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A conservation appraisal of the rare and endemic vascular plants of Pitcairn Island

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Abstract. The flora of the Pitcairn Islands consists of 81 species, of which 10 are endemic. IUCN Red List threat categories show that over 60% of the indigenous flora is threatened within the island, and over 20% is threatened globally. To provide a more objective regional assessment that could prioritise conservation management, a system of threat scores was applied to each taxon based on potential threat due to habitat damage or exploitation. The main threats affecting the flora and vegetation are posed by habitat clearance, spread of invasive species, small population sizes or restricted distributions, erosion, lack of a frugivorous bird and exploitation. Addressing these threats by means of a system of nature reserves, species-specific recovery plans and control of invasive species, erosion and exploitation, will start to combat these problems. However, any conservation activities must be implemented in conjunction with the interests of the local community, and in consultation with them, in order to ensure success.

Introduction

The protection of the unique biological features of island ecosystems presents a considerable challenge not only ecologically, but also because of the fragmented nature of the resource, scattered across all parts of the globe and all political systems (Whittaker 1998). In terms of plant biodiversity, the islands of the world make a disproportionate contribution for their land area and are suffering disproportionate pressure in terms of maintenance of that biodiversity (Whittaker 1998). Oceanic islands can serve as model systems for addressing fundamental questions about biodiversity and conservation: which areas are most likely to develop high species diversity and endemicity, and what makes a particular species or biota vulnerable to extinction (Paulay 1994).

Pitcairn, a relatively young, high volcanic island, lies just south of the Tropic of Capricorn, about half way between New Zealand and South America (Figure 1), and is administered as a British Overseas Territory. The native flora of the Pitcairn group consists of 81 species, representing 49 families and 67 genera. Of these, 10 are endemic to Pitcairn Island (the flora will be discussed in detail elsewhere). The

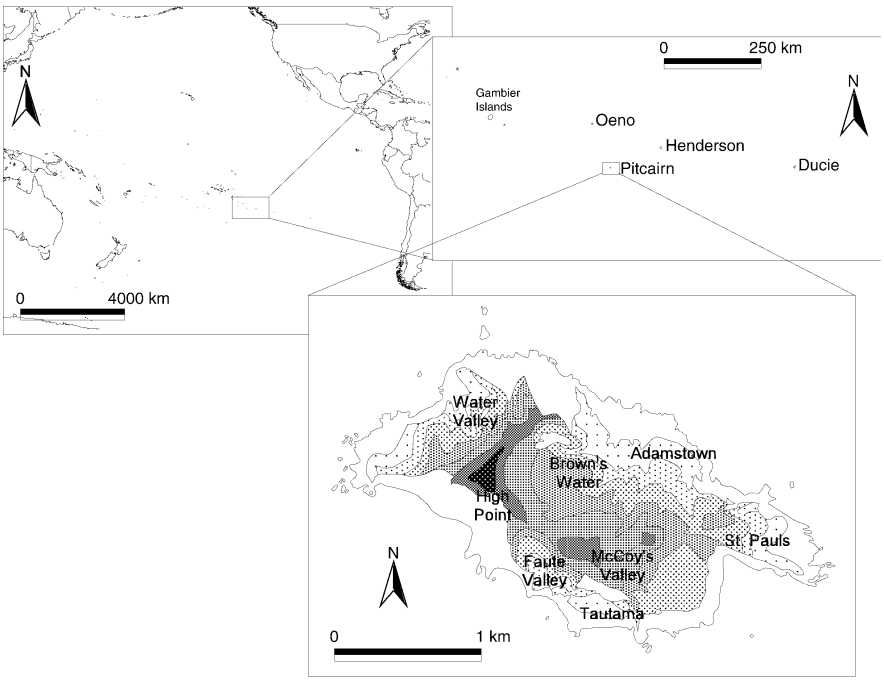

Figure 1. Location of the Pitcairn group of islands. The lower map of Pitcairn Island includes the locations of placenames used in the text.

native flora is largely derived from that of south-eastern Polynesia, with its depauperate nature due to the geographical remoteness of the group, the young geological age of Pitcairn (>1 million years), and the small size of the island (ca. 4 km × 2 km; max alt. 320 m). Following settlement in 1789 by the Bounty Mutineers, human induced habitat change has resulted in a decrease in the amount of native forest and significant reduction in the populations of native species. In addition over 250 species have been introduced to the island, several of which have become aggressive invasive species and dominate over large tracts of land. Kingston (2001) identified eight main vegetation communities on Pitcairn; *Metrosideros collina* woodland, *Homalium taypau* woodland, *Syzygium jambos* woodland, Mixed woodland, weedy scrub, fernlands, coastal rock communities and coastal scrub communities. Currently 40% of the island area is covered by monospecific stands of the invasive species *S. jambos* and *Lantana camara*, and less than 30% of the island is covered by native forest.

In 1995 Waldren et al. published a conservation assessment for the flora of the Pitcairn Island group. In that paper they noted that for Pitcairn Island, there were 21 species for which insufficient data were available for the assignment of IUCN red data categories. They noted the need for an urgent floristic and vegetation study of the island to be undertaken.

The objectives of this paper are three-fold; firstly to provide a regional conservation assessment for the native flora of Pitcairn Island, secondly to identify priority taxa for conservation management, and thirdly to ensure that conservation programmes are feasible and efficient.

Methods

Following a 3-month period of fieldwork in 1997, the flora and vegetation communities of the island were described and mapped in detail. Both individuals and populations of indigenous species were mapped, and their habitat requirements were identified by qualitative and quantitative assessment of the vegetation and by ecological measurements (for details see Kingston and Waldren 2003). During this field period 12 new species records were added to the native flora, and the existence of many more was confirmed (species which had previously been only recorded by sight records, or collected on only one occasion).

IUCN red data threat categories were assigned to all indigenous and endemic pteridophytes using the 2000 IUCN criteria and categories. To provide a more objective regional assessment that could more accurately prioritise conservation needs, a system of threat scores were assigned based largely on modifications of the approaches of Rabinowitz et al. (1986) and Curtis and McGough (1988), and used for the Pitcairn flora by Waldren et al. (1999). The criteria and scores were used to assess threat number, and were derived from the following detailed field observations:

- *Population size* – The class intervals selected weights the scores in favour of smaller populations.

  0 = 1000 + individuals
  1 = 501–1000 individuals
  2 = 101–500 individuals
  3 = 51–100 individuals
  4 = 11–50 individuals
  5 = 5–10 individuals
  6 = 1–4 individuals

- *Distribution* – The scores were calculated for Pitcairn by expressing the number of grid squares (from a 250 m^2 grid overlay) in which a taxon was recorded as proportion (p) of the 75 squares possible, and converting this by a cubic function standardised to give a maximum score of 4. The cubic function weights the scores in favour of taxa that occurred in few grid squares.

$$\text{Score} = \frac{[2(1-p)]^3}{2}$$

- *Ornamental value*

  0 = Taxon not obviously attractive
  1 = Taxon with attractive foliage or flowers

- *Usefulness*

  0 = Taxon with no known or potential uses locally
  1 = Taxon with some potential or minor use
  2 = Taxon representing an important local resource

- *Remoteness*

  0 = Taxon generally occurring in populations remote from tracks or settlement
  1 = Taxon with at least some populations moderately close to trackways
  2 = Taxon with the majority of populations close to trackways and habitation

- *Accessibility*

  0 = Access to all populations very difficult
  1 = Easy access to all populations

- *Habitat specificity*

  0 = Taxon occurs in a variety of habitats
  1 = Taxon occurs in a moderate habitat range
  2 = Taxon restricted to a narrow habitat range

- *Habitat vulnerability*

  0 = At least some of the habitats in which the taxon occurs are stable
  1 = Habitats may become unstable or threatened
  2 = Habitat unstable or threatened
  3 = Taxon occurs in habitats which are unlikely to persist in present form (including vulnerability due to invasive species)

- *Dispersability*

  0 = No factors limiting dispersal ability
  1 = Some factors limiting dispersal ability
  2 = Serious limitations or cessation in dispersal

Threat number was calculated for each taxon by summing the scores for each category. The categories of population size, geographic distribution and habitat

vulnerability have been given a greater weighting in calculating the threat score, and attractiveness and accessibility have been down weighted. We were unable to add a category on regeneration because this was impossible to assess for some taxa. The maximum threat score under this method was 22, with a minimum of zero. All indigenous and endemic pteridophytes were evaluated for threat status.

An additional and IUCN red data threat category was assigned to each species based on their distribution within Pitcairn Island itself. This can be done if the 'area of occupancy' criteria in the IUCN guidelines (criteria B) is ignored. Therefore species which are globally widespread but restricted or threatened on Pitcairn will receive a threat category. This was carried out primarily for comparison with the calculated threat scores.

Results

Table 1 shows that over 60% of the indigenous flora is threatened on Pitcairn, and over 20% is threatened globally, including all of the endemic species. In general there is overall agreement between the threat score and the IUCN category for threat on Pitcairn (Table 2). Anomalies include *Ipomoea macrantha*, ranked 17th by the IUCN criteria, but ranked 5th by the threat score. This is because the threat score considers the threat status of the species' habitat, in this case easily accessible at the main landing point on the island, as well as the species potential for exploitation, in this case large attractive flowers, factors which are not considered by the IUCN analysis. The top three species in the threat scores are all represented by single individuals on Pitcairn. Another anomaly is shown by *Pilea sancti-johannis* which, with a threat number of only 11.04, was assigned Critically Endangered by the IUCN categories, while *Phymatosorus powellii* with a slightly higher threat score of 11.05 was only classified as Vulnerable. This is probably because *P. sancti-johannis* exists in small numbers on a small area of very remote cliffs, while *P. powellii* is more widespread but occurs in easily reached locations and has some potential for exploitation. Similarly, *Lycopodiella cernua* and *M. collina* are both Low Risk under IUCN criteria, but here receive a threat score higher than many Endangered and Vulnerable species, due to the vulnerability of their habitats.

Threats

Clearance of native forest – affecting 38 taxa

This has occurred extensively in the past on Pitcairn through clearance for agriculture, gardens, roadways, firewood and plantations of exotic species. There are references in the island laws from 1828 which reflect a shortage of local timber due to forest clearance, and by the early 1900's they had started obtaining timber from Oeno and Henderson Islands (Gothesson 1997). This has caused a massive reduction in the habitat available to native species, thereby reducing their distributions, population numbers and population sizes. Replanting that has occurred, such as during

Table 1. Number of species in each IUCN Red data threat category for the Pitcairn Island native flora, and also based on the world distributions of Pitcairn species. Percentage of total flora is in brackets after the number of species.

Threat category	Pitcairn status (%)	Global status (%)
Extinct	5 (6.2)	2 (2.5)
Critically Endangered	16 (19.8)	5 (6.2)
Endangered	17 (21)	4 (4.9)
Vulnerable	13 (15.9)	7 (8.64)
Low risk	31 (38.3)	63 (77.8)
Total threatened	50 (61.7)	18 (22.2)

a forestry programme in the late 1950's and 1960's, concentrated on planting useful species such as *Citrus* spp., *Araucaria heterophylla* and *Thespesia populnea*. There is also an immediate threat of damage to remaining forest both through invasive plant species and the various development projects which may come on line in the near future.

Spread of invasive species – affecting 35 taxa

A large number of species (ca. 250) have been introduced to Pitcairn, both accidentally and intentionally, 10 of which are listed in Cronk and Fuller (1995) as problem taxa (including *Psidium cattleianum* which has virtually wiped out native cloud forest on nearby Tubuai). Some have become widespread and troublesome, and include both animals (e.g., rats, mice, wasps, ants and fruit flies) and plants (e.g., *L. camara*, *Sorghum sudanense*). The number of introductions appears to have increased with time, and the problems associated with these species have become acute only over the past five decades. The pace of introductions, both accidental and intentional, does not appear to have decreased in recent years despite a growing awareness of the problems caused by introduced species. The threats to the native biodiversity are mainly due to widespread alien species (e.g., *L. camara*, *Canna indica*) or the as yet poorly dispersed species (e.g., *Crinum asiaticum*, *Carpobrotus edulis*, and *Leucaena leucocephala*) which are not considered by Pitcairners to be a problem. The islanders are more concerned with more typical agricultural weeds (e.g., *Bidens pilosa*, *Euphorbia peplus*) and the spread of *S. jambos*. This latter species is poorly dispersed but it does readily spread in the vicinity of mature trees to eventually form monospecific stands. Large parts of the island above Adamstown are dominated by these stands, which contain few native species. Where these stands occur on steep slopes, the lack of ground flora results in soil erosion. There is some evidence that the spread of *S. jambos* also poses a threat to the islands recently described endemic land snails, as the resultant understory is inimical to these taxa (Preece 1995). Similarly there are few coastal areas where native species dominate, and no areas where some level of invasion has not occurred. *Lantana camara* is known to be responsible for the extinction of at least one species in the Galápagos Islands (Mauchamp et al. 1998). Allelopathic compounds produced in the roots and

Table 2. Threats affecting each of the native Pitcairn species, along with both the Pitcairn and global IUCN status, and the criteria from which this category is derived (IUCN 2000 categories and criteria), and the threat score. Species are listed in order of threat score.

Species	Pitcairn IUCN status and criteria	Proportion on Pitcairn (%)	Global IUCN status and criteria	Threat Score	Threats
Argusia argentea L. f.	CR [B1, D]	<1	LR [lc]	19.84	P, D, B
Osteomeles anthyllidifolia (Sm.) Lindl.	CR [D]	<1	DD/LR [nt]	19.34	P, D, Er, B, Ex
Celtis pacifica G.Planch.	CR [D]	<5	LR [lc]	17.84	C, I, P, D, B
Jasminum didymum G.Forst.	CR [D]	<1	LR [lc]	17.04	C, I, P, D, B, Ex
Ipomoea macrantha Roem. & Schult.	EN [D]	<1	LR [lc]	16.04	P, D, Er
Coprosma benefica W.R.B.Oliver*	CR [A1(c–e), A2, B1, B2(a–e), C1, C2, D]	100	CR [A1(c–e), A2, B1, B2(a–e), C1, C2, D]	15.54	C, I, P, D, B
Lastreopsis pacifica Tindale	CR [D]	<5	LR [lc]	15.19	C, I, P, D, Er
Myrsine aff. *niauensis**	CR [A2 (c), B1, B2(a, b), C2, D]	100	CR [A2 (c), B1, B2(a, b), C2, D]	14.84	P, D, B
Abutilon pitcairnense Fosberg*	CR [A2 (c, e), B1, B2(a, b), C2, D]	100	CR [A2 (c, e), B1, B2(a, b), C2, D]	14.84	I, P, D, Er
Hernandia sonora L.	EN [D]	<1	LR [lc]	14.49	C, P, B
Pisonia umbellifera (J.R.Forst. & G.Forst.) Seem.	EN [D]	<1	LR [lc]	14.25	C, I, P, D
Dianella intermedia Endl.	CR [D]	<1	LR [lc]	14.19	I, P, D, B
Psydrax odorata (G.Forst.) A.C.Sm. & S.P.Darwin	EN [D]	<5	LR [lc]	14.1	C, I, P, B, Ex
Diplazium harpeodes T.Moore	CR [D]	<1	LR [lc]	13.98	C, I, P
Lepidium bidentatum Montin	CR [D]	<1	LR [lc]	13.84	P, D
Ipomoea littoralis Blume	CR [D]	<1	LR [lc]	13.84	I, P, D
Angiopteris chauliodonta Copel.*	CR [A1(c–e), B1, B2(a–e), C2]	100	CR [A1(c–e), B1, B2(a–e), C2]	13.35	C, I, P, Er, Ex
Cenchrus calyculatus Cav.	CR [D]	<1	VU [A2(c-)]	12.84	I, P, D, Er
Xylosma suaveolens (J.R.Forst. & G.Forst.) G.Forst.	EN [D]	<10	LR [lc]	12.6	C, I, P, B
Cyclophyllum barbatum (G.Forst.) N.Hallé & Florence	VU [D1]	<1	LR [lc]	11.76	C, I, B, Ex
Glochidion comitum Florence*	CR [D]	100	CR [D]	11.31	C, I, P, B, Ex
Guettarda speciosa L.	EN [D]	<1	LR [lc]	11.15	C, P, Ex

Table 2. (continued)

Species	Pitcaim IUCN status and criteria	Proportion on Pitcairn (%)	Global IUCN status and criteria	Threat Score	Threats
Phymatosorus powellii (Baker) Pic.Serm.	VU [D]	<5	LR [lc]	11.05	C, I, Ex
Pilea sancti-johannis Florence	CR []	50	CR [D]	11.04	P, D, Er
Hibiscus australense Fosberg	EN [D]	<10	DD/VU [D2]	10.89	I, P, D
Scaevola sericea Vahl	EN [D]	<1	LR [lc]	10.75	P, D, Er
Peperomia sp.*	CR [C2(b)]	100	CR [C2(b)]	10.69	P, D, Er
Ophioglossum nudicaule L.	EN [D]	<1	LR [lc]	10.54	I, P, D, Er
Ophioglossum reticulatum L.	EN [D]	<1	LR [lc]	10.54	I, P, D, Er
Cyathea medullaris (G.Forst.) Sw.	VU [D1]	<1	LR [lc]	10.41	C, I, Ex
Ctenitis cumingii Holttum*	EN [D]	100	EN [D]	10.37	C, I, P
Ipomoea pes-caprae L.	CR [D]	<1	LR [lc]	10.34	I, P, D
Cocculus ferrandianus Gaudich	EN [D]	<1	LR [lc]	10.19	P, D, Er, B
Lycopodiella cernua (L.) Pic.Serm.	LR [lc]	<1	LR [lc]	10.04	D
Alyxia scandens Roem. & Schult.	VU [D]	<1	LR [nt]	10.04	C, I, D, B
Samolus repens Pers.	EN [D]	100	EN [D]	9.69	P, D, Er
Adiantum hispidulum Sw.	VU [D]	<1	LR [lc]	9.61	C, D, Ex
Caesalpinia major (Medik.) Dandy & Exell	VU [D1]	<1	LR [lc]	9.54	D
Haloragis sp.*	EN [D]	100	EN [D]	9.25	I, P, D, Er
Arachniodes aristata (G.Forst.) Tindale	LR [lc]	<1	LR [lc]	9.17	C
Phymatosorus commutatus (Blume) Pic.Serm.	VU [D]	<1	LR [lc]	9.08	C, I
Lepturus repens (G.Forst.) R.Br.	EN [D]	<1	LR [lc]	8.89	P, D, Er
Trichomanes endlicherianum C.Presl	VU [D1]	<1	LR [lc]	8.61	C, D
Cerbera manghas L.	VU [D1]	<1	LR [lc]	8.6	I, Ex
Peperomia rapensis F.Br.	EN [D]	c.20	VU [D2]	8.6	C, P
Thespesia populnea (L.) Sol. ex Corrêa	LR [nt]	<1	LR [lc]	8.6	C, Ex
Bidens mathewsii Sherff*	VU [D1]	100	VU [D1, D2]	8.58	I, Er
Eugenia reinwardtiana (Blume) DC	LR [nt]	<1	LR [lc]	8.55	I, Er, B
Trichomanes tahitense Nadeaud	VU [D1]	<1	LR [lc]	8.48	C

Metrosideros collina (J.R.Forst. & G.Forst.) A.Gray	LR [nt]	<1	LR [nt]	8.44	C, Ex
Morinda myrtifolia A.Gray	LR [nt]	<1	LR [nt]	8.26	I, B
Vittaria elongata Sw.	VU [D1]	<1	LR [lc]	8.26	C, I
Hibiscus tiliaceus L.	LR [lc]	<1	LR [lc]	8.2	C, I, Ex
Homalium taypau H.StJohn*	LR [nt]	100	VU [D2]	8.09	C, I, B, Ex
Glochidion pitcairnense (F.Br.) H.St.John	VU [A1(d), D]	100	VU [A1(d), D1, D2]	7.94	C, I, P, B, Ex
Lycium sandwichense A.Gray	LR [nt]	<1	LR [lc]	7.85	Er, B
Dicranopteris linearis (Burm.) Underw.	LR [lc]	<1	LR [lc]	7.41	
Davallia solida (G.Forst.) Sw.	LR [lc]	<1	LR [lc]	6.62	C, Er
Loxoscaphe gibberosum T.Moore	LR [nt]	<1	LR [lc]	6.26	C, Ex
Christella parasitica (L.) Lév.	LR [lc]	<1	LR [lc]	6.21	C
Peperomia pitcairnensis (Lauterb.) C.DC*	EN [D]	100	EN [D]	5.95	I, P
Psilotum nudum (L.) Beauv.	LR [nt]	<1	LR [lc]	5.69	C
Chamaesyce sparrmannii (Boiss.) Hurus.	LR [lc]	ca.95	VU [D2]	5.6	Er, B
Pneumatopteris costata Holttum	LR [lc]	<1	LR [lc]	5.55	C
Nephrolepis cordifolia (L.) C.Presl	LR [lc]	<1	LR [nt]	5.44	
Asplenium nidus L.	LR [nt]	<1	LR [lc]	5.35	Ex
Apium prostratum Labill.	LR [nt]	<1	LR [lc]	5.08	Er
Asplenium obtusatum G.Forst.	LR [nt]	<1	LR [lc]	5.08	Er
Doodia media R.Br.	LR [nt]	<1	LR [lc]	4.85	C, I
Nephrolepis biserrata (Sw.) Schott	LR [lc]	<1	LR [nt]	4.67	
Taeniophyllum fasciola (G.Forst.) Rchb.	LR [lc]	<1	LR [lc]	4.58	C
Sesuvium portulacastrum (L.) L.	LR [lc]	<1	LR [lc]	4.55	Er
Pandanus tectorius Parkinson ex Z	LR [lc]	<1	LR [lc]	4.53	C, Er
Portulaca lutea Sol. ex Seem.	LR [lc]	<1	LR [lc]	4.33	
Phymatosorus scolopendria (Burm.) Pic.Serm.	LR [lc]	<1	LR [lc]	4	
Peperomia blanda Kunth.	LR [lc]	<1	LR [lc]	3.58	

Table 2. (continued)

Species	Pitcairn IUCN status and criteria	Proportion on Pitcairn (%)	Global IUCN status and criteria	Threat Score	Threats
Asplenium shuttleworthianum Kunze	LR [lc]	<1	LR [lc]	3.55	Er
Pyrrosia serpens (G.Forst.) Ching	LR [nt]	<1	LR [lc]	3.11	C
Nephrolepis hirsutula (G.Forst.) C.Presl	LR [lc]	<1	LR [nt]	2.51	
Capparis cordifolia Lam.	EX/CR [D]	<1	LR [lc]	0	B
Macrothelypteris torresiana (Gaudich) Ching.	DD	<1	LR [lc]	0	C, I, P, D, Er
Pemphis acidula J.R.Forst. & G.Forst.	EX/CR [D]	<1	LR [lc]	0	

Key to IUCN categories: EX = extinct; CR = critically endangered; EN = endangered; VU = vulnerable; LR = low risk (for further details of categories and explanation of the criteria listed in square brackets see IUCN 2000).

Key to threats: C = clearance of native forest; I = spread of invasive species; P = very small population size (<500 individuals); D = highly restricted distribution (score of 3–4 based on threat criterion 2; see Methods); Er = erosion; B = lack of a frugivorous bird; Ex = exploitation (useful or attractive).

* - Endemic species.

Table 3. Population details for *Diplazium harpeodes* on Pitcairn Island. While the species is widespread all populations are unsustainably small.

Location	Juvenile sterile	Mature sterile	Fertile	Total
Faute Valley			1	1
McCoy's Valley			1	1
Big Ridge	2	2	14	18
Tautama			1	1
Aute Valley			5	5
Browns Water		2	1	3
Totals	2	4	23	29

shoots, copious seed production year round, and an ability to spread vegetatively contribute to the success of *L. camara* as an invader (Cronk and Fuller 1995).

Very small population size – affecting 35 taxa

Several taxa have critically low population sizes on Pitcairn itself, which are likely to be prone to pronounced stochastic events. *Diplazium harpeodes* is an example of a species widely distributed in the native forest, but which has consistently small populations (see Table 3). Some species have naturally small population sizes, and some may be recent colonisers on Pitcairn (e.g., coastal taxa such as *Ipomoea littoralis*), but others have almost certainly become reduced in recent years due to habitat clearance (e.g., *Coprosma benefica*, now restricted to 12 individuals; *Angiopteris chauliodonta*, local people have commented on its decline in recent years).

Highly restricted distribution – affecting 30 taxa

Most taxa have highly restricted distributions on Pitcairn; for example the only population of *Lastreopsis pacifica* occurs in an area of just $20\,\text{m} \times 60\,\text{m}$. Species with restricted distributions may or may not have small population sizes. *Lycopodiella cernua* is an example of a species which occurs in only a small area, but whose population is estimated at over 1000 individuals. The restricted distribution is in most cases due to reduced habitat availability caused by forest clearance and invasive species.

Erosion – affecting 25 taxa

Forest clearance leads to soil erosion, particularly if the ground flora is removed or damaged. Inappropriate use of a bulldozer to grade roadways, and lack of surface drainage result in severe erosion. Goat grazing and trampling lead to erosion on exposed ridges and slopes. While some erosion in inevitable on high islands due to climatic effects and landslides, it is clear that the current excessive erosion threatens the native plant species and communities, and also the gardens of the islanders. In 1997 following storms, a wide band of muddy discoloured sea was clearly visible surrounding the island.

Absence of a frugivorous bird – affecting 21 species

A serious threat to the flora of Pitcairn is the lack of a frugivorous bird. About 22 species from Pitcairn Island are dispersed through ingestion by a bird, and a further nine are dispersed by means of adherence mechanisms, whereby birds would be the primary disperser. In some cases germination does not occur until the fleshy coat has been removed, so birds are not simply required for dispersal but also the subsequent establishment of a seedling. Five of the 17 globally threatened species require bird dispersal by ingestion, including the critically endangered endemic species *Myrsine* aff. *niauensis*, *C. benefica* and *Glochidion comitum*. In addition a whole suite of native species (16) are being threatened on the island by the lack of a bird disperser including *Celtis pacifica*, *Cocculus ferrandianus*, *Xylosma suaveolens*, *Psydrax odoratum* and *Cyclophyllum barbatum*.

In this category only species which require direct ingestion by a bird for dispersal and germination are included, but a further 10 species which are dispersed by adherence will also be somewhat affected by the reduced bird populations on the island.

Exploitation – affecting 18 species

Several species are collected as timber for house and road building, for carvings, domestic use, or for ornamentation. Examples are *Cyathea medullaris*, a tree fern whose stems are used for carving inlays (currently dead stems are primarily used); *Psydrax odorata* and *C. barbatum*, which are collected annually as Christmas trees; and *Jasminum didymum* which is collected from the wild for flowers or for transplanting to gardens.

Priorities for conservation actions

Assessment of the entire Pitcairn flora using the IUCN categories and threat scores allows the prioritisation of species for conservation. Critical assessment of these threats results in a prioritisation of the conservation actions required to limit future damage due to these threats and to rectify some of the damage already done.

Protect forest remnants in nature reserves

Three suitable reserve areas can be identified for Pitcairn by employing the technique of complementarity (Figure 2). These areas could protect all of the vegetation communities found in addition to 31 (68.8%) of the species threatened on Pitcairn, and 14 (87.5%) of the globally threatened species. These areas house forest with the highest concentrations of native diversity on the island (Figure 3), as well as being hotspots for threatened species (Figure 4). As these areas are not used by the islanders, no conflict of interest is envisaged if these areas are set aside for conservation.

The three areas are:

- Tautama – a remote valley unused by the islanders, but also archaeologically important as the site of a Polynesian quarry. The reserve area is bounded on all

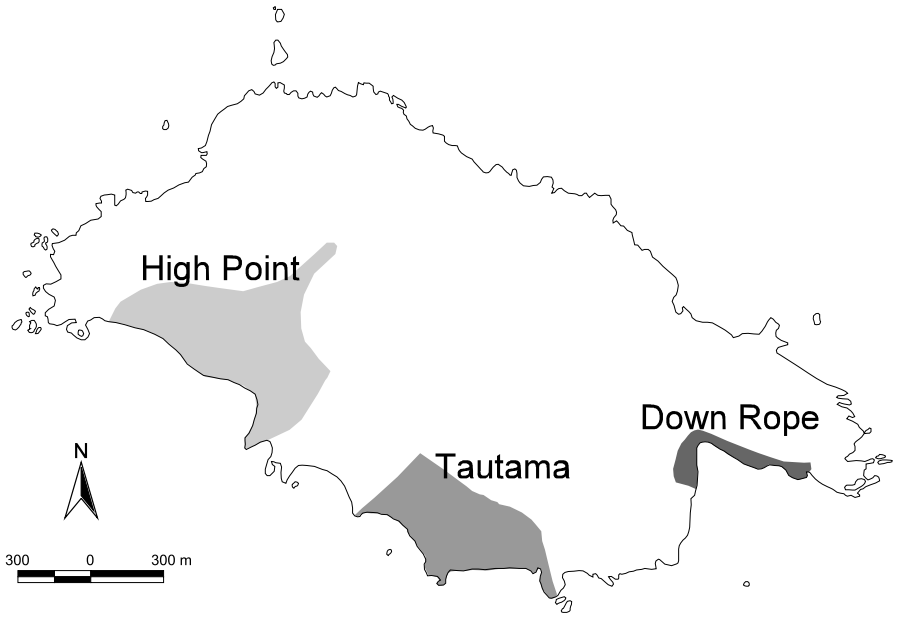

Figure 2. Map of Pitcairn Island to show the location of the three suggested nature reserve areas.

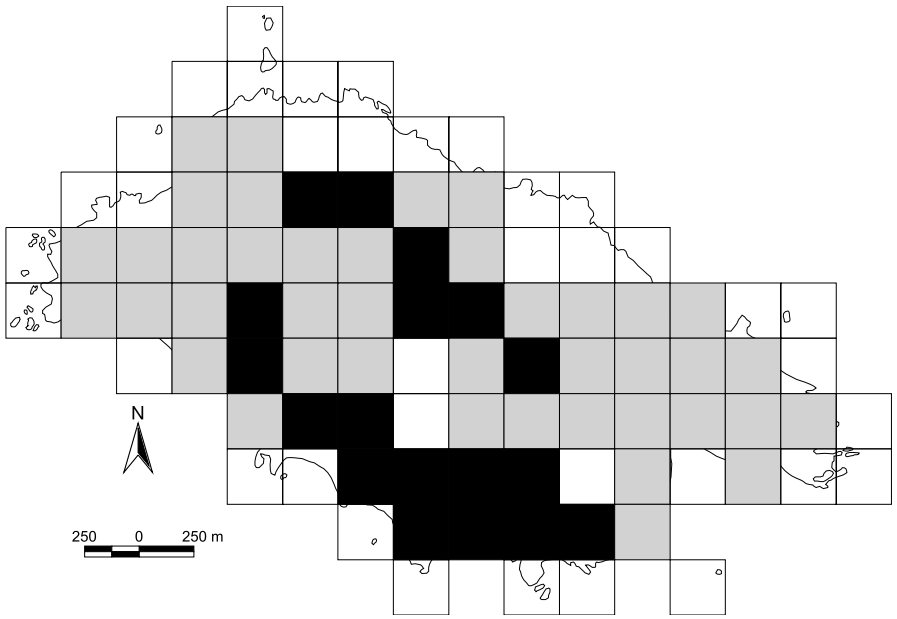

Figure 3. Map of Pitcairn Island to show the locations of 'hotspots of diversity'.

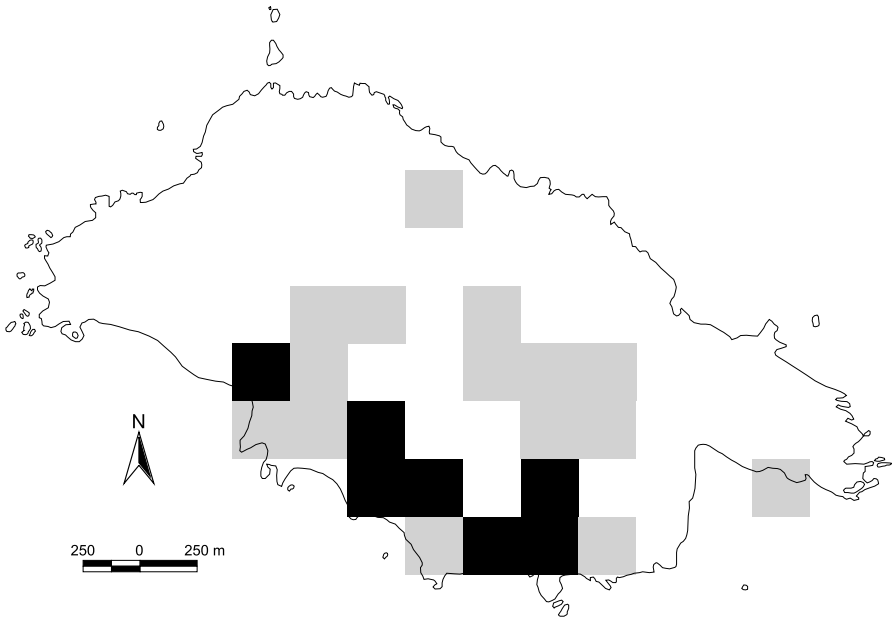

Figure 4. Map of Pitcairn Island to show the location of 'hotspots of threat'.

sides by rides and as such forms a natural ecological unit, with habitats varying from coastal, to forest and cliff slopes.

- High Point – the area around the main ridge, visited by the islanders but not used for agricultural purposes. The area holds a full range of habitats from cloud forest at the highest altitudes, down to coastal slopes at the extreme south of the reserve area. The design of this reserve area is not ideal, with a large protruding tongue to the north increasing the boundary area of the reserve. However, this tongue extends along a ridge which used to house several of the threatened species which do not fall into these three reserves (records from 1934). As such it would be an ideal area to carry out translocations and reintroductions of some species, which would otherwise have no *in situ* protection (e.g., *C. benefica*; the 12 individuals of this endemic species are found among invaded scrub in the vicinity of the Radio Station, and in an area which will may be potentially cleared for an airstrip. Past records indicate that this species used to be found in the vicinity of the High Point ridges, and the habitat there is ideal for this species).
- Down Rope – a remote cliff and pebble beach, but also an archeologically and touristically important site, with occasionally visited Polynesian petroglyphs. This area is unused by the islanders.

The two globally threatened species which fall out of this suggested reserve system are *C. benefica* and *Cenchrus calyculatus*. As discussed previously, *Coprosma benefica* is not likely to persist in its current location, and was previously

recorded from the High Point area. *Cenchrus calyculatus* was only recorded from one accessible coastal locality, and may be more widespread, but this species could be translocated to the coastal reserve site of Down Rope which contains suitable habitat.

Of the 13 species that are threatened on Pitcairn and fall out of the reserve areas, at least four are rare due to limited available habitat and may be recent coastal colonisers (i.e., *Argusia argentea*, *Lepidium bidentatum*, *I. macrantha* and *Scaevola sericea*). Indeed all of these species could also be potentially introduced to the Down Rope area. Three further species (*Trichomanes tahitense*, *Cerbera manghas* and *Adiantum hispidulum*) are native woodland species, and may need to be translocated to new populations, although all show signs of persisting in their current locations and are widespread across Polynesia. *Caesalpinia major*, *Ophioglossum nudicaule* and *Ophioglossum reticulatum* are also widespread in Polynesia, and are likely to persist in their current locations.

While all of these species will require monitoring, the remaining three species which fall out of reserves will require more detailed management:

- *Lastreopsis pacifica* – as discussed previously the population of this species is very small and in the precarious habitat at Brown's Water. Brown's Water has been previously suggested as a reserve area due its high native biodiversity, and the fact that the site is an important watershed. However a major trackway runs along the side of the valley, and erosion of landslides on to the populations of *L. pacifica* are likely. Introduction of a population into suitable damp shaded gullys in Tautama would establish a population within a reserve and away from the potential threats presented at Brown's Water, although monitoring and steps to protect the Brown's Water population should also be taken. The hydrological importance of Brown's Water should be emphasised in support of its conservation.
- *Osteomeles anthyllidifolia* – only a single individual of this species was observed remaining on Pitcairn in a relatively protected site at Ships Landing point. If propagation is successful, individuals could potentially be introduced to the cliffs at Tautama, and used by the islanders as an ornamental.
- *Psydrax odorata* – this species is exploited by the islanders as their 'Christmas tree' and as such is threatened by over collection. However, individuals of this species produce copious amounts of seed, which could be established along Big Ridge or along the ridges at Tautama. This species could also be cultivated around and near Adamstown for use as a timber and as a 'Christmas tree' resource.

Control invasives

There are several priorities when dealing with the existing invasive species. The first is to eradicate potentially invasive species which currently have limited population sizes and are not problematic (e.g., *L. leucocephala* and *P. cattleianum*). The second is the eradication of widespread invasive species and the prevention of further spread of *S. jambos* into remaining native forest. This will be done

by clearance, initially in areas with limited spread of invasive species, and later in more severely affected areas. Control such as this has been successfully employed on Norfolk Island, and is being trialed in some areas on Pitcairn. Control of *L. camara* is a more complex problem and may require biological control (P. Bingelli, personal communication). The third priority is the revegetation of cleared areas with vigorous native species, and especially weedy terrestrial pteridophytes, which may reduce the *S. jambos* regrowth. In some areas mixtures of native and non-invasive useful plants, such as fruit, timber and firewood trees could be used in the re-vegetation. In reserve areas only native stock would be planted. However, *S. jambos* produces dense stands of seedlings in cleared areas, and the soil seedbank may persist for many years, suggesting that ongoing clearance programmes could be required. In addition an improved awareness among the islanders in relation to the potential threats of invasive species, as well as quarantine and customs systems, should alleviate any further problematic introductions.

Species-specific recovery plans

While the IUCN categories for Pitcairn and the threat scores gave similar results, the threat score gives a truer reflection of the overall extinction threat on Pitcairn, as it takes habitat threats and exploitation into consideration. The assignment of both a Pitcairn Island and a World threat status helps to overcome problems presented by the IUCN 'area of occupancy' criteria and aids in prioritising conservation needs for Pitcairn, although the world distribution is the status that should be presented in the IUCN searchable database and in the international forum. Endemic species such as *H. taypau* are not necessarily threatened at the Pitcairn level, but the fact that they occur in such a small area means they require at least regular monitoring, to protect against the populations reduction or extirpation due to stochastic effects.

In many cases species require no specific conservation measures except for monitoring to ensure their populations or habitats do not go into decline. Taxa with restricted distributions or critically small populations may be subject to stochastic problems, and require specific recovery programmes. Knowledge of the genetic diversity within species that were studied in detail (*C. benefica*, *A. chauliodonta* and *L. pacifica*; see Kingston 2001) allowed a more scientific assessment of the species conservation needs and will allow detailed monitoring of the relative success of such programmes. *Ex situ* seed and plant collections held in the island nursery and in the Trinity Botanic Gardens will be used to bulk up existing populations and act as an insurance policy for species threatened by stochastic effects. Management plans detailing breeding and reintroduction programmes are being drawn up and in some cases are in the initial stages of implementation on Pitcairn. Such programmes in tandem with the reserve system should ensure successful conservation.

Of the five species which have critically endangered status for both their Pitcairn and global distribution, two (*C. benefica* and *A. chauliodonta*) are the subject of detailed population genetic analyses to guide their conservation management, two (*Peperomia* sp. and *P. sancti-johannis*) are successfully in cultivation in TCD, and one (*G. comitum*) was not recovered during the most recent botanical visit to

Pitcairn in 1997. This latter species, *G. comitum*, should be refound as a matter of priority on any further visits to Pitcairn, the population assessed and propagated. A further 10 species have a critically endangered status for Pitcairn, but low risk status for their world distributions. The populations of these species should be closely monitored and in several cases the separate populations should be propagated. While these species are not threatened by extinction worldwide, they contribute towards the biodiversity and maintenance of the natural habitats on Pitcairn.

Hibiscus australense is an example of a species for which the world distributional information is deficient, and therefore it is difficult to determine the global conservation status and IUCN category. On Pitcairn the species is endangered, and based on its global area of occupancy (criterion B), which is limited to Pitcairn and the Austral Islands, the world status is at least vulnerable. A survey of the species distribution in the Australs may show it to be also be threatened there, and make it deserving of endangered status. Another species, *Peperomia rapensis*, is also confined to Pitcairn and the Austral Islands, with endangered status on Pitcairn and at least vulnerable status for its worldwide distribution (again based on criterion B). Seed from the Austral Islands (collected in 2000) is germinating in TCD, but propagation of samples from Pitcairn were unsuccessful, probably due to loss of viability during transit from Pitcairn.

All of the other species which qualify as Endangered for both their Pitcairn and global IUCN categories are endemic species, two of which have been successfully propagated at TCD (*Ctenitis cumingii* and *Peperomia pitcairnensis*) and the other of which still requires detailed taxonomic study to determine its identity (*Haloragis* sp.). Detailed population surveys should also be carried out for these species as a matter of urgency. About 10 species are endangered on Pitcairn, but fall into the low risk category for their world distribution. No specific measures are needed for conserving these species, although the populations should be monitored, and the propagation of these species would be beneficial for reintroduction into cleared areas. Vulnerable species similarly require no specific conservation measures, but their propagation for introduction into areas being revegetated would be advantageous.

Erosion control

Erosion problems can only be tackled with specialist engineerings advice, but has been identified by the islanders as a cause for concern. The recent introduction of *C. edulis* as an erosion control has resulted in its expansion into coastal cliffs occupied by native species such as *Asplenium obtusatum* and the endemic *Bidens mathewsii*. Plantings of native species already naturally binding and protecting areas from erosion would be more appropriate, notably *Pandanus tectorius*, pteridophytes such as *Dicranopteris linearis*, and bryophytes such as *Trematodon latinervis*. Erosion due to animal trampling is perhaps less of a problem than on other islands, and attempts at eradication of feral animals such as cats, chickens and rats has occurred. Eradication of goats, which are the main faunal cause of erosion, would be extremely unpopular with the local islanders who maintain these animals in low numbers by culling periodically for food.

Lack of a frugivorous bird

There is no available information as to what species were present (although a *Ducula* sp. is likely to have been present, M. Brooke persona communication 2001), or as to when these birds became extinct, but while some became extinct during the Polynesian occupation, others may have been wiped out more recently as a pest of fruit crops (G. Wragg personal communication). The large scale extinction of birds following the arrival of humans to Polynesian islands is well documented (Paulay 1994; Steadman 1997), and no endemic landbirds remain on Pitcairn Island (Brooke 1995). Trial reintroductions of birds to islands are being considered in the Cook Islands (G. McCormack personal communication), and this is something that could be considered for the future if it is successful elsewhere. The introduction of a fruit dove population (eg the Henderson fruit dove *Ptilinopus insularis;* or another endangered Polynesian *Ducula* sp. or *Ptilinopus* sp.; M. Brooke personal communication 2001) to the Tautama reserve would help to disperse and conserve the native plant species affected.

Control exploitation

This would require sustainable cultivation and harvesting of affected species in some of the revegetated areas. There are currently several such species in cultivation in the island nursery, and these will be transplanted as soon as the trial clearances are completed.

Discussion

Integrating conservation needs with development

The Pitcairn group of islands have recently been subject of much publicity regarding proposed developments of hotel complexes and airstrips on three of the islands (Gammell 2001). Developments on Pitcairn would provide a welcome source of income, and reduce the Islanders' isolation, but may have large environmental impacts; for example, the development of a quarry in an area of native woodland; the locating of a borehole in the only site for *L. pacifica* and the main site for *A. chauliodonta*, and the potential siting of the airstrip through the remaining 12 individuals of *C. benefica*.

While the nearby World Heritage Site of Henderson Island has a full, if unimplemented, management plan, none exists for Pitcairn. The compilation of a biodiversity and sustainable development plan in line with the Convention on Biological Diversity (CBD) would be timely, serving to address development, land tenure and conservation issues, as well as setting out guidelines for further developments.

Clearly, there will be a need for on-going advice and consultation, but the Conservation Officer has already attended a period of training at the Royal Botanic Gardens, Kew, and we are hopeful that future scientific visits to Pitcairn can substantially contribute to the operations of the nursery. Further positions for local

people would be beneficial, especially to provide the manpower needed for some of the clearance projects. The provision of this nursery is an example of close co-operation between a small local community and outside scientific advisors, and this co-operative approach as an essential means of forwarding conservation objectives while providing empowerment of local communities.

It is important to promote sustainable conservation in conjunction with development, to ensure a future income and standard of living for the islanders (Waldren 2002). Over one third of the native-born Pitcairners live away from the island, mostly in New Zealand, with the population now being only 38 permanent residents. A major factor in the depopulation of the island is poverty, with most of the islanders reliant on the sale of carvings to make a living as local government positions are few, part-time and poorly paid.

Feasibility of successful implementation of conservation actions

In situ conservation is time consuming and expensive for individual species, but is more feasible if carried out through the preservation of intact ecosystems, ensuring the well-being of the species they contain, and the maintenance of the processes they support (Synge 1979). By developing the suggested system of nature reserve areas on Pitcairn, species and habitats would be protected with the benefit of saving time, manpower and finance, all precious commodities on the island.

The actions that need to be undertaken can be summarised as follows:

- Negotiate and create reserve areas
- Clear invasive species from these reserves and translocate critical species
- Implement species recovery plans for threatened taxa
- Clear invasive species from other selected areas
- Replant these cleared areas with native, timber and crop trees

Now that the baseline data has been collected the next step is to continue conservation work on Pitcairn. It is important this is carried out soon to prevent further environmental degradation as is common on other islands (Bahn and Flenley 1992; Mauchamp et al. 1998), when a lack of funding and interest mean follow-up work is not completed. In a country such as Pitcairn with a depauperate but interesting and internationally important flora, the potential loss of any species should be sufficient to warrant an active conservation policy.

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