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Tahiti's native flora endangered by the invasion of *Miconia calvescens* DC. (Melastomataceae)

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Abstract. The native flora of tropical oceanic islands is known to be particularly susceptible both to displacement and extinction, following the invasion of alien organisms. *Miconia calvescens* DC. (Melastomataceae), first introduced to Tahiti (French Polynesia, South Pacific Ocean) in 1937 as an ornamental plant, now covers over two-thirds of the island. As it forms dense monotypic stands which have progressively overwhelmed the native forests, this plant pest is a direct threat to the rich Tahitian indigenous flora. Between 40 and 50 species of the 107 species endemic to Tahiti are thought to be on the verge of extinction. *M. calvescens* was finally declared a 'noxious species in French Polynesia' in 1990. Without efficient control efforts and effective endangered plant conservation and protection legislation, *M. calvescens* could cause Tahiti and all the high islands of French Polynesia to become ecological deserts.

Key words. Biodiversity, biological invasion, endangered flora, Melastomataceae, *Miconia calvescens*, oceanic islands, Tahiti.

Résumé. La flore indigène des îles océaniques tropicales est connue pour être particulièrement sensible à un déplacement voire à une extinction d'espèces, suite à l'invasion d'organismes étrangers. *Miconia calvescens* DC. (Melastomataceae), d'abord introduit à Tahiti (Polynésie française, Pacifique Sud) en 1937 comme plante ornementale, recouvre actuellement plus des deux-tiers de l'île. En formant des couverts monospécifiques denses qui ont étouffé progressivement les forêts naturelles, cette plante est un danger direct pour la flore indigène riche de Tahiti. Entre 40 et 50 espèces des 107 plantes endémiques de Tahiti sont supposées être en voie d'extinction. *M. calvescens* a été finalement déclarée espèce nuisible en Polynésie française en 1990. Sans des efforts de lutte et une législation sur la conservation et la protection des plantes en danger efficaces, *M. calvescens* peut transformer Tahiti et toutes les îles hautes de Polynésie française en déserts écologiques.

Mots clés. Biodiversité, flore en danger, île océanique, invasion biologique, Melastomataceae, *Miconia calvescens*, Tahiti.

BACKGROUND

The floristic richness of Tahiti

Tahiti (17°38'S, 149°30'W) is the most well known island of the fourteen that form the Society Archipelago (French Polynesia, South Pacific Ocean) (Fig. 1), so-called by James Cook in 1769 because the islands 'lay contiguous to one another'. Tahiti is also the largest (1045 km^2) and highest (reaching 2241 m) of all the high tropical oceanic islands of French Polynesia. It is also the ecologically richest of the Society Islands, being home to 467 native plant species of which 212 are endemic to the island (*c.* 45% endemicity). Comparably, Nuku Hiva, the largest island (339 km^2) of the Marquesas Archipelago, has 254 native plants including 126 endemics (*c.* 50% endemicity) (Florence, 1993).

Whereas the five coral atolls of the Society group have a poor flora due to their harsh ecological conditions (effects of salt, drought, wind and poor substrate), the nine high islands, and especially Tahiti, have a high floristic richness because of the wide diversity of ecological habitats that occur along the altitudinal gradient (from sea-shore to the summit of volcanoes) that characterize these islands. This factor, combined with the dominant wet Southeast trade winds that blow during the warm and humid season (November to March), creates a strong climatic contrast between the dry leeward coast where rainfall is below 2 m yr^{-1} and the moister windward coast (rainfall >3–4 m per year). Rainfall increases rapidly with elevation, reaching up to 10 m per year in the centre of the island. Average annual temperature is 26°C at sea level (with a 7°C maximal annual variation) but decreases by 0.6°C per 100 m of altitude (Pasturel 1993). Temperatures of 10°C or even 5°C are not

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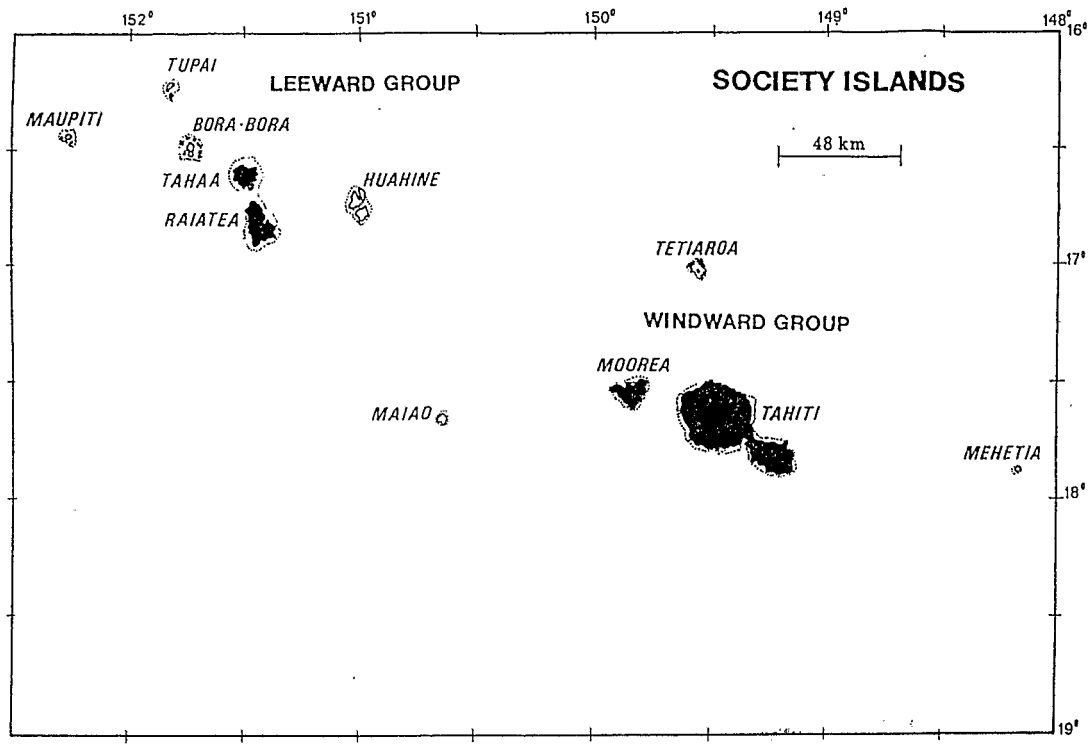

FIG. 1. The islands of the Society Archipelago that have been colonized by *Miconia calvescens* (in black).

unusual on the highest mountain tops of Tahiti. Ten summits exceed 1500 m including three peaks above 2000 m, namely Mont Orohena (2241 m), Mont Aorai (2066 m) and Pito Hiti (2110 m).

The classification of Tahitian plant communities follows the altitudinal gradient (Florence 1993): a xeric coastal zone, a mesic zone of low and middle altitude (including the valleys), a wet zone of middle and high elevation (the rain forests and the montane cloud forests), and a subalpine zone (the ridges, crests and peaks).

About 70% of the endemic plants of Tahiti are located in the montane cloud forest (above 300 m on the windward coast, and above 600 m on the leeward coast) and in the subalpine forest (>1500 m elevation) (Fig. 2). The dense short-stature cloud forest or mossy forest (7–10 m tall) contains a few dominant canopy trees, *Metrosideros collina* (J.R. & J.G. Forster) A. Gray (Myrtaceae, Tahitian name: 'pua rata'), *Weinmania parviflora* J.G. Forster (Cunoniaceae, 'aito moua'), *Alstonia costata* (J.G. Forster) R. Brown (Apocynaceae, 'atahe'). It is also characterized by the tree fern *Cyathea affinis* (J.G. Forster) Swartz (Cyatheaceae, 'mamau'), the liana *Freycinetia impavida* (Gaudichaud ex Homborgh) B. Stone (Pandanaceae, 'ie ie'), a large number of endemic shrubs and small trees such as *Cyrtandra spp.* (Gesneriaceae, 'haahape') and *Psychotria* spp. (Rubiaceae), and a great abundance of epiphytic orchids, mosses and ferns on the trunks and branches of trees.

The subalpine forest is a scrubland dominated by shrubby species such as *Ilex anomala* Hooker & Arnott (Aquifoliaceae, 'mairai'), *Vaccinium cereum* (L.f.) J.G. Forster (Ericaceae, 'opu opu'), *Styphelia tameiameiae* (Chamisso & Schlechtendahl) F. Mueller (Epacridaceae 'aito moua'), by endemic herbs such as *Astelia nadeaudii* Drake (Liliaceae, 'anae'), and by sedges such as *Gahnia schoenoides* J.G. Forster and *Carex tahitensis* F. Brown (Cyperaceae).

The montane vegetation of Tahiti is considered at the present time as 'the largest and finest example of montane rainforest still remaining intact on Oceanic Pacific islands' (Fosberg 1992: 238).

Tahiti was formed by two ancient volcanoes connected by the narrow and low isthmus of Taravao: Tahiti-Nui ('large') is 30 km in diameter, 0.8 million years old, and Tahiti-Iti ('small') is 22 km by 13 km, 0.4 million years old. Into these two volcanoes about 120 valleys with steep slopes have been formed. Many of these valleys have nearly vertical sides of 1000 m high. Charles Darwin (1852: 413) said about Tahiti, after coming from the Andes, 'in the Cordillera, I have seen mountains on a far grander scale but for abruptness, nothing at all comparable with this'.

The deep V-shaped valleys separated by knife-edge ridges and high peaks provide unique microclimates and marked isolation which may have facilitated cases of differentiation and diversification in the flora of the island. For example, among the six Tahitian endemic species of the South eastern Polynesian genus *Sclerotheca* (Campanulaceae: Lobelioideae), two species are restricted to Mont Aorai and two species to Mont Marau (1493 m) and Pito Hiti. The distribution of the five Tahitian endemic species of the genus *Bidens* (Asteraceae) shows a similar pattern, with two species (*B. aoraiensis* M. Grant ex Sherff and *B. orofenensis* M. Grant ex Sherff) strictly located on the dry crests above 1600 m. Another relevant genus is the genus *Fitchia*

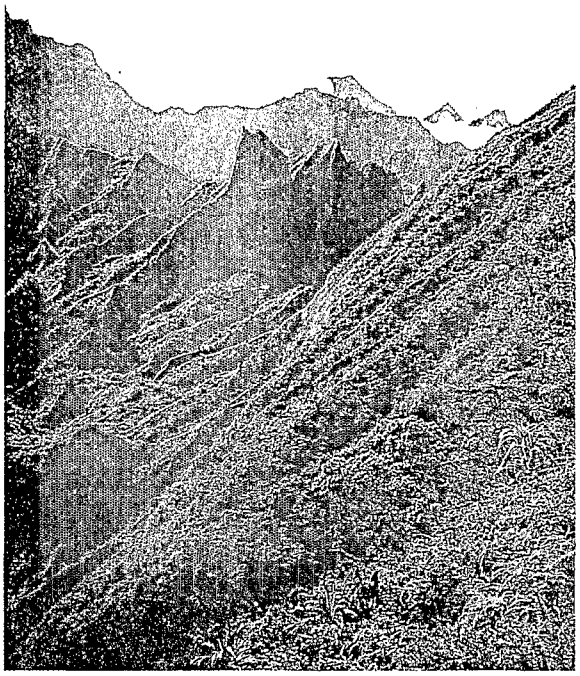

FIG. 2. A view of the native montane cloud forest and the subalpine forest (crests and peaks) at Mont Marau (1490 m), Tahiti.

(Asteraceae) with two endemic arborescent species: *F. nutans* J. Hooker ('anei') is only found in the montane cloud forest, whereas *F. tahitensis* Nadeaud ('tetufera' or 'torometo') grows in the mesic forest (Florence, 1987).

The importance of alien plant introductions

When the first Polynesian migrants arrived 3500–3000 years ago by canoe, they brought with them *c.* thirty domestic plant species. The most notable of these are *Colocasia esculenta* (L.) Schott (Araceae, 'taro'), Tahitian chestnut *Inocarpus fagifer* (Parkinson ex Z.) Fosberg (Leguminosae, 'mape'), breadfruit tree *Artocarpus altilis* (Parkinson ex Z.) Fosberg (Moraceae, 'uru') and wild banana *Musa troglodytarum* L. (Musaceae, 'fei') which represent food sources, *Morinda citrifolia* L. (Rubiaceae, 'nono'), *Cordyline fruticosa* (L.) A. Chevalier (Liliaceae, 'ti') and *Piper methysticum* J.G. Forster (Piperaceae, 'ava') for medicine or ritual value, and bamboo *Schizostachyum glaucifolium* (Ruprecht) Munro (Gramineae, 'ofe') for timber. Among the approximatively fifty adventices that were introduced accidentally, *Merremia peltata* (L.) Merrill (Convolvulaceae, 'pohue'), an extensive liana, forms now tangles in the secondary forests. The native flora of the lowland coastal zone was for a great part replaced with coconut groves, taro marshes, and the valley forest with 'mape', 'uru' and 'ofe'.

The arrival of the first European explorers to Tahiti (Wallis in 1767, Bougainville in 1768, Cook in 1769) led to massive destruction of native habitats, overuse of natural resources, and a dramatic increase in the number of introduced alien plants and animals. As a result, more than 1500 exotic plant species are now present in the Society Islands. They were introduced voluntarily (crop and ornamental plants) or inadvertently (ruderal and adventice species). Many have become naturalized and some have become troublesome weeds or 'plant pests' in the secondary man-disturbed vegetation (Table 1). Although coastal and lowland zones have been completely modified by man, highlands and native montane forests have remained relatively intact and natural—until the introduction of 'the worst of all' (Fosberg 1992: 238): *Miconia calvescens* DC. (Melastomataceae).

MICONIA CALVESCENS, THE 'PURPLE BOTANICAL PLAGUE'

Miconia calvescens, a melastome native to rain forests of Central and South America, was introduced to the Papeari Botanical Garden on Tahiti in 1937 as a garden ornamental. Indeed, this very attractive plant, also called *Miconia magnifica* Triana in horticulture, has large and handsome dark green leaves (up to 1 m long) with purple-violet undersides. In the wild, it grows to the size of a small tree, reaching 10 to 15 m in height.

M. calvescens remained unnoticed for decades after its introduction to Papeari (Tahiti-Nui) and on the plateau of Taravao (Tahiti-Iti) where it had later been planted (Raynal, 1979). The plant awakened the awareness of American and French botanists in the early 1970s when it started to form pure stands on the plateau of Taravao. In less than 50 years, *M. calvescens* has thrived and spread to all the mesic and wetland habitats (mean annual rainfall >2500 mm) between 10 and 1300 m elevation, including the montane cloud forests (Fig. 3). The plant now covers over two-thirds of the island of Tahiti (*c.* >70,000 ha) and was finally declared a 'noxious species in French Polynesia' in 1990. The circumstances are alarming in Tahiti but unfortunately they do not end there: *M. calvescens* has also spread to the surrounding islands of Moorea (20 km from Tahiti), and Raiatea in the Society archipelago where it was introduced as an ornamental in the 1950s (Meyer 1996). A small and isolated population has been noticed in 1995 in the island of Tahaa, separated only by a narrow channel (5 km large) from Raiatea (Meyer, unpublished data) (Fig. 1). *M. calvescens* represents a serious potential threat to the five other high islands of the Society Archipelago (Bora Bora, Huahine, Maiao, Maupiti and Mehetia).

M. calvescens also represents one of the eighty-six plant pests of the Hawaiian archipelago (Smith, 1985) where it was introduced in the early 1970s through the horticultural industries (Gagné *et al.* 1992). 'Wanted' posters were distributed by the Conservation Council for Hawaii in order to document new locations of this 'Purple Botanical Plague' (Gagné & Montgomery, 1991).

A number of ecological and biological characteristics makes *M. calvescens* particularly problematic. The most

TABLE 1. List of twenty main alien invasive plants in Tahiti (*invaders in native forests).

Family	Scientific name	Common English name	Life form	Country of origin	Date of introduction	Altitudinal range (m)
Asteraceae	*Bidens pilosa* L.	Beggar's tick	H	Tropical Amer.	1839	0–1300
	Elephantopus mollis Kunth	Elephant's foot	H	South Amer.	1912	00–800
	Thelechitonia trilobata (= *Wedelia trilobata* (L.) A. Hitchcock)	Wedelia	H		around 1960	00–1300
Bignoniaceae	**Spathodea campanulata* Beauvois	African tulip tree	T	Africa	before 1936	100–1200
	**Tecoma stans* (L.) A. L. Jussieu ex Kunth	Yellow trumpet tree	T	Central Amer.	1845	100–1500
Cecropiaceae	*Cecropia peltata* L.	Trumpet tree	T	South Amer.	before 1890	100–600
Convolvulaceae	*Merremia peltata* (L.) Merrill	Merremia	C	Asia	before 1769	00–500
Cyperaceae	*Cyperus rotundus* L.	Nut grass	H	Eurasia	1922	00–900
	Kyllinga polyphylla Willdenow ex Kunth	Navua sedge	H		before 1881	4000–800
Gramineae	*Melinis minutiflora* Beauvois	Molasses grass	H	Africa	around 1960	0–1600
Mimosaceae	*Mimosa diplotricha* C. Wright ex Sauvalle (= *M. invisa* Martius ex Colla)	Giant sensitive plant	H	South Amer.	1956	0–400
	**Paraserianthes falcataria* (L.) I. Nielsen	Moluca albizia	T	Asia	around 1936	0–700
Melastomataceae	**Miconia calvescens* DC.	Velvet tree	T	Tropical Amer.	1937	10–1300
Myrsinaceae	*Ardisia elliptica* Thunberg	Shoebutton Ardisia	T	Indo-Malaysia	around 1930	10–300
Myrtaceae	*Psidium guava* L.	Common guava	S	Central Amer.	1815	<500
	**Psidium cattleianum* Sabine	Strawberry guava	S	South Amer.	around 1840	10–800
	**Syzygium cumini* (L.) Sheets	Java plum	T	Asia	1880	0–700
Rosaceae	**Rubus rosifolius* J.E. Smith	Thimbleberry	H	Asia	around 1930	50–2000
Verbenaceae	*Lantana camara* L.	Lantana	S	Tropical Amer.	1853	0–1500
	Stachytarpheta urticifolia Sims	Blue rat's Tail	H	Tropical Amer.	before 1912	0–700

The dates of introduction derived from different sources, mainly H. Jacquier (1960), J. Florence (1993), and M. Guérin (pers. comm., 1995). Life form: H = herb; C = climber; S = shrub; T = tree.

important of these include its wide range of germination conditions, ability to tolerate low light levels, relatively fast growth rate leading to early reproductive maturity, prolific and nearly continuous seed reproduction, efficient dispersal of its small berries by birds (introduced passeriformes like the Silvereye *Zosterops lateralis* Latham and the Red-vented Bulbul *Pycnonotus cafer*) and by small rodents (especially Polynesian Rat *Rattus exulans* Peale), large soil seed bank, ability to sprout vigorously after being cut, combination of allo- and autogamy allowing isolated individuals in a new site to reproduce (Meyer, 1994). These characteristics have contributed to make this species particularly competitive towards native plants. *M. calvescens* forms dense monotypic stands suppressing the growth and the regeneration of the native vegetation which is not able to survive the low light conditions. A previous study has shown the significant decrease in the number of native plants as the degree of infestation by *M. calvescens* increases (Gaubert, 1992). Moreover, with a tentacular root system and a high stature (up to 15 m) *M. calvescens* undoubtedly changes the nutrient and water regimes, and is suspected to be a cause of landslides.

In Tahiti, seventy to 100 native plant species including forty to fifty endemics are estimated to be directly threatened by *M. calvescens*. The most endangered endemics are species in the genus *Cyrtandra* (Gesneriaceae, eight species), *Ophiorrhiza* (Rubiaceae, seven species), *Psychotria* (Rubiaceae, six species), *Myrsine* (Myrsinaceae, five species), *Sclerotheca* (Campanulaceae, three species), *Fitchia* (Asteraceae, two species) and *Meryta* (Araliaceae, two species) (Table 2). The *Weinmannia–Alstonia* forests are vanishing especially on the Leeward Coast of Tahiti-Nui (Fig. 3) and on the plateau of Taravao (Tahiti-Iti) where dead fern trees (*Cyathea* spp.) are now commonly found under a contemporary monodominant '*Miconia* forest'.

M. calvescens alters, as Peter Vitousek (1990: 8) pointed out, 'the fundamental rules of existence for all organisms': it also causes the rarefaction of brooding sites and source of food (fruiting plant species) of many Tahitian endemic birds, such as *Acrocephalus caffer* Sparrman (Tahiti Reed-warbler, 'otatare') which occurs only in bamboo thickets and *Butorides striatus patruelis* L. (Tahiti Green heron, 'a'o') which is confined to riverside stands of *Hibiscus tiliaceus* L. (Malvaceae, 'purau').

NEEDS FOR THE FUTURE

Since the alarm sent out by the French botanist Jean Raynal in 1973, who proclaimed that 'Miconia is the number one enemy of the Tahitian flora', nothing was done for several years. Then, in 1988, a research program was set up by the 'Centre ORSTOM de Tahiti' (French Over-Seas Scientific

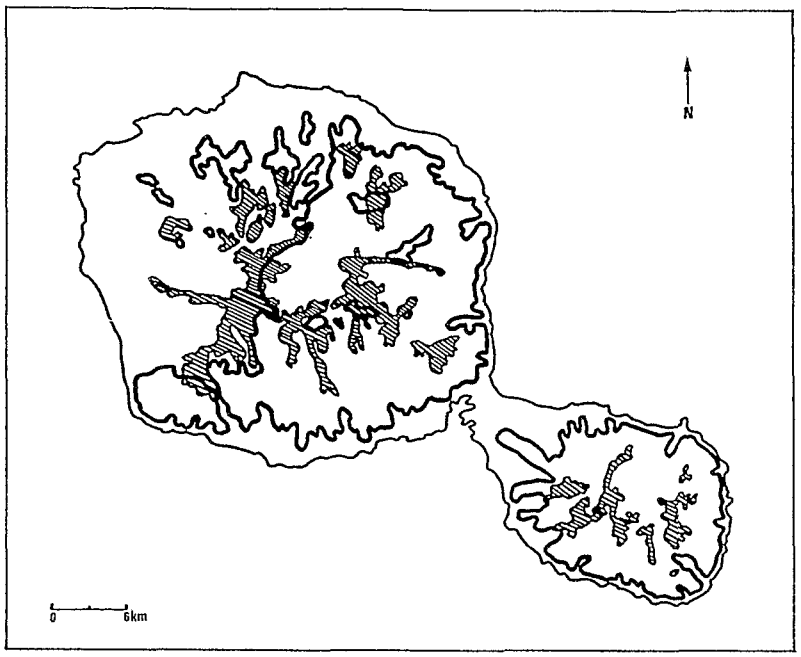

FIG. 3. The distribution of native cloud forests (hatched zone) and the distribution of *Miconia calvescens* (black line) on Tahiti (after Florence, 1993).

and Technical Research Organization) in association with the Ministry of Environment and Research of French Polynesia to study the processes of invasion by *M. calvescens* and to develop efficient control methods against this species. Three punctual but successful control operations, using manual uprooting, were carried out on the island of Raiatea in 1992, 1993 and 1995. Over 450,000 plants of *M. calvescens* were destroyed (J.-P. Malet, pers. comm. 1995). The entire invaded zones were cleaned out and the progression of the plant pest in the island was stopped.

However, without a coherent conservation policy, it is impossible to assess the consequences of plant pests such as *M. calvescens*. The native forests of Tahiti are already endangered by housing, clearing for agriculture, grazing by feral animals, forestry (extensive plantation of Caribbean Pine *Pinus caribbea* Morelet *var. hondurensis* Barett & Golfari, Pinaceae, and *Paraserianthes falcataria* (L.) I. Nielsen, Mimosaceae), and other habitat destruction associated with human activities (e.g. the hydroelectric development in the Papenoo and Faatautia valleys).

From these considerations, several urgent measures should be taken for the conservation of Tahiti's native flora.

(1) A list of endangered endemic plants in Tahiti, their localization and the degree of threat should be compiled and given the highest priority.
(2) A list of main invasive alien plants likely to threat native ecosystems, their distribution and impact on native habitats and species should be also drawn up.
(3) Inventories of the 'Natural Zones of Ecological and Biological Interests', from which most or all alien invasive species are excluded, are needed. The 'Faaiti Territorial Natural Park' (750 ha) created in June 1989 has a low biological interest. Furthermore it still remains simply a 'paper park' without efficient management,
(4) *Ex situ* conservation of endemic species in the Papeari Botanical Garden (which still remains only an ornamental garden) should be developed.
(5) The quarantine system to control the traffic of alien plants, animals and micro-organisms and prevent introduction of other pests should be rigorously enforced.
(6) Research and monitoring efforts should accompany control programmes.
(7) Last but not least, improved conservation action and appropriate education programs are desperately needed.

CONCLUSIONS

The uniqueness and diversity of the endemic Tahitian flora (*c.* 45% of endemicity) can be explained by its geological history, extreme isolation and by the large variation in substrate, topography and climatic variation.

The introduction of alien species may have devastating effects on native biota of oceanic islands, and contribute ultimately to the extinction of many native species (Cronk & Fuller, 1995). In French Polynesia there are already two famous cases of the drastic effect of introduced exotic species. First is the extinction of several endemic species of land snails (*Partula* spp., Partulidae) following the introduction of the carnivorous snail (*Euglandina rosea* Férussac, Oleacinidae) on the island of Moorea. Second is the massive grazing of feral goats on Marquesas islands where the native flora has been supplanted by exotic grasses, and turned into a vegetation now known as the 'desert

TABLE 2. List of some relevant Tahitian endemic plants directly endangered by *Miconia calvescens*. The degree of threat has been adapted from the IUCN (40th Meeting, 30th November 1994, Gland, Switzerland).

Family	Scientific name	Degree of threat
Dicotyledonae		
Araliaceae	*Meryta drakeana* Nadeaud	DD
	Meryta mauruensis Nadeaud	DD
Asteraceae	*Fitchia nutans* J. Hooker	LR
	Fitchia tahitensis Nadeaud	VU
Campanulaceae	*Sclerotheca arborea* (J.G. Forster) A. L. DC	CR
	Sclerotheca jayorum J. Raynal	EN
	Sclerotheca oreades F. Wimmer	VU
Euphorbiaceae	*Glochidion grayanum* (J. Mueller) Florence ined.	EN
	Macaranga taitensis (J. Mueller) J. Mueller	VU
Gesneriaceae	*Cyrtandra bidwillii* Clarke	CR
	Cyrtandra connata Nadeaud	CR
	Cyrtandra geminiflora Nadeaud	DD
	Cyrtandra glabra Banks ex Gaertner	CR
	Cyrtandra induta A. Gray	LR
	Cyrtandra mucronata Nadeaud	LR
	Cyrtandra vairiae Drake	VU
	Cyrtandra vescoi Drake	DD
Hernandiaceae	*Hemandia temarii* Nadeaud	EX?
Leguminosae	*Erythrina tahitensis* Nadeaud	CR
Myrsinaceae	*Myrsine hartii* (M. Grant) Fosberg & Sachet	CR
	Myrsine longifolia Nadeaud	CR
	Myrsine orohenensis (J. Moore) Fosberg & Sachet	DD
	Myrsine ronuiensis (M. Grant) Fosberg & Sachet	CR
	Myrsine vescoi Drake	DD
Nyctaginaceae	*Pisonia graciliscens* (Heimerl) Stenmerik	CR
Rubiaceae	*Ophiorrhiza nelsonii* Seemann	VU
	Ophiorrhiza platycarpa S. Darwin	VU
	Ophiorrhiza scorpioidea Nadeaud	VU
	Ophiorrhiza setosa S. Darwin	VU
	Ophiorrhiza solandri Seemann	VU
	Ophiorrhiza subumbellata J.G. Forster	VU
	Ophiorrhiza tahitensis Seemann	VU
	Psychotria grantii Fosberg	CR
	Psychotria lepiniana (Baillon ex Drake) Drake	VU
	Psychotria marauensis Fosberg & Florence	VU
	Psychotria speciosa J.G. Forster	CR
	Psychotria tahitensis (Drake) Drake	CR
	Psychotria trichocalyx (Drake) Fosberg	CR
Santalaceae	*Santalum insulare* Bertero *var. insulare*	LR
Monocotyledonae		
Orchidaceae	*Calanthe tahitensis* Nadeaud *var. tahitensis*	CR
	Phreatia tahitensis Lindley	LR
	Phaius tahitensis Schlechter	CR
Pterydophyta		
Aspleniaceae	*Tectaria tenuifolia* (Mettenius ex Kuhn) Maxon	VU
Thelypteridaceae	*Amphineuron tildeniae* Holttum	VU
	Plesioneuron tahitense Holttum	VU

EX = extinct, CR = critically endangered, EN = endangered, VU = vulnerable, LR = lower risk, DD = data deficient, NE = not evaluated.

FIG. 4. A slope on the Leeward Coast of Tahiti (Faatautia Valley, 600 m) completely invaded by *Miconia calvescens*.

land'. The biological invasion of the native forests, including the montane forests where 70% of the endemic plants is located, by *Miconia calvescens* can be seen as a third major threat to the biological diversity of French Polynesia. Dense monotypic stands of *M. calvescens* prevent not only regeneration of the native plant species but also removes a habitat for other animals. The possible accidental introduction of this plant pest to other islands in the Pacific should be rigorously controlled.

Invasion of exotic species may be facilitated by natural and anthropogenic perturbations but also in some cases also by insufficient conservation policies and a lack of public awareness. As Lloyd Loope (Loope & Gon, 1989: 5) commented: 'education of the general public and of decision-makers to the importance, uniqueness and vulnerability of island species is probably the most essential requirement'. This could help to maintain Tahiti, perhaps the most famous island in the South Pacific, a natural paradise.

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REFERENCES

Cronk, Q.C.B. & Fuller, J.L. (1995). *Plant invaders*. Chapman & Hall, London.

Darwin, C.R. (1852). *Journal of researches into the natural history and geology of the countries visited during the voyage of H.M.S. Beagle* J. Murray, London.

Florence, J. (1987). Endémisme et évolution de la flore en Polynésie Française. *Bull. Soc. France*, **112**, 370–380.

Florence, J. (1993). La végétation de quelques îles de Polynésie. française. *Atlas de Polynésie française*, Paris, Editions de l'ORSTOM pp. 54–55.

Fosberg, F.R. (1992). Vegetation of the Society Islands. *Pacific Sci.* **46**, 232–250.

Gagné, B.H. & Montgomery, S.L. (1991). *Wanted: location of* Miconia. The Conservation Council of Hawaii.

Gagné B.H., Loope L.L., Meideros, A.C. & Anderson, S.J. (1992). *Miconia calvescens*: a threat to native forests of the Hawaiian Islands. *Pacific Sci.* **46**, 390–391 (Abstract).

Gaubert, H. (1992). Les invasions biologiques en milieu insulaire: le cas de *Miconia calvescens* à Tahiti. Papeete, Centre ORSTOM de Tahiti. (unpublished).

Jacquier, H. (1960). Enumération des plantes introduites à Tahiti. *Bull. Soc. Etudes Océaniennes*, **130**, 117–146.

Loope, L.L. & Gon, S. M. (1989) Biological diversity and its loss. *Conservation biology in Hawaii* (ed. by C.P. Stone and D. B. Stone), pp. 109–117. Honolulu, Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa.

Meyer, J.-Y. (1994) *Mécanismes d'invasion de* Miconia calvescens *en Polynésie Française.* Ph.D. diss., Université des Sciences et Techniques du Languedoc, Montpellier, 126 pp.

Meyer, J.-Y. (1996). Status of *Miconia calvescens* (Melastomataceae), a dominant invasive tree in the Society Islands (French Polynesia). *Pacific Sci.* **50**, 66–76.

Pasturel, J. (1993) La climatologie des îles. *Atlas de la Polynésie française*, Paris, pp. 42–43. Editions de l'ORSTOM.

Raynal, J. (1979) Three examples of endangered nature in the Pacific Ocean. *Systematic botany, plant utilisation and biosphere conservation* (ed. by I. Hedberg), pp. 149–150. Uppsala, Almquist and Wiksell.

Smith, C.W. (1985) Impact of alien plants on Hawaiian native biota. *Hawaii terrestrial ecosystems preservation and management* (ed. by. P. Stone and J.M. Scott), pp. 180–250. Honolulu, Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa.

Vitousek, P.M. (1990) Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. *Oikos*, **57**, 7–13.