococcaceae; Chlorophyta, including *Zygnema, Spirogyra, Ulothrix, Chlamydomonas* and various Desmidiaceae including *Tetmemorus, Cosmarium, Closterium* and *Pleurotaenium*; and Bacillariophyta including *Frustulia* and *Eunotia*.

Elongate shallow pools, 10–20 cm deep and 20–400 m^2 in extent, occur in several areas of the swamp. These pools are virtually devoid of vascular plants except for occasional stunted *Lepironia* and a sedge which is identified provisionally as *Lepidosperma* (this species is not listed by Koyama in Smith, 1979). (d) The edges of the floating peat islands often are raised a few centimetres above water level. These and other raised areas, such as old *Pandanus* stumps, support small patches of more diverse vegetation. A variety of mosses are present, notably *Sphagnum cuspidatum* which forms raised hummocks. Several epiphytic mosses grow on the hummocks and upon woody shrubs rooted in the hummocks. A variety of shrubs, stunted trees (1–2 m high), palms and ferns may be present. This community occupies a very small proportion of the swamp surface but contributes greatly to its diversity. Plant debris is washed up around the edges of the lake by wave action and may contribute nutrients to these edge communities.

(iv) *Aquatic algae*. The lake contains a sparse phytoplankton community dominated by Bacillariophyta, including *Frustulia, Pinnularia, Eunotia* and *Surirella*; Desmidiaceae, including *Closterium, Pleurotaenium, Euastrum, Staurastrum* and *Tetmemorus*; Zygnemataceae including *Zygnema* and *Spirogyra*; and Cyanophyta including *Oscillatoria. Nitella* was found in the lake but is not abundant.

Fauna

The non-aquatic invertebrate fauna in the swamp appears to be limited to a few lepidopterans and the adults of aquatic insect larvae; notably Odonata, Diptera and Trichoptera. A 200 m plankton tow in December 1982 collected only juvenile backswimmers, *Anisops*, and bright orange hydrachnid mites. Benthic samples contained larvae of a ceratopogonid species, and two species of Tanypodinae and Orthocladiinae (Chironomidae). Trichopteran larvae were common and three families were represented: Polycentropodidae, Philopotamidae and Leptoceridae. Large numbers of *Polyplectropus fijianus* Banks and a few *Triaenodes* n.sp. (closest to but not *T. dubia* Mosely) were collected in a light trap. Whirligig beetles (Gyrinidae) genus *Dineutes* were common among the sedges around the lake edge. Large eels, genus *Anguilla,* were fleetingly seen but not caught on baited hooks. Based on size and proportion these are likely to be *A. marmorata* Quoy & Gaimard. No other fish species were observed.

The sedge community around the lake supports few vertebrates. Tadpoles and juveniles of the introduced cane toad, *Bufo marinus* L., were common, and coastal villagers reported the presence of the Fiji ground frog, *Platymantis vitianus* Dumeril., though this was not confirmed. One specimen of the Pacific islands boa constrictor, *Candoia bibroni* Hombron & Jacquinot, was found in the swamp. Despite apparently attractive conditions, no Rallidae (crakes, rails and swamphens) or Anatieae (ducks) were seen or heard. A pair of swamp harriers, *Circus approximans approximans* Peale, was seen patrolling the swamp.

Discussion

The climate of the Tagimaucia crater is of a montane-oceanic type with high rainfall at all seasons and little temperature variation either daily or seasonally. In these respects the climate is similar to hyperhumid equatorial regions, and it differs from many less humid tropical regions which experience one or two drier seasons each year. The composition of the lake water reflects both the climate and the characteristics of the lake basin; including the relatively small ratio of the catchment area to lake area, the rapid flushing of the lake, and the shallow deph of water.

Wetzel (1975) discussed the need to consider the trophic status of lakes not only in terms of the phytoplankton in the water body, but also with reference to the littoral of bog vegetation. Using Wetzel's classification, the Tagimaucia crater can be considered to be a Bog-Dystrophic lake system.

The lake and swamp have similarities to equatorial lowland lakes, swamps and blackwaters that have been described in Malaya

(Furtado & Mori, 1982; Johnson, 1967) and South America (Marlier, 1967; Sioli, 1968) but differ in their water budget, ionic composition and productivity from most tropical African lakes and swamps (Beadle, 1974; Burgis, 1978; Talling & Talling, 1965; Vareschi, 1982; Carter, 1955; Gaudet & Melack, 1981; Ganf, 1974) and Australian lakes (Williams, 1981). In the neighbouring archipelagos of the south-west Pacific there are several islands with volcanic craters containing lakes and swamps but these are within a few metres of sea level and contain slightly to strongly brackish water, e.g. Gaua in Vanuatu, Tikopia in the Solomon Islands, Aunu'u in Samoa, and Niuafo'ou, Tofua and Late in Tonga (Maciolek & Yamada, 1981). There are also a number of raised limestone islands with shallow lagoons which may fluctuate in depth with rainfall or have marine influence, e.g. Nauru, and Nomuka and Vava'u in Tonga.

The comparison with Tasek Bera in Malaya (Furtado & Mori, 1982) is of particular interest since the swamp system has similar water chemistry, algal productivity, and a swamp flora dominated by *Lepironia articulata* and *Pandanus* (*P. helicopus* Kurz). There are, however, many differences; the Malayan swamp is in the equatorial lowlands, with higher temperatures and more seasonal rainfall, and has a richer and taxonomically more diverse flora and fauna. Much of the floristic and faunistic difference including the lower plant diversity may be attributed to biogeographic factors, notably the relative isolation of the Fijian islands. The *Lepironia* swamp at Tasek Bera resembles the marginal swamps at Tagimaucia but Tasek Bera has no equivalent to the floating sedge peat islands.

Most of the water entering the Tagimaucia crater passes over or through the marginal swamps and these apparently function as filters, removing much of the particulate material from the water before it enters the lake. The floating islands appear to receive much of their surface water and nutrients from rainwater, and only the vegetation along the edges of the islands is in close proximity to the lake water. Vegetation patterns observed can be correlated with these differences in water and nutrient supply, and while species such as *Sphagnum cuspidatum* indicate a rain-fed and nutrient poor water supply, species such as *Pandanus taveuniensis* indicate a richer nutrient supply. These differences are also apparent from the growth of *Lepironia* in different parts of the swamp. In the marginal Pandanaceae-rich swamp, *Lepironia* has a biomass of 3–6 $kg\,m^{-2}$; on the edges of the islands the biomass is 2–4 $kg\,m^{-2}$, but away from the island edges the biomass is only 0.05 $kg\,m^{-2}$. These differences in biomass probably give a good indication of differences in productivity and perhaps also the rate of peat formation. On the basis of Ikusima's (1982) observations on *Lepironia* it may be estimated that *Lepironia* gross production ranges from less than 0.5 $g\,m^{-2}\,day^{-1}$ to more than 8 $g\,m^{-2}\,day^{-1}$ in different parts of the Tagimaucia swamp. This encompasses the range from very low to moderately high macrophyte production and is probably indicative of the total gross primary production in these communities.

One consequence of the difference between *Lepironia* growth on the surface and edges of the floating islands is that the islands are likely to extend across the lake surface much more rapidly than they will accumulate peat vertically.

The plant species at Tagimaucia crater are mostly natives (Table 2) and in this respect the swamp differs from swamps in Viti Levu which contain a preponderance of recently introduced species (Ash & Ash, 1984). *Eleocharis, Lepironia* and *Sphagnum* are probably long established and are virtually restricted to swamp habitats. Most of the other vascular plants also occur in forest or disturbed dryland habitats. Recent introductions have colonized the marginal swamps but have not established on the floating islands, e.g. *Clidemia hirta, Mikania micrantha, Paspalum orbiculare* and *Rhynchospora corymbosa.*

For most aquatic animals without aerial life history stages, access to Lake Tagimaucia is only possible through Wainisairi Creek. In many places the creek has cut through overlying scoria and into lava which it has worn smooth. The 820 m drop to the sea is precipitous and is punctuated by waterfalls. The creek may present an insurmountable barrier to upstream migration and subsequent colonization of the lake and catchment by some aquatic organisms including kuhliid fishes and atyid shrimps which are abundant downstream.

Other aquatic taxa such as molluscs, annelids, various crustaceans and gobioid fishes occur in upland parts of Fiji and could probably ascend the creek to the lake, but were not observed. The reasons for their apparent absence are unknown but it seems likely that the relatively low primary productivity of both swamp plants and phytoplankton, the low diversity of vascular plants, low calcium concentrations and low pH of the lake water are contributing factors. *Sicyopterus micrurus* Kaumans, an algal grazing goby with a marine larval stage, occurs above the Wainisavulevu falls near Monasavu in central Viti Levu and the young fish are known to utilize their pelvic sucker to traverse the falls (Ryan *et al.*, 1979). *Sicyopterus micrurus* is present in the lower reaches of the Wainisairi Creek and could probably reach Lake Tagimaucia but have not been recorded there. On the other hand, young eels are evidently able to make the journey from the sea since an eel was observed in the flooded margins of the swamp.

While this study was restricted in scope by the inaccessibility of the crater, and further studies may reveal a more diverse aquatic biota, the low diversity of both the flora and fauna are striking. Several factors may limit the biota.

The area of swamp and lake habitat at Tagimaucia crater is relatively small (213 ha) and these habitats account for only 0.3% of the total land surface of the Fiji Islands. The apparently low primary productivity of the swamp, together with the relatively small area, are likely severely to limit the food availability for, and population of, any large carnivores. During a total of 53 man-days at the crater the only vertebrate carnivores observed were one eel, one boa and (repeatedly) a pair of swamp harriers. Cane toad tadpoles were seen frequently and it seems probable that juvenile cane toads form a substantial part of the carnivores' diet. Cane toads were only introduced to Taveuni within the last century and may have displaced the Fiji ground frog from the crater; if not, then the food web may have been even simpler in the past. While tadpoles feed on algae, adult cane toads feed on insects and may have had a significant impact on the insect fauna; most juvenile cane toads probably migrate from the swamp into the surrounding forest.

Although the lake contains phytoplankton and benthic algae, the fauna is sparse and the only vertebrate carnivore, an eel, was observed in a flooded part of the swamp where it may have been feeding on tadpoles.

On a time scale of 10^4–10^5 years most of the Fijian swamps and lakes are temporary and the biota is therefore unable to persist at a particular locality. Dispersal from sites in other parts of Fiji or from further away is therefore a characteristic of the swamp and lake biota. Those few plants restricted to swamp habitats, such as *Sphagnum cuspidatum* and the sedges *Lepironia articulata* and *Eleocharis dulcis* have ranges extending far from Fiji. Several endemic Fijian plants occur in the Tagimaucia swamp, e.g. *Geniostoma vitiense, Spiraeanthemum vitiense* and *Pandanus taveuniensis,* but these also occur in forest habitats. A third component of the biota is neither restricted to swamp or lake habitats nor endemic to Fiji, e.g. *Metrosideros collina, Rapanea myricifolia* and *Lycopodium cernuum,* and recently introduced species which mostly also occur in habitats disturbed by man, e.g. *Rhynchospora corymbosa, Mikania micrantha* and *Clidemia hirta.*

During the past century many species have been introduced to Fiji either accidentally or deliberately, and there are a number of earlier aboriginal introductions. Natural dispersal to Fiji is limited by its oceanic location and, while other archipelagos may function as 'stepping stones', there are few swamps on these islands to assist in the spread of swamp or lake species.

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