Biodiversity and Conservation **14:** 205–232, 2005.

Extinction threat evaluation of endemic fig trees of New Caledonia: priority assessment for taxonomy and conservation with herbarium collections

STEFAN UNGRICHT[1,2,*], JEAN-YVES RASPLUS[2] and FINN KJELLBERG[1]
[1]*CEFE-CNRS, 1919 route de Mende, F-34293 Montpellier, France;* [2]*CBGP-INRA, Campus International de Baillarguet, F-34988 Montferrier-sur-Lez, France; *Author for correspondence (e-mail: sungricht@hotmail.com)*

Received 14 May 2003; accepted in revised form 14 October 2003

Key words: Collection management, Conservation status, Extinction threat, *Ficus* L., New Caledonia, Oceania, Priority-setting, Restricted-range tree species, Solow-McCarthy *p*-value, Taxonomic status

Abstract. This article focuses on the relationship between priority-setting in conservation and in taxonomy. A simple and generally applicable scheme is presented based on prior quantitative extinction threat evaluation. In the main part of the study we describe the assessment of the herbarium voucher collection date time series of 21 endemic fig tree species of *Ficus* sect. *Oreosycea* (Moraceae). The fig tree assessment is then compared with the available IUCN Red List data and with the collection information on two other groups of endemic tree radiations in New Caledonia: ebonies of *Diospyros* sect. *Maba* (Ebenaceae) and the Iguanura palm lineage (Arecaceae). We find a remarkably low level of extinction threat evident in *Ficus* but a pronounced need to differentiate between true species rarity and putative rarity of potential taxonomic artifacts. To this end it is proposed how such numerical evaluations can be used to set future priorities for the assessment or validation of the taxonomic and conservation status of taxa. The limitations and implications of the evaluation are discussed and relevant criteria for a meaningful analysis of collection records are listed. Finally, putting our results on woody plants into perspective, we briefly review the general conservation situation and outlook of New Caledonia, acknowledging both its high conservation priority and potential.

Abbreviations: Note that different IUCN threat category classifications have been in use during the last decade and that some of the cited categories and their abbreviations have changed (IUCN 1994, 2001).

Prologue

The incentive for this article came with the recent rediscovery of *Ficus pteroporum*, in the mountains of central New Caledonia by one of us (S.U.). This inconspicuous small fig tree species had originally been collected in 1951 by botanists of a Franco-Swiss expedition but apparently never since. It seems that the original description of the species remained largely unnoticed and even escaped the attention of the last reviser (Corner 1970). The question that eventually emanated from this *fait divers* was what, if anything, systematic voucher collections from the tropics can tell us about the extinction threat of endemic species – particularly of those diverse but neglected groups that have traditionally received far less conservation attention than rare birds, mammals or butterflies.

Introduction

Ever since its discovery by Captain James Cook in 1774 on his second circumnavigation and the first brief impressions gained – and specimens collected – by the accompanying naturalists Johann Reinhold Forster and his son Georg, New Caledonia has been particularly famed for its diverse and peculiar flora. The endemic taxa include presumed relics of Gondwanan origin as well as apparently more recent Indo-Malesian elements. Concerning seed plants, 77% of the ca. 3000 currently accepted species are thought to be geographically restricted (i.e., endemic) to New Caledonia (Jaffré et al. 2001). Of particular interest are woody plants which dominate herbaceous taxa at a ratio of 5 : 1 (White 1926). In recent decades this French overseas territory of some 19,000 km^2 (about the size of Israel, New Jersey or Wales), situated in the Coral Sea of the Southwest Pacific Ocean, has come into the spotlight of international conservation attention (IUCN 1986). It was further listed as a Centre of Plant Diversity (Morat et al. 1995) as well as a Biodiversity Hotspot in the various analyses by Myers (1988, 1990), Mittermeier et al. (1998) and Myers et al. (2000), indicating a combination of high levels of species richness, endemism and threat. The island group is ecologically relatively varied and accordingly the vegetation types are more diverse than on neighbouring Melanesian archipelagos like the Solomon Islands (Mueller-Dombois and Fosberg 1998). Annual rainfall ranges from less than 1000 mm on the leeward southwest coast of the main island Grande Terre to more than 4000 mm on the windward slopes of the northeast coast. Soils are equally diverse and New Caledonia is particularly known for its large areas of nutrient poor but heavy metal rich soils derived from ultramafic rocks (Jaffré 1980). The mountain chain that runs along the entire main island rises to a maximal elevation of some 1600 m and consists of more or less isolated massifs, several of which are higher than 1000 m. Apart from the main island, the Loyalty Islands – consisting of raised coral limestone and lying northeast on a parallel axis some 100 km off Grande Terre – represent the largest satellite group with a surface of about 2000 km^2 and a maximal elevation of 140 m (Sautter 1981).

The interface of taxonomy and conservation evaluation is a field of continuous and contentious multifaceted debate (e.g., Forey et al. 1994; Funk and Richardson 2002; McNeely 2002; Golding and Timberlake 2003; Lowry II and Smith 2003). Following the influential works of Fisher, Corbet, Williams, Shannon, Weaver and Simpson in the 1940s, for decades a main thrust of using specimen data was for computing and comparing various diversity indices (e.g., Pielou 1966; Whittaker 1972). However, collection data are also potentially useful for conservation status assessments because they represent a permanent and verifiable voucher for a taxon at a particular point in time and space (Shaffer et al. 1998; Golding 2001; Schatz 2002). Despite this, there seems to be a significant decrease in comprehensiveness and level of detail in the lists of examined specimen in many taxonomic journals due to constraints imposed by new editorial policies, as Snow and Keating (1999) reported. Furthermore, databases that have become accessible on the Internet cover often only type specimens. Hence, there is a huge amount of discounted primary data in the form of specimens housed in the herbaria of the world – and the rarer plants become in the wild, the more valuable their preserved collections become.

Conservation relevant knowledge on population trends does not exist for the vast majority of the several hundred endemic tree species of New Caledonia. This article thus tests the utility of herbarium data as a cost-effective proxy. Collection data can be used in two broad areas of conservation assessments: biodiversity assessments of individual areas (e.g., ter Steege et al. 2000; Ponder et al. 2001) and threat assessments of individual taxa (e.g., MacDougall et al. 1998; Puyravaud et al. 2003). Our analysis provides a case study of the second category but we will touch upon the first in the Discussion and in the Appendix. Clearly, the relevance of tree conservation evaluations reaches beyond the plants themselves. *Ficus* for instance not only supports (and indeed depends on) its specific wasp pollinators (Hymenoptera: Agaonidae) but also frugivorous seed dispersers, namely several bird and bat species, which have already become rare or extinct on other Pacific islands (Compton and McCormack 1999; Cox and Elmqvist 2000). Fig trees are a disproportionately important resource for numerous vertebrates and invertebrates alike (Basset et al. 1997; Shanahan et al. 2001) and are ecologically often characterised as 'strong interactors' or 'keystone species', which may trigger an extinction cascade.

Data on threatened and extinct taxa are being compiled by the Species Survival Commission (SSC) and the Committee on Recently Extinct Organisms (CREO). The Red Lists (also known as Red Data Books) of the International Union for Conservation of Nature and Natural Resources (IUCN, also known as The World Conservation Union) are perhaps the most comprehensive effort to collect comparable data on the conservation status of species. Tree species have become subject of increasing conservation concern lately (Newton et al. 1999, 2003) and in 2000, Fauna & Flora International (FFI) and the World Conservation Monitoring Centre (WCMC) started the Global Trees Campaign, which focuses on trees as flagship species for ecosystem and landscape conservation. Several thousand species had already been listed as threatened with extinction in a first global compilation (Oldfield et al. 1998).

The objectives of the present study are (i) to assess the extinction threat of endemic monoecious taxa of fig trees of New Caledonia, and (ii) to compare the assessment with the available IUCN Red List data on *Ficus* and the plants of New Caledonia in general, as well as (iii) to compare the assessment of the fig trees with two other similar-sized groups of endemic tree taxa of New Caledonia. The proximate aim is to use the method to pinpoint threatened species that have not been considered as being of conservation interest so far and thus the independent comparison and improvement of assessment data rather than to champion the exclusive use of a single evaluation or method. The ultimate objective is rating priorities for species resampling and reassessment in taxonomy and conservation.

We discuss limits and implications of our method and analysis and in the Appendix we briefly review the current conservation situation and outlook of New Caledonia by widening the perspective of our experience with woody plants.

Material and methods

From a conservationist's point of view, the ultimate state to prevent for any given species is 'Extinct'. All categories of threat based on rarity, on the other hand, are inherently vague with potential elements of population size, range size, ecological niche breadth, temporal persistence or taxonomic distinctness (Rabinowitz 1981; Gaston 1997). What is more, they suffer from arbitrary thresholds between rare and not rare, vulnerable and endangered, etc. However, extinction is as simple a concept as it is elusive if one attempts to formalise its indication (Diamond 1987). In fact, the World Conservation Union (IUCN 2001) currently does not prescribe any specific numerical criteria for its designation. Another approach is to preliminarily designate a taxon 'Possibly extinct' which can eventually be upgraded to 'Presumed extinct'. An even simpler one-step procedure is to set an arbitrary time span, usually 50 years, to pass since the last recording for the application of the status 'Extinct' (Smith et al. 1993). However, while this method may well be conservative for species with short generation times, it is much less so for trees. Furthermore, it seems reasonable to make the period one is prepared to wait dependent on how often the taxon was observed or collected before the last sighting or collection. The assessment of so-called 'Lazarus species' has traditionally been a subject in palaeontology for fossil (non-Recent) taxa rather than in conservation for extant (Recent) taxa (Fara 2001), but clearly a previously often recorded taxon is more desperately missing and will more likely be extinct after 50 years of failed registration than a previously rarely recorded one. During the last decade, several numerical methods to assess species have been developed in order to make assessments less subjective (Solow 1993a,b; Burgman et al. 1995, 2000; McCarthy 1998). Essentially, these are numerical analyses of time series based on observation data gained from fieldwork or specimen data gained from collection vouchers. The idea is that if the range of a species is declining or its abundance is diminishing and the species is moving towards extinction, this will eventually become detectable by longer periods of failed registration.

Based on binary observation data Solow (1993a,b) proposed Equation 1 to estimate how overdue the recording of a taxon is and thus to infer its threat:

$$p = \left(\frac{t}{T}\right)^n \tag{1}$$

where p is the probability that the taxon has been recorded n times between the beginning of the assessment period and t, the time at which the species was last recorded while T marks the end of the assessment period. P-values hence indicate the likelihood that the taxa are still extant. Burgman et al. (1995) proposed Equation 2 as a modified form for frequency observation data within discrete time steps (intervals), which is particularly useful for evaluations that include old collections where the exact collection date is often unknown:

$$p = \left(\frac{I_t}{I_T}\right)^n \tag{2}$$

where I_t is the number of time intervals between the start of observations and the last collection of a particular taxon and I_T is the number of time intervals between the start of the observations and the end of the observations. The equation assumes a Poisson distribution (Equation 3) of the collections:

$$p_x = e^{-\mu}\left(\frac{\mu^x}{x!}\right) \tag{3}$$

with x as an integer (0, 1, 2, 3, ...) and it computes the probability p that n records will fall up to interval t assuming a constant chance of observation μ, estimated by Equation 4 as:

$$\mu = \bar{x} = \left(\frac{n}{I_T}\right) \tag{4}$$

and thus randomly located specimens throughout the whole observation period. The 95% confidence limits (c.l. $_{95\%}$) of the mean ($\bar{x}$) for each evaluated taxon are given in Table 1. In order to take into account the collection effort, Equation 5 has been proposed by McCarthy (1998):

$$p = \left(\frac{\sum_{i=1}^{t} e_i}{\sum_{i=1}^{T} e_i}\right)^n \tag{5}$$

where e_i is the measure of collection effort in time interval i. Note that if the collection effort is constant, Equation 5 is reduced to Equation 2. We use calendar years as time intervals, a 100 year observation window from 1902 to 2001 and the total number of *Ficus* specimens, including non-endemic taxa, collected each year as a measure of collection effort. Collections should be independent of one another and duplicates were thus not taken into account. We lack data on the inter-taxon variability of the generation time of the local fig tree species and are thus obliged to neglect this parameter. We further do not use a pluralistic explorative approach, discussing other equations although each would have its own characteristic strengths (statistical power) in detecting diminishing populations under particular abundance and decline models. For comparisons with other proposed equations and their power tests see McCarthy (1998) and Burgman et al. (2000). We rather compare the assessment of one numerical analysis with the expert opinion available in taxonomic treatments and IUCN Red List data.

The main bulk of assessed specimens is housed at the Laboratoire de Phanérogamie of the Muséum National d'Histoire Naturelle (P) in Paris. Other important herbaria included in the survey are: BM, G, K, NOU and Z (for

Table 1. Evaluated endemic *Ficus* taxa in alphabetical order. Interval of most recent recorded collection (t), number of recorded collections (n), mean per interval ($\bar{x}$), confidence limits of the mean (c.l. $_{95\%}$) and resulting extinction threat (p) using Equations 2 and 5. For explanations see text.

	t	n	$\bar{x}$	c.l.$_{95\%}$	$p(2)$	$p(5)$
F. asperula Bureau	2001	106	1.06	0.85–1.28	1.00	1.00
F. austrocaledonica Bureau	2001	139	1.39	1.15–1.64	1.00	1.00
F. barraui Guillaumin	1953	1	0.01	0.00–0.05	0.52	0.28
F. cataractarum Vieill. ex Bureau	2000	20	0.20	0.13–0.30	0.82	0.58
F. crescentioides Bureau	2001	27	0.27	0.18–0.38	1.00	1.00
F. dzumacensis Guillaumin	2000	36	0.36	0.25–0.49	0.70	0.37
F. habrophylla G. Benn. ex Seem.	2001	111	1.11	0.89–1.34	1.00	1.00
F. heteroselis Bureau	Before 1902	1	0.01	0.00–0.05	<0.01	<0.001
F. leiocarpa (Bureau) Warb.	2000	7	0.07	0.03–0.14	0.93	0.83
F. lifouensis Corner	2000	13	0.13	0.07–0.21	0.88	0.70
F. mutabilis Bureau	2000	36	0.36	0.25–0.49	0.70	0.37
F. nitidifolia Bureau	2000	58	0.58	0.44–0.74	0.56	0.20
F. otophora Corner & Guillaumin	2000	18	0.18	0.11–0.28	0.83	0.61
F. otophoroides Corner	2000	26	0.26	0.17–0.38	0.77	0.49
F. pancheriana Bureau	2000	27	0.27	0.18–0.38	0.76	0.48
F. planchonellaefolia Guillaumin	1951	4	0.04	0.01–0.10	0.06	0.01
F. pteroporum Guillaumin	2000	3	0.03	0.01–0.08	0.97	0.92
F. racemigera Bureau	2001	71	0.71	0.55–0.89	1.00	1.00
F. versicolor Bureau	2000	33	0.33	0.23–0.45	0.72	0.40
F. vieillardiana Bureau	2001	60	0.60	0.45–0.76	1.00	1.00
F. webbiana Miq.	2001	118	1.18	0.96–1.41	1.00	1.00
Lower quartile (Q1)	–	13	–	–	–	0.37
Median (Q2)	–	27	–	–	–	0.61
Upper quartile (Q3)	–	60	–	–	–	1.00

addresses see Holmgren et al. (1990), http://www.nybg.org/bsci/ih/). Together, these six herbaria cover a large part of the plant collections available from New Caledonia. In this article we assess and compare herbarium voucher specimens of woody plants and the used shorthand term ‘tree’ is merely a simplification for what is actually a broad range of growth forms that run the gamut from diminutive rheophytes to towering forest trees. The evaluated endemic fig trees have been classified in *Ficus* sect. *Oreosycea* ser. *Austrocaledonicae* by Corner (1960) and the New Caledonian taxa are accepted mainly on the grounds of the most recent descriptive works and revisions by Guillaumin (1959, 1967) and Corner (1970, 1975). More than half of the ever-described species and infraspecific taxa had to be synonymized in the meantime. We thus assessed the 21 endemic taxa, which are listed in Table 1. The collection effort depicted in Figure 1 has been remarkably sustained over several decades largely thanks to the presence of the local research institute and herbarium (NOU) since 1946. The description effort of fig tree taxa as shown in Figure 2 has, following the frantic initial explorative and descriptive period, largely diminished to a low but fairly constant level during the last century.

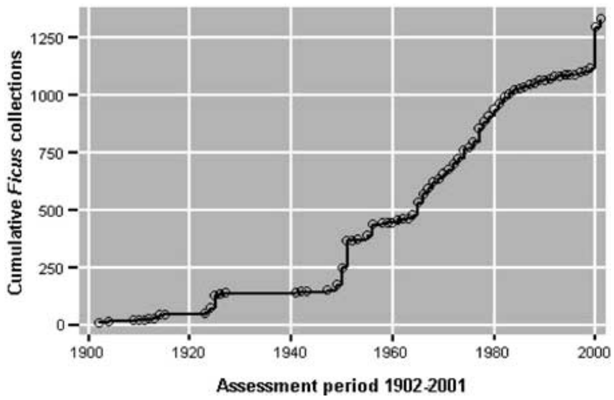

Figure 1. Collection effort based on all *Ficus* collections from New Caledonia (including non-endemic taxa). Cumulative distribution within the century of the chosen assessment window from 1902 until 2001.

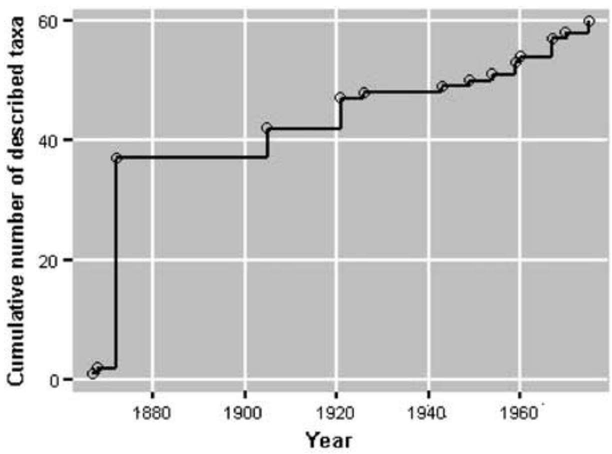

Figure 2. Description effort based on the publication data of the names of endemic monoecious *Ficus* in New Caledonia (including current synonyms). Cumulative distribution from first description in 1867 until 2001.

Results

Extinction threat assessment of Ficus

We found a difference of 2.14 orders of magnitude between the rarest and the most common insular endemic species in the fig tree collections from New Caledonia. For comparison, an exhaustive assessment of half a square kilometre of Panamanian

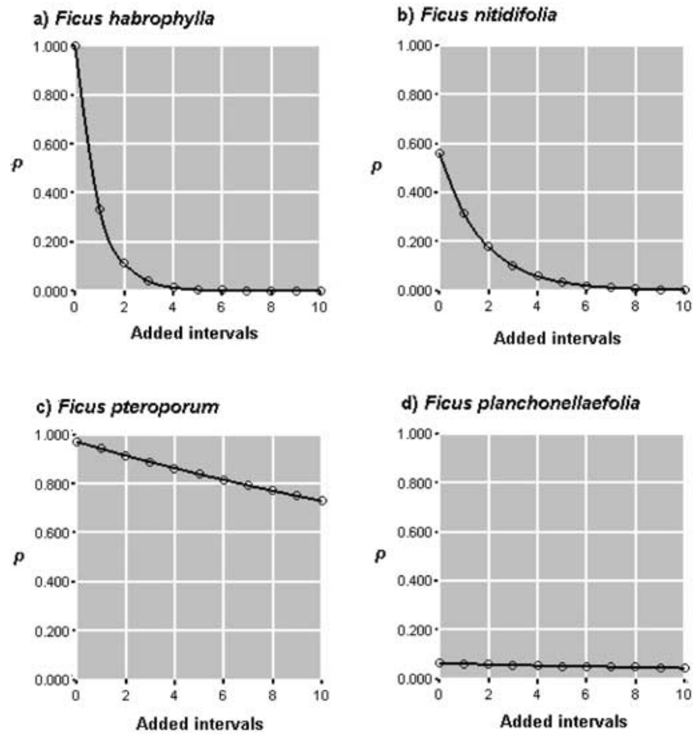

Figure 3. Four examples for the different times to elapse for reaching a particular *p*-value under the scenario that no more samples will be collected during the following assessment intervals (calendar years).

forest showed a much higher amplitude with a difference of 4.60 orders of magnitude for these continental taxa which are not locally endemic (Hubbell and Foster 1986). The calculated *p*-value for each taxon is given in Table 1. According to Equations 2 and 5, $p = 1$ indicates minimal threat and values close to 0 high threat. Not surprisingly for a presumed adaptive radiation, the abundance, ecological breath and geographic distribution vary strongly among the endemic fig trees in New Caledonia. However, there is little threat manifest at first sight using Equation 2: a third of the species having a *p*-value of 1 and 18 out of the 21 species having been recorded during the last 2 years of the time frame. Note that the higher the number of specimens, the easier a trend is detected and the lower the calculated *p*-value for a given period without voucher. To characterise the used equation we plotted scenario *p*-values resulting from further extending the period since the last observation into the future. One representative for each of the four broad patterns are shown in Figure 3, namely *Ficus habrophylla* (high *n*, high *p*), *F. nitidifolia* (high *n*, low *p*), *F. pteroporum* (low *n*, high *p*), and *F. planchonellaefolia* (low *n*, low *p*). The resulting graphs allow gauging the reasonable time to wait before a species could be labelled 'Extinct'. The time span for a *p*-value to reach say 0.01 if the species is not resampled

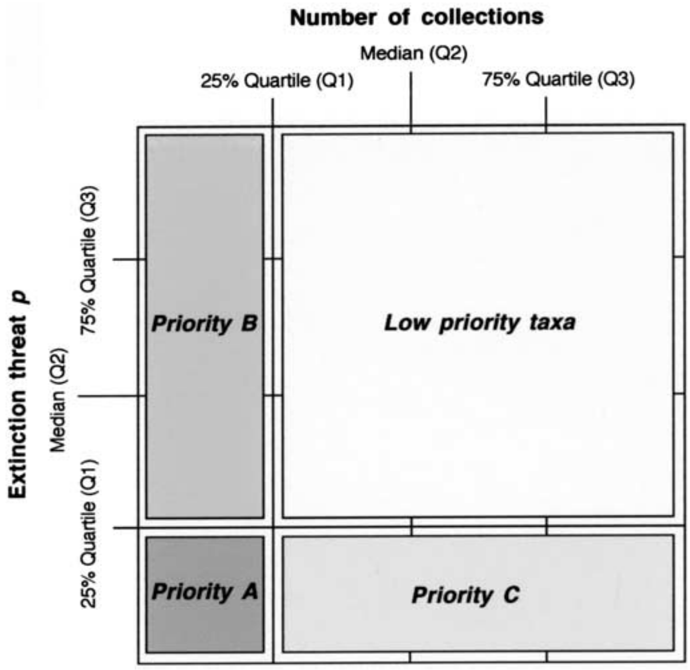

Figure 4. Integration matrix of extinction threat and sampling density resulting in a priority classification for future reassessments of taxonomical validity and conservation status of taxa. For explanations see text.

ranges from 4.2 years in the case of *F. habrophylla* to about 360 years in the case of *F. pteroporum*.

To some extent, the generally high *p*-values can be explained by the high collection effort in recent years. By using Equation 5, which takes into account the changing collection effort, the resulting *p*-values do indeed drop considerably, particularly in the case of species with a formerly high collection frequency as for instance *F. nitidifolia*.

A main concern is the inter-analysis comparability of the inferred threat. Red Lists (IUCN 2001) currently recognise eight categories for evaluated taxa, each with up to five possible criteria, some of which are again subdivided into up to 10 available subcriteria. The often used short-cut category 'Threatened' has been applied differently encompassing various categories, and the within-group variability of assessments of Red List categories during the last decade can thus be bigger than the among-group variability: while Farjon (1994) reports that not less than 36 (84%) of 43 endemic flagship conifers are being threatened, a later assessment by Jaffré et al. (1998) designating only CR, EN and VU species as threatened resulted in merely 11 threatened species (26%, i.e., close to their estimate of the average rate for New Caledonia). Compared with Red List assessments comparability is thus improved by the fact that we correct for evaluation effort and utilise a sole criterion, which in turn results in a single parameter p. If species were not declining and the herbarium records were random, the p-values would be distributed randomly between 0 and 1, thus by chance we would expect 10% of the species to have p-values below 0.1. Burgman et al. (2000) used an arbitrary value of $p = 0.01$ as the threshold for short-listing taxa in an assessment of *Acacia* (Leguminosae) from Australia. Would such a low limit be applied in our analysis, only *Ficus heteroselis* and *F. planchonellaefolia* would be retained as endangered. But rather than accepting this or fixing another specific numerical threshold we use quartiles as a means to assess the collection frequency and p-values. In order to summarise and facilitate interpretation of the available number of specimens and the resulting p-values calculated by Equation 5 and also to allow a priority-setting for subsequent reassessment work, we propose a diagram with four priority classes (Figure 4). The intention is not only to differentiate between the level of threat and thus the conservation priority but also to give an indication of the potential taxonomic reliability of the assessment. Species with a collection number and/or the calculated threat value below the lower 25% quartile (Q1) are thus segregated. This approach, integrating reassessment priorities, is both simple and generally applicable.

Priority A. Taxa with only few collections (and thus hardly known variability) and only old material resulting in a low p-value are potentially threatened but would sensibly have to be classified as 'Data deficient' (DD) in IUCN terms. Our analysis resulted in three species placed in this category: *Ficus barraui*, *F. heteroselis* and *F. planchonellaefolia*. Obviously, the rarest species will always be the ones known only from their type specimen on which the original taxonomic description was based. A taxonomic reassessment of these taxa is imperative, ideally after a targeted resampling. If they are found valid, the taxa will most likely have to be assigned an EX, CR, EN or at least VU status (IUCN 2001).

Priority B. If the few available collections and/or if the description of the taxon is of relatively recent date, the resulting p-value will be higher. Two species fall in this category: *F. leiocarpa* and *F. pteroporum*. A taxonomic reassessment of these doubtful species should still be given priority before an IUCN status is assigned.

Priority C. If there are many specimens available and identification has proven reliable, the taxonomic status is more likely to be well founded. Only *F. nitidifolia* was classified here. A more detailed conservation assessment, for example according to IUCN criteria, can be envisaged. However, although this particular species is restricted to ultramafic substrates, based on our circumstantial field experience we would expect it to be found rather common in the southern province where it occurs even in disturbed habitats as for instance along roads and tracks.

Low priority taxa. Species with both variables above Q1 are less likely to be of immediate conservation concern and 15 out of 21 taxa in the analysis were classified in this category (see Table 1). Note that even very narrowly endemic species with small ecological amplitude such as the rheophytic *F. cataractarum* can fall in this group.

Comparison with IUCN Red List data

Only one of the assessed species (*F. mutabilis*) is currently listed in the global inventory of threatened trees (Oldfield et al. 1998). This particular taxon did not quite qualify for priority C in our analysis. It is one of the few species that can be found on the relatively dry west coast in the characteristic sclerophyllous forest and since this forest is the most endangered major vegetation type in New Caledonia (Bouchet et al. 1995), the species has been listed as 'Vulnerable'. However, the species is not restricted to this area and habitat type (about half of the vouchers are from other areas) and it is thus indeed unlikely to be under immediate extinction threat. Similarly, the above mentioned *F. cataractarum* was classified in the now defunct category 'Rare' in Walter and Gillett (1998); however, even though its habitat as a rock-creeping rheophyte is rather restricted, it is currently not threatened by human intervention and the species is indeed abundant along many of the small rivers of the northeast coast, as has been found during a field verification of old herbarium localities. Summarising the results of the endemic fig tree assessment from New Caledonia, our own results suggest that the data in the IUCN Red Lists will often fall short of providing reliable or consistent information on particular species, an impression recently shared by Kirschner and Kaplan (2002) evaluating other plant groups. Meta-analyses of compiled datasets, such as the use of the speed taxa pass from one Red List category to the next, in order to estimate extinction threat must be discouraged. The figures might be more representative if summed up for a more inclusive clade or region and in Table 2 we thus compiled the data for *Ficus* globally and all the flowering plants/trees of New Caledonia respectively. The table lists the values from the 1997 IUCN Red List of Threatened Plants (http://www.unep-wcmc.org/) and the more recent World List of Threatened Trees (http://www.unep-wcmc.org/) whose data were also integrated into the 2000 and subsequently the 2002 IUCN Red List of Threatened Species (http://www.redlist.org/).

The first question is whether the low extinction threat level is representative for fig trees on a global scale. Worldwide there were 50 *Ficus* taxa or less than 10% of the global species in the Tree Conservation Database (http://www.unep-wcmc.org/). At face value, this percentage seems to correspond rather well with our estimate for New Caledonia and with the average threat level in vascular plants of 12.5% (33,798 spp.) (Walter and Gillett 1998). Both lists compared in Table 2 contain only 27 (not completely congruent) *Ficus* taxa with no record of a species gone extinct. However, low levels of threat on a global scale often merely reflect incomplete knowledge of a group. Nevertheless, of the 10,091 reviewed species for the World List of Threatened Trees (Oldfield et al. 1998) only 375 taxa were classified as 'Data deficient' (4%). This grossly underestimates the problem of taxa based on

Table 2. IUCN Red List data for *Ficus* worldwide and the plants of New Caledonia. Sources: Walter and Gillett (1998), Oldfield et al. (1998), Hilton-Taylor (2000).

1997 IUCN Red List of threatened plants						World List of threatened trees (2000 IUCN Red List of Threatened Species)							
Ficus taxa globally: 27 (incl. *F. mutabilis* V, *F. cataractarum* R)						*Ficus* taxa globally: 27 (incl. *F. mutabilis* VU)							
Ex	Ex/E	E	V	R	I	EX	EW	CR	EN	VU	LR/cd	LR/nt	DD
0	0	2	5	14	6	0	0	3	11	12	0	1	0
New Caledonia: 480 taxa threatened (Ex/E to I)						New Caledonia: 211 taxa threatened (CR to VU)							
Ex	Ex/E	E	V	R	I	EX	EW	CR	EN	VU	LR/cd	LR/nt	DD
5	5	160	214	91	10	4	0	26	64	121	36	2	0

EX, Ex – Extinct; EW – Extinct in the wild; E, EN – Endangered; V, VU – Vulnerable; R – Rare; I – Indeterminate; CR – Critically endangered; LR/cd – Lower risk, conservation dependent; LR/nt – Lower risk, near threatened; DD – Data deficient.

insufficient sampling according to our own work in what is a comparatively well-known tropical area. Our view clearly entails a different emphasis than IUCN's (2001) where it is maintained that the absence of high-quality data should not deter attempts at applying the IUCN criteria and that any method involving estimation, inference or projection is deemed acceptable. The liberal use of the category 'Data deficient' is in fact expressly discouraged and rather seen as a last measure by proposing to make positive use of whatever data are available. Concerning the general threat situation in New Caledonia, the estimated 25% of endemic plants at risk ('Conservation dependent', 'Vulnerable', 'Endangered', or 'Critically endangered') (Jaffré et al. 1998) are clearly above the value our results indicate for the well-sampled *Ficus*. While up to 50 species have been estimated to face impending extinction (Lowry II 1998), as of 1995 only a single endemic vascular plant species had been documented as gone extinct in New Caledonia, incidentally from within a protected area (Bouchet et al. 1995). The species in question, *Pittosporum tanianum*, has been rediscovered in the meantime, less than 10 years after its original description, as has the palm *Pritchardiopsis jeanneneyi* that was considered extinct until 1980 when it was rediscovered by a hunter. Four other candidates were later added to the tally (Walter and Gillett 1998) based on expectations already expressed in Bouchet et al. (1995). A congruent pattern of remarkably few documented extinctions for a floristically relatively well-known Biodiversity Hotspot has been described by Greuter (1994) for the historically much more transformed Mediterranean Basin with about 24,000 vascular plant species but only 31 recorded extinctions and also for Ecuador (part of Tropical Andes and Chocó-Darién-Western Ecuador Hotspots) with about 15,000 species but only 3 recorded (and up to 46 estimated) extinctions by Pitman et al. (2002).

Comparison with other tree radiations

A uniform pattern of extinction threat and extinction documentation would be surprising. We thus also investigated whether the observed pattern of low extinction threat in *Ficus* might indeed be exceptional for endemic trees in this particular Biodiversity Hotspot. In order to get an idea of the variability of the threat situation we compared the fig trees with data on two other endemic tree lineages of relatively well-known tree taxa: the ebonies (Ebenaceae) (White 1992, 1993) and the palms (Arecaceae) (Hodel and Pintaud 1998; Pintaud et al. 1999, 2001). All three analysed groups are part of speciose, essentially pan-tropical genera or families and show primarily Malesian relationships as opposed to genera of presumed Gondwanan origin as for example *Nothofagus* (Fagaceae) or *Araucaria* (Araucariaceae) for which New Caledonia is perhaps more commonly known; and all three groups are sufficiently diverse without belonging to the most species rich groups of woody plant radiations in New Caledonia – as for instance *Phyllanthus* (Euphorbiaceae) or *Psychotria* (Rubiaceae).

Interpreting the compiled data in Table 3, the following aspects seem particularly noteworthy. The absolute number and the percentage of single locality taxa is even

Table 3. Comparison of three woody plant radiations of New Caledonia including fig trees, ebonies and palms. Collection data, IUCN assessment (for abbreviations see Table 2) and habitat specialization. Ebenaceae data: White (1992, 1993). Arecaceae data: Hodel and Pintaud (1998), Pintaud et al. (1999, 2001), Pintaud (personal communication).

		Moraceae Austrocaledonicae-radiation	Ebenaceae Maba-radiation	Arecaceae Iguanura-radiation
Number of evaluated herbarium collections		915	580	720
Number of endemic taxa evaluated		21	24	28
Average number of collections per taxon		44	24	26
Number of taxa known from only one locality		2 (10%)	7 (29%)	9 (32%)
IUCN categories	CR critically endangered	0 (0%)	1 (4%)	2 (7%)
	EN endangered	0 (0%)	2 (8%)	0 (0%)
	VU vulnerable	1 (5%)	8 (33%)	6 (21%)
Substrate	On ultramafic substrate only	3 (14%)	4 (17%)	11 (39%)
	On non-ultramafic substrate only	8 (38%)	13 (54%)	10 (36%)
	On elevated coral limestone only	1 (5%)	1 (4%)	1 (4%)
	On more than one substrate type	9 (43%)	6 (25%)	6 (21%)
Altitude	Above 250 m only	4 (19%)	3 (13%)	15 (54%)
	Above 800 m only	0 (0%)	0 (0%)	6 (21%)
Vegetation	Dry west coast only	0 (0%)	10 (42%)	0 (0%)

higher in the ebonies and particularly in the palms where more than a quarter of the species is only known from one single population. Not surprisingly, the number of IUCN registered taxa is correspondingly much higher than in *Ficus* whose low threat level can apparently not be attributed to a poor sampling density. The emerging picture is equally differentiated concerning habitat specificity. While the fig trees like the palms are most diverse in humid forests, ebonies have a number of taxa restricted to the relatively dry west coast. Another niche limitation is the restriction of a species range to higher altitudes and thus the absence from the plains close to the sea. Here, cut-off altitudes of 250 m (land area of New Caledonia above and below is about the same size) and 800 m (mean of the altitudinal range) are used. Both the fig trees and ebonies do not seem to have an endemic high-altitude montane wet-forest element as is evident in the palms. On the other hand, all three radiations have a small endemic component on the elevated coral substrate of Grande Terre's somewhat neglected neighbouring islands, the young and floristically rather uniform coral islands normally harbouring a Indo-Pacific strand flora of very widespread species (Morat et al. 2001). Note that whether the higher-level taxon which includes the radiation in consideration is endemic to the analysed region is not primarily expected to be relevant to the outcome of the conservation evaluation. Put differently, the fact that the evaluated palm radiation contains several endemic genera whereas the fig tree radiation consist of only a fraction of the genus *Ficus* is irrelevant since taxonomic ranking into Linnaean categories is guided by pragmatism and ultimately arbitrary. Most reserves in New Caledonia cover areas of ultramafic rock-derived soils for which New Caledonia is rightly famous. But is the current reserve network in New Caledonia sufficient for a sustainable preservation of all the evaluated endemic taxa? No. Would it be possible to extend the reserves as to include populations of all known taxa? Realistically no. The most vulnerable species will often be endemic taxa and these are evidently not limited to one habitat or substrate type. Even if such taxa are locally abundant, they are susceptible to threats involving habitat transformation like fire, opencast mining or agricultural use. Morat et al. (1999) see a multitude of small reserves to protect microendemic narrow-range species as a way out. However, leaving aside inherent problems with and questionable effectiveness of small reserves, the large number of endemic seed plant taxa, and particularly the apparently numerous single-population endemics raise doubts that the integral species protection within reserves is a feasible objective (McIntyre 1992). In any case, while we recommend a traditional habitat that is, vegetation-type based approach to reserve selection (see Discussion), single-species management including off-site conservation efforts seem *de rigueur* for especially vulnerable local endemics (see Appendix).

The quantitative assessments above may put into perspective summary judgements such as that by Pitman and Jørgensen (2002) that all of the more than 2000 endemic seed plant species of New Caledonia are threatened with extinction; or that by Myers (1997) according to which New Caledonia has already lost 90% of its primary vegetation, that such a loss leads to the extinction of 50% of the endemic taxa and that thus more than 1000 species if not already extinct, must be expected to be 'living dead'.

Discussion

What are the limitations of our case study? What might be its implications beyond the woody plants of New Caledonia? In the following discussion the focus is on three central issues of extinction threat assessments with herbarium specimens: the data and its bias, quality control of the assigned status and finally priority-setting for the future.

Data and bias. A general feature, particularly of island floras, is that with increased sampling the endemism rate seems to decrease (*contra* Krupnick and Kress (2003) who argue that both diversity *and* endemicity measures will increase with more collecting). This taxonomic artifact due to uneven sampling and local rather than regional, let alone global revisions is demonstrated by the historical development of cited values for several islands. The estimate for New Caledonia for example dropped from more than 95% endemic seed plant species (Baumann-Bodenheim 1956) to about 77% (Jaffré et al. 2001). Lower endemicity estimates after taxonomic revisions across major regions as those in the Flora Malesiana, encompassing several centres of endemism, are indeed likely to be the rule. This virtual decrease is further accentuated by the very real increase of naturalized taxa as a result of global trade and travel (Hobbs and Mooney 1998; Sax et al. 2002). Perhaps the most important bias introduced by emphasising endemic species is the entailing neglect of widely distributed but rare and/or declining taxa. A more contentious issue is the connection of perceived threat with our knowledge of a group (McKinney 1999). This is why New Caledonia is a particularly interesting research area, the most exceptional aspect of its plant life being perhaps not the high level of endemism but the quantity of herbarium records, compared for instance with Madagascar with a similar endemism rate (see Conclusions). In other words, the standard claim that low threat levels may merely reflect insufficient knowledge of the flora is less likely to apply here. Concerning understudied taxa it is helpful to distinguish between taxa with few students per species and those that are poorly sampled. The fig trees of New Caledonia can be classified in the first category but not in the second, in which common species are usually becoming neglected after the initial phase of exploration and the commonness of common species will be underestimated, as will the rarity of rare taxa. Note the difference to the related problem of estimating the 'Area of occupancy' of a taxon for an IUCN Red List assessment (IUCN 2001), which is indeed inherently bound to become smaller (rendering the species more threatened) with increasingly fine mapping resolution (Willis et al. 2003). Just how uneven the taxa are represented in the collections of the world becomes evident when one accepts an estimate based on the Index Herbariorum (Holmgren et al. 1990) of some 300 million specimens (including duplicates, however) being available in public herbaria, resulting in a global average of about 1000 vouchers per known species (compare with the ostensibly well-sampled groups in Tables 1 and 3). Undoubtedly even more skewed are the about 6 million accessions in the gene/seed banks with a strong bias towards agri- and horticulturally interesting taxa. For the time being, the effect of geographical coverage and sample size remains woefully underappreciated in taxonomy where the emphasis has been placed on seemingly endless discussions about species concepts and on multivariate analyses to distinguish putative species rather than the adequacy of the sample the data were gained from in the first place (but see for instance Walsh (2000) for conservation units). To be addressed in a statistically sound fashion, Baum (1996) actually suggested that the sample size in the world's herbaria is far too small for most taxa to tackle most questions. At any rate, Earth's diversity at a species level is so overwhelming that we will not be able to achieve and profit from global high-density sampling for the less popular of the speciose groups with our limited (para)taxonomist manpower.

Quality control. As most would agree, the primary obstacle to any investigation of extinction threat next to the paucity is the quality of the data (May et al. 1995). Currently, compilers of extinction risk data seem to see their main use in awareness and funding promotion. As for example Lucas and Synge (1996, p. 32) commented in a preview of the first global list of threatened plants: "Perhaps the main value of the [IUCN Red] list is symbolic. Listing so many species as threatened is powerful evidence [. . .] and confounds any who might argue that plants are not threatened. The contrast with IUCN's well-known animal list is very striking: there are over five times more known threatened plants than threatened animals, making the case for more investment in plant conservation". However, since the actually documented global plant extinctions in Red Data Lists are numerically not very impressive, other concepts and tools seem more appropriate for *conservation advocacy* (e.g., Biodiversity Hotspots, Megadiversity Countries, or predictions of imminent extinctions based on habitat loss and species-area relations). *Conservation biology* on the other hand should provide field evidence to back up theoretical mass extinction scenarios (Simberloff 1986; Lomborg 2001); at the very least, the limelight on the conservation advocates must not divert attention from the admittedly much more laborious and difficult task of actually documenting extinctions. Ever since Myers (1979), Lovejoy (1980) and Ehrlich and Ehrlich (1981), scenarios typically predict several species to become extinct each hour that passes, while on the online IUCN Red List it is flatly stated that not a single assessed species has been reported to the list administration as gone extinct during the last 6 years (IUCN 2002) – a period during which many thousand 'taxa' have officially disappeared after synonymisation by taxonomists (Zoological Record, http://www.biosis.org.uk). At any rate, if reliable species related information on extinction threat of tropical plants is desired, taxonomic validation procedures have to become a priority beyond internal consistency checks for data integrity in the compiled databases or superficial external reviews. Pointing in the right direction, quality control has come to the forefront of any serious biodiversity assessment programme involving species rich taxa and areas (Wilkie et al. 2003). The obvious importance of sound taxonomy is of course not limited to studies like this but is a prerequisite in conservation evaluation in general. Ideally, assessments are useful spin-off products of taxonomic revisions covering whole areas of endemism if not the whole world. So far, Red Lists enjoyed not the best reputation in taxonomist circles, however. To some extent this is perhaps explainable by the fact that the framework of applicable criteria and categories has repeatedly been corrected in the last decade (IUCN 1994, 2001) resulting in a current version which will ultimately necessitate the reassessment of assigned categories of taxa assessed with the pre-2001 framework (Hilton-Taylor 2001). More importantly, however, many groups have not been revised in recent decades, resulting in listed species based on outdated or premature taxonomy rather than threat, and changes in lists often reflect changes in knowledge rather than changes in conservation status (Burgman 2002; Possingham et al. 2002). Unfortunately, taxonomy itself suffers from a congruent *malaise*. The high rate of concocted monotypic taxa and taxa based on type collections only, without any notion of their variability leads to genus names uninformative regarding the phylogenetic relationship of the included taxon and species names bound for synonymisation upon revision. But to this day, isolated islands or other areas with a high level of known (or suspected) endemism like New Caledonia prompted taxonomists time and again to describe new taxa based on scant material without undertaking a revision of the group in question. From the many described taxa of endemic *Ficus* in New Caledonia, for example, about half were based on a single collection. Not surprisingly, a correspondingly high percentage of described taxa had to be reduced to synonyms eventually. It is inevitable, however, that such synonyms will keep a place in most of the underfunded and undercurated herbaria already suffocating under an increasing backlog of new material. Since many of these taxa were described in specialised taxonomic journals of restricted distribution outside of general revisions or more readily available Floras, the names were applied relatively rarely. This, in turn, resulted in poorly filled species folders, giving a careless compiler the additionally false impression that these taxa are not only currently accepted but also rare. And due to improved databasing and dissemination capacities over the Internet uncritical large-scale compilations must even be expected to increase and may in fact gain wide application. Realistically, a comprehensive Red Data Book of all seed plants should perhaps not be our aim in the first place. The envisaged up-dating interval of 5 – 10 years will prove illusory, the data accumulation being far too slow (Heywood 2003; Heywood and Iriondo 2003). Given that less than 5% of the plant species have been assessed for the 2000 IUCN Red List, the lessons of our slow progress have apparently not been learned and the Global Strategy for Plant Conservation Assessment of the Convention on Biological Diversity (CBD) set the unrealistic target to have all plant taxa evaluated by 2010 (http://www.biodiv.org/).

Priority-setting. It is often claimed that the most pressing question of biodiversity conservation is how to best allocate the limited resources. The two basic subjects of priority-setting, taxonomic groups (taxa) and conservation areas (reserves), must not be confounded however. (i) *Taxa*. Compared with taxon-based priority assessments in conservation, priority-setting in taxonomy has been neglected apart from the obvious bias for beautiful, useful and harmful taxa. Even though the above-mentioned problem of increasing backlogs and generally the cost of specimen acquisition and curation prohibits an indiscriminate approach in collection management and a serendipitous approach regarding taxonomic aims. The result of the numerical screening of herbarium material should be seen as flagging endemic taxa and assembling a ‘wanted’-list of the rare and insufficiently known species, hopefully leading to the discovery of new localities and resulting in crucial material for the corroboration or rejection of their taxonomic status as accepted species. To set priorities, both in taxonomy and conservation, Solow-McCarthy *p*-values based on collection data represent a good compromise in terms of cost, accessibility, accuracy and information content. They give the user the opportunity to set an individual threshold and thus decide on the acceptable degree of reasonable doubt in his evaluation. Allowing for the inherent uncertainty and vagueness in data and categories while maintaining the traditional IUCN classification, application of fuzzy sets (Regan et al. 2000) are being discussed and the software package RAMAS Red List 2.0 (Akçakaya and Ferson 2001) based on Akçakaya et al. (2000) and implementing the new IUCN criteria (IUCN 2001) has become available. (ii) *Reserves*. What are the implications of taxonomic priority-setting, geographically referring to whole areas of endemism, on setting area priorities on a national or international level? Contrary to taxonomists, conservationists hardly ever have the clout to put perceived priorities into practice, conservation implementation usually rather governed by socio-economic and political constraints. The question thus arises whether modern numerical methods for reserve selection are more than academic exercises and lobbying tools. Clearly, the choice of the analysed groups, the scale and delimitation of the geographical areas and the weighting of species richness, endemism, rarity, viability, phylogenetic disparity, and ecological function can make virtually any given result numerically defensible, further complicating primary factors such as available funds and land prices. Even supposing conservationists were indeed granted a mandate to select areas for preservation (e.g., Howard et al. 1998), if resources are scarce why doing a quantitative assessment and priority ranking at all when an accountable group of seasoned local field-biologists or foresters could come up with a list of important areas covering complementary habitats including their ecotones over a mug of coffee? If a species – as the tongue-in-cheek truism in systematics goes – is indeed what a competent taxonomist says a species is, one may be tempted to assume that an important conservation area is what an experienced field-biologist or forester recognises as such. While this would not be a scientifically defensible approach *sensu* Pressey (1994), not even based on explicit and objective criteria, it is less evident whether such a traditional and qualitative habitat-type method would in fact provide a poorer choice than a modern, expensive numerical analysis of a few surrogate taxa (van Jaarsveld et al. 1998). Despite the suggestive title of Balmford and Gaston’s (1999) article, it has not been shown that conducting biodiversity surveys is indeed good value compared to *ad hoc* reserve selection involving land purchases guided by the strategy of complementing already covered vegetation types at local or ecoregions at regional scale (*contra* Pressey and Cowling 2001). In practice, the cost of rigorous assessments (Howard et al. *op. cit.* spent about 100 man-years of survey effort) let alone for embarking on comprehensive taxa inventories render such undertakings off-limits for most of the urgent tasks (Sheil 2001). And on the other hand has the search for readily assessable yet predictive single indicator groups proved to be elusive and is likely to be futile (Lawton and Gaston 2001). Summarising, we are considerably more sceptical than Prendergast et al. (1999) in their mild critique of ivory-tower reserve selection algorithms and thus suggest that numerical priority evaluations are more appropriate on a taxonomic level, highlighting extinction-prone species and needs for taxonomic reassessments, rather than on a geographical level were the habitat and its vegetation instead of areas and its biota make for good-value evaluations (Panzer and Schwartz 1998). Hence, while we do not propose for instance the use of multiple tree radiations as surrogates for reserve selection analyses in New Caledonia, we largely concur with the preliminary qualitative evaluations concerning further reserve desiderata by Veillon (1993), Bouchet et al. (1995), Jaffré et al. (1998) and Morat et al. (1999) (see Appendix).

Conclusions

As a consequence of the topics covered in the Discussion, the described method is particularly suited for an initial conservation triage of relatively poorly known groups in the tropics. Several caveats should be kept in mind but the following eight points are not meant as indispensable conditions for a study. Rather, these feasibility criteria based on our experience with fig trees from New Caledonia are a checklist of our assessment rationale and may be useful for assessing potential pitfalls of numerical analyses based on other collection material. (i) *Endemicity.* Choose the area according to the group or the group according to the area to be considered (Funk 1993; Rodrigues and Gaston 2002). The choice of groups endemic to the area under consideration will avoid assessing local extirpation risk instead of global extinction threat. Remember the fundamental premise and problem of conservation assessments: all species are rare *somewhere*. Red List assessments on regional, national or even local level suffer particularly from this dilemma (Gärdenfors 2001; Gärdenfors et al. 2001). New Caledonia with its numerous endemic radiations is an obvious *terre de prédilection* for complete assessments. (ii) *Taxonomy.* Do not analyse a group without an available taxonomic revision or at least a semicritical Flora as the *Flore de la Nouvelle-Calédonie et Dépendances*. Ideally, however, you will revise the whole group yourself, which will eliminate the following point. (iii) *Identification.* Do not trust previous identifications. Check all the identifications not made or confirmed by the last reviser. Misapplied names in difficult and/or species-rich groups or outdated names in groups with many only recently described taxa can affect a substantial part of the material. In the case of the endemic *Ficus* from New Caledonia about 80% of the herbarium material had already been identified to species at least once, ca. 40% of these specimens were misidentified at least once and additionally ca. 40% were not classified according to the nomenclature of the last reviser. (iv) *Sampling style.* The ideal are collections based on opportunistic and thus approximately random sampling. However, room and workforce constraints and as a result the increasing need for accession policies in natural history collections will make most collections suitable for a few groups only. For the sake of efficiency, try to compile the records of the few most important herbaria for a group rather than those of many less important ones. New Caledonia has a good stock of collections from general collectors handily concentrated in relatively few herbaria. In particular Hugh S. MacKee, one of the last great generalist plant hunters (Morat 1995) was doing fieldwork without leaving aside common species and unspectacular habitats, amassing some 30,000 collections (typically with up to 10 duplicates) from New Caledonia alone. (v) *Sampling evenness*. The evenness of the sampling effort is particularly important in areas of high local endemism (rich in microendemics). The manageable size together with the, for a tropical area, relatively good road infrastructure makes New Caledonia rather evenly sampled in the lowlands. Certain mountain ranges and isolated valleys, however, remain poorly known. (vi) *Collection density*. The Pacific islands beyond New Guinea and its satellites have been highlighted to be the tropical region with outstandingly high collection densities. For floristic work, a rather arbitrary minimal collection density of 100 collections per 100 km^2 was proposed by Campbell (1989); a number unattainable for many large and species-rich tropical areas of endemism in the near future. Using *Ficus* as a representative sample and the percentage of specimens collected by MacKee in our database we extrapolate the total number of herbarium collections from New Caledonia to be between 90,000 and 100,000 (not including duplicates). This translates into a collection density of about 500 collections per 100 km^2, which is somewhat more conservative than the estimate of more than 600 given by Jaffré et al. (1998). (vii) *Appeal and ease of collection*. Inconspicuous taxa or difficult to collect species are collected only by specialists whereas small, accessible trees or herbs with conspicuous flowers and small, easily dried fruit are bound to be collected by general collectors and are thus invariably better represented in herbaria. The tall non-endemic strangler fig trees of New Caledonia for example are not as well sampled as the smaller free-standing endemic species. (viii) *Seasonality and phenology*. Strongly seasonal climates with a very wet rain-season will impede extensive sampling in that period. New Caledonia lies in a part of the Pacific where the seasonal variability of rainfall is not as pronounced as that it would lead to records collected only during the dry-season. Furthermore, fig trees exhibit an essentially asynchronous flowering phenology with certain trees bearing figs at any given time.

Epilogue

As a consequence of the priority-setting we have embarked on a reevaluation and lectotypification of the considered taxa and have thus controlled protologues and type specimens (Ungricht et al. 2003) in order to eventually arrive at a consolidated taxonomic state of the unique fig tree flora of New Caledonia. Confirming our worst expectations, but at the same time demonstrating the need for such reassessments, this undertaking has resulted in the discovery of a gross taxonomic mistake: the original description of *Ficus planchonellaefolia* (mulberry family) highlighted in this study has turned out to be based on material of misidentified Sapotaceae trees (sapodilla family) – another 'species' disappearing by the hands of biologists rather than going extinct in nature.

Acknowledgements

Thanks are primarily due to the collection managers who made their specimens available for study in France (NOU, P), England (BM, K) and Switzerland (G, Z). Fieldwork in New Caledonia was facilitated by Tanguy Jaffré and the indomitable staff at the Institut de recherche pour le développement (IRD, Nouméa). Jean-Christophe Pintaud (IRD, Montpellier) kindly provided collection data on the palms of New Caledonia while Kees Berg (BG) and Terry Pennington (K) helped with critical identifications. Two anonymous reviewers provided further input. This study commemorates the late Frank White whose work on New Caledonian ebonies we cannibalised. The research was financed by a TMR Fellowship of the Swiss National Science Foundation to the first author.

Appendix. Conservation review and outlook of New Caledonia

The main threats to the flora of New Caledonia have little changed in the past 50 years (Catala 1953) and include opencast mining, logging, agricultural land transformation, bush fires, spread of invasive plants (e.g., weeds like *Lantana camara*) and introduction of alien animals (e.g., browsing mammals like the deer *Cervus timorensis*) (see also Morat et al. 1995, 1999; Mittermeier et al. 1996; Jaffré et al. 1998). On the positive side, we note that the overexploitation of plant species concerns probably fewer than a dozen taxa and will further diminish with a rarefaction of the plants concerned. Although there are some 1500 introduced plant species (MacKee 1994), many of them are unable to colonise ultramafic substrate and even introduced animal species often remain restricted to the highly disturbed capital peninsula of Nouméa. Pressure due to tourism – and population density in general – is localised and of comparatively limited scale (McElroy 2002). It is particularly laudable that the critical reforestation of denuded mining areas to prevent further erosion and degradation of the landscape is a priority of local applied research activity (Cornu et al. 2001). Furthermore, there are several active grassroots conservation societies (e.g., Association Endémia, http://www.endemia.nc) hopefully also fostering the environmental awareness among the indigenous Kanaks, especially crucial if the territory should move further towards independence.

New Caledonia has a somewhat intricate environmental legislation of protected areas. Older compilations like Dinerstein and Wikramanayake (1993) but also official international documents like IUCN (1991, 1992), WCMC (1992) and WCMC and IUCN (1998) are partially out of date. As of 1999 there were 26 terrestrial conservation areas falling into three main categories, 'Integral nature reserve', 'Provincial park', 'Special reserve', each with differing legal protection status. In total, these reserves cover some 536 km^2 or about 3% of New Caledonia's land surface. An area of 941 km^2 of natural vegetation has been set aside to protect catchments providing drinking water and on 5631 km^2 mining prospecting is specially regulated, but note that mining is not banned in all wildlife reserves (Morat et al. 1995, 1999; Jaffré et al. 1998, http://www.mnhn.fr/mnhn/chm). A simplification of the legislation as well as a dedicated improvement and long-term enforcement of the accorded protection status in existing conservation areas is rightly deemed a high priority (Giraud-Kinley 1997). There are doubts regarding the present effectiveness of the sometimes small (16 reserves are smaller than 10 km^2) and strongly frequented reserves already set in place on the main island. In one case, the Chute de la Madeleine botanical reserve in southern Grande Terre, established in 1990 and encompassing just 4 km^2, the vegetation state has apparently deteriorated due to uncontrolled recreational use by visitors with off-road vehicles (Farjon 1994) and fire likelihood has increased drastically because of camping activities.

As already mentioned, it seems unlikely that the large number of localised microendemic narrow-range taxa can be integrally protected within reserves. A combination of *ex situ* proliferation, *in vitro* propagation, seed banking, habitat restoration and species translocations or reintroductions is perhaps a more effective approach. The Northern Province of New Caledonia is lagging behind, both in number and total size of protected areas, compared to the much more populous and infrastructure-rich Southern Province (Jaffré et al. 1998). Selected parts of the west coast where range land is spreading and consequently the already few dry forests are further diminishing (Gillespie and Jaffré 2003) as well as pristine, if less diverse, mangrove habitats would certainly justify protection (Veillon 1993). Additionally, the low but nevertheless appreciable endemism in the coralline Loyalty Islands, politically a province of its own, would deserve a substantial protected area, for instance by setting aside tribal land under customary ownership for community-based conservation on Lifou, the largest elevated atoll in the world. Other raised atolls, namely parts of the second largest, Rennell (Mu Nggava) in the Solomons to the north of New Caledonia, as well as tiny Henderson in the Pitcairn group of the Southeast Pacific, were even granted 'Natural world heritage' status by the UNESCO. The subendemic flagship parakeet *Eunymphicus cornutus* on Ouvéa, by far the smallest and most densely populated of the three main Loyalty Islands, should not divert attention from the less disturbed forests on the much larger neighbouring islands of Lifou and Maré.

Obviously, direct impact of conservation research on the outlook of an archipelago is minimal – conservation even in remote corners of the earth being rather determined by economics and politics (Whitten et al. 2001; but see Wright and Lees 1996). However, as seen above, imminent extinction threat in New Caledonia is easily distorted. Also at odds with the oft-cited Biodiversity Hotspot classification depicting New Caledonia as "one of the world's most endangered Biodiversity Hotspots" (Mittermeier et al. 1996, p. 104), and rather concordant with the analysis of Dinerstein and Wikramanayake (1993), the prospects of this remote backwater seem fair. In fact, we believe that most other tropical areas face more severe threats due to less advantageous environmental conditions (e.g., diseases, pests, volcanism, earthquakes, inundations, desertification) but particularly because of the widespread combination of high population density, abject poverty, poor education, low technological standards, devastating civil wars, rampant corruption in government institutions, dysfunctional environmental law enforcement and political as well as economical instability. In other words, New Caledonia's biodiversity is of high conservation priority precisely because of its favourable conservation potential.

References

Akçakaya H.R. and Ferson S. 2001. RAMAS Red List: Threatened Species Classifications under Uncertainty. Version 2.0. Applied Biomathematics, New York.

Akçakaya H.R., Ferson S., Burgman M.A., Keith D.A., Mace G.M. and Todd C.R. 2000. Making consistent IUCN classifications under uncertainty. Conservation Biology 14: 1001–1013.

Balmford A. and Gaston K.J. 1999. Why biodiversity surveys are good value. Nature 398: 204–205.

Basset Y., Novotny V. and Weiblen G. 1997. *Ficus*: a resource for arthropods in the tropics, with particular reference to New Guinea. In: Watt A.D., Stork N.E. and Hunter M.D. (eds) Forests and Insects. Chapman & Hall, London, pp. 341–361.

Baum B.R. 1996. Statistical adequacy of plant collections. In: Stuessy T.F. and Sohmer S.H. (eds) Sampling the Green World: Innovative Concepts of Collection, Preservation and Storage of Plant Diversity. Columbia University Press, New York, pp. 43–73.

Baumann-Bodenheim M.G. 1956. Über die Beziehungen der neu-caledonischen Flora zu den tropischen und den südhemisphärisch-subtropischen bis -extratropischen Floren und die gürtelmässige Gliederung der Vegetation von Neu-Caledonien: Pflanzengeographische Studien 2. Berichte Geobotanischer Forschung am Institut Rübel 1955: 64–75.

Bouchet P., Jaffré T. and Veillon J.-M. 1995. Plant extinction in New Caledonia: protection of sclerophyll forests urgently needed. Biodiversity and Conservation 4: 415–428.

Burgman M.A. 2002. Are listed threatened plant species actually at risk? Australian Journal of Botany 50: 1–13.

Burgman M.A., Grimson R.C. and Ferson S. 1995. Inferring threat from scientific collections. Conservation Biology 9: 923–928.

Burgman M.A., Maslin B.R., Andrewartha D., Keatley M.R., Boek C. and McCarthy M. 2000. Inferring threat from scientific collections: power tests and an application to Western Australian *Acacia* species. In: Ferson S. and Burgman M.A. (eds) Quantitative Methods for Conservation Biology. Springer, Berlin, Germany, pp. 7–26.

Campbell D.G. 1989. The importance of floristic inventory in the tropics. In: Campbell D.G. and Hammond H.D. (eds) Floristic Inventory of Tropical Countries: The Status of Plant Systematics, Collections and Vegetation, Plus Recommendations for the Future. New York Botanical Garden, New York, pp. 5–30.

Catala R.L.A. 1953. Protection de la nature en Nouvelle-Calédonie. Proceedings of the 7th Pacific Science Congress 4: 674–679.

Compton S.G. and McCormack G. 1999. The Pacific Banyan in the Cook Islands: have its pollination and seed dispersal mutualisms been disrupted, and does it matter? Biodiversity and Conservation 8: 1707–1715.

Corner E.J.H. 1960. Taxonomic notes on *Ficus* Linn., Asia and Australasia. Gardens' Bulletin Singapore 17: 405–415.

Corner E.J.H. 1970. *Ficus* subgen. *Pharmacosycea* with reference to the species of New Caledonia. Philosophical Transactions of the Royal Society London B 259: 383–433.

Corner E.J.H. 1975. New taxa of *Ficus* (Moraceae) 2. Blumea 22: 299–309.

Cornu A., Sarrailh J.-M. and Marion F. 2001. Espèces endémiques et restauration écologique en Nouvelle-Calédonie. Bois et Forêts des Tropiques 268: 57–68.

Cox P.A. and Elmqvist T. 2000. Pollinator extinction in the Pacific islands. Conservation Biology 14: 1237–1239.
Diamond J.M. 1987. Extant unless proven extinct? Or, extinct unless proven extant? Conservation Biology 1: 77–79.
Dinerstein E. and Wikramanayake E.D. 1993. Beyond 'hot spots': how to prioritize investments to conserve biodiversity in the Indo-Pacific region. Conservation Biology 7: 53–65.
Ehrlich P. and Ehrlich A. 1981. Extinction: The Causes of the Disappearance of Species. Random House, New York.
Fara E. 2001. What are Lazarus taxa? Geological Journal 36: 291–303.
Farjon A. 1994. Threats to conifers in New Caledonia. Species 23: 25–26.
ForeyP.L., Humphries C.J. and Vane-Wright R.I. (eds) 1994. Systematics and Conservation Evaluation. Clarendon Press, Oxford, UK.
Funk V.A. 1993. Uses and misuses of floras. Taxon 42: 761–772.
Funk V.A. and Richardson K.S. 2002. Systematic data in biodiversity studies: use it or lose it. Systematic Biology 51: 303–316.
Gärdenfors U. 2001. Classifying threatened species at national versus global levels. Trends in Ecology and Evolution 16: 511–516.
Gärdenfors U., Hilton-Taylor C., Mace G.M. and Rodriguez J.P. 2001. The application of IUCN Red List criteria at regional levels. Conservation Biology 15: 1206–1212.
Gaston K.J. 1997. What is rarity? In: Kunin W.E. and Gaston K.J. (eds) The Biology of Rarity: Causes and Consequences of Rare-Common Differences. Chapman & Hall, London, pp. 31–47.
Gillespie T.W. and Jaffré T. 2003. Tropical dry forests in New Caledonia. Biodiversity and Conservation 12: 1687–1697.
Giraud-Kinley C. 1997. Preserving megadiversity: the case of New Caledonia. Asia Pacific Journal of Environmental Law 2: 277–292.
Golding J.S. 2001. Southern African herbaria and Red Data Lists. Taxon 50: 593–602.
Golding J.S. and Timberlake J. 2003. How taxonomists can bridge the gap between taxonomy and conservation science. Conservation Biology 17: 1177–1178.
Greuter W. 1994. Extinctions in Mediterranean areas. Philosophical Transactions of the Royal Society London B 344: 41–46.
Guillaumin A. 1959. Contribution à la flore de la Nouvelle-Calédonie. Mémoirs du Muséum National d'Histoire Naturelle, N.S., Botanique 8: 182–184.
Guillaumin A. 1967. Résultats scientifiques de la mission franco-suisse de botanique en Nouvelle-Calédonie (1950–1952). Mémoirs du Muséum National d'Histoire Naturelle, N.S., Botanique 15: 98–102.
Heywood V.H. 2003. Red Listing: too clever by half? Plant Talk 31: 5.
Heywood V.H. and Iriondo J.M. 2003. Plant conservation: old problems, new perspectives. Biological Conservation 113: 321–335.
Hilton-Taylor C. 2000. 2000 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland.
Hilton-Taylor C. 2001. Applying IUCN Red Data book categories to plants. Plant Talk 26: 34–37.
Hobbs R.J. and Mooney H.A. 1998. Broadening the extinction debate: population deletions and additions in California and Western Australia. Conservation Biology 12: 271–283.
Hodel D.R. and Pintaud J.-C. 1998. The Palms of New Caledonia – Les Palmiers de la Nouvelle-Calédonie. Allen Press, Lawrence, Kansas.
Holmgren P.K., Holmgren N.H. and Banett L.C. (eds) 1990. Index Herbariorum. Part 1. The Herbaria of the World. 8th edn. The New York Botanical Garden, New York.
Howard P.C., Viskanic P., Davenport T.R.B., Kigenyi F.W., Baltzer M., Dickinson C.J., Lwanga J.S., Matthews R.A. and Balmford A. 1998. Complementarity and the use of indicator groups for reserve selection in Uganda. Nature 394: 472–475.
Hubbell S.P. and Foster R.B. 1986. Commonness and rarity in a Neotropical forest: implications for tropical tree conservation. In: Soulé M.E. (ed) Conservation Biology: The Science of Scarcity and Diversity. Sinauer, Sunderland, Massachusetts, pp. 205–231.
IUCN 1986. Review of the Protected Areas System in Oceania. IUCN, Gland, Switzerland.
IUCN 1991. IUCN Directory of Protected Areas in Oceania. IUCN, Gland, Switzerland.

IUCN 1992. Protected Areas of the World: A Review of National Systems. Vol. 1. Indomalaya, Oceania, Australia and Antarctic. IUCN, Gland, Switzerland.

IUCN 1994. IUCN Red List Categories. Version 2.3. IUCN, Gland, Switzerland.

IUCN 2000. 2000 IUCN Red List of Threatened Species (http://www.redlist.org. Accessed 1 August 2002).

IUCN 2001. IUCN Red List Categories. Version 3.1. IUCN, Gland, Switzerland.

IUCN 2002. 2002 IUCN Red List of Threatened Species (http://www.redlist.org. Accessed 1 November 2002).

Jaffré T. 1980. Végétation des roches ultrabasiques de Nouvelle-Calédonie. ORSTOM, Paris, France.

Jaffré T., Bouchet P. and Veillon J.-M. 1998. Threatened plants of New Caledonia: is the system of protected areas adequate? Biodiversity and Conservation 7: 109–135.

Jaffré T., Morat P., Veillon J.-M., Rigault F. and Dagostini G. 2001. Composition and characteristics of the native flora of New Caledonia. Documents scientifiques et techniques, IRD Nouméa, II, 4, Volume spécial: 1–121.

Kirschner J. and Kaplan Z. 2002. Taxonomic monographs in relation to global Red Lists. Taxon 51: 155–158.

Krupnick G.A. and Kress W.J. 2003. Hotspots and ecoregions: a test of conservation priorities using taxonomic data. Biodiversity and Conservation 12: 2237–2253.

Lawton J.H. and Gaston K.J. 2001. Indicator species. In: Levin S.A. (ed) Encyclopedia of Biodiversity. Vol. 3. Academic Press, San Diego, California, pp. 437–450.

Lomborg B. 2001. The Skeptical Environmentalist: Measuring the Real State of the World. Cambridge University Press, Cambridge, UK.

Lovejoy T.E. 1980. A projection of species extinctions. In: Barney G.O. (ed) The Global 2000 Report to the President. US Government Printing Office, Washington, DC, pp. 328–331.

Lowry II P.P. 1998. Diversity, endemism and extinction in the flora of New Caledonia: a review. In: Peng C.-I. and Lowry II P.P. (eds) Rare, Threatened and Endangered Floras of Asia and the Pacific Rim. Institute of Botany, Taipei, Taiwan, pp. 181–206.

Lowry II P.P. and Smith P.P. 2003. Closing the gulf between botanists and conservationists. Conservation Biology 17: 1175–1176.

Lucas G. and Synge H. 1996. 33,730 threatened plants! Plant Talk 7: 30–32.

MacDougall A.S., Loo J.A., Clayden S.R., Goltz J.G. and Hinds H.R. 1998. Defining conservation priorities for plant taxa in southeastern New Brunswick, Canada using herbarium records. Biological Conservation 86: 325–338.

MacKee H.S. 1994. Catalogue des Plantes Introduites et Cultivées de la Nouvelle-Calédonie. Flore de la Nouvelle-Calédonie et Dépendances. 2nd edn. Muséum National d'Histoire Naturelle, Paris, France.

May R.M., Lawton J.H. and Stork N.E. 1995. Assessing extinction. In: Lawton J.H. and May R.M. (eds) Extinction Rates. Oxford University Press, Oxford, UK, pp. 1–24.

McCarthy M.A. 1998. Identifying declining and threatened species with museum data. Biological Conservation 83: 9–17.

McElroy J.L. 2002. The impact of tourism in small islands: a global comparison. In: di Castri F. and Balaji V. (eds) Tourism, Biodiversity and Information. Backhuys Publishers, Leiden, The Netherlands, pp. 151–167.

McIntyre S. 1992. Risks associated with the setting of conservation priorities from rare plant species lists. Biological Conservation 60: 31–37.

McKinney M.L. 1999. High rates of extinction and threat in poorly studied taxa. Conservation Biology 13: 1273–1281.

McNeely J.A. 2002. The role of taxonomy in conserving biodiversity. Journal for Nature Conservation 10: 145–153.

Mittermeier R.A., Werner T.B. and Lees A. 1996. New Caledonia: a conservation imperative for an ancient land. Oryx 30: 104–112.

Mittermeier R.A., Myers N., Thomsen J.B., da Fonseca G.A.B. and Oliveri S. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12: 516–520.

Morat P. 1995. Hugh S. MacKee (1912–1995), bâtisseur de la flore de la Nouvelle-Calédonie. Bulletin du Muséum National d'Histoire Naturelle, 4, Botanique, 17: 139–148.

Morat P., Jaffré T. and Veillon J.-M. 1995. Grande Terre (New Caledonia, France). In: Davis S.D., Heywood V.H. and Hamilton A.C. (eds) Centres of Plant Diversity: A Guide and Strategy for Their Conservation. Vol. 2. WWF and IUCN, Cambridge, UK, pp. 529–537.

Morat P., Jaffré T. and Veillon J.-M. 1999. Menaces sur les taxons rares et endémiques de la Nouvelle-Calédonie. Bulletin de la Société Botanique du Centre-Ouest, N.S., Numéro spécial 19: 129–144.

Morat P., Jaffré T. and Veillon J.-M. 2001. The flora of New Caledonia's calcareous substrates. Adansonia 23: 109–127.

Mueller-Dombois D. and Fosberg F.R. 1998. Vegetation of the Tropical Pacific Islands. Springer, New York.

Myers N. 1979. The Sinking Ark: A New Look at the Problem of Disappearing Species. Pergamon, New York.

Myers N. 1988. Threatened biotas: 'hot spots' in tropical forests. The Environmentalist 8: 187–208.

Myers N. 1990. The biodiversity challenge: expanded hot-spots analysis. The Environmentalist 10: 243–56.

Myers N. 1997. Global biodiversity II: losses and threats. In: Meffe G.K., Carroll C.R. and contributors. Principles of Conservation Biology. 2nd edn. Sinauer, Sunderland, Massachusetts, pp. 123–158.

Myers N., Mittermeier R.A., Mittermeier C.G., da Fonseca G.A.B. and Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Newton A.C., Allnut T.R., Gillies A.C.M., Lowe A.J. and Ennos R.A. 1999. Molecular phylogeography, intraspecific variation and the conservation of tree species. Trends in Ecology and Evolution 14: 140–145.

Newton A., Oldfield S., Fragoso G., Mathew P., Miles L. and Edwards M. 2003. Towards a global tree conservation atlas. UNEP and WCMC/FFI, Cambridge, UK.

Oldfield S., Lusty C. and MacKinven A. 1998. The World List of Threatened Trees. World Conservation Press, Cambridge, UK.

Panzer R. and Schwartz M.W. 1998. Effectiveness of a vegetation-based approach to insect conservation. Conservation Biology 12: 693–702.

Pielou E.C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131–144.

Pintaud J.-C., Jaffré T. and Veillon J.-M. 1999. Conservation status of New Caledonia palms. Pacific Conservation Biology 5: 9–15.

Pintaud J.-C., Jaffré T. and Puig H. 2001. Chorology of New Caledonian palms and possible evidence of Pleistocene rain forest refugia. Comptes rendus de l'Académie des sciences Paris, Sciences de la vie 324: 1–11.

Pitman N.C.A. and Jørgensen P.M. 2002. Estimating the size of the world's threatened flora. Science 298: 989, supporting online table S1.

Pitman N.C.A., Jørgensen P.M., Williams R.S.R., León-Yánez S. and Valencia R. 2002. Extinction-rate estimates for a modern neotropical flora. Conservation Biology 16: 1427–1431.

Ponder W.F., Carter G.A., Flemons P. and Chapman R.R. 2001. Evaluation of museum collection data for use in biodiversity asssessment. Conservation Biology 15: 648–657.

Possingham H.P., Andelman S.J., Burgman M.A., Medellín R.A., Master L.L. and Keith D.A. 2002. Limits to the use of threatened species lists. Trends in Ecology and Evolution 17: 503–507.

Prendergast J.R., Quinn R.M. and Lawton J.H. 1999. The gaps between theory and practice in selecting nature reserves. Conservation Biology 13: 484–492.

Pressey R.L. 1994. *Ad hoc* reservations: forward or backward steps in developing representative reserve systems? Conservation Biology 8: 662–668.

Pressey R.L. and Cowling R.M. 2001. Reserve selection algorithms and the real world. Conservation Biology 15: 275–277

Puyravaud J.-P., Davidar P., Pascal J.P. and Ramesh B.R. 2003. Analysis of threatened endemic trees of the Western Ghats of India sheds new light on the Red Data Book of Indian Plants. Biodiversity and Conservation 12: 2091–2106.

Rabinowitz D. 1981. Seven forms of rarity. In: Synge H. (ed) The Biological Aspects of Rare Plant Conservation. John Wiley, New York, pp. 205–217.

Regan H.M., Colyvan M. and Burgman M.A. 2000. A proposal for fuzzy IUCN categories and criteria. Biological Conservation 92. 101–108.
Rodrigues A.S.L. and Gaston K.J. 2002. Rarity and conservation planning across geopolitical units. Conservation Biology 16: 674–682.
Sautter G. (ed) 1981. Atlas de la Nouvelle-Calédonie et Dépendances. ORSTOM, Paris, France.
Sax D.F., Gaines S.D. and Brown J.H. 2002. Species invasions exceed extinctions on islands worldwide: a comparative study of plants and birds. American Naturalist 160: 766–783.
Schatz G.E. 2002. Taxonomy and herbaria in service of plant conservation: lessons from Madagascar's endemic families. Annals of the Missouri Botanical Garden 89: 145–152.
Shaffer H.B., Fisher R.N. and Davidson C. 1998. The role of natural history collections in documenting species declines. Trends in Ecology and Evolution 13: 27–30.
Shanahan M., So S., Compton S.G. and Corlett R.T. 2001. Fig-eating by vertebrate frugivores: a global review. Biological Reviews 76: 529–572.
Sheil D. 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. Conservation Biology 15: 1179–1182.
Simberloff D. 1986. Are we on the verge of a mass extinction in tropical rain forests? In: Elliot D.K. (ed) Dynamics of Extinctions. John Wiley, New York, pp. 165–180.
Smith F.D.M., May R.M., Pellew R., Johnson T.H. and Walter K.R. 1993. How much do we know about the current extinction rate? Trends in Ecology and Evolution 8: 375–378.
Snow N. and Keating P.L. 1999. Relevance of specimen citations to conservation. Conservation Biology 13: 943–944.
Solow A.R. 1993a. Inferring extinction in a declining population. Journal of Mathematical Biology 32: 79–82.
Solow A.R. 1993b. Inferring extinction from sighting data. Ecology 74: 962–964.
ter Steege H., Jansen-Jacobs M.J. and Datadin V.K. 2000. Can botanical collections assist in a national protected area strategy in Guyana? Biodiversity and Conservation 9: 215–240.
Ungricht S., Rasplus J.-Y. and Kjellberg F. 2003. Nomenclature of the endemic monoecious fig trees (Moraceae: *Ficus* L.) of New Caledonia and Vanuatu (Pacific Ocean). Taxon 52: 319–325.
van Jaarsveld A.S., Freitag S., Chown S.L., Muller C., Koch S., Hull H. et al. 1998. Biodiversity assessment and conservation strategies. Science 279: 2106–2108.
Veillon J.-M. 1993. Protection of floristic diversity in New Caledonia. Biodiversity Letters 1: 88–91.
Walsh P.D. 2000. Sample size for the diagnosis of conservation units. Conservation Biology 14: 1422–1537.
Walter K.S. and Gillett H.J. (eds) 1998. 1997 IUCN Red List of Threatened Plants. WCMC and IUCN, Cambridge, UK and Gland, Switzerland.
WCMC 1992. Global Biodiversity: Status of the Earth's Living Resources. Chapman & Hall, London.
WCMC and IUCN 1998. 1997 United Nations List of Protected Areas. WCMC and IUCN, Cambridge, UK and Gland, Switzerland.
White C.T. 1926. Ligneous plants collected in New Caledonia by C.T. White in 1923. Journal of the Arnold Arboretum 7: 74–103.
White F. 1992. Twenty-two new and little-known species of *Diospyros* (Ebenaceae) from New Caledonia with comments on section *Maba*. Bulletin du Muséum National d'Histoire Naturelle, 4, Botanique 14: 179–222.
White F. 1993. Ebenaceae. Flore de la Nouvelle-Calédonie et Dépendances. Vol. 19. Muséum National d'Histoire Naturelle, Paris, France.
Whittaker R.H. 1972. Evolution and the measurement of species diversity. Taxon 21: 213–251.
Whitten T., Holmes D. and MacKinnon K. 2001. Conservation biology: a displacement behavior for academia. Conservation Biology 15: 1–3.
Wilkie L., Cassis G. and Gray M. 2003. A quality control protocol for terrestrial invertebrate biodiversity assessment. Biodiversity and Conservation 12: 121–146.
Willis F., Moat J. and Paton A. 2003. Defining a role for herbarium data in Red List assessments: a case study of *Plectranthus* from eastern and southern tropical Africa. Biodiversity and Conservation 12: 1537–1552.
Wright S.D. and Lees A.M. 1996. Biodiversity conservation in the island Pacific. In: Keast A. and Miller S.E. (eds) The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Processes. SPB Academic Publishing, Amsterdam, The Netherlands, pp. 445–461.