
10 Montane cloud forests on remote islands of Oceania: the example of French Polynesia (South Pacific Ocean)

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ABSTRACT

Small, isolated patches of tropical montane cloud forest (TMCF) are found in many remote islands of the Pacific region (Oceania). French Polynesia comprises 37 high volcanic islands and islets, all located at more than 5000 km from the nearest continents. TMCFs are found on 12 of them (Huahine, Moorea, Raiatea, Tahaa, and Tahiti in the Society Islands, Fatu Hiva, Hiva Oa, Nuku Hiva, Tahuata, Ua Huka, and Ua Pou in the Marquesas Islands, and Rapa in the Austral Islands), with a total area of up to 8000 ha. Their current individual extent ranges from less than 20 ha (Huahine, Rapa, Tahaa) to c. 1000 ha (Hiva Oa, Nuku Hiva) and more than 5000 ha (Tahiti), the other islands having less than 100–200 ha each. TMCFs are located between 300–400 m.a.s.l. and up to 1600–1800 m.a.s.l. (Tahiti), but are more often found above 800–900 m.a.s.l. They are generally located on the upper slopes of valleys, on high-elevation plateaux, and in gullies and ridges below the summits, with annual rainfall ranging between 3000 and 8500 mm. TMCFs are floristically the most diverse of all plant communities in French Polynesia, with the highest endemism and number of biological types. Between 60% (Moorea, Tahiti, and Rapa) and more than 70% (Raiatea, Hiva Oa, Ua Pou, and Ua Huka) of the endemic vascular plant species are found in the TMCFs, and between 25% (Moorea and Rapa) and 50% (Hiva Oa, Nuku Hiva, and Ua Pou) of these endemics are restricted to these habitats. The TMCFs of the different archipelagos of French Polynesia share many common genera of flowering plants with other Polynesian island groups (e.g. Cook Islands, Samoa, Hawaiian Islands). Current threats include road construction, hydro-electricity development, grazing or trampling by feral ungulates (pigs, goats) and invasion

by alien plant species, especially the tree *Miconia calvescens* in Tahiti and Moorea. Habitat conservation and invasive pest management is urgently needed to save the TMCFs in French Polynesia which still remain unprotected.

INTRODUCTION

Tropical montane cloud forests (TMCFs) in the Pacific region are normally found in small and isolated patches on rugged upland ridges and peaks of high volcanic oceanic islands (Merlin and Juvik, 1995; Mueller-Dombois and Fosberg, 1998). These “islands within islands” of restricted TMCFs occur over a diverse altitudinal range in response to a combination of atmospheric and topographic variables. In general, the cloud forest belt occurs at higher elevations on larger islands and reaches its lowest altitudinal expression on islands near the equator where the dual effects of precipitous mountains in close proximity to the sea, and the extremely humid tropical air (producing a very low lifting condensation level) combine to create TMCFs at elevations as low as 450–600 m.a.s.l. (e.g. Kosrae in the Federated States of Micronesia, Rarotonga in the Cook Islands, and some islands in Samoa and Fiji; Merlin and Juvik, 1995; Raynor, 1995; Watling and Gillison, 1995; Whistler, 1995). The numerous islands of French Polynesia, located in the South Pacific Ocean at more than 5000 km from the nearest continents (Figure 10.1) and scattered over an ocean surface the size of Europe present striking examples of remote small islands with TMCF. This chapter describes the current location and extent, the ecological and botanic characteristics, and the main past and current threats to the TMCFs in French Polynesia. It is based on published literature, personal communications of taxonomists, plant ecologists, and field botanists having worked in these islands, but also and mainly on the author’s extensive field surveys and observations conducted in the last 10 years in all the high volcanic islands of French Polynesia.

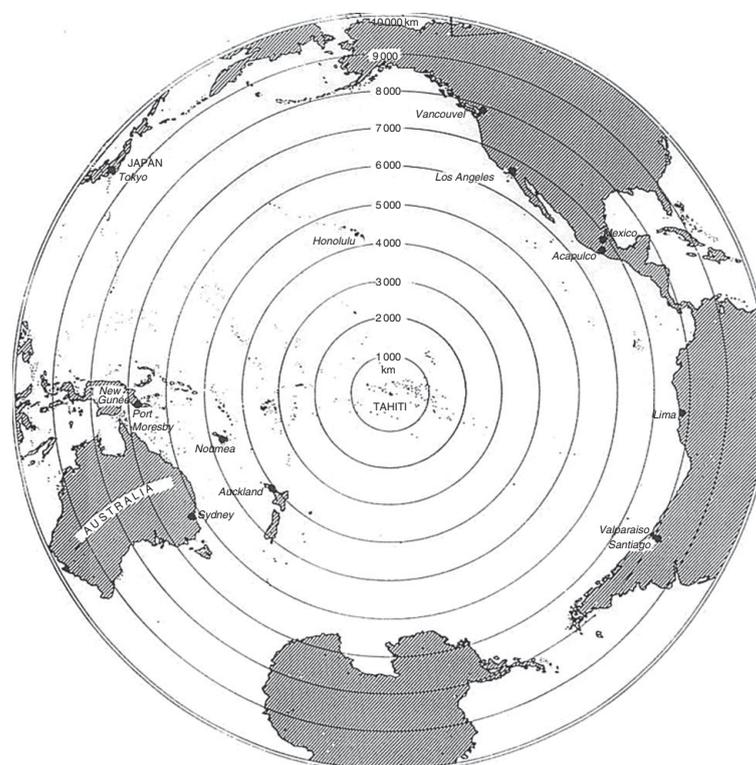


Figure 10.1. Location of the remote islands of French Polynesia in the South Pacific Ocean (centered on the main island of Tahiti).

LOCATION AND EXTENT OF TMCF IN FRENCH POLYNESIA

French Polynesia, a French overseas country located in the South Pacific Ocean between 7° and 35° S and 134° and 154° N, comprises a total of 121 tropical oceanic islands, including 84 atolls, raised atolls, and coral islets, and 37 high volcanic islands and rocky islets. These high islands often present a rugged topography and represent *c.* 80% of the terrestrial area of French Polynesia (2796 km² of a total area of 3521 km²). They are found in four different archipelagos, namely the Austral, the Gambier, the Marquesas, and the Society Islands. TMCFs are found in 12 of these 37 high volcanic islands (Moorea, Huahine, Raiatea, Tahaa, and Tahiti in the Society Islands, Fatu Hiva, Hiva Oa, Nuku Hiva, Tahuata, Ua Huka, and Ua Pou in the Marquesas Islands, and Rapa in the Austral Islands). All of these 12 islands have an area of more than 40 km² and a summit reaching or extending above 600 m elevation (Figure 10.2).

The TMCFs represent an approximate total area of less than 8000 ha, i.e. less than 3% of the total high island terrestrial surface of French Polynesia (Table 10.1). The largest area of TMCF (>5000 ha) is found on Tahiti, the largest and highest island in the Society Islands (1045 km², highest summit at 2241 m.a.s.l.). Relatively large areas of TMCF (*c.* 1000 ha) are found on Nuku Hiva (340 km², 1227 m maximum elevation) and Hivao Oa (314 km², 1276 m elevation), the largest islands in the Marquesas.

Smaller areas (<100–200 ha) are found in the high-elevation zones of Moorea and Raiatea in the Society Islands, and around the summits of Fatu Hiva, Tahuata, Ua Huka, and Ua Pou in the Marquesas Islands. Tiny patches of TMCF (<20 ha each) are found on the summits of the islands of Tahaa (590 m.a.s.l.) and Huahine (669 m.a.s.l.) in the Society Islands, and on the small island of Rapa (40 km², 650 m.a.s.l.) in the Austral Islands. Small areas of montane wet or rain forest exists on some of the highest summits of Bora Bora (located between 600 and 660 m.a.s.l.) in the Society Islands, and on Tubuai, Rurutu, and Raivavae (between 380 and 440 m.a.s.l.) in the Austral Islands but these are not considered true TMCFs (see descriptions below).

ECOLOGICAL DESCRIPTION OF TMCF IN FRENCH POLYNESIA

TMCFs in French Polynesia are characterized by high precipitation (>3000–4000 mm year⁻¹, up to 8500 mm year⁻¹ in the center of Tahiti; Pasturel, 1993), constant high humidity and cool conditions (e.g. 12°C and 50% humidity on Mt. Aorai at 2000 m elevation in Tahiti, 19°C and 75% on Toovii plateau at 900 m.a.s.l. in Nuku Hiva, and 22°C and 85% on Temehani plateau at 600 m.a.s.l. in Raiatea; Papy, 1951), and a diurnal cloud cap. They have been described and classified for Tahiti by previous

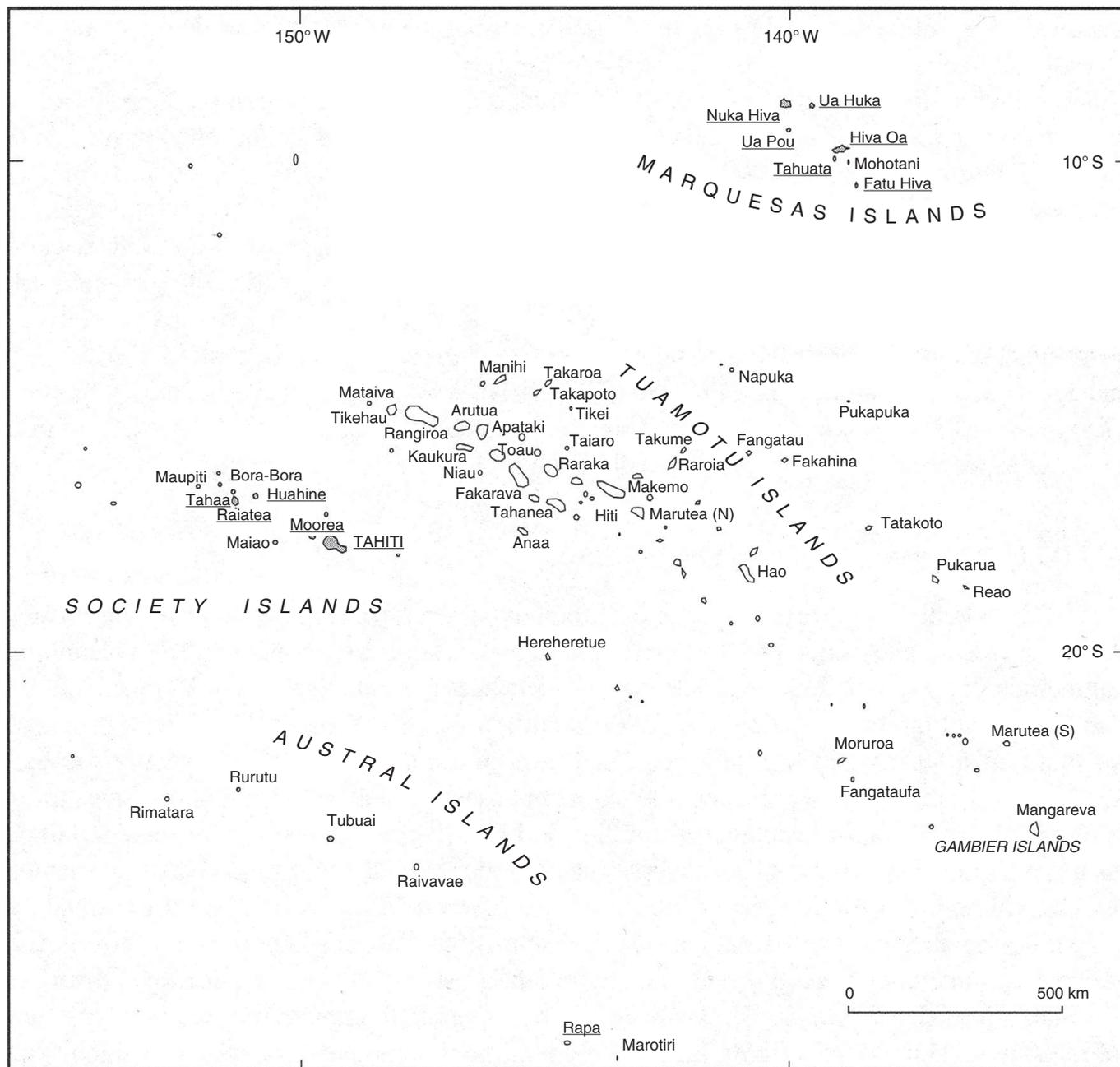


Figure 10.2. The different islands of French Polynesia (South Pacific Ocean), and location of the 12 islands with tropical montane cloud forest (underlined).

authors as (i) “valley head and swale formations” (Setchell, 1922), (ii) “*étage des hautes vallées et des secteurs très humides*” (“upper valley and very humid areas”; Papy, 1948), (iii) “*étage des forêts complexes des stations très humides et peu ensoleillées ou forêt hygrophyte*” (“complex forests of very humid places with little sunshine, or hygrophytic forest”; Papy, 1954), (iv) “*étage de la forêt pluvieuse*” (“rain forest”; Pétard, 1960), (v) “humid high-elevation forests of upper valleys and wet upper slopes and ridges” (Whittier, 1976), (vi) “*forêt de nuages*” (cloud forest; Florence, 1986) or (vii) “mossy forest or cloud

forests” (Fosberg, 1992; Mueller-Dombois and Fosberg, 1998), “*groupement hygrophile de haute altitude*” (“high-elevation hygrophilous formation”; Florence, 1987), (viii) “*forêts ombrophiles d’altitude*” or “*groupements ombrophiles de haute altitude*” (“high-elevation ombrophilous forest”; Florence, 1993), (ix) “*végétation humide de moyenne et haute montagnes*” (“wet vegetation of middle and high mountains”; Florence, 2003), and in the Marquesas, as (x) “high altitude, cold climate vegetation” (Brown, 1931), (xi) “rain forest of the cloud zone” (Adamson, 1936), (xii) “upper-elevation wet forest and

Table 10.1 *Island location, approximate extent, elevational range, and main sites of cloud forest occurrence in French Polynesia. Only the higher volcanic islands with an area of more than 1 km² are listed*

High volcanic islands	Area (km ²)	Highest summit (m.a.s.l.)	TMCF presence	TMCF area (ha)	TMCF elevational range (m)	Main TMCF site names (with highest elevation)
SOCIETY ISLANDS						
Tahiti	1045	2241	yes	>5000	300–1,800	Viriviriterai (1000 m), Terepo (1100 m), Marau (1493 m), Iviroa (1638 m), Ivirairai (1696 m), Aorai (2066 m), Pito Hiti (2110 m) Mauru (1361 m), Aramaoro (1530 m), Teamaa (1532 m), Urufau (1493 m), Tetuferu (1799 m), Teatara (1197 m), Mairenuu (1306 m) Ronui (1332 m)
Raiatea	171	1017	yes	<200	400–1000	Temehani Rahi (770 m), Temehani Ute Ute (780 m), Oropiro (824 m), Toomaru-Tefatua (1017 m)
Moorea	142	1207	yes	<100	800–1200	Tohiea (1207 m), Mouaputa (820 m)
Tahaa	90	590	yes	<20	550–590	Ohiri (590 m)
Huahine	75	669	yes	<20	600–670	Turi (669 m)
Bora Bora	29	727	yes? ^a			Otemanuu (727 m)? ^a
Maupiti	11	380	No			
Maiaoa	8	159	No			
Mehetia	2	435	No			
MARQUESAS ISLANDS						
Nuku Hiva	340	1224	Yes	<1000	900–1200	Tekao (1224 m), Toovii, Ooumu
Hiva Oa	315	1276	Yes	<1000	800–1200	Temetiu (1276 m), Feani (1015 m), Ootua (889 m)
Ua Pou	105	1203	Yes	<200	800–1200	Matahenua (1028 m), Pouakei (1035 m), Oave-Teavahaakiti (1203 m)
Fatu Hiva	85	1125	Yes	<200	650–1000	Mounanui (954 m), Tekou (1114 m), Touaouoho (1125 m)
Ua Huka	83	884	Yes	<50	750–880	Hitikau (884 m)
Tahuata	61	1050	yes	<100	800–1000	Haaioiputeomo (1050 m)
Eiao	40	577	No			
Mohotani	9	520	No			
Hatutaa	7	420	No			
AUSTRAL ISLANDS						
Tubuai	45	422	No			
Rapa	40	650	Yes	<20	550–650	Perau (650 m)
Rurutu	32	389	No			
Raivavae	20	437	No			
GAMBIER ISLANDS						
Mangareva	14	441	No			
Taravai	4	256	No			
Akamaru	2	246	No			
FRENCH POLYNESIA				<8000	300–1800	

^a The highest summit of Mt. Otemanuu (727 m) remains unexplored because of the impossibility of access to the summit, even by helicopter. The other summits of Bora Bora (Mt. Pahia at 660 m, Mt. Hue at 620 m) have montane wet forests but not TMCF (J.-Y. Meyer, personal observation).

Source: Data based on personal field observations by the author (1995–2005) and on personal communications by other botanists.

high-elevation cloud forest” (Florence and Lorence, 1997), and (as noted earlier for Tahiti) as “*formations ombrophiles*” (“ombrophilous formations”; Florence, 1993). These forest are generally low-statured (between 5 and 10 m tall) and have

a one-layer canopy with a multi-storied understory, and abundant epiphytic ferns, orchids, mosses, lichens, and terrestrial ferns.

TMCFs are usually found above 800–900 m elevation on the large islands (Moorea, Nuku Hiva, Hiva Oa, and the leeward side

of Tahiti Nui; Florence, 1986) and up to 1600–1800 m elevation on Tahiti Nui (Florence, 1986), but they can be found at lower elevations on smaller islands (e.g. 450 m.a.s.l. in Raiatea; Papy, 1951, 1954; at 550 m.a.s.l. in Rapa; J.-Y. Meyer, personal observation); at 600 m.a.s.l. in Huahine; J.-F. Butaud, personal communication; at 650 m.a.s.l. in Fatu Hiva; J.-Y. Meyer, personal observation; and at 750 m.a.s.l. on Ua Huka; J.-Y. Meyer, personal observation). Low-elevation cloud forests also occur on those sides of the largest island of Tahiti that are exposed to the dominant south-easterly trade winds (300–400 m.a.s.l. on the eastern and south-western sides of Tahiti Nui and on the peninsula of Tahiti Iti; Papy, 1954; Florence, 1983).

TMCFs are generally located on the upper slopes of valleys, on high-elevation plateaux, on precipitous volcanic necks (e.g. on the Marquesas Islands, Rapa), in the upper parts of ravines, and on ridges located below windswept summits that are covered by low, wet shrubland and sub-alpine communities. The latter have been referred to in various ways, including: (i) “*étage des hauts sommets*” (Papy, 1948, 1951–54) or “high-summits vegetation” (Whittier, 1976), (ii) “*maquis des hauts sommets*” (“high summits scrub”; Florence, 1986), (iii) “*maquis sommitaux*” (“summit scrubs”; Florence, 1987, 1993), (iv) “mossy scrub” (Fosberg, 1992), and (v) “summit wet shrubland” (Florence and Lorence, 1997).

In Tahiti, the most important sites for TMCF are found near Mts. Marau (1493 m), Iviroa (1638 m), Ivirairai (1696 m), Aorai (2066 m), and Pito Hiti (2110 m) on the leeward side, and on Mts. Mauru (1361 m, see Meyer and Florence (1999) for a full description), Urufau (1493 m), Aramaoro (1530 m), Teamaa (1532 m), and Tetuferu (1799 m) on the windward side. They are further found near Mts. Teatara (1197m), Mairenuï (1306 m), and Ronui (1332 m) on the peninsula of Tahiti Iti (Table 10.1).

BOTANIC DESCRIPTION OF TMCF IN FRENCH POLYNESIA

TMCF is the vegetation type in French Polynesia that shows the highest number of biologic types. All TMCFs are characterized by an abundance of epiphytic ferns (especially Hymenophyllaceae or filmy ferns, e.g. *Hymenophyllum* and *Trichomanes*, and Grammitidaceae, e.g. *Grammitis* and *Calymnodon*), orchids (especially in the genera *Bulbophyllum*, *Calanthe*, *Corybas*, *Dendrobium*, *Habenaria*, *Liparis*, and *Phreatia*), mosses (e.g. the large golden tufts of *Spiridens* on tree fern trunks in Tahiti; Whittier, 1976), lichens, and terrestrial ferns (especially Aspleniaceae, Blechnaceae, Lycopodiaceae, and Polypodiaceae). Furthermore, small trees, shrubs, and herbs (mainly Rubiaceae, Gesneriaceae, and Urticaceae) grow in the understory.

Two broad types of TMCF can be recognized on the island of Tahiti, viz. (i) *Weinmannia parviflora* var. *parviflora* – *Alstonia*

costata forest (Florence, 1983, 1986, 1993) with 7–10-m tall canopy, and (ii) *Ilex anomala* – *Streblus anthropophagorum* forest (Florence, 1993), with a canopy of 5–8 m and found in wetter habitats in gullies and on steep slopes. They are also characterized by the presence of the tree ferns *Cyathea* spp. and the native liana *Freycinetia impavida* (Papy, 1954), as well as by the endemic trees and shrubs *Ascarina polystachya*, *Astronidium* spp., *Coprosma taitensis*, *Glochidion* spp., *Metrosideros collina*, *Myrsine* spp., *Pipturus* spp., *Reynoldsia verrucosa*, the epiphytic orchids *Dendrobium* spp., *Phreatia tahitensis*, *Bulbophyllum tahitense*, *Liparis clypeolum*, and the terrestrial ferns *Marattia salicina*, *Diplazium harpeodes*, and *Blechnum* spp. Among the rare endemic flowering plants, the ground orchid *Calanthe tahitensis*, the small trees *Fitchia tahitensis*, *Fuchsia cyrtandroides*, *Melicope* spp., and *Sclerotheca* spp., the shrubs *Psychotria* spp., *Cyrtandra* spp., and *Scaevola tahitensis* and the sub-shrubs *Bidens* spp. and *Ophiorrhiza* spp. are found.

The summit shrublands are dominated by a *Metrosideros collina* – *Weinmannia parviflora* dwarf forest (2–3 m high), with *Vaccinium cereum*, *Styphelia* spp., *Astelia nadeaudii*, the epiphytic ferns *Elaphoglossum samoense* and *Selliguea feeoides*, and the ground fern *Paesia tahitensis*.

Some original sub-types of TMCF can be found on high-elevation plateaux on the island of Tahiti (at Viriviriterai between 800 and 1000 m.a.s.l., at Terepo between 900 and 1100 m.a.s.l.) with a swamp forest dominated by *Metrosideros* – *Alstonia* – *Crossostylis biflora* and *Pandanus papenooense* and the rare endemic orchid *Corybas minutes*. Another example occurs on the island of Raiatea (at Temehani Rahi, Temehani Ute Ute between 400 and 780 m.a.s.l.; Papy, 1954; Meyer, 1996) in the form of a complex of scrub forest, scrub, and dwarf scrub and bogs (Fosberg, 1992; Mueller-Dombois and Fosberg, 1998) dominated by the island endemic *Weinmannia ovalifolia*, *Metrosideros collina* var. *temehaniensis*, *Cyclophyllum barbatum* var. *temehaniense*, *Pandanus temehaniensis*, *Psychotria* spp., *Bidens* spp. as well as the rare island endemics *Apetahia raiateensis*, *Geniostoma clavatum* (Meyer, 1996), and the recently discovered *Fitchia cuneata* (J.-Y. Meyer, personal observation 2005).

In the Marquesas, TMCFs are mainly found on the central mountains such as the Toovii–Tekao–Ooumu ridge on Nuku Hiva (see Meyer and Florence (1999) for a full description), the Temetiu–Feani ridge on Hiva Oa, the Oave–Teavahaakiti ridge on Ua Pou above 800 m elevation, and the Tekou–Touaouho ridge on Fatu Hiva above 650 m.a.s.l. They form a low, dense canopy, 3–5 m tall with *Crossostylis biflora*, *Weinmannia parviflora* var. *marquesana*, *Cheirodendron bastardianum*, *Ilex anomala*, *Metrosideros collina*, *Streblus anthropophagorum*, and *Freycinetia impavida*. Understory endemic trees and shrubs include *Alstonia marquesensis*, *Ascarina marquisensis*, *Claoxylon oomuense*, *Coprosma* spp., *Pipturus henryanus*, *Psychotria* spp., *Trimenia* spp., *Reynoldsia marchionicum*, *Geniostoma* spp.,

Table 10.2 List of 55 genera of vascular flowering plants recorded at more than one cloud forest location in six Polynesian archipelagoes (Rapa in the Austral Islands, Rarotonga in the Cook Islands, the Hawaiian Islands, the Marquesas Islands, the Samoa Islands, and the Society Islands). The genera are listed according to their representation within any two to six of the selected archipelagoes

Two archipelagos	Three archipelagos	Four archipelagos	Five archipelagos	Six archipelagos
<i>Astronidium</i>	<i>Alstonia</i>	<i>Ascarina</i>	<i>Astelia</i>	<i>Alyxia</i>
<i>Cheirodendron</i>	<i>Apetahia</i>	<i>Bidens</i>	<i>Cyrtandra</i>	<i>Coprosma</i>
<i>Crossostylis</i>	<i>Bulbophyllum</i>	<i>Claoxylon</i>	<i>Geniostoma</i>	<i>Freycinetia</i>
<i>Cypholophus</i>	<i>Calanthe</i>	<i>Dendrobium</i>	<i>Glochidion</i>	<i>Melicope</i>
<i>Elatostema</i>	<i>Carex</i>	<i>Dianella</i>	<i>Liparis</i>	<i>Metrosideros</i>
<i>Oparanthus</i>	<i>Eurya</i>	<i>Habenaria</i>	<i>Myrsine</i>	<i>Vaccinium</i>
<i>Peristylus</i>	<i>Fagraea</i>	<i>Meryta</i>	<i>Peperomia</i>	
<i>Phreatia</i>	<i>Fitchia</i>	<i>Omalanthus</i>	<i>Scaevola</i>	
<i>Sclerotheca</i>	<i>Gahnia</i>	<i>Pipturus</i>	<i>Weinmannia</i>	
	<i>Hedyotis</i>	<i>Pittosporum</i>		
	<i>Ilex</i>	<i>Psychotria</i>		
	<i>Ixora</i>	<i>Reynoldsia</i>		
	<i>Korthalsella</i>	<i>Streblus</i>		
	<i>Machaerina</i>	<i>Styphelia</i>		
	<i>Macropiper</i>			
	<i>Pandanus</i>			
	<i>Santalum</i>			

Source: Data for Samoa are based on Whistler (1995, 2002) and Cribbs and Whistler (1996), for Rarotonga on Wilder (1931) and McCormack and Künzle (1995), and for Hawai'i on Wagner *et al.* (1990).

Melicope spp., and *Scaevola* spp. as well as the endemic herbs *Bidens* spp. and *Phyllanthus pacificus*. Associated with these rare endemic species are *Achyranthes marchionica*, *Apetahia* spp., *Hedyotis* spp., *Oparanthus* spp., and the ground orchids *Calanthe marquisensis* and *Habenaria marquesensis*. Tree ferns (*Cyathea* spp.) and the ground ferns *Polystichum marquesensis* and *Paesia rugulosa* are commonly found in the moist forest understory. In disturbed areas, the native climber *Freycinetia impavida* often forms dense thickets, especially on steep slopes, whereas the staghorn fern (*Dicranopteris linearis*) is dominant in more open areas. The wet summits of the highest peaks are covered by a shrubland dominated by *Metrosideros collina*, *Vaccinium ceruum*, and *Styphelia tameiameia* and the epiphytic ferns *Elaphoglossum* spp. and *Selliguea feeoides*.

On Rapa, TMCF is restricted to Mt. Perau between 550 m and 650 m elevation (J.-Y. Meyer, personal observation 2002). The native tree *Metrosideros collina*, the island endemic trees *Weinmannia rapensis* and *Corokia collenettei*, and the tree fern *Cyathea stokesii* are the dominant arborescent species. The island endemic trees and shrubs found in this small TMCF habitat include *Apetahia margaretae*, *Claoxylon collenettei*, *Coprosma* spp., *Eurya rapensis*, *Hedyotis rapensis*, *Meryta* spp., *Myrsine* spp., *Oparanthus coriaceus*, *Styphelia rapae*, and *Vaccinium rapae*, with the island endemic herbs *Astelia rapensis*,

Carex stokesii, the very rare native epiphytic orchid *Liparis clypeolum*, the rare island endemic shrubs *Geniostoma rapense* and *Melicope margaretae*, and sub-shrubs *Haroldiella rapensis* and *Pilea occulta* found in wetter gullies. Small populations of *Pacifigeron rapensis*, one of the seven endemic genera found on Rapa, occur on ridges and cliffs. Many small endemic epiphytic ferns are found on mossy logs including *Elaphoglossum* spp., *Loxogramme parksii*, *Grammitis maireau*, and *Calymnodon* spp.

FLORISTIC AFFINITIES BETWEEN ARCHIPELAGOS

Despite these high levels of endemism, especially at the species level, Pacific Island TMCFs share many common elements. Initial analysis of TMCF taxa at six island (or archipelago) locations in remote Oceania (namely Rarotonga in the Cook Islands, the Hawaiian Islands, Marquesas Islands, Samoa Islands, Society Islands, and Rapa in the Austral Islands) indicated 55 genera of vascular flowering plants recorded from more than one TMCF location. Six genera (10%) were found in all oceanic locations, and 46 genera (84%) in three or more of them (Table 10.2). This indicates a high taxonomic similarity between cloud forests throughout the Polynesian region.

Table 10.3 Number of endemic plant taxa found in cloud forests of selected islands of French Polynesia

ISLAND (archipelago)	Number of endemic genera found in TMCF/Total number of endemic genera in the island (name of the endemic genera)	Number of endemic plant species	Estimated number of species found in TMCF (% of total)	Estimated number of endemic species restricted in TMCF (% of total)
Tahiti (Society)	2/3 (<i>Fitchia</i> , <i>Sclerotheca</i>)	224 ^a	142 ^c (63%)	85 ^c (38%)
Moorea (Society)	2/2 (<i>Fitchia</i> , <i>Sclerotheca</i>)	76 ^a	43 ^c (56%)	19 ^c (25%)
Raiatea (Society)	2/2 (<i>Apetahia</i> , <i>Fitchia</i>)	118 ^a	86 ^c (73%)	47 ^c (40%)
Nuku Hiva (Marquesas)	3/5 (<i>Apetahia</i> , <i>Oparanthus</i> , <i>Plakothira</i>)	84 ^b	54 ^c (64%)	43 ^c (51%)
Hiva Oa (Marquesas)	2/2 (<i>Apetahia</i> , <i>Oparanthus</i>)	82 ^b	59 ^c (72%)	42 ^c (51%)
Ua Pou (Marquesas)	1/1 (<i>Apetahia</i>)	49 ^b	35 ^c (71%)	25 ^c (51%)
Ua Huka (Marquesas)	1/1 (<i>Apetahia</i> extinct ?)	42 ^b	31 ^c (71%)	15 ^c (36%)
Rapa (Austral)	5/7 (<i>Apetahia</i> , <i>Fitchia</i> , <i>Haroldiella</i> , <i>Oparanthus</i> , <i>Pacifigeron</i>)	89 ^a	51 ^c (57%)	24 ^c (27%)

^a Data based on the “Nadeaud botanical data-base” (Florence 1993, J. Florence, personal communications).

^b Data based on the “Vascular Flora of the Marquesas Islands Project” (<http://ravenel.si.edu/botany/pacificislandbiodiversity/marquesasflora/>).

^c Unpublished data based on field observations by the author (1995–2005)

The completeness of this data-set could be improved by adding ferns and fern allies, such as mosses and bryophytes. Oceanic TMCFs are indeed likely to show high generic similarity for these taxa, because of their suitability for long-distance dispersal. Thus, these TMCFs contain numerous floristic elements with temperate biogeographic affinities (e.g. *Astelia*, *Coprosma*, *Vaccinium*), distinguishing them from the low-elevation rain forest flora that is dominated by tropical Malesian and South-East Asian species. Some endemic taxa confined to TMCFs in French Polynesia have peculiar floristic affinities: for example, the Tahitian taxa *Oreobolus* and *Fuchsia* are related to Hawaiian and South American taxa, respectively; the Marquesan species *Trimenia* and *Cheirodendron* with Fiji and Hawai'i, respectively; whereas an affinity with New Zealand is seen with *Hebe* and *Corokia* from Rapa (Meyer, 2004).

TMCF AS PLANT DIVERSITY HOT SPOTS AND REFUGIA FOR ENDEMIC ANIMALS

TMCFs are floristically the most diverse of all plant communities in French Polynesia, with the highest rate of endemism and the highest number of biologic types. Six of the 10 French Polynesian or South-Eastern Polynesian endemic genera are restricted to TMCF (*Apetahia* in the Society and the Marquesas Islands, *Fitchia* in the Society Islands and Rapa, *Oparanthus* in the Marquesas Islands and Rapa,

Haroldiella and *Pacifigeron* in Rapa, and *Sclerotheca* in the Society Islands). It is estimated that between 60% (e.g. in Moorea and Tahiti, Society Islands, and Rapa in the Austral Islands) and over 70% (e.g. in Raiatea, Society Islands, and Hiva Oa, Ua Pou, and Ua Huka, Marquesas Islands) of the endemic vascular plant species are found in the TMCFs, and that between 25% (Moorea, Rapa) and more than 50% (Hiva Oa, Nuku Hiva, Ua Pou) of these endemics are confined to these habitats (Table 10.3).

TMCFs are also the home of several endangered endemic animals such as tree snails (Partulidae) of the genera *Partula* spp. in Tahiti and *Samoana* spp. in the Marquesas (J.-Y. Meyer, personal observations), nesting sea birds (*Pterodroma* spp.) or land birds (*Ducula galeata* on Nuku Hiva, *Pomarea whitneyi* on Fatu Hiva) (J.-Y. Meyer, personal observations), aquatic insects (e.g. endemic damselflies belonging to the genus *Bedfordia*; R. Englund, personal communication) and terrestrial arthropods (e.g. spiders; R. Gillespie, personal communication; weevils belonging to the genus *Rhyncogonus*; E. Claridge, personal communication). In the Marquesas, a large number of endemic insects appear to be dependent on two most common host-plants found in the TMCF, *Metrosideros collina* and *Weinmannia* spp. (Mumford and Adamson, 1934). Other host-plants of importance are *Crossostylis biflora*, *Ilex anomala*, *Vaccinium cereum*, and the endemic Marquesan species of *Cyrtandra* and *Apetahia* (Adamson, 1939), all of them restricted to TMCF.

PAST AND CURRENT THREATS TO TMCF IN FRENCH POLYNESIA

Cloud forests in French Polynesia are located on high mountains in rugged terrain, thus being relatively undisturbed and inaccessible for humans. Natural disturbances such as cyclones and landslides are uncommon in French Polynesia and do not pose any major threat. Prior to European arrival, human disturbances were restricted to only a few activities (cultivation, fire?) as montane forests were considered *tapu* (i.e. forbidden) and the residence of gods (Bachinon, 1990). In deep gullies and valley heads, there are remnant groves of mountain plantain (*Musa troglodytarum*, syn. *M. fehi*), called *fe'i* in the Society Islands and *huetu* in the Marquesas. Plantain was (and still is) one of the main staple foods in French Polynesia along with breadfruit, taro, and sweet potato. According to MacDaniels (1947), "the best plants are found at altitudes of about 600 to 800 meters, near the heads of the valleys [. . .] and will grow at heights of 1200 meters." Pétard (1960) wrote that in Tahiti "*les fei abondent surtout entre 800 et 1200 m, ils atteignent des dimensions énormes*" whereas Oliver (1974) stated that "there are many varieties, that once grew plentifully in large thickets high up the mountain slopes at 600 to 900 meters." The increasing scarcity of mountain plantains at lower elevations may be due to the devastation wrought by feral cattle and pigs, introduced plants (MacDaniels, 1947), and the ravages of the introduced banana-borer *Cosmopolites sordidus* (Mumford and Adamson, 1934).

Current threats to montane forests in the islands include road construction (Mt. Marau, Toovii ridge on Nuku Hiva, Mt. Ootua on Hiva Oa), hydro-electricity development (Mt. Mauru), grazing or trampling by feral ungulates (pigs on Hiva Oa, goats on Rapa), and invasion by alien plant species (mainly the trees *Miconia calvescens*, *Psidium cattleianum*, and *Spathodea campanulata*, and the grass *Melinis minutiflora* on Tahiti and Moorea, *Syzygium cumini* on Hiva Oa, *Syzygium jambos* on Nuku Hiva, *Chrysobalanus icaco* on Raiatea and Fatu Hiva, and the shrub *Rubus rosifolius* in the Society Islands, Hiva Oa and Rapa; Meyer, 2004). The small invasive tree *Miconia calvescens* forms dense monospecific forest stands up to 1300 m elevation and poses a direct threat to the endemic species of TMCFs in Tahiti (Meyer and Florence, 1996) and the other high volcanic islands of French Polynesia.

Habitat conservation and invasive pest management (exclusion of feral ungulates, control of invasive plants) is urgently needed to protect the last of the TMCFs in French Polynesia. The Mt. Marau site (900–1400 m.a.s.l.) on Tahiti was first proposed as a natural park in 1976, and the Toovii–Tekao ridge was proposed to be protected as a natural preserve about 25 years ago, but these proposals have never been implemented. Both sites are currently threatened by new road construction activities. The only protected area that encompasses a small patch of cloud forest in French Polynesia remains the Vaikivi park and natural reserve on the small

island of Ua Huka in the Marquesas. It was declared a protected area in 1995 as it is an important watershed area and offers refuge for rare endemic plant and animal species (Meyer, 1996).

CONCLUSIONS AND PERSPECTIVE

TMCFs represent less than 8000 ha or less than 3% of the terrestrial surface of the 37 high volcanic islands of French Polynesia. They are found in 12 of these islands and occur at different elevations, mostly between 300 and 1800 m.a.s.l. The majority of remaining TMCFs is concentrated on the large islands of Tahiti (Society Islands), and on Nuku Hiva and Hiva Oa (Marquesas Islands). TMCFs in French Polynesia contain a larger percentage of endemic species than other vegetation types (between 50% and 70% for most islands), and six of the 11 French Polynesian or south-eastern Polynesian endemic genera are restricted to these areas. They also act as refugia for numerous endemic birds and invertebrates. For a long time, they have remained virtually pristine. In the words of Mueller-Dombois and Fosberg (1998): "The cloud forest of most of the high mountains of Tahiti is probably as nearly an undisturbed example of Polynesian vegetation as still exists." However, because of their limited extent, TMCFs in French Polynesia are highly vulnerable to disturbance (notably by exotic invader plants) and extinction of endemic species. Research on the botanic (inventories, description of new species) and ecological (phyto-sociology, plant succession, resilience to invasion) aspects of TMCFs in French Polynesia has been limited and thus these are still poorly understood. TMCFs in Polynesian archipelagos and in the Pacific region exhibit high generic similarity but there is substantial scope for comparative studies (including molecular phylogenies) in these unusual forests.

During the last 10–15 years, field surveys and ecological assessments have been conducted in the TMCFs of all the high volcanic islands in French Polynesia, and proposals have been put forward for the protection of some of the most critical areas in the Society Islands (e.g. Mt. Marau, Mt. Mauru, Faufiru plateaux, Temehani plateaux, Viriviriterai and Terepo plateaux), the Marquesas Islands (Mt. Ootua, Temetiu–Feani ridge, Toovii–Tekao ridge), and Rapa (Mt. Perau) in the Austral Islands. It is hoped that this chapter will contribute to a better knowledge and conservation of the TMCFs in French Polynesia which represent botanic and ecological "jewels" in the remote tropical islands of Oceania.

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