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Plant- â Diversity and Composition in Mount Nok and the Waifoi Forest of the Waigeo Raja Ampat Islands: with Special Reference to The Threatened Species

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ABSTRACT

Keragaman â dan Komposisi Tumbuhan di Hutan Gunung Nok dan Waifoi Waigeo Kepulauan Raja Ampat: Dengan Perhatian Khusus Pada Species yang Terancam Kepunahan Raja Ampat merupakan kepulauan di Papua Barat yang terdiri atas sekitar 610 pulau; empat di antaranya merupakan pulau besar (Waigeo, Salawati, Batanta, dan Misool). Ekspedisi dan studi ekologi dilakukan di Gunung Nok dan Hutan Waifoi (Pulau Waigeo) pada tahun 2007. Tujuan ekspedisi ini adalah untuk mempelajari komposisi dan keragaman beta (â-*diversity*) flora Gunung Nok dan Hutan Waifoi yang merupakan area penting di Cagar Alam Pulau Waigeo Timur; mengkaji status populasi dari spesies-spesies endemik atau yang terancam kepunahan; serta mempelajari karakteristik habitat flora endemik atau terancam kepunahan . Survei komposisi dan kelimpahan populasi dilakukan dengan menggunakan metode cuplikan sabuk transek (*transect belts*) dan kuadrat yang disusun secara sistematis bergantian di ke dua sisi sabuk transek di dua lokasi penelitian. Formasi dan keragaman beta vegetasi Gunung Nok diobservasi dengan cara menetapkan titik-titik pengamatan berdasarkan perbedaan karakteristik komunitas vegetasi di sepanjang gradien gunung. Identitas spesies dan posisi keberadaannya dalam strata kanopi dicatat dan diobservasi. Sebanyak 554 *records* tumbuhan berhasil dikoleksi dari lokasi penelitian; lima spesies merupakan tumbuhan endemik Waigeo (*Guioa waigeoensis*, *Alstonia beatricis*, *Calophyllum parvifolium*, *Schefflera apiculata*, dan *Nepenthes danseri*) yang semuanya berkategori terancam kepunahan, sedangkan 42 spesies merupakan endemik New Guinea. *Dendrobium* dan *Bulbophyllum* merupakan dua marga anggrek yang paling beragam berdasarkan jumlah spesies yang ditemukan.

Kata kunci: Keragaman β, komposisi tumbuhan, spesies terancam kepunahan, Gunung Nok, Hutan Waifoi, Waigeo

INTRODUCTION

Raja Ampat is a group of four large islands (namely Waigeo, Batanta, Salawati, and Misool) with more than 600 smaller islands. The islands are located and scattered off the western tip of the Bird's Head of New Guinea and administrated by the West Papua Province of Indonesia. The waters and environment around the Islands have been known as the most biologically diverse marine area in the world, especially in terms of coral reefs and fish

species (Webb 2005; Pemkab Raja Ampat & CI 2006). However, despite for being a biologically very rich area, little is known about the Islands of plant diversity and terrestrial resources (Bappenas 2003; Webb 2005). Detail plant expeditions and surveys focusing on the beta diversity will therefore provide important baseline data for managing and conserving biodiversity sustainablyof the Islands (Webb 2005). Current situations show that higher elevations are vital refuge areas for the survival of many species (both for plants and animals) as much of the lower areas have been disturbed and converted into various land uses. By recording the biodiversity and characteristics occurred along gradient and elevation of a mountain area the total potential will be known, and thus conservation action plans can consequently be constructed effectively.

Geologically the Raja Ampat Islands is also very interesting, by having extensive karst ecosystems, alluvium substrates, acid volcanic and ultrabasic rocks, as well as a number of relatively high mountains (Jepson & Whittaker 2002; Webb 2005; Pemkab Raja Ampat & CI 2006). The floristic diversity is high due to heterogenous substrate conditions, biogeographical factors, and diverse habitat types which range from submontane forests, via forests on karst and acid volcanics, to sago swamps and mangroves. The ultrabasic scrub of Waigeo Island is unique and widely known for its endemic species (Webb 2005). Hill forests on volcanic substrates and karst formations extensively occur in this island. Each island of the Raja Ampat has its own characteristics, especially in terms of vegetation composition and habitat types (BKSDA Papua II 2003). Undoubtedly, the Raja Ampat is botanically very important and valuable, despite their relatively small size compared to the main island Papua (Johns 1995; Johns 1997ab; CI 1999; Webb 2005).

The conservation status of the Raja Ampat Islands is also unique, i.e. the population density is very low, the villagers in general have great concern to conserve their lands, and the traditional government system is still highly influential (Webb 2005). Over the past twenty years, logging had been extensive in a number of areas of the Islands and even almost exhaustive in the lowlands. However, some of the prior logging was relatively light, searching primarily for large trees of Merbau: *Intsia bijuga* and *I. palembanica* (Webb 2005), and thus the potential for the Raja Ampat Islands remains relatively intact. Preventing logging and mining companies to disturb the Islands' key conservation areas is indeed crucial if we intend to sustain the invaluable biodiversity contained.

As part of a larger expedition team called "Ekspedisi Widya Nusantara" organised by the Indonesian Institute of Sciences (LIPI), an expedition team from the Centre For Plant Conservation Bogor Botanic Gardens had surveyed and conducted a floral collecting trip to Mount Nok ("Mt. Buffelhorn") and the Waifoi forest of Waigeo Island from 11 June to 9 July 2007.

The aims of the expedition were: 1) to elucidate the plant β-diversity and

composition of Mount Nok and the Waifoi forest (East Waigeo Nature Reserve), 2) assess the population status of the threatened or endemic species found, and 3) describe their habitat characteristics in order to understand their ecological preferences for conservation action purposes.

MATERIAL AND METHODS

Study and Exploration Area

The study area and expedition locations were focused on the Waifoi Forest and the slope of Mount Nok area within the East Waigeo Island Nature Reserve, the Raja Ampat Islands, at altitudes range from 20 to 630 m above sea level. Bomat Isthmus was also explored but only for the purpose of threatened plant collection. Waifoi Village (Waigeo) was used as the entry point to the Nature Reserve, while the camp established at Kamtabae River (E $130^0$43'38.2" S $0^0$5'53.3") was used as the reference point to explore the surrounding forests. Different directions comprising all four aspects were covered in order to comprehensively cover the study and exploration areas. Hill and lower mountain forests (with slopes ranging from 30 to 70%) dominated the inland nature reserve topography.

East Waigeo Island Nature Reserve was established in 1996 based on the decree of the Indonesian Minister of Forestry No. 251/Kpts-II/1996 covering a total area of 119,000 hectares, located between E $130^0$33'51" and E $130^0$55'54" and between S $0^0$02'27" and S $0^0$08'51". Rainfall recorded at a station on Saunek (Waigeo) was 1.5 m. y^{-1}. The wettest months are April to September.

Vegetation structure and composition

The study area covers: 1) two hectares of mixed age indigenous forest located on top of the Manitalu hill forest within the reserve at an altitude of 183 m, and 2) a gradient along the mount Nok

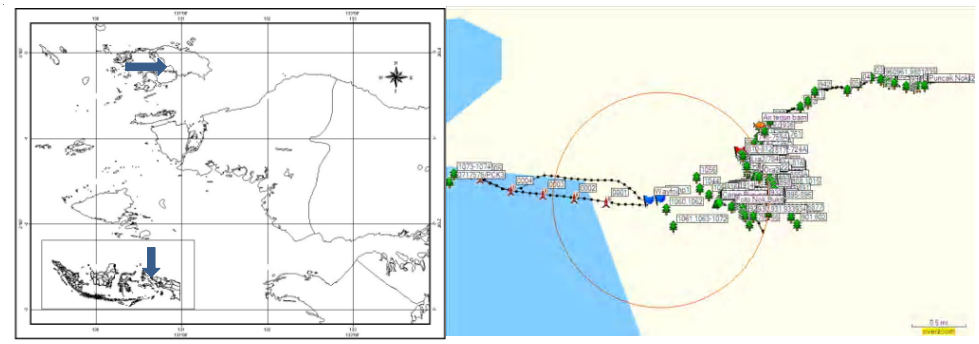

Figure 1. Map of Waigeo Island (left, source: Google 2007) and the detail locations studied in the island (right, with green tree symbols). Coordinates and elevations of all locations (localities) observed were recorded using a GPS. Waifoi village is located at the center of the circle (blue flags), Bomat Isthmus is located at the left most, and the top of Mount Nok is at the right most.

slope started from the Kamtabae River (20 m asl) to the shoulder of the mount Nok at an altitude of 630 m asl. Two belt transects (of 100 m x 10 m each) were established on the Manitalu hill forest and one transect of the same size (100 m x 10 m) was developed on each elevation of the mount Nok to sample the plant composition (formation) and abundance with the major axis orientated north-south derived from a selected compass bearing (Krebs 1989; Cropper 1993). Thus there were 10 quadrats (of 10 m x 10 m) on each elevation. A belt transect of 100 m x 10 m was used because it is an effective, operational size to operate (Ludwig & Reynolds 1988; Krebs 1989). Yet all existing trees within 5 m either side of the major axis of a transect can still be recognized. A series of 26 quadrats (of 2 m x 2 m each) were established at each of the two belt transects established on the Manitalu hill forest to record seedling and shrub composition (following Mueller-Dombois & Ellenberg 1974, Cox 1974, Sokal & Rohlf 1981). Quadrats were arranged systematically in an alternating pattern within the two belt transects developed in order to cover uniformly both sides of the axes (Ludwig & Reynolds 1988).

Each individual tree and sapling within all belt transects developed was identified, the diameter was measured at breast height using a diameter tape, and the relative frequency, relative density, relative dominance, and importance value were calculated using the standard formulas for vegetation analysis (Cox 1974, Krebs 1989). Abundance was calculated by using the density parameter, i.e. number of individuals found within a sampled area (Cropper 1993). Species identity and position in the canopy strata, either main canopy (height $\geq$ 25 m), subcanopy (consisting of two layers: upper subcanopy 15-25 m and lower subcanopy 5-15 m), or understorey (<5 m) were recorded. Damaged or dead plants were not included as their identity would be undescribed. The location of each belt transect was recorded using a Garmin Global Positioning System MAP 175. Land slopes were measured using a clinometer (SUUNTO Optical Reading Clinometer PM-5 made in Finlandia), while soil pH and humidity were measured using a soil tester DEMETRA patent no. 193478 Electrode Measuring System, Tokyo, Japan.

RESULTS

A total of 554 plant records (specimens) were collected from three sites: Kamtabae River, Mount Nok and Bomat Isthmus. However, the results of vegetation analysis included in this study were only from Kamtabae River and Mount Nok while those of Bomat Isthmus were excluded for separate publication. Specimens collected from Bomat Isthmus were highlighted here due to their high conservation values, including *Nepenthes danseri*. Five species found are endemic to Waigeo Island (*Guioa waigeoensis*, *Alstonia beatricis*, *Calophyllum parvifolium*, *Schefflera apiculata*, and *Nepenthes danseri*) and 42 species endemic to New Guinea. The five endemic species have been regarded as threatened by the IUCN (2000, 2008).

Based on the Indonesian Botanic Gardens' Catalogues (1999, 2001), 72 species of the 554 plant records have been determined as new collections for the Indonesian Botanic Gardens. Some living specimens of the new palm species (*Livistona brevifolia*) firstly described by Dowe and Mogea in 2004 from Kawe Island were also found and collected from the Bomat Isthmus, Waigeo.

Vegetation structure of lowland forest

Lowland forest of Waigeo (or New Guinea in general) possesses Malesian characteristics, but without the dominance of dipterocarps. Based on the importance values (Table 3), the forest main canopy was mainly dominated by *Pometia pinnata*, *Tabernaemontana auricantiaca*, *Palaquium obovatum, Celtis philippinensis*, *Intsia bijuga*, *Vatica rassak*, *Semecarpus macrocarpa*, *Artocarpus altilis*, and *Koordersiodendron pinnatum*. The subcanopy mainly consisted of *Pimend lodendron amboinicum*, *Myristica lancifolia*, *Drypetes longifolia*, *Pometia pinnata*, *Syzygium* sp., *Harpulia ramiflora*, *Lansium domesticum*, *Dysoxylum arborescens*, *Cynometra novoguineensis*, *Orania regalis*, and *Dillenia papuana*. Dominat lower subcanopy included small trees and shrub *Aglaia lawii*, the small palms *Licuala gramnifolia* and *Sommieria leucophylla, Ixora kerstingii*, *Garcinia dulcis*, *Maniltoa rosea*, and *M. plurijuga*, while dominant understorey species on the forest floor included *Pandanus* sp., *Elatostema polioneurum*, and the ferns *Nephrolepis dufii* and *Selaginella wildenowii*. Most of the land was composed by laterit ultrabasic soil.

Plant species diversity on hill forest

Hill forests seemed to be moister than forests lower down and the canopy was generally broken and fairly open. These forests indicated species turnover (transition) between lower and higher forests. Although the abundance of each individual species varied significantly, *Decaspermum fruticosum*, *Planchonella catartea*, *Garcinia latíssima*, and *Rhodamnia cinerea* were clearly the most dominant species on this mid-elevation forest class, as shown by their basal area values (Table 1, Figure 2). On the other hand, *Gynotroces axillaris*, *Smilax leucophloa*, *Dysoxylum parasiticum*, *Casuarina rumphiana*, and the Waigeo-endemic species *Alstonia beatricis* consisted of small populations. Interestingly, the population size of the threatened, Waigeo-endemic species *Guioa waigeoensis* was relatively large locally, although the populations tended to clump. The importance value of this species was significantly high (Table 1). In comparison with *G. waigeoensis* (28 plants ha^{-1}), the population size of *A. beatricis* (4 plants ha-1) was much smaller, as shown by its abundance (density). The small population status together with the absence of its seedlings indicated that *A. beatricis* was facing a serious problem to establish. The absence of the seedlings might be due to certain inhibiting factors faced during the seed germination stage. Further research is required to reveal this

phenomenon. Unlike the two endemic species, the populations of *Myrsine rawacensis*, *Pimeleodendron amboinicum* and *Cryptocaria infectonia* were fairly abundant (Figure 2).

Table 2 showed plant species composition (formation) at different elevations on Mount Nok, Waigeo Island, the Raja Ampat Islands. In general, species formation varied with elevations (along the gradient), on which lowland species differed significantly from those of hill and higher lands (i.e. lower montane areas). However, no areas of the Raja Ampat Islands were higher than 1,000 m. Interestingly, pseudomontane vegetation existed on tops of the hills occupying altitudes from 100 m to 200 m. This was shown by the occurrence of the commonly high-inland occupying species, such as *Casuarina rumphiana*, *Decaspermum fruticosum*, *Castanopsis acuminata* and *Livistona rotundifolia*. These species were able to grow at much lower elevations on the island constituting the so-called pseudomontane vegetation, although their densities were relatively low, especially *C. rumphiana* and *L. rotundifolia* (Table 3). The width of their ecological amplitude or their ability to tolerate different climatic conditions might be the case. The proximity of the mountains particularly the forest edges to the ocean created dynamic climatic conditions and might be the driving force to form the "Massenerhebung effect". Mountains surrounded by large ranges tended to

Table 1. Frequencies, densities and basal areas of dominant tree species on Manitalu hill forests (Kamtabae River) within East Waigeo Nature Reserve.

Species	Frequency	Density (individuals ha^{-1})	BA (m^2 ha^{-1})	Importance Value
Alstonia beatricis	0.23	4	0.01	2.42
Rhodamnia cinerea	0.80	30	1.28	6.24
Garcinia latissima	0.69	30	1.33	6.48
Dysoxylum parasiticum	0.23	3	0.15	2.59
Decaspermum fruticosum	0.76	37	1.08	8.57
Planchonella catartea	0.76	34	1.48	8.25
Nephelium cuspidatum	0.38	10	0.30	1.88
Pimeleodendron amboinicum	0.54	20	1.03	6.02
Salacia macrophylla	0.54	9	0.70	3.73
Casuarina rumphiana	0.15	3	0.01	2.02
Cryptocaria infectonia	0.46	25	0.90	5.84
Myrsine rawacensis	0.54	16	0.01	3.54
Buchanania papuana	0.23	4	0.15	2.26
Gynotroces axillaris	0.08	1	0.01	1.10
Guioa waigeoensis	0.46	28	1.28	6.07
Ploiarium alternifolium	0.23	3	0.01	1.22
Northea fasciculata	0.15	4	0.01	1.26

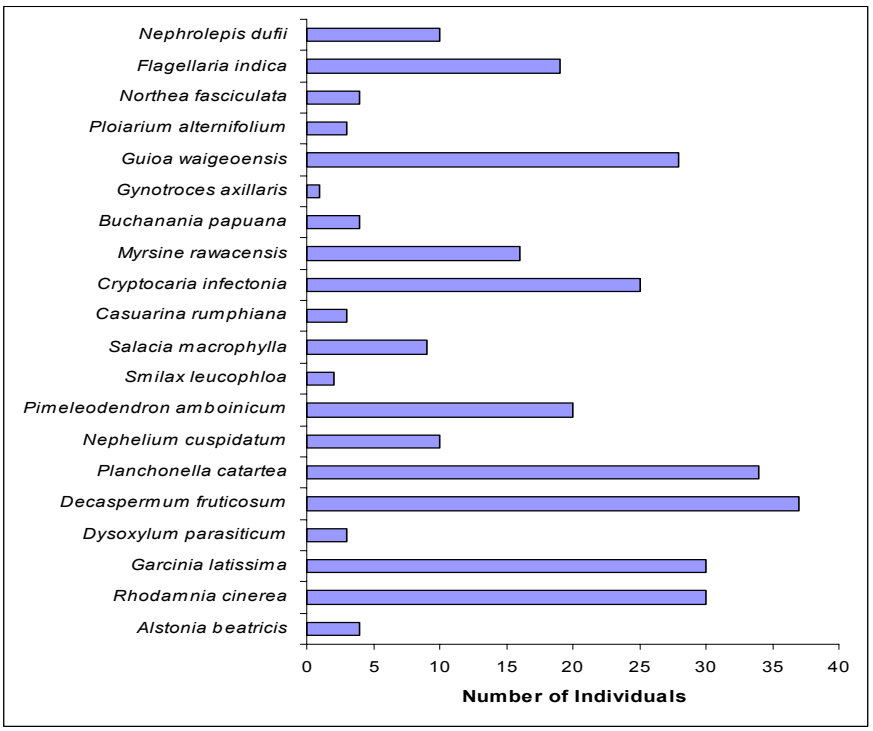

Figure 2. Composition and abundance of plant species occurred on Manitalu hill forests within East Waigeo Nature Reserve (Kamtabae River and the surrounding areas).

have higher tree lines than more isolated mountains (like Mount Nok) due to heat retention and wind shadowing (MacKinnon *et al.* 1996). The pseudomontane areas of Mount Nok seemed to be the most suitable habitats of the Island endemic plant species.

Table 3 showed the abundances of dominant plant species occurred along the altitudinal gradient of Mount Nok, East Waigeo Nature Reserve. While the abundance of most species varied significantly with elevation, that of *Licuala graminifolia* was consistently high along the gradient. *Tabernaemontana aurantiaca, Pometia pinnata*, and *Palaquium obovatum* seemed to dominate lowland areas, while *Celtis philippinensis* and *Intsia bijuga* dominated higher sites. However, the populations of *Intsia bijuga*, *Vatica rassak* and *Nagaia wallichii* seemed to be scattered, with some relatively large colonies were found above 400 m. Small colonies of the threatened species *Schefflera apiculata* and *Calophyllum parvifolium* were found above 600 m above sea level. Interestingly, *Castanopsis acuminata* was one of the most abundant tree species on 400-500 m as this species commonly occurs in much higher altitudes.

In general, the soil thickness varied significantly from site to site, from shallow

Table 2. Plant species composition (formation) at different elevations (β-diversity) on Mount Nok, Waigeo Island, the Raja Ampat Islands, West Papua.

Elevation (m asl)	Species composition (formation)	Dominant species
20 - 100	*Tabernaemontana aurantiaca, Pometia pinnata, Palaquium obovatum, Celtis philippensis, Intsia bijuga, Vatica rassak, Orania regalis, Licuala graminifolia, Orania regalis, Pandanus tectorius, Semecarpus macrocarpa, Artocarpus altilis, Syzygium malaccensis, Psychotria tripendumculata, Dillenia papuana*, and *Sommieria leucophylla.* Further inland*, Hydriastele costata* sometimes occurred.	*Tabernaemontana aurantiaca, Pometia pinnata, Palaquium obovatum, Celtis philippensis, Intsia bijuga, Vatica rassak, Licuala graminifolia,* and *Orania regalis.*
100-200 Hill tops	*Rhodamnia cinerea, Garcinia latissima, Decaspermum fruticosum, Planchonella catartea, Guioa waigeoensis, Licuala graminifolia, Exocarpus latifolius, Cryptocaria infectoria, Semecarpus macrocarpa, Myrsine rawacensis, Casuarina rumphiana, Psychotria tripendumculata, Pimeleodendron amboinicum, Intsia bijuga, Artocarpus altilis,* and *Livistona rotundifolia* very rarely found.	*Rhodamnia cinerea, Garcinia latissima, Decaspermum fruticosum, Planchonella catartea, Guioa waigeoensis*, and *Licuala graminifolia.* PSEUDOMONTANE VEGETATION *Casuarina rumphiana* occurred.
270	*Calophyllum persemile, C. grandiflorum, Pometia pinnata, Artocarpus integer, Licuala graminifolia, Lasianthus purpureus, Knema* sp.*, Gnetum* sp.*, Actinodaphne* sp.*, Gyrinops* sp.*,* and *Canarium* sp.	*Calophyllum persemile, C. grandiflorum, Pometia pinnata, Artocarpus integer, Licuala graminifolia,* and *Lasianthus purpureus.*
350	*Nagaia wallichii, Schima wallichii, Rhodamnia cinerea, Canarium* sp.*, Gironniera* sp.*, Garcinia* sp.*,* and *Fagraea* sp.	*Nagaia wallichii, Schima wallichii, Rhodamnia cinerea,* and *Canarium* sp.
460	*Castanopsis acuminata, Symplocos fasciculata, Celtis philippinensis, Vatica rassak, Pometia pinnata, Parkia* sp.*, Gironniera* sp.*,* and *Pandanus tectorius.*	*Castanopsis acuminata, Symplocos fasciculata, Celtis philippinensis, Vatica rassak,* and *Pometia pinnata.*
545	*Celtis philippinensis, Poliosma ilicifolia, Pangium edule, Palaquium* sp.*, Calophyllum persemile, Pandanus* sp.*, Actinodaphne* sp.*, Elaeocarpus* sp.*, Helicia* sp.*, Heritiera javanica, Smilax* sp.*, Inga* sp.*, and Calyptrocalix* sp. The orchid *Phalaenopsis amabilis* scattered, small population.	*Celtis philippinensis, Poliosma ilicifolia, Pangium edule, Palaquium* sp.*, Calophyllum persemile, Pandanus* sp.*, Actinodaphne* sp.*,* and *Elaeocarpus* sp.
560	*Intsia bijuga, Celtis philippinensis, Calophyllum persemile,* and *Castanopsis acuminata.* Some orchid populations abundant, growing on very steep, narrow mount ridges *(Dendrobium macrophyllum, D. amboinensis, Ceratostylis* sp.*, Cadetia* sp.*, Eria javanica, Thelasis* sp.*, and Appendicula* sp.*).* Begonias grew very well.	*Intsia bijuga, Celtis philippinensis, Calophyllum persemile,* and *Castanopsis acuminate.*
630	*Wendlandia* sp.*, Phytosporum ramiflorum, Heritiera javanica, Intsia bijuga, Oleandra* sp. The endemics *Schefflera apiculata* and *Calophyllum parvifolium* found. Rocky habitats, very steep, land slides easily, slope 80-90%. Cliff walls were formed by rock piles, united by plant root systems.	*Wendlandia* sp.*, Phytosporum ramiflorum, Heritiera javanica,* and *Intsia bijuga.*

(16 cm) to very thick (more than 1.5 m). The shallow soils commonly occurred on top of hills, consequently the plants were rarely tall and the roots seemed to be short and small. *Decaspermum fruticosum*, *Planchonella catartea*, and *Garcinia latíssima* were the most abundant species on this shallow soils. Broken and open canopy was common, especially on steep slopes. In contrast, taller and larger trees mainly occurred on lowland forests, particularly on the alluvial soils (such as *Pimelodendron amboinicum*, *Vatica rassak*, *Palaquium obovatum*, and *Celtis philippensis*) and volcanic soils (such as *Intsia bijuga*, *Pometia pinnata*, and *Koordersiodendron pinnatum*). Soil textures generally consisted of clayed-silt and sandy-silt formations, describing the most extensive lowland vegetation on Waigeo. Detail results of the soil laboratory analysis were reported separately.

DISCUSSIONS

Five species found have been regarded as threatened and vulnerable to extinction, indicating an urgent conservation action to carry out. *Alstonia beatricis* or Pulai Waigeo (the IUCN Category: VU D2) and *Schefflera apiculata* (VU D2) are endemic to Waigeo. Both species constituted small scattered populations and even suppressed in the case of *A. beatricis*. *A. beatricis* is a small tree occurring only on tops of the island hills and preferring a dry, relatively open habitat. *S. apiculata* occurred on the slopes of Mount Nok at an altitude of 600 to 700 m. The species leaf characteristics were interesting compared to those of other members of the genus *Schefflera*.

The threatened pitcher plant *Nepenthes danseri* (VU B1+2b) was found in Bomat Isthmus (Waigeo) occupying a very dry open karst habitat, with an average air humidity of 25 per cent and temperature of 33^0C during the day time in June 2007. Most individuals occurred on very steep slopes ranging from 70 to 80 per cent, growing on ultrabasic soils (pH > 7.2) and coexisting with *Casuarina rumphiana*, *Decaspermum bracteatum*, *Baeckea fruticans*, *Styphelia abnormis*, and *Pinanga rumphianum*. *Guioa waigeoensis* and *Calophyllum parvifolium* populations were also vulnerable (VU D2) showing a clumped spatial distribution pattern. However, ecological information about these two threatened species is still very limited.

Potential and attractive species and their conservation values

Economically potential small palms collected include *Sommieria leucophylla*. The individuals of this species showed different leaf colours, in which two variants have been recorded in terms of the abaxial leaf surface colour (some were green while others were grey). Taxonomically, this is an interesting discovery requiring further investigation. The other economically promising small palms found were *Areca macrocalyx*, *Dransfieldia micrantha*, and *Pinanga rumphianum*.

Partly soil types seemed to determine plant species composition, both

Table 3. Relative frequencies, densities and dominances of plant species occurred at different elevations on Mount Nok, East Waigeo Nature Reserve, Waigeo.

Elevation (m asl)	Species	Relative Frequency	Relative Density	Relative Dominance	Importance Value
20-100	*Tabernaemontana aurantiaca*	4.62	6.41	8.28	19.31
	Pometia pinnata	3.75	7.22	6.81	17.78
	Palaquium obovatum	3.44	4.48	5.24	13.16
	Celtis philippensis	2.85	3.25	4.82	10.92
	Intsia bijuga	1.46	2.97	4.43	8.86
	Vatica rassak	2.10	2.38	4.33	8.81
	Licuala graminifolia	4.11	4.64	0.04	8.79
	Orania regalis	2.31	3.22	2.06	7.59
	Pandanus tectorius	2.44	2.41	1.35	6.20
	Semecarpus macrocarpa	2.32	1.82	1.46	5.60
	Artocarpus altilis	2.19	1.61	1.62	5.42
	Syzygium malaccensis	1.38	1.60	1.66	4.64
	Psychotria tripendumculata	1.07	2.13	1.38	4.58
	Dillenia papuana	0.92	1.27	1.40	3.59
	Sommieria leucophylla	1.26	2.08	0.02	3.36
	Hydriastele costata	0.64	1.01	0.42	2.07
	Other species (52)	63.14	51.50	54.68	169.32
100-200	*Rhodamnia cinerea*	5.03	7.02	0.22	12.25
	Garcinia latissima	4.52	5.23	1.33	11.08
	Decaspermum fruticosum	3.36	6.71	0.85	10.92
	Planchonella catartea	4.11	6.01	0.76	10.88
	Guioa waigeoensis	3.32	4.19	1.64	9.15
	Licuala graminifolia	4.60	4.42	0.02	9.04
	Exocarpus latifolius	3.24	4.01	1.45	8.70
	Cryptocaria infectoria	2.43	3.88	1.10	7.41
	Semecarpus macrocarpa	1.19	3.02	1.22	5.43
	Myrsine rawacensis	1.58	2.71	1.01	5.30
	Casuarina rumphiana	1.48	2.26	1.25	4.99
	Psychotria tripendumculata	1.64	2.01	1.30	4.95
	Pimeleodendron amboinicum	1.16	1.84	1.04	4.04
	Intsia bijuga	0.74	1.18	2.08	4.00
	Artocarpus altilis	0.81	1.22	1.67	3.70
	Livistona rotundifolia	0.38	1.01	1.18	2.57
	Other species (58)	60.41	43.28	81.88	185.57
	Calophyllum persemile	4.53	6.83	6.26	17.62
	Calophyllum grandiflorum	4.34	5.02	6.47	15.83

Table 3. Continued

Elevation (m asl)	*Species*	Relative Frequency	Relative Density	Relative Dominance	Importance Value
270	*Pometia pinnata*	3.26	6.29	4.81	14.36
	Artocarpus integer	3.71	5.47	2.28	11.46
	Licuala graminifolia	5.17	4.72	0.06	9.95
	Lasianthus purpureus	4.15	4.03	0.86	9.04
	Knema sp.	4.01	2.81	1.88	8.70
	Gnetum sp.	2.31	3.22	1.88	7.41
	Actinodaphne sp.	2.96	2.30	0.17	5.43
	Gyrinops sp.	2.73	1.43	1.14	5.30
	Canarium sp.	0.94	2.02	1.03	3.99
	Other species (46)	61.89	55.86	73.16	190.91
350	*Nagaia wallichii*	6.57	5.81	4.24	16.62
	Schima wallichii	4.33	6.04	4.46	14.83
	Rhodamnia cinerea	4.27	5.27	3.82	13.36
	Canarium sp.	2.78	3.41	3.27	9.46
	Gironniera sp.	3.12	4.37	0.46	7.95
	Garcinia sp.	2.04	2.14	2.86	7.04
	Fagraea sp.	3.82	1.81	1.08	6.71
	Other species (42)	73.07	71.15	79.81	224.03
460	*Castanopsis acuminata*	7.17	6.83	4.22	18.22
	Symplocos fasciculata	5.36	4.02	6.45	15.83
	Celtis philippinensis	3.29	3.24	4.83	11.36
	Vatica rassak	3.76	3.27	3.43	10.46
	Pometia pinnata	4.15	4.32	0.48	8.95
	Parkia sp.	3.14	2.05	2.85	8.04
	Gironniera sp.	2.86	2.81	2.04	7.71
	Pandanus tectorius	2.41	1.54	2.49	6.44
	Other species (45)	67.86	71.92	73.21	212.99
545	*Celtis philippinensis*	5.51	6.52	5.28	17.31
	Poliosma ilicifolia	3.46	7.51	5.81	16.78
	Pangium edule	2.36	3.56	4.24	10.16
	Palaquium sp.	2.46	3.65	3.81	9.92
	Calophyllum persemile	1.89	1.53	3.44	6.86
	Pandanus sp.	2.27	1.22	3.32	6.81
	Actinodaphne sp.	2.32	4.46	0.01	6.79
	Elaeocarpus sp.	2.42	2.14	2.03	6.59
	Helicia sp.	1.23	2.65	1.32	5.20
	Heritiera javanica	1.63	1.56	1.41	4.60
	Inga sp.	2.54	1.25	0.63	4.42
	Smilax sp.	0.44	1.58	0.62	2.64
	Calyptrocalix sp.	1.17	1.27	0.14	2.58

Table 3. Continued

Elevation (m asl)	Species	Relative Frequency	Relative Density	Relative Dominance	Importance Value
	Other species (41)	70.30	61.10	67.94	199.34
560	*Intsia bijuga*	6.53	6.53	5.25	18.31
	Celtis philippinensis	4.44	7.01	4.83	16.28
	Calophyllum persemile	3.38	3.55	4.23	11.16
	Castanopsis acuminata	2.43	4.25	2.84	9.52
	Other species (48)	83.22	78.66	82.85	244.73
630	*Wendlandia* sp.	5.71	4.32	4.28	14.31
	Phytosporum ramiflorum	3.76	6.21	3.81	13.78
	Heritiera javanica	2.48	3.44	3.24	9.16
	Intsia bijuga	2.76	2.35	2.81	7.92
	Oleandra sp.	1.79	1.63	2.44	5.86
	Schefflera apiculata	1.67	2.12	1.02	4.81
	Calophyllum parvifolium	0.87	0.96	1.01	2.84
	Other species (43)	80.96	78.97	81.39	241.32

in Mount Nok and the Waifoi forest. Species compositions occurred on volcanic and karst formations were considerably different. *Pometia pinnata*, *Tabernaemontana auricantiaca*, *Artocarpus altilis*, *Intsia bijuga*, *Vatica rassak*, *Rhodamnia cinerea*, *Decaspermum fruticosum*, and *Planchonella catartea* grew very well on volcanic substrates. The palm species *Licuala graminifolia*, *Orania regalis* and *Sommieria leucophylla* also preferred these substrates. On the other hand, the palms *Hydriastele costata* (synonym: *Gulubia costata*) and *Livistona brevifolia* habitat preferences were clearly dry karst habitats particularly ultrabasic rocks.

Hydriastele costata seemed to be a prominent indicator species of the karst ecosystem. On the other hand, *Hydriastele rhopalocarpa* occurred on inland hill forests on volcanic substrates. Palms are indeed important elements of many tropical forests and often show specific ecological preferences (Tomlin-son 1979; House 1984) and local or regional patterns of association (Kahn & Mejia 1990; Moraes 1996; Svenning 1999). Some palm species appear to be adapted to specific edaphic conditions, such as soil formation, quality, type, and drainage (House 1984; Moraes 1996).

A number of attractive species were also found, including *Maniltoa rosea*, *M. plurijuga*, *Pothos scandens*, *Tapeinocheilos* sp., and the broad leaf species *Dillenia papuana*. Promising species for their economic uses occurred on the Nature Reserve include *Cynometra novoguineensis*, *Piper* sp., and *Raphidophora* sp. Valuable orchids were also recorded including *Dendrobium macrophyllum*, *Dendrobium lasianthera*, and *Dendrobium capituliflorum*. Most orchid species occurred on Mount Nok and Kamtabae River were epiphytic, comprising 103

different species. In contrast, the terrestrial species found at the same sites were only 31 species. *Dendrobium* and *Bulbophyllum* were the most diverse genera in these two localities, indicated by their greatest species numbers found, consisting of 32 and 16 species respectively. Most orchid individuals lived on the upper parts of trunks or stems of the host trees.

CONCLUSIONS

Five plant species found (*Alstonia beatricis*, *Schefflera apiculata*, *Nepenthes danseri*, *Guioa waigeoensis*, and *Calophyllum parvifolium*) have been regarded as threatened, indicating their urgent conservation actions. The pitcher plant *N. danseri* found in Bomat Isthmus seemed to be very vulnerable to extinction locally due to its current threats and habitat vulnerability. In order to conserve these threatened species the persistence of their coexisting species and protected habitat are very crucial. The populations of some of the threatened species were dominated by young plants, reflecting a growing population in which regeneration and recruitment still continue in some sites. However, habitat conversion and human disturbance clearly threatened the persistence of these species. Population sizes and structures of the threatened and endemic species varied spatially with volcanic and karst formations being the most favourable habitat in which most of the species occurred. By protecting these types of habitat, the threatened and endemic species populations will be sustained for a long term. This information can be used to set criteria and priorities for protecting representative suitable sites both within and outside the nature reserve. As seedlings and young plants in several locations were suppressed or even absent, *in situ* management should focus on monitoring and managing the survival of the young stages to assist them to establish successfully. Given expected patterns of forest disturbance and conversion over the next few decades, the most important step is to protect high quality habitat in dedicated conservation reserves.

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