Rapid Assessment Program

RAP
Bulletin
of Biological
Assessment
45

A Rapid Biodiversity Assessment of the Kaijende Highlands, Enga Province, Papua New Guinea

Stephen J. Richards
(Editor)

Center for Applied Biodiversity Science (CABS)

Conservation International

Conservation International – Papua New Guinea

Papua New Guinea Department of Environment and Conservation

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Organizational Profiles

CENTER FOR APPLIED BIODIVERSITY SCIENCE (CABS)

The Center for Applied Biodiversity Science (CABS), the scientific hub of Conservation International, works to link science and action to guide the conservation of nature worldwide.

Conservation initiatives have garnered significant political support in the last quarter century, as is evident in the international consensus around instruments such as the 1992 Convention on Biological Diversity. Political and economic support alone, however, is not enough to preserve the Earth's dwindling biodiversity. The conservation community can only be effective if it is equipped with clear goals, objectives, and strategies grounded in reliable and verifiable scientific research. There is still much to learn about the Earth's natural diversity, its role in ecosystem function and related services, and the most effective ways to preserve it.

Scientists at CABS work to fill these knowledge gaps. Founded in 1999 with generous support from the Gordon and Betty Moore Foundation, CABS brings together a staff of more than 70 research scientists who are highly respected in their fields and dedicated to saving our biodiversity.

CONSERVATION INTERNATIONAL

Conservation International (CI) is an international, non-profit organization based in Arlington, VA. CI's mission is to conserve the Earth's living natural heritage, our global biodiversity, and to demonstrate that human societies are able to live harmoniously with nature.

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CONSERVATION INTERNATIONAL – PAPUA NEW GUINEA

CI-PNG is a non-profit organization working to identify high priorities for conservation in Papua New Guinea. CI works in collaboration with land/marine owners and other key stakeholders including Provincial Governments, Local Level Governments, the Department of Environment and Conservation, the National Fisheries Authority, the private sector and other NGOs. CI-PNG focuses on biodiversity research and surveys, establishment of protected areas, environment and conservation education and awareness, community livelihood programs, and good governance and institutional strengthening programs with the aim of building community-based capacity for long term management of high-priority conservation sites.

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PAPUA NEW GUINEA DEPARTMENT OF ENVIRONMENT AND CONSERVATION (DEC)

The Department of Environment and Conservation has the statutory responsibility to survey, document and preserve Papua New Guinea's biological diversity. The central office is in the capital Port Moresby but the Department has representatives based at major resource projects throughout PNG and staff are involved in a variety of conservation initiatives around the country.

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SOUTH AUSTRALIAN MUSEUM

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This survey was instigated through discussions between Porgera Joint Venture (PJV) and Conservation International and funding for the project was provided by grants to Conservation International from the Gordon and Betty Moore Foundation and PJV. PJV (formerly of Placer Dome and now of Barrick) provided tremendous logistical support that ensured the survey was an outstanding success. We are particularly grateful to Charles Ross, Tim Omundson, Robert Cogger, Jim McNamara and Ikising Petasi of PJV for their ongoing support. Ikising Petasi of the PJV Environment Department undertook the complex and often difficult task of field logistics and Joel More Polaiya from PJV Community Affairs worked day and night to drive us to cold, rainy, and remote survey localities. The PJV Community Affairs personnel were most helpful in providing liaison with local communities, and Peter Bosip (CI-PNG) also assisted with the initial community consultation process prior to the survey. Gai Kula (CI-PNG), Andrew Beehler, Paulus Kulmoi (DEC), Ali Towati and Demas Ama also contributed substantially to the success of this project.

We are most grateful to the Papua New Guinea Department of Environment and Conservation (DEC) and the Enga Provincial Government for approving this project, and to Barbara Roy of DEC for approving our export permits. DEC laid the ground-work for this project through their early recognition that this area is of outstanding conservation value, a fact reflected in their recommendation that the Kaijende Highlands should be considered for protection in a Conservation Area.

Production of this RAP report was facilitated by Conservation International's RAP program, particularly Peter Hoke, Leeanne Alonso and Jennifer McCullough. Mark Denil of Conservation International's Mapping Program kindly produced the excellent map of the study area. Deidre Fogg, of CI's Melanesia Program, also provided important support for the initiative. Finally, Kristofer Helgen would like to thank Pat Wooley for helpful discussions about earlier mammal surveys in the area.

Report at a Glance

A RAPID BIODIVERSITY ASSESSMENT OF THE KAIJENDE HIGHLANDS, ENGA PROVINCE, PAPUA NEW GUINEA

Expedition Dates
August 19–September 9, 2005

Description of Expedition
This 22-day RAP Expedition surveyed several sites in the Kaijende Highlands, a vast near-uninhabited expanse of montane habitat near Porgera in Enga Province, Papua New Guinea (PNG). The RAP survey sites were located in lower montane rainforest (Lake Tawa), in upper montane rainforest (Paiela Road) and in subalpine grassland and stunted upper montane rainforest mosaics (Omyaka and Waile Creek) in Papua New Guinea's central cordillera. The first RAP survey site at Omyaka was located at the boundary between subalpine grassland dotted with *Cyathea* tree-ferns, and stunted montane rainforest at an elevation of 3,200 m. The second survey site was located in lower montane rainforest at Lake Tawa at an elevation of 2,100–2,400 m. This site was in a remarkable closed valley at the edge of a series of interconnected lakes that drained from the valley through one or more sink-holes. The third RAP survey site was centred on the Porgera mine and involved short forays to a series of 'sub-sites' including disturbed habitats around Suyan Village (~2,200 m), upper montane forest at Paiela Road (~2,800–2,900 m) and subalpine grasslands at Waile Creek and the Porgera Reservoir (3,000–3,200 m). All of the sites, including the remote Lake Tawa valley, showed signs of human activities but they all (except Suyan Village) provided access to high-quality, relatively undisturbed habitats.

Reason for the RAP Survey
The flora and fauna of Enga Province are probably less well known than that of any other province in Papua New Guinea. The lack of information about Enga's biodiversity is surprising because the province hosts a major mine that has developed significant infrastructure in the vicinity of the mining operation, and because the conservation values of the vast Kaijende Highlands region were recognized nearly 20 years ago when this expanse of montane habitats was recommended for consideration as a Wildlife Management Area.

To redress this deficiency Conservation International, with support from the Porgera Joint Venture (PJV) mining operation, undertook a major Rapid Assessment Program (RAP) biodiversity survey to collect data on the species richness and conservation status of plants, herpetofauna, birds and mammals in the near-pristine montane habitats of the Kaijende Highlands. The information collected during this RAP expedition will be used to promote the conservation significance of this vast wilderness area to local communities and to the PNG Government. It will also be used to inform and guide future conservation activities in the region by local communities, the PJV mining operation, and government agencies at the provincial and national levels. We hope that the outstanding conservation values of the Kaijende Highlands

documented during this survey will provide impetus for the declaration of this spectacular region as a Conservation Area.

MAJOR RESULTS

The major focus of this RAP expedition was to document the area's fauna and flora, but one of the overwhelming conclusions of all survey participants was that the Kaijende Highlands is an area of spectacular topography and scenic beauty. Few regions on the island of New Guinea can rival the breathtaking grandeur of the region's rugged montane landscapes, and these outstanding physical features should be targeted for conservation action and to assess tourism potential.

In total the RAP survey documented 643 species (Table 1), including at least 16 species of plants and eight species of frogs that are new to science. The RAP team recorded significant range extensions for several poorly known and threatened taxa including the Giluwe Rat (*Rattus giluwensis*), the Long-bearded Melidectes (*Melidectes princeps*) and the poorly known frogs *Litoria becki* and *Callulops glandulosus*. The Ribbon-tailed Astrapia (*Astrapia mayeri*), a spectacular bird of paradise with a severely circumscribed distribution, was common at Lake Tawa and the extensive high-montane habitats in the region appear to support a good diversity of large mammals. Together these observations suggest that hunting pressure in the Kaijende Highlands has not decimated the fauna there to the extent that it has over much of montane New Guinea.

Species New to Science

Plants

Acronychia richards-beehlerii
Dimorphanthera sp. nov.
Diplazium sp. ?nov.
Diplycosia sp. nov.
Glochidion sp. nov.
Glossorhyncha sp. nov. A
Glossorhyncha sp. nov. B
Jasminum sp. nov.
Macaranga sp. nov.
Pilea sp. nov.
Pneumatopteris sp. nov.
Polyosma sp. nov.
Rapanea sp. nov.
Saurauia sp. nov.
Syzygium sp. nov. A
Syzygium sp. nov. B

Amphibians

Albericus sp. nov. 1
Albericus sp. nov. 2
Callulops sp. nov. 1?
Choerophryne sp. nov. 1
Cophixalus sp. nov. 1
Oreophryne sp. nov. 1
Oreophryne sp. nov. 2
Oreophryne sp. nov. 3
New Genus, New species 1

Species of Conservation Concern

Amphibians

Albericus fafniri (?) (DD)
Callulops glandulosus (DD)
Litoria becki (VU)

Birds

Astrapia mayeri (NT)
Casuarius bennetti (NT)
Harpyopsis novaeguineae (VU)
Salvadorina waigiuensis (VU)
Melidectes princeps (VU)
Epimachus fastuosus (VU)

Mammals

Zaglossus bartoni (EN)
Dasyurus albopunctatus (VU)
Murexia naso (DD)
Dendrolagus dorianus (VU)

Table 1. Number of native species recorded during the 2005 Kaijende Highlands RAP survey.*

	Total	Omyaka	Paiela	Lake Tawa	Suyan
Plants	492	141	202	257	–
Herpetofauna	19	5	6	11	2
Birds	102	41	48	61	37
Mammals	30	12	5	18	7
Total	**643**	**199**	**261**	**347**	**46**

*Sampling effort was not equivalent among sites. Sampling around Suyan was predominantly serendipitous. 'Omyaka' includes Waile Creek (see text) for all taxa except plants.

Thylogale calabyi (EN)
Phalanger gymnotis (DD)
Mallomys istapantap (LR/nt)
Protochromys fellowsi (VU)
Pseudohydromys ellermani (VU)
Rattus giluwensis (LR/nt)
Uromys anak (LR/nt)
Tadarida kuboriensis (under *Tadarida australis*) LR/nt

KEY CONSERVATION RECOMMENDATIONS

(see Executive Summary for additional recommendations)

- *Conservation of high-montane grassland/forest mosaics.* We recommend that the high-montane grassland habitat mosaics of the Kaijende Highlands receive particular conservation attention. These habitats are scenically spectacular, and they retain a suite of large mammals that are of significant conservation concern. This RAP survey discovered a number of new species that may be endemic to these habitats. Climate change and increasing frequency of fires may deleteriously impact these habitats. A sustainable management plan should be developed in conjunction with local communities to reduce the impacts of these threats.

- *Community education.* Hunting of large mammals in the Kaijende Highlands may well be unsustainable. PJV and Conservation International would be well advised to commission and disseminate posters, fact sheets, and/or small field guides that illustrate local wildlife, discuss its significance to local communities, and emphasize such concepts as rarity and sustainable hunting. The impact and educational value of such postings and publications could be vastly increased by including relevant text in Tok Pisin, English, and Ibile or other appropriate local languages.

- *Mt. Kaijende Highlands Conservation Area.* The Kaijende Highlands are an area of spectacular scenic beauty and represent a vast near-uninhabited expanse of near-pristine high montane habitats. Conservation International, PJV and DEC are working together with local communities to have this region formally gazetted as a protected area. We hope that the results of this RAP survey will add impetus to this process.

Executive Summary

INTRODUCTION

Papua New Guinea (PNG) is an independent state occupying the eastern half of New Guinea, the world's largest and highest tropical island. In recognition of its extensive remaining forest cover, spectacular biological diversity and low human population density, New Guinea has been recognised as one of the world's five High Biodiversity Wilderness Areas (Mittermeier et al. 2003). In addition to extensive low- and mid-elevation tropical forests, New Guinea has extensive high-montane environments, particularly along the central mountainous spine of the island. This central cordillera, formed by uplift resulting from the collision of the Australian Plate with the Pacific Plate, presents dramatic gradients of topography, elevation, temperature and rainfall that have promoted rapid evolution of an exceptionally diverse biota. Although the montane birds and flora of New Guinea have been moderately well documented (e.g. Royen 1982, Beehler et al. 1986), documentation of most biota at high elevations has been sporadic at best and major gaps in survey effort continue to hinder meaningful discussions about conservation priorities for, and biogeographic relationships among, the New Guinean biota.

With an area of 12,800 km^2 Enga Province in Papua New Guinea's central highlands region includes a higher proportion of upper montane (>3,000 m) environments than any other province in Papua New Guinea (Löffler 1977). It is also the site of the Porgera Mine, a major open-pit gold mining operation that accounts for 14% of the country's export earnings, making it the world's eighth largest gold producer in terms of 2005 output. Remarkably, despite the substantial infrastructure established by this mining operation, Enga Province appears to have the lowest biological survey effort of any province in the country. Prior to this RAP survey only a handful of collections had been made in the province. The proximity of Porgera Mine to the vast Kaijende Highlands provided the opportunity to redress this paucity of biological information through a RAP biodiversity survey designed and conducted by Conservation International and the PNG Department of Environment and Conservation, and sponsored by the Porgera Joint Venture mining operation.

Scope of Project

The RAP biodiversity survey reported here was undertaken as part of a long-term commitment by Conservation International (CI) to assist with the establishment of a Conservation Area covering the Kaijende Highlands of Enga Province. Discussions between CI, the PNG Department of Environment and Conservation (DEC) and the Porgera Joint Venture partners (PJV) resulted in a consensus that CI would play a lead role in developing the project. To this end CI has established an office at Porgera with funding support from PJV. Locally-based CI staff are working with local landowners and local NGOs to establish the area (see Map) as a Conservation Area under the Conservation Area Act with assistance from the DEC.

The Mt. Kaijende Conservation Area will have a management plan and a development plan, rules, a management committee, and the steps towards establishment will allow for participation by the general public and by landowners. Follow-up awareness activities during 2007 have generated substantial support from local landowners, the PNG Mining Department and other stakeholders.

The RAP results reported here are the result of a successful partnership between CI, DEC, PJV and a number of local communities. We hope that the information gathered during this survey will play a useful role in informing the development of sustainable management strategies for this spectacular region.

RAP SURVEY OVERVIEW AND OBJECTIVES

Conservation International's Rapid Assessment Program (RAP) is an innovative biological inventory program designed to use scientific information to catalyze conservation action. RAP methods are designed to rapidly assess the biodiversity of highly diverse areas and to train local scientists in biodiversity survey techniques. Since 1990, RAP's teams of expert and host-country scientists have conducted 60 terrestrial, freshwater aquatic (AquaRAP), and marine biodiversity surveys and have contributed to building local scientific capacity for scientists in 26 countries. Biological information from previous RAP surveys has resulted in the protection of millions of hectares of tropical forest, including the declaration of protected areas in Bolivia, Peru, Ecuador, and Brazil and the identification of biodiversity priorities in numerous countries.

The primary objective of this RAP survey was to document the plant, herpetofauna, bird and mammal diversity of the Kaijende Highlands, a vast region of near-uninhabited montane forest and grasslands in Enga Province. The information we gathered will be used to make recommendations about the conservation significance of, and management options for, the remarkable biodiversity of this area. Survey sites were selected to include the major habitat types contained within the proposed Mt. Kaijende Conservation Area.

The specific aims of this RAP survey were to:

- Produce an overview of the diversity and conservation significance of selected plant and animal taxa at elevations between 2,000 and 3,300 m.
- Evaluate threats to biodiversity of the region, and recommend management strategies for their mitigation that are relevant to local communities, government agencies, and the nearby Porgera Mine.
- Provide on-site training in biodiversity inventory techniques for staff from DEC.
- Make RAP data available for decision-makers at all levels of Government, and to local communities, NGOs and the general public, with a view to promoting the establishment of a Conservation Area in the Mt. Kaijende Highlands.

Study Area

The Kaijende Highlands incorporate an extensive area of montane habitats (>2,000 m elevation) adjacent to the Porgera Mine in Enga Province, Papua New Guinea (see Map). Population density in the proposed Conservation Area is extremely low, but trails linking small villages and others used by hunters criss-cross the area. A well-travelled trail through the high-montane grasslands of the Kaijende Highlands links Porgera Town with the Mt. Kare goldfields.

As in most areas of Melanesia, land ownership in this region is complex and numerous clans lay claim to parts of the Kaijende Highlands. The area behind Mt. Kumbepara, from Omyaka to the Porgera Reservoir, is owned by the Pulumaini, Angalaini, Tieni and Aipakani clans. The Omyaka camp site was on Pulumaini land. The Lake Tawa area belongs to people from Kole and Kanzawi villages (Paiela) who also own the Mt. Kare area. The Paiela Road area is owned by the Pulumaini, Angalaini, Tieni and Tuanda clans. Land around Suyan is owned by the Aipakani-Kealo/Pepe (Suyan Camp), and the Timain and Paiam clans (areas behind Suyan).

Site Descriptions

The climate of the Kaijende Highlands area, extrapolated from rainfall and temperature data collected at the PJV Environment Department offices on the Porgera Mine site at around 2,200 m, is relatively aseasonal. Mean monthly minimum air temperature recorded daily between 2001 and 2004 varied between just 11.3 and 13.0°C and mean monthly maximum temperature varied between 18.8 and 21.0°C (Figure 1). Precipitation is high, with a long-term (1974 – 2006) mean annual rainfall of 3,679.6 mm (range 2,505.8 – 4,413.0 mm) but rainfall shows a more pronounced seasonal effect than temperature (Figure 2). The mean monthly rainfall calculated for each month over 33 years was 306.6 mm when calculated across all months, but there are distinctly wetter and drier 'seasons' with a maximum mean monthly rainfall of 370 mm in March and a minimum of 246.6 mm in July. Figure 2 shows long-term (1974 – 2006) mean monthly rainfall and the 2005 total rainfall for Porgera Mine to illustrate the period leading up to and including this RAP survey. The RAP survey was conducted during a year when rainfall in September was much higher than the long-term mean. However maximum and minimum monthly rainfall totals at Porgera over the same period do not follow the trend shown by the monthly means illustrated in Figure 2; they show that most months can be extremely wet (> 450 mm) or extremely dry (<150 mm) in any given year.

Although the Porgera climate data probably broadly reflect conditions at the lower elevations throughout the Kaijende Highlands, including Lake Tawa, it should be noted that climate in the area varies dramatically with topography and altitude. The highest elevations of the Kaijende Highlands experience climatic conditions that are much more extreme than those reported for Porgera, and air temperatures recorded in the upper-montane grasslands around Omyaka and Waile Creek during this survey regularly dropped to 5°C. Unfortunately, comprehensive rainfall and temperature data for these high-montane sites are unavailable.

The survey was conducted around four major 'sites' at elevations between 2,000 m and 3,400 m. These localities provided access to a range of habitats including montane grasslands, upper montane forests, mid-montane forest, and disturbed mid-montane forest regrowth and gardens. Geologically, this highland area is on the New Guinea Fold Belt (Hill and Hall 2003), and lies to the south of the complex system of geological terranes that have accreted to northern New Guinea (Pigram and Davies 1987). The survey schedule and location of major sites are presented in Table 1. The major vegetation formations of the study area are described in detail in Chapter 1 and a gazetteer for, and brief descriptions of vegetation at, each major site and each 'sub-site' are presented in Appendix 1. The general topography of Lake Tawa, and the location of significant collection sites and habitats around this valley are illustrated in Figure 3.

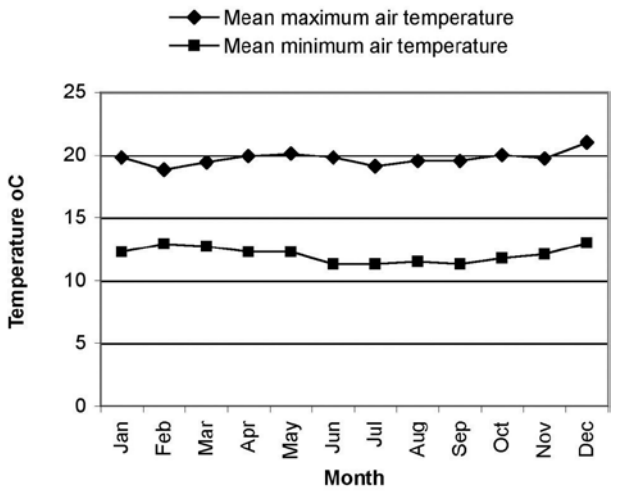

Figure 1. Mean monthly minimum and maximum air temperature recorded daily between 2001 and 2004 at the Porgera Mine.

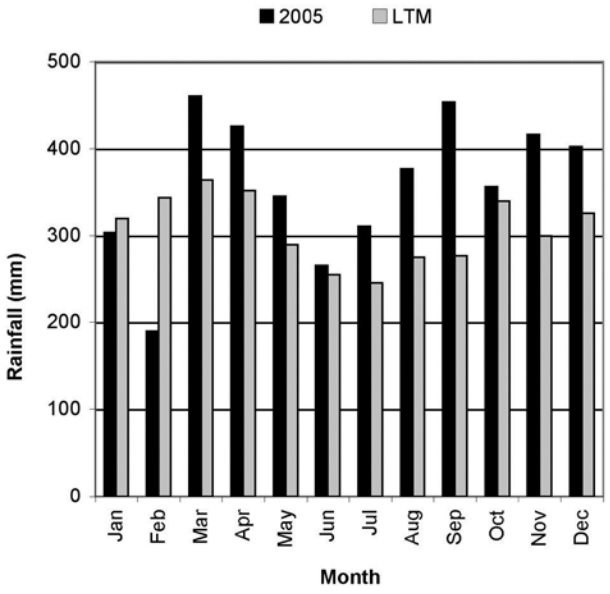

Figure 2. Long-term (1974–2006) mean monthly rainfall and total monthly rainfall for 2005 at the Porgera Mine. The RAP survey was conducted between 19 August and 9 September 2005.

SUMMARY OF RAP RESULTS BY TAXONOMIC GROUP

Vegetation

The flora of the Kaijende Highlands occurs in three principal vegetation formations: 1) lower montane forest, 2) upper montane forest, and 3) subalpine grassland. A total of 492 tracheophytic plant species were documented during this survey including 112 ferns and lycophytes, 6 gymnosperms, 69 monocots, and 305 dicots from a total of 262 genera. At least 16 plants are determined as species new to science, including five arborescent taxa, five understory shrubs, two vines, two orchids, and two ferns.

Herpetofauna

Seventeen frog and two reptile species were documented from montane forests and montane grassland habitats in the Kaijende Highlands. At least eight of the frog species are undescribed and one of these probably warrants recognition as a new genus. This survey documented the second known population of *Callulops glandulosus*, and a very large species of *Albericus* found at Lake Tawa may represent only the second known population of *A. fafniri*. Both of these species were considered Data Deficient by the Global Amphibian Assessment. One other frog, *Litoria becki*, found only in high-montane grassland habitats, was considered Vulnerable in the recent Global Amphibian Assessment. Although the reptile fauna was depauperate, this reflects the high-elevation focus of our survey and the low diversity is probably typical of sites at similar elevations elsewhere in New Guinea. One of the two species documented, a skink of the genus *Sphenomorphus*, may represent an undescribed taxon.

Birds

Nineteen days of surveys, including a series of 'walking censuses' undertaken at key sites, detected 102 species of birds. The Long-bearded Melidectes (*Melidectes princeps*) was recorded for the first time west of the Mount Hagen massif. The Ribbon-tailed Astrapia (*Astrapia mayeri*), a spectacular long-tailed species with a severely circumscribed distribution centered on our study area, was common from 2,117 m at Lake Tawa to 3,200 m at Omyaka Camp. Although the Crested Bird of Paradise (*Cnemophilus macgregorii*) was not encountered on this survey, one local informant at Omyaka Camp stated that it was present and the species was apparently collected in a DEC field survey (Kula 1989). It appears that there is a substantial geographic break in this species' range between the Hagen/Giluwe area and the Star Mountains of Papua (Indonesia). This provides an intermedi-

ate-stage example of Diamond's "drop-out" phenomenon (Diamond 1972). The Kaijende Highlands support a rich upland bird fauna that might best be conserved through the creation of a large contiguous community-managed reserve that encompasses uninhabited traditional hunting lands.

Mammals

This survey confirmed the occurrence of one monotreme, 18 marsupials, nine rodents, two bats, and two non-native placental mammals (wild-living dogs and pigs) in the Kaijende Highlands. Previous surveys in this area had recorded just one marsupial species, three rodent species, and one bat species that were not detected in the current survey. Our survey brings the total number of native marsupials, rodents, and bats recorded in the Kaijende Highlands to 35 and in Enga Province to 39. Significant new records for the Kaijende Highlands include the third vouchered locality for Calaby's Pademelon (*Thylogale calabyi*) and the first record of the Giluwe Rat (*Rattus giluwensis*) outside of the immediate vicinity of Mt. Giluwe in Southern Highlands Province.

Table 1. Summary of survey schedule and major site locations of the Kaijende Highlands RAP survey.

Site	Coordinates	Elevation (m)	Dates (2005)	# Days survey effort
Suyan Camp & vicinity	05°29'09" S, 143°08'07" E	2,200	19 August & other brief visits	~ 1
Omyaka Camp	05°31'37" S, 143°03'23" E	3,200	20–25 August	5
Lake Tawa	05°35'43" S, 142°50'26" E	2,117–2,400	26 August–3 September	7
Paiela Rd & Waile Creek	Various (see Appendix 1)	2,800–3,200	4–9 September	6

Figure 3. Aerial view of Lake Tawa showing A) bivouac; B) sinkholes in photo 23; C) limestone outcrops; D) photographic station for photo 24; E) *Pandanus* savanna to the north and northeast of camp (see photo 29, color plates).

Other species of conservation concern that occur in the Kaijende Highlands include the echidna *Zaglossus bartoni* and the tree-kangaroo *Dendrolagus dorianus*.

CONSERVATION RECOMMENDATIONS

Protection of important habitats

The *Cyathea* savanna that dominates the Kaijende upper montane zone at elevations between 3,000 m and at least 3,400 m is unique to the island of New Guinea. These upper montane habitats and vegetation formations are not protected by existing conservation initiatives in Papua New Guinea. Because island endemism is higher in Upper Montane Forest and subalpine environments than in the low elevation habitats typically covered by many conservation areas in Papua New Guinea, protection of the Kaijende Highlands will provide security for a number of endemic taxa presently excluded from conservation consideration. This survey has identified a suite of plants, frogs and mammals that appear to be dependent on these subalpine environments. The high-altitude tree fern savanna, tussock grassland, and adjacent upper montane (elfin) forests also support a poorly known assemblage of mammal species that have become rare or disappeared from many other montane sites in New Guinea.

Another habitat that may require specific targeting for conservation action is limestone outcrops. Three new plant species were associated with karst formations during the 2005 RAP survey and additional surveys are required to determine whether these localized habitats harbor a substantial endemic plant or animal biota.

The Kaijende Highlands not only harbor a large number of poorly known and significant species and habitats, but the landscapes of the region are scenic and visually stunning. The aesthetic beauty of the Kaijende Highlands provides a further compelling argument for protection of these montane habitats. The *Cyathea* grassland panoramas at Omyaka and Waile Creek and the lakeside vistas at Lake Tawa are among the most spectacular ever encountered by the RAP team, and the dramatic limestone pinnacles emerging from dense mid-montane forest near Porgera are breathtaking.

Our results strongly vindicate the current efforts to establish a Wildlife Conservation Area in the Kaijende Highlands. Conservation International, the PNG Department of Environment and Conservation and PJV are working with local communities to develop a sustainable, long-term conservation plan for the proposed Conservation Area. We hope that the results of our survey will be used to promote interest in the Kaijende Highlands among local communities, and among decision makers in Local, Provincial and National Governments. Particular attention should be placed on educating local landowners about the significance of their unique biota on a global scale, about the importance of adopting sustainable hunting practices to ensure the long-term survival of many bird and larger mammal species that are becoming scarce in the mountains of New Guinea, and about the benefits of protecting their montane forests and grasslands from increasingly frequent fires and other destructive human activities. With the interest and support of the local communities, the Kaijende Highlands could become a model protected area in Papua New Guinea.

Species-specific recommendations

Studies are needed to assess in greater detail the distribution, abundance, and threats faced by wallabies, tree-kangaroos, and echidnas in the Kaijende Highlands. These large mammals have disappeared from most areas with high human population density throughout New Guinea. Although *Zaglossus* and at least three different kangaroo species (*Dendrolagus dorianus, Dorcopsulus vanheurni,* and *Thylogale calabyi*) still persist in the vicinity of Porgera, the 2005 RAP team did not encounter living animals of these species. They were documented solely based on information from informants or from trophy jaws. Clearly there is at least some hunting pressure on these animals. Obtaining information about abundance, hunting pressure, and microdistribution of large mammals in the region is a high priority if these species are to be conserved in the long term. These studies will require the assistance and knowledge of local communities, and might prove to be a straightforward and manageable project, perhaps one that can be undertaken by a sponsored student or a PJV Environmental Officer.

Future Research

The cost and logistical challenges of working in New Guinea's remote high-montane environments are a major impediment to research. As a result, most upper montane habitats on the island remain very poorly documented. The success of our Kaijende survey was due in large part to the logistical support provided by the Porgera mine, and also to the infrastructure, including roads, that has been established in the surrounding district. Few areas in Papua New Guinea offer such advantages for an ongoing program of conservation assessments and biological studies.

Long-term monitoring programs

The upper montane habitats of the Kaijende Highlands provide an opportunity to monitor long-term floristic change caused by global warming. Upper Montane Forest is acutely responsive to temperature shifts induced by climatic change, as demonstrated by palynological evidence from Holocene sediments. Baseline studies should be established that not only document subsequent shifts in upper montane forest composition and distribution, but also examine concurrent changes in abundance and assemblage structure of animal taxa associated exclusively or primarily with these habitats. Fauna identified as high priorities for monitoring programs include a new genus and species of frog known only from grasslands at Omyaka, and a number of large mammal species that may already be under threat from over-hunting.

Biodiversity surveys

The results of the short Kaijende Highlands RAP survey were spectacular and it is clear that additional biodiversity surveys

targeting habitats and elevations not covered during the 2005 RAP survey will document numerous additional species in the proposed Mt. Kaijende Conservation Area. Additional surveys will also be critical for assessing the distribution and conservation status of a number of threatened or significant species encountered or otherwise documented during the 2005 RAP survey (e.g. *Thylogale calabyi*, *Zaglossus bartoni* and *Dendrolagus dorianus*, three new species of microhylid frogs, several new plant species). Inasmuch as the flora and vertebrate fauna of the Upper Montane Forests are highly significant from a conservation perspective but relatively depauperate in terms of species richness, a series of targeted surveys could provide the most comprehensive biodiversity assessment of Upper Montane Forest and grasslands for any area in New Guinea to date.

All participants in the Kaijende RAP survey noted that extending biodiversity survey activities to areas below 2,000 m elevation would dramatically increase the variety of biota documented. With support from PJV a trans-watershed biodiversity survey transect extending from the Kaijende Highlands to the lowlands along the Strickland River would be an ambitious project that would put the Kaijende Highlands fauna and flora in a broad biological and biogeographic context. In addition, with community support any future extension of the boundaries of the Conservation Area to accommodate contiguous habitats below 2,000 m elevation would substantially increase the biodiversity values of the Conservation Area.

Ecotourism potential

Tourism is a small but potentially lucrative business for Papua New Guinea. Few areas in the country can boast the combination of spectacular scenery and established infrastructure of the Kaijende Highlands region. Properly marketed, the Kaijende Highlands could attract visitors from elsewhere in PNG and from overseas. Formal designation of the Kaijende Highlands as a Conservation Area will increase the area's attractiveness as a travel destination. However it should be recognized that the tourism market is small. Studies to assess the potential of specialised eco-tours, or the promotion of research-based 'tourism' should be conducted as a matter of priority.

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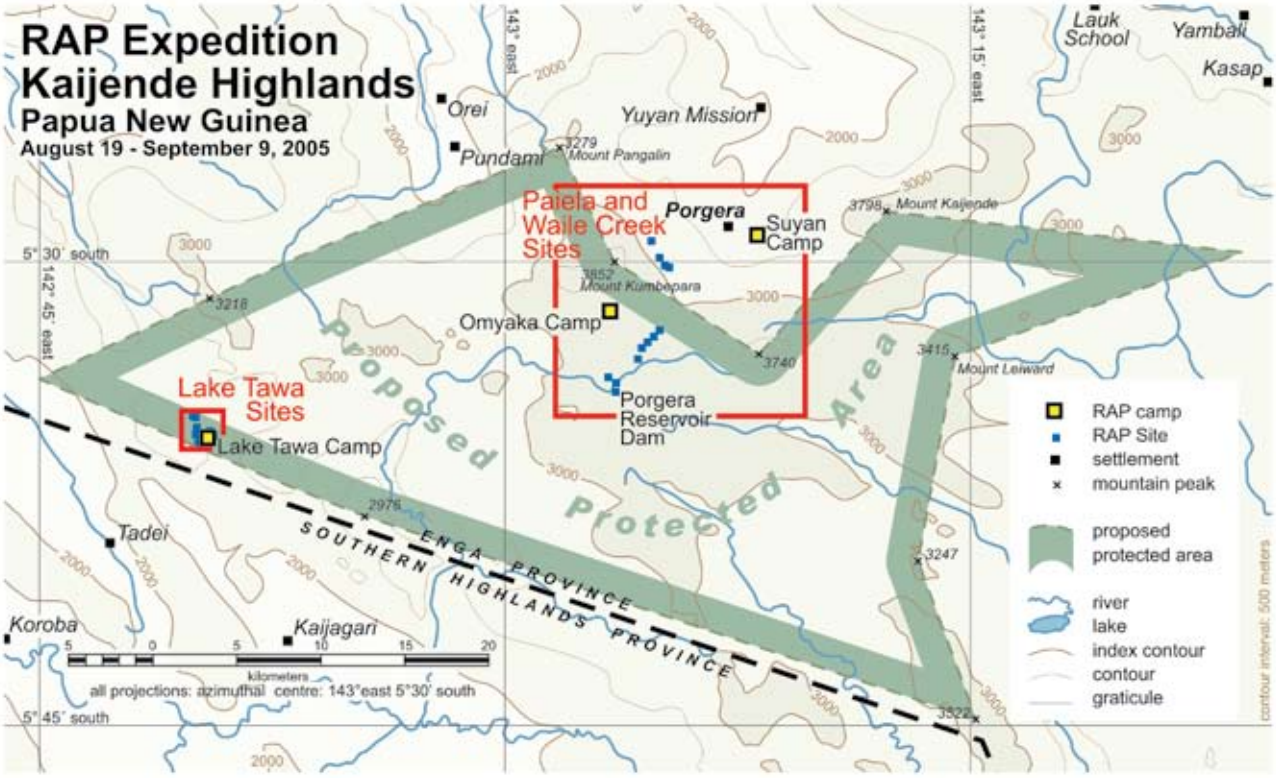
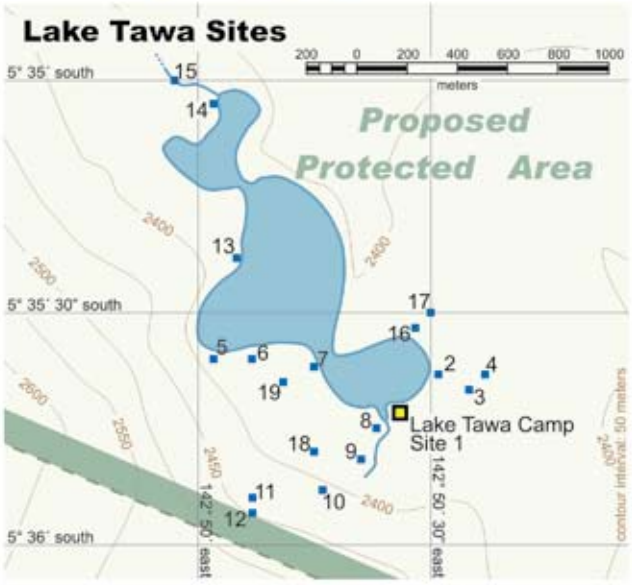
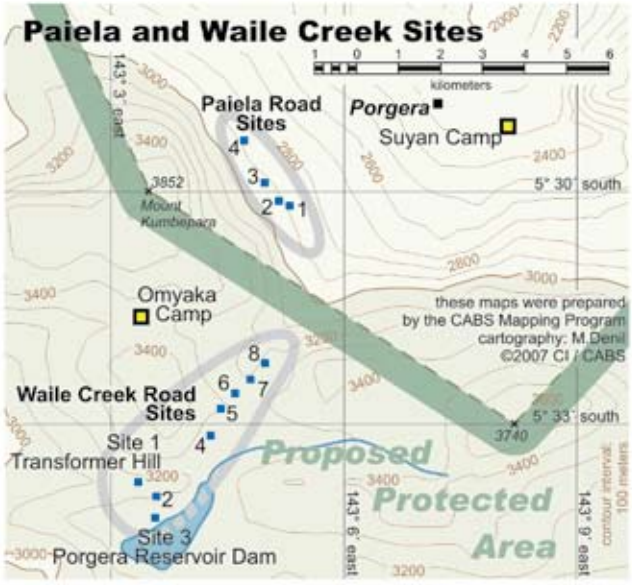

RAP Expedition
Kaijende Highlands
Papua New Guinea
August 19 - September 9, 2005
Orei
Yuyan Mission
Pundami
3279
Mount Pangalin
Paiela and
Waile Creek
Sites
Porgera
Suyan
Camp
3798
Mount Kaijende
3852
Mount Kumbepara
Omyaka Camp
3740
3415
Mount Leiward
Lake Tawa
Sites
Lake Tawa Camp
Porgera
Reservoir
Dam
Proposed
Protected
Area
2976
SOUTHERN HIGHLANDS PROVINCE
ENGA PROVINCE
Tadei
3247
Koroba
Kaijagari
3522
Lauk
School
Yambali
Kasap
143° east
143° 15' east
142° 45' east
5° 30' south
5° 45' south
all projections: azimuthal centre: 143°east 5°30' south
kilometers
RAP camp
RAP Site
settlement
mountain peak
proposed
protected area
river
lake
index contour
contour
graticule
contour interval: 500 meters


Lake Tawa Sites
5° 35' south
5° 35' 30" south
5° 36' south
142° 50' east
142° 50' 30" east
meters
Proposed
Protected Area
Lake Tawa Camp
Site 1
contour interval: 50 meters


Paiela and Waile Creek Sites
kilometers
143° 3' east
143° 6' east
143° 9' east
Paiela Road
Sites
Porgera
Suyan Camp
3852
Mount
Kumbepara
5° 30' south
5° 33' south
Omyaka
Camp
these maps were prepared
by the CABS Mapping Program
cartography: M.Denil
©2007 CI / CABS
Waile Creek Road
Sites
Site 1
Transformer Hill
Site 3
Porgera Reservoir Dam
3740
Proposed
Protected
Area
contour interval: 100 meters


New Guinea
north
PAPUA NEW GUINEA
map
area
INDONESIA
PORT
MORESBY
0° equator
5° south
10° south
125° east
130° east
135° east
140° east
145° east
150° east
155° east
kilometers

Numbers in brackets refer to specimen vouchers (plants only). Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

1. *Decaspermum alpinum* is a perfume-flowered species easily seen in upper montane forests of the Porgera district. (20147).

2. *Ilex archboldiana*. The retuse leaves are usually provided with a minute apiculum in the sinus. (19754).

3. *Quintinia kuborensis* is a frequency dominant at high elevations, often forming monospecific patches in the upper canopy. (19712).

4. *Vaccinium apiculatum*. A common arborescent species of subalpine shrubberies. (19574).

5. *Vaccinium apiculatum*. Raceme detail. The narrowly urceolate corolla is initially green or white, turning pinkish-red at anthesis. (19574).

6. *Xanthomyrtus compacta*. A dominant nanophyllous species in the upper montane zone, vegetatively distinguishable from other small-leaved associates by the verrucose branchlets. (19752).

7. *Drimys piperita* entity *coriacea*. (20319).

8. *Drimys piperita* entity *montis-wilhelmi*. (19713).

9. *Vaccinium schoddei* is a terrestrial shrub with long arching stems (horizontal branchlets in photo) and cordate-amplexicaul leaves. The flowers are whitish-pink in bud and dark purple when mature. (19592).

10. *Vaccinium striicaule* var. *adenodes*. A common subarborescent on forest edges at Omyaka. The calyx lobes are occasionally furnished with a distinct apical gland. (19751).

11. *Chionochloa archboldii* in the subalpine grassland. The culms are generally 1.5–2.0 m tall. (19655).

12. *Hypericum* shrub association at Waile Creek, dominated by *H. macgregorii* and *H. papuanum*.

Numbers in brackets refer to specimen vouchers (plants only). Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

13. *Coprosma papuensis* ssp. *discolor* occurs as ascending shrubs (shown) or subscandent plants with trailing branches. (19598). *Libocedrus papuana* var. *papuana* is a large tree in the background. (19594).

14. Flowering branch of *Coprosma papuensis* ssp. *discolor*. The setose stipules have a large central lobe. (19598). Although unrecorded by the RAP survey, *C. divergens* is probably present at Kaijende and will be easily recognized by its opposite leaves (3-whorled in *C. papuensis*; see Gardner 2002).

15. *Styphelia suaveolens* is widely distributed from Western Malesia to the Solomon Islands. The species can be found as erect shrubs, as small prostrate subshrubs, or even as dwarfed 20 cm tall monoaxial plants in montane bogs. (19599).

16. *Ischnea elachoglossa* is a caespitose bog herb (pictured in water pools) with pentamerous disk florets. The species is known mainly from specimens originating in Indonesian Papua, and has been infrequently found in PNG. The only previous record for the Highlands was from Mt Giluwe in Southern Highlands Province. (19718).

17. *Keysseria radicans* (closest to) ssp. *radicans*. A suffrutex with vinelike branches, shown in cushion bogs at Omyaka. The 30 mm wide heads are the largest recorded for any *Keysseria*. (19681). This genus of 10 species is known from Borneo, Sulawesi, New Guinea, and Hawaii (Koster 1975).

18. *Potentilla foersteriana* var. *foersteriana* is a common rosulate herb in bogs and subalpine grassland at Omyaka. The inconspicuous inflorescence consists of small yellow flowers. (19629).

19. *Potentilla papuana*. The long-peduncled inflorescence immediately distinguishes this species from the sympatric *P. foersteriana*. Vegetative parts are densely sericeous. (19627).

20. *Vaccinium amblyandrum* var. *pungens* growing as miniature 20 cm plants. (20260).

21. *Vaccinium amblyandrum* var. *pungens*. Flowers are solitary with white or pale pink corollas. (20260).

22. Lake Tawa. Aerial view of the catchment lakes and surrounding vegetation.

23. Lake Tawa. The southeastern end of the basin is a limestone zone with numerous sinkholes (Australian Survey Corps 1979).

24. Wide-field view of the scenic surroundings at Lake Tawa. Pollen stratigraphies from nearby swamps should be informative.

Numbers in brackets refer to specimen vouchers (plants only). Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

25. Lake Tawa riparian community. The plants shown are primarily *Polygonum*, *Hypericum*, and *Hydrocotyle*.

26. *Hydrocotyle sibthorpioides*, a dominant repent herb on the Tawa lakefront.

27. Small ascending stems of *Hypericum* cf. *papuanum,* intermingling with *Hydrocotyle* at Lake Tawa.

28. Aerial view of the *Pandanus* savanna, north of the Lake Tawa camp-site.

29. *Pandanus* savanna at Lake Tawa. Anthropogenic influence is an unlikely explanation for the presence and distribution of this unusual vegetation, whose occurrence is probably related to poor soil conditions. There are no indications of former burning at the site.

30. *Saurauia* sp. nov. The deliquescent shrubs have the smallest leaves (<20 mm long) of any Papuasian congener. (20310).

31. *Saurauia* sp. nov. Closer view of the inflorescence. The calyces are reddish-purple, petals white. There are 4–5 styles. (20310).

32. *Polyscias ledermannii*, an arborescent species related to *P. belensis* but distinguished from the latter by crenate leaflets (entire in *P. belensis*). (19974).

33. *Dimorphanthera* sp. nov. A common scandent species on forest margins at Omyaka. Corollas are white, cupular, and pubescent. The presence of 10 isomorphous stamens indicates a relationship to Sleumer's section *Pachyantha*. (19571).

34. *Macaranga* sp. nov. Forest trees 15–20 m tall on limestone. The leaves are thickly coriaceous, rugose, and white beneath. (19931).

35. *Palmeria clemensae.* The foliar indument is dimorphic, with small fulvous-stellate hairs on undersurfaces, and much longer hyaline hairs along veins. (19981).

36. *Syzygium* sp. nov. The new species is very common in the *Pandanus* fringe around Lake Tawa. Calyces are smooth and entire in fresh flowers, but are deeply channelled after drying. (19987B).

Numbers in brackets refer to specimen vouchers (plants only). Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

37. *Jasminum* sp. nov. Savanna plants (shown) are typically low-growing subshrubs 20–30 cm tall with horizontally spreading branches. Internodes are contracted in comparison to forest congeners. (20298).

38. *Jasminum* sp. nov. The salverform corolla has a pinkish-red tube and white limb. (20298).

39. *Rubus* sp., '*diclinus-trigonus*' facies. Prostrate floricanes with a dense orange-brown indument on stems and abaxial leaf surfaces. (20093A).

40. *Rubus* sp., '*diclinus-trigonus*' facies. Flowers are fragrant and large, with pink sepals 7 mm long and white petals 10–12 mm long. (20225).

41. *Acronychia richards-beehlerii.* Subcanopy trees with yellow flowers and fruits. The drupes are conspicuously fissured and rugose. (20119).

42. *Pilea* sp. nov. A common species resembling a *Pipturus pullei* in architecture and habit. Leaves are decussate and congested. The bright red nutlets are arranged in axillary glomerules. (20277).

43. *Gaultheria pullei* var. *pullei* is an aromatic shrub of forest margins, old mine workings, and cleared summits (Sleumer 1967). The genus is represented in New Guinea by six endemic species. (20304).

44. *Dimorphanthera keysseri*, the most common *Dimorphanthera* in the proposed WMA. (19575).

45. *Dimorphanthera keysseri*. The flowers have the characteristic androecium of the *Pachyantha* facies. (19575).

46. *Rhododendron beyerinckianum* hybrid. Hybridization with *R. phaeochitum* is suggested by the variegated red and white flowers, and by the corolla tubes with hairy interior surfaces. (20289).

47. *Rhododendron commonae*, flowering profusely at Omyaka in late August. (19670).

48. *Rhododendron inconspicuum*. In its broad circumscription (Royen 1982), the species can have red, pink, or white (shown) flowers. (20311).

Numbers in brackets refer to specimen vouchers (plants only). Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

49. *Rhododendron macgregoriae* var. *macgregoriae* is possibly the most common vireya in PNG. Corollas in Omyaka-Waile Creek populations can be yellow (shown), light orange, or yellow with orange-red lobes. (19796).

50. [top] Treefern savanna. The Waile Creek savanna is the only formation of its kind with drive-through accessibility.
51. [bottom] Fire-induced dieback from the 1998 El Niño event near Omyaka (3,450 m). Widespread effects were recorded in PNG forests during the last climatic disturbance, including environments from sea level to the high montane zone (Takeuchi 2003). If El Niño occurrences increase in frequency as a result of global warming, large-scale conversions of UMF to subalpine grassland can be expected in the Kaijende region. This will involve an expansion of areas presently coded as Ga and Gi (treefern savanna in part). The changes will probably be accompanied by corresponding increases in scrub vegetation (Sc) as taller forest is converted to open woody growth. Unless future climatic disturbances are of exceptional intensity, biodiversity losses should not be particularly severe. Upper montane forests are floristically depauperate and many of their elements also occur in the open scrub. Since the epiphytic flora is species-poor, losses in that component will be similarly small. El Niño impacts to the LMF and the lower elevation flora could be of far greater consequence.

52. *Passiflora mollissima* is a naturalized vine in montane Malesian environments (de Wilde 1972) and other insular ecosystems (e.g. HDOA 1992).

Alien species near Porgera are concentrated along service roads and adjacent areas, showing that the transport network is unintentionally facilitating the dispersal of unwanted plants. Future introductions of weedy species are likely to spread using existing roadways as conduits. Construction of new facilities in the conservation zone should be considered against the likelihood of such impacts.

53. *Lupinus* cv *Russell* hybrid. This legume is common in New Zealand and has been reported within PNG from the Eastern Highlands (Verdcourt 1979).

54. *Olearia durifolia* Koster, or aff. (20255). *Olearia* collections are generally difficult to identify. The existing treatments (Koster 1966, Royen 1982) rely primarily on the microscopic morphology of the leaf hairs, characters which are not easily determined. Even when a specimen is carefully keyed out, the result often will not match the assigned name. The variation in certain species is either much wider than presently recognized, or there are more taxa in need of formal description.

55. *Olearia pallida* Koster. Forest margin shrubs at Waile Creek. The abaxial indument consists of long-stipitate stellate hairs with acicular arms radiating in all directions. (20307).

56. *Olearia platyphylla* var. *cinerea* as compact shrubs on rock rubble. (20299).

57. *Olearia platyphylla* var. *cinerea*. Closer view of the inflorescence: involucre 7 mm long; ligule 7 mm long, white; disk yellow, 7–8 florets. (20299).

58. *Olearia rufa* is a regrowth shrub in forest clearings at Waile Creek. Leaves are opposite, abaxially orange-brown tomentose, and with stellate 5–8-rayed hairs. (20279).

59. *Olearia rufa*. The large panicles are composed of heads with 4–6 disk florets. (20279).

60. *Saurauia giluwensis* is a common species on forest margins near Porgera Reservoir. Leaves are densely and abaxially orange-brown furfuraceous. The flowers have 4–5 styles. (20259).

Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

61. *Muehlenbeckia monticola* occurs as prostrate vines or climbers from sea level to over 3,000 m elevation. The species is present at Porgera mainly in disturbed areas such as road embankments, landslides, construction sites, and forest regrowth.

62. Pinnacle limestone between Porgera and Lake Tawa.

63. The vast expanse of near-uninhabited montane forest and grassland in the Kaijende Highlands between Porgera and Lake Tawa.

64. Cyathea grasslands above 3000 m elevation at Waile Creek near the Porgera Reservoir.

65. Interior of the low stature Upper Montane Forest around Omyaka and Waile Creek.

66. Montane Bog at about 3,200 m elevation on a small ridge adjacent to the Omyaka Camp.

67. Local landowner at Omyaka Camp. The landowners have tremendous knowledge about the plants and animals on their land.

68. The sheer cliffs of Mt. Kumbepara dominate the skyline along the Paiela Road. Dense forest along the base of the mountain adjacent to Paiela Road contained a number of new and interesting plant and animal taxa.

69. Lake Tawa in early morning mist. This picturesque lake is surrounded by extremely biodiverse rainforest.

70. This small, undescribed microhylid frog of the genus *Albericus* was common at Lake Tawa and Paiela Road.

71. An undescribed species of *Cophixalus* that called from deep at the base of moss clumps at Omyaka and Paiela Road. Males called only during the afternoon, and two were found guarding egg masses deep within humus in the alpine meadow adjacent to Omyaka Camp.

72. This beautiful treefrog of the genus *Litoria* was collected by local assistants at Suyan Village.

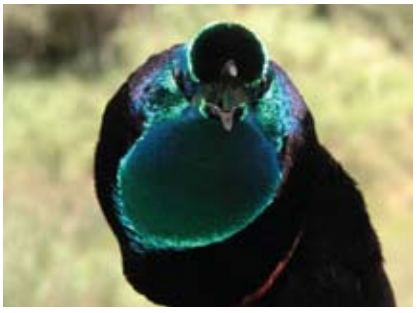
Photos 1–27, 29–61 by Wayne Takeuchi. Photos 28, 62–84 by Stephen Richards.

73. Microhylid frogs dominate the upper-montane habitats of the Kaijende Highlands. This bizarre species probably represents a new genus and species. It was found only in the montane grasslands adjacent to Omyaka Camp at around 3,200 m elevation.

74. Few reptiles were documented during the Kaijende RAP survey. This small skink may be undescribed. It was collected from the Camp's Pit-toilet on the final day at Lake Tawa by SJR. No one else volunteered.

75. Ornithologist Bruce Beehler with a male Ribbon-tailed Astrapia (*Astrapia mayeri*). This spectacular species was common at Lake Tawa.

76. Sclaters Whistler (*Pachycephala soror*) is a beautiful species that is widespread at mid-elevations in the central mountains. This bird was collected in mist-nets from forest adjacent to Lake Tawa.



77. A male Ribbon-tailed Astrapia (*Astrapia mayeri*) at Lake Tawa. This species, the last of the Birds of Paradise to be described, has a very small range that fortunately includes the proposed Mt. Kaijende Conservation Area.

78. A Wattled Ploughbill (*Eulacestoma nigropectus*). This bizarre bird was captured in a net at Lake Tawa.

79. Kris Helgen and local assistants with a Mountain Cuscus (*Phalanger carmelitae*) at Lake Tawa. Local hunters are extremely skilled at detecting and capturing possums and other larger mammals.

80. Collecting mammal bones from an owl pellet deposit in a rock outcrop near the Porgera Reservoir revealed jaws of at least eight small mammal species.

81. Live traps were set for small mammals along track-ways in the grasslands and forest around Lake Tawa.

82. *Rattus giluwensis*. This poorly-known rat was previously known only from the vicinity of Mt. Giluwe in Southern Highlands Province.

83. The Sugar Glider (*Petaurus breviceps*) is a common and widespread species throughout lowland and montane New Guinea. This animal was found in the forest at Lake Tawa.

84. The attractive Eastern Striped Bandicoot (*Microperoryctes ornata*) is a common species in forest at moderately high elevations across the central mountains of New Guinea. A single specimen was collected in an Elliott Trap at Lake Tawa.

Chapter 1

Vascular plants of the Kaijende Highlands, Papua New Guinea: Taxonomic and vegetation survey

Wayne Takeuchi

SUMMARY

The flora of the Kaijende Highlands is described from a rapid assessment survey of its principal montane habitats, with specific emphasis on three vegetation formations: 1) lower montane forest, 2) upper montane forest, and 3) subalpine grassland. Species-level determinations are provided for most of the 759 specimens obtained during the survey. The checklist of inventoried species includes 492 tracheophytic taxa (112 ferns and lycophytes, 6 gymnosperms, 69 monocots, and 305 dicots), from a total of 262 genera.

At least 16 plants are determined as species new to science, including five arborescent taxa, five understory shrubs, two vines, two orchids, and two ferns. Other botanical results are presented with commentary on their presumed significance. The collective findings are distilled into a conservation-focused discussion highlighting the taxonomic and ecosystem value of the most notable plants.

INTRODUCTION

The botanical survey in regional context

Although the true size of its inventory is unknown and subject to considerable speculation, there is no doubt that New Guinea is home to one of the world's richest floras. According to most modern estimates, approximately 15,000–20,000 species are probably present on the island (Davis et al. 1995). Using orchids and ferns as benchmarks for extrapolation, the most recent assessment places the upper limit at 25,000+ vascular plants (Supriatna 1999).

A remarkable feature of New Guinea's floristic diversity is that several groups attain levels of species richness usually seen only on continental spatial scales. Ferns, for example, are represented by an astonishing total of 3,000 species (Parris in press) and orchids by 2,800 species (Vogel and Schuiteman in press). This extraordinary diversity has arisen largely under the influence of one of the most active orogenies on earth. The Central Cordillera has the highest peaks in Malesia and the richest assortment of montane plant life in the Indo-Malayan region. With an estimated 5,000–6,000 species in 9,000 sq. km (Davis et al. 1995), the area centered on Mt. Wilhelm and its environs (including all of the Kaijende Highlands) comprises one of the world's five phyto-maxima for vascular plant diversity (Barthlott et al. 1996, 2005).

Despite Papua New Guinea's (PNG) floristic wealth, our knowledge of this resource is still substantially incomplete. Seven of the 10 species of *Homalium* are known only from single specimens (Craven 1979, Steenis 1982), and of the 50 species of Papuasian *Marsdenia*, 32 are still known just from their type localities (Forster 1995). There are similar examples of sampling gaps in virtually every major plant family. The documentation deficiencies can be attributed in large part to the erratic spatial distribution of past collecting. Although the number of botanical surveys in PNG has increased substantially since 1950, many areas remain practically unknown (Frodin 1990).

The unevenness in exploration coverage is reflected in two geographic patterns on the horizontal and vertical dimensions: 1) collections density decreases from east to west, with Indonesian Papua (previously Irian Jaya) having received considerably less attention than PNG, and 2) documentation intensity increases markedly with elevation, such that montane environments are generally much better known than the lower elevation flora. However there is a manifest spottiness superimposed over these large-area patterns. Thus while the Highlands provinces have the best collective documentation of any administrative or biotic region in PNG, many individual districts on the cordillera are still poorly surveyed. Enga has the lowest sampling coverage of any province in PNG (as measured by representation in the New Guinea Force and Lae Herbarium number series) despite the high collections density for the Highlands as a whole (Takeuchi and Golman 2001). The unexpected number of taxonomic discoveries made during the Kaijende survey is primarily attributable to these spatial disparities in historical activity.

METHODS

The Kaijende Highlands botanical survey was centered on two field camps and along service roads near the Porgera Joint Venture (PJV) open-pit mine in Enga Province, PNG.

The first study site at Omyaka was an irregular mosaic of mossy forest and *Chionochloa-Arundinella-Deschampsia* grassland (camp at 05°31'37" S, 143°03'23" E, 3,200 m elevation). A second venue at Lake Tawa (camp at 05°35'43" S, 142°50'26" E, 2,117 m elevation) consisted primarily of colline communities arranged in bands around a closed valley. The Lake Tawa locality included an unusual series of catchment lakes draining into sinkholes at the southeastern head of the basin. Most areas examined during the survey are situated inside a potential conservation zone currently under consideration for Conservation Area designation.

Twelve days of intensive fieldwork were allocated to the bivouac localities: August 21–24 at Omyaka and August 26–September 2 at Lake Tawa. The remaining period from September 4–9 was devoted to walk-through inspection of habitats between Porgera Town and the Porgera Reservoir, using the PJV staff accommodations (Suyan Camp) as a logistical base.

The Kaijende study was organized on sampling procedures commonly employed in Conservation International (CI) biosurveys (Mack 1998, Mack and Alonso 2000, Beehler and Alonso 2001). As with previous operations, the botanical fieldwork was focused exclusively on tracheophytic plants (i.e. ferns, gymnosperms, and angiosperms). Herbarium specimens were taken from all fertile taxa encountered by three surveyors, using tree climbers and 15 m extensible pruning poles as required. Sterile specimens were not collected.

Accessory documentation in the form of bottled flowers, xylarium samples, and photographs (5-megapixel digital imagery) were obtained from selected collections. Specimens for exsiccatae were secured in sets of 1–12 duplicates and field-packed in 70% ethanol for subsequent processing at Lae. Identifications were done primarily at the PNG Forest Research Institute (FRI) and Lae National Herbarium (LAE), using keys from formally published literature and/or by comparison to authoritatively annotated reference sheets. If several revisions are available for a particular genus or family, the most recent one was selected as a basis for the identifications.

The plant collections have been compiled in a checklist, with taxonomic comments and determination credits appended as appropriate. Genera were assigned to families in conformity (p. p. maj.) with the following sources: ferns and lycophytes (Holttum 1959, Croft 1986), gymnosperms (Laubenfels 1988), and angiosperms (Angiosperm Phylogeny Group 1998, 2003).

RESULTS

General description of the vegetation

The surveyed areas are classified by the Forest Inventory Mapping System (FIMS; the planning database of the PNG Forest Authority) primarily under vegetation codes **L** (small crowned lower montane forest), **Mo** (very small crowned montane forest), **Ga** (alpine grassland), and **Gi** (subalpine grassland), (see Hammermaster and Saunders (1995a) for a description of these units). The reader is also referred without further comment to map overlay SB 54-8, showing the spatial distribution of vegetation types throughout the Porgera-Koroba region (Hammermaster and Saunders 1995b).

Existing forest classification systems for PNG are constrained by the unwieldy mapping scales at which they are presented. Many communities encountered by the survey team are discretely repeating entities easily recognized on the ground, but are below the spatial resolution capability of the FIMS, a system generally available only in 1:250,000 scale. Even the limited-issue 1:100,000 agency maps are inadequate for tracking specialized communities (e.g. montane bogs, lacustrine habitats, limestone outcrops) which are typically small in size but of considerable conservation interest. Despite its limitations, there is no typing system in New Guinea more versatile than FIMS. The alternative schemes (Paijmans 1975, 1976; Johns 1977; Saunders 1993a, b) lack the digital and GIS (Geographic Information System) linkages afforded by the FIMS classification.

The most significant vegetation units seen during the survey are described below with specific reference to dominant or indicator species, irrespective of whether the communities are included on the FIMS. In cases where the community corresponds to a particular mapping category, the applicable codes are indicated in parentheses.

Upper montane forest (Mo). This formation (acronym UMF) generally occurs above 3,000 m, and is often described as 'mossy forest' or 'elfin woodland'. It includes forest types

traditionally regarded as 'subalpine'. Under the FIMS classification subalpine forests are not recognized as structurally distinct entities, and are lumped into an inclusive 'Mo' designation [see Grubb and Stevens (1985) for evidence against this procedure]. All of the genera considered diagnostic for the UMF (Hammermaster and Saunders 1995) are present at Omyaka. Subalpine forest (sensu Grubb and Stevens 1985) is also present in the proposed WMA as tracts of appreciable size, even though their existence is obscured by the FIMS methodology. A transition from UMF to *Nothofagus*-dominant and coniferous forest (codes LsN and Lc) occurs at lower elevations near the border with Southern Highlands Province (Hammermaster and Saunders 1995b), but the RAP reconnaissance did not enter those formations.

The Kaijende UMF is characterized by low (<10–14 m) trees with gnarly moss-enveloped stems and depauperate crowns. Microphyllous and nanophyllous taxa are dominant to such an extent that representatives from different families are very similar in vegetative aspect and difficult to distinguish except by close inspection. *Decaspermum alpinum*, *Eurya brassii*, *Ilex archboldiana*, *Prunus pullei*, *Quintinia kuborensis*, *Symplocos cochinchinensis* var. *orbicularis*, *Syzygium alatum*, *Vaccinium apiculatum*, and *Xanthomyrtus compacta* are the most common arborescent taxa (Photos 1–6). The tallest trees are represented mainly by gymnosperms, but the emergents are not conspicuous, being only slightly higher than the surrounding forest and consisting for the most part of widely scattered *Libocedrus papuana* var. *papuana*, *Podocarpus crassigemmis*, *Phyllocladus hypophyllus*, and *Dacrydium imbricatus* var. *robustus*. *Drimys piperita* (as entities *coriacea*, *heteromera*, and *montis-wilhelmi*), is the most frequent undershrub (Photos 7– 8).

Melicope brassii, *M. robbinsii*, *Olearia durifolia*, *O. platyphylla* var. *cinerea*, *O. spectabilis*, *Vaccinium amblyandrum*, *V. schoddei*, and *V. striicaule* var. *adenodes*, are conspicuous woody taxa on forest margins (Photos 9–10). The border vegetation often forms a structurally distinct scrub (code Sc) with the same signature genera as the UMF proper, but with reduced statures (<6 m) and higher population densities. At Omyaka the forest-scrub and grassland formations combine in a highly irregular mosaic composed of interpenetrating strips, fingers, and islands. This situation is beyond the mapping capability of the FIMS, and such areas are typically charted as composite entities (e.g. as 'Mo/Ga/Sc' at Omyaka Camp).

Many vining species of *Rubus*, including *R. archboldianus*, *R. lorentzianus*, *R. montis-wilhelmi*, and *R. royenii* var. *hispidus*, are present in the forest-grassland contact. The local populations of the *R. diclinus-trigonus* complex are of particular taxonomic interest and significance. However with the exception of *Rubus* and *Dimorphanthera*, lianes were notable more for their overall absence or rarity than for any special occurrences. In contrast to other montane localities, the epiphytic flora was poorly developed but two new orchids have been determined from the collections (N. Howcroft pers. comm.).

Tussock grassland (Ga, Gi). Kaijende Highland environments include large expanses of tussock grassland which appear homogeneous in gross aspect, but which actually exhibit considerable differentiation in species composition and community structure. This spatial variation probably reflects differences in successional status and fire incidence. At Omyaka Camp (located several kilometers from the access road and thus presumably with reduced fire frequencies), the dominant grass is the large tussock-forming *Chionochloa archboldii* (Photo 11). *Arundinella furva* and *Deschampsia klossii* are smaller and relatively minor species interspersed through the *Chionochloa* clusters. In areas with more human traffic (e.g. Porgera Reservoir and the Reservoir access road), a shift in species composition is evident, and *Poa keysseri* ssp. *keysseri* becomes the dominant bunchgrass. The likelihood of greater fire influence at these latter sites is implied by higher frequencies of *Imperata conferta* (kunai), and *Eulalia leptostachys*, taxa which often indicate for disturbance.

Although the open areas are mapped by FIMS exclusively as Ga- and Gi-coded grassland, several floristically discrete associations were discerned within those formations. There are for example, sizable areas of heath-like shrubbery scattered through the grass and consisting of *Hypericum macgregorii*, *H. papuanum*, *Coprosma papuensis* ssp. *discolor*, *Drapetes ericoides*, *Rhododendron commonae*, and *Styphelia suaveolens*. At Omyaka (e.g. 05°31'31" S, 143°03'13" E) the *Hypericum* association can encompass areas of a hectare or more, often dominating the inter-ridge clearings (Photos 12–15). On a more local basis, the continuity of the grassland is also broken by large ferny patches of *Blechnum revolutum*, *Plagiogyria egenolfioides* var. *decrescens*, *Gleichenia erecta*, and *G. vulcanica*. Of particular interest are the extensive savanna-like sections where tree ferns assume visual and stature prominence. *Cyathea dicksonioides* and *C. atrox* var. *inermis* are co-dominants within this association. Other species (*C. lepidoclada*, *C.* aff. *magna*) are also occasionally present as volunteers or possibly as relicts from a retreating UMF margin.

The non-grass associations intergrade with the grassland sens. str. in such a way that sharp divisions cannot be drawn on the ground. But they are still taxonomically and structurally recognizable as separate units. For conservation purposes, the FIMS procedure of lumping all open areas into a common grassland classification is too inexact. Several communities of exceptional composition and interest are hidden by such a procedure.

Montane bogs (Ga, Gi, Sc, in part). Bogs of the Kaijende Highlands are comprised of two principal facies: one dominated by *Sphagnum*, and the other by hemispherical hummocks or cushions of *Astelia alpina*, *Danthonia oreoboloides*, and *Oreobolus*. The *Sphagnum* facies is found in hollows and flats where the water table is suspended on the surface. Hummock bogs are apparently not under topographic control and can form even on knolls and moderate slopes. Both types occur in grassland mapped by FIMS as 'Ga' and 'Gi', or in conjunction with low scrub (Sc). Indi-

vidually and collectively the bogs are of very limited size and thus particularly susceptible to disturbance and alteration. Because of their small areas, they are invisible to all existing systems of vegetation classification in spite of their distinctive appearance.

As with other plant associations in the Kaijende grasslands, the bogs intergrade with surrounding vegetation. However they have a common core of diminutive character taxa including *Drosera peltata* ssp. *peltata*, *Eurya brassii* ssp. *apiculata*, *Gentiana ettingshausenii*, *Ischnea elachoglossa*, *Keysseria radicans*, *Myriactis cabrerae*, *Potentilla foersteriana*, *P. papuana*, *Ranunculus wahgiensis*, *Scirpus crassiusculus*, *S. mucronatus* ssp. *clemensiae*, *S. subtilissimus*, *Vaccinium amblyandrum*, and *V. stellae-montis* (Photos 16–21).

The Kaijende bogs are approximately assignable to the short grass bog, *Astelia* subalpine bog, and hard cushion bog of earlier investigators (Wade and McVean 1969, Hope 1976b). In view of the considerable variation exhibited by Papuasian mires, it is hardly surprising that the Porgera examples differ in many respects from the associations discerned elsewhere. *Sphagnum* bogs for example are not regarded as comprising a discrete facies on New Guinea summits, although they are clearly present in the Foja Mts. of Indonesian Papua (pers. obs.) as well as in the Kaijende Highlands.

In addition to the *Sphagnum* and hummock bogs with their characteristic physiognomy, there are numerous areas of similarly poor drainage scattered through the grassland. These swampy sections often have slow-moving water flowing along well-defined channels. An edible watercress (*Rorippa nasturtium-aquaticum*), usually forms a dense groundcover in such situations. Drainage lines in *Cyathea* savanna are clearly visible even over considerable distances because of color contrasts between the *Rorippa* and adjacent vegetation.

Lower montane forest (L). The lower montane forest (acronym LMF) was seen only around the closed valley at Lake Tawa. Canopy statures in this formation are much higher than in the UMF (to ca. 30 m at Lake Tawa) and collections were correspondingly harder to obtain. Unlike the subalpine zone, where most of the woody taxa have probably been enumerated, the greater part of the LMF flora undoubtedly remains unrecorded. Of the 23 character genera for the LMF (fide Hammermaster and Saunders 1995a), only eight were checklisted at Lake Tawa.

The forest types at Lake Tawa are arranged in elevationally sequenced bands around the valley floor (Photos 22–23). This is clearly shown by the FIMS, and was also verified by ground reconnaissance. Of particular interest are the limestone outcrops (05°35'54" S, 142°50'07" E) where three new species were discovered. Unfortunately the *Nothofagus* forest to the southwest of the camp could not be reached because of rugged terrain.

Syzygium (particularly *S. effusum*), *Symplocos cochinchinensis* ssp. *leptophylla* (vars. *leptophylla* and *monticola*), and *Lithocarpus rufovillosus* were apparently the most frequent canopy trees in the Lake Tawa LMF, but impressionistic evaluations of this sort are not always reliable. An observer's attention is understandably directed at fertile taxa, and such plants will tend to receive excessive weight in post-survey reporting. Under different phenological circumstances, rapid assessment estimates could change substantially. Unlike the high-elevation formations at Omyaka, the Lake Tawa stands were predominantly sterile during the survey's visit and the identities of many overstory species were not determinable.

Irrespective of the unfavorable canopy conditions, *Cyathea atrospinosa* and *C. magna* were clearly the most exceptional understory plants in terms of frequency and visual apparency. The ground layer was generally species-poor and mostly represented by urticates.

Near the floor of Tawa valley, the LMF has a well defined border with emergent stands of 20 m+ *Pandanus* (section *Intraobtutus*). On its downslope side the forest border opens abruptly into a herbaceous mat association surrounding the catchment basin lakes (Photo 24). The lakefront zone is comprised primarily of *Cardamine keysseri*, *Hydrocotyle sibthorpioides*, *Hypericum* cf. *papuanum*, *Isachne pauciflora*, *I. villosa*, *Oenanthe javanica*, *Oxalis corniculata* var. *sericea*, *Polygonum longisetum*, *P. strigosum*, and *Viola arcuata*, and is under water during periods of high rainfall (Photos 25–27). In foothills to the north and west, multistoried LMF forest is replaced by pandan savanna-scrub with a *Dicranopteris-Gleichenia*-Ericaceae groundlayer (Photos 28–29). *Pandanus* crowns of this latter vegetation are often festooned by pendulous sprays of *Asplenium nutans* and *Belvisia validinervis* var. *longissima*. *Vaccinium auriculifolium* and *Glochidion* sp. nov. (aff. *dumicola-oogynum*) are the most common savanna shrubs.

Noteworthy collections

The expedition checklist currently consists of 492 vascular plant taxa (Appendix 2). Included in the collective accounting are 112 pteridophytes (ferns and lycophytes), 6 gymnosperms, 69 monocots, and 305 dicots. The tallies are distributed through 25 pteridophyte families, 3 gymnosperm families, 87 Angiosperm Phylogeny Group families, and a cumulative total of 262 genera.

No claim is made regarding the comprehensiveness of the Kaijende checklist. Rapid assessment procedures are incapable of achieving sampling saturation and will usually reveal only the most salient qualities of an investigated flora. However the large number of montane taxa represented by multiple gatherings is a circumstantial indication that a substantive coverage of the macroflora has probably been secured.

Porgera is a locality of major economic importance to PNG (the open-pit mine accounts for 14% of the country's export earnings and was the world's eighth largest gold producer in terms of 2005 output), so it is reasonable to assume *a priori* that botanical collections have already been taken from the general vicinity. Despite this expectation, examination of LAE institutional logbooks shows no evidence of

earlier work in the district. From the number of significant findings made by the survey, it can be inferred that floristic exploration either has not occurred within the proposed conservation tract, or was superficial in scope.

Distributional records, rare taxa of conservation value, species new to science, and other noteworthy plants, are briefly presented in the following narrative. Author citations are specified in the text when a binomial is not on the checklist. Numbers refer to the survey vouchers. First sets and holotypes are at LAE; second sets at Arnold Arboretum. Residual duplicates have been distributed to appropriate specialists at other institutions.

Actinidiaceae

Saurauia sp. nov., ser. *Setosae*; Lake Tawa: 20066; Paiela Road: 20087; Waile Creek: 20310. Photos 30–31.

There are three collections of a distinctive microphyllous species with conspicuously serrate leaves. The erect inflorescence is seemingly uniflorous, but on some branches the flowers are dichasial, so the new plant is probably best placed in *Setosae* rather than *Uniflorae* (but see comments in Smith 1941: 502). *Saurauia altiterra*, *S. giluwensis*, and *S. trugul* are frequent associates.

Identifications in this genus are particularly problematic. The last comprehensive treatment (Diels 1922) has become acutely outdated by events over the past 85 years. Royen (1982) reviews only the alpine taxa.

Although the various species of *Saurauia* are among the most characteristic plants of montane environments, few botanists are willing to attempt determinations in this speciose and unrevised genus. At Lae Herbarium the unnamed collections are nearly 3x the number of identified sheets (975/344 by manual count), a proportion which is probably similar to the holdings in other herbaria. Many identifications are of dubious accuracy.

Araliaceae

Polyscias belensis Philipson; Lake Tawa: 19771.

Polyscias belensis was known to Philipson (1978, 1979) from a small number of specimens obtained in Irian Jaya (Lake Habbema) and from Morobe Province (Wau-Aseki) in PNG. A recent collection from the Bismarck Range represented the first report of this species from the PNG Highlands (Takeuchi 1999a). Judging from material present at Lae Herbarium, there are no contemporary records other than the Bismarck gathering.

Polyscias belensis and *P. ledermannii* (Photo 32) can be found in mixed populations and are easily confused when occurring together. Although rarely reported by botanists, the many sightings from Lake Tawa suggest that *P. belensis* may be more common than previously suspected.

Athyriaceae

Diplazium sp. ?nov.; Lake Tawa: 19952.

The survey specimen appears to represent a new taxon distinguished by large cordate scales on the pinnae bases.

Elaeocarpaceae

Aceratium ledermannii Schltr.; Lake Tawa: 19949.

The species of the *ledermannii-oppositifolium* complex are lowland plants with documented occurrences to 300 m elevation (Coode 1981: 43). The survey collection from 2,300 m represents a substantial extension in vertical range.

Ericaceae

Dimorphanthera sp. nov.; Omyaka Camp: 19571; Waile Creek: 20206. Photo 33.

Dimorphanthera sens. lat. was recently revised by Stevens (2004). The expedition numbers are closest to *D. ingens* (Sleumer) Stevens on the latest treatment, but differ in the fascicled inflorescence, and by the indument on pedicels and the corolla tube.

Diplycosia sp. nov.; Paiela Road: 20000.

The new species is similar to *D. lamii* J.J. Sm., but has considerably smaller flowers (corolla to 3 mm long).

Vaccinium stellae-montis Sleumer; Omyaka Camp: 19699.

Formerly regarded as endemic to the Star Mts. The Omyaka specimens are from miniature plants in *Sphagnum-Oreobolus* bogs.

Euphorbiaceae

Breynia collaris Airy Shaw; Lake Tawa: 19996.

Breynia collaris is a high elevation shrub known from four collections originating in the Eastern Highlands (Airy Shaw 1980). LAE has only one genuinely annotated specimen (Brass 30440; cited in the protologue). The survey record extends the species range slightly to the west and into Enga Province.

Glochidion sp. nov., aff. '*dumicola-oogynum*' facies; Lake Tawa: 19806, 19994, 20025.

The new species has the smallest leaves and fruits of any Papuasian congener, and capsules strongly resembling those of *Phyllanthus*. The similarity to *Phyllanthus* is so pronounced that the plant was repeatedly misidentified in the field. However the connate stamens, absence of disk glands, and the styles united into a cylindrical column, are more characteristic of *Glochidion*.

Macaranga sp. nov.; Lake Tawa: 19931, 19938. Photo 34.

The large single stipules and long-peduncled inflorescence indicate a clear relationship to Whitmore's '*longistipulata* group' (Whitmore 1980). Among the members in that complex, the new species is closest to *M. papuana* (J.J. Sm.) Pax and Hoffm., but is immediately distinguished by the thickly coriaceous leaves and entire fruits (leaves thin-textured and fruits furnished with flexible processes in *M. papuana*).

Lomariopsidaceae

Elaphoglossum angustifrons Holtt.; Lake Tawa: 19842.

At the time of the last generic treatment (Holttum 1978) *E. angustifrons* was known only from the type specimen, obtained 12 miles north of Minj in Western Highlands Province. Shortly after the Holttum revision, the fern was also found in the Mt. Hagen area by Parris and Croxall (coll. nos. 8176, 8177, 9388). The latest collection from Lake Tawa is the third known locality for the species and the first record for Enga Province.

Monimiaceae

Palmeria clemensae Philipson; Lake Tawa: 19981. Photo 35.

Palmeria clemensae is a widely distributed but infrequently collected species (Philipson 1982: 98). There are no prior reports of this vining plant from Enga Province or from the former Western Highlands District to which Enga had been administratively attached until 1975.

The survey specimen is an example of Philipson's 'western form', distinguished by leaves with bristly hairs concentrated along the veins.

Myrsinaceae

Rapanea (=*Myrsine*) sp. nov.; Waile Creek: 20275.

The new species has an unusual combination of red corollas, consistently pentamerous flowers, and a lepidote indument on vegetative parts. On Royen's (1982) treatment the survey collection falls between *R. borgmannii* Royen and *R. communis* Royen (=*R. cacuminum* and *R. leucantha* respectively, fide Sleumer). Using Sleumer's (1986) key, all credible leads end in impasse and the affinity is uncertain.

Myrtaceae

Syzygium sp. nov., aff. *goniocalyx* (Laut.) Merr. & Perry; Lake Tawa: 19873, 19987B. Photo 36.

The deeply channeled calyx tube is very distinctive and suggestive of *Syzygium goniocalyx*. However the vegetative characteristics are inconsistent with that species. In the most recent revision for Papuasia, Hartley and Perry (1973) provided a provisional key to a conspectus of 138 species. Many hundreds of unidentified collections have been made in the ca. 30 years since their preliminary review. At least 20 undescribed species are probably present in these newer gatherings.

Syzygium sp. nov., aff. *malaccense* (L.) Merr. & Perry; Lake Tawa: 20018.

The flowers of the presumed novelty have the characteristic appearance of *S. malaccense* sens. lat., but the small suborbicular leaves are far outside the range of variation even for that polymorphic complex.

Oleaceae

Jasminum sp. nov.; Omyaka Camp: 19581, 19596; Waile Creek: 20298. Photos 37–38.

The new species differs from the related *J. domatiigerum* in the small glabrous leaves without domatia, conspicuously glandular-punctate undersurface, and the terminal congested inflorescence. Several LAE collections of this taxon have been annotated by R. Kiew as *J. domatiigerum* var. nov. Royen (1982) had noted the existence of foliar variation in *J. domatiigerum* and uncharacteristically adopted an excessively wide interpretation of that species. However the variation is not random. In contrast to collections referred to *J. domatiigerum*, the Kaijende populations are found only as long-branching shrubs in the tree fern savanna or its margins, and never as forest climbers.

Orchidaceae

Glossorhyncha spp. nov.; Lake Tawa: 20035; Waile Creek: 20241 ex Beehler (dets. by N. Howcroft).

Two collections of *Glossorhyncha* have been determined as undescribed species and are presently under study for future publication by N. Howcroft (pers. comm.).

Polyosmaceae

Polyosma sp. nov., aff. *occulta* Reeder; Paiela Road: 20148.

The undescribed *Polyosma* with foliaceous bracts is nearest to *P. occulta*, but differs significantly from that species in the following respects (corresponding character states for *P. occulta* in parentheses): vegetative parts glabrous (velutinous or puberulent); lamina oblanceolate, 1.5–2.5 cm long (elliptic or oblong-elliptic, 3.5–5.0 cm long); racemes 1.0–1.5 cm long, axes glabrous (3–6 cm long, rachis subvillous); bracts unlobed and glabrous (tri-lobed and subsericeous); flowers 2–8 (8–20); calyx 2.5 mm long, (4.5 mm long), tube 0.9–1.0 mm by 0.7 mm (2 mm by 1.5 mm); corolla 0.8 mm diam. (2 mm diam.). Reeder (1946) gives an informative discussion of the *occulta* facies and related species.

Polypodiaceae

Selliguea costulata (Ces.) Wagner & Grether; Lake Tawa: 19877 ex Beehler.

The survey collection from 2,300 m represents a substantial extension in elevational range. *Selliguea costulata* had been previously recorded from sea level to 1,600 m (Hovenkamp 1998a: 43, 1998b: 198). At higher elevations this species merges with *S. lauterbachii* (Brause) Hovenkamp, and the two ferns can be difficult to separate (ibid.). The continuous nature of the variation is exemplified by another survey collection (20017A, from the same locality as 19877) in which the diagnostic features for each taxon are intermixed.

Ranunculaceae

Ranunculus uncostigma Merr. & Perry, or aff.; Paiela Road: 20104, 20190; Waile Creek: 20293.

The species was previously known from two collections obtained in Indonesian Papua (Irian Jaya) during the Archbold Expedition of 1938–9 (Merrill and Perry 1943, Royen 1982). *Ranunculus* is a common genus in high montane habitats, but many botanists apparently ignore these plants, judging from the fact that most of the existing material has been acquired by relatively few collectors. Notwithstanding their small size, *Ranunculus* species are not difficult to find and are easy to collect.

The identification of many taxa is complicated by variability in indument, leaf form, and staminal number. Royen's (1982) key is frequently unworkable because supposedly diagnostic character states often fall between the couplets or apply in part to either fork. Nearly every botanical author comments on the desirability for more collecting within their specific areas of interest, to a point where such advisories are almost banal. However the need for serial collections is especially obvious in this genus.

Rosaceae

Rubus sp., aff. '*diclinus-trigonus*' facies; Paiela Road: 20093A; Waile Creek: 20225. Photos 39–40.

The survey collections have the leaf characteristics of *R. diclinus* and the flower dimensions of *R. trigonus*. Kalkman (1987) noted the close relationship between these species but accepted their separation because of presumed distinctions in leaflet and flower size. Possible hybridization is indicated by the intermixing of characters in Kaijende populations, although *R. diclinus* and *R. trigonus* are not represented in the survey collections. The presence of an intergrading series also suggests that the *diclinus-trigonus* facies comprises a single continuum of variation, and may be undeserving of recognition as separate taxa.

Rubiaceae

Psychotria sphaerothyrsa Val.; Lake Tawa: 19940.

This species was previously recorded from West Sepik Province (two collections; Sohmer 1988) and Central Province (one collection; Merrill and Perry 1946). In more recent years, *P. sphaerothyrsa* has been found in the lowland forests of Crater Mountain (Takeuchi 1999b). The survey specimen was obtained at a substantially higher elevation (2,340 m) than the 1,000 m limit previously supposed for *P. sphaerothyrsa*. The new locality record also exhibits several aberrant qualities relative to the species sens. str. (the usual character states of *P. sphaerothyrsa* are given in parentheses) viz., the conspicuously hairy leaves (entire plant glabrous), 13–18 secondary veins per side (22–28 pairs), pyrenes 7–8 mm long (3–4 mm long), and branchlets emyrmecophilous (branchlets ant-inhabited). In other respects, particularly the unusual double-inframarginal vein, the Lake Tawa specimen shows good agreement with *P. sphaerothyrsa*. Although the nonconforming features may be sufficient to justify recognition of a new taxon, the differences are also reasonably attributable to elevation-related variation. The Kaijende plants are thus provisionally regarded as an extreme form in an ecoclinal series whose elements will eventually be connected by future collecting. Sohmer (1988) was uncertain of the fruit color. The ripe pyrenes at Lake Tawa were red.

Rutaceae

Acronychia emarginata Laut.; Lake Tawa: 20017B.

An occurrence record from Enga Province is added to the poor documentation for *A. emarginata*, known with certainty from six prior collections. The Lake Tawa specimen was from limestone.

Acronychia foveata Hartley; Lake Tawa: 20065.

Acronychia foveata is an infrequently collected endemic, previously recorded only from Morobe and Southern Highlands Province. The four known collections are historical specimens from LAE's early institutional series (NGF 21201!, 37080!, 37090!, 39820!).

Acronychia richards-beehlerii Takeuchi 2007; Paiela Road: 20119. Photo 41.

The new plant is distinguished from all Papuasian congeners by the combination of trifoliolate leaves and deeply fissured ovary and fruits. The epicarp is conspicuously rugose in the manner of *A. foveata* and *A. smithii* Hartley, but the former species has unifoliolate leaves and the latter has unfissured ovaries and fruits. On Hartley's (1974a, b) treatment the Kaijende specimen is superficially similar to the Australian endemics *A. suberosa* C.T. White and *A. chooreechillum* (F.M. Bailey) C.T. White.

Solanaceae

Solanum nolense Symon; Lake Tawa: 19904.

Solanum nolense was previously known only from the type collection, a fruiting specimen obtained in 1977 between Mendi and Nol. Symon's (1985) protologue explicitly notes that the upper parts of the plant are unarmed. The Kaijende material is amply aculeate over the entire length of the stem axis, including the uppermost sections. The partially inermous character of the type is thus coincidental, and not germane to the species. Unlike most Papuasian congeners, the petals are white. A complete specimen with fruits and anthetic flowers was found at Lake Tawa.

Thelypteridaceae

Mesophlebion sp. nov.; Waile Creek: 20272.

A peculiar species, exactly matching Pullen 5117, annotated by Holttum as *Mesoneuron spinuliferum* sp. nov., but apparently a nomen nudum requiring formal description.

Pneumatopteris sp. nov., aff. *caudata* (Holtt.) Holtt.; Lake Tawa: 19947.

The new species was found on limestone exposures above Lake Tawa. It is closest to *P. caudata* but differs in the creep-

ing rhizome, smaller pinnae, and the glabrous indusia and veins.

Pneumatopteris petrophila (Copel.) Holtt.; Lake Tawa: 19953.

Except for the Papuan type, *P. petrophila* is known primarily from a few localities in northeastern PNG (Holttum 1973, 1981). The survey specimen was obtained on a limestone outcrop with *Pneumatopteris* sp. nov.

Urticaceae

Pilea sp. nov., aff. *zaranensis* Royen; Paiela Road: 20144; Waile Creek: 20277, 20283. Photo 42.

The three collections are unlike any urticate sheet at LAE, although the species is very common on forest margins and in *Cyathea* savanna. The new taxon's identifying features are the extensively branched and sprawling habit, strigulose indument, and small leaves (to only 1.5 cm long) with conspicuously toothed margins. On adaxial surfaces the lamina is distinctively marked by black discoid glands.

DISCUSSION

Comparisons with other surveys

On a per diem basis, the expedition's 759 collections are among the highest sampling results achieved by CI-RAP assessment in PNG. Compared to other surveys of equivalent duration, the 491-morphospecies checklist is also one of the better enumerations produced by recent investigations.

Upper montane vegetation is typically species depauperate in relation to lower elevation habitats, so reduced taxonomic counts are expected even with good collections coverage. The Kaijende sampling productivity is mainly attributable to reduction of canopy statures at the UMF study sites and a resulting increase in the accessibility of collection targets. Exemplary service infrastructure, and logistical support of a quality rarely experienced by field teams, also contributed significantly to the advantages afforded by in situ conditions.

Even without these factors it is generally much easier to develop checklists of montane plants in comparison to lowland ones because of the favorable phenologies to be found at higher elevations. Most plants in the UMF have substantially longer flowering periods relative to the LMF flora (Grubb and Stevens 1985). Surveyors on a limited schedule are thus more likely to find fertile individuals in upland habitats like Omyaka, and will nearly always get poorer results from sites like Lake Tawa. Similar elevational patterns have been consistently experienced by RAP botanists on Papuasian surveys (e.g. Takeuchi and Wiakabu 2001). In UMF-subalpine environments at least some individuals of a given species will be found in fertile condition, while the same is not true when working in lowland areas.

The taxonomic results at Porgera can be compared with a recent survey in the Karius Range (April 24–May 9, 2005, at localities 40 km SSW and 52 km SSE of Lake Tawa; see Takeuchi 2005). The Karius survey used the same procedures applied at Porgera; with three botanical surveyors on a 16-day field itinerary, but was focused on lower elevations (bivouacs at 1,370 m and 2,270 m). The Karius tallies are listed below with the corresponding Kaijende figures in parentheses:

From a total of 568 (759) collections, the Karius census recorded 401 (492) vascular plant taxa, consisting of 89 (112) ferns and lycophytes, 3 (6) gymnosperms, 21 (69) monocots, and 288 (305) dicots. The registers were distributed through 23 (25) pteridophyte families, 3 (3) gymnosperm families, 84 (87) Angiosperm Phylogeny Group families, and a cumulative total of 250 (262) genera. It should be noted that while the values are similar in most categories, the Karius numbers were based on substantially fewer collections, and half of the time was spent on limestone karst. The comparative figures primarily reflect 1) an increase in diversity of herbaceous plants at higher elevations, and 2) the greater efficiency of floristic surveys conducted in upper montane environments. An expected reduction of generic-level diversity in UMF habitats [see review of montane floristic patterns in Grubb and Stevens (1985) and Paijmans (1976)] is not apparent in the cross-tabulations. The superior collections coverage achieved at Kaijende conceals some of the taxonomic patterns that should ordinarily have emerged in the comparison with lower elevation environments. Checklists from Doma Peaks (Gillison 1970, Kalkman and Vink 1970), Fatima Basin-Mt. Kerigomna (Grubb and Stevens 1985), Mt. Jaya (Hope 1976b), Mt. Trikora (Mangen 1993), and Mt. Wilhelm (Hoogland 1958, Wade and McVean 1969, Johns and Stevens 1971) provide floristic summaries of other upper montane localities.

Ecological and biogeographic status of the Kaijende flora

Enga Province is one of the most rugged physiographic districts in Papuasia, as seen by the fact that its 12,800 sq. km territory includes a higher proportion of upper montane (>3,000 m) environments than any other province in eastern New Guinea (Löffler 1977). Because of the prevalence of high elevation habitats, areas like Kaijende are characterized by pronounced dominance of microtherm families, most notably by Cunoniaceae, Epacridaceae, Ericaceae, Geraniaceae, Myrsinaceae, Podocarpaceae, Ranunculaceae, Rosaceae, Theaceae, Violaceae, and Winteraceae. These temperate-latitude elements are represented by genera with geographic affinities to the northern hemisphere (e.g. *Ranunculus*, *Rhododendron*, *Vaccinium*, *Viola*) or by a distinct Antarctic component of southern origins [e.g. *Astelia, Coprosma, Dacrydium, Drimys, Gaultheria, Gunnera, Olearia, Podocarpus, Rapanea, Rubus, Styphelia, Trochocarpa*, and *Xanthomyrtus*; see Good (1960), Steenis (1972), Whitmore (1975), Hartley (1986) and Thorne (1986)]. Floristic connections to the temperate latitudes are especially apparent in Kaijende's montane bogs, which are essentially displaced temperate-continental communities.

Ericaceae is the most diverse woody family in habitats above 3,000 m (Photos 43–45). Two of its principal genera,

Rhododendron and *Vaccinium*, are represented entirely by taxa restricted to New Guinea, most of these having ranges extending over large areas of the Central Divide (e.g. *Rhododendron beyerinckianum*, *R. commonae*, *R. herzogii*, *R. inconspicuum*, *R. macgregoriae*, *R. scabridibracteum*, *Vaccinium amblyandrum*, *V. finisterrae*, and *V. reticulato-venosum*; Photos 46–49). Similar patterns of island-wide endemism are also exemplified by Elaeocarpaceae (all recorded taxa), *Epilobium* (all recorded species), Myrsinaceae (all recorded taxa), *Olearia* (all species except *O. pallida*), Orchidaceae (most taxa; see Vogel and Schuiteman in press), *Rubus* (all species except the indigenous *R. moluccana*), Theaceae (all recorded species), and Winteraceae (all recorded species). The remainder of Kaijende's montane flora is generally comprised of plants distributed through at least two provinces (e.g. *Vaccinium apiculatum*, *V. auriculifolium*, *V. schoddei*). Notwithstanding the new species discovered on the RAP survey, localized endemics like *Solanum nolense* are an exception.

The overall paucity of geographically restricted taxa is consistent with New Guinea's Quaternary history of climatic and floristic change. During the last glacial age from 22,000 to 10,000 yrs BP, the alpine and subalpine zones were forced downwards to elevations below 2,500 m (Hope 1976a). As part of this adjustment, treelines were depressed by 1,200 m (Hope 1973) and may have stabilized at 2,000–2,300 m throughout the cordillera until ca. 12,000 yrs BP (Powell and Hope 1976). At Tari and Koroba, palynological cores from 30,000+ yrs BP show signs of upper montane species occurring as low as 1,500 m, clearly implying a dramatic shift in vegetation belts (Hope 1976a). Previous glacial periods during the Pleistocene were at least as severe, being accompanied by extension of subalpine formations into habitats where beech is now dominant. In some areas, *Nothofagus* forests probably reached 1,400 m, far below their contemporary centers (Gillieson et al. 1989). Climatically induced displacements of such magnitude would have connected different summits on the Divide through extension of their montane vegetation, a process nowadays reflected in the relative scarcity of local endemics and the higher incidence of wider-area endemism.

An obvious consequence of past climatic change is that the principal features of the Kaijende flora have only been determined within the last 15,000 years, primarily during the interglacial recovery of vegetation zones. For higher elevation sites like Omyaka, the existing community mosaic would have established more recently, at 8,000–9,000 yrs BP, according to pollen sequences at comparable elevations on Mt. Wilhelm (see timeline in Hope 1976a). Kaijende montane formations are thus relatively youthful floristic environments, having migrated into their present positions with the Holocene lifting of forest zones. It is very unlikely that the botanical novelties discovered by the survey evolved in situ. More probably the new plants originated at lower elevations and moved with the vegetation belts during the post-ice age amelioration of climate. The alternative scenario, of accelerated local speciation occurring within the Holocene period, seems less plausible, given the overall scarcity of geographically restricted Highland endemics.

Certain parts of the Kaijende flora may still be reassembling at their contemporary stations. Because events of the past several thousand years have required fairly rapid extensions in range, it is unlikely that the flora of the region has been able to adjust in real time. A floristic lag effect is probable, and its existence can be inferred from the spatial heterogeneity of Kaijende-area forests, in particular by the very dissimilar species compositions and frequencies between ecologically equivalent sites (e.g. at Omyaka and areas west of Porgera Reservoir). UMF formations in the Kaijende region are arguably in a state of ongoing reconstitution at the higher elevations, and the equilibrium of the climatic-climax forest has not yet been achieved.

Many aspects of Holocene forest change remain poorly understood. Few studies have been undertaken on New Guinea paleoenvironments since the pioneering work of the 1970s, and although patterns of vegetation change at the upper elevations seem clear enough, corresponding events at lower elevations are largely conjectural.

Thus while there is no question that floristic environments at Kaijende have been profoundly destabilized in the last 15,000 years, it is less clear whether these influences extended over the entire conservation district. The lower parts of the proposed WMA fall within the potential elevational limits of forest replacement as determined from palynological studies at other sites. But whether or not the ice age expansion of subalpine conditions descended to the lower edges of the Kaijende tract remains unknown. In this connection it is interesting to note that the depositional-basin lakes and swamps at Lake Tawa (2,200 m) are coincidentally positioned at the reconstructed contact between the paleohistorical UMF and LMF (2,200–2,500 m; see Hope 1976a: figure 11). Stratigraphic and palynological analysis of sediment cores from Lake Tawa could prove highly illuminating.

An anthropogenic origin for the tree fern savanna?

The *Cyathea* savanna is unique to the island of New Guinea and has consequently attracted widespread attention as one of Papuasia's classic floristic environments (Photo 50). Due to its visually appealing qualities, the savanna has been a frequent subject of photographic depiction [inter alia Holttum 1963: 107 (showing *C. dicksonioides*), 129-130 (from Enga's Sugarloaf, with *C. atrox* var. *inermis*), Mangen 1993: 77 (as 'treefern shrubland' from Mt. Trikora), Paijmans 1976: 89 (same as Holttum but with a wider visual field), Wade and McVean 1969]. At Kaijende this formation is exceptionally well developed, comprising one of the largest and most conspicuous landscapes in the upper montane zone from 3,000 m to at least 3,400 m. In other montane areas, the savanna attains its best development from 2,700–3,300 m elevation (Paijmans 1976).

Unlike other vegetation types at Kaijende, there is considerable disagreement over the ecological status of the savanna-grassland. The prevailing view is that nearly all Papuasian grasslands (with the notable exception of occurrences at or above treeline) are of anthropogenic origin (Hammermaster and Saunders 1995a). Paijmans (1976) for example, regarded *Cyathea* savanna as a fire disclimax, recognizing the apparent role played by anthropogenic burning in the creation and maintenance of open grassy areas. This interpretation of the savanna as a secondary vegetation derived from former forest was also adopted by Brass (1941) and by Wade and McVean (1969).

The effects of fire during periods of drought have been described by many observers (e.g. White 1975, Paijmans 1976, Hope 1983, Johns 1986). The Omyaka vegetation has clear evidence of such influences, with charred logs and tree stumps scattered through the forest-grassland transition in many places near the former camp-site. According to a local guide, the savanna and scrub mosaic centered on 05°31'28" S, 143°03'12" E (Photo 51) was burned in 1998 during the last El Niño event. It is likely that fires set by travellers passing through the vicinity have been a frequent occurrence in the past, and that burning is not restricted just to periods of severe drought. The highly irregular forest-grassland boundary in this general area, and its typical configuration as tongues and strips apparently shaped by wind, are very suggestive of fire etiology.

Although the present-day spatial correspondences between burning and *Cyathea* savanna are unequivocal, this connection does not preclude a natural origin for such communities. Based on paleohistorical reconstruction from pollen diagrams, Hope (1976a) concluded that large expanses of treefern savanna were present on Highlands summits prior to 10,000 yrs BP, and may have even extended above treeline to form communities for which there is no longer any existing analogue.

On this interpretation the relationship between fire and *Cyathea* savanna is not a cause and effect connection, but more akin to facilitation: anthropogenic burning favoring the spread of a natural community because of the inherent fire tolerance of its components. If the *Cyathea* grasslands were indeed present at a time when human influence can be discounted, the characterization of such areas as anthropogenic artefacts is overthrown. However the natural-status argument is not without uncertainties of its own. Palynological reconstruction is highly inferential; the determination of pollen spectra in sediment stratigraphies is affected by many factors and assumptions that cannot be precisely quantified (Tauber 1965, Faegri 1966, Faegri et al. 1989). In view of the conspicuous lack of consensus from past debate, the status of these intriguing landscapes is best regarded as remaining unresolved, even though their apparent restriction to New Guinea seems to favor the natural origin hypothesis. *Cyathea* is a common genus in other Malesian habitats where fires also occur, yet the treefern savanna facies has not been recorded elsewhere in the region. If such areas are the result of disturbance, it is difficult to see why the presumed causative process has failed to generate the same response in apparently equivalent situations.

CONSERVATION RECOMMENDATIONS

Botanical imperatives for a Kaijende conservation district

Environmentalists understandably emphasize biotic criteria in the selection of proposed conservation easements. Oftentimes the practical aspects of reserve management receive scant attention from enthusiastic scientist-administrators, yet the commonplace non-biological issues relating to site accessibility, ambiance, operational costs etc., will often determine the viability of medium- and long-term activities within such tenements. Every existing protected area can boast of the presence of new and endemic taxa within their areas of oversight. The proposed Mt. Kaijende Highlands Conservation Area will be no different. However for planning purposes, it is more useful to consider the potentially unique aspects of a Kaijende initiative relative to the many Wildlife Management Areas (WMAs) already in existence.

What exactly are the potential advantages of a Kaijende conservation project for botany? And in what way(s) will the establishment of yet another conservation zone provide opportunities beyond what is already available elsewhere? In any retrospective analysis of what has been learned during the recent survey, these should be the summary points deserving of explicit enumeration, beyond the mere discussion of taxonomic discoveries made by RAP reconnaissance:

1. Kaijende environments are disproportionately represented by upper montane habitats and vegetation formations that are not protected by existing initiatives in Papua New Guinea. Island endemism is higher in UMF and subalpine environments than in low elevation habitats of the sort covered by many WMAs. Insofar as conservation should be focused on the preservation of unique biotic assets, the Kaijende Highlands plan is well placed to provide security for endemic taxa presently excluded from conservation consideration.

The biogeographic profile of the Kaijende flora differs markedly from lowland and colline conservation districts where the vegetation is primarily of tropical composition. Although Kaijende communities are species-depauperate, they include many plants found only in the highest parts of the Central Cordillera. Because of the elevation constraints, taxonomic and biogeographic studies involving these taxa can only be pursued in areas like the Waile Creek-Omyaka tract.

For similar reasons, Kaijende's montane habitats are especially appropriate for monitoring long-term floristic change caused by global warming. The UMF is acutely responsive to temperature shifts induced by climatic change, as demonstrated by palynological evidence from Holocene sediments. Baseline studies could be established to exploit Kaijende's

geographic advantages, in recognition of opportunities that cannot be replicated at other localities.

2. Not unexpectedly, summit environments in the Dividing Ranges are typically among the most remote and logistically challenging environments in New Guinea. Service infrastructures are very poor or nonexistent in such places, with the unfortunate result that many upper montane habitats remain inadequately known despite their intrinsic botanical value.

The Kaijende survey illustrates the potential rewards of working in habitats where access and support facilities are of a quality commensurate with the biotic value of a site. Every protected area (in PNG mostly WMAs) has biodiverse environments in an exemplary state of preservation, otherwise the conservation imperative for those areas would not have arisen in the first place. However few localities can offer the same advantages of accessibility and facilities support provided by current operations at Porgera mine. The survey's successes were in large part attributable to the infrastructural resources present in the surrounding district. There is ample reason for anticipating that future scientific activities could be enhanced to the same extent as the recent undertaking.

3. Kaijende habitats are scenic and visually stunning landscapes. Their picturesque qualities cannot be reduced to objective argumentation in the manner of taxonomic discovery, but aesthetic considerations should be as much a part of site evaluation as the more conventional aspects of RAP appraisal. The landscape panoramas at Omyaka and Lake Tawa are among the most photogenic ever experienced by the assessment team. While many conservation districts are characterized by gloomy forests laden with pests and parasites, the Kaijende localities are comparatively pleasant and easy environments for exploration and research. The upper montane areas are often cold and misty (there was a hail fall on August 22 and daytime temperatures typically averaged a chilly 5° C), but on balance there are few conservation venues in PNG as amenable to recreational and study activities.

Mine-site rehabilitation

As PJV enters the final phase of operations at Porgera, activities relating to corporate withdrawal will become of increasingly greater urgency. The adoption and implementation of a reforestation strategy for areas impacted by the mine will undoubtedly be of particular concern.

A logical way of proceeding on this issue is to first identify the components of floristic succession in nearby environments, and to then apply these processes to the exit plan. Floristic indigens should receive preferential attention in such an endeavor, instead of importing alien plants that may or may not prove suitable as mine-site colonizers. By the very fact of their presence in endemic communities, local species will be the most adaptable to Porgera conditions. The least desirable action that PJV could undertake is to introduce potentially invasive species which later act as seed sources for contamination of the conservation tract. Many Kaijende habitats are open-aspect successional environments presenting opportune targets for invasion. The UMF and adjacent formations are presently in relatively unspoiled condition. Although 16 alien species were registered from habitats above 3,000 m, the non-native flora is primarily confined to roadsides and other avenues of human entry (Photos 52–53). Only two adventives were seen at Lake Tawa. Since the conservation initiative is proceeding under PJV auspices, the counterproductive nature of unintended impacts is self-evident.

Seral environments near Porgera are dominated by woody species from four genera: *Olearia* (six spp.), *Saurauia* (five spp.), *Symplocos* (one sp. with three vars.) and *Vaccinium* (eight spp.). Although other volunteer taxa are present in newly cleared sites (e.g. *Glochidion, Omalanthus, Macaranga*, and *Mallotus*) these are decidedly less prominent in terms of area coverage and frequency.

Reforestation trials should assess the suitability of all common pioneers, but the naturally dominant volunteers will be the most promising initial candidates in any revegetation exercise (Photos 54–60). For purposes of planning orientation, project principals should examine regrowth areas at the Pass (05°32'13" S, 143°04'59" E), where the candidate genera (*Olearia, Saurauia, Symplocos, Vaccinium*) are conspicuous invaders of quarry-rock rubble, clearly showing that the taxa involved do not require mineralized substrate for establishment. A similar capability for colonizing bare ground is also seen in several vining species; viz. *Gonocarpus halconensis, Muehlenbeckia monticola* (Photo 61), and especially the many species of montane *Rubus* found in grasslands and forest margins. The last genus however, is represented by unpleasantly thorny plants and would be less desirable as a designed groundcover.

The arborescent species of potential value in mine-site restoration can be extracted from Appendix 2. Among the entries on that list, *Symplocos cochinchinensis* requires separate consideration for its taxonomic and ecological variability. This species, more than any other in Papuasia, occurs in a confusing continuum of entities extending from sea-level to tree-line, and will probably exhibit a complementary range of ecological tolerances for specific site conditions. It may be possible to select for ecotypes pre-adapted to PJV environmental requirements, drawing from the wide assortment of forms seen at Kaijende.

The likelihood of clinal variation should be incorporated into the provenance trials for *Symplocos* outplant selection. Of the three varieties on the survey checklist, var. *orbicularis* is the most common, but is centered at elevations about 1,000 m above the mine site. The nominate variety and var. *monticola* are probably more suitable choices for revegetation at Porgera itself. It is appropriate to note that varietal distinctions cannot be consistently applied to individual plants, and numerous intermediates will defy classification (Nooteboom 1975, 1977). Provenance testing should examine the full

suite of Porgera-area morphotypes, irrespective of how they fit into the existing taxonomy.

The success of the restoration program will be ultimately dependent on recreating the patch dynamics responsible for long-term stability in most forest communities. Even-aged stands are intrinsically unstable because cohorts of identical age will progress through their maturational stages in synchrony, and will senesce simultaneously at the end of their life cycle. This process has been examined on ecosystem scales in environments where the forest canopy is monodominant and composed of single-generation cohorts (most notably in Hawaii forests: Gerrish and Mueller-Dombois 1980, Mueller-Dombois 1986). Unless an attempt is made to establish a self-sustaining community whose members are not one-generational, a population crash of the reforested areas will eventually occur.

Concerns relating to social and corporate responsibility are outside the scope of RAP assessment. But even so, the design of truly effective mitigative strategies will require thoughtful consideration of the factors governing community stability. Many site restoration programs are actually small-scale plantations, a circumstance which virtually ensures future instability. As noted before, the long-term success of a restored vegetation is best achieved by duplicating natural patterns, and this entails deliberate establishment of spatial, taxonomic, and demographic heterogeneity in the reconstructed communities.

Recommendations for future work

There is considerable scope for future inquiry. RAP biologists are merely a point element in conservation, and an 18-day reconnaissance can only provide a broad sketch of potentially fruitful directions. Much of the work done by the floristic team occurred in the high elevation zone above 3,000 m, which is probably the least speciose environment at Kaijende. From the insights obtained thus far, even better outcomes are likely if future activity is shifted to the south, against the border with Southern Highlands Province, and in the lowest parts of the conservation easement. Diversity will increase in step with elevation reduction. The vegetation below 2,000 m, where ice age perturbations would have been of lesser severity (the 2,200 m contour is the lower limit of a paleohistorical ecotone) should receive preferential attention. These lower montane habitats may have acted as Quaternary refugia for the oldest elements of the Kaijende flora. Even during the degenerative phases of former glacial maxima, plant communities could have retained a continuity in time and space at the lower elevations, while upland environments near Omyaka and Porgera were experiencing wholesale upset and replacement. Correspondingly greater opportunities for taxonomic discovery can be expected in the lower parts of the district, although operations there will not be easy because of the distance from logistical centers.

Because an overwhelmingly large portion of the proposed protected area lies above 2,000 m, additional conservation benefits could be realized by lowering the elevational boundary of the Conservation Area to 1,500 m. The best way of achieving this is by extending the proposed easement to the west, into the Pori drainage (Southern Highlands Province). Biotic imperatives have no correlation to political or administrative lines, and paleohistorically stable environments are likely to be inadequately represented if the protected area is confined to Enga Province. Although sociopolitical constraints may effectively prevent such an extension, a 500 m addition in altitudinal range would make a significant contribution to the protected area's floristic coverage.

The pinnacle karst habitats near Porgera are deserving of future investigation and should preliminarily be accorded a high conservation priority. With sheer-faced ridges and razor-like summits, pinnacle limestone is one of the most spectacular topographies in the Malesian tropics. Within PNG the only examples of this geological formation (also known as arete or doline karst) are restricted to the Porgera subdistrict (Löffler 1977). The characteristic knife-edged appearance of the doline facies is particularly striking in aerial perspective (Photo 62). With the discovery of three new plants on the Lake Tawa limestone, the doline occurrences are logical targets for future exploration, despite the difficult logistics involved in their study.

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Chapter 2

Herpetofauna of the Kaijende Highlands, Enga Province, Papua New Guinea

Stephen J. Richards

SUMMARY

A total of 17 frog and two reptile species were documented from montane forests and montane grassland habitats in the Kaijende Highlands region of Enga Province, Papua New Guinea. At least eight of the frog species are undescribed and one of these probably warrants recognition as a new genus. This survey documented the second known population of *Callulops glandulosus*, previously known only from a single specimen collected at 3,340 m elevation on Mt. Kerewa, and a very large species of *Albericus* found at Lake Tawa may represent only the second known population of *A. fafniri*. One other frog, *Litoria becki*, was previously known only from montane grassland on Mt. Wilhelm and Mt. Giluwe and was considered a Vulnerable species in the recent Global Amphibian Assessment. The reptile fauna was depauperate, reflecting the high-elevation focus of this survey. However one of the two species documented, a skink of the genus *Sphenomorphus*, may represent an undescribed taxon.

The open, montane *Cyathea*-grassland habitats typical of the highest elevations of the Kaijende Highlands represent a significant habitat for at least four frogs. Two of these are undescribed species that did not occur in upper montane forests and they are probably restricted to high-montane grasslands. These grassland habitats may be under threat from global warming and the frogs and other fauna that are confined predominantly or exclusively to them should be considered at risk of extinction.

INTRODUCTION

The high-montane herpetofauna of New Guinea's central mountainous spine has been patchily documented. The Archbold Expeditions to Mt. Michael, Mt. Wilhelm, Mt. Dayman and the Lake Habbema area made significant collections of high-elevation herpetofauna that were examined predominantly by R.G. Zweifel at the American Museum of Natural History (e.g. Zweifel 1972). Other significant, but sporadic collections of amphibians and reptiles at high elevations in New Guinea have revealed a fauna dominated by microhylid frogs and small scincid lizards in the genera *Papuascincus* and *Lobulia* (Greer et al. 2005, Zweifel et al. 2005). Large reptiles are generally rare due to the persistently cold wet conditions at these elevations, but a spectacular exception is the rarely encountered Boelen's Python which occurs at elevations exceeding 2,000 m (O'Shea 1996).

Frogs in New Guinea occur at elevations up to 4,000 m elevation (Zweifel 2000) although species richness attenuates markedly at elevations above about 2,000 m, and is extremely low above 3,000 m. The herpetofauna occurring at these high elevations includes a number of interesting evolutionary lineages that are poorly represented at lower elevations (e.g. Greer et al. 2005) and a number of species that appear to be restricted to a unique, alpine grassland/*Cyathea* habitat. Because high-montane environments are thought to be at great risk from cli-

mate change many of these species may be at risk of extinction (e.g. Greer et al. 2005).

Unfortunately logistical difficulties associated with accessing the remote and rugged mountains of New Guinea preclude cost-effective surveys of most areas, and documentation of the species richness and distributions of high-elevation herpetofaunas is far from complete. This clearly constrains attempts to prioritize conservation actions in these vast alpine environments across New Guinea's central cordillera. The survey reported here provides the first data on herpetofaunal assemblages in the previously unsurveyed and sparsely populated Kaijende Highlands region of Enga Province, Papua New Guinea.

METHODS

Study sites

Frogs and reptiles were documented at three major sites: 1) Omyaka and Waile Creek, 2) Paiela Road, and 3) Lake Tawa. Several additional records were obtained serendipitously in the vicinity of Suyan Village. The field schedule and site descriptions are presented in the Executive Summary and a comprehensive description of vegetation types and floristic variation for each site is provided in Chapter 1. The major features of each site that were significant for herpetofaunal assemblages are described below.

Site 1. Omyaka and Waile Creek, High-Montane Grassland

The rolling montane grasslands at Omyaka and Waile Creek presented a mosaic of grassland and *Cyathea*-dominated habitats. Small, slow-flowing streams occurred in the gullies and many of these were choked by dense vegetation. A series of open-water bog habitats (see Chapter 1) were scattered across the grasslands, particularly near the Omyaka Camp. Dense, low-stature moss forest dominated the periphery of the grasslands at Omyaka.

Site 2. Paiela Road, Upper Montane Forest

Collections were undertaken along the Paiela Road at elevations between 2,800–2,900 m. Several torrential streams that intersect the road were searched for tadpoles during the day, and for frogs at night. The dense, mossy forest along the road contained patches of *Pandanus* trees that harbored at least one frog species not documented in any other habitat. Disturbed vegetation and the grassy road verges were also searched at night, and large numbers of *Papuascincus* eggs and adults were discovered under stones at the edge of the road.

Site 3. Lake Tawa, Lower Montane Forest and Lakeside Grasslands

This site had the widest variety of habitats for frogs and reptiles. The dense grassy verges of Lake Tawa provided habitat for small tree-frogs, the very wet lower montane forest was a spatially complex environment for terrestrial and arboreal microhylid frogs, and a series of small streams provided habitat for at least one species of torrent-dwelling hylid frog.

Field methods

Surveys were conducted at each site using techniques that followed closely those used in previous RAP surveys (e.g. Richards et al. 2000). At each site, I first identified all accessible habitats and then with 1–3 local assistants conducted intensive searches for frogs and reptiles in each. During the day we searched for heliothermic (basking) reptiles along forest trails and stream banks. Small lizards of the genus *Papuascincus* were collected by hand or after being stunned with a large rubber band. We searched for nocturnal reptiles by walking along forest trails and stream banks at night with a headlamp. Tadpoles were collected by dip-netting in ponds and streams. In torrential streams the dip-net was placed down-stream of rocks, which were then turned to dislodge tadpoles that were hiding underneath. Dislodged tadpoles were swept into the net by the current. Frogs were detected at night by conducting visual-encounter and aural surveys along streams, and in and around small ponds. We also conducted extensive visual and aural searches in the montane grasslands and along forest trails away from water to detect microhylid frogs that have a life cycle independent of free-standing water.

Because frog calls are an important diagnostic character, I recorded the advertisement calls of frogs with a Sony TCM-5000 Tape Recorder and a Sennheiser ME66 microphone. Each species was photographed alive before preparation of voucher specimens. Specimens were euthanized by submersion in chlorotone (for frogs), or with lethal injection of chlorotone for reptiles. Specimens were fixed in 10% formalin solution, and then stored in 70% ethanol. Samples of liver tissue for DNA analyses were extracted from up to five specimens of each species and stored in 95% ethanol.

Voucher specimens will be deposited in the Natural Sciences Resource Centre collection of the University of Papua New Guinea (UPNG), and the South Australian Museum, Australia (SAMA).

RESULTS AND DISCUSSION

A total of 17 frog and two reptile species were documented from three major habitat types in the Kaijende Highlands. Species richness was highest at the lowest-elevation site (11 species at Lake Tawa; ~ 1,120 m) and lowest at the highest-elevation sites (5 species at Omyaka and Waile Creek; ~ 3,100–3,400 m) (Table 2.1).

The reptile fauna was dominated by a single species of *Papuascincus* (see species accounts below). This lizard was abundant on the alpine grasslands and in open sunny areas around Lake Tawa. Large numbers of eggs of this species were found under loose soil beneath rocks along the verge of Paiela Road. A single specimen of a potentially undescribed *Sphenomorphus* was found at Lake Tawa. No snakes were

observed during the survey although it is likely that the Boelen's Python *Morelia boeleni* occurs in the region. Few snakes in New Guinea occur at the elevations we focused on.

The frog fauna was dominated by the family Microhylidae, with 13 of the 17 species (76%) belonging to this group. Eight of the microhylid species (62%) appear to be undescribed but perhaps more significantly two of the three undescribed microhylids documented from the alpine grassland/*Cyathea* habitats were never heard calling from, or found within, forest habitats. These species, namely *Oreophryne* sp. 3 and the putative new microhylid genus (Table 2.1; species accounts, below) may be threatened by modification of these grassland habitats (including modified fire regimes and invasion of grasslands by rainforest) in response to global warming.

The observation that a suite of frogs and lizards across the top of New Guinea's central cordillera appear to be high-montane grassland specialists (see e.g. Zweifel et al. 2005 for further examples) provides a rare faunal perspective on the debate over the origin of these uniquely New Guinean environments (Takeuchi, Chapter 1). There has been disagreement about whether these habitats originated via, and are maintained by, human influence or whether they have a longer evolutionary history. The documentation of numerous small microhylid frogs having morphologies indicative of low motility (short limbs and squat bodies) and with ranges restricted exclusively to these habitats at sites across New Guinea, argues strongly for a long evolutionary history for these environments.

Table 2.1. Herpetofauna species documented in three major habitats in the Kaijende Highlands, Papua New Guinea.

Species	High-Montane Grassland 3,200 m	High-Montane Moss Forest 2,900 m	Montane Forest 2,100–2,300 m
FROGS			
Hylidae			
Litoria arfakiana		X	X
Litoria becki	X		
Litoria iris			X
Microhylidae			
Albericus fafniri ?			X
Albericus sp. nov. 1		X	X
Albericus sp. nov. 2		X	
Callulops glandulosus		X	
Callulops wilhelmanus ?			X
Choerophryne sp. nov.			X
Cophixalus shellyi			X
Cophixalus sp. nov.	X		
Oreophryne notata			X
Oreophryne sp. nov. 1			X
Oreophryne sp. nov. 2		X	
Oreophryne sp. nov. 3	X		
Gen. nov., sp. nov.	X		
Ranidae			
*Rana daemeli**			
REPTILES			
Scincidae			
Sphenomorphus cf. *cinereus*			X
Papuascincus stanleyanus / *morokanus* complex	X	X	X
Total	**5**	**6**	**11**

*call record only, Suyan Camp, Porgera

Although it is possible that these taxa were 'gap species' in previously forest-dominated landscapes that have taken advantage of rapidly expanding alpine grasslands following the arrival of humans in the New Guinea hinterland, at least for some frog lineages this does not appear to be likely. For example most *Oreophryne* species documented from montane grasslands are squat, short-legged forms with reduced digital discs that are presumably well adapted for living semi-fossorial lives in the montane grasslands (Zweifel et al. 2005). There do not appear to be morphologically similar *Oreophryne* species occupying either closed forest or small forest gaps today. At Omyaka the grassland frogs were not found in forest habitats immediately adjacent to the grassland, despite occurring in high densities within centimeters of the forest edge. Furthermore at the slightly lower elevation Paiela Road site the only forest-dwelling *Oreophryne* was typical of most members of the genus, having long limbs and large digital discs. Although not conclusive these observations indicate an evolutionary response to the high-montane environment rather than a rapid (geologically) colonization of human-induced alpine grassland environments by 'pre-adapted' semi-fossorial and terrestrial forms from surrounding forest.

Apart from the new species discovered in the Kaijende Highlands this survey documented the second known populations of the microhylid frogs *Callulops glandulosus* and *Albericus fafniri*, and the third known population of the hylid frog *Litoria becki*. The former two species were designated as Data Deficient, and the latter as Vulnerable in the recent Global Amphibian Assessment (GAA 2006). *Callulops glandulosus* was common in disturbed roadside habitats along Paiela Road but was not found elsewhere during the survey indicating that it may have narrow altitudinal or habitat requirements. The frogs tentatively identified as *Albericus fafniri* were documented at Lake Tawa only. In general morphology and call structure the Lake Tawa frogs closely resemble *A. fafniri* but they are much larger than the type specimens of that species (e.g. Menzies 1999), reaching nearly 27 mm SVL. This is the largest size recorded for this genus and it is possible that additional studies will reveal that the Lake Tawa population represents an additional undescribed species.

The herpetofauna of the Kaijende Highlands appeared to be poorly known by local informants, presumably because it plays little role in their daily lives. This was reflected in the fact that few local names were provided for the species encountered. All small microhylid frogs, and juveniles of larger microhylids (including *Callulops*) are called 'Fandamonge' in the Ipili language. Adult *Callulops* are called 'Susu'; *Litoria arfakiana* are called 'koko'; and the brightly coloured *Litoria iris* is called 'Sanalia'. The skinks *Papuascincus* sp. and *Sphenomorphus* sp. are called 'ka-u'. These names should be treated with some caution because attempts to clarify local names of herpetofauna met with substantial uncertainty and disagreement among informants. In contrast, local informants eagerly reported that large, edible frogs occurred at lower altitudes, and that these frogs had specific names.

ANNOTATED LIST OF HERPETOFAUNA SPECIES

FROGS

Hylidae

Litoria arfakiana (Peters and Doria, 1878)
A moderately large (SVL 47 mm) torrent-dwelling treefrog. As currently recognized this species is common and widespread in the central mountains of New Guinea. However it is a species 'complex' and the nominate species may be restricted to far-western New Guinea. Günther (2006) has provided a description of the call and tadpole of what is probably 'true' *L. arfakiana*. The Kaijende Highlands population is poorly known, and call data and genetic studies are required. At Lake Tawa a gravid female was captured on low vegetation over a small stream above a waterfall and at Paiela Road a subadult was collected from vegetation adjacent to a rocky torrential stream. The nominate species is considered Least Concern by the Global Amphibian Assessment (GAA).

Litoria becki (Loveridge, 1945)
A moderately large (SVL 34-44 mm) treefrog, previously known with certainty only from montane grassland at the type locality on Mt. Wilhelm, with a possible second population on Mt. Giluwe. At Omyaka and Waile Creek it was found exclusively in and near small open-water bogs in open grassland. Classified as Vulnerable by the GAA, the Kaijende Highlands population represents a significant range extension.

Litoria iris (Tyler, 1962)
A small (SVL 30-38 mm) swamp- and pool-dwelling treefrog that is common and widespread in the mountains of central and eastern New Guinea. It was abundant at Lake Tawa where males called from grass around the lake verge. Classified as Least Concern by the GAA. Two specimens collected by locals in the vicinity of Suyan, Porgera, lack call data but differ sufficiently from the Lake Tawa specimens to indicate that they may represent a different, undescribed species (Photo 72).

Microhylidae

Albericus fafniri Menzies, 1999
A very large (SVL to 27 mm), scansorial species of *Albericus*. Found only at Lake Tawa where males called from low vegetation in wet Lower Montane Forest after rain. This species is tentatively identified as *A. fafniri*, a species previously known only from the type locality near Mendi (Menzies 1999). The Lake Tawa population has a call and morphology similar to, but is much larger than, the type series of *fafniri*. Further studies are required to determine its taxonomic status. *Albericus fafniri* was considered Data Deficient by the GAA.

Albericus sp. nov. 1 (Photo 70)
This small (SVL 14-18 mm) scansorial species was found at Lake Tawa and, less commonly, at Paiela Road. At both sites males called from very low foliage (< 0.5 m high) in wet mossy forest after rain. It is an undescribed species.

Albericus sp. nov. 2
A medium-sized (SVL 17-19 mm) arboreal species; found only at Paiela Road where males called exclusively from *Pandanus* trees in Upper Montane Forest. Many individuals called from > 5 m high making collections difficult. It is an undescribed species.

Callulops glandulosus (Zweifel, 1972)
A moderately small (SVL 34-44 mm) species of *Callulops* previously known only from a single specimen collected at Mt. Kerewa (Zweifel 1972). It was common, but occurred patchily, at Paiela Road where males called from the base of dense grass tussocks after heavy rain. The Kaijende Highlands population represents a range extension of 57 km from the type locality and is only the second known population of this species. It was considered Data Deficient by the GAA.

Callulops wilhelmanus ? (Loveridge, 1948)
A moderately large (SVL to ~ 55 mm) species of *Callulops* found only at Lake Tawa Camp. This species was uncommon, or at least difficult to detect. Males called infrequently in the early morning around camp. This species lacks digital discs and may be *Callulops wilhelmanus* but differs from other populations of that species by having a distinctly mottled (vs. uniform) venter and in having juveniles with a dramatically blotched dorsal color pattern.

Choerophryne sp. nov.
A tiny (SVL 9-10 mm) terrestrial-scansorial frog; This undescribed species was found only at Lake Tawa where males called from semi-concealed positions in litter and low foliage in wet mossy forest after rain. Calling was restricted to approximately two hours each day, between ~ 5.30 and 6.30 pm, and again briefly at dawn in wet conditions.

Cophixalus shellyi
A small (SVL to ~18 mm) terrestrial-scansorial frog. It was found only at Lake Tawa where males called on bright sunny days from deep in litter. Calls were heard only infrequently at night, from low in dense foliage. This species was commonly encountered in litter in the camp during the day. Classified as Least Concern by the GAA due to its wide distribution in the mountains of New Guinea, *C. shellyi* is in fact a complex of at least four species each with distinct calls.

Cophixalus sp. nov. 1 (Photo 71)
A moderately small (SVL 17-21 mm) undescribed species of *Cophixalus*. Differs from most congeners by lacking distinct digital discs. Males called from deep in humus in montane grassland at Omyaka and Waile Creek, and under shallow litter and humus at the forest verge at Paiela Road. At Omyaka calling males were found guarding egg clutches deep within moss clumps.

Oreophryne notata Zweifel, 2003
Zweifel (2003) recently described this small (SVL 15.5-18 mm) arboreal species. It was common in mossy lower montane forest at Lake Tawa where males called from leaves up to 3 m above ground at night after rain. It was previously known from several sites in Southern Highlands Province and a single locality in Western Province (Zweifel 2003).

Oreophryne sp. nov.1
This moderately large (SVL 23-28 mm), undescribed species has greatly expanded finger and toe discs. It was common in mossy forest at Lake Tawa where males called intermittently from low foliage (< 2 m high) at night after heavy rain.

Oreophryne sp. nov. 2
A medium-sized (SVL 21-26 mm) scansorial species that shares with *O. notata* a distinct, inverted-U mark on the snout. It differs from that species by its larger size and advertisement call. It was found only in Upper Montane Forest at Paiela Road where males called from low foliage after heavy rain at night. During the day several specimens of this undescribed species were found under stones next to the road.

Oreophryne sp. nov. 3
A small (SVL 16-22 mm) undescribed frog found only in high-montane grassland adjacent to the Porgera Reservoir at Waile Creek. Males called from ~20–50 cm high in *Poa keysseri keysseri* clumps after rain. It was absent from Upper Montane Forest at the same elevation (3,100–3,200 m) in this area and its distribution in the grasslands was also patchy and may be influenced by subtle differences in vegetation. For example while this species was common in grass tussocks adjacent to the Porgera Reservoir it was absent from *Chionochloa archboldii*-dominated grassy habitats at nearby Omyaka during several days of field work at that site.

New genus, new species (Photo 73)
A very distinctive, short-legged microhylid frog (SVL 19-27 mm). Many specimens exhibit bright orange coloration on the dorsum and venter. This species was found only in high-montane grassland at Omyaka, and was absent from similar habitats at nearby Waile Creek. Males called from holes in moss on the ground, from small burrows in the edges of *Sphagnum* / *Oreobolus* bogs, or occasionally from low perches on the stems of *Cyathea* trees. This new species exhibits a number of myological features that are unique to the *Albericus* / *Choerophryne* clade of Australopapuan microhylid frogs but differs conspicuously from all known members of this group in a number of morphological features. It probably warrants recognition as a new genus. Genetic, osteological and myological studies are underway.

Ranidae

Rana daemeli (Steindachner, 1868)

A large (SVL ~ 80 mm) riparian species that is widespread in the southern and northern lowlands of New Guinea and in Cape York Peninsula, Australia. Several specimens were heard calling in a small densely vegetated stream at Suyan Camp during this survey. The elevation of this population (~2,200 m asl) is unusually high for this predominantly lowland species.

Reptiles

Scincidae

Papuascincus stanleyanus/morokanus

A common species that was active in the sun at all sites. It belongs to a taxonomically difficult complex of montane skinks. Final identification remains to be determined, but the Kaijende Highlands population is likely to represent a known species of this complex. Large numbers of lizards were found beneath stones along the edge of Paiela Road during the day, and numerous egg clutches of this species were found buried in shallow soil beneath these stones. Some clutches appeared to be recently laid, and others contained eggs that were mature and that hatched during handling. A number of clutches appeared to be 'communal', containing eggs at a number of different stages.

Sphenomorphus sp. cf. *cinereus*

A moderately large terrestrial/semi-fossorial skink. This genus is taxonomically chaotic. The single specimen captured at Lake Tawa appears to represent an undescribed taxon related to *S. cinereus* (G. Shea, pers. comm.).

CONSERVATION RECOMMENDATIONS

The Kaijende Highlands represent a vast wilderness area of spectacular visual beauty and the montane forests and grasslands are home to a number of frog species that may be endemic to this area. There are a number of conservation 'positives' in the region:

- The area is remote and human population density is low.
- The region is spectacularly beautiful so tourism is a potential source of future income if developed carefully in collaboration with local landowners.
- The nearby Porgera Mine is well situated to assist with long-term studies of the environment, particularly studies of the impacts of climate change on montane fauna and flora.

There are also a number of threats to the area's herpetofaunal diversity:

- The Omyaka and Waile Creek grasslands are on major traditional trading routes. Traffic on these walking trails is heavy so hunting of large game is common although the small and potentially endemic frogs are of little interest to local landowners as a resource.
- Increased traffic on these trails risks a major increase in the frequency of fires that have the potential to significantly alter these alpine grassland assemblages.
- Global warming may significantly alter these high-montane environments. One potential outcome of changed temperature and moisture regimes is the expansion of forest habitats into montane grasslands. This would undoubtedly lead to the eventual extinction of at least two and possibly more of the grassland frog species.

Specific recommendations

1. Work with local communities to formalize the Conservation Area currently proposed for the Kaijende Highlands.
2. Encourage local communities to draft regulations for this protected area that take particular account of burning practices to minimize the impact of this activity on vulnerable grassland habitats and their herpetofaunal species.
3. Produce a color-illustrated booklet about the region's herpetofauna and general biodiversity for local communities, to promote interest and enthusiasm in their biological heritage.
4. Encourage local communities to protect critical habitats. For frogs this includes identifying through follow-up surveys the distribution of grassland species within the protected area and then targeting areas with significant populations for conservation action.
5. Examine the costs/benefits/likelihood of success of establishing a long-term monitoring program, run by trained local assistants, of populations of 3–4 target taxa including the new genus and other grassland-restricted frogs.

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Chapter 3

Birds of the Kaijende Highlands, Enga Province, Papua New Guinea

Bruce M. Beehler and Robert Sine

SUMMARY

Nineteen days of surveys at four sites between 2,117 m and 3,200 m elevation in the Kaijende Highlands of western Papua New Guinea detected 102 species of birds. The Long-bearded Melidectes (*Melidectes princeps*) was recorded for the first time west of the Mount Hagen massif. It presumably ranges westward at high elevations to the Strickland Gap. The Ribbon-tailed Astrapia (*Astrapia mayeri*) was common from 2,117 m at Lake Tawa to 3,200 m at Omyaka Camp. We did not encounter Stephanie's Astrapia (*Astrapia stephaniae*). Its western-most range extension must lie east of Porgera valley in the north, although it extends west to the Doma Peaks/Tari Gap area in the south.

The Crested Bird of Paradise (*Cnemophilus macgregorii*) was not encountered on this survey, but one local informant at Omyaka Camp stated that it was present and it was collected during a 1989 survey (Kula 1989). It appears that this species is rare or absent between the Hagen/Giluwe area and the Star Mountains of Papua (Indonesia). This provides an intermediate-stage example of Diamond's "drop-out" phenomenon (Diamond 1972). The Kaijende Highlands support a rich upland bird fauna that might best be conserved through the creation of a large contiguous community-managed reserve that encompasses uninhabited traditional hunting lands. This could serve as a useful biodiversity offset for the Porgera mine operation.

INTRODUCTION

Study of the geographic distribution of birds in Papua New Guinea has reached the phase where most field surveys provide fine-tuning of the elevational and geographic distribution of a few interesting species endemic to Papua New Guinea, while also confirming the excellent state of our knowledge of many of the more common and widespread species (Coates 2001). This rapid assessment of the bird fauna of the Kaijende Highlands produced some interesting distributional records that help to further clarify the pattern and process of differentiation of the montane forest birds of New Guinea.

Few surveys of the western highlands regions of Papua New Guinea have been undertaken, but most of these were individually comprehensive (see Frith and Beehler 1998, Appendix 2). To the southeast of our area of focus, the Mount Hagen massif was surveyed repeatedly for birds between 1938 and 1956 by Shaw Mayer, Blood, Gilliard, and Bulmer, and Mount Giluwe was worked between 1961 and 1973 by the Schoddes, Clissold, Sedlacek, and Mirza (in Frith and Beehler 1998, Appendix 2).

To the south and west of our area of focus, surveys were conducted as follows: The Tari Gap/Doma Peaks were surveyed between 1983 and 1991 by Mackay, the Friths, a PNG Department of Environment and Conservation (DEC) team, and Laska (in Frith and Beehler 1998, Appendix 2). The Victor Emanuel and Hindenburg Ranges were surveyed between 1954 and 1997 by Gilliard, Bell, Mirza, Wanga, Murray, and Gregory (in Frith and Beehler 1998, Appendix 2).

The Enga highlands of Kompiam (east of the Kaijende Highlands) were surveyed by Whiteside in 1994 (in Frith and Beehler 1998, Appendix 3), and the Kaijende Highlands above the Porgera mine were surveyed by a DEC team in the 1980s (G. Kula pers. comm.). Here we report the results of a brief but intensive survey of the Kaijende Highlands conducted at elevations between 2,117 m a.s.l. and 3,200 m a.s.l.

METHODS AND STUDY SITES

Field methods

Birds were surveyed during daily walking censuses and these data were supplemented by mist-netting (at Lake Tawa only) and through interviews with knowledgeable local naturalists who accompanied and assisted our field parties. 'Walking Censuses' were conducted by the senior author in the early morning, mid-morning, and again in the afternoon. Early morning surveys were typically three hours long and the later surveys were usually two hours long. During each survey the observer walked slowly and quietly through a selected habitat, and noted all birds heard and seen. An attempt was made to count individuals once per walk. The main objective of the surveys was to record all bird species present in each habitat, with a secondary objective being to obtain a general indication of relative species abundance.

Mist-netting at Lake Tawa followed standard procedures (Beehler and Mack 1999). Nets were set in places where high capture rates could be expected, including thickets, ridgecrests, and areas of regenerating low vegetation. They were operated and tended from dawn to dusk, and in some instances nets were opened at night to capture bats and night birds. Birds were weighed and measured and then marked by cutting the tip of an outer tail feather. Recaptured birds were released from the net without being measured again.

Study sites

Intensive surveys were conducted at the four sites described below. Additional details on the vegetation and habitat characteristics of each site can be found in Chapter 1.

Omyaka Camp (5°31' 37" S, 143° 03' 23" E, 3,200 m elevation) was situated in the forested verge of an open grassland valley. The main walking track from Porgera to the Mount Kare mine traverses the center of the valley. A forest mosaic dominates the slopes and the bases of the slopes around the valley, whereas alpine tussock grass and scattered treeferns dominate the valley floor. The forest was low (typically no more than 12 m), closed-canopy upper montane/subalpine forest. Trees were moss-encrusted and trunks were twisted and irregular. The tree flora included broadleaf taxa (e.g., *Decaspermum*, *Eurya, Ilex, Prunus, Quintinia, Symplocos, Syzygium, Vaccinium, Xanthomyrtus, fide* Takeuchi, Chapter 1, this volume) and gymnosperms (e.g., *Libocedrus, Podocarpus, Phyllocladus, Dacrydium*, *fide* Takeuchi, Chapter 1, this volume). These gnarly elfin woodlands were edged by a shrubland (with *Vaccinium, Melicope, Olearia, fide* Takeuchi, Chapter 1, this volume) that gave way to grasslands.

Lake Tawa Camp (5°35'43"S, 142°50'26" E, 2,117 m) was set in a remarkable closed montane basin whose catchment drained exclusively through one or more major sinkholes. The basin features several small inter-connected lakes, whose level rose and fell with the rainfall because of low drainage capacity of the sinkholes. A narrow band of lake-associated grassland encircled the lakes, and *Pandanus*-dominated forest bordered the grasslands. The forest interior was lower montane closed forest containing *Syzygium, Symplocos, and Lithocarpus (fide* Takeuchi, Chapter 1, this volume). Flat ridgetops that we visited exhibited a *Pandanus* scrub with scrambling ferns dominating the ground layer.

Paiela Road (5°30'12"S, 143°5'6" E, 2,800–2,900 m). We surveyed this road daily while based at the mine camp at Suyan. The road traverses the northeastern face of Mount Kumbepara, extending from the Waile Creek Road junction in a mainly north-westerly direction. It cuts through relatively undisturbed upper montane forest that afforded excellent conditions for bird survey.

Mine Environs and Suyan Forest (5°29'12" S, 143° 9'E, 2,150 m). We observed birds in and around the Suyan mine camp, and on one full day we observed birds in the adjacent Suyan forest. Accessible habitats were a mix of open mid-montane valley habitats (gardens, grasslands, casuarinas groves, re-growth, remnant forest). The Suyan forest gave access to a lower montane bird fauna that was absent in other sites outlined above. We only imperfectly surveyed this elevational zone because our main focus was the more pristine uplands. We suggest that the zone below 2,200 m merits additional ornithological survey.

RESULTS AND DISCUSSION

Survey results

Nineteen days of surveys at four camps between 2,117 m and 3,200 m elevation in the Kaijende Highlands of western Papua New Guinea detected 2,378 individuals of 102 species of birds between 21 August and 9 September 2005. Sixty-two individuals of 26 species were mist-netted at Lake Tawa. Walking censuses at the three principal sites produced comparable numbers of individuals based on similar total search efforts, ranging from 23 to 36 individuals per hour. The summary results of the walking censuses are presented in Table 3.1, and the total numbers of individuals of each species on each census are presented in Appendix 3. Because of the random and fragmentary nature of the Mine/Suyan observations they are not comparable with those from the three primary survey sites, but these results are incorporated into the species list presented in Appendix 4. The discussion that follows focuses mainly on the results obtained from the three major survey sites.

Over the elevational span extending between 2,117 m and 3,200 m there is a linear decrease in species richness with

Table 3.1. Results of 'walking censuses' of birds in the Kaijende Highlands region, Papua New Guinea.

Location	Surveys/hours	Number of individuals	Number of individuals/hr	Number of Species
Omyaka Camp (3,200 m)	12 surveys/29 hrs	864	28	41
Paiela Road (~2,900 m)	7 surveys/22 hrs	785	36	48
Lake Tawa (2,117 m)	13 surveys/32 hrs	731	23	56

increasing elevation (Figure 3.1). This inverse relationship between elevation and species richness has been reported elsewhere in New Guinea (Diamond 1972, Beehler 1982). Although it is neither new nor counter-intuitive, this is a robust result that can be demonstrated with minimal field effort. It is one of the ornithological "laws" that governs the structuring of bird communities in montane New Guinea (Diamond 1972, Beehler 1982). Given our ability to demonstrate this with a low-investment survey methodology, we suggest the entire elevational range from sea level to 4,000+ m should be surveyed rapidly using walking surveys once there is a compendium of bird recordings for all species along the transect. Such a complete transect has never been attempted. Twenty-five hours at each elevational zone should be adequate to generate a robust dataset. This can then be used to tease out additional environmental patterns, especially the question regarding the putative "spike" in species richness in the hill forest zone, which is likely to be a sampling artifact (Kikkawa and Williams 1971).

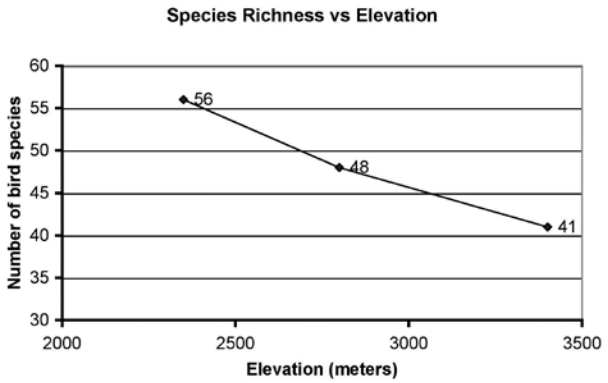

Figure 3.1. Elevational trend in species richness of birds in the Kaijende Highlands.

Distributional notes

A series of notes on the distribution of lesser-known bird species, and those with particular distributional anomalies is presented below.

***Clytoceyx rex* (Shovel-billed Kingfisher)**

This widespread but rarely observed species was common and vocal at Lake Tawa. It was recorded on 8 of 13 surveys and several birds were heard singing at dawn every morning. We also heard individuals singing at dusk. It was observed at close range on several occasions. A high count of six individuals was made on 30 August.

***Petroica bivittata* (Mountain Robin)**

This uncommon upper montane species was encountered on two surveys at Omyaka Camp and was also observed there during non-survey periods.

***Melidectes princeps* (Long-bearded Melidectes)**

This rarely seen and striking high-elevation honeyeater was previously known only as far west as the Hagen Massif. It was observed on six surveys at Omyaka Camp, mainly foraging in shrubbery at the interface between forest and grassland where it was greatly outnumbered by the smaller but similar Sooty Melidectes (*Melidectes fuscus*). On our 12 censuses we counted 11 Long-bearded Melidectes and 70 Sooty Melidectes. Our record of this species represents a northwestward range extension of 100 km. The Long-bearded Melidectes and Short-bearded Melidectes (*M. nouhuysi*) are sister taxa and their relative ranges had stood out as peculiar until recently — with an unexplained gap of several hundred kilometers between the two species. The range of the Short-bearded Melidectes is currently known to extend from Papua Province into the Star Mountains of far-western Papua New Guinea (Gregory and Johnston 1993). Given the pattern exhibited by the ranges of other high cordilleran bird species (e.g., Chestnut Forest-Rail, Splendid Astrapia) the Short-bearded Melidectes presumably ranges eastward to the Strickland Gap. We suggest that the Long-bearded Melidectes ranges westward to that same lowland barrier. This species-pair is hypothesized to have speciated across this major barrier for montane birds.

***Melidectes rufocrissalis* (Yellow-browed Melidectes)**

The lesser-known twin of the *Melidectes belfordi/rufocrissalis* species-pair was found on the grounds of the Suyan Camp, inhabiting wooded copses set among gardens. It occupies a lower elevational zone than does the more abundant and better-known Belford's Melidectes, with which it read-

ily hybridizes in areas of contact (Gilliard 1959). Belford's Melidectes was abundant at Omyaka Camp (mean of 14 individuals per survey) and along the Paiela Road (mean of 16 per survey), and was common at Lake Tawa (mean of 9 per survey). This hybridizing species-pair has caused taxonomic consternation for generations (see Mayr and Gilliard 1952, Gilliard 1959, Diamond 1967, 1972) mainly because of the complex and patchy distribution of *M. rufocrissalis* in the central range of New Guinea, combined with the apparent hybrid ancestry of some populations. Unlike the *M. princips/M. nouhuysi* species pair, this one is presumably considerably older, making the unraveling of its history more difficult. It is particularly unusual that the lower-elevation form (*rufocrissalis*) is confined to central New Guinea, whereas the higher-elevation form (*belfordi*) ranges from the Weyland Mountains of the far west to the far southeast of the Owen Stanley Range. The rather straightforward northwest-southeast vicariance that typifies Diamond's "drop-out" model (Diamond 1972) cannot explain this species-pair's distribution. Diamond (1967) noted that most records for *rufocrissalis* were from the northern watershed, and that it is closely related to the morphologically similar *M. leucostephes* of the Bird's Head region of far western Papua Province and *M. foersteri* from the uplands of the Huon Peninsula. In fact *rufocrissalis* is well distributed in the southern watershed, the Tari and Porgera valley populations being two examples. Molecular analyses of component taxa will be required to more fully understand the evolution of this remarkable group. The *Melidectes belfordi/rufocrissalis* species-pair offers a wonderful and challenging speciation/hybridization phenomenon whose study will provide an important insight into the geographic differentiation of montane forest birds of New Guinea.

***Cnemophilus macgregorii* (Crested Bird of Paradise)**

Although the cnemophilines are no longer considered to be birds of paradise (Cracraft and Feinstein 1999), they remain a fascinating New Guinean cordilleran lineage of uncertain provenance. In the absence of a new taxonomic disposition or group-name, for convenience we retain the original nomenclature in our discussion. The range of the Crested Bird of Paradise is unusual. Like the Blue Bird of Paradise (*Paradisaea rudolphi*) it is confined primarily to mainland New Guinea east of the Strickland Gap. However whereas the Blue Bird of Paradise is entirely confined to territory east of the Strickland, the Crested Bird of Paradise shows a less clear-cut range. It is only found regularly and commonly east of the Gap, but there are a few records from west of the Gap, ranging as far west as east-central Papua. Most strange of all, is that the range of *Cnemophilus macgregorii* exhibits a major hiatus between Mount Hagen/Doma Peaks and the Star Mountains of Papua (see Frith and Beehler 1998, page 184). We searched for this species in vain in the Kaijende uplands, but at least one of our informants reported the species to be present and Kula (1989) collected voucher specimens from the region in 1989. Thus the Crested Bird of Paradise is common east of the Strickland Gap, but very rare or absent for several hundred kilometers west of the Gap. It then occurs in sparse numbers far west of the Strickland Gap, but apparently does not range as far west as the western terminus of the main cordillera (as does its sister form, Loria's Bird of Paradise). In sum, the species is common in the eastern two-fifths of the central cordillera, more or less absent in the central fifth of New Guinea, sparse in the west-central fifth of New Guinea, and absent from the westernmost fifth of the island.

Although the Strickland Gap seems to be important as a distributional barrier dividing young montane-dwelling species-pairs (e.g., Chestnut/Forbes' Forest-Rails, Splendid/Ribbon-tailed Astrapias, Short-bearded/Long-bearded Melidectes), most montane species (e.g., Loria's Bird of Paradise, Belford's Melidectes, Common Smoky Honeyeater, Red-collared Myzomela, Papuan Lorikeet, Great Wood-swallow, and many others) or species-pairs (*Astrapia, Melidectes, Parotia*) range from one end of the Cordillera to the other (Beehler et al. 1986, Frith and Beehler 1998).

The strange range of the Crested Bird of Paradise seems to exemplify an intermediate step in Diamond's "drop-out" phenomenon. Diamond invoked his "drop-out" model to explain how eastern and western sub-populations achieved geographic isolation along a continuous montane cordillera. The Crested Bird of Paradise seems to have achieved this range disjunction. The western population now has an opportunity to differentiate from the eastern population. This major range discontinuity is much as Diamond illustrated for the Papuan Treecreeper (Diamond 1972). One pressing question arises from the discontinuity of the Crested Bird of Paradise's range. What ecological or demographic process produces these discontinuities? Why is the species common in the east, very rare or absent in the middle of its range, and sparse in the west? Is it simply a stochastic process? Getting a clear answer to this question would provide an important insight into the mechanism of montane speciation in the birds of New Guinea.

The Crested Bird of Paradise's range offers some insight into the possible history of the currently truncated, east-New Guinea only range of the Blue Bird of Paradise. Indeed the range of the former species might closely resemble the Blue's current range if all of the western populations (already rare or very rare) become extinct. Both the Crested and the Blue Birds of Paradise appear to be "older" lineages (neither have extant close sister forms) and thus it is safe to assume that both, at some earlier time, occurred along the entire length of the central cordillera (as Loria's Bird of Paradise does today) but that the western segments of the population have declined — partially in the case of the Crested, and completely in the case of the Blue. These appear to be "senescent" ranges of aging lineages. A similar but reverse pattern can be found for the Yellow-breasted Bird of Paradise, a close relative of Loria's and Crested Birds of Paradise. In the case of the Yellow-breasted Bird of Paradise it is the far eastern

populations of its cordilleran range that have become extinct, leaving just the central and western components.

***Astrapia mayeri* (Ribbon-tailed Astrapia)** (Photos 75, 77)
The Kaijende Highlands are the heartland of the circumscribed range of this remarkable species, the last of the birds of paradise to be described to science (Stonor 1939). We encountered no populations of this species' eastern sister form, Stephanie's Astrapia (*Astrapia stephaniae*) on our survey, and we were told by informants that the "black-tails" were not present in the area. We know from detailed species-mapping of these two species (Frith and Beehler 1998) that Stephanie's Astrapia occurs 165 km to the southeast (Wabag, Kompiam), and 45 km to the south-south-west (Doma Peaks, Ambua). These two *Astrapia* species hybridize freely where they come into contact, but *Astrapia mayeri* generally occupies higher elevations than *A. stephaniae*. At Lake Tawa *Astrapia mayeri* was common (9 of 13 walking surveys). This is the lowest documented elevation that the species has been recorded (2,117 m) although Coates (2001) mentions a record as low as 1,800 m. In the Ambua/Doma Peaks region, where both species are present, *Astrapia mayeri* is found to occupy higher elevations (above 2,500 m). The western terminus of the distribution of *A. mayeri* is unknown, but it is probably the Strickland Gap. The Splendid Astrapia (*Astrapia splendidissima*) inhabits the high ranges west of the Strickland Gap. It will be interesting to determine whether *A. mayeri* and *A. splendidissima* meet and hybridize north of the Gap along the central range, north or northwest of the eastward bend of the Strickland in Hewa country.

CONSERVATION RECOMMENDATIONS

The Kaijende Highlands are spectacular, with remarkable monumental features and wilderness qualities worth conserving. The bird fauna adds to the value of this resource. At least four species of birds of paradise (Brown Sicklebill, Ribbon-tailed Astrapia, King of Saxony Bird of Paradise, Short-tailed Paradigalla) inhabit the uplands, and additional species (Superb Bird of Paradise, Black Sicklebill) inhabit forests at lower elevations. The New Guinea Harpy Eagle and Shovel-billed Kingfisher also add biodiversity value to these environments. A community-delineated and managed reserve, focused on uninhabited traditional hunting lands, might be an appropriate vehicle for conserving these remarkable sub-alpine and upper montane environments and their wildlife.

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Chapter 4

The mammal fauna of the Kaijende Highlands, Enga Province, Papua New Guinea

Kristofer M. Helgen

SUMMARY

I surveyed five sites in the Kaijende Highlands of Enga Province, Papua New Guinea between 25 August and 9 September 2005 to assess the diversity of mammals in this region. This survey confirmed the occurrence of one monotreme, 18 marsupials, nine rodents, two bats, and two non-native placental mammals (wild-living dogs and pigs). Previous surveys of the Kaijende Highlands during the 1980s recorded at least one marsupial species, three rodent species, and one bat species that were not detected in the current survey. This brings the total number of native marsupials, rodents, and bats recorded in the Kaijende Highlands to 35 and in Enga Province to 39. However estimates of inventory completeness suggest that many species remain to be detected and that the local mammal fauna is likely to be twice as diverse as currently recorded.

The Kaijende Highlands mammal fauna includes a poorly known assemblage of rare and threatened species restricted to high-altitude tree fern savanna, tussock grassland, and adjacent upper montane (elfin) forests. These include the wallaby *Thylogale calabyi,* the rodent *Rattus giluwensis,* an unnamed species of bandicoot (*Microperoryctes* sp.), and an unnamed genus and species of rodent. Important range extensions for New Guinea mammals include the third vouchered locality for Calaby's Pademelon (*Thylogale calabyi*) and the first record of the Giluwe Rat (*Rattus giluwensis*) outside of the immediate vicinity of Mt. Giluwe in Southern Highlands Province. Other species of conservation concern that occur in the Kaijende Highlands include the echidna *Zaglossus bartoni* (as documented by informants) and the tree-kangaroo *Dendrolagus dorianus* (as documented by "trophy" mandibles). Inasmuch as the Kaijende Highlands continue to support a largely intact mammal community that has not been reduced in diversity by overhunting, it is a region of great interest and importance for conservation.

INTRODUCTION

Enga Province has received less attention in surveys of mammalian biodiversity than any other province in Papua New Guinea. The paucity of mammal records for Enga Province is notable because the mammal faunas of several neighboring provinces (particularly Southern Highlands, West Sepik, Western, and Madang Provinces) have been the targets of considerable field collecting and systematic study (e.g. Morren 1989, Flannery and Seri 1990, Hyndman and Menzies 1990, Leary and Seri 1997, Flannery 1995, Bonaccorso 1998, Helgen 2007a). The few mammal specimens collected during previous survey work in Enga Province are deposited in the Papua New Guinea National Museum and Art Gallery (PNGNM) and the University of Papua New Guinea (UPNG), both in Port Moresby, and the Western Australian Museum (WAM) in Perth. Brief examinations of Enga specimens in these institutions prior to our 2005 RAP survey revealed just 18 mammal species, reinforcing the need for a more comprehensive assessment of the Province's mammal fauna.

Previous records of mammals from Enga Province derive from three main sources. Two rodent species (*Pogonomys loriae, Pogonomys sylvestris*) and four marsupial species (*Cercartetus caudatus, Phalanger carmelitae, Dactylonax palpator, Petaurus breviceps*) were collected at Wapenamanda (05°38'36"S, 143°53'43"E) by G. George, R. Mackay, and J. Mangi in the late 1960s. Some of these specimens were apparently transported alive to Baiyer River Sanctuary and the specimens were subsequently deposited at the PNGNM. At least 11 species were collected by Pat Woolley and collaborators during a survey of Porgera in 1980 and these specimens were deposited at WAM, PNGNM and UPNG (see below). Finally, Bonaccorso (1998) reported a record of *Miniopterus schreibersii* from Enga Province (collected at Mt. Leiwaro, see below). In addition to these definite Enga records, the American Museum of Natural History in New York and the Australian Museum in Sydney hold small series of specimens that originated from Yaramanda, a village that straddles the border between Enga Province and adjacent Western Highlands Province, but many if not most of these are explicitly marked "Western Highlands" District or Province. PNGNM also holds a specimen of *Mallomys rothschildi* from "Lumus, Enga Province" but this may in fact refer to the locality of Lumis (= Lumusa), situated in Western Highlands Province.

In this chapter I report the results of a mammal survey conducted between 25 August and 9 September 2005 at five sites in the Kaijende Highlands of Enga Province.

MATERIALS AND METHODS

Data collection and sampling methods

Because the majority of Melanesian mammals can only be reliably identified by comparison with museum specimens (Flannery 1995, Bonaccorso 1998, Helgen 2007a), scientific efforts to document mammalian biodiversity in New Guinea require the collection and long-term preservation of voucher specimens. I obtained voucher specimens on the 2005 RAP survey by excavating osteological material from owl pellet deposits and a rock shelter site, scavenging osteological material of naturally-deceased animals, and by collecting animals by live-trapping (cage and Elliott traps), lethal trapping (snap traps), and hunting with residents of the Kaijende Highlands.

Protocols for capture and handling of mammals followed standard guidelines established by the American Society of Mammalogists for animal care and use (American Society of Mammalogists 1998). For each specimen prepared as a museum voucher, standard external measurements were taken with a ruler (total length, tail length, hind foot length with and without the claws, ear length, and in the case of bats, forearm length) and Pesola scales (body mass). The sex and maturity of each specimen were assessed in the field, and microhabitat and other ecological data were noted for each specimen. Vouchers were prepared as study skins and skeletons, or as fluid preparations (fixation in 10% formalin, then transferred to 70% ethanol for long-term storage). For each freshly collected specimen, liver (and in some cases, kidney) tissue was preserved in 95% ethanol for subsequent genetic analyses. Some small mammals were photographed in life in semi-natural settings. Specimens from the Kaijende Highlands RAP survey are deposited in the mammal collections of the Papua New Guinea National Museum and Art Gallery, Port Moresby (PNGNM), the Australian Museum, Sydney (AM), and the South Australian Museum, Adelaide (SAM), along with their associated temporal, geographic, ecological, and mensural data, and genetic samples. These museum abbreviations are used throughout this chapter. Other institutions referenced by abbreviation herein include the American Museum of Natural History, New York (AMNH); the Bernice P. Bishop Museum, Honolulu (BPBM); and the Australian National Wildlife Collection, CSIRO, Canberra, Australia (CSIRO). Common names generally follow Flannery (1995), but in a few cases (among rodents) where taxonomic changes have necessitated a change in vernacular usage, common names follow Musser and Carleton (2005).

Study sites, site-specific trapping protocols and capture rates

The mammal survey focused on two areas, both in the Kaijende Highlands of Enga Province; 1) the vicinity of Lake Tawa, and 2) the area accessible by roads in the immediate vicinity of the town of Porgera and the Porgera Joint Venture (PJV) mining operation.

Lake Tawa Camp (05°35'43"S, 142°50'26"E) was situated at approximately 2,200 m elevation in lower montane forest (*sensu* Grubb and Stevens 1985). This site, described in more detail by Takeuchi (Chapter 1, this volume), was accessed by helicopter and consisted of several small interconnected sinkhole lakes fringed with grassland, and surrounded by forest dominated by *Pandanus.*

I established several trap-lines in the forest around Lake Tawa for 'removal trapping' of small mammals. Up to 50 medium-sized Elliott live traps (two transects) and 20 Victor rat traps (one transect) were set each night, for seven nights, on the forest floor and in vegetation and low trees up to 3 meters above the ground. Several traps were lost and broken over the course of the week, and total trap-nights was 425, with 45 catches (= 11% trap success) representing six species (*Rattus niobe, Paramelomys rubex, Peroryctes raffrayana, Microperoryctes ornata, Pseudohydromys ellermani,* and *Murexia naso*; see species accounts below). The terrestrial murines *Rattus niobe* (69% of captures) and *Paramelomys rubex* (20% of captures) dominated in the forest understorey. Six cage traps were also set each night along animal runways in the grasslands fringing Lake Tawa (Photo 81) and in adjacent forests, without success.

Mist-nets set by day by Beehler for catching birds (Chapter 3, this volume) were monitored at night for opportunistic bat-catching. Six nights of netting yielded only two species, one bat (the blossom-bat *Syconycteris australis,* five captures)

and one marsupial (the glider *Petaurus breviceps*, one capture). A double-stringed harp trap was erected each night for six nights along presumed flyways and entrance points in the forest near Lake Tawa without success.

Mammals were also documented at Lake Tawa by day hunting, scavenging, rock shelter excavation, sightings, and examination of spoor. Day hunting involved searching for roosting and sleeping sites of arboreal mammals during the day. Specimens of two species, the marsupials *Dactylonax palpator* and *Phalanger carmelitae*, were obtained in this manner. We did not hunt mammals at night. Scavenging involved searching opportunistically for mammal remains in the vicinity of camp. Cranial (and other) remains of five species (*Dorcopsulus vanheurni, Phalanger carmelitae, Pseudochirops cupreus, Uromys anak,* and *Sus scrofa*) were collected, all in sufficiently excellent condition to serve as good voucher material. I excavated osteological remains of small mammals, mainly mandibles and maxilla, from the surface levels of a rock shelter site situated on a ridge between two sinkhole lakes near camp; remains of at least five species (Table 4.1) were excavated at this site. Two species were documented at the Lake Tawa site by spoor (*Dendrolagus dorianus*), or by both sightings and spoor (*Canis familiaris*).

Porgera: A secondary effort was concentrated at three sites in the vicinity of Porgera: 1) Suyan Village, 2) Paiela Road and 3) Waile Creek including the Porgera Reservoir.

In Suyan Village (05°29'S, 143°09'E) I purchased from local hunters trophy jaws representing six medium-sized and large mammals (Table 4.1), including the macropodids *Dendrolagus dorianus* and *Thylogale calabyi*.

At Paiela Road I set up trap-lines (20 Elliott traps and 5 cage traps) in transects along a creek in upper montane forest (05°30'07"S, 143°04'44"E; 2,900 m asl) for three nights, resulting in the capture of three specimens of *Rattus niobe* in the Elliotts (= 5% trap success) and one specimen of *Uromys anak* in a cage trap (= 7% trap success). I also obtained trophy jaws of three medium-sized mammals from local hunters encountered along Paiela Road (Table 4.1).

At Waile Creek I set 25 Elliott traps per night for four nights, in alpine grassland adjacent to the Porgera Reservoir (ca. 05°33'56"S, 143°03'35"E, 3,010 m) and the Porgera power transformer station (05°33'45"S, 143°03'21"E, 3,076 m), resulting in the capture of eight *Rattus giluwensis* and 10 *Rattus niobe* (= 18% trap success). *Rattus niobe* were trapped in alpine grassland and adjacent upper montane forest but *R. giluwensis* was found only in the grassland. I collected a substantial quantity of bone from an owl pellet deposit in a rock outcropping in alpine grassland near the Porgera Reservoir (Photo 80), including jaws of at least eight small mammal species (Table 4.1). Given the altitude of this collection site (ca. 3,000 m), the only likely candidate for producing these deposits is the Sooty Owl, *Tyto tenebricosa* (see Beehler et al. 1986).

Omyaka Camp

A single skull of a wallaby (*Dorcopsulus* cf. *vanheurni*) was collected by survey personnel at Omyaka Camp (05°31'37"S, 143°03'23"E, 3,203 m) a few days prior to my arrival for the RAP survey (see below).

RESULTS

The mammal fauna of the Kaijende Highlands

During this survey I documented the occurrence of 32 mammal species including one monotreme, 18 marsupials, nine rodents, two bats, and two non-native placental mammals (wild-living dogs and pigs). Combined with the limited data available from previous surveys of the Kaijende Highlands during the 1980s these results increase the total number of native marsupials, rodents, and bats recorded in the Kaijende Highlands to 35 and in Enga Province to 39. Of this latter number, 33 are documented from the area by vouchered museum material, one (*Neophascogale lorentzii*) is documented by a photograph, and four (*Zaglossus bartoni, Crossomys moncktoni, Parahydromys asper,* and *Tadarida kuboriensis*) are documented by what I consider to be unambiguous informant information or reasonably established sightings, as discussed and defended below.

Because our understanding of the taxonomy and geographic distribution of many New Guinean mammals remains in a fairly basic state (Helgen 2007a, 2007b), I have summarized below all available data for each mammal species documented in the Kaijende Highlands. Included are all taxa documented during the 2005 RAP survey, and the four additional species recorded during previous surveys in the region. The taxonomic status of these four species was verified during the author's examination of museum specimens. These species accounts add to our meager knowledge of many poorly-known species, and provide the first major sketch of the mammal community of Enga Province as a whole. It is my hope that the combined taxonomic identifications, ecological contexts, and other information in this list will be useful far beyond the borders of Enga Province and will substantially complement existing regional summaries of New Guinean mammals (e.g. Laurie 1952, Lidicker and Ziegler 1968, Flannery and Seri 1990, Leary and Seri 1997, Cole et al. 1997, Aplin 1998, Aplin et al. 1999).

Order Monotremata, Family Tachyglossidae (Echidnas)

Zaglossus bartoni (Thomas, 1907) (Eastern Long-Beaked Echidna)

This largest of extant monotremes (5–10 kg) occurs in forests and upland grasslands from sea level to an elevation of at least 4,150 m along the length of New Guinea's central cordillera and in the outlying mountain ranges of the Huon Peninsula (Flannery and Groves 1998). It is now rare across much of its geographic range, probably because of widespread and intensive subsistence hunting with the aid of dogs, and it remains common today only in areas of very low human population density (George 1978, Flannery 1995). The subspecies in the Porgera region is presumably *Z. b. diamondi*, the distribution of which stretches from Papua New Guinea's Eastern Highlands to the Paniai (= Wissel) Lakes

of Papua Province, Indonesian New Guinea (Flannery and Groves 1998). I did not observe or collect this rare species during our survey effort in the Kaijende area, but hunters in the region are universally familiar with this animal, known by the name *Foreke* in the Ibile language. One informant recalled a recent sighting in tussock grasslands near the Porgera Reservoir along Waile Creek Road, which many travelers traverse between Porgera and Mt. Kare daily.

Order Dasyuromorphia, Family Dasyuridae (Carnivorous Marsupials)

Dasyrus albopunctatus Schlegel, 1880 (New Guinea Quoll)
This medium-sized dasyurid (500–1000 g) is a scansorial carnivore that inhabits forested areas between sea level and 4,000 m elevation across most of the island of New Guinea. I did not find it during our survey, but all local hunters that I interviewed were familiar with this quoll, known by the name *Forete* in the Ibile language. Its occurrence in the Kaijende Highlands is substantiated by a mandible collected from a cave deposit at Porgera by T. Mala in 1985 (UPNG 1810).

Murexia hageni Laurie, 1952 (Small Eastern Mountain Dasyure)
This small dasyurid (ca. 30 g) is a nocturnal, largely terrestrial insectivore that inhabits high montane forests in Papua New Guinea (1,600 to 3,400 m elevation). In the past, *M. hageni* has usually been considered a synonym of *M. habbema* (Tate and Archbold, 1941) (Flannery 1995, Van Dyck 2002). However, the taxonomy and distribution of *Murexia* (including the nominal genera *Micromurexia, Murexechinus,* and *Paramurexia* of Van Dyck (2002); cf. Krajewski et al. (2000)) are currently under review by Helgen and Darrin Lunde (in litt.), who recognize *M. hageni* as a distinct species endemic to Papua New Guinea's central and Eastern Highlands regions (Helgen 2007a, 2007b).

Most of what is known about the biology of *M. hageni* was reported by Woolley (1989) and Woolley et al. (1991), who studied this species at Porgera in 1985 with spool-and-line tracking methods. It is also represented by a voucher specimen from Porgera collected by Woolley and deposited at PNGNM. During our RAP survey, remains of this species were recovered from owl pellet accumulations in alpine grassland adjacent to the Porgera Reservoir along Waile Creek Road.

Murexia naso (Jentink, 1911) (Long-Nosed Dasyure)
This medium-sized species of *Murexia* is a scansorial carnivore that is widely distributed in upland forests (1,400-2,800 m) along the central cordillera (Flannery 1995, Van Dyck 2002, Helgen 2007b).

In forest near Lake Tawa I trapped a single adult male specimen of *M. naso* (65 g). The specimen was taken in a Victor trap baited with a dead bird and placed on a large log that had fallen across a creek.

Neophascogale lorentzii (Jentink, 1911) (Speckled Dasyure)
This medium-sized dasyurid is known from montane forests (1,200–3,900 m elevation) throughout much of the central cordillera. It was not recorded during our survey, and I know of no museum specimens from the vicinity of Porgera. However, Flannery (1995a) figured a photograph of *N. lorentzii* (by P. Woolley and D. Walsh) taken at Mt. Paiam, a peak overlooking Porgera (Flannery mistakenly attributed this locality to Western Highlands Province). This photograph of *Neophascogale* from the Kaijende Highlands provides the only record of the species between the Star Mountains region (Telefomin, West Sepik Province) and Mt. Giluwe and the Lavani Valley in Southern Highlands Province (all specimens at BPBM).

Order Peramelemorphia, Family Peramelidae (Bandicoots)

Microperoryctes ornata (Thomas, 1904) (Eastern Striped Bandicoot) (Photo 84)
The striped bandicoot *Microperoryctes ornata* is endemic to forested habitats at higher altitudes along the central cordillera (1,000–3,600 m elevation). It is a relatively small terrestrial omnivore that lives in burrows in the ground (Flannery 1995, Helgen 2007). Recognition of *M. ornata* as a species distinct from *M. longicauda* follows Helgen and Flannery (2004). A single adult male (400 g) was trapped in forest at Lake Tawa with an Elliott trap placed amongst fallen ripe *Pandanus* fruits. This is the first record of the species in Enga Province.

Microperoryctes sp. nov. (Subalpine Striped Bandicoot)
Examination of the large collections of *Microperoryctes* in world museums (see Helgen 2007a) indicates that an undescribed species of striped bandicoot occurs on the highest peaks of central and eastern Papua New Guinea, with known localities associated with tussock grasslands above the treeline (> 3,000 m elevation). Museum specimens referred to this taxon (Helgen in prep.) derive from Mt. Giluwe, SHP (BPBM), Mt. Wilhelm, Chimbu Province (AMNH), and Mt. Albert Edward, Central Province (AM, AMNH). Mandibles and maxilla extracted from owl pellet accumulations from a rock outcropping in tussock grassland along Waile Creek Road are tentatively referred to this unnamed species on the basis of mandibular and molar morphology.

Peroryctes raffrayana (Milne-Edwards, 1878) (Raffray's Bandicoot)
This medium-sized bandicoot is a terrestrial, nocturnal omnivore that is widespread in hill and mountain forests throughout New Guinea at elevations between sea level and 4,000 m. It occurs in forests along the northern and southern slopes of the central cordillera, in the outlying mountain ranges of the Huon and Vogelkop Peninsulas, and in the smaller north coastal ranges (Helgen 2007b). During the RAP survey I trapped two specimens in forest near Lake Tawa Camp. A juvenile male (195 g) was taken in an Elliott trap set overnight on the ground amongst fallen ripe *Pandanus* fruits. A large adult female (900 g) was taken in a Victor

Table 4.1. Mammal fauna documented from the Kaijende Highlands, Enga Province.
"Tawa" refers to Lake Tawa. "Suyan", "Paiela", "Reservoir", and "Power" reference sites along access roads in the vicinity of Porgera (see text). "Omyaka" refers to Omyaka Camp. Shaded columns at right indicate records that are not backed by a voucher specimen from the 2005 RAP. The light gray column indicates taxa recorded from the Kaijende Highlands on the basis of informant interviews only during the 2005 RAP (see text). The dark gray column indicates taxa documented at Porgera by Woolley and colleagues in 1985 but not collected during the 2005 RAP.
v = documented by voucher specimen(s) collected by survey personnel
r = documented by osteological remains excavated from a rock shelter or cave
o = documented by osteological remains recovered from owl pellet accumulations
t = documented by osteological remains recovered as trophy material from local hunters
s = documented by a sighting or sign as verified by the author
x = documented during this survey on the strength of unambiguous descriptions from local informants (column marked in light grey)

Site	Tawa	Suyan	Paiela	Reservoir	Power	Omyaka	Informant	Porgera
Approximate Elevation (m)	**2200**	**2300**	**2900**	**3000**	**3100**	**3200**	**> 2000**	**2500–2900**
Year	**2005**	**2005**	**2005**	**2005**	**2005**	**2005**	**2005**	**1985**
Monotremata (Tachyglossidae)								
Zaglossus bartoni							x	
Dasyuromorphia (Dasyuridae)								
Dasyurus albopunctatus							x	r
Murexia hageni				o				
Murexia cf. *longicaudata*	v							
Neophascogale lorentzii								v
Peramelemorphia (Peramelidae)								
Microperoryctes ornata	v, r							
Microperoryctes sp.				o				
Peroryctes raffrayana	v							
Diprotodontia (Macropodidae)								
Dendrolagus cf. *dorianus*	s	t						
Dorcopsulus vanheurni	v					v		
Thylogale calabyi		t						
Diprotodontia (Petauridae)								
Dactylonax palpator	v				s			
Petaurus breviceps	v, r							
Diprotodontia (Phalangeridae)								
Phalanger carmelitae	v	t	t					
Phalanger gymnotis							x	
Phalanger sericeus	r	t				s		
Diprotodontia (Pseudocheiridae)								
Pseudochirops cupreus	v	t	t					
Pseudochirulus forbesi							x	
Pseudochirulus mayeri				o				
Diprotodontia (Burramyidae)								
Cercartetus caudatus	r			o				
Rodentia (Muridae)								
Coccymys ruemmleri				o				
Crossomys moncktoni							x	

continued

Table 4.1. *continued*

Site	Tawa	Suyan	Paiela	Reservoir	Power	Omyaka	Informant	Porgera
Approximate Elevation (m)	**2200**	**2300**	**2900**	**3000**	**3100**	**3200**	**> 2000**	**2500–2900**
Year	**2005**	**2005**	**2005**	**2005**	**2005**	**2005**	**2005**	**1985**
Mallomys istapantap			t					
Mammelomys lanosus								v
Parahydromys asper							x	
Paramelomys rubex	v, r							
Protochromys fellowsi								v
Pseudohydromys ellermani	v							
Rattus giluwensis				v, o	v			
Rattus niobe	v		v	v, o	v			
Uromys anak	v	t	v	o				
Gen. nov., sp. nov.								v
Chiroptera (Pteropodidae)								
Syconycteris australis	v							
Chiroptera (Molossidae)								
(?) *Tadarida kuboriensis*				s				
Carnivora (Canidae)								
Canis familiaris	s							
Artiodactyla (Suidae)								
Sus scrofa	v	s						
Total	**18**	**7**	**5**	**9**	**3**	**2**	**6**	**5**

rat trap baited with rat entrails and fur and set overnight on a fallen log over a creek. Examination of her pouch revealed eight teats, with one small pouch young (date of collection 1 September). This is the first record of the species in Enga Province.

Order Diprotodontia, Family Macropodidae (Kangaroos)

Dendrolagus dorianus Ramsay, 1883 (Doria's Tree-Kangaroo)

Doria's Tree-Kangaroo is a relatively large (ca. 10 kg) arboreal macropodid distributed throughout the mountain ranges of New Guinea's central cordillera, where it occurs most commonly at higher elevations (above 1,500–2,000 m) in the highlands of central Papua New Guinea and West Papua (Flannery and Seri 1990, Flannery et al. 1996). Several geographic forms have been described, and more study is needed to confirm whether these are distinctive subspecies or a complex of parapatric species (Bowyer et al. 2003, Helgen 2007b). The form of Doria's Tree-Kangaroo represented in the Kaijende Highlands is presumably *Dendrolagus dorianus notatus* Matschie, 1916, which according to Flannery (1995) occurs "from Garaina to the Strickland River." Several trophy jaws of this kangaroo were obtained at Suyan Village. These jaws should be of particular interest in future taxonomic and geographic studies of *D. dorianus* in that they are unusually massive, with teeth larger than most *D. dorianus* museum specimens that I have examined (lower cheektooth row in two complete Suyan jaws = 38.5 – 40.6 mm versus 33.6 – 38.8 mm in 30 adult *D. dorianus* jaws at AM, AMNH, and CSIRO that were collected throughout the central cordillera). The exact provenance of the Suyan specimens is not known, but an elder at Suyan informed me that hunting occurred predominantly near the village (maybe within a half-day or day's walk). As far as I am aware, this is the first record of *D. dorianus* in Enga Province. It is known by the name *Andaia* in the Ibile language. Tree-kangaroo claw marks almost certainly representing this species were evident on trees along the forest edge in the immediate vicinity of Lake Tawa.

Hunters from Porgera were also familiar with Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi* Thomas, 1908), another central cordilleran congener that is easily recognized by its red-brown and gold patterning. It is known by the local Ibile name *Milipu* but it was universally agreed by hunters that *D. goodfellowi* occurs only at lower elevations

and not in the Kaijende Highlands above 2,000 m. Historically, *D. goodfellowi* occurred throughout most of the eastern central cordillera, probably from low foothills up into mid-montane oak forests. In areas of broad co-occurrence with *D. dorianus* it is probably restricted to forest formations at lower elevations (usually below 1,500 m) than *D. dorianus* (e.g. Hide et al. 1984). *D. goodfellowi* occurs as high as 2,865 m in the Star Mountains (Flannery 1995). Both *D. dorianus* and *D. goodfellowi* have been locally extirpated from many areas of New Guinea where they occurred until recent decades (Bulmer and Menzies 1972, George 1978, Flannery 1995, Martin 2005).

Dorcopsulus vanheurni (Thomas, 1922) (Small Dorcopsis)
This small mountain wallaby (1.5–2.5 kg) is widely distributed in the mountains of New Guinea, where it occurs in forests at elevations between 800 m and 3,200 m (Helgen 2007b). Our survey team scavenged a skin and skull of this species from a fresh kill by a New Guinea singing dog (*Canis familiaris*) in the grassy surrounds of Lake Tawa. Local hunters sighted other individuals in the same area during the day. This species apparently moves through the grass along well-worn runways that extend into adjacent forests. Cage traps set along these runs (baited with fruit) failed to capture any wallabies. This is the first record of *D. vanheurni* in Enga Province. It is known by the name *Wasana* in the Ibile language.

An additional *Dorcopsulus* skull was collected by Steve Richards and other members of the survey team at Omyaka Camp, above the treeline at around 3,200 m elevation. Preliminary comparisons indicate that the craniodental conformation of this skull is distinctive relative to other specimens collected from throughout the mountains of New Guinea and referred to *D. vanheurni*. *Dorcopsulus vanheurni* is not known to occur above the treeline and a detailed study of taxonomic boundaries and geographic variation in *Dorcopsulus* will be needed before the taxonomic status of this unusual skull can be firmly established. One possibility is that it represents a previously undiscovered high-altitude wallaby species. Clearly, a more complete series of specimens from high elevations near Porgera is needed to investigate the status of this potentially new taxon.

Thylogale calabyi Flannery, 1992 (Calaby's Pademelon)
Thylogale calabyi is a little-known, medium-sized wallaby (probably 2–4 kg) previously recorded in the literature only from subalpine grassland habitats (≥ ca. 2,800 m elevation) on two peaks in Papua New Guinea — Mt. Giluwe in Southern Highlands Province and Mt. Albert Edward in Central Province (Flannery 1992). The presence of *T. calabyi* in the Kaijende Highlands is documented by a single trophy jaw collected in the village of Suyan (Figure 4.1). This identification has been confirmed by a direct comparison of the trophy jaw with the holotype of *T. calabyi* at AM and is only the third documented site of occurrence for the species. Ken Aplin (in litt.) informs me that *T. calabyi* is also represented

Figure 4.1. Trophy jaw of *Thylogale calabyi* discovered in the village of Suyan in the Kaijende Highlands. It represents only the third documented site of occurrence for this species. Scale Bar = 25 mm.

in trophy jaw collections at AM taken at Pureni (05°51'S, 142°49'E) in Southern Highlands Province. Wallaby sign observed in subalpine meadows on Mt. Michael, Eastern Highlands Province (Steve Richards, in litt.), indicates that Calaby's Pademelon may also occur on this high peak. These scattered records indicate a disjunct geographic distribution for the species, centered on remnant upland sub-alpine grasslands throughout the eastern portion of New Guinea's central cordillera (Figure 4.2).

Pademelons have disappeared from upland meadows throughout much of New Guinea. Fossil remains document the apparent extinction of two species in the Snow Mountains of West Papua during the Holocene (Hope 1981; Flannery 1995, 1999). Calaby's Pademelon was probably present until recent decades in subalpine meadows on Mt. Wilhelm (Chimbu Province) (Flannery 1992, 1995). These Holocene and modern declines are likely to be associated (at least in part) with the arrival of dogs in the highlands and their widespread use by indigenous hunters. The discovery that *T. calabyi* still occurs in the Kaijende region is thus a result of considerable significance for conservation. Subalpine habitats in the Kaijende Highlands may be one of the largest tracts of habitat remaining for this Endangered species.

Order Diprotodontia, Family Petauridae (Striped Possums and Gliders)

Dactylonax palpator Milne-Edwards, 1888 (Long-Fingered Triok)
This striped possum is widespread in New Guinea's montane forests at elevations of 850–3,000 m, where it lives in tree hollows and in terrestrial burrows. An adult female was

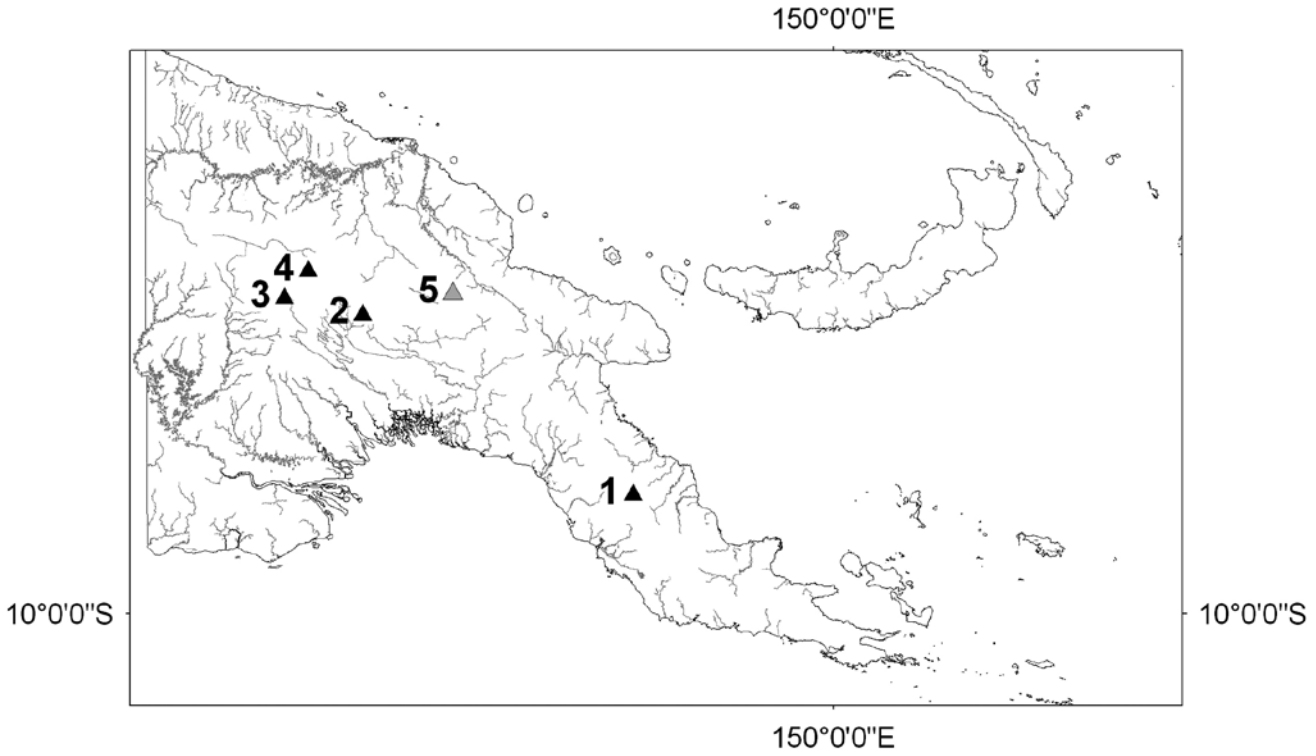

Figure 4.2. Distribution of *Thylogale calabyi*. Vouchered localities: 1. Mt. Albert Edward, Central Province, type locality of *T. calabyi*. 2. Mt. Giluwe, Southern Highlands Province. 3. Pureni, Southern Highlands Provinces. 4. Porgera, Enga Provinces. 5. Mt. Wilhelm, Chimbu Province, (shaded gray rather than black to indicate this is an unvouchered locality where *T. calabyi* may have occurred in the past, even if it does not persist today (see Flannery 1992)).

obtained from hunters at Lake Tawa, who found the animal resting by day in a tree hollow. The pouch of this animal contained a single young weighing 45 g. I also smelled the characteristic scent of this species near the Porgera transformer substation, in stunted upper montane forest at the alpine grassland ecotone (ca. 3,000–3,100 m elevation). This appears to be the upper altitudinal limit for this species throughout New Guinea (Helgen 2007b). This species is called *Piawini* in the Ibile language, but this name may also be a general term for striped possums.

Almost nothing has previously been reported previously about reproduction in *D. palpator* (Flannery 1994, 1995). A review of available data shows that all museum specimens reported to have pouch young contain only a single juvenile in the pouch (n = 6; specimens at AM, BMNH). Although there are two mammae in the pouch, only one seems to be functional at a time. Hide et al. (1984) reported that two females collected on Mt. Karimui were each accompanied by a single subadult male, presumably their nearly-grown offspring. In raising a single young, *D. palpator* contrasts with the sympatric striped possum *Dactylopsila trivirgata*, which more commonly has two pouch young (five of eight litters, based on examination of specimens at AM and BMNH).

The average body mass of four *D. palpator* mothers with pouch young (based on specimens at AM, including the Lake Tawa specimen) is 340 g (range 300–390 g).

Petaurus breviceps Waterhouse, 1838 (Sugar Glider) (Photo 83)
This common and widespread, small (mass ca. 50–120 g) forest-living glider is common in nearly all forest formations in New Guinea between sea level and at least 3,000 m elevation. It was recorded at Lake Tawa, where an adult female (49 g) was captured at night in a mist net. Osteological material of this species was collected at a rock shelter site in the same area, and its characteristic vocalizations were heard near our camp.

Order Diprotodontia, Family Phalangeridae (Cuscuses)
Phalanger carmelitae Thomas, 1898 (Mountain Cuscus)
This medium-sized cuscus (mass ca. 1.5–2.5 kg) is widespread, and often common, in montane forests between 1,350 and 3,800 m elevation (Helgen 2007b) throughout the central cordillera and on the Huon Peninsula (Flannery 1994, 1995). One adult female (mass 1.8 kg) with a very small pouch young (crown-rump length 15 mm, mass < 1 gram) was found sleeping in a tree hole during the day

by local assistants in forest around Lake Tawa (Photo 79). Another young adult female (1.15 kg) was found in the same area, sleeping by day in pandanus fronds. Trophy jaws representing this species were purchased from hunters at Suyan Village and on the Paiela Road.

Phalanger gymnotis (Peters and Doria, 1875) (Ground Cuscus)
The Ground Cuscus is a medium-sized to large (mass ca. 2–5 kg) terrestrial phalanger that is widespread in lowland and montane forest (0–2,700 m elevation) throughout New Guinea. Although I did not document this Cuscus at any site our assistants at Lake Tawa were familiar with the species — they described its appearance and habits unambiguously and used the Ibile name *Wapia* for it. Its occurrence in the Kaijende Highlands is substantiated by a voucher specimen from Porgera at PNGNM, collected by G. George in 1980.

Phalanger sericeus Thomas, 1907 (Silky Cuscus)
The Silky Cuscus is a medium-sized (mass ca. 2–2.5 kg) scansorial phalanger endemic to montane forest at elevations between 1,500 and 3,900 m along New Guinea's central cordillera. Externally it superficially resembles *Phalanger carmelitae* and it is sometimes confused with that species (Menzies and Pernetta 1986, Flannery 1995). This species is represented by trophy jaws purchased at Suyan Village near Porgera. As far as I am aware, this is the first record of the species in Enga Province. *Phalanger sericeus* is also probably the cuscus observed by Steve Richards (pers. comm.) and other members of the survey team in the vicinity of Omyaka Camp at 3,200 m elevation.

Order Diprotodontia, Family Pseudocheiridae (Ringtail Possums)
Pseudochirops cupreus (Thomas, 1897) (Coppery Ringtail)
This large ringtail (1.5–2.5 kg) is a common inhabitant of montane forests throughout New Guinea's central cordillera; it has a wide altitudinal range, extending from 1,350 to 4,000 m. Three complete skulls of this species were recovered in forest near Lake Tawa, and trophy jaws were purchased at Suyan Village and on the Paiela Road. *P. cupreus* is apparently called *Tanakai* in the Ibile language and this name was also applied to photographs of *Pseudochirops corrinae* (Thomas, 1897), another species which is likely to occur in the Kaijende Highlands. PNGNM holds additional osteological material representing *P. cupreus* collected from caves at Porgera in 1985 by T. Mala and P. Lambley.

Pseudochirulus forbesi (Thomas, 1887) (Painted Ringtail)
This medium-sized ringtail (400–1000 g) is a common inhabitant of montane forests in New Guinea, occurring throughout the eastern half of the central cordillera and in various isolated ranges (Flannery 1995, Helgen 2007b). It has been recorded from 450–3,800 m elevation but most records are from between 1,200 and 2,800 m (Helgen 2007b). The subspecies in central Papua New Guinea, including Enga Province, is *P. f. larvatus* (Forster and Rothschild, 1911). I did not document *P. forbesi* during the RAP survey, but Kaijende hunters were familiar with this species, called *Inalapei* in the Ibile language, which they identified from a photograph. Its occurrence in the Kaijende Highlands is substantiated by an adult male voucher specimen weighing 600 g that was collected from moss forest at 2,400 m on Mt. Waruwari by P. Woolley in 1985 (PNGM 24739).

Pseudochirulus mayeri (Rothschild and Dollman, 1932) (Pygmy Ringtail)
This small ringtail (100–200 g) is a common inhabitant of montane forests from 1,200 to at least 4,200 m elevation throughout New Guinea's central cordillera. Jaws of this species were recovered from owl pellet deposits in rock outcroppings in tree fern savanna adjacent to the Porgera Reservoir. P. Woolley collected a single specimen of *P. mayeri* at Porgera on June 6th 1985 — an adult female (PNGM 24746), weighing 151 g, with one pouch young. This species is called *Onopipi* in the Ibile language.

Order Diprotodontia, Family Burramyidae (Pygmy Possums)
Cercartetus caudatus (Milne-Edwards, 1877) (Long-Tailed Pygmy Possum)
This tiny possum (mass ca. 20 g) occurs across the entire length of the central cordillera and in the outlying mountains of the Vogelkop and Huon Peninsulas. It is a scansorial insectivore that occurs in montane forests and adjacent alpine grasslands at elevations between 1000 and 3700 m (Helgen 2007b). Osteological remains of this species were obtained from a rock shelter site at Lake Tawa and from owl pellet accumulations in a rock outcropping in alpine grasslands near the Porgera Reservoir. Several local informants applied the Ibile name *Penjo* to a photograph of this species.

Order Rodentia, Family Muridae (Rats and Mice)
Coccymys ruemmleri (Tate and Archbold, 1941) (Rümmler's Mouse)
This small scansorial murine (mass ca. 30 g) is a common inhabitant of montane forests and alpine grasslands throughout the central cordillera between 1,900 and 4,100 m elevation (Flannery 1995, Helgen 2007b). Jaws of this species were found in owl pellets in alpine grassland along Waile Creek Road near the Porgera Reservoir.

Crossomys moncktoni Thomas, 1907 (Earless Water-Rat)
Crossomys moncktoni is the most aquatic of all murine rodents and is classified in a monotypic genus (Thomas 1907). A medium-sized species (ca. 200 g), it is endemic to New Guinea's central cordillera where it occurs in fast-flowing streams in montane forests between 1,200 and 3,600 m elevation (Flannery 1995, Musser and Carleton 2005, Helgen 2007b). Previous compilations of museum records documented *Crossomys* only from the eastern portion of the central cordillera, with the Kikori River Basin (Southern Highlands Province) providing the westernmost record (Flannery 1995). However Helgen (2007b) reported a specimen from the Baliem Valley, demonstrating that its

distribution extends far into western New Guinea. There are no records from Enga Province and we did not document any specimens during our survey, despite intensive streamside trapping along the Paiela Road. However a hunter on the Paiela Road was familiar with this species, calling it by the Ibile name *Ambulimawa* and reporting that it occurs in streams along the Paiela Road. He provided an accurate description of the species' semi-aquatic habits, size, webbed feet, and lack of external ears, amounting to what I consider an unambiguous description of *Crossomys*. The only other rodent with which *Crossomys* might be easily confused is another gray, semi-aquatic hydromyin, *Baiyankamys shawmayeri* (see Helgen 2005b) which probably occurs in the Kaijende Highlands, but has external ears. Although I am confident that *Crossomys* occurs in the Kaijende Highlands on the basis of my discussion with this Paiela hunter, verification of this species' occurrence in the region is still needed.

Mallomys istapantap Flannery, Aplin, and Groves, 1989 (Subalpine Giant-Rat)
Three species of *Mallomys* — large, scansorial and arboreal "woolly-rats" — co-occur in the central cordillera in Papua New Guinea — *M. aroaensis, M. rothschildi,* and *M. istapantap* (Flannery et al. 1989, Helgen 2007a). On the Paiela Road I purchased from a local hunter a single trophy jaw representing a species of *Mallomys*; comparison with voucher material at the Australian Museum confirms the Kaijende specimen as *M. istapantap,* the largest of the *Mallomys* species in New Guinea (adult mass ca. 1.9 kg). This record of *M. istapantap*, and another record from Dokfuma in the Star Mountains (Helgen 2007a), are significant in that they bridge a large gap in this species' previously recorded distribution. There were previously no records of this species between Mt. Giluwe and Lake Habbema. The distribution of *M. istapantap* is now known to extend across most of the central cordillera (Figure 4.3).

Mammelomys lanosus (Thomas, 1922) (Highland Mammelomys)
This medium-sized rat (ca. 100 g) occurs in upland forests (1,000–3,200 m) of the central cordillera and North Coastal Ranges (Flannery 1995, Musser and Carleton 2005, Helgen 2007). I did not collect it during the 2005 RAP, but WAM holds a series of specimens from Porgera collected by Pat Woolley (K. Aplin, in litt.).

Paramelomys rubex (Thomas, 1922) (Mountain Paramelomys)
Paramelomys rubex is a small, largely terrestrial, omnivorous rat that occurs in montane areas from 900 to 3000 m elevation throughout New Guinea (Flannery 1995). It is often the most common terrestrial mosaic-tailed rat in New Guin-

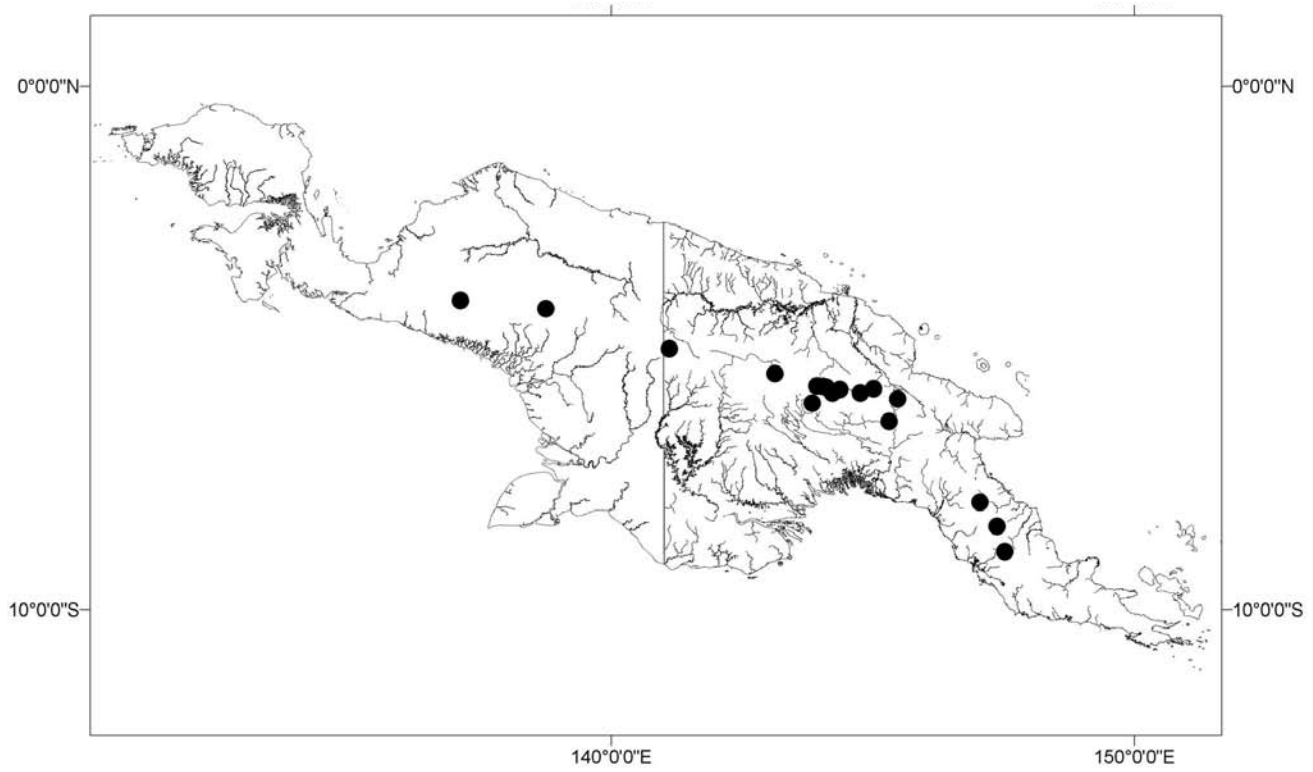

Figure 4.3. Distribution of *Mallomys istapantap* (adapted from Helgen 2007a).

ean montane forests. However, current taxonomic interpretations of *P. rubex* are likely to incorporate multiple distinct, currently undiagnosed species (Helgen 2007a).

I trapped many individuals at Lake Tawa, both in Elliott and snap traps, mostly on the ground but also on logs and low trees 1–2 m off the ground. Successful baits included peanut butter and oats, live worms, and pieces of a dead bird scavenged in the forest. After *Rattus niobe,* this was the most commonly trapped small mammal at Lake Tawa. However, no *Paramelomys* were trapped in upper montane forests along the Paiela Road, or in elfin forest or tree fern savannas along Waile Creek Road near the Porgera Reservoir and transformer station.

Parahydromys asper (Thomas, 1906) (Waterside Rat)
This semi-aquatic murine (ca. 500 g) occurs in all montane areas of New Guinea, including the entire length of the central cordillera, the isolated mountain ranges along the north coast, and on the Huon and Vogelkop peninsulas. In the central cordillera *P. asper* occurs at altitudes between 700 and 2,800 m (Helgen 2005b). Local informants in the Kaijende Highlands were familiar with this rodent, describing accurately its large lips and vibrissae, color, body size, general semi-aquatic habits, and waterside burrows. Although these descriptions could conceivably refer to a species of *Hydromys,* no *Hydromys* are known to occur above 2000 meters elevation (Helgen 2005b). Informants used the Ibile name *Poske* for this animal. Based on this information, and because it occurs along the length of the central cordillera to the east and west of Enga Province, there is little doubt that *Parahydromys* occurs in the Kaijende Highlands. Nevertheless, voucher material to confirm this species' occurrence in the region is still needed.

Protochromys fellowsi (Hinton, 1943) (Papuan Protochromys)
This little-known, small murine (mass ca. 80 g) was considered a species of *Melomys* until it was placed in a newly-erected monotypic genus, *Protochromys,* by Menzies (1996). It occurs in mossy forests at elevations between 1,800 and 2,800 m in the central highlands of New Guinea, with records from Porgera and the Hagen and Bismarck Ranges (Flannery 1995, Menzies 1996). Local population abundance appears to be variable. The species was reported as being common at some sites (Brass 1964, Menzies and Dennis 1979) but our survey did not encounter this species; the Porgera record (based on vouchers at PNGNM) was cited by Menzies (1996).

Pseudohydromys ellermani (Laurie and Hill, 1954)
This small, insectivorous, terrestrial moss-mouse inhabits mossy forests between 1,400–2,800 m elevation in the central portion of the central cordillera, with records from Lake Habbema in the west to Mt. Kaindi in the east (Helgen 2005a, 2007a). Along with *Pseudohydromys germani,* this species was previously classified in the genus *Mayermys* (see Helgen 2005a), which was subsumed into *Pseudohydromys* by Musser and Carleton (2005) and Helgen (2007a). I collected an adult female of this species (mass 15 g) in closed forest near Lake Tawa at 19:00 hrs. The snap trap was baited with a large live grub and placed at the base of a fallen log that formed a bridge over a small stream.

Rattus giluwensis Hill, 1960 (Giluwe Rat)
This distinctive montane murine was previously known only from the immediate vicinity of a single mountain peak, Mt. Giluwe, in Southern Highlands Province, Papua New Guinea (Taylor et al. 1982, Flannery 1995). Its capture in the Kaijende Highlands represents a range extension of major importance. I trapped seven individuals of this species (adult mass 50–100 g) in Elliott traps (baited with breadstuffs) along the Waile Creek Road in alpine grasslands near the Porgera transformer substation and the Porgera Reservoir. This short-tailed, large-headed, golden-brown rat has a highly distinctive appearance, superficially resembling a hamster (Photo 82).

Taylor et al. (1982) wrote that "The climate on Mt. Giluwe is cold and wet, and the surface humus, in which the tussock grasses grow, is subject to constant fracturing and reshaping by needle ice…The rats must utilize natural crevices and form burrow systems and extensive runways throughout the friable humus. Alpine bogs are common on at least the western slopes of Mt. Giluwe and thus much of the soil is continuously waterlogged." *Rattus giluwensis* occurs in a similar ecological context in upland grasslands in the Kaijende Highlands.

Rattus niobe Thomas, 1906 (Moss-Forest Rat)
Current taxonomic interpretations of *Rattus niobe* (Musser and Carleton 2005, Helgen 2007b) restrict its occurrence to the eastern half of the New Guinean central cordillera. Even with the taxonomic exclusion of a number of former synonyms (Musser and Carleton 2005, Helgen 2007b), the taxonomy of *Rattus niobe* is highly problematic and it probably incorporates multiple species that may be widely sympatric in the mountains of Papua New Guinea. With this caveat, I have tentatively identified the most common murine collected at Lake Tawa and in the Porgera area as *Rattus niobe*. This small (adult specimens from Lake Tawa weighed 40–50 g), largely terrestrial rat was trapped at all trapping stations during the survey (see "Study site", above). Detailed study of the comparative anatomy and genetics of trapped specimens will be needed to evaluate the tentative hypothesis that all specimens from the 2005 RAP survey represent a single biological species.

Uromys anak Thomas, 1907 (Black-Tailed Giant-Rat)
This large scansorial rodent is often common in forested areas above 2,000 m elevation throughout the central cordillera and on the Huon Peninsula (Groves and Flannery 1994), and extends as low as 850 m in some areas. No other *Uromys* occurs above 1,900 m in New Guinea. At Lake Tawa one of our local assistants found a skull of this species,

complete with mandible, on the ground. The skull exhibited braincase damage consistent with a raptor kill. Along the Paiela Road I also trapped an immature male (300 g) *Uromys anak* in a cage trap that was set overnight beside a stream and baited with fruit, lunchmeat, and bread. The Ibile names *Maiyanke* and *Poko* are applied to this species. The Beehler name *Kojo* is sometimes applied to this species.

A new genus and species of murine rodent

Two specimens of an unnamed genus and species of rodent were collected at 2,650 m elevation at Porgera by P. Woolley in May 1985. It is a small (30 g), chestnut-brown terrestrial "moss-mouse." The Kaijende specimens were identified as "*Pseudohydromys occidentalis*" by Jackson and Woolley (1993) and were deposited at WAM and PNGNM. Their taxonomic status was discussed in detail by Helgen (2007a). An unnamed congener occurs further to the west in the Star Mountains of West Sepik and Western Provinces. The Porgera taxon was not encountered during our 2005 survey of the Kaijende Highlands but, like its congener from the Star Mountains, it probably occurs in upper montane forest and along the alpine grassland-forest ecotone (Helgen 2007b). This new taxon is the only mammal species currently known only from the Kaijende Highlands. I will formally describe it in a forthcoming paper.

Order Chiroptera, Family Pteropodidae (Fruit-Bats)

Syconycteris australis (Peters, 1867) (Common Blossom-Bat)

This small pteropodid bat is the most commonly mist-netted bat in New Guinea and is found across the island from sea level to 3,000 m elevation. Five adults were collected during mist-netting in forest at Lake Tawa (forearms 41–43 mm, mass 13–17.5 g). Two of three adult females, collected on 30 and 31 August 2005, were pregnant. Fetal crown-rump lengths were 17 and 10 mm, respectively. The wing membranes of one individual were marked with de-pigmented spots in a left-right symmetrical arrangement, a trait not previously reported for *S. australis* (Lawrence 1991, Bonnacorso 1998).

As far as I am aware, these are the first records of *Syconycteris* in Enga Province (cf. Lawrence 1991, Bonnacorso 1998). No other bats were collected in six nights of mist-netting at Lake Tawa. Small bats, including both small pteropodids (such as *Syconycteris*) and insectivorous bats ("Microchiroptera"), are apparently referred to as *Apaiyake* in the Ibile language.

Order Chiroptera, Family Vespertilionidae (Evening Bats)

Miniopterus schreibersii (Kuhl, 1819) (Common Bentwing-Bat)

We did not document the occurrence of any vespertilionid bats in the Kaijende Highlands during our survey. The only record from the province appears to be Bonaccorso's (1998) report of *Miniopterus schreibersii* from Mt. Leiwaro (5°33'S, 143°14'E), a locality that lies in, or in close proximity to, the Kaijende Highlands. I am unfamiliar with the voucher material on which this record is based but I presume that it is deposited at PNGNM. *Miniopterus schreibersii* has a broad altitudinal distribution in New Guinea (sea level to at least 2,900 m) and a wide global geographic distribution, occurring (as currently understood) in Africa, Eurasia, the Malay Archipelago, and Oceania (Simmons 2005).

Order Chiroptera, Family Molossidae (Free-Tailed Bats)

? Tadarida kuboriensis McKean and Calaby, 1968 (New Guinea Mastiff-Bat)

This molossid bat is found only in forested habitats along the central cordillera of New Guinea, where it has been recorded from six scattered localities at elevations between 1,900 and 2,950 m (Flannery 1995, Bonaccorso 1998). During our survey, unidentified bats which I took to be molossids were observed hawking insects around several security lights in alpine grassland at the Porgera Reservoir (~3,100 m elevation). Harp trapping at this site (two nights) was unsuccessful so the bats' identity remains to be verified. This population can probably be sampled from this exact location in the future. Because it is the only New Guinean molossid known to occur above 2,000 m, I tentatively attribute the record to *Tadarida kuboriensis*.

Order Carnivora, Family Canidae (Dogs)

Canis (lupus) familiaris Linnaeus, 1758 (New Guinea Singing Dog)

Dogs are represented in New Guinea both by domesticated village dogs, commonly used for hunting throughout the island, and by distinctive highland populations of feral dogs referred to as "New Guinea Singing Dogs". Wild-living dogs have probably been present in New Guinea for only about 3,000 years (Hope 1981). As I note in a forthcoming review (Helgen 2007b), "singing dog" populations are biologically interesting and deserve continued ecological study, but neither molecular (e.g., Leonard et al. 2002) nor morphological evidence (particularly in light of the morphological plasticity of the domesticated dog) support the explicit taxonomic claim that these dogs represent a distinct canid species ("*Canis hallstromi*"), as some have recently argued (see Koler-Matznick et al. 2003).

New Guinea Singing Dogs were present, though fleeting from sight, at Lake Tawa. At least one animal was seen by one of our local guides, who scavenged a freshly-killed *Dorcopsulus* wallaby from it for our scientific collection. We also collected singing dog scat samples for potential future dietary and genetic analyses. Our local assistants assured us that the dogs at Lake Tawa were truly wild-living dogs, and there were no villages near our relatively remote camp.

Order Artiodactyla, Family Suidae (Pigs)

Sus scrofa Linnaeus, 1758 (Feral Pig)

Pigs occur as both domesticated and wild-living (feral) populations throughout the island of New Guinea (Hide 2004). They were apparently introduced to New Guinea by humans several thousand years ago (Flannery 1995). Bones and teeth of pigs were found in the forest near Lake Tawa,

and free-ranging domesticated pigs were common in and around Porgera.

DISCUSSION

Notes on Inventory Completeness

On the basis of their recorded global geographic distributions and ecological requirements (Menzies 1991, Flannery 1995, Bonaccorso 1998, Helgen 2007a, 2007b), it is estimated that an additional 4–6 marsupial species, 12–16 rodent species, and 10–13 bat species are likely to occur in the Kaijende Highlands, an indication that efforts aimed at inventorying mammals in the area are far from complete.

Inventory completeness: Marsupials

I have demonstrated that at least 19 species of marsupials occur in the Kaijende Highlands at and above 2,200 m. At least four additional marsupials are expected to occur in the Kaijende Highlands, including three small dasyurids (*Murexia wilhelmina, Murexia naso, Phascolosorex brevicaudata*; see Helgen 2007b for taxonomy) and one ringtail possum (pseudocheirid) — the 'Plush-Coated Ringtail`, *Pseudochirops corinnae*. All four of these species are widespread in montane forests at and above 2,200 m in the central cordillera, extending at least from the vicinity of Wau (PNG) in the east to the Snow and Weyland Mountains in the west (Flannery 1995, Helgen 2007a, 2007b). These taxa are most commonly encountered in undisturbed montane forests. There is no reason to anticipate their absence from the Kaijende fauna. Instead, failure to detect the three dasyurid species in the area can probably be attributed to insufficient trapping efforts at Lake Tawa — I suggest that more extensive trapping and use of pitfall traps would probably record their presence. It is also highly likely that a greater emphasis on hunting, particularly at night, would record the presence of *Pseudochirops corinnae* at Lake Tawa. Collection of larger series of trophy mandibles from communities around Porgera might show that it also persists in that area.

Populations of two other marsupial species in particular might be expected in the Kaijende Highlands — Stein's Cuscus (*Phalanger vestitus*) and the Common Striped Possum (*Dactylopsila trivirgata*). Both of these taxa are widespread in the central cordillera of New Guinea and their altitudinal distribution extends above 2,000 m (Flannery 1995). However *P. vestitus* appears to be patchily distributed throughout the cordillera, being common in some areas and absent or extremely uncommon in others (Flannery 1994, 1995; Menzies and Pernetta 1986, Menzies 1991, Helgen 2007b). This phenomenon is not well-understood, but Flannery (1995) indicated that the species may be largely restricted to primary montane oak forests at middle altitudes (1,200 to 2,200 m). *Dactylopsila trivirgata* has been recorded in central cordilleran montane forests at elevations as high as 2,400 m; however, it may not occur in the immediate vicinity of our survey sites because it is more typically encountered in forests below 2,000 m (Helgen 2007b).

Inventory completeness: Rodents

I have confirmed that at least 12 species of rodents occur in the Kaijende Highlands at and above 2,200 m asl. At least 12 additional terrestrial and scansorial rodent species (*Abeomelomys sevia, Anisomys imitator, Hyomys goliath, Mallomys aroaensis, Mallomys rothschildi, Lorentzimys nouhuysi, Paramelomys mollis, Melomys rufescens, Pogonomys loriae, Pogonomys sylvestris, Rattus steini,* and *Rattus verecundus*) almost certainly occur in the Kaijende Highlands. All of these taxa occur at elevations above 2,000 m throughout much of the length of the New Guinean central cordillera, both to the east and west of Enga Province. At least three of these species (*Mallomys rothschildi, Pogonomys loriae,* and *Pogonomys sylvestris*) have been recorded from elsewhere in the province (see Introduction). It is highly likely that one additional amphibious rat (*Baiyankamys shawmayeri*), one or two additional species of moss-mice (*Pseudohydromys* spp.), and a terrestrial hydromyin species of *Paraleptomys* or *Leptomys* occur in the area. The latter taxa are two ecomorphologically similar genera that replace one another along the central cordillera from west to east, respectively, somewhere between Telefomin and Mt. Karimui (Helgen 2005b, 2007a; Musser et al. 2007).

During the 2005 RAP I trapped rodents for only a few days at each site. Failure to record most if not all of these 12–16 species in the Kaijende Highlands probably reflects insufficient trapping efforts and the difficulty of obtaining unambiguous identifications of these morphologically similar taxa from local informants in the absence of voucher material. This was compounded by the fact that I was unable to hunt animals at night in montane forests and as a result failed to secure vouchers of large nocturnal rats like *Mallomys* and *Hyomys*). Future efforts aimed at surveying the rodent fauna of Enga Province's montane forests should ideally include both longer-term removal trapping (with snap traps and/or Sherman/Elliott traps) and pitfall trapping. In addition, focused collection of trophy jaws from other communities around Porgera would probably yield osteological material of larger rats (*Anisomys imitator, Hyomys goliath, Mallomys aroaensis,* and *Mallomys rothschildi*) because these species are large enough to be targeted as food items and their incisors are used for carving in many areas of New Guinea.

Inventory completeness: Bats

In New Guinea bats are most diverse and most abundant in tropical lowland rainforest and species richness decreases precipitously above 1,000 m elevation (Helgen 2007b). Chiropteran faunas in high montane forests (above 2,000 m) are especially depauperate. Two of New Guinea's six families of bats (Emballonuridae and Rhinolophidae) are not known to occur above 2,000 m on the island, and the remaining families (Pteropodidae, Hipposideridae, Vespertilionidae,

and Molossidae) are represented above this elevation only by a relatively small number of species (five, one, eight, and one respectively). Thus it was not entirely surprising to record only two species of bats in the Kaijende Highlands where all of our survey effort took place above 2,100 m. However, despite the depauperate fauna expected at these altitudes the actual chiropteran component of the Kaijende mammal fauna is undoubtedly larger than we documented, and our failure to mist-net or harp-trap certain expected species is puzzling. An additional 10 –13 additional species of bats may occur in the area and these can be divided into four categories.

First, seven bat species that are widespread in New Guinea's lowland forests (*Dobsonia moluccensis, Miniopterus macrocneme, Miniopterus schreibersii, Murina florium, Nyctophilus microtis, Philetor brachypterus,* and *Pipistrellus angulatus*) extend regularly or occasionally to altitudes above 2,000 m, and should be expected in the Kaijende area between 2,000 and 2,800 m, especially in areas with caves. At Lake Tawa I searched intensively in *Pandanus* holes and hollows and in hanging vegetation for forest-tree roosters such as *Murina florium* (or molossid bats), without success.

Second, several bat species which are montane specialists (*Nyctimene cyclotis* [including *N. certans*], *Syconycteris hobbit,* and *Pipistrellus collinus*) are widespread along the central cordillera and should occur in montane forests in the Kaijende Highlands up to elevations of 2,800–3,000 m. All three of these species are apparently rather easily caught in mist-nets in areas where they are common, so their absence from our sampling at Lake Tawa is interesting.

Third, two additional montane endemics (*Hipposideros corynophyllus,* recorded only from the Snow and Star Mountains, and *Nyctophilus microdon* known from the nearby Eastern Highlands, Chimbu, Western Highlands, and Southern Highlands Provinces of PNG) could occur in the mountains of Enga Province as well.

Fourth and finally, the rare Bulmer's Fruit-bat, *Aproteles bulmerae*, apparently an obligate cave rooster, might occur in caves in the Kaijende Highlands. This little-known species (classified in a monotypic genus) was initially described by Menzies (1977) based on Late Pleistocene fossil material from Mt. Elimbari in Chimbu Province. The only known modern specimens have originated from montane sites in Western, Eastern Highlands, and Chimbu Provinces (reviewed by Flannery (1995) and Bonaccorso (1998)). This Critically Endangered species apparently occupies caves only in areas with low human disturbance, and may well occur in remote caves in Enga Province. If present in the Kaijende Highlands, it would deserve a great deal of conservation attention including strict protection of animals and roosting sites.

Future efforts to more intensively survey the Kaijende Highlands chiropteran fauna should ideally focus on locating caves and sampling bats at cave roosts to document the presence of *Miniopterus* spp., *Dobsonia moluccensis*, or even *Aproteles*. Focused collection of trophy jaws from more local communities in the vicinity of Porgera could yield osteological material of *Dobsonia moluccensis,* a large bat often commonly hunted where it occurs, or even *Aproteles* if it survives in the Kaijende Highlands.

CONSERVATION RECOMMENDATIONS

The 2005 Kaijende Highlands RAP has dramatically increased our knowledge of the mammal fauna of Enga Province, raising the number of species documented in the province from 18 to 39 and recording a number of rare and threatened mammals.

While much has been learned, our knowledge of the Kaijende mammal fauna nevertheless remains relatively slim. If mammalogical research in the Kaijende Highlands continues in collaboration between PJV and Conservation International, I would recommend that it be focused along two particular paths. First, basic biodiversity surveys, such as the survey work discussed herein, should continue, incorporating more sites and additional habitats. It has been suggested above that all previous mammalogical research in Enga Province, including the 2005 RAP, has probably documented less than 50% of the actual Kaijende Highlands mammal fauna. Further surveys will undoubtedly record additional species in the area, potentially including species of conservation concern and focus such as the Critically Endangered Bulmer's Fruit-Bat (*Aproteles bulmerae*). Additional basic survey work will certainly add to our knowledge of what species occur in the region and, if focused on new sites and habitats, will also begin to illuminate a more detailed picture of the distribution and abundance of individual species (and habitat-associated species assemblages), including those taxa of special interest to conservation efforts (see below). Secondly, more tightly targeted ecological studies are needed to assess in greater detail the distribution, abundance, and threats faced by certain "focal species" in the region. In particular, two groupings of mammals in the Kaijende Highlands can be singled out for their conservation importance.

The first group consists of the larger terrestrial mammals of the region, particularly macropodids and echidnas, which are often targets of concerted hunting pressure. Wallabies, tree-kangaroos, and echidnas have disappeared from most areas with high human population density and high hunting pressure throughout New Guinea (Bulmer and Menzies 1972; George 1978; Flannery 1992, 1995; Flannery and Groves 1998; Martin 2005). The fact that *Zaglossus* and at least three different kangaroo species (*Dendrolagus dorianus, Dorcopsulus vanheurni,* and *Thylogale calabyi*), all good proxy taxa for understanding hunting pressure, still persist in the vicinity of Porgera is a good sign that hunting has not yet resulted in mammal extirpations in the area. On the other hand, the only reason we know that two of these four species occur at Porgera is because they are represented in trophy jaw collections held by local hunters, demonstrating that there is at least some hunting pressure on these animals.

Indeed, the major result of our RAP survey has been to improve our understanding of what species definitely occur in the Kaijende Highlands. Apart from predictable elevational associations, no detailed information is yet available regarding the true extent of their abundance, threats, or microdistribution in the region, as potentially influenced by habitat availability and hunting. These are important topics for further study, particularly in the case of echidnas and kangaroos. Attempts to map the occurrence and estimate the abundance of these focal taxa in the vicinity of Porgera would require the assistance and knowledge of local communities, and might prove to be a straightforward and manageable project, perhaps one that can be undertaken by a sponsored student or a PJV Environmental Officer.

A second group of focal taxa is an assemblage of rare, threatened, and/or range-restricted species found within the Kaijende Highlands area only in high-altitude habitats such as tree fern savanna, tussock grassland, and adjacent upper montane (elfin) forests. This group of species partially overlaps with the last; it includes the Eastern Long-Beaked Echidna (*Zaglossus bartoni*), Calaby's Pademelon (*Thylogale calabyi*), the Giluwe Rat (*Rattus giluwensis*), the Subalpine Giant-Rat (*Mallomys istapantap*), an unnamed species of bandicoot (*Microperoryctes* sp.), and the unnamed genus and species of rodent discussed above. The last species is the only mammal currently thought to be endemic to the Kaijende Highlands, although many of the other species occur in only a few other subalpine and alpine landscapes in New Guinea.

The concentration of mammal species associated with alpine and subalpine habitats suggests that the expansive *Cyathea* tree fern savannas and tussock grasslands of the Kaijende Highlands have a long history as natural formations, even if they are facilitated in part by anthropogenic impacts today (Walker and Flenley 1979; see Takeuchi, this volume). Because of the unique fauna they support, these habitats are of profound conservation value. The area of extent and environmental quality of these open alpine habitats and the status of the mammals they support are prime subjects for a long-term monitoring study.

Many mammal species in the Kaijende Highlands are clearly valued by local Enga communities as entities with both practical (i.e. as sources of food, hides, and bone tools) and/or spiritual value (i.e. as prestige trophies, totems, and characters in traditional belief systems). New Guinean communities often provide a great deal of important knowledge (both traditionally inherited and personally acquired) to visiting biologists, regarding the basic biology and local use of fauna and flora. Their often intricate knowledge of wildlife and wildlife habitats attests to the importance of this biota in the daily lives of local people. However, New Guinean villagers are often unaware of the distribution or importance of individual species outside of this local context. As scientists, we can complement the natural history knowledge and assistance of local communities by illuminating the importance of familiar natural elements in a wider perspective—perspective gained by systematic study of fauna and flora from many other localities and of museum specimens from many different areas. I suspect that many villagers would be glad to learn, for example, that the Kaijende Highlands are one of only three or four areas where a rare species of kangaroo (*Thylogale calabyi*) can be found, and one of only two areas where a rodent that is a common and easily recognizable animal in the Kaijende Highlands (*Rattus giluwensis*) is known to occur. It may also be valuable for local communities to learn that unsustainable hunting in many other areas of Papua New Guinea has resulted in the local loss of important mammals such as echidnas and tree kangaroos. Armed with this greater perspective regarding the comparative importance of Kaijende species and habitats, it is possible that greater value might be attached to these and other animals, even beyond the traditional economic and spiritual importance that may be imparted to them. Thus, providing local communities with information about the basic natural history of local mammals could be one of the most important steps that might be taken toward the long-term conservation of larger, rarer, or geographically restricted mammals in the region. PJV and Conservation International would be well-advised to commission and disseminate posters, fact sheets, and/or small field guides that illustrate local wildlife, discuss its significance to local communities, and emphasize such concepts as rarity and sustainable hunting. The impact and educational value of such postings and publications could be vastly increased by including relevant text in Tok Pisin, English, and Ibile or other appropriate local languages. This is one positive step for environmental management and community outreach that is not incumbent on additional, extensive background research.

Apart from such environmental outreach initiatives, few concrete steps can be taken with regard to conservation, management, and/or protection of native mammals in the vicinity of Porgera, without a better understanding of their distribution, abundance, and threats that they face. Only once data from broader survey efforts and more focused research on individual focal species are available can more specific recommendations for conservation and management be made. Research on biodiversity conservation in the Kaijende Highlands has just begun.

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Appendix 1

Gazetteer of sites surveyed in the Kaijende Highlands and a brief description of their major vegetation characteristics

Wayne Takeuchi

Site	Coordinates	Elevation (m)	Habitat Description
Suyan Camp, Porgera	05°29'09" S, 143°08'07" E	2,200	Anthropogenic – gardens and regrowth
Omyaka Camp, Helipad adjacent Bivouac	05°31'37" S, 143°03'23" E	3,200	margin of mossy montane forest
Omyaka Site 1	05°31'35" S, 143°03'16" E	3,185	Sphagnum-*Oreobolus* bog with numerous *Rhododendron* shrubs, surrounded by low-stature mossy montane forest
Omyaka Site 2	05°31'32" S, 143°03'16" E	3,209	Sphagnum-*Oreobolus* bog complex with pools of standing water, surrounded by low-stature mossy montane forest
Omyaka Site 3	05°31'28" S, 143°03'12" E	3,218	Sphagnum-*Oreobolus* bog complex surrounded by forest burn from the 1998 El Nino
Omyaka Site 4	05°31'31" S, 143°03'22" E	3,225	mossy montane forest on ridge next to bivouac
Omyaka Site 5	05°31'31" S, 143°03'13" E	3,236	low-stature mossy montane forest on margin of Sphagnum-*Oreobolus* bog complex
Lake Tawa Camp Bivouac	05°35'43" S, 142°50'26" E	2,117	margin of mossy montane forest at bivoauc
Lake Tawa Site 1	05°35'43" S, 142°50'26" E	2,192	mossy montane forest along footpath to Mt. Kare
Lake Tawa Site 2	05°35'38" S, 142°50'31" E	2,225	low-stature mossy montane forest midway from helipad to *Pandanus* savanna)
Lake Tawa Site 3	05°35'40" S, 142°50'35" E	2,264	margin of *Pandanus-Dicranopteris* savanna community
Lake Tawa Site 4	05°35'38" S, 142°50'37" E	2,290	*Pandanus-Dicranopteris* community
Lake Tawa Site 5	05°35'36" S, 142°50'07" E	2,198	margin of second lake below bivoauc, along footpath to Porgera
Lake Tawa Site 6	05°35'36" S, 142°50'02" E	2,275	advanced forest regrowth in *Pandanus* fringe zone, second lake below bivouac
Lake Tawa Site 7	05°35'37" S, 142°50'15" E	2,238	herbaceous community along second lake below bivouac
Lake Tawa Site 8	05°35'45" S, 142°50'23" E	2,192	edge of natural growth montane forest directly opposite bivouac
Lake Tawa Site 9	05°35'49" S, 142°50'21" E	2,210	grassy slopes of sinkholes near bivouac
Lake Tawa Site 10	05°35'53" S, 142°50'16" E	2,230	*Pandanus* margin of mossy montane forest on lower slopes of limestone ridge
Lake Tawa Site 11	05°35'54" S, 142°50'07" E	2,340	mossy montane forest about halfway to summit of limestone ridge near bivouac
Lake Tawa Site 12	05°35'56" S, 142°50'07" E	2,400	mossy montane forest, subcrest of limestone ridge near bivouac,
Lake Tawa Site 13	05°35'23" S, 142°50'05" E	2,207	herbaceous lakeside community along second lake below bivouac

continued

Site	Coordinates	Elevation (m)	Habitat Description
Lake Tawa Site 14	05°35'03" S, 142°50'02" E	2,240	sandstone gorge at end of lake below bivouac
Lake Tawa Site 15	05°35'00" S, 142°49'57" E	2,243	river flowing into lakes below bivouac
Lake Tawa Site 16	05°35'32" S, 142°50'28" E	2,249	mossy montane forest at top of waterfall
Lake Tawa Site 17	05°35'30" S, 142°50'30" E	2,275	forest clearing around abandoned bush hut
Lake Tawa Site 18	05°35'48" S, 142°50'15" E	2,232	mossy montane forest at top of small ridge near bivouac
Lake Tawa Site 19	05°35'39" S, 142°50'11" E	2,237	*Pandanus* margin of mossy montane forest
Paiela Road Site 1	05°30'11" S, 143°04'52" E	2,875	mossy montane forest, near junction of Paiela Road and Quarry Road
Paiela Road Site 2	05°30'07" S, 143°04'44" E	2,908	stream in mossy montane forest
Paiela Road Site 3	05°29'53" S, 143°04'33" E	2,850	margin of mossy montane forest near base of limestone escarpment
Paiela Road Site 4	05°29'20" S, 143°04'17" E	2,898	margin of mossy montane forest near end of limestone escarpments
Waile Creek Road Site 1 (Transformer Hill)	05°33'45" S, 143°03'21" E	3,076	mosaic of alpine grassland and patches of low-stature mossy montane forest
Waile Creek Road Site 2	05°33'56" S, 143°03'35" E	3,010	alpine grassland, junction of Waile Creek Road and Tari Track, near Porgera Reservoir
Waile Creek Road Site 3 (Porgera Reservoir Dam and Spillway)	05°34'13" S, 143°03'34" E	3,010	alpine grassland and anthropogenic communities
Waile Creek Road Site 4	05°33'09" S, 143°04'17" E	3,108	alpine grassland, near 2 km mark along pipeline
Waile Creek Road Site 5	05°32'48" S, 143°04'25" E	3,134	herbaceous regrowth in grassy clearings and quarry rock near water-tank
Waile Creek Road Site 6	05°32'36" S, 143°04'36" E	3,081	margin of mossy montane forest below the Pass
Waile Creek Road Site 7	05°32'25" S, 143°04'48" E	3,054	patches of mossy forest in alpine grassland at 4 km mark on pipeline
Waile Creek Road Site 8	05°32'13" S, 143°04'59" E	3,027	mixed community mosaic of mossy forest interspersed with regrowth from anthropogenic activities nr 4.5 km mark on pipeline

Appendix 2

Plant species recorded in the Kaijende Highlands

Wayne Takeuchi

Species recorded 19 August– 9 September 2005.
P = present, documented by collection(s) and Pw = present, but without collection.

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
FERNS AND LYCOPHYTES			
Adiantaceae			
Adiantum aneitense Carr		P	
Cheilanthes papuana C. Chr.			P
Aspleniaceae			
Asplenium acrobryum Christ		P	
Asplenium adiantoides (L.) C. Chr.		P	
Asplenium nutans Rosenst.		P	P
Asplenium steerei Harrington		P	
Athyriaceae			
Diplazium sp. ?nov.		P	
Blechnaceae			
Blechnum fluviatile (R. Br.) Lowe ex Salomon	P		
Blechnum hieronymi Brause		P	
Blechnum keysseri Rosenst.		P	
Blechnum revolutum (Alderw.) C. Chr.	P		P
Blechnum rosenstockii Copel.			P
Cyatheaceae			
Cyathea aeneifolia (v.A.v.R.) Domin			P
Cyathea atrospinosa Holtt.		P	
Cyathea atrox C. Chr. var. *inermis* Holtt.	P		Pw
Cyathea dicksonioides Holtt.	P		Pw
Cyathea hornei (Baker) Copel.		P	
Cyathea lepidoclada (Christ) Domin	P		
Cyathea magna Copel.		P	
Cyathea (closest to) *magna* Copel.			P
Cyathea microphylloides Rosenst.		P	
Cyathea perpelvigera v.A.v.R.		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Cyathea physolepidota Alston		P	
Dicksonia hieronymi Brause		P	
Davalliaceae			
Davallia repens (L.f.) Kuhn	Pw		P
Davallodes novoguineense (Rosenst.) Copel.		P	
Rumohra adiantiformis (Forst.) Ching			P
Dennstaedtiaceae			
Dennstaedtia magnifica Copel.			P
Dennstaedtia cf. *penicillifera* v.A.v.R.		P	
Dennstaedtia scandens (Bl.) Moore		P	
Histiopteris squamulata Holtt.	P		P
Hypolepis alpina (Bl.) Hook.	P	P	Pw
Pteridium aquilinum (L.) Kuhn		P	
Dipteridaceae			
Dipteris conjugata Reinw.		P	
Dryopteridaceae			
Dryopteris sparsa (Ham.) O. Kuntze		P	
Dryopteris subarborea (Baker) C. Chr.			P
var. *quadripinnata* Rosenst.			
Dryopteris wallichiana (Spreng.) Hyl.			P
Polystichum alpinum Rosenst.			P
Polystichum hooglandii Nakaike			P
Polystichum keysserianum Rosenst.		P	
Polystichum pullenii Nakaike			P
Polystichum takakii Nakaike			P
Stenolepia tristis (Bl.) v.A.v.R.	P		P
Equisetaceae			
Equisetum ramosissimum Desf. ssp. *debile* (Vauch.) Hauke	Pw		Pw
Gleicheniaceae			
Dicranopteris linearis (Burm. f.) Underw. var. *linearis*	Pw	P	Pw
Gleichenia bolanica Rosenst.	P		
Gleichenia brassii C. Chr.		P	
Gleichenia erecta C. Chr.	P		
Gleichenia vulcanica Bl.	P		
Grammitidaceae			
Calymmodon atrichus Copel.	P		
Ctenopteris bipinnatifida (Baker) Copel.	P		
Ctenopteris brassii Copel.	P		
Ctenopteris integripaleata Copel.		P	
Ctenopteris subsecundodissecta (Zoll.) Copel.		P	
Ctenopteris venulosoides Copel.		P	P
Ctenopteris s.l.; *Prosaptia contigua* (Forst.) Presl	P		
Ctenopteris s.l.; *Prosaptia davalliacea* (F.v.M. & Baker) Copel.	P		

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Grammitis padangensis (Baker) Copel.	P		
Grammitis scabristipes (Baker) Copel.	P	P	
Grammitis sumatrana (Baker) Copel.		P	
Hymenophyllaceae			
Hymenophyllum geluense Rosenst.	P		
Hymenophyllum imbricatum Bl.		P	
Hymenophyllum s.l.; *Amphipterum humatoides* Copel.	P		
Hymenophyllum s.l.; *Mecodium bismarckianum* (Christ) Copel.		P	
Hymenophyllum s.l.; *Mecodium reinwardtii* (v.d.B.) Copel.			P
Hymenophyllum s.l.; *Myriodon brassii* (C. Chr.) Copel.	P		
Trichomanes pallidum Bl. (*Pleuromanes*)		P	
Lindsaea Group			
Lindsaea pulchella (J.J. Sm.) Mett. ex Kuhn var. *blanda* (Mett. ex Kuhn) Kramer		P	
Sphenomeris chinensis (L.) Maxon (close to) var. *divaricata* (Christ) Kramer		P	
Lomariopsidaceae			
Elaphoglossum angustifrons Holtt.		P	
Elaphoglossum sclerophyllum v.A.v.R.	P	P	
Lycopodiaceae			
Huperzia aff. *serrata* (Thunb.) Trevisan			P
Lycopodium clavatum L.	P		
Lycopodium divaricatum Grev. & Hook.; (*L. clavatum* L., s.l.)	P		
Lycopodium scariosum G. Forst.	P		P
Lycopodium volubile G. Forst.		P	
Lycopodium wightianum Grev. & Hook.	P		
Palhinhaea cernua (L.) Vasc. & Franco; =*Lycopodiella*		P	Pw
Marattiaceae			
Marattia cf. *coronata* Copel.		P	
Oleandraceae			
Nephrolepis cordifolia (L.) Presl		P	
Oleandra sibbaldii Grev.		P	
Ophioglossaceae			
Ophioglossum pendulum L.		Pw	
Plagiogyriaceae			
Plagiogyria egenolfioides (Baker) Copel. var. *decrescens* (C. Chr.) Zhang & Noot.	P		Pw
Polypodiaceae			
Belvisia mucronata (Fee) Copel. var. *mucronata*		P	P
Belvisia novoguineensis (Rosenst.) Copel.		P	
Belvisia validinervis (Kunze) Copel. var. *longissima* (Holtt.) Hovenkamp & Franken		P	
Belvisia validinervis (Kunze) Copel. var. *validinervis*	P		P
Goniophlebium demersum (Brause) Rödl-Linder		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Microsorum papuanum (Baker) Parris		P	
Selliguea albidosquamata (Bl.) Parris		P	
Selliguea costulata (Ces.) Wagner & Grether		P	
Selliguea (close to) *costulata* (Ces.) Wagner & Grether		P	
Selliguea enervis (Cav.) Ching	P		P
Selliguea enervis (Cav.) Ching the gramineous *'lamprophyllus'* form		P	P
Selliguea enervis (Cav.) Ching the dimorphic *'senescens-spathulatus'* form		P	
Selliguea plantaginea Brackenr.	P		Pw
Pteridaceae			
Pteris blumeana Agardh		P	
Pteris brassii C. Chr.	P		
Pteris wallichiana Agardh		P	P
Tectaria Group			
Ctenitis s.l.		P	P
Lastreopsis novoguineensis Holtt.			P
Thelypteridaceae			
Coryphopteris klossii (Ridl.) Holtt.		P	
Parathelypteris beddomei (Baker) Ching		P	
Plesioneuron dryopteroideum (Brause) Holtt. (closest to) var. *dryopteroideum*			P
Plesioneuron marattioides (Alston) Holtt.		P	
Pneumatopteris petrophila (Copel.) Holtt., or aff.		P	
Pneumatopteris superba (Brause) Holtt.		P	
Pneumatopteris sp. nov.		P	
Pronephrium womersleyi Holtt.		P	
Pseudophegopteris aurita (Hook.) Ching			P
Sphaerostephanos acrostichoides (Desv.) Holtt.		P	
Sphaerostephanos archboldii (C. Chr.) Holtt.		P	
Sphaerostephanos sp.			P
Vittariaceae			
Loxogramme paltonioides Copel.		P	
Loxogramme (closest to) *paltonioides* Copel.		P	P
Loxogramme subselliguea (Baker) Alston	P		
Vittaria elongata Sw. var. *angustifolia* Holtt.		P	
GYMNOSPERMS			
Cupressaceae			
Libocedrus papuana F.v.M. var. *papuana*	P		Pw
Pinaceae			
Pinus caribaea Morelet			P
Podocarpaceae			
Dacrydium imbricatus (Bl.) de Laub. var. *robustus* de Laub.		P	Pw

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Phyllocladus hypophyllus Hook. f.	Pw	P	Pw
Podocarpus (closest to) *crassigemmis* de Laub.			P
Podocarpus pseudobracteatus de Laub.		P	
MONOCOTS			
Araceae			
Alocasia macrorrhizos (L.) G. Don		Pw	
Alocasia nicolsonii Hay			Pw
Colocasia esculenta (L.) Schott		Pw	
Cyperaceae			
Carex cruciata Wahl. var. *rafflesiana* (Boot) Noot.		P	P
Carex michauxiana Boeck. var. *asiatica* (Hulten) Ohwi	P		
Carex oedorrhampha Nelmes		P	
Gahnia javanica Zoll. & Mor. ex Mor.	P		
Scirpus crassiusculus (Hook.) Benth.	P		
Scirpus mucronatus L. ssp. *clemensiae* Kukenth.	P		
Scirpus subtilissimus (Boeck.) S.T. Blake	P		
Eriocaulaceae			
Eriocaulon hookerianum Stapf		P	
Hemerocallidaceae			
Geitonoplesium cymosum A. Cunn.		P	
Iridaceae			
Sisyrinchium pulchellum (R. Br.) F.v.M.	P		Pw
Juncaceae			
Juncus effusus L.	P		P
Juncus prismatocarpus R. Br.	P		
Laxmanniaceae			
Cordyline fruticosa (L.) A. Chev.		Pw	
Liliaceae			
Astelia alpina R. Br.	P		
Orchidaceae (dets. by N. Howcroft)			
Agrostophyllum earinoides Schltr.		P	
Bulbophyllum sp., sect. *Peltopus*	P		
Cadetia aprinoides (J.J. Sm.) A.D. Hawkes		P	
Cadetia sp., sect. *Ptero-Cadetia*		P	
Ceratostylis cf. *flavescens* Schltr.	P		
Ceratostylis sp.		P	
Dendrobium alaticaulinum Royen		P	
Dendrobium brevicaule Rolfe ssp. *calcarium* (J.J. Sm.) Reeve & Woods	P		
Dendrobium cuthbertsonii F.v.M.		P	
Dendrobium dichroma Schltr.	P		
Dendrobium masarangense Schltr. var. *theionanthum* (Schltr.) Reeve & Woods		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Dendrobium nardoides Schltr.			P
Dendrobium prostheciglossum Schltr.		P	
Dendrobium vexillarius J.J. Sm. var. *albiviride* (Royen) Reeve & Woods		P	
Epiblastus cf. *montihageni* Royen		P	
Epiblastus pulchellus Schltr.		P	
Epiblastus sp.		P	
Glomera aurea Schltr., or aff.		P	
Glossorhyncha sp. nov. A		P	
Glossorhyncha sp. nov. B			P
Liparis sp., sect. *Distichon*		P	
Mediocalcar aff. *crenulatum* J.J. Sm.		P	
Microtatorchis clavicalcarata J.J. Sm.			P
Oberonia sp.		P	
Phreatia aff. *quadrata* Schltr.		P	
Phreatia sp. A, sect. *Bulbophreatia*		P	
Phreatia sp. B, sect. *Bulbophreatia*		P	
Spathoglottis parviflora Krzl.			P
Pandanaceae			
Freycinetia sp.		P	
Pandanus sp., sect. *Intraobtutus*		P	
Poaceae			
Agrostis avenacea Gmelin			P
Arundinella furva Chase	P		
Chionochloa archboldii (Hitchc.) Conert	P		P
Danthonia oreoboloides (F.v.M.) Stapf	P		
Deschampsia klossii Ridl.	P		
Eulalia leptostachys (Pilg.) Henrard			P
Imperata conferta (Presl) Ohwi			P
Isachne pauciflora Hack.		P	
Isachne villosa (Hitchc.) Reeder		P	
Mischanthus floridulus (Labill.) Warb.		Pw	P
Nastus productus (Pilg.) Holtt.	Pw		Pw
Oplismenus hirtellus (L.) P. Beauv.		P	
Poa annua L.			P
Poa keysseri Pilg. (closest to) ssp. *keysseri*			P
Sacciolepis indica (L.) Chase		P	
Setaria roemerii Jansen		P	
Typhaceae			
Typha angustifolia L.		P	
Zingiberaceae			
Alpinia albipurpurea (Royen) R.M. Smith, or aff.	P		
Riedelia geluensis Laut.		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Riedelia sp., aff. *geluensis* Laut.		P	
Riedelia subalpina Royen	P		
DICOTS			
Actinidiaceae			
Saurauia cf. *achyrantha* Diels		P	
Saurauia altiterra Royen			P
Saurauia bifida Warb.		P	
Saurauia giluwensis Royen			P
Saurauia aff. *naumannii* Diels		P	P
Saurauia aff. *occulta* A.C. Smith			P
Saurauia (closest to) *scaberrima* Laut.	P		
Saurauia trugul Royen			P
Saurauia sp., ser. *Setosae*, *holotricha* facies		P	
Saurauia sp. nov., ser. *Setosae*		P	P
Anacardiaceae			
Rhus caudata Laut.		P	
Apiaceae			
Hydrocotyle sibthorpioides Lamarck	P	P	P
Oenanthe javanica DC.		P	
Apocynaceae			
Alyxia cacuminum Markgr.		P	
Alyxia subalpina Markgr.		P	
Hoya sp.		P	
Parsonsia sanguinea (Wernh.) Markgr.		P	
Aquifoliaceae			
Ilex archboldiana Merr. & Perry	P	P	P
Ilex spicata Bl.		P	
Araliaceae			
Harmsiopanax harmsii K. Schum. ex K. Schum. & Laut.	P		P
Polyscias belensis Philipson		P	
Polyscias ledermannii Harms		P	
Polyscias royenii Philipson		P	
'Schefflera' dentata Frodin		P	P
'Schefflera' setulosa Harms		P	
'Schefflera' simbuensis Frodin, or aff.	P		P
Asteraceae			
Adenostemma hirsutum (Bl.) DC.		P	
Adenostemma lavenia (L.) Kuntze		Pw	
Ageratum conyzoides L.		Pw	
Anaphalis lorentzii Laut. form *lorentzii*	P		
Anaphalis mariae F.v.M. form *alba* Koster	P		
Anaphalis mariae F.v.M. form *mariae*			P
Arrhenechthites novoguinensis (S. Moore) Mattf. ssp. *novoguinensis*		P	P

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Bidens pilosa L.			Pw
Blumea arnakidophora Mattf.		P	
Blumea papuana S. Moore			P
Blumea sylvatica (Bl.) DC. cf. var. *macrophylla* (Bl.) Randeria			P
Cirsium vulgare (Savi) Ten.			P
Crassocephalum crepidioides (Benth.) S. Moore		Pw	
Erigeron sumatrensis Retz			P
Erigeron sp., *Senecio* facies			P
Gnaphalium involucratum Forst.			P
Helichrysum bracteatum (Vent.) Andrews	P		
Ischnea elachoglossa F.v.M.	P		
Keysseria radicans (F.v.M.) Mattf.	P		
Lactuca laevigata (Bl.) DC. var. *laevigata*	Pw		P
Myriactis cabrerae Koster	P		
Olearia durifolia Koster	P		
Olearia durifolia Koster, or aff. (deviant)	P		P
Olearia pallida Koster, or aff.	P		P
Olearia platyphylla Mattf. var. *cinerea* (Mattf.) Koster		P	P
Olearia rufa Koster			P
Olearia spectabilis Koster	P		
Olearia sp., *lepidota-platyphylla* facies, closer to *platyphylla*	P		
Papuacalia kukul (Royen) Veldkamp			P
Senecio brassii Belcher	P		
Senecio papuanus (Laut.) Belcher	P		
Sonchus asper (L.) Hill form *hydrophilus* (Boulos) Koster	Pw		P
Tetramolopium ciliatum Mattf.			P
Tetramolopium macrum (F.v.M.) Mattf. var. *glabrescens* Koster	P		
Vernonia cuneata Less.		P	
Begoniaceae			
Begonia kaniensis Irmscher		P	
Bignoniaceae			
Tecomanthe volubilis Gibbs		P	
Boraginaceae			
Cynoglossum hellwigii Brand			P
Brassicaceae			
Brassica oleracea L.			P
Cardamine keysseri Schulze		P	
Rorippa nasturtium-aquaticum (L.) Hayek	P		P
Caprifoliaceae			
Sambucus canadensis L.			P
Caryophyllaceae			
Cerastium papuanum Schltr. ssp. *phaenops* Mattf.	P		P

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Sagina papuana Warb.	P		P
indet.		P	
Chloranthaceae			
Chloranthus erectus (Buch.-Ham.) Verdcourt		P	
Clusiaceae			
Garcinia archboldiana A.C. Smith, or aff.		P	
Garcinia assugu Laut., or aff.		P	
Coriariaceae			
Coriaria papuana Warb.			P
Cucurbitaceae			
Gynostemma pentaphylla (Thunb.) Makino			P
Urceodiscus belensis (Merr. & Perry) de Wilde & Duyfjes		P	
Cunoniaceae			
Spiraeopsis papuana (Pulle) Perry		P	
Daphniphyllaceae			
Daphniphyllum gracile Gage var. *gracile*			P
Daphniphyllum papuanum Hallier f. var. *tuberculatum* (T.C. Huang) T.C. Huang		P	
Droseraceae			
Drosera peltata Thunb. ssp. *peltata*	P		
Elaeocarpaceae			
Aceratium ledermannii Schltr.		P	
Dubouzetia novoguineensis A.C. Smith		P	
Elaeocarpus polydactylus Schltr., Coode group 1		P	
Elaeocarpus polydactylus Schltr., Coode group 3			P
Elaeocarpus ptilanthus Schltr.		P	
Elaeocarpus sayeri F.v.M. var. *altigenus* (Schltr.) Weibel		P	
Sericolea gaultheria (F.v.M.) Schltr. var. *gaultheria*	P		
Sericolea pullei (Laut.) Schltr.		P	
Epacridaceae			
Styphelia suaveolens (Hook. f.) Warb.	P		Pw
Trochocarpa dekockii (J.J. Sm.) H.J. Lam	Pw		P
Ericaceae			
Dimorphanthera alpina J.J. Sm. var. *alpina*	P		
Dimorphanthera anchorifera J.J. Sm.		P	
Dimorphanthera cornuta J.J. Sm. var. *cornuta*	Pw		P
Dimorphanthera dekockii J.J. Sm. var. *dekockii*		P	
Dimorphanthera keysseri (Diels) Stevens	P		P
Dimorphanthera sp. nov., aff. *ingens* (Sleum.) Stevens	P		P
Diplycosia morobeensis Sleum. var. *morobeensis*		P	
Diplycosia rupicola Sleum.	P		
Diplycosia sp. nov., aff. *lamii* J.J. Sm.		P	
Gaultheria mundula F.v.M. var. *mundula*	P		

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Gaultheria pullei J.J. Sm. var. *pullei*			P
Rhododendron beyerinckianum Koord.		P	P
Rhododendron commonae Foerster	P		P
Rhododendron herzogii Warb.			P
Rhododendron inconspicuum J.J. Sm.			P
Rhododendron macgregoriae F.v.M. var. *macgregoriae*		P	P
Rhododendron prostratum Sleum.			P
Rhododendron rarum Schltr.			P
Rhododendron scabridibracteum Sleum.		P	
Vaccinium amblyandrum F.v.M. var. *pungens* Sleum.	P		P
Vaccinium apiculatum Sleum.	P		
Vaccinium auriculifolium Sleum.		P	
Vaccinium finisterrae Schltr.			P
Vaccinium reticulato-venosum Sleum.		P	
Vaccinium schoddei Sleum.	P		P
Vaccinium stellae-montis Sleum.	P		
Vaccinium striicaule Sleum. var. *adenodes* Sleum.	P	P	
Euphorbiaceae s.l.			
Breynia collaris Airy Shaw		P	
Claoxylon nubicola Airy Shaw			P
Glochidion macrocarpum Bl. ssp. *orientale* Airy Shaw		P	
Glochidion (closest to) *nobile* Airy Shaw		P	
Glochidion sp. nov., aff. *dumicola-oogynum* facies		P	
Macaranga albescens Perry		P	
Macaranga carrii Perry var. *leonardii* (Perry) Whitm.			P
Macaranga sp. nov., aff. *papuana* (J.J. Sm.) Pax & Hoffm.		P	
Omalanthus arfakiensis Hutch.			P
Omalanthus nervosus J.J. Sm.		P	P
Fabaceae			
Lupinus cv Russell hybrid			P
Trifolium dubium Sibth.			P
Trifolium repens L.			P
Trifolium rueppellianum Fres.			P
Fagaceae			
Lithocarpus rufovillosus (Markgr.) Rehd.		Pw	
Gentianaceae			
Gentiana ettingshausenii F.v.M.	P		
Swertia papuana Diels	P		P
Geraniaceae			
Geranium niuginense Veldkamp	Pw		P
Gesneriaceae			
Aeschynanthus sp. A		P	
Aeschynanthus sp. B			P

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Aeschynanthus sp. C			P
Cyrtandra arfakensis Schltr.		P	
Cyrtandra aff. *aundensis* Royen		P	P
Cyrtandra sp., sect. *Axillanthe*		P	
Goodeniaceae			
Scaevola oppositifolia R. Br.		P	
Gunneraceae			
Gunnera macrophylla Bl.		P	P
Haloragaceae			
Gonocarpus halconensis (Merr.) Orchard			Pw
Hypericaceae			
Hypericum macgregorii F.v.M.	P		
Hypericum papuanum Ridl.	P		
Hypericum cf. *papuanum* Ridl. (deviant)		P	
Lamiaceae			
Plectranthus scutellarioides (L.) R. Br.		P	
Lauraceae			
Litsea sp.		P	
Loranthaceae			
Decaisnina cf. *hollrungii* (K. Schum.) Barlow		P	
Melastomataceae			
Astronia ledermannii Mansf.		P	
Beccarianthus aff. *acutifolius* (Mansf.) Maxw.		P	
Medinilla interiacens Bodegom		P	
Medinilla rubiginosa Cogn.		P	
Poikilogyne cordifolia (Cogn.) Mansf.		P	
Monimiaceae			
Levieria nitens Perkins		P	
Levieria squarrosa Perkins			P
Palmeria arfakiana Becc.		P	P
Palmeria clemensae Philipson		P	
Palmeria schoddei Philipson			P
Steganthera hirsuta (Warb.) Perkins		P	
Steganthera ilicifolia A.C. Smith			P
Moraceae			
Ficus erythrosperma Miq.		P	
Streblus glaber (Merr.) Corner		P	
Streblus urophyllus Diels var. *urophyllus*			P
Myrsinaceae			
Embelia cotinoides (S. Moore) Merr.			P
Maesa bismarckiana Mez			P
Maesa haplobotrys F.v.M.		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Rapanea involucrata Mez		P	
Rapanea leucantha K. Schum.		P	
Rapanea papuana (Hemsl.) Mez	P		
Rapanea rhombata Royen			P
Rapanea sp. nov., aff. *cacuminum-leucantha* facies			P
Myrtaceae			
Decaspermum alpinum Royen	Pw		P
Decaspermum forbesii Baker	Pw		P
Kania eugenioides Schltr.		P	
Metrosideros ramiflora Laut., or aff.		P	
Octamyrtus behrmannii Diels		P	
Octamyrtus pleiopetala Diels		P	
Syzygium alatum (Laut.) Diels	P		Pw
Syzygium effusum (A. Gray) C. Muell.		P	
Syzygium fastigiatum (Bl.) Merr. & Perry		P	
Syzygium sp. nov., aff. *goniocalyx* (Laut.) Merr. & Perry		P	
Syzygium sp. nov., aff. *womersleyi-malaccense* facies		P	
Xanthomyrtus compacta (Ridl.) Diels	P		Pw
Xanthomyrtus papuana Merr. & Perry		P	
Ochnaceae			
Schuurmansia henningsii K. Schum.		Pw	
Oleaceae			
Chionanthus brassii (Kobuski) Kiew		P	
Jasminum domatiigerum Lingelsh.		P	
Jasminum sp. nov., aff. *domatiigerum* Lingelsh.	P		P
Onagraceae			
Epilobium detznerianum Schltr. ex Diels	P		
Epilobium hooglandii Raven	P		
Epilobium keysseri Diels	P		P
Epilobium prostratum Warb.			P
Oxalidaceae			
Oxalis corniculata L. var. *sericea* Knuth		P	P
Passifloraceae			
Passiflora mollissima (H.B.K.) Bailey			P
Piperaceae			
Piper abbreviatum Opiz			P
Piper bolanicum Schltr. ex R.O. Gardner	P		P
Piper gibbilimbum C. DC.		P	P
Piper macropiper Pennant		P	
Piper novoguineense Warb.		P	P
Piper triangulare Chew		P	
Pittosporaceae			
Pittosporum pullifolium Burk. ssp. *pullifolium* var. *pullifolium*	P	P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Pittosporum ramiflorum (Zoll. & Mor.) Miq. var. *ramiflorum*		P	P
Plantaginaceae			
Plantago major L.			P
Polygonaceae			
Muehlenbeckia monticola Pulle			P
Polygonum longisetum DeBr.		P	
Polygonum nepalense Meissn.			P
Polygonum runcinatum D. Don		P	
Polygonum strigosum R. Br.		P	
Rumex brownii Campd.			P
Rumex crispus L.			P
Polyosmaceae			
Polyosma sp. nov., aff. *occulta* Reeder			P
Proteaceae			
Helicia cf. *commutata* Sleum.		P	
Ranunculaceae			
Clematis phanerophlebia Merr. & Perry		P	P
Ranunculus schoddei Eichler			P
Ranunculus uncostigma Merr. & Perry, or aff.			P
Ranunculus wahgiensis Eichler	P		P
Rhamnaceae			
Alphitonia ferruginea Merr. & Perry		Pw	
Rhamnus nipalensis (Wall.) Lawson ex Hook.			P
Rosaceae			
Acaena anserinifolia (Forst.) Druce	P		
Potentilla foersteriana Laut. var. *foersteriana*	P		
Potentilla papuana Focke	P		
Potentilla parvula Hook. ex Stapf	P		P
Prunus costata (Hemsl.) Kalkm.	P		
Prunus pullei (Koehne) Kalkm.	P		
Rubus archboldianus Merr. & Perry			P
Rubus ferdinandi-muelleri Focke		P	
Rubus lorentzianus Pulle	P		
Rubus moluccanus L. var. *moluccanus*	Pw		P
Rubus montiswilhelmi Royen	P		
Rubus papuanus Schltr. ex Diels			P
Rubus royenii Kalkm. var. *hispidus* Kalkm.	P		P
Rubus sp., *'diclinus-trigonus'* facies	Pw		P
Rousseaceae			
Carpodetus arboreus (K. Schum. & Laut.) Schltr.			P
Rubiaceae			
Argostemma aff. *bryophilum* K. Schum.	P		

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Coprosma nertera F.v.M. var. *papuana* (Val.) Heads	P		
Coprosma papuensis Oliv. ssp. *discolor* (Royen) R.O. Gardner	P		P
Galium subtrifidum Reinw. ex Bl.			P
Gardenia pallens Merr. & Perry		P	
Hedyotis aff. *verticillata* (L.) Lamk		P	
Mussaenda cf. *ferruginea* K. Schum.			P
Psychotria chrysantha Merr. & Perry			P
Psychotria coodei Sohmer ined.			P
Psychotria dieniensis Merr. & Perry			P
Psychotria leucococca Laut.		P	
Psychotria lorentzii Val.			P
Psychotria sphaerothyrsa Val.		P	
Psychotria sp., aff. *dieniensis* Merr. & Perry		P	
Psychotria sp. (vining)		P	
Timonius avenis Val. var. *avenis*		P	
Timonius belensis Merr. & Perry		P	
Rutaceae			
Acronychia emarginata Laut.		P	
Acronychia foveata Hartley		P	
Acronychia richards-beehlerii			P
Melicope brassii Hartley			P
Melicope mucronata Merr. & Perry	P	P	
Melicope robbinsii Hartley	P	P	
Melicope rubra (Laut. & K. Schum.) Hartley		P	P
Sabiaceae			
Meliosma pinnata (Roxb.) Maxim. ssp. *macrophylla* (Merr.) Beus.			P
Salicaceae			
Casearia ripicola Sleum.		P	
Santalaceae			
Cladomyza cuneata Danser		P	
Cladomyza sp., *'dubia-cuneata'* facies	P		
Sapindaceae			
Dodonaea viscosa (L.) Royen		P	
Saxifragaceae			
Astilbe cf. *rivularis* D. Don		P	
Scrophulariaceae			
Buddleja asiatica Lour.			P
indet.			P
Solanaceae			
Physalis peruviana L.			P
Solanum nolense Symon		P	
Sphenostemonaceae			
Quintinia brassii Reeder			P

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
Quintinia kuborensis Royen	P		P
Sphenostemon papuanus (Laut.) Steen. & Erdtman		P	Pw
Symplocaceae			
Symplocos cochinchinensis (Lour.) S. Moore ssp. *leptophylla* (Brand) Noot. var. *leptophylla*		P	
Symplocos cochinchinensis (Lour.) S. Moore ssp. *leptophylla* (Brand) Noot. var. *monticola* Noot.		P	
Symplocos cochinchinensis (Lour.) S. Moore ssp. *leptophylla* (Brand) Noot. var. *orbicularis* (Hemsl.) Noot.	P		P
Theaceae			
Eurya brassii Kobuski ssp. *apiculata* Barker	P		
Eurya brassii Kobuski ssp. *brassii*	P		
Eurya fragilis Barker	P		
Eurya tigang K. Schum. & Laut.			P
Ternstroemia britteniana F.v.M.		P	
Thymelaeaceae			
Drapetes ericoides Hook.	P		
Wikstroemia androsaemifolia Decne		P	
Trimeniaceae			
Trimenia papuana Ridl.		P	
Urticaceae			
Cypholophus pachycarpus Winkler			P
Elatostema aff. *serra* Winkler		P	
Nothocnide mollissima (Bl.) Chew			Pw
Pilea cuneata Winkler		P	
Pilea melastomoides (Poir.) Bl.		P	P
Pilea papuana Winkler		P	
Pilea rubiacea Ridl. var. *latifolia* (Winkler) Winkler	P		P
Pilea sp. nov., aff. *zaranensis* Royen			P
Pipturus montanus Royen			P
Pipturus pullei Winkler		P	P
Pouzolzia pentandra (Roxb.) Benn. & Br.		P	
Procris grueningii (Winkler) Johns		P	P
Violaceae			
Viola arcuata Bl.		P	
Viola kjellbergii Melchior	P		P
Vitaceae			
Cayratia sp.		P	
Winteraceae			
Drimys piperita Hook. f. entity *coriacea*			P
Drimys piperita Hook. f. entity *heteromera*	P		P
Drimys piperita Hook. f. entity *montis-wilhelmi*	P		
Zygogynum calothyrsum (Diels) Vink			P
Zygogynum cf. *idenburgensis* A.C. Smith		P	

continued

Taxon	Omyaka	Lake Tawa	Paiela Road + Waile Creek
INDETERMINABLE COLLECTIONS			
sp. 1 (Lamiales)		P	
sp. 2		P	
sp. 3		P	
sp. 4			P
Total	**141**	**257**	**202**

Appendix 3

Total number of birds counted on 'Walking Censuses' in the Kaijende Highlands

Bruce M. Beehler

See Appendix 4 for scientific names and distributional records of all bird species within the study area.

See next page for Appendix 3.

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Dwarf Cassowary													1																			
Black Kite																																
Brahminy Kite																														1	1	1
Spotted Marsh Harrier					1																											
Black-mantled Goshawk																												1				
New Guinea Harpy-Eagle																					1		1									
Long-tailed Buzzard																																1
Salvadori's Teal																		1			1	1										
Grey Teal																				4												
Pacific Black Duck													1	8	2	3		5		6	12			2								
Brown Quail			5		2	2		1				1	1		1																	
Buff-banded Rail																																
Forbes' Forest-Rail(?)															1																	
Brown Cuckoo-Dove																																
Black-billed Cuckoo-Dove																	1		1			1									1	
Great Cuckoo-Dove																	1				1	1										
Bronze Ground-Dove																	1															

continued

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Ornate Fruit-Dove																																
White-breasted Fruit-Dove													1	2		1	1		1		2	3	1	1								
Papuan Mountain Pigeon	5					4											1				1						1		2	2	1	3	
Goldie's Lorikeet													14	3		8	4	7	3	3	3	2		10	1							
Papuan Lorikeet	6		2	1		5	2		8			1	1	1	3		3	1	1	1	1	1	4	2	2	2		3			4		
Yellow-billed Lorikeet																																2
Plum-faced Lorikeet	15	7	9	8	6	5	3	7	12	2	12	2					1									2	5	9	3	1	14	3	
Orange-billed Lorikeet		2				2	5				2			2	1	2	1	4			5	2						2	2			3	
Brehm's Tiger-Parrot																								1			2				1	
Painted Tiger-Parrot				2			1	1																								
Red-breasted Pygmy-Parrot																																3
Brush Cuckoo																																
Fan-tailed Cuckoo					1												1	1			1				1		1		1		1	
Rufous-throated Bronze-Cuckoo														1			1		1		1						2	1	1	2	2	1	
Sooty Owl																																
Feline Owlet-nightjar																																

continued

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Mountain Nightjar																								1						1		
Mountain Swiftlet	2	2		1	1	1	3	2		1	1		1	11	3	5	2	1	4	2	2	2	1	7	2	3		1	1	7	2	1	1
Glossy Swiftlet	1		2		2	2		4	2	1	2	1					1	2			2				1	9	9	8	12	8	9	8	2
Shovel-billed Kingfisher													1	3			4	2	3		6		3		4							
Sacred Kingfisher																																
Rainbow Bee-eater																												20				
Pacific Swallow																																
Alpine Pipit						2	2																									
Hooded Cuckoo-shrike														1																1		
Black-bellied Cuckoo-shrike													3	1	2		2		2			2	2		1							
Long-tailed Shrike																					1											
Pied Chat	1		3				1	1			1																				1	1
Island Thrush	15	2	2		3	3			1	2	1	1														1				2	4	
Lesser Melampitta			2		1	1		2	3		1	1	1		1								1		2	1	2		2	2	3	2	
Blue-capped Ifrita						2	1		1			1					3			1	2		1		2				3	2	2	1	
Tawny Grassbird	10	1	9	1	6	6	2	1	1	1	1	3	1	3	2	2	4	2	3	1	4	2	1		4	2	3	4	3	4	2	2	1
Island Leaf-Warbler																																3
Orange-crowned Fairy-wren																																
Mountain Mouse-warbler	2	1	2	1		1	1	1	1		1	1		1	1		2		3		2		2	1	2		5	3	2	1	3	3	
Large Scrubwren					3	1	1	4	6					2	5		3	1		4	4		5	2		1		4	2	1	4	4	

continued

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Papuan Scrubwren									2			1							3		4					5	5	3	6	7	5	6	
Buff-faced Scrubwren																																4
New Guinea Thornbill							3																						1	3	1	5	
Brown-breasted Gerygone	1		4				1			1	1	1		4											1	1		1	1		1		4
Dimorphic Fantail	1	1	2	4	1	2	1		2	1	1	2	1				5	3	1	1	1		1		1	1	2		1	3	2	1	
Friendly Fantail	3		1	1		2	2	1	1	1		1			1		1			4	1	1	3	1		1	3	1	2	1	2	3	1
Black Fantail																	2	1			1	1		1	1								1
Willie Wagtail																																	2
Black Monarch																						1		1									
Canary Flycatcher															1						2			3			1	1	1	2	2	1	2
Garnet Robin									2																				1	1	1	1	
Mountain Robin		2								2																							
Black-breasted Boatbill							2	1	2				1	1	1	1	1	3	1		3	1	2	1			1	2		2	2		
Black-throated Robin																											1		2	1	2		
Ashy Robin																			2														
"Greater Ground-Robin"?																													1	2	1		
Lesser Ground-Robin																	1		1	1	2			1	1								
White-winged Robin	1		6	3	1	3	3	1	4		2	1																		1	1	3	
Blue-grey Robin																				1		1	1	1									1

continued

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Sclater's Whistler																	1								1								
Regent Whistler																															1	4	
Brown-backed Whistler	1	1				1	2	1	2	1	1																1	1		1	1	4	1	
Rufous-naped Whistler	1	3	1	1	6	1			1	1	1	1	2	2			1								1	1		1	1	1	3	3	3	
Black Sittella																																	
Papuan Flowerpecker																																	1
Fan-tailed Berrypecker	1		4	1		1	2	1	2		2			1	2		1							2	1	1	4	1	1	1	4	5	1	
Crested Berrypecker	3	1	5	5	2	1	7	6	5			3																			3		2	
White-eye species																	6																	10
Olive Straightbill																																	
Red-collared Myzomela	1	1				2		2																			17	11	12	9	10	15	6	2
Black-throated Honeyeater	4	1	6	4	2	7	1		4	1	2	3	2	3	2	3	8	2	4		4	1		4	2		5	5		1	1	1	1	1
Rufous-backed Honeyeater													1	1	1		1	4	5	1	2	2	6	3	7									
Grey-streaked Honeyeater	3	1	2	3	5		3	2	3	1	4	2															7	8	5	8	6	5	5	
Sooty Melidectes	10	4	5	5	4	6	5	3	8	6	3	6															1	5	3		2	2		
Long-bearded Melidectes	1		2		3	2	2		1																								
Belford's Melidectes	20	15	21	13	10	18	9	9	27	7	11	13	3	6	5	6	13	10	11	8	10	6	9	10	15		14	17	11	17	20	17	13	

continued

	OMYAKA CAMP 3,200 m												LAKE TAWA 2,120m												Paiela Road 2,900 m							
Transect Details	21Aug:0600-0900 Omyaka	21Aug:1400-1600 Omyaka	22Aug:0600-0900 Omyaka	22Aug:1030-1230 Omyaka	22Aug:1600-1800 Omyaka	23Aug:0600-0900 Omyaka	23Aug:1000-1200 Omyaka	23Aug:1400-1600 Omyaka	24Aug:0600-0900 Omyaka	24Aug:1045-1245 Omyaka	24Aug:1450-1650 Omyaka	25Aug:0600-0900 Omyaka	26Aug:1600-1800 Tawa	27Aug:0600-0900 Tawa	27Aug:1350-1550 Tawa	27Aug:1700-1800 Tawa	28Aug:0600-0900 Tawa	28Aug:1618-1918 Tawa	29Aug:0600-0900 Tawa	29Aug:1300-1500 Tawa	30Aug:0610-0910 Tawa	30Aug:1240-1440 Tawa	31Aug:0615-0915 Tawa	31Aug:1651-1851 Tawa	1Sep:0615-0915 Tawa	4Sep:0937-1237 Paiela Rd	5Sep:0713-1013 Paiala Rd	5Sep:1024-1224 Paiela Rd	6Sep:0614-1014 Paiela Rd	7Sep:0629-0929 Paiela Rd	8Sep:0600-0900 Paiela Rd	10Sep:0600-0900 Paiela Rd	9Sep:0800-1400 Suyan Forest, 2,200 m
Yellow-browed Melidectes																																10
Common Smoky Honeyeater	10	5	6	6	6	4	5	5	10	2	2	1	5			4	5	2			2	5	6	6	3	6	13	5	1	7	10	4	2
Blue-faced Parrot-Finch	2		1														1									1	3	1			1		1
Hooded Mannikin																	4	3	3													
Mountain Firetail			1		1		1																			1	2		2	4	3	1	
Great Wood-swallow																																
Crested Bird of Paradise				?																												
Loria's BoP																						1			1							
Short-tailed Paradigalla														1							1				1							
Brown Sicklebill																	2	1	4				1	1	1		2		2		2	1	
Black Sicklebill																																
Ribbon-tailed Astrapia	1		1			1	3		1		1	1	2	3		1	1			1	1	4	1		1	1	9	1	1	1	6	3	
Superb Bird of Paradise																																
King of Saxony Bird of Paradise															1		2	1	2			1	1	1	1		4	1	1	1	2	2	
Total individuals during censuses	**121**	**50**	**104**	**60**	**67**	**88**	**74**	**56**	**112**	**31**	**53**	**48**	**43**	**61**	**36**	**36**	**93**	**57**	**59**	**39**	**86**	**42**	**55**	**63**	**61**	**87**	**125**	**105**	**95**	**118**	**148**	**105**	**57**
Total no. species = 102																								**Grand total number of individuals**							**2,435**	

Appendix 4

Bird species documented at four sites in the Kaijende Highlands of Enga Province, Papua New Guinea

Bruce M. Beehler and Robert Sine

Species		Mine & Campus (2,200 m)	Suyan Forest (2,200 m)	Lake Tawa (2,100–2,300 m)	Paiela Road (2,900 m)	Omyaka Camp (3,200 m)
Dwarf Cassowary	*Casuarius bennetti*			X		
Black Kite	*Milvus migrans*	X				
Brahminy Kite	*Haliastur indus*	X	X		X	
Spotted Marsh Harrier	*Circus spilonotus*					X
Black-mantled Goshawk	*Accipiter melanochlamys*				X	
New Guinea Harpy-Eagle	*Harpyopsis novaeguineae*			X		
Long-tailed Buzzard	*Henicopernis longicauda*		X			
Salvadori's Teal	*Salvadorina waigiuensis*			X		
Grey Teal	*Anas gibberifrons*			X		
Pacific Black Duck	*Anas superciliosa*			X		
Brown Quail	*Coturnix australis*	X		X		X
Buff-banded Rail	*Gallirallus philippensis*	X				
Forbes' Forest-Rail(?)	*Rallicula forbesi*			X		
Brown Cuckoo-Dove	*Macropygia amboinensis*	X				
Black-billed Cuckoo-Dove	*Macropygia nigrirostris*	X		X	X	
Great Cuckoo-Dove	*Reinwardtoena reinwardtii*			X		
Bronze Ground-Dove	*Gallicolumba beccarii*			X		
Ornate Fruit-Dove	*Ptilinopus ornatus*	X				
White-breasted Fruit-Dove	*Ptilinopus rivoli*			X		
Papuan Mountain Pigeon	*Gymnophaps albertisii*			X	X	X
Goldie's Lorikeet	*Psitteuteles goldiei*	X		X		
Papuan Lorikeet	*Charmosyna papou*			X	X	X
Yellow-billed Lorikeet	*Neopsittacus musschenbroekii*		X			
Plum-faced Lorikeet	*Oreopsittacus arfaki*			X	X	X
Orange-billed Lorikeet	*Neopsittacus pullicauda*			X	X	X
Brehm's Tiger-Parrot	*Psittacella brehmii*			X	X	
Painted Tiger-Parrot	*Psittacella picta*					X

continued

Species		Mine & Campus (2,200 m)	Suyan Forest (2,200 m)	Lake Tawa (2,100–2,300 m)	Paiela Road (2,900 m)	Omyaka Camp (3,200 m)
Red-breasted Pygmy-Parrot	*Micropsitta bruijnii*		X			
Brush Cuckoo	*Cacomantis variolosus*	X				
Fan-tailed Cuckoo	*Cacomantis flabelliformis*			X	X	X
Rufous-throated Bronze-Cuckoo	*Chrysococcyx ruficollis*			X	X	
Sooty Owl	*Tyto tenebricosa*			X		
Feline Owlet-nightjar	*Aegotheles insignis*			X		
Mountain Nightjar	*Eurostopodus archboldi*			X	X	
Mountain Swiftlet	*Collocalia hirundinacea*	X	X	X	X	X
Glossy Swiftlet	*Collocalia esculenta*	X	X	X	X	X
Shovel-billed Kingfisher	*Clytoceyx rex*			X		
Sacred Kingfisher	*Todiramphus sanctus*	X				
Rainbow Bee-eater	*Merops ornatus*				X	
Pacific Swallow	*Hirundo tahitica*	X				
Alpine Pipit	*Anthus gutturalis*					X
Hooded Cuckoo-shrike	*Coracina longicauda*			X	X	
Black-bellied Cuckoo-shrike	*Coracina montana*			X		
Long-tailed Shrike	*Lanius schach*	X		X		
Pied Chat	*Saxicola caprata*	X				X
Island Thrush	*Turdus poliocephalus*				X	X
Lesser Melampitta	*Melampitta lugubris*			X	X	X
Blue-capped Ifrita	*Ifrita kowaldi*			X	X	X
Tawny Grassbird	*Megalurus timoriensis*	X		X	X	X
Island Leaf-Warbler	*Phylloscopus poliocephalus*		X			
Orange-crowned Fairy-wren	*Clytomyias insignis*					
Mountain Mouse-warbler	*Crateroscelis robusta*			X	X	X
Large Scrubwren	*Sericornis nouhuysi*			X	X	X
Papuan Scrubwren	*Sericornis papuensis*			X	X	X
Buff-faced Scrubwren	*Sericornis perspicillatus*		X			
New Guinea Thornbill	*Acanthiza murina*				X	X
Brown-breasted Gerygone	*Gerygone ruficollis*	X	X	X	X	X
Dimorphic Fantail	*Rhipidura brachyrhyncha*			X	X	X
Friendly Fantail	*Rhipidura albolimbata*		X	X	X	X
Black Fantail	*Rhipidura atra*		X	X		
Willie Wagtail	*Rhipidura leucophrys*	X				
Black Monarch	*Monarcha axillaris*			X		
Canary Flycatcher	*Microeca papuana*		X	X	X	
Garnet Robin	*Eugerygone rubra*				X	X
Mountain Robin	*Petroica bivittata*					X
Black-breasted Boatbill	*Machaerirhynchus nigripectus*			X	X	X

continued

Species		Mine & Campus (2,200 m)	Suyan Forest (2,200 m)	Lake Tawa (2,100–2,300 m)	Paiela Road (2,900 m)	Omyaka Camp (3,200 m)
Black-throated Robin	*Poecilodryas albonotata*				X	
Ashy Robin	*Poecilodryas albispecularis*			X		
"Greater Ground-Robin"?	*Amalocichla sclateriana*				X	
Lesser Ground-Robin	*Amalocichla incerta*			X		
White-winged Robin	*Peneothello sigillatus*				X	X
Blue-grey Robin	*Peneothello cyanus*		X	X		
Sclater's Whistler	*Pachycephala soror*			X		
Regent Whistler	*Pachycephala schlegelii*				X	
Brown-backed Whistler	*Pachycephala modesta*				X	X
Rufous-naped Whistler	*Aleadryas rufinucha*			X	X	X
Black Sittella	*Daphoenositta miranda*			X		
Papuan Flowerpecker	*Dicaeum pectorale*		X			
Fan-tailed Berrypecker	*Melanocharis versteri*			X	X	X
Crested Berrypecker	*Paramythia montium*				X	X
White-eye species	*Zosterops* sp.	X	X	X		
Olive Straightbill	*Timeliopsis fulvigula*			X		
Red-collared Myzomela	*Myzomela rosenbergii*		X		X	X
Black-throated Honeyeater	*Lichenostomus subfrenatus*		X	X	X	X
Rufous-backed Honeyeater	*Ptiloprora guisei*			X		
Grey-streaked Honeyeater	*Ptiloprora perstriata*				X	X
Sooty Melidectes	*Melidectes fuscus*				X	X
Long-bearded Melidectes	*Melidectes princeps*					X
Belford's Melidectes	*Melidectes belfordi*			X	X	X
Yellow-browed Melidectes	*Melidectes rufocrissalis*	X	X			
Common Smoky Honeyeater	*Melipotes fumigatus*		X	X	X	X
Blue-faced Parrot-Finch	*Erythrura trichroa*			X	X	X
Hooded Mannikin	*Lonchura spectabilis*	X		X		
Mountain Firetail	*Oreostruthus fuliginosus*				X	X
Great Wood-swallow	*Artamus maximus*	X				
Crested Bird of Paradise	*Cnemophilus macgregorii*					?
Loria's BoP	*Cnemophilus loriae*			X		
Short-tailed Paradigalla	*Paradigalla brevicauda*			X		
Brown Sicklebill	*Epimachus meyeri*			X	X	
Black Sicklebill	*Epimachus fastuosus*		X			
Ribbon-tailed Astrapia	*Astrapia mayeri*			X	X	X
Superb Bird of Paradise	*Lophorina superba*	X				
King of Saxony Bird of Paradise	*Pteridophora alberti*			X	X	
	Total species 102	**23**	**20**	**61**	**48**	**41**

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